NEMA Standards Publication ICS 61800-4-2004

Adjustable Speed Electrical Power Drive Systems


Published by:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, Virginia 22209

www.nema.org

© Copyright 2004 by the National Electrical Manufacturers Association. All rights including translation into other languages, reserved under the Universal Copyright Convention, the Berne Convention for the Protection of Literary and Artistic Works, and the International and Pan American Copyright Conventions.
NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its standards and guideline publications.

NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, expressed or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller’s products or services by virtue of this standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.
3.1.22 rated a.c. current ...................................................................................................... 12
3.1.21 rated fundamental voltage........................................................................................ 11
3.1.20 rated voltage............................................................................................................. 11
3.1.19 characteristic current harmonics .............................................................................. 11
3.2.1 line-side input power,
3.2.6 supply transient energy ............................................................................................ 13
3.1.17 total distortion factor,
3.1.16 total distortion ratio,
3.1.15 total distortion content,
3.1.14 total harmonic distortion, \( THD \).
3.1.13 harmonic content, \( HC \).
3.1.12 interharmonic component
3.1.11 interharmonic frequency
3.1.10 harmonic component
3.1.9 harmonic frequency (order h)
3.1.8 fundamental component (or fundamental)
3.1.7 fundamental frequency
3.1.6 power conversion efficiency,
3.1.5 PDS efficiency, \( \eta_P \)
3.1.4 regeneration
3.1.3 harmonic filter
3.1.2 point of coupling
3.1.1 a.c. power drive system (PDS)
3.2 PDS Input Parameters
3.3.10 dynamic short-circuit output current
3.3.9 apparent converter output power, \( S_a \)
3.3.8 a.c. converter output power, \( P_{a1} \)
3.3.7 converter output filter
3.3.6 d.c. link
3.3.5 snubber (circuit)
3.3.4 converter d.c. link current, \( I_d \)
3.3.3 converter d.c. link voltage, \( U_d \)
3.3.2 converter input filter
3.3.1 converter section (voltage above 1kV)
3.2.6 supply transient energy
3.2.5 voltage unbalance (imbalance)
3.2.4 voltage imbalance
3.2.3 input total power factor, \( \lambda_i \)
3.2.2 line-side input apparent power, \( S_L \)
3.2.1 line-side input power, \( P_L \)
3.4 PDS Output Parameters
3.3.11 operating frequency range
3.3.10 dynamic short-circuit output current
3.3.9 apparent converter output power, \( S_a \)
3.3.8 a.c. converter output power, \( P_{a1} \)
3.3.7 converter output filter
3.3.6 d.c. link
3.3.5 snubber (circuit)
3.3.4 converter d.c. link current, \( I_d \)
3.3.3 converter d.c. link voltage, \( U_d \)
3.3.2 converter input filter
3.3.1 converter section (voltage above 1kV)
3.2.5 voltage unbalance (imbalance)
3.2.4 voltage imbalance
3.2.3 input total power factor, \( \lambda_i \)
3.2.2 line-side input apparent power, \( S_L \)
3.2.1 line-side input power, \( P_L \)
3.4.1 load envelope ................................................................. 15  
3.4.2 minimum operating speed, \( N_{\text{min}} \) ......................................................... 15  
3.4.3 maximum operating speed, \( N_{\text{max}} \) ......................................................... 15  
3.4.4 base speed, \( N_0 \) ...................................................................................... 15  
3.4.5 field weakening operation ................................................................. 16  
3.4.6 air-gap torque pulsation ................................................................. 16  

3.5 Control ...................................................................................... 16  
3.5.1 control system .............................................................................. 16  
3.5.2 controlled variable ......................................................................... 16  
3.5.3 service variable .............................................................................. 16  
3.5.4 operating variable ........................................................................... 16  
3.5.5 open-loop control ........................................................................... 16  
3.5.6 feedback control/closed-loop control ............................................. 16  
3.5.7 stimulus ........................................................................................ 16  
3.5.8 disturbance .................................................................................... 16  
3.5.9 time response ................................................................................ 17  
3.5.10 step response ................................................................................ 17  

3.6 Tests ......................................................................................... 17  
3.6.1 type test ..................................................................................... 17  
3.6.2 routine test .................................................................................. 17  
3.6.3 sampling test ................................................................................ 17  
3.6.4 special test .................................................................................. 17  
3.6.5 acceptance test ............................................................................ 17  
3.6.6 commissioning test ....................................................................... 17  
3.6.7 stimulus ....................................................................................... 18  
3.6.8 separate component test ............................................................... 18  
3.6.9 drive system test ........................................................................... 18  

