FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of WA OSH Regulations 1996 (Division 12, Construction Industry – consultation on hazards and safety management) to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:


Enquiries relating to the technical content of a Design Standard should be directed to the Principal Engineer, Electrical (Power) Section, Engineering Branch. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Manager, Engineering Branch

This document is prepared without the assumption of a duty of care by the Water Corporation. The document is not intended to be nor should it be relied on as a substitute for professional engineering design expertise or any other professional advice.

Users should use and reference the current version of this document.

© Copyright – Water Corporation: This manual and software is copyright. With the exception of use permitted by the Copyright Act 1968, no part may be reproduced without the written permission of the Water Corporation.
DISCLAIMER

Water Corporation accepts no liability for any loss or damage that arises from anything in the Standards/Specifications including any loss or damage that may arise due to the errors and omissions of any person. Any person or entity which relies upon the Standards/Specifications from the Water Corporation website does so that their own risk and without any right of recourse to the Water Corporation, including, but not limited to, using the Standards/Specification for works other than for or on behalf of the Water Corporation.

The Water Corporation shall not be responsible, nor liable, to any person or entity for any loss or damage suffered as a consequence of the unlawful use of, or reference to, the Standards/Specifications, including but not limited to the use of any part of the Standards/Specification without first obtaining prior express written permission from the CEO of the Water Corporation.

Any interpretation of anything in the Standards/Specifications that deviates from specific Water Corporation Project requirements must be referred to, and resolved by, reference to and for determination by the Water Corporation’s project manager and/or designer for that particular Project.
**REVISION STATUS**

The revision status of this standard is shown section by section below.

<table>
<thead>
<tr>
<th>SECT.</th>
<th>VER./REV.</th>
<th>DATE</th>
<th>PAGES REVISED</th>
<th>REVISION DESCRIPTION</th>
<th>RVWD.</th>
<th>APRV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>0/1</td>
<td>19.11.02</td>
<td>1-3</td>
<td>1.1, 1.3, 1.4, 1.7, 1.8 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>0/2</td>
<td>30.09.04</td>
<td>10, 11</td>
<td>1.2, revised; 1.3 DS28 included; 1.5 IEC61000-6.4 &amp; 6.2 included</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>1/0</td>
<td>30.06.06</td>
<td>12, 13</td>
<td>1.2, 1.3, 1.6, 1.7 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>1/1</td>
<td>30.04.07</td>
<td>13</td>
<td>1.5 (c) included</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>1/3</td>
<td>30.08.11</td>
<td>12-14</td>
<td>1.1, 1.2, 1.3, 1.5, 1.7 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>1</td>
<td>1/6</td>
<td>12.07.17</td>
<td>14-16</td>
<td>1.3, 1.4, 1.7, 1.8 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>2</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>2</td>
<td>0/2</td>
<td>30.09.04</td>
<td>12</td>
<td>Revised 1st sentence</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>3</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>3</td>
<td>1/1</td>
<td>30.04.07</td>
<td>16</td>
<td>3.1 (d) included</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>3</td>
<td>1/2</td>
<td>02.06.09</td>
<td>15</td>
<td>3.1, 3.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>3</td>
<td>1/3</td>
<td>30.08.11</td>
<td>15</td>
<td>3.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>4</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>4</td>
<td>0/1</td>
<td>19.11.02</td>
<td>1, 2</td>
<td>4.2, 4.6, 4.7 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>4</td>
<td>1/1</td>
<td>30.04.07</td>
<td>18</td>
<td>4.7, 4.10 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>4</td>
<td>1/2</td>
<td>02.06.09</td>
<td>16-18</td>
<td>4.4, 4.6, 4.7, 4.10-4.12 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>4</td>
<td>1/3</td>
<td>30.08.11</td>
<td>17-20</td>
<td>4.6, 4.11, 4.12</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>5</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>5</td>
<td>1/0</td>
<td>30.06.06</td>
<td>19</td>
<td>5.1, 5.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>5</td>
<td>1/2</td>
<td>02.06.09</td>
<td>19</td>
<td>5.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>5</td>
<td>1/3</td>
<td>30.08.11</td>
<td>21-22</td>
<td>5.1.1, 5.1.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>5</td>
<td>1/4</td>
<td>31.07.13</td>
<td>24-25</td>
<td>5.1.2 revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>6</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>0/1</td>
<td>19.11.02</td>
<td>3, 4</td>
<td>6.4.5, 6.8 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>0/2</td>
<td>30.09.04</td>
<td>18, 19</td>
<td>6.1, 6.2, 6.4, 6.5 revised, 6.8 last sentence revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>1/0</td>
<td>30.06.06</td>
<td>20-22</td>
<td>6.1, 6.2, 6.5, 6.6, 6.8.1-6.8.4 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>1/1</td>
<td>30.04.07</td>
<td>20</td>
<td>6.3 (d) included</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>1/2</td>
<td>02.06.09</td>
<td>20, 23</td>
<td>6.1, 6.1.2, 6.2, 6.10 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>1/3</td>
<td>30.08.11</td>
<td>23-26</td>
<td>6.1.1, 6.2, 6.3, 6.8.1, 6.8.3, 6.10 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>6</td>
<td>4/4</td>
<td>31.07.13</td>
<td>28</td>
<td>6.6 revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>6</td>
<td>1/6</td>
<td>12.07.17</td>
<td>26</td>
<td>6.1.1 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
</tbody>
</table>
## REVISION STATUS

<table>
<thead>
<tr>
<th>SECT.</th>
<th>VER./REV.</th>
<th>DATE</th>
<th>PAGES REVISED</th>
<th>REVISION DESCRIPTION</th>
<th>RVWD.</th>
<th>APRV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>0/1</td>
<td>19.11.02</td>
<td>1, 3, 4</td>
<td>7.3.2, 7.7.4 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>0/2</td>
<td>30.09.04</td>
<td>22-26</td>
<td>7.7.1-7.7.4, 7.8.2, 7.8.3 revised, 7.9.2 Fig 7.1 &amp; last sent revised, 7.9.3 Fig 7.2 &amp; last sent revised, 7.9.4 Fig 7.3 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>1/0</td>
<td>30.06.06</td>
<td>24-31, 33</td>
<td>7.1, 7.3.1, 7.6, 7.7.1, 7.7.3, 7.8.1-7.8.7, 7.9.1-7.9.9, 7.10, 7.11 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>1/1</td>
<td>30.04.07</td>
<td>25, 26, 31, 32</td>
<td>7.7.1, 7.7.3, 7.9.10, 7.11 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>1/2</td>
<td>02.06.09</td>
<td>24-33</td>
<td>7.1, 7.1.1-7.1.6, 7.2, 7.2.1-7.2.7, 7.3, 7.3.1-7.3.8, 7.4, 7.4.1-7.4.6, 7.5, 7.6, 7.6.1, 7.6.2, 7.7, 7.8 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>1/3</td>
<td>30.08.11</td>
<td>28-29, 33-35</td>
<td>7.1.4, 7.1.5, 7.1.6, 7.3.5, 7.4.1, 7.4.3</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>7</td>
<td>1/4</td>
<td>31.07.13</td>
<td>36</td>
<td>7.32 revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>7</td>
<td>1/6</td>
<td>12.07.17</td>
<td>30, 40</td>
<td>7.1.3, 7.6.1 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>8</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>0/1</td>
<td>19.11.02</td>
<td>1-4, 9, 12-15</td>
<td>8.1.1, 8.1.6, 8.2.1, 8.2.6, 8.3.3, 8.10.3, 8.13, 8.15, 8.18, 8.19 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>0/2</td>
<td>30.09.04</td>
<td>29-31, 33-37, 39-43</td>
<td>8.1.2 1st sentence revised, 8.1.3 revised, 8.1.7 First para revised, 8.2.3 revised, 8.2.7 1st para revised, 8.7 (a)&amp;(e) CEP-7-C included, 8.9.1, Fig 8.1, 8.9.2, 8.9.3-8.9.12, 8.10, 8.11.3, 8.11.5, Table 8.1, 8.11.6, 8.15, 8.17(a),(f)&amp;(g), 8.18 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>1/0</td>
<td>30.06.06</td>
<td>34, 35, 37, 39, 40, 41-45</td>
<td>8.1-8.2.4, 8.2.6, 8.2.8, 8.2.10, 8.2.11, 8.2.12, 8.5, 8.7, 8.9.2, 8.9.4, 8.9.8, 8.9.9, 8.9.11, 8.9.12, 8.11, 8.11.14, 8.12.1, 8.15 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>1/1</td>
<td>30.04.07</td>
<td>35, 42-44, 46</td>
<td>8.2.12, 8.11.7, 8.15 revised, 8.19 included</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>1/2</td>
<td>02.06.09</td>
<td>34-39, 41, 45-49</td>
<td>8.1, 8.2.1, 8.2.3, 8.2.4, 8.2.6, 8.2.12, 8.3.3, 8.5-8.9, 8.9.8, 8.11.14, 8.12.5, 8.14, 8.15, 8.19-8.21 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>1/3</td>
<td>30.08.11</td>
<td>40-41, 43-45, 46, 50-52, 54-55, 56</td>
<td>8.2.4, 8.2.6, 8.2.9, 8.2.11, 8.2.12, 8.7, 8.9.8, 8.11.5, 8.11.14, 8.15, 8.19.1, 8.19.2, 8.20, 8.21</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>8</td>
<td>1/4</td>
<td>31.07.13</td>
<td>49-50,63</td>
<td>8.7, 8.21 Revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
</tbody>
</table>
## REVISION STATUS

<table>
<thead>
<tr>
<th>SECT.</th>
<th>VER./REV.</th>
<th>DATE</th>
<th>PAGES REVISED</th>
<th>REVISION DESCRIPTION</th>
<th>RVWD.</th>
<th>APRV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1/6</td>
<td>12.07.17</td>
<td>54-59</td>
<td>8.11.7, 8.11.14, 8.15, 8.19.1, 8.19.2 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>9</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>0/1</td>
<td>19.11.02</td>
<td>1</td>
<td>9.1,9.2 revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>0/2</td>
<td>30.09.04</td>
<td>44, 45, 47-50</td>
<td>9.1, 9.2, Fig 9.1, 9.3, Fig 9.2, 9.4, Fig 9.3, 9.5, 9.7, 9.12.1 Fig 9.4, 9.12.2 Fig 9.5, 9.13 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>1/0</td>
<td>30.06.06</td>
<td>48-51, 55-57</td>
<td>9.2, 9.3, 9.5, 9.12.1, 9.12.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>1/1</td>
<td>30.04.07</td>
<td>47</td>
<td>9.3 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>1/2</td>
<td>02.06.09</td>
<td>50, 51, 54, 55, 57-59</td>
<td>9.3, 9.4, 9.7, 9.8, 9.12.1, 9.12.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>9</td>
<td>1/3</td>
<td>30.08.11</td>
<td>57-58, 61, 63-64</td>
<td>9, 9.2, 9.3, 9.4, 9.5, 9.8, 9.9 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>0/2</td>
<td>30.09.04</td>
<td>51-53</td>
<td>10.1.2, 10.2, 10.6 revised; 10.5 new title</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>1/0</td>
<td>30.06.06</td>
<td>59</td>
<td>10.1.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>1/1</td>
<td>30.04.07</td>
<td>47</td>
<td>10.1.2 – table revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>1/2</td>
<td>02.06.09</td>
<td>61-63</td>
<td>10.1.2, 10.2, 10.5.1-10.5.4 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>1/3</td>
<td>30.08.11</td>
<td>67-68</td>
<td>10.1.2, 10.2</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>10</td>
<td>1/4</td>
<td>31.07.13</td>
<td>74</td>
<td>10.1.2 revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>10</td>
<td>1/6</td>
<td>12.07.17</td>
<td>75</td>
<td>10.7 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>11</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>11</td>
<td>0/2</td>
<td>30.09.04</td>
<td>54</td>
<td>11.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>11</td>
<td>1/0</td>
<td>30.06.06</td>
<td>63</td>
<td>11.1, 11.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>11</td>
<td>1/6</td>
<td>12.07.17</td>
<td>77</td>
<td>11.1, 11.3 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>12</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>12</td>
<td>0/2</td>
<td>30.09.04</td>
<td>55</td>
<td>12.3 and 12.6 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>12</td>
<td>1/0</td>
<td>30.06.06</td>
<td>64</td>
<td>12.1, 12.3, 12.4, 12.6 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>12</td>
<td>1/3</td>
<td>30.08.11</td>
<td>72</td>
<td>12.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>12</td>
<td>1/4</td>
<td>31.07.13</td>
<td>74</td>
<td>12.9 revised</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>13</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>13</td>
<td>0/2</td>
<td>30.09.04</td>
<td>57</td>
<td>13.1 Fig 13.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>13</td>
<td>1/3</td>
<td>30.08.11</td>
<td>75</td>
<td>13.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>13</td>
<td>1/6</td>
<td>12.07.17</td>
<td>80</td>
<td>13 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
</tbody>
</table>
## REVISION STATUS

<table>
<thead>
<tr>
<th>SECT.</th>
<th>VER./REV.</th>
<th>DATE</th>
<th>PAGES REVISED</th>
<th>REVISION DESCRIPTION</th>
<th>RVWD.</th>
<th>APRV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0/0</td>
<td>01.08.00</td>
<td>All</td>
<td>New Version</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>0/1</td>
<td>19.11.02</td>
<td>All</td>
<td>Revision</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>0/2</td>
<td>30.09.04</td>
<td>59-61</td>
<td>14.1.1-14.1.3, 14.2-14.2.1, 14.3.1, 14.4.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>1/0</td>
<td>30.06.06</td>
<td>71-73</td>
<td>14.2.6, 14.3.1, 14.3.3, 14.4.2 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>1/1</td>
<td>30.04.07</td>
<td>66</td>
<td>14.1.2, 14.2, 14.2.5 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>1/2</td>
<td>02.06.09</td>
<td>69-71</td>
<td>14.1.1-14.1.3, 14.2.1, 14.2.2, 14.2.6 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>1/3</td>
<td>30.08.11</td>
<td>76-77, 79</td>
<td>14.2.1, 14.2.5, 14.3.1 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>14</td>
<td>1/6</td>
<td>12.07.17</td>
<td>80</td>
<td>14 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>15</td>
<td>1/1</td>
<td>30.04.07</td>
<td>70-72</td>
<td>15 new section</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>15</td>
<td>1/2</td>
<td>02.06.09</td>
<td>74-76</td>
<td>15.1, 15.3, 15.5-15.7 revised</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>15</td>
<td>1/3</td>
<td>30.08.11</td>
<td>81-85</td>
<td>15.5, 15.6, 15.7, 15.8, 15.9, 15.10, 15.11</td>
<td>NHJ</td>
<td>AAK</td>
</tr>
<tr>
<td>15</td>
<td>1/6</td>
<td>12.07.17</td>
<td>80</td>
<td>15 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>16</td>
<td>1/4</td>
<td>31.07.13</td>
<td>93-104</td>
<td>All</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>16</td>
<td>1/6</td>
<td>12.07.17</td>
<td>81</td>
<td>6.1.2 revised</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
<tr>
<td>17</td>
<td>1/5</td>
<td>30.04.16</td>
<td>100-106</td>
<td>New section</td>
<td>NHJ</td>
<td>MH</td>
</tr>
<tr>
<td>App A</td>
<td>1/6</td>
<td>12.07.17</td>
<td>100-116</td>
<td>New appendix</td>
<td>NHJ</td>
<td>MSP</td>
</tr>
</tbody>
</table>
Design Standard DS 22
Ancillary Plant and Small Pump Stations - Electrical

CONTENTS
Section                                      Page
1 INTRODUCTION                               14
  1.1 Purpose................................................................. 14
  1.2 Scope ................................................................. 14
  1.3 References ............................................................. 14
  1.4 Definitions ............................................................ 15
  1.5 National Standards ................................................... 15
  1.6 Use of Type Specifications .......................... 15
  1.7 Electrical Safety ......................................................... 15
  1.8 Mandatory Requirements ................................. 16
  1.9 Quality Assurance ....................................................... 16
    1.9.1 Equipment Suppliers ................................................ 16
    1.9.2 Installers .......................................................... 16
    1.9.3 Acceptance Tests .................................................... 16
2 BACKGROUND INFORMATION .......................... 17
3 MOTORS RATING ................................................. 18
  3.1 General Criteria for Selection of Motor Rating ........... 18
  3.2 Pump Drives ............................................................ 18
4 MOTOR SPECIFICATIONS .............................. 19
  4.1 Rating ................................................................. 19
  4.2 Type ................................................................. 19
  4.3 Standard Specifications ................................................ 19
  4.4 Enclosures and Type of Cooling ................................... 19
  4.5 Voltage Rating .......................................................... 19
  4.6 Windings ................................................................. 19
  4.7 Overtemperature Protection of Windings ...................... 20
  4.8 Bearings ................................................................. 20
  4.9 Motor Resonant Speeds ............................................... 20
  4.10 Load Protection ........................................................ 20
  4.11 Torque Characteristic ................................................. 20
    4.11.1 General ............................................................. 20
    4.11.2 Torque Requirements for Quadratic Loads .................... 21
    4.11.3 Torque Requirements for Autotransformer Starting ........ 21
    4.11.4 Use of Electronic Soft Starters ............................... 22
  4.12 Motor Inrush Current ............................................... 22
  4.13 VSC Fed Submersible Borehole and Sewage Motors ........ 22
5 SELECTION OF SWITCHBOARD LOCATION .......... 23
  5.1 Pump Station Switchboards ............................................ 23
    5.1.1 General ............................................................. 23
    5.1.2 Outdoor Switchboards .............................................. 23
  5.2 Incoming Main Switchboards for Sole Use Transformers .... 24
6 INCOMING SUPPLY ............................................ 25
  6.1 Supply Arrangements ................................................. 25
    6.1.1 General ............................................................. 25
    6.1.2 Supplies to Bore Hole Pump Stations .......................... 25
  6.2 Main Switches .......................................................... 25
6.3 LV Feeders .................................................................................. 26
6.4 Transformer Overcurrent Protection Settings .............................. 26
6.5 Metering .................................................................................... 26
6.6 Corporation Substations .......................................................... 27
6.7 Substation Earthing ............................................................... 27
6.8 Emergency Incoming Supply ..................................................... 27
6.8.1 Earthing of Alternator Windings Neutral Point ....................... 27
6.8.2 AVR Characteristics for Alternators on Non Linear Loads .... 27
6.8.3 Alternator AVR Power Supply ............................................. 27
6.8.4 Sizing of Engines and Associated Alternators ..................... 27
6.9 Supply Authority Substations ................................................. 28
6.10 Transformer Sizing ................................................................. 28

7 MOTOR STARTING AND SPEED CONTROL 29
7.1 Voltage Disturbances ............................................................... 29
7.1.1 Voltage Level Disturbance Limits within the Installation ........ 29
7.1.2 Voltage Harmonic Distortion Limits within the Installation ..... 29
7.1.3 Voltage Level Disturbance Limits at Supply Authority P.C.C. ... 29
7.1.4 Continuous Voltage Harmonic Distortion Limits at Supply Authority P.C.C. 30
7.1.5 Starting Harmonic Distortion Limits at Supply Authority P.C.C. 30
7.1.6 Stations Supplied from the L.V. Distribution ......................... 31
7.2 Motor Starting General ............................................................ 31
7.2.1 Maximum Starting Frequency ............................................ 31
7.2.2 Approved Types of Starter ................................................ 31
7.2.3 Not Approved Types of Starter .......................................... 31
7.2.4 Variable Speed Controllers as Starters ............................... 32
7.2.5 Starting Small Motors ....................................................... 32
7.2.6 Starting High Torque Loads ................................................ 32
7.2.7 Starting Quadratic Torque Loads ........................................ 32
7.3 Electronic Soft Starters ............................................................ 32
7.3.1 Application ........................................................................ 32
7.3.2 Principle of Operation ....................................................... 33
7.3.3 Six Wire Connection .......................................................... 33
7.3.4 Three Wire Connection ...................................................... 34
7.3.5 Surge Protection ............................................................... 35
7.3.6 Line Contactors ............................................................... 35
7.3.7 By Pass Contactors .......................................................... 35
7.3.8 Type 2 Coordination ........................................................ 35
7.4 Variable Speed Controllers ..................................................... 36
7.4.1 Types of Variable Speed Controller .................................... 36
7.4.2 Motor Harmonic Current Losses ........................................ 37
7.4.3 Transformer Eddy Current Losses ...................................... 37
7.4.4 Electromagnetic Interference from Variable Speed Controllers 37
7.4.5 Isolation ............................................................................ 37
7.4.6 Resonance ......................................................................... 38
7.5 Calculation of Voltage Fluctuation .......................................... 38
7.6 Calculation of Harmonic Distortion .......................................... 38
7.6.1 Calculation of Harmonic Distortion for Electronic Soft Starters 38
7.6.2 Calculation of Harmonic Distortion for Variable Speed Controllers 39
7.7 Typical Impedances for Overhead Lines .................................. 40
7.8 Typical Impedances for Transformers ...................................... 40

8 SWITCHBOARDS 41
8.1 Mid-Range Low Voltage Switchboards .................................... 41
8.2 Minor Low Voltage Switchboards .......................................... 41
8.2.1 Definition ........................................................................... 41
8.2.2 Standards ........................................................................................................... 41
8.2.3 Special Service Conditions ............................................................................... 41
8.2.4 Construction ..................................................................................................... 41
8.2.5 Rated Diversity Factor ..................................................................................... 42
8.2.6 Degree of Protection ......................................................................................... 42
8.2.7 Rated Insulation and Operating Voltages ......................................................... 42
8.2.8 Creepage Distances ......................................................................................... 42
8.2.9 Rated Impulse Withstand Voltage .................................................................. 42
8.2.10 Rated Short-Time Current ............................................................................ 42
8.2.11 Internal Arcing Fault Protection ...................................................................... 43
8.2.12 Type Specifications ......................................................................................... 43

8.3 Busbars .................................................................................................................. 43
8.3.1 Arrangement of Busbars ................................................................................... 43
8.3.2 Continuous Current Rating of Busbars ........................................................... 43
8.3.3 Access to Busbar Joints .................................................................................... 44

8.4 Location of Controls .............................................................................................. 44
8.5 Protection General .................................................................................................. 44
8.6 Protection Grading .................................................................................................. 45
8.7 Thermal Overcurrent Protection .......................................................................... 45
8.8 Thermistor Motor Protection .................................................................................. 47

8.9 Current Transformers ............................................................................................. 47
8.9.1 General .............................................................................................................. 47
8.9.2 Standards .......................................................................................................... 47
8.9.3 Primary Current Rating ..................................................................................... 48
8.9.4 Short Time Thermal Current rating ................................................................. 48
8.9.5 Rated Operating Voltage ................................................................................. 48
8.9.6 Rated Insulation level ....................................................................................... 48
8.9.7 Rated Secondary Current .................................................................................. 48
8.9.8 Accuracy Class .................................................................................................. 48
8.9.9 Accuracy Limit Factor ...................................................................................... 48
8.9.10 Burden ............................................................................................................ 48
8.9.11 Rated Secondary Limiting e.m.f. .................................................................. 49
8.9.12 Example Rating Calculation for Current Transformer .................................. 49

8.10 Rogowski Coil Current Sensors .......................................................................... 50
8.10.1 Primary Current Rating ................................................................................... 50
8.10.2 Short Time Current Rating ............................................................................. 50
8.10.3 Rated Operational Voltage ............................................................................. 50
8.10.4 Rated Insulation Level .................................................................................... 50
8.10.5 Rated Secondary Current ................................................................................ 50
8.10.6 Accuracy Class ................................................................................................ 50
8.10.7 Accuracy Limit Factor ..................................................................................... 50
8.10.8 Burden ............................................................................................................ 50

8.11 Electrical Surge Protection Equipment .............................................................. 51
8.11.1 Service Entry Surge Protection ....................................................................... 51
8.11.2 Factors Affecting Surge Levels ....................................................................... 51
8.11.3 Surge Diverter Residual Voltage .................................................................... 51
8.11.4 Effect of Main Circuit Inductances ................................................................ 52
8.11.5 Effect of Voltage Wave Reflections ................................................................ 52
8.11.6 Impulse Voltage Rating of Power Electronic Equipment ............................ 52
8.11.7 Location and Connection of Surge Diverters .................................................. 52
8.11.8 Rating of Surge Diverter Fault Current Limiting Fuses .................................. 53
8.11.9 Surge Protection of Separately Mounted Equipment ..................................... 53
8.11.10 Surge Diverter Discharge Current Rating ...................................................... 53
8.11.11 Surge Diverter Protection Level ................................................................. 53
8.11.12 Surge Diverter Maximum Continuous Operating Voltage .......................... 53
8.12 Switchgear ............................................ 53
  8.12.1 Thermal Derating ........................................ 53
  8.12.2 Connecting Cables ...................................... 54
  8.12.3 Circuit Breaker Type ................................... 54
  8.12.4 Motor Control .......................................... 54
  8.12.5 Fast Transient Burst Suppression ....................... 54
8.13 General Construction of Switchboards ...................... 54
8.14 Power and Control Circuits ................................ 54
8.15 Switchboard Control Functions .............................. 55
8.16 Supply Voltage Quality Monitoring ......................... 55
8.17 Lamp and Actuator Colours ................................ 55
8.18 Separate Drive Circuits ................................... 56
8.19 Monitoring Requirements for Small Pump Stations ....... 56
  8.19.1 Energy ................................................. 56
  8.19.2 Current and Power ....................................... 57
8.20 Orientation of Outdoor Switchboards ....................... 57
8.21 Motor Cable Disconnection Cubicles ......................... 57
9  EARTHING .................................................. 58
  9.1 Type of Earthing Systems .................................... 58
  9.2 Earthing Systems - LV Supply to Site ..................... 58
  9.3 Earthing Systems – On Site Supply Authority Transformer .... 58
  9.4 Earthing Systems – HV Supply from On Site Transformer .... 62
  9.5 Connections to Steelwork .................................... 64
  9.6 Prevention of Corrosion in Earthing Systems ............... 64
  9.7 Calculation of Electrode Earthing Resistance .............. 65
  9.8 Voltage Grading in Earthing System ........................ 65
  9.9 Earthing and Surge Protection of Submersible Bore Hole Motors .. 65
  9.10 Labelling of Earthing Cables ............................... 65
  9.11 Earthing of Pipeline Mounted Instrumentation ............. 65
  9.12 Earthing of Steel Pipelines ................................ 66
  9.12.1 Above Ground Steel Pipelines ........................... 66
  9.12.2 Below Ground Steel Pipelines ......................... 66
  9.13 Earthing Cable Screens .................................... 67
  9.14 Earthing at Water Tanks ................................... 68
10  CABLES ..................................................... 69
  10.1 Cable Types .................................................. 69
    10.1.1 Conductor Type ........................................ 69
    10.1.2 Cables for Specific Purposes .......................... 69
  10.2 Cables for VVVF Drives .................................... 70
  10.3 Fault Rating .................................................. 71
    10.3.1 Switchboard Wiring ...................................... 71
    10.3.2 Distribution Cables ..................................... 71
  10.4 Continuous Rating of Cables ................................ 71
  10.5 High Voltage Cable Terminations ........................... 71
    10.5.1 Manufacturer’s Recommendations ....................... 71
    10.5.2 Dead-break Elbow Connectors ........................... 72
    10.5.3 Indoor Air Insulated Terminations ...................... 72
    10.5.4 Pole Top Terminations ................................... 72
  10.6 Conduits and Cable Trays/Ladders ......................... 72
  10.7 Minimum Cable Separation .................................. 72
11  PUMP STATION LIGHTING .................................... 74
  11.1 Internal Lighting ........................................... 74
11.2 External Lighting .......................................................... 74
11.3 Prevention of Falls ...................................................... 74

