4.1.7 Tank or enclosure finish

Temperature limits and tests shall be based on the use of a nonmetallic pigment surface paint finish. It should be noted that metallic-flake paints, such as aluminum and zinc, have properties that increase the temperature rise of voltage regulators, except in direct sunlight. Unless otherwise specified, the tank finish shall conform to Light Gray Number 70, Munsell Notation 5BG 7.0/0.4. Finishing of voltage regulators shall meet requirements specified in IEEE Std C57.12.31.⁶

4.2 Loading at other than rated conditions

IEEE Std C57.91 provides guidance for loading at other than rated conditions including the following:

- a) Ambient temperatures higher or lower than the basis of rating
- b) Short-time loading in excess of nameplate kVA with normal life expectancy
- c) Loading that results in reduced life expectancy

NOTE—IEEE Std C57.91 is a guide rather than a standard. It provides the best known general information for the loading of voltage regulators under various conditions based on typical winding insulation systems, and is based upon the best engineering information available at the time of preparation. The guide discusses limitations of ancillary components other than windings that may limit the capability of voltage regulators. When specified, ancillary components and other construction features (cables, bushings, tap changers, liquid expansion space, etc.) shall be supplied such that they in themselves will not limit the loading to less than the capability of the windings.

4.3 Unusual service conditions

Conditions other than those described in 4.1 are considered unusual service conditions and, when prevalent, should be brought to the attention of those responsible for the design and application of the voltage regulator. Examples of some of these conditions are discussed in 4.3.1 through 4.3.3.

4.3.1 Unusual temperature and altitude conditions

Voltage regulators may be used at higher or lower ambient temperatures or at higher altitudes than specified in 4.1, but special consideration should be given to these applications. Annex A and IEEE Std C57.91 provide information on recommended practices.

4.3.2 Insulation at high altitude

The dielectric strength of voltage regulators that depends in whole or in part upon air for insulation decreases as the altitude increases due to the effect of decreased air density. When specified, voltage regulators shall be designed with larger air spacing using the correction factors of Table 1 to obtain adequate air dielectric strength at altitudes above 1000 m (3300 ft).

4.3.2.1 Insulation level

The minimum insulation necessary at the required altitude can be obtained by dividing the standard insulation level at 1000 m (3300 ft) by the appropriate correction factor from Table 1.

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SHADE MAY BE AS PER INDIAN STANDARD IS-5 OR AS PER PURCHASER SPEC

⁶ Information on references can be found in Clause 2.

TABLE 3 MAY BE DELETED IN INDIAN CONTEXT

Table 3—Preferred ratings for liquid-immersed 60 Hz step-voltage regulators (single phase)

| Nominal system voltage | BIL (kV) | kVA | Line amperes |
|------------------------|----------------------|------------|--------------|
| 2400/4160Y | 60 | 50 | 200 |
| | | 75 | 300 |
| | | 100 | 400 |
| | | 125 | 500 |
| | | 167 | 668 |
| | | | |
| | | 250 | 1000 |
| | | 333 | 1332 |
| | | 416 | 1665 |
| 4800/8320Y | 75 | 50 | 100 |
| | | 75 | 150 |
| | | 100 | 200 |
| | | 125 | 250 |
| | | 167 | 334 |
| | | 250 | 500 |
| | | | |
| | | 333 | 668 |
| | | 416 | 833 |
| 7620/13 200Y | 95 | 38.1 | 50 |
| | | 57.2 | 75 |
| | | 76.2 | 100 |
| | | 114.3 | 150 |
| | | 167 | 219 |
| | | 107 | |
| | | 250 | 328 |
| | | 333 | 438 |
| | | 416 | 546 |
| | | 500 | 656 |
| | | 667 | 875 |
| | | 833 | 1093 |
| | | 1000 | 1312 |
| 12.000 | 05 | | 1312 |
| 13 800 | 95 | 69 | 50 |
| | | 138 | 100 |
| | | 207 | 150 |
| | | 276 | 200 |
| | | 414 | 300 |
| | | 552 | 400 |
| | | 667 | 483 |
| | | | 604 |
| | | 833 | |
| 11100/010101 | 1.50 | 1000 | 725 |
| 14 400/24 940Y | 150 | 72 | 50 |
| | | 144 | 100 |
| | | 288 | 200 |
| CYV | | 333 | 231 |
| | | 432 | 300 |
| 10 21 | | 576 | 400 |
| | | 667 | 463 |
| - | 100 C | | |
| | | 833 | 578 |
| | - Constitution de la | 1000 | 694 |
| 19 920/34 500Y | 150 | 100 | 50 |
| | | 200 | 100 |
| | | 333 | 167 |
| | | 400 | 201 |
| | | 667 | 334 |
| | | | |
| | | 833 | 418 |
| | | 1000 | 502 |
| 34 500 | 200 | 173 | 50 |
| 54500 | | | |
| 54 500 | | 345 | 100 |
| 54 500 | | 345 518 | 100 150 |