3.7 Symbols ....................................................................................... 18  
3.7.1 type test ..................................................................................... 18  

4 OVERVIEW OF DRIVE SYSTEM TOPOLOGIES  
4.1 Topologies Classification .............................................................. 21  
4.2 Converter Configuration ............................................................... 21  
4.2.1 Indirect converter ........................................................................... 21  
4.2.2 Direct converter ............................................................................ 22  
4.2.3 Commutation mode ........................................................................ 22  
4.3 Motor Type .................................................................................. 22  
4.4 By-Pass and Redundant Configurations ........................................... 23  
4.5 Regenerative and Dynamic Braking ................................................ 24  
4.5.1 Regenerative braking ................................................................... 24  
4.5.2 Dynamic braking .......................................................................... 25  

5 SERVICE CONDITIONS  
5.1 Installation and Operation ............................................................ 26  
5.1.1 Electrical service conditions ......................................................... 26  
5.1.2 Environmental service conditions ................................................ 29  
5.1.3 Commissioning ........................................................................... 31  
5.2 Transportation .............................................................................. 31  
5.2.1 Climatic conditions ........................................................................ 31  
5.2.2 Mechanical conditions ................................................................. 32  
5.3 Storage of Equipment ................................................................. 32  
5.3.1 General ....................................................................................... 32  
5.3.2 Climatic conditions ........................................................................ 33  
5.3.3 Specific storage hazards ............................................................... 33  

6 RATINGS  
6.1 Power Drive System (PDS) ........................................................... 34
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1.1 General</td>
<td>34</td>
</tr>
<tr>
<td>6.1.2 PDS input ratings</td>
<td>34</td>
</tr>
<tr>
<td>6.1.3 PDS output ratings</td>
<td>34</td>
</tr>
<tr>
<td>6.1.4 PDS efficiency and losses</td>
<td>35</td>
</tr>
<tr>
<td>6.1.5 PDS overload capability</td>
<td>36</td>
</tr>
<tr>
<td>6.2 Converter</td>
<td>37</td>
</tr>
<tr>
<td>6.2.1 Converter input ratings</td>
<td>37</td>
</tr>
<tr>
<td>6.2.2 Converter output ratings</td>
<td>37</td>
</tr>
<tr>
<td>6.2.3 Efficiency and losses</td>
<td>38</td>
</tr>
<tr>
<td>6.3 Transformer</td>
<td>39</td>
</tr>
<tr>
<td>6.4 Motor</td>
<td>39</td>
</tr>
<tr>
<td>6.4.1 Motor input ratings</td>
<td>39</td>
</tr>
<tr>
<td>6.4.2 Motor output ratings</td>
<td>39</td>
</tr>
<tr>
<td>7 Steady State Performance</td>
<td>41</td>
</tr>
<tr>
<td>7.1 Steady State</td>
<td>41</td>
</tr>
<tr>
<td>7.1.1 Steady state</td>
<td>41</td>
</tr>
<tr>
<td>7.1.2 Deviation band</td>
<td>41</td>
</tr>
<tr>
<td>7.1.3 Selection of deviation band (steady state)</td>
<td>42</td>
</tr>
<tr>
<td>7.2 Dynamic Performance</td>
<td>42</td>
</tr>
<tr>
<td>7.2.1 General</td>
<td>42</td>
</tr>
<tr>
<td>7.2.2 Time responses</td>
<td>43</td>
</tr>
<tr>
<td>7.2.3 Frequency response of the control</td>
<td>47</td>
</tr>
<tr>
<td>7.3 Process Control Interface Performance</td>
<td>48</td>
</tr>
<tr>
<td>7.3.1 General</td>
<td>48</td>
</tr>
<tr>
<td>7.3.2 Analog input performance</td>
<td>48</td>
</tr>
<tr>
<td>7.3.3 Analog output performance</td>
<td>49</td>
</tr>
<tr>
<td>7.3.4 Digital input performance</td>
<td>49</td>
</tr>
<tr>
<td>7.3.5 Digital output performance</td>
<td>50</td>
</tr>
<tr>
<td>7.3.6 Performance of communication links</td>
<td>50</td>
</tr>
<tr>
<td>8 PDS MAIN COMPONENTS</td>
<td>51</td>
</tr>
<tr>
<td>8.1 Responsibilities</td>
<td>51</td>
</tr>
<tr>
<td>8.2 Transformer</td>
<td>52</td>
</tr>
<tr>
<td>8.2.1 Introduction</td>
<td>52</td>
</tr>
<tr>
<td>8.2.2 Specification and rating</td>
<td>52</td>
</tr>
<tr>
<td>8.2.3 Impedances</td>
<td>54</td>
</tr>
<tr>
<td>8.2.4 Common mode and d.c. voltages</td>
<td>54</td>
</tr>
<tr>
<td>8.2.5 Specific requirements</td>
<td>55</td>
</tr>
<tr>
<td>8.3 Converter and Associated Controls</td>
<td>55</td>
</tr>
<tr>
<td>8.3.1 Object</td>
<td>55</td>
</tr>
<tr>
<td>8.3.2 Design requirements</td>
<td>56</td>
</tr>
<tr>
<td>8.4 Motor</td>
<td>57</td>
</tr>
<tr>
<td>8.4.1 Introduction</td>
<td>57</td>
</tr>
<tr>
<td>8.4.2 Design requirements</td>
<td>57</td>
</tr>
<tr>
<td>8.4.3 Performance requirements</td>
<td>57</td>
</tr>
<tr>
<td>8.4.4 Mechanical system integration requirements</td>
<td>58</td>
</tr>
<tr>
<td>8.4.5 Voltage stress of the motor winding insulation system</td>
<td>59</td>
</tr>
<tr>
<td>8.4.6 Designation of essential data</td>
<td>63</td>
</tr>
<tr>
<td>9 PDS INTEGRATION REQUIREMENTS</td>
<td>65</td>
</tr>
<tr>
<td>9.1 General Conditions</td>
<td>65</td>
</tr>
<tr>
<td>9.1.1 Overview</td>
<td>65</td>
</tr>
<tr>
<td>9.2 Special Conditions</td>
<td>66</td>
</tr>
<tr>
<td>9.2.1 Interactions between drive components</td>
<td>66</td>
</tr>
<tr>
<td>9.2.2 Information to be exchanged</td>
<td>67</td>
</tr>
<tr>
<td>9.3 Integration of Components with Voltages above 1,000 V</td>
<td>68</td>
</tr>
</tbody>
</table>