12 VALVE ACTUATORS .......................................................... 75
12.1 General ........................................................................ 75
12.2 Electricity Supply .......................................................... 75
12.3 Ambient Conditions ..................................................... 75
12.4 Enclosure Class ............................................................ 75
12.5 Electrical Protection ..................................................... 75
12.6 Rating ........................................................................ 75
12.7 Anti-Condensation Heaters ............................................. 76
12.8 Auxiliaries ................................................................. 76
12.9 Isolation Requirements ................................................ 76

13 HYDRAULIC SURGE VESSELS ......................................... 77

14 SWITCHBOARD CONTROLLING SYSTEMS ....................... 77

15 LOCAL AREA PRESSURE BOOSTER PUMP STATIONS ........... 77

16 UNINTERRUPTIBLE POWER SUPPLIES .............................. 78
16.1 Definition .................................................................... 78
16.2 Standards .................................................................... 78
16.3 Application ................................................................... 78
16.4 Types of UPS Topology .................................................. 78
16.4.1 UPS Topologies in Current Use .................................. 78
16.4.2 UPS Topologies Covered by AS 62040 ....................... 79
16.4.3 Rating Limits .......................................................... 79
16.5 Line Interactive with bypass UPS .................................... 79
16.5.1 Output Dynamic Performance .................................... 79
16.5.2 Topology ............................................................... 80
16.5.3 Operation ............................................................. 80
16.7 Comparison between Types of UPS .................................. 83

17 DIESEL ENGINE STARTING BATTERY SYSTEMS .............. 89
17.1 Scope .......................................................................... 89
17.2 Standards .................................................................... 89
17.3 Acronyms and Definitions ............................................... 89
17.4 Discussion .................................................................... 89
17.5 Investigation of Battery Types ........................................ 90
17.5.1 Lead Acid Technology ............................................... 91
17.5.2 Lithium Ion Technology ............................................. 91
17.6 Characteristics and Performance of Preferred Batteries ....... 92
17.6.1 VRLA AGM Flat Plate and Spiral Roll Batteries .......... 92
17.6.2 Lithium Iron Phosphate Batteries ............................... 92
17.7 Battery Management Systems/Chargers ........................... 93
17.7.1 VRLA Battery Chargers ............................................. 93
17.7.2 Lithium Iron Phosphate Battery Management System ... 93
17.8 Summary and Recommendations ..................................... 94

A0 SWITCHBOARD CONTROL FUNCTIONS ............................. 97

A1 HYDRAULIC SURGE VESSELS .......................................... 98
A1.1 Principle of Operation .................................................. 98
A1.2 Controller ................................................................. 99

A2 SWITCHBOARD CONTROLLING SYSTEMS ...................... 99
A2.1 General ...................................................................... 99
A2.1.1 Definition ............................................................ 99
A2.1.2 Separation .......................................................... 100
A2.1.3 Housing..........................................................................................100
A2.2
Hardware Format ..................................................................................100
A2.2.1 General .......................................................................................100
A2.2.2 Electromagnetic Compatibility......................................................101
A2.2.3 Programmable Memory.................................................................101
A2.2.4 Power Supplies ............................................................................101
A2.2.5 Input/Output Voltage .................................................................101
A2.2.6 Inputs .........................................................................................102
A2.2.7 Outputs ......................................................................................102
A2.2.8 Equipment Separation ...............................................................102
A2.3
Logic Diagrams ....................................................................................103
A2.3.1 General ....................................................................................103
A2.3.2 Use of Block Logic Format ........................................................103
A2.3.3 Arrangement of Logic Drawings ................................................103
A2.4
PLC Programming and Documentation ..............................................104
A2.4.1 General ....................................................................................104
A2.4.2 Ladder Diagrams ......................................................................104
A3
HIGH LEVEL AREA BOOSTER PUMP STATIONS .................................104
A3.1
General ............................................................................................104
A3.2
Shortcomings of HLAB Pump Stations ............................................105
A3.3
Incoming Power Supply ..................................................................105
A3.4
Standby Power Supply ..................................................................105
A3.5
Pump Characteristics ......................................................................106
A3.6
Maintaining Pressure at Zero flow ..................................................106
A3.7
Hydraulic Parameters ......................................................................106
A3.8
Cascade Control Functions ...............................................................107
A3.9
Pump Suitability for Cascade Control ..............................................108
A3.10
Determination of Step Down Set Points ..........................................109
A3.11
Example Calculation .......................................................................109
A3.12
Equipment Redundancy ..................................................................111
A3.13
Maximum Starting Frequency ..........................................................111
A3.14
Electrical Control System Specification .......................................112
A3.15
PLC Logic Diagrams .......................................................................112
A3.16
Related Mechanical Standard ..........................................................112
1 INTRODUCTION

1.1 Purpose

The Water Corporation has adopted a policy of outsourcing most of the electrical engineering and electrical detail design associated with the procurement of its assets. The resulting assets need to be in accordance with the Corporation’s operational needs and standard practices.

The design standard (i.e. Electrical Design Standard DS22) sets out design standards and engineering practice which shall be followed in respect to the design and specification of electrical works being acquired by the Corporation.

This design standard does not address all issues that will need to be considered by the Designer in respect to a particular installation.

It is the Corporation’s objective that its assets will be designed so that these have a minimum long term cost and are convenient to operate and maintain. In respect to matters not covered specifically in this standard, the Designer shall aim his designs and specifications at achieving this objective.

This design standard is intended for the guidance of electrical system designers and shall not be quoted in specifications (including drawings) for the purpose of purchasing electrical equipment or electrical installations except as part of the prime specification for a major design and construct (D&C) contract.

1.2 Scope

The scope of this standard (i.e. Electrical Design Standard DS22) covers the design of electrical equipment in locations where the short circuit fault level is not more than 10 kA or where the Service Protective Device is a current limiting circuit breaker or fuse having a peak cut off current of not more than 17 kA at the site prospective fault level.

The scope of this standard covers individual drives rated no greater than 150 kW and transformers rated not greater than 315 kVA.

The scope of this standard covers ancillary plant in major pump stations and in both major and minor treatment works, as well as in small pump stations (including small bore sites).

1.3 References

Reference shall be made to the following associated design standards and drawings:

DS 20.2 Design Process for Minor Power Electrical Works
DS 21 Major Pump Station – Electrical
DS 24 Electrical Drafting
DS 26 Type Specifications
DS 28 Water and Wastewater Treatment Plants - Electrical
DS 29 Arc Flash hazard Assessment of Switchgear Assemblies

Water Corporation Electrical Standard Drawings - Small Pump Stations - MN01 planset Series.
1.4 Definitions

Asset Manager  The Corporation officer responsible for the operation of the asset being acquired.

Corporation  The Water Corporation (of Western Australia)

Designer  The consulting engineer carrying out the electrical design.

Principal Engineer  Principal Engineer Electrical (Power), Engineering Branch

1.5 National Standards

(a) Electrical installations shall be designed in accordance with the latest edition of AS3000 and except where otherwise specified in this design manual, major pump station electrical design shall be carried out in accordance with the latest edition of all other relevant Australian Standards. In the absence of relevant Australian Standards, relevant international, other national, or industry standards shall be followed.

(b) Except where a concession is obtained from Energy Safety, electrical design shall be in accordance with the W.A. Electrical Requirements Manual (WAER) produced by the Energy Safety Division (EnergySafety) of the Department of Consumer & Employment Protection.

(c) Except where a concession is obtained from the Supply Authority, the electrical design of all installations to be connected to the Supply Authority system shall be designed in accordance with their requirements. Such requirements include the Western Australian Distribution Connection Manual.

(d) All electrical equipment, which incorporates electronic switching or electronic measuring circuits, shall be specified to be in accordance with the European standards IEC 61000-6.4 and IEC 61000-6.2 for Electromagnetic Emissions and Immunity respectively. In addition, all such equipment shall be specified to have been approved by the Australian Communications Authority in respect to Electromagnetic Compatibility.

1.6 Use of Type Specifications

Type Specifications (Design Standard DS26) have been prepared in order to assist the specification of electrical work designed in accordance with this Design Standard (DS22) and these Type Specifications shall be used for this purpose whenever practical. Where a relevant type specification does not exist, the Designer shall prepare an appropriate specification based on this design standard.

1.7 Electrical Safety

Electrical installations shall be designed to facilitate safe operation and maintenance of the electrical plant.

In respect to High Voltage equipment, mechanically or key interlocked isolating switches, earthing switches and access covers shall be employed wherever practical so as to prevent access to live conductors. In instances where interlocking is not practical, High Voltage isolating and earthing switches and access doors shall be protected with Water Corporation’s EL1 keyed locking systems. Systems employing a “Safety PLC” for High Voltage interlocking shall not be permitted.

Access doors providing access to exposed live Low Voltage conductors, shall be protected with Water Corporation’s EL2 equivalent keyed locking systems (Bilock).
Remote closing of High Voltage or Low Voltage circuit breakers via the SCADA system shall NOT be permitted

1.8 Mandatory Requirements

In general the requirements of this standard are mandatory. If there are special circumstances which would justify deviation from the requirements of this standard, the matter shall be referred to the Principal Engineer for his consideration. No deviation from the requirements of this standard shall be made without the written approval of the Principal Engineer. Such dispensation, if granted, applies only to the case in question based on the merits of the argument and does not set a precedent.

1.9 Quality Assurance

It is a requirement of the Corporation that the following QA systems be applied to electrical equipment manufacturers and electrical installers.

1.9.1 Equipment Suppliers

Suppliers of major electrical equipment (such as transformers, motors, variable speed drives, switchgear, switchboards, instrumentation equipment) shall only supply equipment from a Manufacturer that has in place a Quality Management System certified by an accredited third party to AS/NZS ISO 9001:2000 or an approved equivalent.

1.9.2 Installers

Installers of major electrical equipment (such as transformers, motors, variable speed drives, switchgear, switchboards, instrumentation equipment) shall have in place a Quality Management System certified by an accredited third party to AS/NZS ISO 9001:2000 (excluding Clause 7.3 Design & Development) or an approved equivalent.

1.9.3 Acceptance Tests

In tender documents in which acceptance tests are specified, the cost of providing works tests (including associated test certificates) and site tests (including associated test certificates) shall be shown as separate items in the Bill of Quantities so that:

(a) it can be verified that sufficient funds have been allowed to carry out such testing satisfactorily, and

(b) it is clear that works tests and site tests are separate critical deliverables.
2 BACKGROUND INFORMATION

Prior to the preparation of electrical designs for small pump stations, the Designer shall gather the following background information for use during the design process.

(a) Single Unit Pumping Duty kW

(b) Pump Duty Flow Rate litres/second

(c) Pump Duty Head metres of water

(d) Pump non overloading kW Upper Limit (not applicable to sewage pumps)

(e) Number of Duty Units initially

(f) Number of Duty Units in 5 years

(g) Number of Standby Units initially

(h) Number of Standby Units in 5 years

(i) Nominal Speed of Pump Sets

(j) Station Maximum Pump kW Demand initially

(k) Station Maximum Pump kW Demand in 5 years

(l) Pump Type (Centrifugal, Turbine, Helical Rotor, etc)

(m) Estimated Pump Set running hours/year

(n) Whether 1 or 2 Duty Levels are required

(o) Estimated 1st Duty Starts/hour

(p) Estimated 2nd Duty starts/hour

(v) Maximum Allowable Station Shut-Down Period hours

(q) Direction of Rotation of Motor viewed from Coupling End

(r) Hydraulic Control Parameters

(s) Whether Low Sound Level Plant is required

(t) What Alarm facilities are required

(u) What Water Treatment Facilities are required

(v) What Other Ancillary Equipment is required

(w) Whether Emergency Electrical Supply Facilities are Required

(x) What SCADA I/O is required

(y) What Switchboard Space is required for SCADA and Associated Communications Equipment.
3 MOTORS RATING

3.1 General Criteria for Selection of Motor Rating

(a) Motors shall be rated at not less than 110% of the maximum motor operating load kW.

(b) The 10% margin specified above provides for:

(i) a 5% margin of error in respect to the pump load requirements,

(ii) a 5% derating to allow for phase voltage unbalance if the motor is to be connected directly to the supply mains to allow for a negative phase sequence voltage of up to 2%,

(iii) a 5% derating to allow for harmonic current generated by a variable speed controller, if the motor is to be connected to the latter. (If the variable speed controller is fitted with an output filter so as to prevent the flow of harmonic currents to the motor, this amount of derating can be reduced somewhat depending on the voltage regulation of the filter).

(c) Motors mounted outdoors in direct sunlight shall be derated by a further 10% so as to allow for additional heating due to sunlight.

(d) The motor rated selected shall be the smallest rating available which meets the above ratings.

(e) For variable speed drive (PWM) applications, the variable speed controller shall not be sized smaller than the motor rating.

3.2 Pump Drives

Pump duty point kW shall be calculated as follows:

\[ P_{\text{kW}} = 9.81 \times 10^{-3} F H \eta^{-1} \]

where

- \( P_{\text{kW}} \) = kW at duty point
- \( F \) = flow rate in litres/sec. at duty point
- \( H \) = head in metres at duty point
- \( \eta \) = pump efficiency per unit at duty point

Further to subsections 3.1(a) and 3.1(b) above, since pump loads may vary considerably from the nominal duty point due to changes in hydraulic conditions, motors driving pumps shall have an S1 rating of not less than 120% of the pump kW demand at the specified maximum duty point, or 110% of the pump kW demand at the pump non overloading duty point, whichever is the least.

However, if thermistor or RTD motor winding protection is used, the S1 rating of the motor (after derating as per subsections 3.1 if applicable) need exceed only 110% of the pump maximum duty point kW demand.
4 MOTOR SPECIFICATIONS

4.1 Rating

The S1 kW output rating of motors shall be determined as per Section 3.

4.2 Type

In general, the motors shall be cage type induction motors. However, in special cases where the supply system impedance is high relative to the size of the motor, the use of slip ring induction motors may need to be considered. Such instances shall be referred to the Principal Engineer for his approval.

4.3 Standard Specifications

The motors shall be in accordance with the requirements of AS 1359 and be of a type tested design.

4.4 Enclosures and Type of Cooling

All motors rated up to 90 kW, other than bore hole motors, shall be totally enclosed fan cooled type to minimise maintenance costs.

All motors to be installed out of doors shall have enclosures rated at IP56D in accordance with AS 60529.

4.5 Voltage Rating

The nominal voltage rating of all motors shall be the same as the nominal voltage rating of the supply to which the motor is to be connected, e.g. motors to be connected to a 440 volt, 3 phase supply shall have a nominal rating of 440 volt, 3 phase, not 415 volt, 3 phase.

4.6 Windings

(a) Winding insulation temperature rating shall be not less than Class 155 (F) to IEC 60085.

(b) Motors shall be designed to have a full load temperature rise of not more than 80°C so as to allow full load operation of motors in full sun outdoors with shade temperatures up to 55°C.

(c) Stator windings on motors rated greater than 22 kW shall be delta connected.

(d) Motor windings shall be specified to have an impulse withstand voltage rating of not less than 3.1*V_n and a dV/dT rating of 4.3*V_n /μs, where V_n is the motor nominal rated operating voltage.

Because the voltage waveform generated by variable speed controllers contains fast transients, the turn to turn insulation in motors connected to such controllers will be stressed considerably more than that in motors connected to sinusoidal voltage supplies. Consequently, unless output filtering is used, motors to be connected to variable speed controllers shall be specified for such duty. The motor manufacturer shall be informed if the motor is to be used in conjunction with a variable speed controller so that the manufacturer may take account of the increased level of harmonic currents and the increased voltage stress on the insulation.

Variable speed controllers shall be fitted with dV/dT filters to limit the dV/dT ratio of the voltage waveform of the supply to the associated motor to less than 4.3*V_n /μs unless the motor winding has a dV/dT rating not less than 31*V_n /μs.
4.7 **Overtemperature Protection of Windings**

(a) All conventional standard cage motors rated ≥ 11 kW shall be fitted with thermistor protection.

(b) All submersible sewage pump motors shall be specified to be fitted with thermistor winding protection. Alternative means of winding temperature protection recommended by the manufacturer may be utilized.

(c) All submersible bore hole motors rated greater than 22 kW shall be specified to be fitted with thermistor or RTD winding protection. The Designer shall check with the Client whether continuous temperature monitoring is required for the application.

(d) Where over temperature protection of motor windings is to be provided by thermistor protection, the thermistors shall be embedded in the windings during the manufacturing process. Fitting of thermistors to motor windings after motor manufacture shall not be permitted.

Three thermistors each having resistance of 1000 ohms at trip temperature shall be installed, one in each phase winding. Thermistors shall be connected in series and brought out into a suitable terminal box.

**Note:** It is left to the discretion of the Designer whether to use RTD winding protection rather than thermistor protection and determined on the merit of the application and associated additional costs.

4.8 **Bearings**

(a) Bearings in motors, other than bore hole motors, shall be ball or roller type and shall be grease lubricated with an extreme pressure grease such as Shell Alvania EPLF2.

(b) Provided that the predicted running hours for the motor over a 10 year period of operation of the plant is less than the rated life of motor bearings, motors other than submersible motors shall be fitted with sealed for life bearings in those motor ratings for which such bearings are available. Otherwise all motors other than submersible motors shall be fitted with bearings which have grease nipples and automatic grease pressure venting systems.

4.9 **Motor Resonant Speeds**

Where a load is to be driven by a variable speed drive, the Designer shall ensure that neither the motor nor the load has resonant speeds within the proposed drive speed range. Induction motors designed for fixed speed operation shall be specified not to have resonant speeds within +/- 20% of nominal speed.

4.10 **Load Protection**

(a) Motors driving loads which are prone to jamming shall be fitted with electronic shear pin protection.

(b) Motors rated greater than 22 kW driving sewage pumps which are prone to air locking shall be fitted with underload protection preferably of the underpower rather than under current type.

4.11 **Torque Characteristic**

4.11.1 **General**

Reduced voltage motor starting is used to reduce the starting current taken from the electrical supply.
However, the torque generated by a motor is proportional to the current in the motor windings squared.

Hence if the motor winding current is to be reduced during starting, the torque available to accelerate the motor and its associated load will be reduced by the square of the current reduction.

4.11.2 Torque Requirements for Quadratic Loads

The pump torque requirement during starting of a quadratic load such as a centrifugal pump, over the speed range 30% to 100% pump full speed, will be proportional to the square of the speed. At zero speed the pump torque requirement can be expected to be approximately 15% of pump maximum torque falling to approximately 10% of pump full load torque at 30% of pump full speed.

For motor starting to be successful, the motor must generate more torque than the pump requirement over the entire speed range from standstill to pump full speed. For normal cage motor designs, the motor starting torque curve will be closest to the pump starting torque curve at 75% synchronous speed.

On the basis of the pump full load being 90% of the motor rated full load, and after taking into account a small margin of accelerating torque, the motor must generate, at 75% synchronous speed, under reduced voltage starting, a torque of 57% motor full load torque (i.e. 63% pump full load torque).

4.11.3 Torque Requirements for Autotransformer Starting

(a) If an autotransformer is used, the line current will be determined as follows:

\[ I_{ma} = \frac{I_n - I_{tm}}{N^2} \]

where

\[ I_{ma} = \text{motor starting current} \]

\[ I_n = \text{line current using an autotransformer starter,} \]

\[ N = \text{autotransformer tapping per unit (e.g. = 0.65)} \]

\[ I_{tm} = \text{autotransformer magnetising current,} \]

\[ = \text{say 15% line current (conservative estimate)} \]

Hence using an autotransformer starter on a voltage tapping of less than 80%, the per unit reduction in motor torque is less than the square of the per unit reduction in motor current.

(b) For a typical single cage motor driving a centrifugal pump with a full speed torque requirement of 90% of motor full speed rated torque, the autotransformer tapping to be used shall be determined by the motor infinite bus D.O.L. torque at 75% synchronous speed (0.75 NT) and the pump full load torque (FLT) as follows:-

(i) motor 0.75 NT ≥ 175% pump FLT - 65% tap

(ii) motor 0.75 NT ≥ 150%, <175% pump FLT - 70% tap

(iii) motor 0.75 NT ≥ 130%, <150% pump FLT - 75% tap

(c) For a typical single cage motor driving a centrifugal pump with a full speed torque requirement of 80% of motor full speed rated torque, the autotransformer tapping to be used shall be determined by the motor infinite bus D.O.L. torque at 75% synchronous speed (0.75 NT) and the pump full load torque (FLT) as follows:-
(i) motor 0.75 NT ≥ 155% pump FLT - 65% tap
(ii) motor 0.75 NT ≥ 135%, <155% pump FLT - 70% tap
(iii) motor 0.75 NT ≥ 120%, <135% pump FLT - 75% tap

(d) The values given in sub-paras (b) and (c) above allow for a 10% drop in supply voltage during starting.

(e) If the motor infinite bus D.O.L. torque at 75% synchronous speed is less than 120% of pump full load torque, it may be preferable to use an electronic soft starter.

4.11.4 Use of Electronic Soft Starters

If an electronic soft starter is used, the motor torque will fall as the square of the reduction in motor current. For example, a motor which is suitable for starting with a 65% tap autotransformer starter and which draws 265% motor full load current, would draw 335% motor full load current if used to start the same load with an electronic soft starter.

However, the advantage diminishes for motors requiring autotransformer starters with autotransformer tap settings higher than 75%.

For such motors and electronic soft starters, the starting currents depend on the motor infinite bus D.O.L. torque at 75% speed (0.75 NT) and the pump full load torque (FLT).

For typical motors driving pumps which have a full load torque requirement of 90% of motor full speed rated torque, the maximum currents taken during electronic soft starting will be as follows:-

(i) motor 0.75 NT = 140%, pump FLT - 4 times motor FLC
(ii) motor 0.75 NT = 125%, pump FLT - 4.5 times motor FLC
(iii) motor 0.75 NT = 100%, pump FLT - 4.9 times motor FLC.

4.12 Motor Inrush Current

Generally locked rotor current is limited to 6 to 7 times full load current. In any case the motor locked rotor current shall not exceed 8 times full load current.

4.13 VSC Fed Submersible Borehole and Sewage Motors

Submersible borehole and sewage pump motors driven by PWM variable speed controllers (VSC) shall employ sinusoidal filters on the output of the VSC. Such measures eliminate the need for special screened cable, insulated bearings, enhanced insulation and further derating due to harmonic heating in the motor windings. However care must be taken in the selection of the appropriate sine filter.

There are two types of sine filters:

- Type 1 - those which provide both phase to ground and phase to phase filtering, and
- Type 2 - those which provide only phase to phase filtering.

Type 2 sine filters (symmetric), despite all their advantages, are not able to improve the common mode problems. The use of Type 1 sine filters (symmetric plus asymmetric) will eliminate bearing damage, eliminate the need for shielded motor cables, almost eliminate parasitic earth currents and obviate the need to limit cable length.
5 SELECTION OF SWITCHBOARD LOCATION

5.1 Pump Station Switchboards

5.1.1 General

At installations where the pumping plant proper is located indoors the pump station switchboard shall be located in the same building, wherever this is practical. Where this is not practical, such switchboards shall be either indoor switchboards housed in transportable enclosures, or outdoor switchboards, all within the limits specified hereunder,

Transportable Enclosures

Switchboards shall be permitted to be housed in transportable enclosures provided the latter:

(a) are of robust weatherproof construction,
(b) are adequately thermally insulated,
(c) are sized to provide adequate space for operators and service personnel,
(d) are fitted with automatic changeover duty and standby air conditioners sized to take account of the heat losses from the switchboard,
(e) are compliant with the accessibility and emergency exit facility requirements of AS/NZS 3000 and,
(f) are fitted with ambient temperature monitoring with remote alarm facilities.

5.1.2 Outdoor Switchboards

(a) Pump station switchboards shall not be housed outdoors in metal kiosks.
(b) At a particular installation, the pump station switchboard proper shall be permitted to be located outdoors provided:

(i) the maximum allowable shut down time is greater than 100 hours

(ii) the number of switchboard cubicles is not greater than eight.

(iii) any variable speed controllers and associated filters are provided with the degree of protection specified in clause 8.2.6 of this Design Standard,

(iv) any variable speed controllers and associated filters comply with the requirements listed paras. 5.1.2 (c) to 5.1.2 (g) hereunder.

(c) In the South West Land Division of Western Australia outdoor switchboards, which are not provided with sun shade, shall not house variable speed controllers for motor loads greater than 30 kW.

(d) In the South West Land Division of Western Australia outdoor switchboards, which are provided with sun shade, shall not house variable speed controllers for motor loads greater than 37 kW.

(e) In areas of Western Australia other than the South West Land Division outdoor switchboards, which are provided with sun shade, shall not house variable speed controllers for motor loads greater than 30 kW.
(f) In areas of Western Australia other than the South West Land Division of the State, switchboards containing variable speed controllers shall not be located outdoors without sun shade.

(g) Variable speed controllers to be installed in outdoor switchboards shall be derated for operation in a cubicle internal ambient temperature of 55°C.

Sine filters and dV/dt filters to be installed in outdoor switchboards shall be derated for operation in a cubicle internal ambient temperature of 60°C.

The full load heat rise in switchboard cubicles housing the above equipment shall not cause the ambient temperature of the air surrounding such equipment to exceed the values specified below:

(i) For cubicles to be installed as per clause 5.1.2 (d) the outside ambient temperature shall be taken as 45°C

(ii) For cubicles to be installed as per clause 5.1.2 (c) the outside ambient temperature shall be taken as 45°C and a further 5°C shall be allowed for heating by direct solar radiation.

(iii) For cubicles to be installed as per clause 5.1.2 (e) the outside ambient temperature shall be taken as 50°C

Such heat rise values shall be verified by type test or by calculation in accordance with AS 60890 - 2009.

5.2 **Incoming Main Switchboards for Sole Use Transformers**

If the supply to the site is via a Supply Authority owned sole use transformer, the incoming main switchboard shall be an outdoor switchboard located contiguous with (i.e. immediately adjacent to) the transformer compound.

If necessary the pump station switchboard may be separate from the main switchboard.
6 INCOMING SUPPLY

6.1 Supply Arrangements

6.1.1 General

(a) In respect to supply and metering arrangement requirements, reference should be made to W.A. Electrical Requirements (WAER), the Western Power/Horizon Power publication entitled “Western Australian Distribution Connection Manual” and standard drawings MN01 inclusive.