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| | Nominal system voltage | BIL (kV) | kVA | Line amperes | |
|---|---------------------------|-----------|-----|--------------|------|
| | 6600/11430Y | 95 | 33 | 50 | 1 |
| | | | 66 | 100 | |
| | | | 99 | 150 | |
| | | | 132 | 200 | |
| | | | 198 | 300 | |
| | | | 264 | 400 | |
| | | | 330 | 500 | |
| | | | 396 | 600 | |
| | | | 462 | 700 | |
| | | | 528 | 800 | |
| | 11000 | 95 | 55 | 50 | 1 |
| | | | 110 | 100 | |
| | | | 165 | 150 | |
| | | | 220 | 200 | |
| | | | 330 | 300 | |
| | | | 440 | 400 | |
| | | | 550 | 500 | |
| | | | 660 | 600 | |
| | | | 770 | 700 | |
| | | | 880 | 800 | |
| | 15000/25980Y | 150 | 75 | 50 | 10-C |
| | SECTION I | MAY BE DE | | | |
| | 02011011 | | 300 | 200 | |
| | | | 450 | 300 | |
| | | | 600 | 400 | |
| | | | 750 | 500 | |
| | | | 900 | 600 | |
| | 22000 | 150 | 110 | 50 | |
| | | | 220 | 100 | |
| | | | 330 | 150 | |
| | | CN | 440 | 200 | |
| | | | 660 | 300 | |
| | | | | 400 | |
| | 33000 | 170 | 165 | 50 | 1 |
| | | LOK I | 330 | 100 | |
| 1 | 33000 | | 495 | 150 | |
| | | | 660 | 200 | |

Table 4—Preferred ratings for liquid-immersed 50 Hz step-voltage regulators (single phase)

| Line amperes 667 1000 1334 577 866 1155 219 328 437 656 874 1093 1312 209 313 418 | kVA 625 937 1250 625 937 1250 625 937 1250 625 937 1250 625 937 1250 2000 2667 3333 4000 625 | Line ampere 833 1250 1667 721 1082 1443 274 410 546 874 1166 1458 1750 |
|---|--|---|
| 1000 1334 577 866 1155 219 328 437 656 874 1093 1312 209 313 | 937 1250 625 937 1250 625 937 1250 2000 2667 3333 4000 625 | 1250 1667 721 1082 1443 274 410 546 874 1166 1458 1750 |
| 1334 577 866 1155 219 328 437 656 874 1093 1312 209 313 | 1250 625 937 1250 625 937 1250 2000 2667 3333 4000 625 | 1667 721 1082 1443 274 410 546 874 1166 1458 1750 |
| 577 866 1155 219 328 437 656 874 1093 1312 209 313 | 625 937 1250 625 937 1250 2000 2667 3333 4000 625 | 721 1082 1443 274 410 546 874 1166 1458 1750 |
| 866 1155 219 328 437 656 874 1093 1312 209 313 | 937 1250 625 937 1250 2000 2667 3333 4000 625 | 1082 1443 274 410 546 874 1166 1458 1750 |
| 1155 219 328 437 656 874 1093 1312 209 313 | 1250 625 937 1250 2000 2667 3333 4000 625 | 1443 274 410 546 874 1166 1458 1750 |
| 219 328 437 656 874 1093 1312 209 313 | 625 937 1250 2000 2667 3333 4000 625 | 274 410 546 874 1166 1458 1750 |
| 328 437 656 874 1093 1312 209 313 | 937 1250 2000 2667 3333 4000 625 | 410 546 874 1166 1458 1750 |
| 437 656 874 1093 1312 209 313 | 1250 2000 2667 3333 4000 625 | 546 874 1166 1458 1750 |
| 656 874 1093 1312 209 313 | 2000 2667 3333 4000 625 | 874 1166 1458 1750 |
| 874 1093 1312 209 313 | 2667 3333 4000 625 | 1166 1458 1750 |
| 1093 1312 209 313 | 3333 4000 625 | 1458 1750 |
| 1312 209 313 | 4000 625 | 1750 |
| 209 313 | 625 | |
| 313 | | |
| | 0.0.7 | 261 |
| 418 | 937 | 391 |
| | 1250 | 523 |
| 628 | 2000 | 837 |
| 837 | 2667 | 1116 |
| 1046 | 3333 | 1394 |
| 1255 | 4000 | 1673 |
| 125.5 | 625 | 156.8 |
| 188.3 | 937 | 235.4 |
| 251 | 1250 | 314 |
| 377 | 2000 | 502 |
| 502 | 2667 | 669 |
| 628 | 3333 | 837 |
| 694 | 4000 | 926 |
| 84 | 625 | 105 |
| 125.5 | 937 | 156.8 |
| 167 | | 209 |
| 251 | 2000 | 335 |
| 335 | | 446 |
| | | 557 |
| 502 | 4000 | 669 |
| | 1255 125.5 188.3 251 377 502 628 694 84 125.5 167 251 | 1255 4000 125.5 625 188.3 937 251 1250 377 2000 502 2667 628 3333 694 4000 84 625 125.5 937 167 1250 251 2000 335 2667 418 3333 |