© Copyright 2004 by the National Electrical Manufacturers Association.
Foreword

This document is an adaptation of the IEC Standard 61800-4 with the addition of requirements pertinent to use of these devices in the U.S. U.S. differences are indicated with (U.S. Differences) and italics.

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

5) The IEC provides no marking procedure to indicate its approval and cannot be held responsible for any equipment declared to be in conformity with one of its standards.

6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61800-4 was prepared by IEC sub-committee 22G: Semiconductor power converters for adjustable speed electric drive systems, of IEC technical committee 22: Power electronic systems and equipment.

Annexes A, B and C are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

• reconfirmed;
• withdrawn;
• replaced by a revised edition, or
• amended.

© Copyright 2004 by the National Electrical Manufacturers Association.
1.1 SCOPE AND OBJECT

It applies to power drive systems (see figure 1) with converter voltages (line-to-line voltage), between 1 kV a.c. and 35 kV a.c., input side 50 Hz or 60 Hz, and load side frequencies up to 600 Hz. Requirements for voltages above 15 kV are not included and are defined by agreement between the manufacturer and the system supplier.

For power drive systems, with voltages above 1 kV, using a step-down input transformer and/or a step-up output transformer in connection with a low voltage converter (below 1 000 V), IEC 61800-2 applies. EMC aspects are covered in IEC 61800-3.

U.S. NOTE: EMC Immunity and Emission requirements of IEC 61800-3 are not applicable within the U.S. Specific safety requirements for drive systems with voltage above 1 kV will be covered in IEC 61800-5.

This standard gives the characteristics of the converters, their topologies and their relationship with the complete a.c. drive system. It also states their performance requirements with respect to ratings, normal operating conditions, overload conditions, surge withstand capabilities, stability, protection, a.c. line earthing, topologies and testing. Furthermore, it deals with application guidelines, such as control strategies, torsion analysis, recommendations for earthing and drive system component integration.