(b) Electrical supply from a Supply Authority shall be taken at Low Voltage with the Supply Authority metering being at Low Voltage and the associated transformer and High Voltage switchgear being Supply Authority owned.

(c) In respect to supplies taken at Low Voltage, supply from a Supply Authority owned sole use transformer has the advantage that while the metering is done at Low Voltage, the point of common coupling in respect to disturbances to the voltage waveform is at the High Voltage terminals of the transformer. Consequently the starting current limitations for installations connected to a sole use transformer are less stringent than those applicable to installations connected directly to the Supply Authority’s Low Voltage distribution.

6.1.2 Supplies to Bore Hole Pump Stations

(a) If the supply to a bore hole pump station is via a Supply Authority owned “sole use” transformer, special precautions must be taken to prevent surge currents from High Voltage surge diverters flowing to earth via the bore hole motor and pump casings (thus over stressing the motor winding insulation).

(b) Consequently, if the supply to a bore hole pump station is via an overhead High Voltage line and the “sole use” transformer is to be pole mounted, the transformer protection surge diverters should be located one line bay back from the transformer pole and should be connected to a separate earthing electrode so as to minimize High Voltage surge.

(c) Similarly, if the supply to a bore hole pump station is via an overhead High Voltage line and the “sole use” transformer is to be ground mounted, the High Voltage cable protection surge diverters should be located one line bay back form the cable termination pole and should be connected to a separate earthing electrode.

(d) Probably the above arrangements will not be in accordance with the Supply Authority’s standard practice and the implementation of these arrangements will have to be negotiated with the Supply Authority. The cost of providing a separate earth electrode for the Supply Authority’s High Voltage surge diverters shall be to the Corporation’s account.

6.2 Main Switches

The function of the Service Protective Device (SPD) is to protect the incoming consumer’s mains and the metering equipment. In situations where the site main switchboard is integral with the pump station switchboard the installation Main Switch does not need to be fitted with protective releases to carry out the same function as the SPD and consequently the Main Switch can be a non-auto circuit breaker provided that the length of conductor between SPD and the line side terminals of the next line of protection does not exceed 3 metres and the cables are protected suitably (AS/NZS 3000:2007).

Each motor circuit breaker release and associated motor overload protection must grade with the SPD.

The possible use of protection equipment which has zone selectivity functionality shall be investigated in this regard if time based grading is found to be difficult in a particular application.
6.3 LV Feeders

(a) Incoming supply LV mains cables shall be double insulated unarmoured cable protected above ground by medium duty steel conduit to AS 1074 and below ground by Heavy Duty PVC underground conduit to AS 2053.

(b) In the instances where the pump station is more than 40m from the point of supply a separate LV pump station switchboard shall be installed and the LV incoming main switchboard located as close as is convenient to the point of supply, so that the length of incoming LV mains cable is minimised.

(c) Incoming supply mains cables for 80 amp supplies shall be single core 25 mm\(^2\) copper conductor XLPE cables and for 100 amp supplies shall be single core 25 mm\(^2\) copper conductor XLPE cables.

(d) Incoming supply mains cable from the transformer shall be rated for the full load current output of the transformer taking into account the site installation and temperature derating factors as per AS 3008.

6.4 Transformer Overcurrent Protection Settings

The High Voltage fuses supplying Corporation owned transformers provide only short circuit protection. Overload protection must be provided by Low Voltage circuit breaker protection. Where a Supply Authority owned sole use transformer is provided, the SPD shall be a withdrawable circuit breaker with thermomagnetic releases and this device will provide the transformer overload protection. The Supply Authority must approve the protection settings for SPD’s.

For Corporation owned transformers the Main Switch shall be withdrawable circuit breaker with thermomagnetic releases.

For a Supply Authority owned sole use transformer or for a Corporation owned transformer with a rated temperature rise of 60/65\(^\circ\)C, the current protection minimum pick up current setting should be set at not more than 105\% of transformer nominal rated current.

For a Corporation owned transformer with a rated temperature rise of 50/55\(^\circ\)C, the over current protection minimum pick up current setting should be set at not more than 115\% of transformer nominal rated current.

6.5 Metering

All pump station perimeter fence personnel access gates should be locked with the relevant Operations Branch standard series padlock, and the electrical standard EM1 keyed locking system padlock in series. Where supply authority metering equipment is located within the pump station building, the building access door should be fitted with a dual barrel lock with night latch, having both the relevant Operations Branch standard series lock barrel and the electrical standard EM1 keyed locking system barrel. Since the electrical standard EM1 keyed locking system lock can be opened by the supply authority meter readers master key, supply authority meter readers thus will be able to obtain access to their equipment as required by Electricity Act Regulations.

As specified in WA Electrical Requirements, supplies with a maximum demand as defined by AS 3000 of not more than 100 amp will be metered with full current meters.

Supplies above this size will be fitted with current transformer metering. These CT’s will be located within the main switchboard. If the switchboard is located indoors, the kWh meters may be located in a meter box on an internal face of a pump station wall rather than in the main switchboard. However, if the switchboard is located outdoors, the meters should be fitted in the switchboard proper...
behind doors fitted with EM1 keyed locking system locks in order to provide supply authority meter reader access. Viewing windows shall not be provided in such doors because of their susceptibility to vandal damage.

Switchboard cubicle doors covering supply authority kWh meters should be labelled as such.

6.6 Corporation Substations

Transformers rated up to and including 200 kVA can be pole mounted and then will not require substation enclosures. Similarly 160 kVA URD type pad mounted substations may be used without substation enclosures. Pole mounted transformers and URD type pad mounted transformers shall be in accordance with the Water Corporation’s type specifications (DS26) for such transformers.

A clearance of 6 metres shall be provided between URD type pad mounted transformers and kiosk type transformers and any adjacent buildings.

The designer shall ensure that the W.A. Electrical requirements are adhered to with respect to the submission of designs for High Voltage sites. The Designer shall make such submissions. Design submissions (consisting of single line diagrams, protection grading diagrams, earthing diagrams, site layout, equipment selections etc) shall be approved by the Supply Authority prior to the start of the detail design.

6.7 Substation Earthing

Earthing arrangements for substations shall be as described in Section 9.

6.8 Emergency Incoming Supply

6.8.1 Earthing of Alternator Windings Neutral Point

If a standby generating set is being connected to a switchboard with a MEN connection, the neutral and earthing connections shall be as shown on Fig. 2.2 of AS 3010.1:2005.

If a standby generating set is being connected to a switchboard without a MEN connection, the neutral and earthing connection shall be as shown on Fig. 2.8 of AS 3010.1:2005.

6.8.2 AVR Characteristics for Alternators on Non Linear Loads

The main requirement is that the alternator automatic voltage regulator (AVR) shall be three phase sensing and shall respond to the RMS value of the alternator output voltage.

6.8.3 Alternator AVR Power Supply

A separate permanent magnet generator power supply for the AVR shall be specified for alternators supplying relatively large non-linear loads.

A separate permanent magnet generator power supply for the AVR is recommended for alternators supplying relatively large motor loads in order to minimize the effects of motor starting currents.

6.8.4 Sizing of Engines and Associated Alternators

(a) The engine shall be sized for standby duty with the load being defined in terms of the prime power requirement and the 24 hour average power requirement, both as defined in ISO 8526.1. Oversizing diesel engines results in performance and maintenance problems and should be avoided.

(b) The alternator shall be sized to be able to supply the maximum continuous kVA demand with a minimum power factor of 0.8.
(c) The generator shall be capable of supplying motor loads and shall be sized such that voltage dips due to motor starting comply with the requirements of clause 7.1.1(b) of this Design Standard.

(d) Variable speed controllers demand non-linear currents from the electrical supply and these currents cause distortion of the input voltage waveform, the amount of distortion being dependent on the supply sub-transient impedance. The sub transient impedance of an alternator is approximately 3 times the impedance of a similar sized transformer, so that generally the harmonic distortion problem is much worse if the installation is being supplied from a generator than if it is being supplied by a transformer. This problem could be overcome by oversizing the alternator by a factor of 3. However this would require a non-standard generating set arrangement, thus limiting availability. Oversizing the generator is not considered a practical solution in the commercial sense for portable generating sets.

(e) In the normal generating set, the alternator rated kVA will be 125% of the engine kW prime power rating.

(f) If a pump station is to include variable speed drives and the installation is to be made suitable for supply from a generating set, the variable speed controllers may need to be fitted with A.C. line reactors depending on the ratio of non-linear load to total load and whether or not the variable speed controllers are fitted with D.C. bus reactors or D.C. bus filters. The Designer shall carry out calculations to determine whether A.C. line reactors are required, and if so, to determine the size of such reactors. (refer note at clause 7.4.1e)

(g) If the generating set is normal in respect to engine and alternator ratings and the non-linear load consists of 6 pulse uncontrolled converters, A.C. line reactors will not be required provided that the ratio of non-linear load kW is less than 40% of the generating set engine prime power kW.

(h) If the generating set is normal in respect to engine and alternator ratings and the non-linear load consists of 6 pulse uncontrolled converters fitted with D.C. bus filters and 5% A.C. line reactors, the harmonic voltage distortion will be acceptable provided that the non-linear load kW is less than 90% of the generating set engine prime power kW.

6.9 Supply Authority Substations

Where the supply authority provide a supply authority owned transformer (often in padmount kiosk configuration) on a Corporation site, and provided on a “sole use” basis, the supply is at low voltage (point of attachment) and the Point of Common Coupling (PCC) is at high voltage. The supply authority substation is owned by the supply authority and paid for, either in full or on a proportional basis, by the Corporation. Refer to clause 9.3 for the earthing arrangement.

6.10 Transformer Sizing

Transformers shall be sized to be the next standard size above the maximum kVA demand of the site and selected to take into account the voltage disturbance/voltage distortion limits discussed in Section 7.
7 MOTOR STARTING AND SPEED CONTROL

7.1 Voltage Disturbances

Motor starting and operation of non-linear loads such as electronic soft starters and variable speed controllers cause disturbances in the voltage waveforms at the point of common coupling with the Supply Authority network and within the Corporation’s electrical installation. Voltage dips during starting and harmonic distortion of the voltage waveform due to the operation of electronic equipment are the principal types of voltage disturbance and these are discussed hereunder.

7.1.1 Voltage Level Disturbance Limits within the Installation

At points of common coupling within the Corporation’s installation motor starting shall not cause:

(a) the voltage to dip more than 15% (IEC 61000-2-4 Class 3) when the installation is being supplied from the Supply Authority network,

(b) the voltage to dip more than 20% when the installation is being supplied from an on-site Corporation generating set having the voltage regulator set to 5% above nominal voltage.

7.1.2 Voltage Harmonic Distortion Limits within the Installation

(a) At points of common coupling within the Corporation’s installation operation of electronic equipment including electronic soft starters and variable speed controllers shall not cause:

(i) the 3 second mean r.m.s. voltage waveform distortion to exceed 15% (IEC 61000-2-4),

(ii) the 10 minute mean r.m.s. voltage waveform distortion level to exceed 10% (IEC 61000.2.4 and BSEN 50160), or

(iii) the voltage waveform notching level to exceed 20%.

The above limits shall apply when the installation is being supplied from the Supply Authority Network and when it is being supplied from an on-site generating set.

(b) Within the Corporation’s installation, any electronic equipment which uses the 50 Hz signal (e.g. for timing or phase reference) shall either, incorporate 50 Hz band pass filtering, or shall be supplied via a 50 Hz band pass filter.

7.1.3 Voltage Level Disturbance Limits at Supply Authority P.C.C.

(a) The permissible level of voltage dip at the point of common coupling with the Supply Authority network caused by motor starting will be determined ultimately by the Supply Authority.

(b) Western Power’s Technical Rules specify that the limits on voltage dips caused by individual consumers on Western Power 22 kV and 33 kV networks shall be determined in accordance with AS/NZS 61000.3.7 and it can be assumed that other Supply Authorities will apply similar limits.

(c) If at a particular proposed installation, the minimum period between motor starts will be greater than 10 minutes and the motor start kVA will be less than 0.4% of the short circuit kVA, AS/NZS 61000-3-7 recommends that the Supply Authority permit the installation to be connected without further examination.

(d) Generally this will be the case for pump stations with the electrical configurations shown on Standard Drawings MN01. Otherwise reference should be made to Design Standard DS21 Clause 4.3.3.
7.1.4 Continuous Voltage Harmonic Distortion Limits at Supply Authority P.C.C.

(a) The permissible level of harmonic voltage at the point of common coupling with the Supply Authority network caused by an individual consumer will be determined ultimately by the Supply Authority.

(b) Calculation of applicable limits for continuous harmonic distortion to the voltage waveform at the point of common coupling with the Supply Authority are discussed in detail in Section 4 of Water Corporation Design Standard DS21. Calculation of the harmonic limits by this method is relatively complicated and it is probable that the Supply Authority will not be prepared to undertake this design work for the relatively small installations covered by the scope of the Design Standard.

(c) Western Power’s Technical Rules specify that the limits on harmonic voltage distortion caused by individual consumers on Western Power 22 kV and 33 kV networks shall be determined in accordance with AS/NZS 61000-3-6 and it can be assumed that other Supply Authorities will apply similar limits.

(d) In relation to installations having agreed low power demand (i.e. within the scope of this Design Standard) and where the point of common coupling is at High Voltage, AS/NZS 61000-3-6 clause D2.2 Note 4 recommended that the Supply Authority should not set the limit on individual harmonic levels at below 0.1%.

Provided that this limit will not be exceeded in respect to such an installation, it can be assumed that the installation will be acceptable to the Supply Authority.

(e) The short circuit ratio \( R_{sc} \) for a particular installation is defined as the ratio of short circuit fault kVA to load kVA at the point of common coupling with the Supply Authority network. If at a particular proposed installation, \( R_{sc} \) is more than 1000, AS/NZS 61000-3-6 recommends that the Supply Authority permit the installation to be connected without further examination.

(f) AS/NZS 61000-2-12 does not cover installations which have a Low Voltage point of common coupling with the Supply Authority network.

Western Power have previously specified a voltage waveform total harmonic distortion limit of 1.5% for such installations and, in the absence of any instructions to the contrary, this value must be assumed to be the current requirement. (In most cases, where the installation has a Low Voltage point of common coupling, an unfiltered 6 pulse variable speed drive will not cause total harmonic distortion of the Low Voltage waveform of greater than 1.5% provided that the value of \( R_{sc} \) is greater than 200).

7.1.5 Starting Harmonic Distortion Limits at Supply Authority P.C.C.

(a) The permissible level of voltage harmonic distortion at the point of common coupling with the Supply Authority network caused by motor starting will be determined ultimately by the Supply Authority.

(b) AS/NZS 61000-3-6 does not address voltage distortion limits due to short duration bursts of harmonic currents.

(c) AS/NZS 61000-2-12 specifies that for High Voltage public networks, the ratio between the total harmonic distortion (THD) compatibility limit due to short duration (<3 sec.) bursts of harmonic currents which are not less than 10 minutes apart and the continuous THD compatibility limit shall be 1.38 (11÷8).
7.1.6 Stations Supplied from the L.V. Distribution

(a) If the supply authority provides a transformer to power a particular site at their own cost (a distribution substation as opposed to a sole use substation, they retain the right to supply other consumers from that transformer (either immediately or in the future). In such cases, the pump station supply shall be considered to be from LV distribution.

(b) Normally the supply authority will agree without detailed investigation to motors rated up to and including 22 kW being supplied direct from the supply authority LV distribution provided that LV distribution is readily available.

(c) In pump stations supplied from the supply authority LV distribution, fixed speed motors rated greater than 4 kW shall be started with either closed transition auto transformer starters or electronic soft starters.

7.2 Motor Starting General

7.2.1 Maximum Starting Frequency

The type of motor starting to be used will depend on the size of motor, the capacity of the supply authority supply to the pump station, the location of the pump station and the type of pump to be started.

Maximum Starting Frequency for a pump emptying or filling a tank, the maximum starting frequency for a motor-pump unit is determined by the pump flow rate and the control volume of the control tank.

If:

\[ Q_p = \text{pump flow rate m}^3/\text{hr} \]
\[ V_c = \text{control volume m}^3 (\text{i.e. volume between start level and stop level}) \]
\[ N = \text{maximum number of starts per hour} \]

Then \[ N = Q_p \times (4V_c)^{1/3} \text{starts per hour} \]

7.2.2 Approved Types of Starter

The type of starter to be used in any particular application shall be selected from the following list of preferred types, depending on the starting requirements of the application:

(a) direct on line starters

(b) closed transition autotransformer starters

(c) electronic soft starters (only as per clause 7.3.1).

(d) variable speed controllers

(e) secondary resistance starters

7.2.3 Not Approved Types of Starter

The following types of starter are not approved for general use and shall not be selected without special approval from the Principal Engineer.

(a) star delta starters
(b) open transition autotransformer starters
(c) primary reactance starters
(d) primary resistance starters including liquid resistance starters.
(e) electronic soft starters (except as per clause 7.3.1).

7.2.4 Variable Speed Controllers as Starters

(a) Motors controlled by variable speed controllers can deliver full load torque over the whole speed range from stopped to full speed, in some cases without exceeding the motor rated full load current. However, such controllers incorporate converters which introduce harmonics into the mains supply network and do so for the whole operating time, not just during the starting time.

(b) If the fault level at the site is low it will be necessary to incur further significant expense to reduce the harmonic distortion of the supply waveform to acceptable limits as detailed hereunder.

(c) The use of variable speed controllers merely to limit disturbances to the mains supply network is an expensive option and shall be employed only as a last resort.

7.2.5 Starting Small Motors

Normally motors rated up to, and including, 4 kW should be started DOL (direct-on-line) unless some special mechanical characteristic of the load requires slow acceleration during the start sequence. However, in locations having very limited electrical supply capacity, assisted starting may be required for such motors.

7.2.6 Starting High Torque Loads

All helical rotor pump motors should be started DOL, (or with secondary resistance starters as a last resort.

7.2.7 Starting Quadratic Torque Loads

(a) Drives connected to quadratic loads, such as centrifugal pumps are required to generate enough torque to accelerate the pump to more than 93% full speed without exceeding the required starting current limit.

(b) Reduced voltage starters including auto transformer starters and electronic soft starters limit the starting current and thus the starting torque (Clause 4.11 refers).

7.3 Electronic Soft Starters

7.3.1 Application

(a) For the reasons explained in clauses 4.11 and 7.2.7 electronic soft starters are not the best option for limiting starting current on motors driving centrifugal pumps unless:

   (i) there are mechanical reasons which require the motor output torque to increase as a continuous ramp function during starting, or
   (ii) there are mechanical reasons which require the motor output torque to decrease as a continuous ramp function during stopping.

(b) Electronic soft starters shall not be used solely to limit motor starting current unless specially approved in writing by the Principal Engineer.
(c) During stopping and starting electronic soft starters on pump drives will draw up to 4 times full load current at about 75% nominal speed. If an electronic soft starter is used to ramp pump flow up and down, the motor will be required to operate at this speed for much of the ramping time and significant heating of the motor windings will result.

(d) The ramping up times and ramping down times on electronic soft starters fitted to submersible bore hole motors shall not exceed 4 seconds.

(e) The ramping up times and ramping down times on electronic soft starters fitted to motors having insulation temperature ratings matching to their rated temperature rises shall not exceed 8 seconds.

(f) The ramping up times and ramping down times on electronic soft starters fitted to motors having a Class B temperature rise and class F insulation shall not exceed 15 seconds.

(g) Electronic soft starters shall not be used to control motors driving high inertia loads such as shaft driven bore hole pumps or pumps fitted with fly wheels.

7.3.2 Principle of Operation

Electronic soft starters limit the RMS starting current by delaying the current flow after each current zero as shown diagrammatically for a resistive load in Fig. 7.1 hereunder. For an inductive load, the current waveform will be rounded off and delayed.

Nevertheless, this starting method introduces a significant amount of harmonic current in the mains supply network. Only odd harmonic currents will be produced, the order of magnitude of which compared to the fundamental will vary from 20% for the 5th harmonic to 5% for the 19th harmonic.

Fig 7.1
Thyristor Limited Current Waveform in a Resistive Load

7.3.3 Six Wire Connection

The six wire connection for electronic soft motor starters is as shown at Fig. 7.2 hereunder.
Connections shown are for clockwise rotation when facing the motor drive end. For anti-clockwise rotation connect the incoming line white phase to starter terminal L3 and the incoming line blue phase to starter terminal L2.

This connection provides direct monitoring of the actual currents flowing in the motor windings. The advantage of this connection is that the electronic soft starter can be reduced in rating as the currents are 0.58 lower. Consequently, this connection shall be used wherever practical.

### 7.3.4 Three Wire Connection

The simplest form of connection for solid state soft starters is the three wire connection shown at Fig. 7.3 hereunder.
This form of connection has the advantage that the starter is in line and the motor cable need be only three core. This will be a particular advantage if the associated motor is a bore hole submersible motor.

7.3.5 Surge Protection

Because of the solid state components in electronic soft starters, these units are more susceptible to failure resulting from voltage surges than are electromechanical items of switchgear. Such voltage surges may be caused by lightning or by High Voltage switching.

Consequently, Low Voltage surge diverters shall be provided on the incoming terminals of motor control centres or switchboards housing electronic soft starters.

7.3.6 Line Contactors

Line contactors provide isolation of the starters when the motors are not running and consequently further reduce the probability of damage to electronic soft starters due to voltage surges. Line contactors shall be provided on all electronic soft starters.

7.3.7 By Pass Contactors

The voltage drop across conducting thyristors is approximately 0.5 volt. The use of bypass contactors eliminates the associated losses and the resulting increase in enclosure temperature. By pass contactors shall be installed on all electronic soft starters on drives which run continuously for periods of 15 minutes or longer.

7.3.8 Type 2 Coordination

Electronic soft starters shall be fitted with semiconductor protection fuses in accordance with AS 60269.4.0 so as to provide Type 2 co-ordination in accordance with AS 60947.4.2. Such fuses shall be connected as shown in Fig. 7.2 and Fig. 7.3.
7.4 Variable Speed Controllers

7.4.1 Types of Variable Speed Controller

(a) Variable speed controllers in the output power range covered by this Design Standard are normally of the type having an uncontrolled 6 pulse converter input and a pulse width modulated (PWM) output.

(b) Variable speed controllers in this range are available with controlled converter inputs. However such units give rise to voltage waveform notching problems and such units should be avoided wherever practical. The problem of waveform notching is discussed in Design Standard DS21.

(c) Because of its rectifier action, the input current an uncontrolled converter contains a significant number of harmonics and in practice the magnitude of these harmonic currents will be markedly different from the theoretical values.

(d) Harmonic current levels can be derived theoretically on the basis of an infinite bus power supply. However, in practice harmonic current levels depend on the impedance of the supply system. In addition most variable speed controllers incorporate some form of internal harmonic filtering as standard which will significantly affect the level of harmonic current drawn by the variable speed controller.

(e) In order to reduce the harmonic demand, individual variable speed controllers may be fitted with such devices as DC bus filters, A.C. line reactance, A.C. line filters, or a combination of such devices, either as standard or as add on modules. Such devices shall be purchased from the vendor as part of each variable speed controller. **Note:** AC line filters connected to VSCs generally have leading power factor at low load and may present problems when connected to a generating set supply. Such circumstance can drive the alternator into over voltage conditions potentially causing incorrect operation or damage to the load or the alternator. The ability of an alternator to absorb reactive power is defined by a reverse kVAR limit therefore alternator capability curves must be consulted during design.

(f) The dV/dt ratio of the raw output voltage waveforms from PWM variable speed controllers is high and application of this voltage waveform to the motor terminals may over stress the motor insulation depending on the length of motor cable and the type of motor insulation.

(g) Variable speed controllers shall have a switching frequency of 3 kHz, except when used in conjunction with sine filters, in which case the switching frequency shall match the requirements of the sine filter.

(h) IEC 60034.25 specifies the requirements for motors designed specifically for operation with VSC’s. A motor complying with the requirements of IEC 60034.25 shall be permitted to be connected directly to the output terminal of a controlling VSC with a switching frequency of 3 kHz by a screened cable of a length not greater than 60 metres.

(i) AS 60034.17 specifies the requirements for type of motors which were designed primarily for 50 Hz sine waveform operation, when these are operated supplied from VSC’s. A motor complying with the requirements of AS 60034.17 shall be permitted to be connected directly to the output of a controlling VSC with a switching frequency of 3 kHz by a screened cable of a length not greater than 30 metres.

(j) A motor complying with the requirements of AS 60034.17 shall be permitted to be connected to the output of a controlling VSC with a switching frequency of 3 kHz via a 500 V/μs dV/dt filter by a screened cable of a length not greater than 100 metres.
(k) Submersible bore hole motors and submersible sewage pump motors shall be connected to VSC’s only via suitable sine filters.

(l) VSC’s supplying motors with a shaft height of greater than 280 mm should be fitted with high frequency common mode magnetic core inductors around the motor cables, unless the motor is fitted with an insulated non drive end bearing.

7.4.2 Motor Harmonic Current Losses

(a) The efficiency of fixed speed motors supplied with a voltage having a harmonic distortion level at the maximum value allowable as defined in clause 7.1.2 can be expected to suffer approximately a 3% reduction in efficiency and the Designer shall allow for this reduction in available output from fixed speed drive.

(b) Depending on the modulation algorithm used in the particular variable speed controller, motors connected to PWM variable speed controllers may suffer a reduction in efficiency of up to 5% (Clause 3.1 and IEC 60034-17 refers).

7.4.3 Transformer Eddy Current Losses

Transformer eddy current copper losses are increased significantly by the higher harmonic currents.

However, as a general rule for transformers of ratings within the scope of this design standard, provided that the total current load on the transformer does not exceed 90% of transformer rating and the overall current partially weighted harmonic distortion (PWHD) does not exceed 25%, the total transformer losses will not exceed transformer rated losses. (PWHD is defined in IEC 61000.3.4)

7.4.4 Electromagnetic Interference from Variable Speed Controllers

(a) Unless input filtering is provided, PWM switching will cause common mode interference voltages to appear on the incoming supply cables to the variable speed controller.

(b) If an isolating transformer is being provided, the interference problems shall be avoided by providing an earthed screen between the primary and secondary windings and by installing screened cable between the transformer and the variable speed controller. Otherwise input common mode filtering shall be provided.

(c) The output voltage waveform generated by the PWM type of variable speed controller is at a high frequency and contains multiple recurring fast transients unless output filtering is provided (Clause 7.4.1 refers). Consequently, unless output filtering is provided, the cable connecting the variable speed controller to the motor shall be screened, with the screen earthed at both ends.

(d) The types of screened cable to be used with variable speed controllers are discussed in Section 10.

7.4.5 Isolation

(a) If the variable speed drive is required to be fitted with an emergency stop function in accordance with AS/NZS 3000 clause 2.3.5, the variable speed controller shall be supplied via a line side contactor in order to provide complete drive isolation under emergency stop conditions.

(b) If the controller is to be de-energised as part of normal operations, isolation shall be achieved by use of a line side contactor rather than a circuit breaker.