Table 5—Preferred ratings for liquid-immersed 60 Hz step-voltage regulators (three phase)

| Nominal system | DIL (LAD | Self- | cooled | Self-cooled/fo | rced-cooled |
|----------------|----------------|----------|--------------|----------------|--------------|
| voltage | BIL (kV) | kVA | Line amperes | kVA | Line amperes |
| 6600/11430Y | 95 | 500 | 253 | 625 | 316 |
| | | 750 | 379 | 937 | 474 |
| | | 1000 | 505 | 1250 | 631 |
| | | 1500 | 758 | 2000 | 1010 |
| 11000 | 95 | 500 | 262 | 625 | 328 |
| | | 750 | 394 | 937 | 492 |
| | | 1000 | 525 | 1250 | 656 |
| | | 1500 | 787 | 2000 | 1050 |
| 15000/25980Y | 150 | 500 | 111 | 625 | 139 |
| | 5-537-55-54-54 | 750 | 167 | 937 | 208 |
| | ION MAY | 1000 | 222 | 1250 | 278 |
| SECT | ION MAY | BEDEDEIL | ±D INBINDIA | AN COMTEX | 444 |
| | | 2000 | 444 | 2667 | 593 |
| | | 2500 | 556 | 3333 | 741 |
| 22000 | 150 | 500 | 131 | 625 | 164 |
| | | 750 | 197 | 937 | 246 |
| | | 1000 | 262 | 1250 | 328 |
| | | 1500 | 394 | 2000 | 525 |
| 33000 | 170 | 500 | 87 | 625 | 189 |
| | | 750 | 131 | 937 | 164 |
| | | 1000 | 175 | 1250 | 219 |

Table 6—Preferred ratings for liquid-immersed 50 Hz step-voltage regulators (three phase)

5.2.3 Supplementary voltage ratings

In addition to their rated voltage, as defined in 5.2.2, voltage regulators shall deliver rated kVA output without exceeding the specified temperature rise per Table 2 at the operating voltages given in Table 7.

Voltage regulators with multitapped voltage transformers and/or utility windings may be operated at voltages other than the rated voltage, as specified per the nameplate, and shall deliver rated line amperes without exceeding the temperature limits of Table 2 and as specified per the nameplate.

| Table 7—Supplementary | voltage ratings for 60 Hz voltage regulators |
|-----------------------|--|
| | LANOED TO VOLTAGEO INUNDIAN |

| TABLE / MAY BE C | HANGED TO VOL | <u>TAGES_IN INDIAN CO</u> NTE | X |
|------------------|---------------|-------------------------------|---|
| Number of phases | Rated voltage | Operating voltage | |
| Single phase | 7620 | 7200 | |
| 154 4 | 4330 | 4160 | |
| Three phase | 5000 | 4800 | |
| V AV | 8660 | 8320 | |
| | 13 200 | 12 470 | |
| | 13 800 | 13 200 | |