(c) If the controller is to be left energized, except under emergency stop conditions, the controller’s cooling fans shall be thermostatically controlled as part of the manufacturer’s standard design.
7.4.6 Resonance

Resonance is possible in transformer fed installations which include both power factor capacitors and variable speed controllers. As a rule of thumb such resonances will be avoided provided that the capacitor kVAR is not more than 20% of the supply transformer rating. Since variable speed controllers operate at a relatively high power factor, resonance is not likely to be a problem as far as installations covered by the scope of this Design Standard are concerned.

7.5 Calculation of Voltage Fluctuation

(a) The Designer shall calculate the motor starting kVA and shall obtain the short circuit fault level kVA from the Supply Authority.

(b) In accordance with Table 4 of AS/NZS 61000.3.7 if the motor starting kVA is less than 0.4% of the short circuit fault level kVA at the point of common coupling with the Supply Authority High Voltage network, the Designer may assume that the voltage dip at the point of common coupling with the Supply Authority High Voltage network caused by motor starting is acceptable without further examination.

(c) If the motor starting kVA is more than 0.4% of the short circuit fault level kVA at the point of common coupling with the Supply Authority network, the Designer shall obtain the site supply source impedance value from the Supply Authority and shall carry out formal and recorded calculations to determine the voltage dip at the point of common coupling with the Supply Authority network caused by motor starting currents, so as to confirm that the allowable voltage dip limits will not be exceeded.

(d) Similarly the Designer shall carry out formal and recorded calculations so as to verify conformance with voltage dip limits at the points of common coupling within the Corporation’s installation, both with the supply from the Supply Authority’s network and from the standby generator, if the latter is ever to be provided on either a permanent or temporary basis.

(e) All above calculations shall be made taking into account the “real” and “imaginary” parts of all of the parameters involved.

(f) Unless the actual values of the relevant parameters are known, including the torque speed curve(s) of the particular motor(s) and particular pump(s) to be used in the installation, the following values of starting current shall be used in the above calculations.

(i) for D.O.L. starting, 7 times the motor rated full load current at a power factor of 0.30,

(ii) for electronic soft starting 4.5 times the motor rated full load current at a power factor of 0.40 (refer clause 4.11)

(iii) for autotransformer starting, 3.2 times the motor rated full load current at a power factor of 0.30,

A current spike of more than 4 times motor full load current will occur at autotransformer starter change over to full voltage as the motor rotor is pulled into synchronism with the stator rotating magnetic field. However, this current will be largely resistive and can be ignored as far as voltage dip calculations are concerned.

7.6 Calculation of Harmonic Distortion

7.6.1 Calculation of Harmonic Distortion for Electronic Soft Starters

The principle of operation of electronic soft starters is discussed in clause 7.3.
The Designer shall obtain the site supply source impedance value from the Supply Authority and shall carry out formal and recorded calculations so as to verify conformance with voltage waveform harmonic distortion limits at the points of common coupling within the Corporation’s installation, both with the supply from the Supply Authority’s network and from the standby generator, if the latter is ever to be provided on either a permanent or temporary basis.

Similarly the Designer shall carry out formal and recorded calculations to determine the harmonic distortion to the voltage waveform at the point of common coupling with the Supply Authority H.V. network caused by motor starting currents, so as to confirm that the allowable harmonic distortion limits will not be exceeded.

Unless the Supply Authority H.V. network fault level at the point of common coupling is particularly low, the harmonic distortion at a point of common coupling within the Corporation’s installation will be the critical factor.

All of the above harmonic distortion calculations may be made taking into account only the “imaginary” parts of the parameters involved.

For the purposes of these calculations, the harmonic current content of an electronic soft starter at a current limit of 4 times full load current shall be taken to be as follows:

(a) 3rd harmonic 10% of the fundamental,
(b) 5th harmonic 20% of the fundamental,
(c) 7th harmonic 14% of the fundamental,
(d) 11th harmonic 9% of the fundamental,
(e) 13th harmonic 7% of the fundamental,
(f) Higher harmonics negligible

7.6.2 Calculation of Harmonic Distortion for Variable Speed Controllers

The amount of harmonic current taken by a particular variable speed controller depends on the source impedance of the supply to the variable speed controller, the load, the harmonic filtering built in to the controller as standard, and any external filtering provided in the line to the controller.

Calculation of harmonic current values is complicated without the use of a computer model of the particular variable speed controller together with any filtering and source impedances. Fortunately such computer programmes are available, including some from various manufacturers of variable speed controllers.

Using such a computer programme the Designer shall carry out formal and recorded calculations to determine the harmonic currents taken and the harmonic distortion to the voltage waveform caused at the point of common coupling with the Supply Authority network due to operation of the variable speed controller(s) so as to confirm that the allowable harmonic distortion limits will not be exceeded.

Similarly the Designer shall carry out formal and recorded calculations as to verify conformance with voltage waveform harmonic distortion limits at the points of common coupling within the Corporation’s installation, both with the Supply Authority’s network and from the standby generator, if the latter is ever to be provided on either a permanent or temporary basis.

If the variable speed controller selected ultimately for installation is of a different make or model to the unit on which the engineering design was based, the Designer shall repeat the above calculations with appropriate parameters entered into the computer programme.
7.7 Typical Impedances for Overhead Lines

The following values may be used in association with calculations described at Section 7.5 and 7.6.

Overhead line reactance is approximately 0.38 ohms per kilometre for normal rural 3 phase construction using copper or aluminium conductors. Where high tensile steel conductors are used, this figure is increased to approximately 0.7 ohms per kilometre.

Overhead line resistance varies of course with the type and size of the conductor used. Resistance values for the various conductors in common use in normal rural HV construction are:

- 6/1.0 (6/1/.118in) ACSR (common for rural lines) 0.68 ohms/kilometre
- 6/1.4 (6/1/.093in) ACSR 1.09 ohms/kilometre
- 3/2.75 High tensile galvanised steel 10.3 ohms/kilometre
- 7/2.03(7/.080in) copper 0.79 ohms/kilometre
- 7/1.63(7/.064in) copper 1.23 ohms/kilometre

7.8 Typical Impedances for Transformers

The following values may be used in association with calculations described at Section 7.5 and 7.6.

<table>
<thead>
<tr>
<th>HV Rating (kV)</th>
<th>6.6</th>
<th>11</th>
<th>22</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>KVA Rating</td>
<td>Impedance %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>3.7</td>
<td>3.7</td>
<td>3.6</td>
<td>4.4</td>
</tr>
<tr>
<td>63</td>
<td>3.9</td>
<td>3.9</td>
<td>4.7</td>
<td>5.9</td>
</tr>
<tr>
<td>100</td>
<td>3.7</td>
<td>3.7</td>
<td>3.8</td>
<td>4.4</td>
</tr>
<tr>
<td>200</td>
<td>3.7</td>
<td>3.7</td>
<td>3.8</td>
<td>4.2</td>
</tr>
<tr>
<td>315</td>
<td>4.4</td>
<td>4.4</td>
<td>5.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Note: Western Power standard impedances can be as low as 3.3% for ≤ 100 kVA and 4% for ≤ 315 kVA.
8 SWITCHBOARDS

8.1 Mid-Range Low Voltage Switchboards

This clause has been deleted. Switchboards requiring a full load rating of more than 440 amps or a short circuit current rating of more than 10 kA are now beyond the scope of this standard and are required to be designed in accordance with Electrical Design Standard DS21.

8.2 Minor Low Voltage Switchboards

8.2.1 Definition

For the purposes of this standard, a Low Voltage switchboard shall be classified as a minor Low Voltage switchboard if the switchboard:

(a) has a full load current rating not greater than 440 amps, and

(b) is rated for installation only in the low fault current level situations described AS 3439.1 clauses 8.2.3.1.1 and 8.2.3.1.2 (i.e. as specified Clause 8.2.10).

8.2.2 Standards

Minor Low Voltage switchboards shall be type tested or partially type tested switchboards design constructed and tested in accordance with:

AS/NZS 3439.1 Low voltage switchgear and control assemblies – Type tested and partially type tested assemblies, and

AS 60529 Degrees of protection provided by enclosures (IP Code).

8.2.3 Special Service Conditions

(a) The maximum ambient air temperature outside switchboards to be installed to the South West Region of Western Australia shall be taken to be 45°C whether the switchboard is to be installed indoors or outdoors.

(b) The maximum ambient air temperature outside switchboards to be installed in regions of Western Australia other than the South West Region shall be taken to be 50°C whether the switchboard is to be installed indoors or outdoors.

(c) For outdoor switchboards not provided with full shade, an additional internal temperature rise of 5°C shall be allowed for solar heating.

(d) Under maximum ambient and operating conditions, the air temperature rise within switchboard compartments due to equipment losses shall be such that the temperature of air surrounding any item of electrical equipment does not exceed the equipment’s maximum ambient temperature rating.

8.2.4 Construction

(a) Minor Low Voltage switchboards shall be sheet metal enclosed switchboards of the Form 1 type of enclosure in accordance with AS/NZS 3439.1 Annex D Fig. D2.

(b) Minor Low Voltage switchboard enclosures shall be of robust construction and shall be protected against corrosion by painting or powder coating to not less than ISO service category 4.
(c) Minor Low Voltage Switchboards with a full load rated current greater than 100 amps shall be of the multiple cubicle type in accordance with AS/NZS 3439.1 clause 2.3.3.2 and shall be arranged so that the outgoing terminations are separated from incoming terminations.

(d) All conductors on the line side of the incoming service protection device in minor Low Voltage switchboards shall be insulated fully.

(e) Outdoor Minor Low Voltage switchboard cubicles shall be constructed of 3mm marine grade aluminium and painted gloss white. The rear door of the switchboard shall be fitted externally with a label stating “Danger 415 Volts behind”.

8.2.5 Rated Diversity Factor

Minor Low Voltage switchboards shall have a rated diversity factor of 1.0.

8.2.6 Degree of Protection

(a) Indoor switchboard cubicles shall be such that electrical equipment is provided with a degree of protection of not less than IP53.

The installation of such switchboards shall be such as to minimize the possibility of water falling or impinging onto the switchboard. Floor mounted switchboards shall be mounted on a fabricated plinth so that water splashed onto the floor cannot enter the switchboard proper.

Any enclosure of such plinths shall be arranged as to prevent the entrapment of water or of sewerage gases.

(b) Outdoor switchboard cubicles shall be such that electrical equipment is provided with a degree of protection of either IP56 or IP55W.

8.2.7 Rated Insulation and Operating Voltages

Minor Low Voltage switchboards shall have a rated insulation voltage in accordance with AS 3439.1 of 440 volts or the highest phase to phase operating voltage of equipment mounted in the switchboard, whichever is the greater.

Low Voltage (415V) switchboards shall have a rated operating voltage of not less than 440 volts.

8.2.8 Creepage Distances

Creepage distances across insulating surfaces within minor Low Voltage switchboards shall not be less than the values shown in Table 16 of AS/NZS 3439.1 for atmospheric pollution degree 3. Wherever practical, creepage distances in accordance with the values shown for atmospheric pollution degree 4 shall be provided.

8.2.9 Rated Impulse Withstand Voltage

Minor Low Voltage switchboards shall have a rated impulse withstand voltage rating of 6 kV.

8.2.10 Rated Short-Time Current

Minor Low Voltage switchboards shall be rated for connection to an electrical supply having a prospective fault level of not more than 10 kA or a fault current cut off limit of not more than 17 kA.

Unless the main circuit is protected by meter fuses rated not greater than 100 amp, the main circuit in minor Low Voltage switchboards shall have a short time current rating of not less than 10 kA for 1 second.
8.2.11 Internal Arcing Fault Protection

(a) Minor Low Voltage switchboards shall incorporate measures to provide increased security against the occurrence or effects of internal arcing faults. Such measures shall be based on the guidelines given in AS/NZS 3439.1 Appendix ZC.

(b) The line side of the switchboard short circuit protective device (SCPD) shall be fully insulated. The fault current flowing into the switchboard shall be limited by the SCPD and shall limit the \(I^2t\) let through energy to \(\leq 1.8 \times 10^6\) amp\(^2\)*secs at a prospective fault current level of 10 kA. Hence, arc fault verification tests shall not be required.

(c) Compartments shall have no accessible bare conductors (i.e. all conductors are insulated when all insulating covers and sleeves are in place).

8.2.12 Type Specifications

The following Type Specifications are suitable for specifying the various types of Minor Low Voltage switchboards:

DS26-10 Type Specification for Minor L.V. Switchboards (for > 100 amps, \(\leq 200\) amps, indoors and outdoors)

DS26-11 Type Specification for Extended Range Minor Outdoor L.V. Switchboards (for >200 amps, \(\leq 440\) amps, indoors and outdoors)

DS26-24 Type Specification for L.V. Motor Control Centre Type Switchboards (for >200 amps, \(\leq 440\) amps, indoors only).

DS26-36 Type Specification for Minor L.V. Switchboards (for \(\leq 100\) amps, indoors and outdoors)

DS26-38 Type Specification for Distribution Boards \(\leq 200\) amps

8.3 Busbars

8.3.1 Arrangement of Busbars

For preference, busbars which are substantially in one plane shall be arranged in order Red - White - Blue as follows:

(a) When the run of busbars is horizontal, Red shall be on top, or to the left, or farthest away, as viewed from the front of the switchboard.

(b) When the run of busbars is vertical, the red shall be left, or farthest away as viewed from the front of the switchboard.

(c) When the neutral busbar is in the same plane as the phase busbar, the neutral shall occupy an outer position, and shall be readily distinguishable from the phase busbars.

Busbars not arranged as above shall be colour coded in each compartment.

8.3.2 Continuous Current Rating of Busbars

The continuous current rating of main busbars shall be not less than the rating of the incoming circuit breaker or main fuses.

In the case of motor control centre type switchboards, the continuous current rating of busbar droppers to equipment stacks shall be not less than 120% of the rating of the stack when fully equipped and not less than 50% of the continuous rating of the main busbars.
8.3.3 Access to Busbar Joints

Good engineering practice requires that access to all electrical equipment and conductors be provided for in switchboard designs to allow for replacement of faulted components. AS3000 specifies that electrical equipment which requires attention shall be installed to provide an adequate and safe means of access and working space for such attention.

The degree of accessibility necessary to any particular component depends on the risk of failure and the consequence of a prolonged outage due to such a failure. It is accepted that switchboards which require dismantling of other equipment to provide access to busbar chambers comply with the minimum requirements of AS3000 and therefore may be installed legally without back access. However, in general the Corporation cannot afford to risk prolonged plant outages and consequently the practice of installing multi-tier switchboards in such a manner to necessitate substantial dismantling of the switchboard to obtain access to busbar joints, shall be avoided wherever practical.

The risk and consequence of busbar failure for a typical single tier motor control centre type switchboard is so small, that these can be installed without rear access in any application.

Where a typical multi-tiered motor control centre type switchboard is to be retrofitted into an existing building, space limitations may require that it be installed without back access, despite the increased risk. In such cases, inspection and testing of busbar bolted joints at site prior to installation shall be specified, and shall include checking that all joint resistances are below 4 micro-ohms. In new installations, 600 mm shall be provided behind multi-tiered motor control centre type switchboards.

Switchboards in the “back to back” configuration shall not be permitted. In the case of motor control centre type switchboards, rear access cable zones shall not be permitted.

8.4 Location of Controls

All operator control devices including operating handles, control switches, indicators and meters shall be specified to be located no more than 1.8 metres and not less than 0.3 metres above floor level. The location of meters, secondary indicators, fault relays, etc. in a panel separate from the associated main switchboard panel shall be permitted provided that control switches and on-off indicators are mounted on the main switchboard panel with which these are associated.

8.5 Protection General

(a) For the purposes of this standard, protection equipment is defined as those electrical devices which are arranged to monitor the operation of associated plant and to shut down that plant automatically if conditions occur which jeopardise the safety of personnel or which will lead to damage to the plant.

(b) Protection equipment shall be set to trip marginally above the full load rating of the associated plant rather than marginally above the normal operating load because the latter settings may lead to nuisance tripping due to minor variations in the associated process. (Refer to Clause 8.7 in respect to the setting of thermal over load relays).

(c) A repeated cycle of protection tripping and resetting can lead to equipment failure and in some circumstances may be dangerous. Provision shall not be made for remote resetting of protection equipment unless sufficient telemetry is also provided to enable the remote operator to assess the cause of the trip and to ascertain that the fault conditions no longer exist.

(d) Protection equipment shall not be arranged to be reset automatically unless the associated control circuit is arranged to confirm that the prime cause of the fault has been corrected previously.
For the purposes of this standard, protection equipment has been classified as either primary or secondary protection as follows:

(i) Primary protection is defined as that essential protection equipment without which the plant shall not be operated even under close and continuous operator supervision. Instantaneous, earth leakage and thermal overcurrent relays, fuses and circuit breakers shall be considered primary protection.

(ii) Secondary protection is defined as that protection equipment without which the plant can be permitted to operate under close and continuous operator supervision. Overtemperature relays, flow and pressure relays, sequence detectors, etc. shall be considered secondary protection.

Primary protection shall act as directly as possible on the associated circuit and shall not be connected via PLC’s or similar equipment. Switchboards shall be designed so that plant can operate in the “emergency” mode with only primary protection connected.

Where the safety of personnel would be endangered by the failure of a protection or alarm circuit, the circuit should, where practical, be arranged so that the probable mode of circuit failure would result in a safe (usually shut down) alarm condition. Where only equipment would be endangered by the failure of a protection or alarm circuit, the circuit should be arranged to maximise overall plant reliability and to minimise false trips and alarms.

Pump condition monitoring and protection shall also comply with the requirements of DS32 Pump Stations – Mechanical, clause 3.13.

8.6 Protection Grading

Protection equipment shall be arranged so that adequate grading is provided between all such devices over the range of fault currents available at the particular site. Adequate grading shall be provided also between the Corporation’s protection equipment and the supply authority’s protection equipment. The possible use of protection equipment which has zone selectivity functionality shall be investigated in this regard if time based grading is found to be difficult in a particular application.

Coordination shall be provided between starters and their associated short circuit protection devices in accordance with AS 60947.4.1 - Type 2.

This requirement shall be deemed to be satisfied for a particular contactor and overload relay if:

(i) the contactor and overload relay are used in conjunction with a specified short circuit protection device which has been tested and certified to provide the combination with type 2 coordination, or

(ii) the contactor and overload relay are used in conjunction with a short circuit protection device which limits the $I^2t$ at 10 kA to less than the $I^2t$ at 10 kA let through of the above specified short circuit protection device.

8.7 Thermal Overcurrent Protection

Conventional motors and submersible sewage pump motors rated greater than 45 kW and submersible bore hole motors rated greater than 22 kW shall be protected by Sprecher & Schuh Type CEF-1 electronic motor protection relays or by other approved electronic motor protection relays having tripping characteristics similar to Sprecher & Schuh CEP-7-C electronic motor protection relays.
(b) Conventional motors and submersible sewage pump motors rated not greater than 45 kW, and submersible bore hole motors rated not greater than 22 kW shall be protected by approved bimetal thermal overload relays having tripping characteristics similar to Sprecher & Schuh Type CT bimetal thermal overload relays, or by approved electronic overload relays having tripping characteristics similar to Sprecher & Schuh Type CEP-7-C electronic motor protection relays.

(c) For submersible bore hole motors rated greater than 22 kW, the overload protection relay tripping current/time setting shall be 6FLC/4 seconds.

(d) For conventional motors and submersible sewage pump motors rated not greater than 45 kW and for submersible bore hole motors rated not greater than 22 kW, the overload protection relay tripping current/time setting shall be 6FLC/10 seconds. (Refer clause 7.3 for special requirements if electronic soft starters with ramping down facility are to be used).

(e) It would be more appropriate to use an overload protection relay with a tripping current/time setting of 6FLC/4 seconds for submersible bore hole motors rated not greater than 22kW. However, in order to achieve such a setting, protection relays of the type specified in sub clause (a) above would be required and the cost of such relays is relatively high in respect to the cost of such motors. Consequently, in view of the relatively small improvement in the level of protection provided by these more expensive relays in this application, their use to protect submersible bore hole motors rated at not greater than 22kW cannot be justified.

(f) Fixed speed motors which are not fitted with thermistor protection shall be provided with thermal over current relays as primary overload protection. In such cases, if a thermal over current relay is installed in series with the line to its associated motor, the relay shall be set at 100% motor nominal maximum continuous operating current. Alternatively in such cases, if a thermal over current relay is installed in series with the delta connections of its associated motor, the relay shall be set at 58% motor nominal maximum continuous operating current.

(g) Fixed speed motors which are fitted with thermistor protection also shall be provided with thermal over current relays as primary overload protection. In such cases, if a thermal over current relay is installed in series with the line to its associated motor, the relay shall be set at 100% motor nominal maximum continuous operating current. Alternatively in such cases, if a thermal over current relay is installed in series with the delta connections of its associated motor, the relay shall be set at 58% motor nominal maximum continuous operating current.

NOTE: Western Power’s technical rules allow for up to 2% negative sequence voltages in Low Voltage supplies.

A cage induction motor must be derated 5% in order to account for the additional heating which would be caused by negative sequence voltages of this magnitude (refer clause 3.1). However, 2% negative sequence voltages in the incoming supply to the motor will cause unbalanced phase currents with the highest phase current being typically 13% above the average phase current. Hence, at 95% load the current in one motor phase could be 8% above motor rated full load current without the motor being overheated. Therefore, if regular nuisance tripping is experienced, motors fitted with thermistors may have the thermal over current relay set to not greater than 110% motor nominal maximum continuous operating current (64% if in series with delta connections).
(h) Thermal over current relays installed in series with the line to associated variable speed drive motors shall be set at 100% motor nominal maximum continuous operating current, regardless of whether or not the associated motors are fitted with thermistor protection.

(i) Short circuit protection on reduced voltage starters controlling sewage pumps which are rated not more than 22 kW shall be set up to the DOL limit subject to adequate grading to allow for difficult starts due to “ragging” of the pump.

8.8 Thermistor Motor Protection

Motors to be protected by thermistor protection should be specified to have three thermistors connected in series, each having a temperature-resistance characteristic such that the resistance of each thermistor at trip temperature is 1000 ohms. The thermistor protection relay shall be set to trip if the thermistor loop resistance rises above 3000 ohms (clause 4.7 refers).

8.9 Current Transformers

8.9.1 General

The equivalent circuit of the current transformer is as shown hereunder (Fig 8.1).

For a protection current transformer the magnitude of the rated burden admittance \( z_{1} \) will be between one and two orders larger than the magnetising admittance \( y \). "Knee point voltage" is defined as the point at which a 10% increase in secondary emf produces a 50% increase in exciting current \( I_{e} \). It is, therefore, the point at which \( y \) starts to increase substantially with increased secondary emf, i.e. the point at which the CT starts to saturate.

"Rated Secondary Reference Voltage" of a protection CT is the rms value of secondary voltage upon which the performance of the CT is based. For a protection CT the Rated Secondary Reference Voltage will be less than, but of the same order as, the knee point voltage.

The equivalent circuit of the metering current transformer will be similar to that shown in Fig 8.1. However, the accuracy of same will be much improved and hence the magnetising admittance will be much reduced. Metering current transformers are usually designed to work over a range of 10% to 125% of rated current (which contrasts with the protection current transformers which are designed to work at up to the accuracy limit factor times 100% rated current).

8.9.2 Standards

Current transformers shall be in accordance with AS 60044.1 or with IEC 60044.1 and shall be designated in full in accordance with one or other of these standards.
8.9.3 Primary Current Rating

In any particular circuit, the primary current rating of associated current transformers shall be the next largest available current rating greater than the circuit continuous maximum demand current and shall not be greater than twice the continuous maximum demand current.

8.9.4 Short Time Thermal Current rating

Current transformers shall have a short time thermal current rating not less than the short time current rating specified for the whole of the associated switchboard with the exception that current transformers installed on the load side of current limiting fuses need only have a short time thermal current rating providing an allowable let through I^2t greater that the total I^2t of the associated current limiting fuse.

8.9.5 Rated Operating Voltage

Current transformers shall have a rated operating voltage not less than the rated operating voltage specified for the whole of the associated switchboard.

8.9.6 Rated Insulation level

Current transformers shall have a rated insulation level not less than the rated insulation level specified for the whole of the associated switchboard.

8.9.7 Rated Secondary Current

Metering current transformers shall have a secondary current rating of 5 amp.

Protection current transformers shall have a secondary current rating of either 1 amp or 5 amp.

8.9.8 Accuracy Class

Metering current transformers shall be accuracy class 1.0 M (i.e. rated current error of 1.0 % phase error of 1.8 rad at 100% current).

Protection current transformers shall be of accuracy class 5P (i.e. rated composite error of not more than 5%).

Protection current transformers to be used in balanced protection applications may require to be of a higher accuracy class (i.e. Class PX.)

8.9.9 Accuracy Limit Factor

Metering current transformers shall have a rated accuracy limit factor of not less than 1.20.

Protection current transformers shall have a rated accuracy limit factor of not less than 10.

8.9.10 Burden

Current transformers shall have a rated burden VA in accordance with the following:

\[ Q_r = (Q_d + Q_w + Q_t) \]

where:

\[ Q_r \] = CT rated burden VA at rated secondary current

\[ Q_d \] = rated burden VA at the CT rated secondary current of the switchboard mounted instruments, relays, trip coils and other devices to be operated by the CT
Qw = burden VA of the CT secondary circuit switchboard wiring at the CT rated secondary current
Qt = burden VA of external test instruments
    = 2.0 VA for 5 A secondaries
    = 1.0 VA for 1 A secondaries

8.9.11 Rated Secondary Limiting e.m.f.

The rated secondary limiting e.m.f. (expressed in volts) for a protection current transformer shall be determined as follows:

\[ V_{sl} = \frac{Qr \times F}{Is} \]

where:

Qr = CT rated burden VA at rated secondary current, amps
F = CT rated accuracy limit factor
Is = CT rated secondary current, amps

8.9.12 Example Rating Calculation for Current Transformer

As an example the Protection Class CT rating required for a 560 kW 6.6 kV slip ring motor fitted with a GE Multilin 269 plus overcurrent and earth fault relay would be as follows:

If = fault current available in the motor circuit
    = 1800 amp

Id = motor full load current = 59 amps

Ih = motor high set trip current = 480 amps

Ir = CT rated primary current = 100 amps

Sf = scale factor
    = Ir/Id = 100/59 = 1.695 (which is less than 2, so is OK)

Is = CT rated secondary current = 5 amp

Qd = relay rated burden at rated current = 0.1 VA

Qw = burden VA of the CT secondary circuit at rated current
    = 2.5 VA (by separate calculation)

Qt = burden VA of external test instruments at rated current
    = 2.0 VA

Qr = CT rated burden VA at rated secondary current
    = (Qd+Qw+Qt)
\[(0.1+2.5+2) = 4.6\text{VA}, \text{say} 5\text{VA}\]

\[
F = \text{CT rated accuracy limit factor}
\]
\[
= 1h/(I_d*S_f)
\]
\[
= 480/(59*1.695) = 4.8
\]

Hence select \(F = 10\) which is the next highest standard value and the lowest value allowed in accordance with para. 9.9.8 above.

\[
V_{sl} = Q_r*F/I_s = 5*10/5 = 10\text{volt}
\]

Hence the CT specification to AS/NZS 60044.1 would be: 5VA, Class 5P10, 100/5A.

8.10 Rogowski Coil Current Sensors

8.10.1 Primary Current Rating

In a particular circuit, the maximum operating range of associated Rogowski coil current sensors shall not be more than five times the circuit continuous maximum demand current.

8.10.2 Short Time Current Rating

Rogowski coil current sensors shall have a short time current rating not less than the short time current rating specified for the whole of the associated switchboard with the exception that Rogowski coil current sensors installed on the load side of current limiting fuses need only have a short time current rating providing an allowable let through \(I_2t\) greater than the total \(I_2t\) of the associated current limiting fuse.

8.10.3 Rated Operational Voltage

Rogowski coil current sensors shall have a rated operating voltage not less than the rated operating voltage specified for the whole of the associated switchboard.

8.10.4 Rated Insulation Level

Rogowski coil current sensors shall have a rated insulation level not less than the rated insulation level specified for the whole of the associated switchboard.

8.10.5 Rated Secondary Current

Rogowski coil current sensors shall have a secondary current rating of 1 amp at the maximum operating current.

8.10.6 Accuracy Class

Rogowski coil current sensors shall have a rated composite error of not more than 5\% over the complete operating range.

8.10.7 Accuracy Limit Factor

Rogowski coil current sensors shall have a rated accuracy limit of not less than 10 times the maximum operating current.

8.10.8 Burden

Rogowski coil current sensors shall have a rated burden VA in accordance with the following:

\[
Q_r = (Q_d + Q_w + Q_t)
\]
where:

\[ Q_r = \text{sensor rated burden VA at the sensor rated secondary current} \]

\[ Q_d = \text{rated burden VA at the sensor rated secondary current of the switchboard mounted relays, trip coils and other devices to be operated by the sensor.} \]

\[ Q_w = \text{burden VA of the sensor secondary circuit switchboard wiring at the sensor rated secondary current} \]

\[ Q_t = \text{burden VA of external test instruments} = 1.0 \text{ VA for 1 A secondaries.} \]

### 8.11 Electrical Surge Protection Equipment

#### 8.11.1 Service Entry Surge Protection

Appropriate surge diverters shall be installed so as to provide service entry incoming voltage surge protection on all electrical installations within the scope of this design standard. Such surge diverters shall be connected and protected as detailed hereunder.

#### 8.11.2 Factors Affecting Surge Levels

A lightning surge into an electrical installation may cause a destructive over voltage at a particular location within the installation depending on:

(i) the residual voltage and protective range of any surge diverters installed within the installation

(ii) the surge voltage attenuation caused by line side inductances,

(iii) the surge voltage amplification caused by voltage wave reflections at sudden changes of circuit impedance.

#### 8.11.3 Surge Diverter Residual Voltage

The phase to earth protective voltage level provided by a Low Voltage surge diverter connected to a main circuit depends on the residual voltage across the surge diverter and the voltage drops across the connecting leads to the surge diverter.

Because of the fast time of the surge current when the surge diverter conducts, the voltage drop across the surge diverter connecting leads is considerable.

\[ V_c = L \times D \times \frac{di}{dt} \]

where

\[ V_c = \text{voltage drop across connecting leads, volts} \]

\[ L = \text{per unit inductance of connecting leads} = 1.2 \text{ micro henries per metre} \]

\[ D = \text{total length of connecting leads i.e. from phase to fault current limiting fuse, from fault current limiting fuse to surge diverter, and from surge diverter to main earth bar.} \]

\[ di = \text{surge current peak, amps} \]

\[ dt = \text{front time of surge current (usually taken to be 8 micro seconds)} \]
For example, if the peak surge current is 5 kA and the length of connecting leads is 1 metre, the voltage drop across the connecting leads will be 750 volts.

8.11.4 Effect of Main Circuit Inductances

For 240/415 volt three phase circuits AS 3439.1 (IEC 60439) recommends that equipment located near the service entry have a rated impulse level of 6 kV, reducing to 4 kV at distribution circuit level and to 2.5 kV at load level. These recommendations suggest that the inductances of circuit wiring cause significant attenuation of a surge current peak voltage.

8.11.5 Effect of Voltage Wave Reflections

IEC 61643-12 suggests that in general surge voltage increases due to reflections of the surge voltage waveform may be disregarded at locations within 10 metres of Low Voltage surge diverters. However such surge voltage increases may occur if the load presents a high impedance i.e. surge voltage reflections may occur at open contacts or more importantly at converter inputs.

Provided that the surge diverters are in accordance with clause 8.11.12 and are installed in accordance with clause 8.11.7, the residual voltage at the surge diverters will be a little less than the 2 kV and will be higher as the conductor length between the surge diverters and the VSC’s (or electronic soft starters) increases.

Surge diverters shall not be required on separately mounted VSC’s, provided that the VSC’s have a common mode impulse voltage rating of > 4 kV and the cable length between the surge diverters and the VSC’s is < 10 metres. Similarly, surge diverters shall not be required on separately mounted electronic soft starters, provided that the electronic soft starters have a common mode impulse voltage rating of > 4 kV and the cable length between the surge diverters and the electronic soft starters is < 10 metres.

8.11.6 Impulse Voltage Rating of Power Electronic Equipment

Despite the preferred impulse withstand voltage values quoted in AS 3439.1 (IEC 60439), the standards covering variable speed converters and electronic soft starters only require an impulse withstand voltage rating of 2 kV.

8.11.7 Location and Connection of Surge Diverters

Low Voltage surge diverters shall be fitted on the load side of the installation Main Low Voltage Circuit Breaker as close as practical to the latter consistent with minimizing the length of surge diverter connecting leads (para. 8.11.3 refers). It should be noted that the associated protective zone extends on both the line and load sides of the surge diverters.

On Main switchboards which incorporate a MEN link, Low Voltage surge diverters shall be connected phase to neutral. The switchboard equipment shall be arranged in such a way that the complete length of connecting leads (i.e. phase to earth bar) shall not exceed 1 metre.

On switchboards not incorporating a MEN link, Low Voltage surge diverters shall be connected to earth and neutral to earth. The switchboard equipment shall be arranged so that the complete length of connecting leads (i.e. phase to earth bar) shall not exceed 1 metre. Similarly, the arrangement shall be such that the length of the connection lead neutral to earth bar shall be not more than 1 metre.

On switchboards other than Main switchboards incorporating an MEN link, Low Voltage surge diverters shall be connected phase to earth. The switchboard equipment shall be arranged in such a way that the complete length of connecting leads (i.e. phase to earth bar) shall not exceed 1 metre.

Cables connecting to earth electrodes shall be terminated onto the earth bar as close as practical to the Low Voltage surge diverter connecting lead terminations as possible. Surge diverters shall not be mounted hard up against one another or hard up against other equipment.
8.11.8 **Rating of Surge Diverter Fault Current Limiting Fuses**

Phase connections to Low Voltage surge diverters shall be via HRC fuses rated at 63 amps or the largest fuse which will grade with the main circuit protection, whichever is the least.

8.11.9 **Surge Protection of Separately Mounted Equipment**

Separately mounted variable speed drives, electronic soft starters and distribution switchboards housing electronic equipment shall be fitted with additional surge diverters connected phase to earth and neutral to earth.

8.11.10 **Surge Diverter Discharge Current Rating**

Low Voltage surge diverters shall have a nominal discharge current rating of not less than 20 kA 8/20 μs in accordance with IEC 61643.1 (which is approximately equivalent to 4kA 10/350 μs and approximately 2 coulombs). Low Voltage surge diverters shall have a three shot maximum discharge current rating of not less than 40 kA 8/20 μs in accordance with IEC 61643.1.

8.11.11 **Surge Diverter Protection Level**

Low Voltage surge diverters shall have a voltage protection level of not more than 850 volts at 3 kA discharge current.

8.11.12 **Surge Diverter Maximum Continuous Operating Voltage**

Low Voltage surge diverters shall have a rated continuous operating voltage not less than 275 volts.

8.11.13 **Surge Diverter Type Specification**

Low Voltage surge diverters shall be in accordance with Corporation Type Specification DS26-32.

8.11.14 **Surge Protection of Extra Low Voltage Equipment**

(a) IEC 61326.1 defines Extra Low Voltage control and signal cables as being “long lines” if such cables run outside buildings, or run entirely within buildings and are more than 30 metres long.

For the purpose of this Design Standard, the term “buildings” shall mean:

(i) metal framed and/or reinforced concrete buildings in which the metal framing and concrete reinforcement are bonded and earthed, and

(ii) metal outdoor switchboard enclosures.

Extra Low Voltage control and signal cables which are “long lines” as defined above shall be connected into electronic control equipment such as PLC’s only via suitable surge protectors, Critec Type LSP or approved equivalent.

8.12 **Switchgear**

8.12.1 **Thermal Derating**

Switch gear designed in accordance with AS3439.1 is rated at 35°C and needs to be derated when used in higher temperature ambient conditions.

Except where special site conditions require switchboards to be designed for higher operating temperatures, switchboards shall be designed on the basis that the maximum ambient temperature within the switchboard will be 50°C for indoor switchboards and 60°C for outdoor switchboards.
Normally, switchgear to be installed in indoor switchboards shall be derated to 88% of its nominal rating.

Similarly switchgear to be installed in outdoor switchboards shall be derated to 79% of its nominal rating. Similar deratings shall be applied to starter autotransformers. However, electronic soft starters rated for operation in ambient conditions of 35°C shall be derated to 77% of their nominal rating for installation in indoor switchboards and to 63% of their nominal rating for installation in outdoor switchboards.

8.12.2 Connecting Cables

Switch gear designed in accordance with AS3439.1 depends to some extent on the connecting cables to act as a heat sink.

Table 8 of AS3439.1 specifies the required size of copper conductor in interconnecting cables for various nominal ratings of switchgear under rating tests.

Cables used to interconnect various items of switchboard equipment shall be PVC insulated and sized in accordance with Table 8 of AS3439.1 for the nominal rating of the switchgear (i.e. not for the derated value).

8.12.3 Circuit Breaker Type

Circuit breakers shall be air break type.

8.12.4 Motor Control

Operational control of motors shall be by air break contactors. Circuit breakers or manually operated switches shall not be used for this purpose.

8.12.5 Fast Transient Burst Suppression

All contactor coils and similar solenoids shall be fitted with RC fast transient burst suppressors.

All DC relay coils shall be fitted with reverse diode or varistor overvoltage suppressors.

8.13 General Construction of Switchboards

Switchboards shall be specified to be constructed in accordance with the Corporation’s Type Specifications for L.V. Switchboards (refer Design Standard DS 26).

8.14 Power and Control Circuits

Switchboard power and Low Voltage control circuits shall be in accordance with the Corporation’s standard power and control circuits and shall allow the operation of individual drives under emergency manual control with primary protection only (clause 8.5 refers).

Automatic and normal manual control with both primary and secondary protection shall be implemented via switchboard controlling systems as detailed in Section 14.

Control interconnections between various drive control circuits and their associated switchboard controlling system shall be at Extra Low Voltage.

In general, control interconnections between various drive control circuits shall be via the switchboard controlling system. However Extra Low Voltage control interconnections shall be permitted between variable speed controllers operating in master/slave mode. Direct connections between Low Voltage drive control circuits shall not be permitted.
Control switches and push buttons which control directly the operation of motors shall be hardware devices mounted on the switchboard Low Voltage control panel for the associated drive rather than being software functions within the switchboard controlling system.

8.15 Switchboard Control Functions

Plant control is now beyond the scope of this design standard and will become a subject addressed in a different design standard.

In the meantime this section of DS22 has been retained as Appendix A0 for information purposes only.

8.16 Supply Voltage Quality Monitoring

The motor protective devices will provide protection against motor over heating due to incoming supply under voltage or phase imbalance. However such devices are manually reset and will require a visit to site by a suitably qualified person to assess the cause of the tripping and to determine whether or not the device can be reset. In order to minimise the operation of motor protective devices due to supply under voltage or phase failure, a phase failure and under voltage relay shall be installed to monitor the incoming supply voltages into each installation.

In the event of the supply voltages moving outside the set limits for more than a prescribed time, the control logic shall be arranged so that the plant is tripped off before the motor overheating protective device can operate. The control logic shall be arranged to prevent restarting until the supply voltages have returned to a healthy state for a reasonable period of time to allow the complete operation of any relevant supply authority High Voltage reclosers.

The phase failure and under voltage relay shall be self-resetting and shall be arranged to trip if:

(a) the supply negative sequence voltage is more than 10%

(i.e. 5% setting on rms type 2P740 phase failure relay).

(b) the supply voltage falls below 80% of nominal voltage.

Since the starting of motors within the installation may cause short term under voltage dips greater than the value specified above, the control system shall be arranged so that the phase imbalance and under voltage trip function is disabled during motor starting periods.

Phase failure and under voltage relays shall be of a type suitable for operation in conjunction with motor loads.

It should be noted that phase failure relays can detect only relatively large phase voltage imbalances such as would be caused by a blown High Voltage incoming line fuse.

Smaller phase imbalances, caused for example by unbalanced incoming High Voltage line construction, may be sufficient to trip motor protective devices but may not be large enough to be detected by phase failure relays.

8.17 Lamp and Actuator Colours

Lamps on switchboards associated with motor control should be colour coded as follows:
(a) Fault tripped condition - Amber (flashing if unacknowledged)
(b) Off condition - Green
(c) Run condition - White
(d) Interlock operating - White
(e) Alarm (abnormal) - Yellow/Amber (flashing if unacknowledged)
(f) Switch or Circuit Breaker closed - Red
(g) Switch or Circuit Breaker open - Green
(h) Valve closed - Green
(i) Valve open - White

Actuators on switchboards should be colour coded as follows:

(a) Start condition - Green
(b) Stop condition - Red
(c) Emergency stop - Red
(d) Reset condition - Blue
(e) Acknowledge - Black
(f) Lamp test - Black

8.18 Separate Drive Circuits

Each drive circuit shall be complete and independent of other drive circuits i.e. each drive circuit shall include a separate isolator, separate short circuit and overload protection devices, a separate starter (or variable speed controller), motor cable and motor. Variable speed controllers shall not be shared between various drives.

8.19 Monitoring Requirements for Small Pump Stations

8.19.1 Energy

All pump stations with a maximum pumping power demand of greater than 15 kW shall be equipped by the Supply Authority with “smart” site energy meters so as to provide the following kWhr and kVARhr data:

a) site operating energy (kWhr) accumulated continuously within the pump station RTU and derived from an energy pulse train from the Supply Authority site energy meter.

b) site operating energy (kWhr) accumulated within the pump station RTU in half hourly increments and derived from an energy pulse train.

c) site operating kVARhr accumulated continuously within the pump station RTU and derived from a kVARhr pulse train from the Supply Authority site energy meter.

d) site operating kVARhr accumulated within the pump station RTU in half hourly increments and derived from a kVARhr pulse train.
If half hourly pulses are available from the Supply Authority site energy meter, these should be used to calculate the values required as per b) and c) above, otherwise half hourly pulses generated within the RTU shall be used.

8.19.2 Current and Power

Operational staff rely heavily on current monitoring for their day to day operations, hence current monitoring shall be included for all pumps in the range of this Design Standard (0-150 kW). Current transducers shall be fitted to each motor circuit of small pump stations and bores.

Furthermore, power transducers shall be fitted to all bore motor circuits and to each motor circuit greater than 45 kW for small pump stations.

8.20 Orientation of Outdoor Switchboards

The switchboard orientation shall be such that the front doors of the switchboard face the pumping units. Adequate hard standing area shall be provided around the switchboard to facilitate maintenance activities. As a minimum the hard standing area shall extend 1000mm from the front edge of the switchboard and 1500mm from the rear edge of the switchboard.

8.21 Motor Cable Disconnection Cubicles

In order to assist with removal of pumping units from wet well sewage pump stations, submersible bores and the like, motor cable disconnection cubicles may need to be provided depending upon the requirements of the project.

Such motor cable disconnection cubicles shall be:

a) constructed from marine grade aluminium, painted white, minimum IP56 and one access door,

b) no more than 1.2 metres in height,

c) fitted with Perspex shrouds over all terminals within the cubicle,

d) fitted with “vandal resistant” bolts to the door,

e) fitted with a label on the door stating “Danger 415 Volts behind” and,

f) fitted with a trip limit switch on the door and wired as an alarm point to SCADA.

g) two point door locking system
9 EARTHING

All earthing system designs shall be based on soil resistivity tests conducted at the site under dry soil conditions. The designer is responsible for arranging soil resistivity tests during Engineering Design (Primary Design drawings).

9.1 Type of Earthing Systems

The type of earthing system to be employed shall depend upon the type of electrical supply to the site. Required earthing arrangements applicable to the various types of electrical supply to the site are defined hereunder.

9.2 Earthing Systems - LV Supply to Site

If the electrical supply to the site is provided at Low Voltage from a Supply Authority transformer located off the site, the earthing system shall comply with the requirements of AS 3000 for a MEN installation with the added requirement that the overall earthing resistance of the installation electrical earthing system shall be not more than 15 Ohms. Individual earth electrodes earth resistance shall be less than 30 Ohms. The various earthing connections for such a system are shown at Fig. 9.1.

![Fig. 9.1: Major Earthing Connections for a Small Pump Station Supplied at L.V. from an ‘Off Site’ Transformer](image)

9.3 Earthing Systems – On Site Supply Authority Transformer

If the supply to the site is at Low Voltage from a Supply Authority owned transformer located on the site, the earthing system shall comply with the requirements of AS 3000 for a Low Voltage MEN installation with the added requirement that the overall earthing resistance of the Low Voltage installation electrical system shall be not more than 15 Ohms.
In such circumstances the Supply Authority shall supply and install the H.V. earthing system which shall be kept separate from the Corporation’s L.V. earthing system (except that these will be connected via the consumer’s mains neutral cable and the switchboard neutral to earth link). Reference shall be made to clause 6.1.2 in respect to the special arrangements to be made for earthing High Voltage surge diverters on High Voltage aerial lines supplying bore hole pump stations.

If the installation Main Switch is located on the Pump Station Switchboard, the various major earthing connections shall be as shown at Fig. 9.2.

If the incoming switchboard housing the installation Main Switch is separated from the pump station switchboard by less than 50 metres, the various major earthing connections shall be as shown at Fig.9.3.

If the incoming switchboard housing the installation Main Switch is separated from the pump station switchboard by more than 50 metres, the various major earthing connections shall be as shown at Fig.9.4.

**Fig. 9.2**

*Major Earthing Connections for Supply from ‘On Site’ Supply Authority Transformer with Main Switch on Pump Station Switchboard*
Fig. 9.3

Major Earthing Connections for Supply from ‘On Site’ Supply Authority Transformer with Main Switch < 50m from Pump Station Switchboard
Fig 9.4

Major Earthing Connections for Supply from ‘On Site’ Supply Authority Transformer with Main Switch > 50m from Pump Station Switchboard
9.4 Earthing Systems – HV Supply from On Site Transformer

If the L.V. supply to the site is via a Corporation owned transformer, a separate earthing system as described in AS 2067 shall be implemented as detailed in either Fig. 9.5 or Fig. 9.6 as appropriate. The minimum separation distance between the H.V. and L.V. earthing systems shall be 4 metres. Design of the HV earth electrode system shall comply with the requirements of AS 2067 and DS23 for safe touch and step voltage and section 11.3 of DS21.

Fig. 9.5
Major Earthing Connections for Supply from Water Corporation Owned Aerial Connected Transformer
Fig. 9.6

Major Earthing Connections for Supply from Water Corporation Owned Cable Connected Transformer
9.5 Connections to Steelwork

(a) Where it is necessary to connect earth cables to pipework or structural steel, a stainless steel set screw shall be welded to the steel to provide a corrosion free earthing stud.

(b) The concrete reinforcing steel in floor slabs and precast concrete panels shall be brought out for earthing in accordance with AS 1768, and shall be connected to earth as shown in Figs 9.1, 9.2, 9.3, 9.4, 9.5 and 9.6.

Since concrete has a relatively low resistivity, electrically bonded reinforcing steel in concrete members which are in direct contact with the ground will reduce the overall electrical earth ground resistance and can be of a significant benefit in this regard.

In locations where the soil resistivity is less than 30 ohm-metres (e.g. in damp black soil or swampy situations), there is a small risk of galvanic corrosion of the reinforcing steel due to the galvanic couple between the steel and the electrical system copper electrode. In such locations a galvanic isolator (e.g. DEI) should be installed between the reinforced concrete and the earth electrode system.

(c) Bonding shall be installed across all pump station pipework equipment such as flexible joints, meters, valves and pumps.

(d) Grid flooring, metallic cable trench covers, metallic cable trays, stairs, ladders and all structural steel work shall be bonded together and connected to the pump station main earth bar.

(e) Any sections of metallic fencing located under aerial High Voltage lines shall be earthed to the pump station High Voltage earthing system by two earthing connections, one either side of the point where the High Voltage aerial line crosses the fence line.

(f) All major earthing cable connections shall be made with separate bolts for each cable so that one cable can be disconnected for testing without interfering with other earthing circuits.

(g) A detailed description of the required earthing at valve/meter pits is at section 11 of DS21, as is a more detailed description of bonding requirements for concrete reinforcing steel and structural steel.

9.6 Prevention of Corrosion in Earthing Systems

(a) Earth grading rings shall be of copper cable, and earthing electrodes shall be copper clad. All major earthing cables shall be copper and shall be terminated with suitable crimp connectors.

(b) Wherever practical, stainless steel bolts, nuts and washers should be used for earth connections in locations exposed to the weather.

(c) All bolted connections in earthing systems shall be above ground and accessible for inspection.

(d) All steel work below ground within 10m of copper earthing electrodes or earth mats, should be bitumen coated or encased in concrete in order to minimise galvanic corrosion of the steel or its zinc coating.
9.7 **Calculation of Electrode Earthing Resistance**

The formula for calculating the D.C. earthing resistance of a vertical electrode is:

\[ R_{vdc} = 0.368 \times \rho \times \log \left( \frac{4 \times L}{d} \right) / L \]

where:
- \( R_{vdc} \) = vertical electrode D.C. earthing resistance, ohm
- \( \rho \) = soil resistivity, ohm*metre
- \( L \) = electrode length, metres
- \( d \) = electrode diameter, metres

Use of the D.C resistance value is valid in respect to lightning surges and short term A.C. earth faults. However, it should be noted that for longer duration A.C. earth currents, a vertical electrode and its surrounding soil becomes a short loss transmission line which will exhibit an earth impedance which is considerably higher than the electrode’s D.C. earth impedance.

9.8 **Voltage Grading in Earthing System**

(a) In order to protect personnel against excessive touch voltages outside the kiosk substation, a 35mm² hard drawn copper grading ring shall be installed around the kiosk, 1m from it and at a depth of 500mm. The grading ring shall be connected to the kiosk earth bar from two diagonally opposite connections on the ring.

(b) Buried grading rings are not required in the case of pole mounted transformers. However, in such instances the ground area within 2m of any electrode or steel transformer pole should be paved with 25mm thick hot mix paving (laid on a suitably compacted and stabilised substrate), in order to provide protection against step voltages.

9.9 **Earthing and Surge Protection of Submersible Bore Hole Motors**

Since submersible bore hole motors are installed under water, the metallic case of the motor acts as an earth electrode. The current trend is to install non-metallic bore hole casings and non-metallic bore hole pipes, so that in some installations the case of the submersible bore hole motor may have the least earth resistance of all of the metalwork connected to the earthing system. In such cases, the submersible bore hole motor earthing conductor shall be rated as for the installation main earthing conductor in accordance with AS3000.

Because of the nature of their construction, submersible bore hole pumps are more susceptible to damage from voltage surges than are other motors. Consequently, if the delivery pipework running from the bore site is steel, a set of L.V. surge diverters should be considered, during design, to be fitted in the switchboard across the submersible motor cable termination.

9.10 **Labelling of Earthing Cables**

All major earth connection cables shall be labelled clearly at both ends.

9.11 **Earthing of Pipeline Mounted Instrumentation**

Electronic instrumentation transducers which are mounted on the main pipeline, or in pipe work within the pump station, shall be electrically isolated from the associated pipework and shall be earthed separately to the instrumentation earth bar.
9.12 Earthing of Steel Pipelines

9.12.1 Above Ground Steel Pipelines

(a) Above ground steel pipelines shall be earthed and bonded at the pump station as shown in Fig 9.7 in order to protect electrical plant against lightning damage, and for personnel safety.

(b) Wherever above ground pipelines terminate electrically, i.e. at an isolating flange, the above ground pipeline shall be connected to a local earthing electrode having an earthing resistance not more than 5 Ohms in accordance with AS/NZS 4853.

(c) If insulated flanges are fitted as shown in Fig 9.7, isolator/surge protectors (ISP) or galvanic isolators (GI) shall be fitted across insulating joints in above ground pipelines to limit the surge voltage that can appear across each insulating joint.

Note: The appropriate application of an ISP or GI, such as those from Dairyland Electrical Industries (D.E.I.), will provide D.C. isolation and A.C. continuity. These ISP/GI’s have low standard peak voltage blocking levels (typically 20V) and are intended for safe electrical isolation of cathodically protected systems subject to 50Hz power faults, systems which are coupled to an AC source and systems subject to lightning transients.

Fig. 9.7

Earth Bonding for Above Ground Pipelines

9.12.2 Below Ground Steel Pipelines

(a) If below ground steel pipelines connecting to pump stations are cathodically protected, these may need to be electrically isolated from the pump station pipework. In such cases the earth bonding shall be as shown in Fig. 9.8.
(b) Insulated joint protectors with a rated D.C. breakdown voltage of 500 V shall be fitted across insulating joints in below ground pipelines to limit the surge voltage that can appear across each insulating joint to 1000 V.

(c) Earthing at transitions between below ground and above ground steel pipelines shall be arranged in a similar manner to that shown in Fig. 9.8. In such cases the above ground steel pipeline shall be connected to local earthing electrodes having an earthing resistance not more than 5 Ohms in accordance with AS/NZS 4853.

9.13 Earthing Cable Screens

Screens or screened cables associated with variable speed controllers shall be grounded at both ends e.g. the screen or a cable connecting the output of a variable speed controller to a motor shall be connected to the variable speed controller chassis at the variable speed controller end and to the motor frame at the motor end.

Screened cables associated with variable speed controllers shall be terminated at both ends with cable glands which provide a 360° connection of the screen to the associated earthed gland plate.
Otherwise, the screen on each cable shall be continued as far as practical along the cable, so that the twisted screen pigtail connecting to the associated earthed gland plate is kept as short as practical.

### 9.14 Earthing at Water Tanks

Earthing, bonding and the provision of lightning air terminals at water tanks shall be designed in accordance with the requirements of AS/NZS 1768.

Lightning protection design of power and instrumentation equipment shall be in accordance with the requirements of the DS20 and DS40 series of design standards.