5.3 Supplementary continuous-current ratings

Single-phase step-voltage regulators rated up to 34.5 kV, inclusive, and rated 668 A and below shall have supplementary continuous-current ratings on intermediate ranges of steps as shown in Table 8. Maximum continuous current shall be 668 A.

| Iy Minimum 1955 1955 1955 1955 1955 3380 3910 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5870 5880 5380 10170 5870 6480 10170 6480 10170 6480 10750 117930 117330 117930 117330 117930 117330 117930 26880 28100 28100 28100 28100 28100 28100 | Single phase Three phase Voltage supply ratio Maximum at ampress Maximum at moress Maximum at ampress Maximum at moress Maximum at ampress Maximum at moress Maximum at moress Maximum at moress Maximum at moress Maximum at ampress Maximum at moress Maximum at mores Maxima Maxima Maximu | | Regulator voltage rati | age rating (V) | | 7 | Input voltage (V) | | Output v | Output voltage (V) |
|---|---|--------------------------------------|--------------------------|-----------------------|--------------------------------------|---------------|-------------------------------------|-----------------------|----------|---|
| 1955 2625 2750 2070 1955 2625 2750 2070 3800 3800 3580 4140 3870 5870 8250 6210 3870 5870 8250 6210 5870 5870 8250 6210 5870 5870 8250 6210 5870 5870 8250 6210 5870 5870 8250 6210 5870 5870 8250 6210 5870 11550 12600 9490 5870 5870 14300 14300 5870 5870 8000 8250 5870 5870 14300 14300 5870 5870 14300 1760 5870 5870 8000 8250 6210 5870 5870 14490 15126 11400 10750 14490 15126 11400 1790 11730 11730 14490 15128 11400 11730 15120 | 1955 2625 2750 2070 1955 2800 3580 2380 2380 3380 2550 4760 3580 2070 3910 5570 5500 4140 3580 5870 8250 5500 6210 3580 5870 8250 5500 6210 3580 5870 8250 5500 4140 5500 5870 8250 5500 7170 9090 5870 5800 11 5500 7170 900 5870 5800 14<300 14<300 10 700 5870 5800 15 12 900 5690 5870 5800 14<300 14<300 10 760 5870 5800 14<300 14<300 10 760 5870 5800 14 10 760 5690 5800 10 10 760 10 760 6210 5800 14 11 760 11 | Nominal system voltage | Single phase | Three phase | Voltage supply ratio ^a | 1417 1 1 | Maximum at rated-load amperes | Maximum at no-load | Minimum | Maximum at rated-load amperes or at |
| 1955 2625 2750 2070 1955 2625 2750 2070 3380 4550 4560 3870 3910 5500 8140 3580 3870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 5870 8250 5210 5870 5870 9990 9525 7170 5870 11 550 12 100 9490 5600 5870 5870 14 300 14 300 10 760 5870 5870 8260 6210 5600 5870 5870 14 300 14 300 10 760 5870 10 170 14 300 14 300 10 760 5870 5870 6480 1900 16 400 10 750 14 490 15 180 10 760 11 730 11 730 14 490 15 180 11 400 11 7920 15 140 | 1955 2625 2750 2070 1955 3800 4550 4760 3880 3810 4550 5770 3870 8250 5700 3870 8250 5500 4140 3870 8250 5210 5700 5870 8250 5500 8250 5500 4140 5870 5900 <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>no-load</th></td<> | | | | | | | | | no-load |