With respect to the tank, the philosophy is not to protect the tank from a direct strike but rather guide the lightning surge safely to ground. In this regard, it is important to establish a connection from the air termination to a lightning earthing system with a combined resistance to earth of less than 10 ohms. Depending upon the type of tank construction this will involve either two down conductors from the air termination or simply a connection from the metallic tank base to the earthing system. Furthermore, the connection to the earthing system shall be via suitably rated DC De-couplers (e.g. DEI SSD Solid State De-coupler) to provide corrosion/cathodic protection isolation.

For the purpose of this section, the air termination is defined as the metallic roof of the tank and the lightning earthing system is defined as a bare copper conductor buried encircling the tank (grading ring), spaced one metre from the tank wall and connected to three equally spaced earth electrodes along the circumference of the grading ring. The down conductor is defined as an insulated copper conductor from the air termination to the earthing system.

Guidance relating to the basic earthing requirements outlined above for various types of tank construction is given below:

1. Steel roof of ground level concrete tank: Two down conductors terminated into the earthing system.
2. Steel roof of ground level steel tank: Two connection points from the base of the tank to the earthing system.
3. Concrete roof of ground level concrete tank: No earthing requirements for the tank.
4. Concrete roof of elevated concrete tank supported on concrete columns or shaft: Earthing and bonding of any internal metallic structure.
5. Steel roof of elevated concrete tank supported on concrete columns or shaft: Two down conductors terminated into the earthing system. Earthing and bonding of any internal metallic structure.
6. Steel roof of elevated steel tank supported on concrete columns: Two down conductors terminated into the earthing system.

Steel roof of elevated steel tank supported on steel frame: Two connection points from the base of the tank to the earthing system.
10 CABLES

10.1 Cable Types

10.1.1 Conductor Type

All cables shall have copper conductors.

10.1.2 Cables for Specific Purposes

The types of cables to be used for various specific purposes shall be as listed hereunder.

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>CABLE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light current switchboard cables</td>
<td>Refer DS26.09</td>
</tr>
<tr>
<td>PLC/RTU input/output cables (external to switchboards)</td>
<td>Twisted pair(s) cable, 7 strand conductor ≥ 0.5mm² PVC insulated, overall screened, PVC sheathed</td>
</tr>
<tr>
<td></td>
<td>cables, SWA if liable to mechanical damage, use of common return conductor not permitted.</td>
</tr>
<tr>
<td>240 volt control cables (external to switchboards)</td>
<td>Multi-core cable ≥ 7 strand conductor ≥ 1.5mm² PVC insulated, PVC sheathed cables, SWA if liable</td>
</tr>
<tr>
<td></td>
<td>to mechanical damage.</td>
</tr>
<tr>
<td>Incoming cables to transformer HV terminals and/or incoming cables to</td>
<td>Single core XLPE insulated cables constructed with copper conductor, semi-conducting screen,</td>
</tr>
<tr>
<td>33/22/11kV HV switchboards (see notes 1,2)</td>
<td>XLPE insulation, heavy duty copper screen, tape bedding double brass taping PVC sheathed overall,</td>
</tr>
<tr>
<td></td>
<td>rated and sized to suit both continuous and fault current requirements, and laid in trefoil groups.</td>
</tr>
<tr>
<td></td>
<td>As an alternative to double brass taping, termite protection may be provided in the form of a PVC</td>
</tr>
<tr>
<td></td>
<td>sheath with a nylon jacket and an overall sacrificial PVC sheath.</td>
</tr>
<tr>
<td>Cables between transformer LV terminals and the associated LV switchboard</td>
<td>Single core XLPE insulated PVC sheathed cable</td>
</tr>
<tr>
<td>Station lighting and general purpose power</td>
<td>Single core PVC in PVC conduit</td>
</tr>
<tr>
<td>Submersible bore motor cables (see note 4)</td>
<td>3 core and insulated earth, R-EP-90 insulated, R-CSP-90 sheathed cable to AS 3116, or Siemens</td>
</tr>
<tr>
<td></td>
<td>Hydrofirm or equivalent (approved for drinking water applications)</td>
</tr>
<tr>
<td>Submersible sewage motor cable (see note 4)</td>
<td>3 core &amp; earth flexible, tinned copper conductors, integral pilot thermistor cores, EPR/CSP</td>
</tr>
<tr>
<td>Conventional motors ≤ 15kW (see note 4)</td>
<td>3 core and earth PVC insulated PVC sheathed cables either SWA or in conduit</td>
</tr>
</tbody>
</table>
### Conventional motors > 15kW ≤ 30kW (see note 4)
- Single core PVC insulated PVC sheathed cables in conduit or in ducts suitably protected

### Conventional motors > 30kW ≤ 150kW (see note 4)
- Single core XLPE insulated PVC sheathed cables in conduits or in ducts, and suitably mechanically protected. Cables above 50mm² in ducts to be in trefoil groups

### Cables connecting L.V. variable speed controller to associated isolating transformers. (see note 3)
- Symmetrically shielded 3 phase cable(s) rated 0.6/1 kV, and as described further in paragraph 10.2 hereunder.

### Low Voltage variable speed variable speed controller PWM output cables:
- Symmetrically shielded 3 phase cable(s) rated 0.6/1 kV and as described further in paragraph 10.2 hereunder.

### Pipeline and structural steel bonding and earthing cables
- 1 core PVC (green with yellow stripe), sized 70mm² or size of station main earth conductor, whichever is the greater

### Pipeline counterpoise earthwire
- 35mm² stranded bare hard drawn copper conductor

**Note 1:** Applies to cable buried direct or cables in buried PVC conduit. Cables installed in ducts within the confines of the building may be specified without termite protection.

**Note 2:** When cables are installed in conduits, the conduits shall be 150mm diameter.

**Note 3:** Not required if RFI suppression scheme is fitted to the variable speed controller.

**Note 4:** Cables shall be rated for the full load current of the motor.

### 10.2 Cables for VVVF Drives

(a) Variable speed controller cables referred to in paragraph 10.1.2 shall be symmetrically constructed shielded cables either with three symmetrically placed internal protective earth cores or with a shield rated as the protective earth. Phase conductors, internal protective earth cores and the shield shall be copper.

(b) If internal protective earth cores are provided, the conductivity of the shield shall be not less than 10% of the conductivity of each phase conductor.

(c) The combined conductivity of the shield and the internal protective earths (if fitted) shall be not less than the conductivity of each phase conductor for cables ≤ 16 mm², and not less than 50% of the conductivity of each phase conductor for cables >16 mm².

(d) The cable screen shall consist of either double copper tape screen or a single copper tape screen overlaid with a copper wire screen. Copper braid screens shall not be used for fixed installations. Cable screens shall be terminated and earthed concentrically. Double copper tape screens shall be terminated in glands employing a lead clamping cone. Combined single copper tape and copper wire screens shall be terminated in armoured cable cable-glands.

(e) Variable speed controller cables shall be rated for a maximum conductor temperature of 75°C and shall be site derated accordingly.
10.3 Fault Rating

10.3.1 Switchboard Wiring

Where practical, cable tails between major circuit busbars and auxiliary circuit fuses should be protected against short circuit faults by the installation of busbar mounted fault current limiters. The size of the fault current limiters should be as shown in the Type Specification for Switchboard Construction.

Where the installation of busbar mounted fault current limiters is not practical, short cable tails may be installed between the busbar connection point and the line side of the auxiliary circuit fuse, provided the conditions specified in the Type Specification for Switchboard Construction are satisfied.

10.3.2 Distribution Cables

The fault rating of a cable depends on the allowable temperature rise of the conductor and insulation and on the thermal storage capacity of the cable. Most manufacturers publish data relating allowable fault current and fault duration to cable size for various types of cable.

The fault capacity of all cables selected shall be checked against the protective equipment to be used to ensure the adequacy of the latter. Such checks shall include a check of the earth fault capacity of cable screens against the relevant earth fault protection equipment.

10.4 Continuous Rating of Cables

The continuous current rating of power cables depends to a large extent on the rate that heat generated by cable losses can be dissipated. Various derating factors are applicable to take account of various ambient parameters. Reference shall be made to AS 3008 Electrical Installations - Selection of Cables and to the Electrical Research Association publication Current rating Standards for Distribution Cables, Part I and III, for the applicable derating factors.

10.5 High Voltage Cable Terminations

10.5.1 Manufacturer’s Recommendations

All cable terminations shall be made in strict accordance with the manufacturer’s recommendations. Clearances in air shall be maintained at the manufacturer’s recommended level or at the value specified in the relevant Australian Standard, whichever is the greater. Attention shall be taken to ensure that recommended phase to phase and phase to earth clearances for unscreened sections of the cable terminations are maintained.
10.5.2 Dead-break Elbow Connectors

Dead-break elbow cable terminations on screened single core XLPE insulated cables shall be made with approved fully screened, cold fit, dead-break elbow connectors such as Raychem Types RSTI and RSES dead-break elbow connectors (depending on current rating).

10.5.3 Indoor Air Insulated Terminations

Screened single core XLPE insulated cables within switchboards and air insulated cable boxes shall be terminated with approved heat shrink cable terminations such as Raychem series IXSU-F heat shrink terminations.

If the spacing between bushings is such that insulating boots are required to be fitted over the bushings, such insulating boots shall be approved cold applied insulating boots of an appropriate voltage rating e.g. Raychem type RCAB for voltages up to 11 kV.

10.5.4 Pole Top Terminations

Pole top terminations on single core XLPE cables shall be made with approved outdoor heat shrink terminations, such as Raychem Type OXSU-F heat shrink terminations.

10.6 Conduits and Cable Trays/Ladders

Conduits shall have the colours stipulated in AS1345. Conduits shall be orange for power cables. Conduits for communication cables shall be white. Low voltage cables installed in underground conduit is preferred to direct buried and shall be applied wherever practical.

Outdoor cable trays and ladders shall be installed with covers. Indoor cable trays and ladders shall be installed with covers if exposed to the risk of mechanical damage.

10.7 Minimum Cable Separation

As far as is practical, the minimum separation between power cables and signal cables shall be as stated below:

<table>
<thead>
<tr>
<th>Class of Signal</th>
<th>Example</th>
<th>Separation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 Sensitive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Slightly sensitive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Slightly interfering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Interfering</td>
</tr>
<tr>
<td>1 Sensitive</td>
<td>Low level, analogue, sensors/probes, measuring, Profibus, Ethernet</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>2 Slightly sensitive</td>
<td>Low level digital, low level DC power supplies, control circuits to resistive loads</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>
### Control circuits with inductive loads, clean AC power supplies, main power supplies 0.6/1kV, ≤400A

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Slightly interfering</td>
<td>500</td>
<td>200</td>
<td>-</td>
</tr>
</tbody>
</table>

### Switching power supplies, VSD circuits, major LV power circuits, >400A

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Interfering</td>
<td>1000</td>
<td>500</td>
<td>200</td>
</tr>
</tbody>
</table>

### HV cable (≤33kV),

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>HV Cable</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

The table above shows 5 types of signal cable categories and the spacing required between them.

“Sensitive” means the signal on the cable is sensitive to interference. “Interfering” means the signal on the cable causes interference.

For example, if the signal on cable 1 is “slightly interfering” and the signal on cable 2 is ‘sensitive’, the distance between the cables should be 500mm.

These separation distances may be reduced if separate metallic conduits or metallic (preferably magnetic material) cable trays/ducts are provided for power and/or signal cables. Such separation distances shall be in accordance with the recommendations of IEC 61000-5-2, BS 6739, HB29-2007, AS3080 and reputable company product installation guides.

A minimum separation of 1 m shall be maintained between HV cables and any power or signal cable, no matter what barrier is provided.
11 PUMP STATION LIGHTING

11.1 Internal Lighting

Interior lighting within pump stations and indoor substations shall be designed in accordance with the AS1680 series of standards. The lighting levels and other characteristics shall be designed so as to conform with the recommendations given in AS/NZS 1680.2.4 Table E1 Item 43 for Petroleum, Chemical and Petrochemical Works.

Where necessary, additional lighting fittings should be located so that the inside of switchboard cubicles can be reasonably illuminated if open for maintenance.

Single 36W tube fittings (mounted on suitable trunking wherever practical) should be used as light sources. However, high bay light fittings may be used if the design of the building allows, and adequate provision is made to enable servicing of these fittings. The high bay lighting system shall be arranged so the light fitting assembly can be lowered to the floor level for maintenance.

The main lighting in the pump station shall be evenly distributed over a 3 phase circuit switched by a contactor so that possible stroboscopic effects with rotating plant are avoided. Emergency lighting shall be installed for access lighting in the vicinity of rotating plant during periods of up to 15 minutes after mains failure.

11.2 External Lighting

All doorways, valve and flowmeter pits within the pump station environs, and all pipework trenches adjacent to the pump station walls should be illuminated to an average value of 10 lux.

All substations shall be provided with sufficient lighting for safety of access and equipment operation.

All lighting fittings used externally should be fitted with guards to minimise possible damage by small arms fire and similar acts of vandalism.

All external doorway lighting should be controlled by a single ‘on-off’ switch located on the pump station building wall. Where the pump station is located inside a perimeter security fence, the switch should be located on the external face of the wall adjacent to the main personnel access door. Where the pump station building is not provided with a perimeter security fence, this switch should be located on the internal face of the wall adjacent to the main personnel access door.

Lighting on pipework trenches adjacent to the pump station building should be controlled similarly.

Wherever practical, external light fittings should be mounted on the walls of the pump station. The number of lighting poles within the pump station enclosure should be minimised, so that as few as possible obstructions are presented to trucks maneuvering in the pump station yard.

External lighting shall be designed in accordance with AS/NZS 1158.

11.3 Prevention of Falls

Reference shall be made to the Corporation’s standard S151- Prevention of Falls regarding lighting fixtures in pump stations and buildings.
12 VALVE ACTUATORS

12.1 General

Electrically powered actuators for valves used in water supply systems and treatment plants are usually of the 'part-turn' or 'multi-turn' type.

The part-turn actuator is the simpler and cheaper of these two types and its use is usually restricted to relatively small valves requiring to be simply opened or shut, without any requirement for positioning to any intermediate position, and without any restrictions on the speed of operation.

The electricity supply to the valve actuator shall be via a padlocked isolator.

12.2 Electricity Supply

Electrically powered valve actuators shall be specified to operate from one of the following power sources as appropriate:

(a) 3 phase 4 wire grounded neutral, 415V +6% -11% line to line, 50Hz +2.5%, AC.
(b) 1 phase grounded neutral, 240V +6% -11%, 50Hz +2.5% AC.
(c) 24V +25% -15%, unsmoothed, unfiltered DC.

12.3 Ambient Conditions

All electrically powered valve actuators shall be specified for operation as specified in Sub-Sectioon 12.6 with a maximum inlet cooling air temperature of not less than 60°C. This maximum inlet cooling air temperature rating requirement shall be increased to 80°C for actuators to be located in the North West or at other hot exposed sites. Actuators to be installed outdoors shall also be rated for operation in direct sunlight.

12.4 Enclosure Class

Preferably the enclosure class specified for electrically powered valve actuators should not be less than IP66D. If the actuator is to be installed in a location which can be subject to flooding, then an IP68 rating shall be specified. If enclosures rated at IP65 are used, additional protection against driving rain must be provided. Enclosures rated less than IP65 shall not be used externally. Enclosures rated less than IP44 shall not be used in any circumstances.

12.5 Electrical Protection

Protection against excess electrical winding temperature in the form of factory fitted thermistors or thermostats should be specified on all electrically powered actuators. Thermistor protection is essential on units having a maximum ambient cooling air temperature rating of less than 80°C and generally should be preferred.

12.6 Rating

The duties for multi-turn actuators shall be:

(a) ON/OFF Control

     S2 (Short time duty), 15 minutes

(b) Inching
S4 (Intermittent periodic duty with starting), 25% (Cyclic duration factor), 60 starts per hour.

(c) Modulating

S4 (Intermittent periodic duty with starting), 25% (Cyclic duration factor), 600 starts per hour

The specified maximum number of starts per hour shall be not less than 20 for part turn actuators.

12.7 Anti-Condensation Heaters

Electrically powered valve actuators should be specified with continuously operating, low wattage, anti-condensation heaters in the switchgear enclosures unless the enclosure is rated at IP68. (The rating of such heaters can be expected to be of the order of 5W.) Provision of winding anti-condensation heaters is not usually necessary.

12.8 Auxiliaries

All electrically powered valve actuators should be specified with open and close overtorque switches, and open and close position limit switches.

All multi-turn actuators should be specified to be capable of being fitted with two additional adjustable intermediate position switches.

The rating of all the above switches should be specified to be not less than 250V 5A AC or 30V 5A DC.

Actuators intended for regulating duty should be specified with 4 wire 4-20mA position transmitters, the power supply for which is derived from the actuator power supply.

12.9 Isolation Requirements

The designer shall design valve actuator systems such that these are capable of being safely isolated by an authorised person who is not a Licensed Electrical Worker. All electrically actuated valve installations shall incorporate electrical isolating devices for the power supply to actuators. Such devices shall be either:

(a) Decontactor or,

(b) Switch socket with interlock and padlock facility

The design of isolating facilities shall satisfy the following requirements/features:

(i) Located adjacent or close (within visual range) to the actuator;

(ii) Location is not subject to flooding and suitably IP rated;

(iii) Mounted on a suitable stand;

(iv) Suitably labelled to identify the isolation device with the associated valve;

(v) Where not secured from vandalism, the device shall be installed in a suitable IP56 aluminium enclosure.
13 HYDRAULIC SURGE VESSELS
The control of hydraulic surge vessels is now beyond the scope of this design standard and will become a subject addressed in a different design standard.
In the meantime this section of DS22 has been retained as Appendix A1 for information purposes only.

14 SWITCHBOARD CONTROLLING SYSTEMS
Plant control is now beyond the scope of this design standard and will become a subject addressed in a different design standard.
In the meantime this section of DS22 has been retained as Appendix A2 for information purposes only.

15 LOCAL AREA PRESSURE BOOSTER PUMP STATIONS
The control of high level booster pump stations is now beyond the scope of this design standard and will become a subject addressed in a different design standard.
In the meantime this section of DS22 has been retained as Appendix A3 for information purposes only.
16  **UNINTERRUPTIBLE POWER SUPPLIES**

16.1 **Definition**

An uninterruptible power supply (UPS) is defined in AS 62040.1.1 as a combination of converters, switches and energy storage devices (for example batteries) constituting a power system for maintaining continuity of load power in case of input power failure.

16.2 **Standards**

UPS’s are covered by the following Australian Standards:

- **AS 62040.1.1** Uninterruptible power systems (UPS) - General and safety requirements for UPS used in operator access areas.
- **AS 62040.1.2** Uninterruptible power systems (UPS) - General and safety requirements for UPS used in restricted access locations.
- **AS 62040.2** Uninterruptible power systems (UPS) - Electromagnetic compatibility (EMC) requirements.
- **AS 62040.3** Uninterruptible power systems (UPS) - Method of specifying the performance and test requirements.

16.3 **Application**

(a) UPS’s are most commonly used to maintain continuity of power supply to electronic equipment which incorporates an internal switch mode power supply (SMPS).

(b) Switch mode power supplies can maintain the associated internal supplies for at least 10 milliseconds at full load and somewhat longer at lighter loads. Consequently if the application is such that the load on the UPS consists solely of electronic equipment with internal switch mode power supplies, interruptions in the UPS output voltage will be acceptable provided these are not longer than 10 milliseconds.

(c) Switch mode power supplies provide galvanic isolation between the incoming power supply and the associated electronic circuits. Consequently if the UPS load equipment consists solely of electronic equipment with switch mode power supplies, there is no need for the UPS to provide galvanic isolation.

16.4 **Types of UPS Topology**

16.4.1 **UPS Topologies in Current Use**

The following general types of UPS topologies are in current use.

(a) line interactive,
(b) double conversion
(c) standby,
(d) standby- ferro,
(e) delta conversion on line
16.4.2 UPS Topologies Covered by AS 62040

The following UPS topologies are described in Annex B of AS 62040.3:

(a) line interactive,
(b) line interactive with bypass
(c) double conversion,
(d) double conversion with bypass,
(e) passive standby

UPS’s provided in accordance with this Design Standard shall be either “line interactive with bypass” type or “double conversion with bypass” type, unless approved otherwise in writing by the Principal Engineer.

16.4.3 Rating Limits

For the reasons detailed hereunder UPS’s rated greater than 5 kVA are usually of the double conversion with bypass type while UPS’s rated less than 750 watts are usually of the line interactive with bypass type.

Which type of UPS topology is used for applications in the output range 750 watt to 5,000 watt will depend on the application and shall be determined by the Designer after consideration of the “pro and cons” of the two topologies as described hereunder.

16.5 Line Interactive with bypass UPS

16.5.1 Output Dynamic Performance

The line interactive with bypass type of UPS can provide an output dynamic performance as shown in Figure 16.1 and defined in AS 62040.3 as classification 1

![Figure 16.1](image-url)
16.5.2 **Topology**

The topology of the line interactive with bypass UPS is shown at Figure 16.2.

![Figure 16.2](image)

16.5.3 **Operation**

(a) When AC input voltage is present the power interface equipment shown in Figure 16.1 filters the A.C input supply, suppresses voltage spikes and provides sufficient voltage regulation to operate within classification 1 output dynamic performance requirements.

(b) In the normal mode of operation, the load is supplied with conditioned power via a parallel connection from the A.C. input and the UPS inverter, with the input power coming from the A.C. input supply and approximately 10% of the rated current of the UPS being supplied to maintain battery charge.

(c) When the A.C. input supply voltage is out of UPS preset tolerances, the inverter and the battery maintain continuity of output voltage and the UPS switch disconnects the A.C. input supply to prevent back feed from the inverter. Such transitions may cause the UPS output voltage to fall to zero for up to 1 milliseconds.

The UPS continues to supply the load for the duration of the stored energy time or until the A.C. input voltage returns to normal.

(d) The bypass switch can be used to connect the load directly to the incoming supply in the event of:
(i) UPS failure,
(ii) load current transients (i.e. inrush currents or fault currents),
(ii) peak loads

(e) While the line interactive will filter the voltage being supplied to the load, it will not alter the wave shape of the current being drawn by the load.

Consequently if the load consists of electronic equipment with switch mode power supplies without power factor correction, the load current will be drawn in short duration peaks.

### 16.6 Double Conversion with bypass UPS

#### 16.6.1 Output Dynamic Performance

The double conversion with pass type of UPS can provide an output dynamic performance as shown in Figure 16.3 and defined in AS 62040.3 as classification 3

![Figure 16.3](image)

**Figure 16.3**

#### 16.6.2 Topology

The topology of the double conversion with bypass UPS is shown at Figure 16.4.
16.6.3 Operation

(a) In the normal mode of operation, the load is supplied primarily by the rectifier inverter combination, i.e. all of the load current flows through the rectifier/inverter combination.

(b) When the A.C. input supply voltage is out of UPS preset tolerances, the UPS enters the stored energy mode of operation, where the battery/inverter combination continues to support the load for the duration of the stored energy time, or until the A.C. supply returns to within UPS design tolerances, whichever is the sooner.

(c) In the event of a rectifier/inverter failure, or the load current becoming excessive, either transiently or continuously the UPS enters the bypass mode in which the load is supplied temporarily via the bypass line.

However in some makes of double conversion UPS, such transitions may cause the output voltage to drop to zero for up to 10 milliseconds.

(d) Most modern UPS designs incorporate a separate battery charger module as shown in Figure 16.4.

(e) As well as performing the A.C. to D.C. conversion, the rectifier section provides power factor correction, so that it draws current from the A.C. line as a smooth sine wave rather than in pulses even though currents drawn by the load may be drawn in pulses.
(f) Double conversion without bypass can be used to convert from 50 Hz to 60 Hz, and vice versa, if required.

16.7  Comparison between Types of UPS

16.7.1  Losses
In normal operation only approximately 10% of the load current flows through the rectifier/inverter combination in a line interactive UPS, whereas in a double conversion UPS all of the load current flows through the rectifier/inverter combination. Consequently the heat losses from a double conversion UPS are much higher than those from a line interactive UPS.

16.7.2  Reliability
A line interactive UPS has a smaller component count than a double conversion UPS and so theoretically the line interactive UPS should be the more reliable. However the quality of design and manufacture may have a greater impact on reliability.

16.7.3  Physical Size
Even though double conversion UPS’s have a greater component count than line interactive UPS’s, the components in the former are smaller, so that the physical dimensions and weight of a typical double conversion UPS will be smaller than those of a line interactive UPS of the same kW rating.

16.7.4  Power Factor Correction
Unlike the double conversion UPS, the line interactive UPS does not incorporate power factor correction, so that load currents drawn, from line interactive UPS’s, by switch mode power supplies, will be drawn in pulses from the A.C. incoming supply.

16.7.5  Operation from a Generating Set
(a) AS 62040.3 requires the specification to include source impedance and generator characteristics.

(b) Normally double conversion UPS’s are equipped with power factor correction which means that a double conversion UPS will present a largely capacitive impedance to the incoming supply system. However generating sets can supply only approximately 10% of alternator rated current at 0.1 power factor. On the other hand, line interactive UPS’s do not present this problem.

16.7.6  Tolerance to A.C. Input Voltage Disturbances
Double conversion UPS’s can tolerate greater A.C. input voltage disturbances without reverting to stored energy mode than can line interactive UPS’s.

16.7.7  Battery Voltage
Since line interactive UPS’s are relatively small, these can be equipped with Extra Low Voltage batteries, whereas double conversion UPS’s usually are designed with higher battery voltages

16.7.8  Local Availability
(a) Line interactive industrial UPS’s are readily available as single phase units with ratings up to 3 kVA and suitable for indoor or outdoor installation.
(b) Double conversion general purpose UPS’s suitable for use in air conditioned environments are readily available as follows:

(i) single phase/single phase - $1 \leq 1 \text{kVA} \leq 4 \text{kVA}$
(ii) single phase/three phase - $6 \leq 6 \text{kVA} \leq 8 \text{kVA}$,
(iii) three phase/single phase - $10 \leq 10 \text{kVA} \leq 60 \text{kVA}$
(iv) three phase/three phase - $10 \leq 10 \text{kVA} \leq 900 \text{kVA}$

(c) Double conversion industrial UPS’s suitable for use in indoor environments without air conditioning are available as follows;

(i) single phase to single phase - $5 \leq 5 \text{kVA} \leq 200 \text{kVA}$
(ii) three phase to three phase - $10 \leq 10 \text{kVA} \leq 200 \text{kVA}$

16.7.9 Type Specifications

Type Specification DS26.30 covers double conversion general purpose and double conversion industrial UPS’s.

Type Specification DS26.31 covers line interactive industrial UPS’s.

16.7.10 Cost

Both the capital cost and the running costs of double conversion UPS’s are higher than those of line interactive UPS’s.

16.8 Manual Isolation and Bypass Switches

(a) Double conversion UPS’s with static bypass facilities shall be fitted in addition with internal manual bypass switches to facilitate the checking of the UPS while maintaining the supply to the load from the bypass electrical supply.

(b) All UPS’s shall be provided with external bypass and isolation switches which isolate the UPS from the incoming supply and the load.

If the battery voltage exceeds 48 VDC, such switches shall also isolate the UPS proper from the battery supply.

(c) Suitable warning notices shall be provided to warn against the hazards due to multiple sources of electrical supply

16.9 Operator Interface Panel

All UPS’s shall be provided with operator interface panels which shall display UPS operating mode, alarms, etc.

16.10 Communications

All UPS’s shall be provided with communications links which shall allow remote monitoring of the operating status of the associated UPS.

16.11 Batteries

16.11.1 Types of Battery
(a) Nickel cadmium batteries could be used in UPS installation, However there are inherent environmental problems associated with the disposal of this type of battery and consequently the use of such batteries should be avoided if this is practical.

(b) In lead acid batteries, the electrodes are made of various alloys and compounds of lead and these electrodes are generally referred to as plates.

A sulphuric acid electrolyte is used to provide an electrical connection between positive and negative plates and the electrical energy is stored by reversible chemical conversions at the plates and within the electrolyte.

(c) Lead acid batteries which provide direct access to the acid electrolyte are termed “flooded batteries” or “vented batteries” Such batteries could be used in some UPS installations but would present considerable operation and maintenance problems.

(d) Most UPS installations employ valve regulated lead acid (VRLA) batteries in which the electrolyte is restrained.

This Standard is based on the use of such batteries.

16.11.2 VRLA Batteries General

(a) VRLA batteries are often described as “sealed lead acid batteries”. These batteries are sealed under normal operating conditions, but include pressure relief valves to vent gases in the event of overcharging.

(b) The acid electrolyte in VRLA batteries is trapped within each battery cell so that the possibility of spillage of the acid electrolyte is avoided, i.e. VRLA batteries are leak proof.

(c) VRLA batteries would be better described as “recombinant batteries” because in these batteries the oxygen evolved at the positive plates combines with the hydrogen ready to evolve at the negative plate, so recreating water

(In the vented battery these gases escape, thus requiring the periodic addition of distilled water.)

(d) There are two types of VRLA batteries, i.e. the absorbed glass mat (AGM) battery and the Gel battery as described further hereunder.

16.11.3 AGM Batteries

In the AGM type of VRLA battery, the acid electrolyte is held within glass mats between the plates (as opposed to freely flooding the plates)

The glass mats are made of fine glass fibres woven into mats so to provide the surface areas needed to hold sufficient acid electrolyte on the cells over their design life.

In the AGM battery the pores in the glass mat provide a densely porous medium to the oxygen to facilitate its movement from the positive electrode to the negative electrode.

16.11.4 Gel Batteries

In the Gel type of VRLA battery, the acid electrolyte is combined with fumed silica making the resultant mass gel like and immobile.
In the Gel battery, the cracks in the gel provide a densely porous medium to the oxygen to facilitate its movement from the positive plate to the negative plate.

16.11.5 AGM versus Gel Comparison

(a) Gel batteries are better than AGM batteries in the following respects:
   (i) Service life,
   (ii) Capacity stability over life,
   (iii) Thermal runaway,
   (iv) Endurance of cycles,
   (v) Battery design constraints,
   (vi) Deep discharge tolerance.

(b) AGM batteries are better than Gel batteries in the following respects:
   (i) Internal resistance,
   (ii) Power density,
   (iii) Cost

16.11.6 Service Life

(a) Generally the service life of a VRLA battery is defined as the time taken for the battery amp*hour capacity to fall to 80% of the battery design amp*hour capacity.
   (However some manufacturers quote service life as being the time taken to fall to 60% of the battery design life.)

(b) The design life of a VRLA battery depends on the type and make of battery and is generally 5 or 6 years. However Gel batteries with a design life of up to 18 years are available.

(c) For normal VRLA expected battery service life values are given for batteries operated at 20°C. and the expected service life is halved for every 8°C to 10°C temperature rise above 20°C.
   (The reduction in service life with ambient temperature for Gel type batteries with tubular positive electrodes is less, i.e. the battery capacity is reduced by 30% for every 8°C to 10°C temperature rise above 20°C.

(e) However Gel batteries with small amounts of silver alloyed into the lead electrodes are available for high ambient temperature applications such that these batteries have a service life of 4 years at operating temperatures up to 70°C.

16.11.7 Capacity Stability

(a) AGM batteries are prone to the electrolyte in the glass mat separators drying out during service life which increases the internal resistance and which causes the glass mat separators to contract, thus reducing contact with the plates.

(b) On the other hand in the Gel battery, the gel creeps with time thus maintaining good contact with the plates.

16.11.8 Internal Resistance

The lower internal resistance of AGM batteries means that these batteries are ideal for UPS applications in air conditioned environments because under float charging the lower internal resistance means that charging times are reduced.
16.11.9 Thermal Runaway

(a) The internal resistance of a VRLA batteries falls as the battery temperature increases. With float voltage, charging the drop in internal resistance results in an increase in charging current and hence a cycle of increased heating and increased current until the battery is overheated and destroyed.

(b) In addition, AGM batteries have a lower diffusion resistance thus a higher internal recombination rate than Gel batteries because in the latter diffusion is hindered by the gel and the micro porous separator.

(c) Further, the heat conduction from the battery electrodes and to the environment via the battery case is approximately 15% better in the Gel battery than in the AGM battery.

(d) Thus AGM batteries are more prone to thermal runaway than Gel batteries, so that Gel batteries are more suitable for use in higher temperature environments.

16.11.10 Cycle Endurance

(a) Both AGM and normal Gel batteries provide good cycle life with the latter being better in this respect.

(b) Excessive cycling can cause acid stratification in AGM batteries as well as the formation of dendrite structures on the plates, which in turn leads to reduced service life.

(c) Gel batteries are available which are specially designed for multiple cycle duty. These batteries are not as good in other respects and should not be specified for applications not involving very high cyclic duty.

16.11.11 Battery Design Constraints

(a) Tubular plate design is possible in Gel batteries which has the benefit described para. 16.10.6 above.

(b) The cell height in AGM batteries is limited to approximately 350 mm whereas no such restrictions apply to Gel batteries

16.12 Application to Environmental Conditions

(a) Line interactive uninterruptible power supplies may be installed in the following locations provided that they are specified accordingly:

(i) indoors in a control room environment,
(ii) indoors in a weather protected environment (other than a control room environment), or
(iii) outdoors

(b) Double conversion uninterruptible power supplies may be installed in the following locations provided that they are specified accordingly:

(i) indoors in a control room environment, or
(ii) indoors in a weather protected environment (other than a control room environment).
(iii) shall not be installed in an outdoor environment.
(c) Type specifications DS26.31 and DS26.30 shall be specifications to be used for line interactive uninterruptible power supplies and double conversion uninterruptible power supplies respectively.
17 DIESEL ENGINE STARTING BATTERY SYSTEMS

17.1 Scope
This section of the standard applies to battery systems for diesel engines which are designed for service in a fixed location and which are permanently connected to the load.

Batteries operating in such applications are called ‘stationary batteries’.

A battery system is defined as the batteries and associated battery chargers or battery management systems.

The scope of this section covers the general requirements, characteristics, performance requirements and selection rules of battery systems for diesel engine standby power supplies.

17.2 Standards
Batteries and battery chargers are covered by the following Australian Standards:

- AS 2149-2003 Starter Batteries – Lead-Acid
- AS 61429 Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135
- AS 4029.3-1993 Stationary Batteries – Lead-Acid. Part 3: Pure lead positive plasted plate type
- AS 2562 Hydrometers – Portable syringe-type for lead-acid batteries
- AS/NZS 2401.2-1995 Battery Chargers for Lead-acid Batteries – Domestic type – Battery Chargers for valve-regulated cells
- AS 4044 -1992 Battery Charges for Stationary Batteries

17.3 Acronyms and Definitions
AGM – Absorbed Glass Mat
BMS - Battery Management System
DOD - Depth of Discharge
LiFePO4 – Lithium Iron Phosphate
LTO - Lithium Titanate LTO
NCA - Lithium Nickel Cobalt Aluminium
NMC - Lithium Nickel Manganese Cobalt
SLA – Sealed Lead Acid
UPS - Uninterruptable Power Supply
VRLA - Valve Regulated Lead Acid

17.4 Discussion
The Water Corporation operates diesel engine battery power plants in varied climatic conditions throughout Western Australia. The North West region of the state can reach maximum temperatures of 49°C (Bureau of Meteorology 2015) with high humidity and dust levels.

These power plants are often remote and unmanned leading to a desire for a minimal maintenance regime. It is therefore important to address the service life implications of battery systems in
uncontrolled, often high temperature harsh environments, so as to reduce risks to the Corporation’s network.

Battery integrity is integral to the stand-by power function for emergency diesel engine system applications.

There have been a number of battery explosions involving VRLA batteries without access to electrolyte, fitted to back-up/emergency diesel engine systems, exposed to high operating temperatures and subject float charging.

A fully sealed VRLA battery does not allow for benign release of gasses generated under continuous charging. In high temperature environments cells can suffer water loss to the extent the electrolyte falls below the top edge of plates. A low resistive bridge can form at the top of the plates and when current starts to flow, it can cause an arc or spark in one of the cells to intensify that condition. Subsequent electrode warping causes a short and explosion of mixture of hydrogen and oxygen gasses.

This section of the standard addresses alternative battery types and battery charges/BMSs for diesel engine starting systems.

Ampere hours, the general measurement of battery capacity over some number of hours, are irrelevant in power applications such as engine starting. Voltage stability at high current varies greatly among the many different battery types. In cranking applications, the ability to supply amperes for 30 seconds is not guaranteed by a quantity of ampere hours at the 5, 8 or 20 hour rate.

The battery selection shall provide for 6 cranking cycles of 5 seconds as minimum.

Recommendations on the selection of diesel engine starting battery systems for floating operation are given in Section 8, Summary and Recommendations.

17.5 Investigation of Battery Types

The investigation into existing batteries determined three main battery types that can be used for the diesel engine starting systems:

- Lithium iron phosphate, LiFePO4
- VRLA AGM Flat Plate or Spiral Roll type
- VRLA ‘flooded’ type that can be periodically topped up electrolyte

The diagram below illustrates the range of batteries examined for the diesel engine starting application.
17.5.1 Lead Acid Technology

Lead acid batteries are one of the oldest rechargeable battery chemistries and have dominated the market due to their low cost and well researched characteristics (Buchmann 2011). In modern lead acid batteries the electrodes are manufactured from lead calcium alloys and these electrodes suspended in diluted sulphuric acid, which is then the electrolyte.

A sulphuric acid electrolyte is used to provide an electrical connection between positive and negative plates and the electrical energy is stored by reversible chemical conversions at the plates and within the electrolyte.

Conventional lead acid batteries which provide direct access to the electrolyte are termed ‘flooded batteries’, ‘wet’ cells or ‘vented batteries’. ‘Flooded’ batteries can be used in emergency diesel engine starting system installations, but may present some operation and maintenance problems. This type of battery needs to be frequently topped up with water due to electrolysis of water to hydrogen and oxygen.

Known for its simplicity Valve Regulated Lead Acid batteries have a pressure relief valve which will activate when the battery starts building pressure of hydrogen gas, generally a result of being recharged.

VRLA batteries are available fully sealed without access to electrolyte or can be provided with caps to top up electrolyte.

Majority of the current VRLA batteries have the diluted acid electrolyte solution immobilized, either by soaking a fiberglass mat in it (absorbed glass-mat, AGM), or by turning the liquid into a paste-like gel by the addition of silica and other gelling agents (Gel). In this type of VRLA recombinant gas batteries, the gases are retained within the battery as long as the pressure remains within safe levels. Under normal operating conditions the gases can then recombine within the battery itself, sometimes with the help of a catalyst, and no topping-up is needed. However, if the pressure exceeds safety limits, safety valves open to allow the excess gases to escape, and in doing so regulate the pressure back to safe levels.

VRLA AGM cells may be made of flat plates similar to a conventional flooded lead acid battery, or may be made in a spiral roll form to make cylindrical cells.

17.5.2 Lithium Ion Technology

Lithium batteries have been around for nearly 20 years. The term lithium ion refers to a family of batteries in which ions move from the negative electrode (anode) to the positive electrode (cathode) during discharge and back again when being charged. The point to note in this definition is that it refers to a ‘family of batteries’. Just like the VRLA family which contains AGM and Gel types, there are a number of different ‘lithium ion’ technologies within the lithium ion family.

They each utilise different materials for their cathode and (to a lesser degree) anode and as a result exhibit different characteristics. They are therefore best suited for different applications.

It is usually the material composition of the cathode which gives its name to the lithium ion type, with the anode more often than not graphite. Lithium titanate is one such exception.

There are numerous types of lithium ion batteries and each having a technology suitable for different application.

The important thing to note is that the best battery technology depends on the application e.g. LiFePO4 batteries are extremely stable and safe to use. This safety, combined with their light weight has seen them picked up widely for use in both military and commercial applications.
17.6 Characteristics and Performance of Preferred Batteries

17.6.1 VRLA AGM Flat Plate and Spiral Roll Batteries

VRLA AGM batteries offer several advantages compared with VRLA ‘flooded’ lead acid and conventional lead acid batteries. The battery can be mounted in any position, since the valves only operate on over pressure faults.

The hydrogen suppression efficiency (measure of hydrogen and oxygen gasses recombination within the cell) in valve-regulated AGM cells varies with cell technology, but typically exceeds 90%. Since the battery system is designed to be recombinant and eliminate the emission of gases on overcharge, room ventilation requirements are reduced, and no acid fume is emitted during normal operation.

AGM batteries employ a glass micro fibre mat separator that holds the liquid electrolyte like a sponge. Shrinkage of a separator does not occur as the battery ages and the electrolyte remains in direct contact with the plates.

The main downside to the AGM design is that the immobilizing agent also impedes the chemical reactions that generate current. For this reason, the AGM batteries have lower peak power ratings than equivalent conventional battery designs. The service life and reliability experience with VRLA batteries is varied, although generally accepted to be poorer than traditional vented cells.

VRLA AGM made in a spiral roll has one excellent advantage over the flat plate type in as much that because the cells are separate; their heat accumulation values are low.

VRLA AGM batteries:
- Suitable for deep discharge current applications e.g. engine starting (internal resistance 1.2 mΩ to 4.5 mΩ). The lower the resistance, the less restriction the battery encounters in delivering the needed power spikes.
- Have shorter recharge time than flooded lead acid
- Typically 500 discharge/charge cycles at 50% Depth of Discharge
- Cannot tolerate overcharging: overcharging leads to premature failure
- Have shorter useful life, compared to properly maintained wet cell battery
- Compared with flooded lead acid battery, discharge significantly less hydrogen gas
- AGM batteries are by nature, safer for the environment, and safer to use than flooded lead acid battery
- No cell equalising charge is required
- Can be used or positioned in any orientation
- VRLA AGM flat plate battery is approximately 40% cheaper than equivalent VRLA AGM spiral roll type
- VRLA AGM flat plate battery is approximately three to six times cheaper than equivalent lithium iron type of battery

17.6.2 Lithium Iron Phosphate Batteries

Lithium iron phosphate discovered in 1999 is a well know lithium technology in Australia due to its wide use and suitability for a wide range of applications. Compared to other lithium ion types such as lithium cobalt and lithium manganese it has over twice the cycle life and is much less prone to thermal runaway which can result in the battery catching fire and thus has hindered the uptake in lithium ion batteries in the past.

The cell voltage of 3.2V/cell also makes it the lithium technology of choice for sealed lead acid replacement in a number of key applications, including diesel engine starting systems.

LiFePO4 battery capacity fade behaviour, primarily the result of loss of active lithium that is most likely associated with anode degradation, and life modelling for this battery has not been well
established. More importantly, there is little insight regarding the aging mechanisms associated with this type of battery.

The lithium iron phosphate technology is characterised by:
- Internal resistance 2 mΩ to 20 mΩ
- Low combustion energy, therefore, excellent safety characteristics
- Good use of capacity, can accept 80% Depth of Discharge
- Typically 5000 discharge/charge cycles at 70% Depth of Discharge
- Moderate specific energy Whr/kg or Whr/L
- Despite dramatic reduction in cost over the past decade, LiFePO4 batteries remain expensive. A LiFePO4 battery cost is three to six times more than equivalent size of VRLA AGM battery.

Lithium ion batteries require a Battery Monitoring System for safety and to protect the cells from damage.

17.7 Battery Management Systems/Chargers
17.7.1 VRLA Battery Chargers

Current limited float charging or temperature compensation of the float voltage in accordance with the manufacturer’s recommendation shall be specified for alleviating the risk of thermal runaway. Furthermore, the charger shall include a facility to stop charging when the ambient temperature exceeds a specified maximum.

Avoid boost (fast) charging as this only charges the surface of battery plates, can increase the chance of overheating, cause permanent damage and lead to excessive build-up of explosive gasses. A manually selectable boost charge facility is authorised only during engine start and run periods.

It is critical to consult the battery manufacturer to ensure that the battery charger and charge rates are properly selected, and maintenance schedules are established.

As dictated by battery manufacturer’s recommendations, batteries require a multistage charge sequence for perfect and accurate charging.

Modern multistage chargers deliver four primary charge stages:
- Bulk charge, around 80% of the battery capacity is recovered at this stage
- Absorption charge, the remaining 20% capacity is replaced allowing the current to drop as the battery approaches its full charge
- Float, the charge voltage is lowered and held at a constant and safe predetermined level. This prevents the battery from being overcharged
- Maintenance, this stage is a regular timed ‘return to bulk’ stage

The VRLA battery chargers shall provide the following protection features:
- Reverse polarity, e.g. with user replaceable fuses
- Over charge, initiation of a fault shutdown and raise of a fault alarm
- Over temperature, unit shutdown and raise of a fault alarm
- Output short circuit, e.g. with user replaceable fuses. This will initiate a fault shutdown and raise a fault alarm
- Temperature sensing/battery temperature sensor where temperature compensation of the float voltage in accordance with the manufacturer’s recommendation
- Cooling, forced air ventilation if specified by a manufacturer

17.7.2 Lithium Iron Phosphate Battery Management System

LiFePO4 batteries require a Battery Monitoring System for equipment safety and to protect the cells from damage.
A BMS protects the batteries from a number of potentially damaging and unsafe scenarios such as:
- Over temperature
- Over charge/discharge current and voltage
- Cell not balancing themselves through charge/discharge cycles
- Short circuit

External cell level balancing is required to maintain a consistent state of charge in the long term. LiFePO4 batteries are not self-balancing meaning the cells do not balance themselves through charge/discharge cycles. Individual cells must be monitored for over/under voltage and temperature conditions. This is essential to ensure equipment safety and increase life span.

The BMS shall monitor the following parameters:
- Voltage: total voltage, voltages of individual cells
- Temperature: temperature of individual cells
- State of charge
- Depth of discharge
- Current: current in or out of the battery

These will initiate a warning alarm.

In addition the BMS monitors and protects for the following parameters:
- Over-current
- Over-voltage (during charging)
- Under-voltage (during discharging)
- Over-temperature

These will initiate a fault shutdown and raise a fault alarm.

Detection devices should incorporate a short delay to avoid spurious operation of alarms by transient voltages.

17.8 Summary and Recommendations

The diesel engine starting systems are required to be designed to provide long service life capability in adverse environmental conditions.

Conventional lead acid non-valve regulated batteries can be used in diesel engine starting system installations but these batteries present high personal and equipment safety risk if not correctly maintained. Furthermore, conventional lead acid non-valve regulated battery systems are characterised by high maintenance cost. The lead acid non-valve regulated batteries are not recommended for use for diesel engine starting systems unless regularly maintained.

Fully sealed VRLA batteries without access to electrolyte, under continuous charging and high temperature can suffer water loss and have been known to explode. This type of battery shall not be used in diesel engine starting systems installations.

Lithium ion battery technology has potential to provide significant savings in the future. Scaling up the lithium battery technology for diesel engine starting applications is still problematic since issues such as costs, stability of performance, wide operational temperature and materials availability, are still to be resolved. The lithium ion technology is unproven for this application and environment, therefore at this stage, is not recommended for use. Development of lithium battery technology product standards and field verification may well lead us towards reassessing their use for diesel engine starting systems in the future.
Where a regular (monthly) maintenance regime can be implemented for the site, then conventional VRLA ‘flooded’ type batteries that can be periodically topped up with electrolyte are recommended. In these instances, temperature compensated chargers shall also be specified.

Where a reduced maintenance regime is required for the site, then VRLA AGM Flat Plate or VRLA AGM Spiral Roll batteries with temperature compensated chargers are recommended.
APPENDIX A

Control System
A0 SWITCHBOARD CONTROL FUNCTIONS

(a) All sites are to be integrated into the Corporation wide supervisory control and data acquisition (SCADA) system or at least be “SCADA ready” for when these are able to be integrated.

(b) Normally the control logic for each small pump station having an electrical rating within the scope of the design standard shall be implemented, via the above standard Low Voltage control circuits, by the use of a single programmable logic controller (PLC) functioning as the “controlling system” as defined at Fig. 1 of AS/NZS 4382 and by use of a SCADA system remote terminal unit (RTU) functioning as the connection to the “superordinated controlling system”, again as defined at Fig. 1 of AS/NZS 4382. All local control and protection functions shall be executed in the PLC.

(c) For small standalone sewerage pump stations only, (i.e. those which are not located within waste water treatment plants), normal operational control and monitoring functions shall be incorporated into the RTU. However, a very small PLC controlled by a single contact on an independent level probe shall be installed to provide basic load control of the pumping plant in the event of an RTU failure. This PLC shall be programmed in accordance with the Corporation’s standard logic diagram for this particular emergency control application.

(d) The RTU’s to be used for the control of small standalone sewerage pump stations shall be of a make and model approved by the Principal Engineer. Such RTU’s shall be provided by the manufacturer already programmed for control and monitoring in accordance with a standard Water Corporation specific programme which has been approved by the Principal Engineer. However, facilities shall be provided for entering project specific parameters into the programme.

(e) The above RTU’s shall be provided with detailed descriptions of the control logic, preferably in the Corporation’s control block logic form, so as to facilitate factory testing of the switchboard controlling system.

(f) Subject to the written approval of the Principal Engineer, minor variations may be made to the standard power voltage control and metering circuits so as to make use of functions which are built into the RTU as standard functions. No such modifications will be approved unless it can be demonstrated that the functions in questions are in fact manufacturer’s standard built in functions, the reliability of which has been approved by extensive field trials and experience.

(g) The switchboard controlling system shall be in accordance with Section 14 of the Design Standard.

(h) An Operator’s Interface Panel may be provided for viewing critical status and alarm points and to provide protected access to trip points. Operator Interface Panels installed in indoor switchboards shall be rated for operation at a maximum temperature of not less than 50°C whereas Operator Interface Panels installed in outdoor switchboards shall be rated for operation at maximum temperature of not less than 60°C.
A1 HYDRAULIC SURGE VESSELS

A1.1 Principle of Operation

(a) Hydraulic Surge Vessels may be necessary at pump stations to dampen pressure surges in pipelines that can be caused by sudden changes in flow rate. The basic operation of a hydraulic surge vessel electrical installation is shown diagrammatically in Fig. A1.1 and the detailed logic is shown in the Corporation’s FS00 series of drawings.
The air in the sealed space above the water acts as a pneumatic spring and hence damps sudden pressure changes in the pipeline.

The purpose of the compressor is simply to make up enclosed air lost by dissolving into the water or by air system leakage.

Since the operation of the vessel is dependent on the volume of air at normal operating pressure, no temperature compensation is provided in the air measurement system. This means that the allowable variation in and the subsequent selection of the K factors must be such that the normal diurnal variation in temperature does not initiate control or alarm functions. Seasonal temperature variations are catered for by the normal air make-up or release operations over time.

The time delay settings for a particular site should be determined by observing the settling time for PV ($t_o$) after shutting down a pump. Delay times should be set as follows:

\[ t_1 = 2t_o \]
\[ t_2 = 3t_o \]
\[ t_3 = 4t_o \]

PV$_{\text{max}}$ (%) should be determined such that, for process conditions $L_{\text{nom}}$ and $P_{\text{nom}}$ the normalised value of PV will be 50%.

The PV set point should be set initially at 50%.

### A1.2 Controller

(a) Standard drawings FS00-2-8.1 and FS00-2-8.2 detail the standard logic necessary to achieve the mode of operation shown diagrammatically in Fig A1.1.

(b) The above standard logic shall be coded into the common control PLC in the pump station associated with the surge vessel.

### A2 SWITCHBOARD CONTROLLING SYSTEMS

#### A2.1 General

#### A2.1.1 Definition

(a) The switchboard controlling system (as defined by IEC 60050-351) shall consist of the programmable logic controller(s) and associated ancillary equipment which control the switchboard main circuit equipment via the switchboard Low Voltage control circuits.

(b) The switchboard controlling system shall interface with the associated supervisory control and data acquisition system (SCADA) or with the associated treatment plant overall control system.
A2.1.2 Separation
(a) Generally the switchboard controlling system shall be separate from the associated SCADA system and from the treatment plant overall control system.

(b) However for small sewage pump stations only, the switchboard controlling system logic may be implemented within the associated SCADA system remote terminal unit (RTU). In the case where the RTU is used in this manner the RTU shall comply with the requirements of this section.

(c) However, all of the requirements specified hereunder in respect to software format, logic conventions, controller programming and logic documentation shall apply to all switchboard controlling systems regardless of where the logic is to be executed.

A2.1.3 Housing
(a) SCADA system RTU’s and PLC’s shall be located so as to minimise fast transient burst interference from the main power circuit equipment.

(b) For High Voltage switchboards and for Low Voltage switchboards rated >100 amps, the switchboard controlling system and associated SCADA system remote terminal unit (RTU) shall be housed in a cubicle or cubicles separate from the associated main switchboard.

(c) For Low Voltage switchboards rated ≤ 100 amps, the switchboard controlling system and associated RTU may be housed within the switchboard.

(d) Within a pump station having a separate cubicle housing the switchboard controlling system, this cubicle shall be designated as the Pump Control Cubicle.

A2.2 Hardware Format
A2.2.1 General
(a) Switchboard controlling systems shall incorporate industrial programmable logic controllers (PLC’s) in accordance with AS IEC 61131.

(b) The input power supply to PLC’s, RTU’s and other electronic equipment in major pump stations shall be at 24 VDC, whereas the input power supply to such equipment in treatment plants shall be at either 240 VAC or 24 VDC in accordance with the requirements of DS28.

(c) 24 VDC input power supplies to the above electronic equipment shall be battery backed and shall have the negative rail earthed.

(d) 240 VAC input power supplies to the above electronic equipment shall be via battery backed uninterruptible power supplies.

(e) Switchboard controlling systems installed in Major Pump Stations shall employ a separate PLC for the control functions associated with each pumping unit, and a separate PLC for the common control function. Such PLC’s shall be interconnected via an Ethernet switch in the manner indicated on Corporation drawing FS00-8-2.

(f) Switchboard controlling systems for small pump stations as defined in clause 1.2 of this Design Standard shall be implemented using a single PLC.

(g) Switchboard controlling systems shall include an operator interface providing a visual display of the state of the electrical system being controlled and providing a means of resetting protection equipment.
In its simplest form, such an operator interface would consist of indicating lights and fault reset push buttons.