| 1955 2625 2750 2070 3380 4550 4760 3580 3870 8500 8140 3580 5870 8250 8250 6210 5870 8250 5500 4140 5870 8250 5500 4140 5870 8960 11 550 12 100 9490 5870 5380 6910 11 550 12 100 9490 5870 5380 6930 7260 5500 4140 5870 5380 6630 16 760 5690 5870 10 750 14 300 14 300 10 760 5870 8000 8380 6860 11 400 11 240 13 800 14 490 15 120 14 400 11 240 15 120 14 490 15 128 11 400 11 730 11 4400 15 180 11 400 11 400 11 730 15 120 14 490 15 180 12 420 11 730 11 730 15 120 14 490 15 180 12 420 <td>1955 2625 2750 2070 3380 4550 4760 3580 3870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 8960 11 550 12 100 9490 5717 9090 5500 4140 16 70 5870 8960 11 550 12 100 9490 5710 5910 14 300 14 300 10 760 5700 5800 8860 5800 11 400 10 170 14 300 14 300 16 760 570 6480 8360 8380 6570 6560 11 240 8180 13 860 14 490 15 125 11 400 11 730 11 4490 15 126 15 180 11 400 11 900 11 730 15 120 15 120 15 420 18 400 12 420 11 730 15 120 15 120 15 120 18 400 11</td> <td>2400</td> <td>2500</td> <td>TC</td> <td>20</td> <td>1955</td> <td>2625</td> <td>2750</td> <td>2070</td> <td>2750</td> | 1955 2625 2750 2070 3380 4550 4760 3580 3870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 8250 5500 4140 5870 8960 11 550 12 100 9490 5717 9090 5500 4140 16 70 5870 8960 11 550 12 100 9490 5710 5910 14 300 14 300 10 760 5700 5800 8860 5800 11 400 10 170 14 300 14 300 16 760 570 6480 8360 8380 6570 6560 11 240 8180 13 860 14 490 15 125 11 400 11 730 11 4490 15 126 15 180 11 400 11 900 11 730 15 120 15 120 15 420 18 400 12 420 11 730 15 120 15 120 15 120 18 400 11 | 2400 | 2500 | TC | 20 | 1955 | 2625 | 2750 | 2070 | 2750 |
| 3380 4550 4760 3580 3910 5570 5500 4140 5870 8250 5500 4140 5870 8250 5500 6210 5870 8250 5500 6210 5870 8250 5500 4140 5870 8250 5500 4140 5870 5380 7170 9900 5700 5380 693 7260 590 5380 5380 693 7260 590 5380 5380 693 7260 570 5870 10170 14300 14300 10760 5870 8000 8250 6210 570 6480 8000 8380 6860 11400 11 11 11<400 | 3380 4550 4760 3580 3910 5570 5500 4140 5870 8250 5500 4140 5870 8250 5500 6210 5870 8250 5500 6210 5870 8250 5500 4140 5870 910 5255 7170 5870 910 5255 7170 5870 6480 8250 6590 5870 11550 12100 9490 5870 6480 8250 6210 5870 6480 8380 6570 6480 8380 6570 6400 6480 8380 6570 11400 10750 14400 15125 11400 11790 14490 15125 11400 11730 11730 15125 11400 11730 15120 15180 12420 11730 15120 15180 12420 | 2400/4160Y | 2500 | | 20 | 1955 | 2625 | 2750 | 2070 | 2750 |
| 3910 5250 5500 4140 5870 5870 8250 6210 5870 5870 8250 6210 5870 5250 5500 4140 5870 5250 5500 4140 5870 5250 5500 4140 5870 5500 11560 5500 6775 9090 9525 7170 900 11560 14300 14300 5380 641300 14300 14300 5380 6600 8380 6570 5380 6210 8380 6570 5480 8000 8380 6570 6480 8360 14490 15120 11730 14490 15180 11400 11730 14490 15120 18975 11730 14490 15120 18975 11730 15120 15180 12420 11730 15120 15180 12420 11730 15120 1580 12420 117 | 3910 H 520 5500 4140 5870 8250 520 520 5210 5870 8250 525 7170 6210 5870 8250 525 7170 6210 5870 5380 5300 4140 525 6210 5870 5380 61300 12100 9490 525 6675 5300 11350 12100 9490 560 5870 5380 61300 14300 10760 590 5870 5800 14300 14300 10760 500 5870 5800 6480 8380 650 610 5870 6480 8380 6570 6660 6480 8380 6570 6860 11400 11240 11240 11490 15125 11400 11730 114490 15126 11400 12420 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 | 2400/4160Y | T | 4330 | 34.6 | 3380 O | 4550 | 4760 | 3580 | 4760 |