For Major Pump Stations and for those Minor Pump Stations which utilize analogue control signals, the operator interface would consist of liquid crystal display panels incorporating system state indications (faults, etc), analogue values, control set points, analogue trends, alarm histories, etc. Typical screen displays for operator interfaces in Major Pump Stations are shown on Corporation standard drawings FS00-8-3.1/6.

(e) Switchboard controlling systems shall be implemented in such a manner that failure of the liquid crystal display will not interfere with the operation of the pump station. Touch screen software switches shall not be used as duty select switches or as unit control mode select switches.

(f) However touch screens may be used as a means of adjusting analogue control circuit set points, provided the access to such functions is software limited to authorized personnel.

A2.2.2 Electromagnetic Compatibility

(a) All electronic equipment used in switchboard controlling systems shall be certified to comply with the requirements of AS/NZS 61000.6.1. regarding electromagnetic emissions in respect to residential, commercial and light industrial locations.

(b) PLC’s used in a switchboard controlling system shall be certified to comply with the requirements for operation in Zone B environments in accordance with Criterion A as defined in AS IEC 61131-2.

(c) Other electronic equipment used in switchboard controlling systems shall comply with the requirements of AS/NZS 61000-4-4 Level 3 in respect to fast transient burst interference.

(d) Other electronic equipment used in switchboard controlling systems shall comply with the requirements of AS/NZS 61000-4-5 Level 3 in respect to electrical surge protection.

A2.2.3 Programmable Memory

PLC’s shall be of a type which employs a solid state non-volatile memory for the working programme memory. PLC employing integrated circuit EEPROM memories for this function are preferable.

A2.2.4 Power Supplies

All PLC power supplies shall be protected against voltage transients and similar forms of electromagnetic interference (EMI).

A2.2.5 Input/Output Voltage

The operating voltage of all PLC input/output circuits should be limited to Extra Low Voltage as defined in AS 3000. PLC’s shall have a rated supply voltage tolerance of +10% - 15% of nominal supply voltage.
A2.2.6 Inputs

(a) Cable which run in switchboard cubicles containing main circuit equipment, and which are being connected to PLC’s rated at less than Zone C in accordance with AS IEC 61131 Criterion A shall be connected via ferrite chokes.

(b) Cables which run in switchboard cubicles containing main circuit equipment, and which are being connected to RTU’s and other electronic equipment rated at less than Level 4 in accordance with AS/NZS 61000-4-4 shall be connected via ferrite chokes.

(c) Where analogue inputs are required these shall have a 4-20mA range.

(d) PLC’s, SCADA, RTU’s and other electronic equipment used in switchboard controlling systems shall employ optically isolated digital signal inputs which shall have Type 1 characteristics as defined in AS IEC 61131.2.

(e) Digital inputs into PLC’s, RTU’s and other electronic equipment shall be of the 24 VDC current sinking type. The inherent problem with current sourcing digital inputs is that a short circuit to earth will not appear as a fault. Consequently, the associated fuse will not operate and the input will see the status as a closed input.

(f) Digital inputs into PLC’s, RTU’s and other electronic equipment shall be light current (15 mA maximum). Any contacts generating such inputs shall be of a type suitable for this application in order to avoid malfunction due to dust or surface corrosion on the contact surfaces. Any contacts which do not have a wiping action shall be of the dust proof type.

Special bifurcated “PLC input” auxiliary contacts should be preferred where practical. In some instances it may be necessary to install special interface relays to provide the correct type of contact input.

(g) Wherever possible a spare input capacity of 20% shall be provided. Digital signal input cards shall not exceed 16 inputs.

A2.2.7 Outputs

(a) Generally, digital outputs should be fully isolated relay contact outputs. All PLC output relay contact loads shall be fitted with switching voltage surge suppression devices to eliminate contact arcing. Care should be taken to ensure that the output contact load connected is consistent with the PLC output contact rating and the equipment life required.

(b) Relay contact outputs shall not be used for outputs which have a long term average switching rate exceeding 5 per hour. PLC’s shall use current sourcing output modules.

(c) Wherever possible, the spare output capacity should be 20%.

A2.2.8 Equipment Separation

(a) In order to avoid radiated electromagnetic interference, a separation of not less than 100 mm shall be maintained between the case of any piece of equipment which contains repetitive electronic switching devices and the case of any other piece of electronic equipment, except where both pieces of equipment are of the same manufacture and the manufacturer advises that a lesser clearance will be acceptable.

(b) Similarly, a separation of not less than 100 mm shall be maintained between the power supply cable running to any piece of equipment which contains electronic circuitry and the case of any other piece of equipment which contains electronic repetitive switching devices, except where both pieces of equipment are of the same manufacture and the manufacturer advises that a lesser clearance will be acceptable.
A2.3 Logic Diagrams

A2.3.1 General

(a) Formal logic diagrams for all logic to be executed within the switchboard controlling system shall be designed, drawn and approved prior to the commencement of PLC programme coding.

(b) Logic diagrams shall be arranged for ease of understanding rather than economy of logic elements.

(c) The convention shall be adopted that latch “sets” override “resets”.

(d) Electrically maintained latches shall be used for on/off control functions.

(e) Permanent memory latches shall be used for protection and alarm functions.

A2.3.2 Use of Block Logic Format

(a) Switchboard logic functions shall be designed and documented in the block logic format, not in the system functional chart format, nor in ladder logic format.

(b) Logic programmes shall be arranged in modules with each module having a total input/output count of not more than 32.

(c) Inputs and outputs to logic modules shall be either PLC external connections or internal linkages designated as “Internal Buses”.

(d) Module boundaries shall be arranged so that Internal Buses only occur at ‘Milestones’ in the logic flow.

(e) All Internal Buses shall be annotated on the logic diagram describing the Milestone represented.

A2.3.3 Use of Standard Logic Modules

Wherever practical switchboard pump control logic functions shall be programmed using the Water Corporation’s standard pump station logic module system.

A2.3.3 Arrangement of Logic Drawings

(a) An exact copy of the current revision of each standard logic module used in the logic design for the particular project shall be given a project specific drawing number and made a drawing in the project drawing set. Such drawings shall include a note confirming that the logic shown is an exact copy of the logic shown on the specified revision of the associated FS00-2 or FS01-2 series standard drawing.

(b) Any special logic modules developed for a particular application shall be documented on separate project specific logic module diagram drawings in the same form as shown on the Water Corporation’s standard pump station logic module diagram drawings.

(c) The interconnection of standard modules and any special modules shall be shown on project specific module connection diagrams in the same form as shown on the Water Corporation’s typical pump station logic module connection diagram drawings. These project specific module connection diagrams shall show the drawing number and revision number for each of the standard logic modules included in the diagram.

(d) Separate project specific logic module connection diagrams shall be prepared for each pump station unit and for the common control function.
A2.4  PLC Programming and Documentation

A2.4.1  General

(e) All PLC programme coding shall be developed on a PC based high level language programmer.

(b) PLC programme read out and documentation shall be in block logic format or in the ladder diagram format. PLC programmes shall be independent of programme scan order. PLC programming shall be in the same logic modules as shown on the relevant logic diagram.

(c) Standard logic modules shall be coded into the PLC programme in accordance with the instructions for use detailed on Corporation drawing FS00-1-2 for major pump stations and Corporation drawing FS01-1-2 for small pump stations.

A2.4.2  Ladder Diagrams

(a) Where the PLC coding documentation is in the ladder diagram format, an introduction shall be included at the beginning of the ladder diagram documentation. The introduction shall include a list of the logic modules and their functions. It also shall include a list of Internal Buses used.

(b) All ladder diagram "Contacts" and "Coils" relating to Internal Buses and external I/O shall be labelled with the same descriptions used in the logic diagram. Annotations shall be included on ladder diagrams to explain the function of each programme module.

(c) Contacts and Coils internal to programme modules shall be labelled descriptively if this will aid understanding of programme function. Internal Buses and external I/O should be labelled in upper case lettering. All other lettering should be lower case. As far as is practicable within the limits of the particular PLC being used, contacts, coils, and logic rungs should be cross referenced. Similarly, as far as is practicable, coils should be arranged in coil number order within each programme module. Each latch reset function shall be located immediately before the associated latch set function.

(d) Once the programme has been tested successfully, the programmer shall mark up the project drawing set logic diagrams (including the logic diagrams for the standard logic modules used) to show the PLC address of each logic bus and logic function.

A3  HIGH LEVEL AREA BOOSTER PUMP STATIONS

A3.1  General

(a) Ground level tanks are often located on hill tops so as to provide water pressure to consumers located down the hill. In order to provide water pressure to consumers located at higher levels, previous practice has been to provide relatively small tank on a high tank stand next to the ground level tank and to supply such consumers from this tank. In such situations a small pump station is provided and operated under float switch control maintain water in the small tank. However such “water towers” are relatively expensive and unsightly.

(b) The basic purpose of a High Level Area Booster (HLAB) pump station is to provide water pressure to consumers in high level areas using variable speed pumps pumping directly into the local water distribution system.

In these systems the pump station differential pressure shall be controlled to a specified value at any particular flow rate from zero flow rate up to the water distribution system maximum demand flow rate.

(c) HLAB pump stations consist of multiple identical pumps with a cascade control system controlling pump speed and number of operating pumps so as to maintain the required pressure...
over the flow rate demand range. The number of operating pumps is increased and decreased in proportion to the flow rate demand.

(d) The control system is based on the use of a cascade controller complying with the requirements of Type Specification DS26.33.

(e) The control system is such that, at any one time, all operating pumps run at the same speed.

(f) If the cascade controller were to be arranged to control the pump station delivery gauge pressure, the hydraulic characteristics of centrifugal pumps are such that the control system could provide compensation for only a relatively small variation in suction pressure. Consequently HLAB pump stations designed in accordance with this Design Standard shall be based on controlling the differential pressure between the pump suction and the pump delivery.

(g) In order to compensate for pipework friction head loss, it is desirable to arrange for the pump station differential pressure to increase slightly as the pump station flow rate increases.

In practice it will be found, that at best, the pressure versus flow rate characteristics of available pumps will mean that the set increase in pump station differential pressure from no flow to maximum flow rate will need to be limited to less than 40%. However, depending on the pump selected, this value may be much lower.

A3.2 Shortcomings of HLAB Pump Stations

While HLAB pump stations have the advantages of lower capital cost and better public acceptance, they have the following disadvantages in respect to the alternative described in para. A3.1(a):

(a) the control equipment is technically more complex which may be a maintenance problem in remote areas,

(b) maintaining the water pressure relies on power being available continuously, whereas the water in an elevated tank will provide water supply pressure for the time that it takes for the elevated tank to empty,

(c) the continuous pump operation and the increased need for standby generating plant increases the average acoustic noise levels emanating from the pump station, and

(d) since these pump stations must be controlled on the basis of pump station differential pressure, variations in pump station suction pressure will be reflected as variations in pump station delivery pressure.

As a consequence HLAB pump stations must pump from a relatively local suction tank.

A3.3 Incoming Power Supply

The incoming electrical supply arrangement shall be in accordance with standard drawings MN01. The Main Switchboard (housing the service protective device and metering) and the Pump Station Switchboard may be separate or combined depending upon project requirements.

A3.4 Standby Power Supply

All HLAB pump stations shall be provided with facilities for the connection of a standby generating set.
Whether a standby generating set is installed permanently will be decided on a project by project basis depending on the criticality of the water supply, the dependability of the power supply and the level of access to a portable generating set.

A3.5 Pump Characteristics
(a) The flow rate versus performance characteristics of centrifugal pumps are often specified graphically with pump output flow rate being assigned the symbol Q defined in m$^3$/hr or litre/sec. and with pump differential pressure being assigned the symbol H and specified in “metres head of water”

\[(1 \text{ m}^3/\text{hr} = 0.278 \text{ litre/sec.} \quad 1 \text{ metre head of water} = 9.8 \text{ kPa})\]

In the following discussions flow rates are specified in m$^3$/hr and assigned the symbol Q. and pressures are specified in metres (head of water) but given the standard symbol for pressure, i.e. the lower case “p”.

(b) The performance characteristics of centrifugal pumps are substantially non-linear.

(c) Reducing the pump speed reduces both output pressure and flow rate.

Pump output pressure varies as the square of pump speed and pump output flow rate varies directly with the pump speed. These relationships are known as the “affinity laws”

(d) Pump differential pressure versus flow rate characteristics at various speeds for a typical HLAB pump are shown at Figure A3.1 together with pump efficiency versus flow rate characteristics.

(e) If pump cavitation is to be avoided, a pump cannot be operated beyond the “end of curve” point on the pressure/flow rate curve for a particular pump speed, i.e. the pump must not be operated under pressure/flow rate conditions outside the shaded area shown on Figure A3.1.

(f) From the typical example shown at Figure A3.1, it can be seen that pump efficiency falls sharply at flow rates less than 30% of pump end of curve flow rate for any particular speed.

(g) Pump suitability for cascade control is discussed at clause A3.9.

A3.6 Maintaining Pressure at Zero flow
(a) Even at minimum speed some outflow from a pump is required to prevent the pump from overheating. Consequently in order to maintain the pressure with no outflow from the pump station either:

(i) a diaphragm tank shall be installed on the delivery main so that the pump drives can be put into sleep mode, or

(ii) a bypass line shall be installed to circulate a small amount of water from the delivery main back to the suction main (preferably into the suction tank).

(b) If a bypass line is installed, the control system shall be arranged so that the bypass line is closed if the demand is such that more than one pump is required to operate.

A3.7 Hydraulic Parameters
(a) Pump hydraulic parameters used in the following discussions are defined hereunder. (Figure A3.3 refers).
(i) \( N = \) pump speed as a % of 50 Hz pump speed,

(ii) \( N_{\text{max}} = \) pump maximum speed setting % of 50 Hz pump speed,

(iii) pressure/flow rate curve = pressure versus flow rate relationship at speed \( N \)

(iv) \( p_{so} = \) pump shut off pressure at speed \( N \)
     (i.e. pump pressure at no flow at speed \( N \))

(v) \( p_{soma} = \) pump shut off pressure at speed \( N_{\text{max}} \)

(vi) \( p_{ec} = \) pump end of curve differential pressure at speed \( N \)

(vii) \( p_{ec_{\text{max}}} = \) pump end of curve differential pressure at \( N_{\text{max}} \)

(viii) \( Q_{ec} = \) pump end of curve flow rate at speed \( N \)

(ix) \( Q_{ec_{\text{max}}} = \) pump end of curve flow rate at speed \( N_{\text{max}} \)

(x) \( \frac{\delta Q}{\delta N} = \) slope of flow rate versus speed curve at particular pressure and at a particular
     flow rate- refer Fig. A3.4

(xi) \( n_p = \) number of pumps

(xii) \( Q_{umax} = \) individual unit pump flow rate at pressure \( p_{ts} = Q_{ts}/n_p \) - refer A3.7(b)(iii)

(b) Control system hydraulic parameters used in the following discussions are defined hereunder.

(i) \( p_{0t} = \) system zero flow rate theoretical differential pressure

(ii) \( p_{ts} = \) differential pressure with all pumps operating, set point ,
     (i.e. pressure for total pumping capacity set point)

(iii) \( Q_{ts} = \) system maximum flow rate with all pumps operating at \( p_{ts} \), set point (i.e. total
     pumping capacity flow rate at \( p_{ts} \) set point)

(iv) \( p_{1s} = \) differential pressure with one pump operating, set point

(v) \( p_{shs} = \) pump station maximum allowable suction pressure, set point,

(vi) \( p_{sls} = \) pump station minimum allowable suction pressure, set point,

A3.8 Cascade Control Functions

A3.8.1 Differential Pressure Control
For reasons discussed at para. A3.9 pump station pressure control shall be on the basis of pump
station differential pressure rather than pump station delivery gauge pressure.

A3.8.2 Suction Pressure
The cascade controller shall shut the pump station down should the suction pressure rise above the
allowable maximum pump station suction pressure (\( p_{shs} \)), or fall below the allowable minimum pump
station suction pressure \(p_{sls}\), but shall allow the system to restart once the suction pressure is within acceptable limits.

**A3.8.3 Control Pressure Curve**

(a) Ideally the cascade controller should be able to be set to increase the output pressure from pump station zero flow to pump station maximum flow with pump station output pressure rising approximately in proportion with the square of the flow rate, so as to compensate for friction head loss in the delivery pipe work.

(b) However it is not practical in cascade controllers using pump speed as a measure of flow rate to control the output pressure in accordance with such an ideal control pressure curve.

(c) Consequently these cascade controllers shall increase the pump differential pressure set point in rising steps approximately in proportion to the square of the flow rate, i.e. rather than following a continuously rising control pressure curve.

System pressure step ups shall be set to occur at pump station total flow rate increments of \(Q_{\text{max}}\) i.e. at the staging on of each additional pump.

In Figure A3.2 pressure step downs have been set midway between step up flow rates. The example system design detailed in para. A3.11 has assumed these values.

Figure A3.3 indicates the pump pressure/flow rate operating characteristics for each control step.

(d) Pump speeds corresponding to the required step up and step down flow rates shall be calculated as per example calculation at clause A3.11.

These calculated pump step up and step down speeds in terms of Hz shall be entered into the cascade controller

(e) Once pump speed has reached the set step up speed for a particular pressure control step, the cascade controller shall call in an additional pump and reduce the pump speed of the operating pumps accordingly.

(f) Similarly for all control pressure steps other than the initial step, once the pump speed falls to less than the set step down speed for a particular pressure control step, the cascade controller shall drop out one pump and increase the pump speed of the operating pumps accordingly.

(g) At each pressure step, the pump shall operate over the flow rate range defined by the step up and step down speed settings.

(h) System step up and step down flow rates for the typical example at clause A3.11 are shown on Figure A3.2. The related pump step up and step down flow rates are shown on Figure A3.3

**A3.9 Pump Suitability for Cascade Control**

(a) Within a cascade controlled system the pump step down flow rate can be as low as 25 % of pump controlled full speed flow rate.

(b) As shown in Figure A3.4, the ratio of flow rate change to speed change \(\frac{\delta Q}{\delta N}\) rises sharply at lower flow rates.

(c) The cascade control system uses pump speed as a measure of flow rate, which provides an adequate level of control precision.
(d) Pumps in such systems should be selected such that, in step 1 the pump pressure/flow rate operating conditions will always be above the end of curve pressure limit, i.e. \( p_{ts} \) must be above \( p_{ec\text{max}} \).

(e) It can be seen from Figure A3.3 that there is limited scope to move these operating characteristics up and down to account for variations in suction pressure, which accounts for the requirement that the basis of control is required to be the differential pressure across the pump station.

As a general rule \( p_s \) should not be greater than 140\% of \( p_{ec} \) at 100\% rated speed and \( p_{0t} \) should not be less than 25\% of \( p_s \) at 100\% rated speed.

### A3.10 Determination of Step Down Set Points

(a) Step down and step up frequencies shall be determined graphically on the basis of flow rates as indicated in a typical example in para. A3.11.

It should be noted that the controller steps down in stage order with a delay between successive steps. Consequently it does not matter if the step down frequencies are close together.

(b) An example of the design process is given hereunder.

### A3.11 Example Calculation

(a) Figure A3.2 illustrates the determination of set points for a typical HLAB pump station.

(b) In these calculations pressures are expressed in metres H\(_2\)O.

(c) In this example the following operational requirements were:

(i) \( p_{ts} = 22 \text{ metres} \)
   = system maximum flow rate differential pressure setting

(ii) \( Q_{ts} = 44 \text{ cub.m/hr} \) = system maximum flow rate at pressure \( p_s \)

(iii) \( p_{0t} = 18 \text{ metres} \) = system zero flow rate theoretical differential pressure

(iv) \( n_p = 4 \) = number of duty pumps

(v) \( Q_{umax} = Q_{ts} / n_p = 44/4 = 11 \text{ cub.m/hr} \)
   = individual pump flow rate at pressure \( p_{ts} \)

(d) On the basis of values given in para. A3.11(c) the system pressure/flow rate control curve for Figure A3.2 is determined as follows:

\[
N_{\text{max}} = \text{pump maximum speed setting}
\]

In this example, \( N_{\text{max}} \) is selected to be 100\% of 50 Hz pump speed,

on \( N_{\text{max}} \) curve in figure A3.3, \( p_{st} - p_{0t} = 22-18 = 4 \text{ metres} \)

= pipe friction head at \( Q_{ts} \)

\( Q_{ts}/2 = 44/2 = 22 \text{ cub. m/hr} = 50\% \) system maximum flow rate

Friction head at \( Q_{ts}/2 = (p_{ts} - p_{0t}) \times 0.5^2 = 1 \text{ metre} \)
Hence control pressure at \( Q_{ts} / 2 = 18 + 1 = 19 \) metres
Thus the control curve is drawn as a smooth curve through
18 metres at zero flow,
19 metres at 22 cub. m/hr,
22 metres at 44 cub. m/hr

(e) All pumps step up at an individual pump flow rate of 11 cub. m/hr i.e. at \( Q_{\text{umax}} \), as shown on
Figure A3.3

(f) On the basis of system step down flow rates shown in Figure A3.2 the per pump step down
flow rates are as follows:

(i) stage 2 per pump step down flow rate = \( 0.5 \times 11 / 2 = 2.75 \) cub. m/hr
(ii) stage 3 per pump step down flow rate = \( 1.5 \times 11 / 3 = 5.5 \) cub. m/hr
(iii) stage 4 per pump step down flow rate = \( 2.5 \times 11 / 4 = 6.88 \) cub. m/hr

(g) The step pressures derived in Figure A3.2 are as follows;

\[
\begin{align*}
\text{p}_{\text{step 1}} &= 18.3 \text{ metres} = p_{s1} \\
\text{p}_{\text{step 2}} &= 19 \text{ metres} \\
\text{p}_{\text{step 3}} &= 20.2 \text{ metres} \\
\text{p}_{\text{step 4}} &= 22 \text{ metre} = p_{s}
\end{align*}
\]

(h) In order to generate pump step down speeds it is necessary to generate flow rate versus speed
curves at \( p_{\text{step 1}}, p_{\text{step 2}}, p_{\text{step 3}} \) and \( p_{\text{step 4}} \) using the flow rate values at each step pressure on the
pressure/flow rate curves provided.

Points on each such curve are determined from Figure A3.3 as hereunder. (Refer para. A3.5(c)
in respect to calculation of speeds at zero flow rate.)

(i) If pressure = \( p_{\text{step 1}} = 18.3 \) m,
at 0 cub.m/hr, speed = \( 80 \times (18.3/19.5)^{0.5} = 77.5 \% \)
at 5.2 cub.m/hr, speed = 80%
at 9.6 cub.m/hr, speed = 90%
at 12.5 cub.m/hr, speed = 100%

(ii) If pressure = \( p_{\text{step 2}} = 19 \) m,
at 0 cub.m/hr, speed = \( 80 \times (19/19.5)^{0.5} = 79.0 \% \)
at 3.6 cub.m/hr, speed = 80%
at 9.2 cub.m/hr, speed = 90%
at 12.3 cub.m/hr, speed = 100%

(iii) If pressure = \( p_{\text{step 3}} = 20.2 \) m,
at 0 cub.m/hr, speed = \( 80 \times (20.2/19.5)^{0.5} = 81.4 \% \)
at 8.4 cub.m/hr, speed = 90%
at 11.8 cub.m/hr, speed = 100%

(iv) If pressure = \( p_{\text{step 4}} = 22 \) m,
at 0 cub.m/hr, speed = \( 80 \times (22/19.5)^{0.5} = 85.0 \% \)
at 6.9 cub.m/hr, speed = 90%
at 11.0 cub.m/hr, speed = 100%
Each of the required flow rate versus speed curves is generated by drawing a smooth curve through the relevant points determined above, as shown on Figure A3.4

(i) The required speeds at each of the required step down flow rates are determined from Figure A3.4 as indicated.

The required step down frequencies thus determined and corrected to nearest whole number frequency are:

- Step 2: 79.5% = 40 Hz
- Step 3: 84.5% = 42 Hz
- Step 4: 90.0% = 45 Hz

(j) The required speeds at each of the required step up flow rates can be determined from Figure A3.4 as indicated.

The required step up frequencies thus determined and corrected to nearest whole number frequency are:

- Step 1: 94.4% = 47 Hz
- Step 2: 95.5% = 48 Hz
- Step 3: 97.4% = 49 Hz

(k) From Figure A3.3, $p_{\text{ecmax}}$ on the 94.4% speed pressure/flow rate curve is estimated at 16 m which is less than the $p_0$ value of 18 m, i.e. $p_{\text{ecmax}} < p_0$ as required para. A3.9 (d), so O.K.

A3.12 Equipment Redundancy

(a) Water supply HLAB pump stations provide a critical service in that the failure of such a pump station means that the supply of water ceases to consumers served by the pump station.

Consequently such pump stations shall be designed with a sufficient level of redundancy, so that the failure of any one component, other than the cascade controller itself, shall not cause the pump station to cease to perform its primary function. However some interruption to some minor functions shall be permitted.

(b) Control systems are available which incorporate a standby cascade controller as well as the duty cascade controller. Whether a standby cascade controller is installed shall be decided on a project by project basis depending on the criticality of the water supply and the availability of maintenance staff.

(c) Adequate facilities shall be provided to allow supervisory control and monitoring of the pump station from a local operator interface panel and from a SCADA system central control station.

A3.13 Maximum Starting Frequency

(a) If a diaphragm tank is required, the size of the tank will be determined by the Mechanical Designer.

(b) The size of the diaphragm tank is dependent in part on the permissible frequency of starting of the pump drive, the smaller the allowable starting frequency, the larger must be the diaphragm tank.
Since a variable speed drive will not draw more than full load current when starting, a high frequency of starting can be permitted.

Consequently up to 200 starts per hour shall be permitted.

A3.14 Electrical Control System Specification

The electrical control system shall comply with Type Specification DS26.33 and with the Water Corporation FS01-9-21/35 series of standard drawings.

A3.15 PLC Logic Diagrams

(a) The control system specified in Type Specification DS26.33 is required to operate under the supervisory control of an on-site PLC.

(b) PLC logic shall be implemented in accordance with the standard logic diagrams documented on Water Corporation standard drawings FS01-9- 21/35.

These drawings have been prepared for a PLC supervising two cascade controllers, but also shall be used for applications requiring only one cascade controller.

(c) Such use shall be in accordance with para. 6.2(b) of the Standard Logic Systems Directions for Use as documented on Water Corporation standard drawing FS01-1-2.

(d) The nomenclature specified for applications requiring two cascade controllers shall be retained on logic drawings for applications requiring only one cascade controller.

A3.16 Related Mechanical Standard

The mechanical design requirements for HLAB pump stations are specified in Design Standard DS32-02 High Level Area Booster Pump Stations – Mechanical.
Pumped liquid = water
Liquid temperature = 20°C
Density = 998.2 kg/m³

Individual Pump Flow Rate vs Speed

Figure A3.1
Figure A3.2
Figure A3.3
Figure A3.4

- Step 1 = 18.5 metres
- Step 2 = 19 metres
- Step 3 = 20.2 metres
- Step 4 = 22 metres

Individual Pump Flow Rate vs Speed
END OF DOCUMENT