| 5870 5870 8250 6210 5870 5870 8250 6210 5870 5500 4140 5870 5500 5500 4140 5870 5500 5500 4140 5870 5500 5500 5170 5870 5800 11550 12100 9490 5870 5800 8250 6210 5690 5870 5800 14300 14300 10760 5870 5800 8380 6560 5700 5870 5800 8380 6570 6510 5870 5800 8380 6560 11400 10750 14490 15126 11400 11400 11730 17730 14490 15126 11400 11730 17730 14490 15126 11400 11730 17730 15126 12420 12420 11730 17730 15126 12420 | 5870 5870 8250 6210 5870 5850 8250 6210 5870 5250 5500 4140 5870 5250 5500 4140 5870 5500 11550 9990 9525 7170 5870 5800 11550 12100 9490 5690 5380 5800 14300 14300 10760 5690 5870 5800 8380 6570 5600 5870 5800 8380 6570 5690 6210 1170 14300 14300 10760 6480 8360 8380 6570 6800 6480 8360 8760 6860 11400 11240 11490 15120 11400 11400 11730 11730 14490 15180 12420 11730 11730 15120 15800 12420 11770 14490 15180 12420 11400 11730 11730 15120 1580 12420 <td>4800</td> <td>5000</td> <td>5000</td> <td>40</td> <td>3910 H</td> <td>5250</td> <td>5500</td> <td>4140</td> <td>5500</td> | 4800 | 5000 | 5000 | 40 | 3910 H | 5250 | 5500 | 4140 | 5500 |
| 5870 8250 8250 6210 3910 5250 5500 4140 39560 11 550 12 100 9490 5870 8960 11 550 12 100 9490 5870 5870 8000 5590 14 300 10 760 5870 5870 8000 8250 6210 990 5870 5800 8000 8250 6210 990 5870 5800 8000 82380 6210 670 6480 8000 8380 6860 11400 11400 10750 14 300 14 300 10760 680 6860 10750 14 490 15 120 14 400 12 420 11400 11730 1730 14 490 15 125 11 400 11 400 11730 1770 23 100 24 200 18 975 12 420 11730 15 120 15 180 17 420 18 975 11 400 11730 15 120 15 180 17 420 18 975 12 420 11 | 5870 8250 8250 6210 3910 5250 5500 4140 3910 5250 5500 4140 5775 9090 9525 7170 8860 11550 12100 9490 5380 6930 7260 5690 5870 8000 8250 6210 5870 8000 8250 6210 5870 8000 8380 6500 5870 8000 8380 6500 6210 8000 8380 6500 6480 8000 8380 6500 611240 14490 15180 11400 11240 14490 15180 12420 11730 14490 15180 12420 11730 1730 15120 18975 11730 16500 15180 12420 11730 15120 15840 12420 11730 15120 1580 12420 11730 15120 15860 25760 20 | 7200 | 7620 | | 60 | 5870 A | 8000 | 8250 | 6210 | 8250 |
| 3910 5250 5500 4140 6775 9090 9525 7170 8960 11550 12100 9490 5380 6030 7260 5690 5870 5870 8250 6490 5870 5800 8380 6570 6480 5870 8380 6570 6480 8380 6570 6210 6210 8380 6570 6210 6210 8380 6570 6210 6480 8360 8380 6570 6480 8360 8380 6570 6480 8360 8380 6560 11240 11240 14300 11400 11730 14490 15180 11400 11730 14490 15180 12420 11730 17720 14490 15125 11400 11730 17720 14490 15126 12420 11730 15120 1580 12420 12420 11730 1550 2190< | 3910 5250 5500 4140 6775 9090 9525 7170 8960 11550 12100 9490 5380 500 14300 10760 5870 5870 8250 6010 5870 5870 8250 6210 5870 5800 8250 6210 5870 5800 8250 6210 5870 5800 8250 6210 5870 5800 8250 6210 5870 5800 8380 6570 6480 8380 6570 6210 6480 8360 8380 6570 6480 8360 8380 6570 6480 8360 8380 6570 6480 8360 14490 15180 1720 14490 15180 11400 11730 14490 15180 12420 11730 15120 1540 18975 11730 15120 1580 12420 11730 | 7200 | | 8660 | 60 | 5870 Z | 8250 | 8250 | 6210 | 8250 |
| 6775 9090 9525 7170 8960 11550 12100 9490 5380 6930 7260 5690 5380 10170 014300 14300 10760 5870 5870 8000 8250 6210 5870 5870 8000 8380 6210 5870 5870 8000 8380 650 6210 700 14300 14300 10760 6480 5830 64130 14300 11400 10750 6480 8380 650 6210 6480 8360 8380 650 6210 11240 8000 8380 6560 11400 11730 11 1490 15120 14490 15120 11730 11 14490 15120 14490 12420 11730 11730 15120 15840 12420 11730 15230 21910 17180 <td>6775 9090 9525 7170 8960 11550 12100 9490 5380 6930 7260 5690 5870 5870 8000 8250 5690 5870 5870 8000 8250 6210 5870 5800 83380 6570 6210 5870 5800 83380 6570 6210 5870 5800 83380 6570 6210 6480 8000 83380 6570 6210 6480 8360 8380 6570 6210 6480 8360 8380 6570 6210 10750 14490 15180 11400 11 1730 14490 15180 12420 11400 11730 17750 14490 15180 12420 11730 15120 1540 12420 12420 11770 15720 15580 12420 11730 <td< td=""><td>4800/8320Y</td><td>5000</td><td>1</td><td>40</td><td>3910 O</td><td>5250</td><td>5500</td><td>4140</td><td>5500</td></td<></td> | 6775 9090 9525 7170 8960 11550 12100 9490 5380 6930 7260 5690 5870 5870 8000 8250 5690 5870 5870 8000 8250 6210 5870 5800 83380 6570 6210 5870 5800 83380 6570 6210 5870 5800 83380 6570 6210 6480 8000 83380 6570 6210 6480 8360 8380 6570 6210 6480 8360 8380 6570 6210 10750 14490 15180 11400 11 1730 14490 15180 12420 11400 11730 17750 14490 15180 12420 11730 15120 1540 12420 12420 11770 15720 15580 12420 11730 <td< td=""><td>4800/8320Y</td><td>5000</td><td>1</td><td>40</td><td>3910 O</td><td>5250</td><td>5500</td><td>4140</td><td>5500</td></td<> | 4800/8320Y | 5000 | 1 | 40 | 3910 O | 5250 | 5500 | 4140 | 5500 |
| 8960 11 550 12 100 9490 5380 6930 7260 5690 5380 6930 7260 5690 5870 8000 8250 6210 5870 8000 8380 6570 6480 8000 8380 650 6210 8000 8380 650 6210 8000 8380 650 6480 8000 8380 650 11240 8000 8380 656 11240 8360 14 490 15 12 11730 11 4490 15 12 11 400 11730 14 490 15 12 11 400 11730 11 730 15 120 15 120 11730 15 750 15 180 12 420 11730 15 750 15 180 12 420 11730 15 750 15 180 12 420 11730 15 750 15 180 12 420 11730 15 750 15 800 12 420 11730 26 190 27 435 21 530 <td>8960 11 550 12 100 9490 5380 6930 7260 5690 5870 8000 8250 6210 5870 8000 8380 6210 5870 8000 8380 6570 5870 8000 8380 6570 6210 8000 8380 6570 6480 8000 8380 6560 6180 8360 14 300 11 400 11 240 13 860 14 520 11 400 11 240 8360 65180 11 900 6480 8360 65180 11 400 11 240 17 130 14 490 15 125 17 790 14 490 15 126 12 420 17 790 15 120 15 180 17 420 17 730 15 120 15 180 17 180 16 230 20 920 21 910 17 180 28 100 36 205 37 950 21 530 28 100 36 205 37 950 29 760 28 100 36 205 37 950<td>8320</td><td>1</td><td>8660</td><td>69.3</td><td>6775 H</td><td>0606</td><td>9525</td><td>7170</td><td>9525</td></td> | 8960 11 550 12 100 9490 5380 6930 7260 5690 5870 8000 8250 6210 5870 8000 8380 6210 5870 8000 8380 6570 5870 8000 8380 6570 6210 8000 8380 6570 6480 8000 8380 6560 6180 8360 14 300 11 400 11 240 13 860 14 520 11 400 11 240 8360 65180 11 900 6480 8360 65180 11 400 11 240 17 130 14 490 15 125 17 790 14 490 15 126 12 420 17 790 15 120 15 180 17 420 17 730 15 120 15 180 17 180 16 230 20 920 21 910 17 180 28 100 36 205 37 950 21 530 28 100 36 205 37 950 29 760 28 100 36 205 37 950 <td>8320</td> <td>1</td> <td>8660</td> <td>69.3</td> <td>6775 H</td> <td>0606</td> <td>9525</td> <td>7170</td> <td>9525</td> | 8320 | 1 | 8660 | 69.3 | 6775 H | 0606 | 9525 | 7170 | 9525 |
| 5380 530 7260 5690 10170 14300 14300 10760 5870 8000 8250 6210 5870 8000 8380 6570 6210 14300 14300 10760 6210 14300 14300 10760 6210 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6560 11240 8000 8380 6560 11240 14490 15180 11400 17250 14490 15125 11400 17730 14490 15125 11400 17730 17730 15120 18975 11730 15120 1580 12420 11730 15750 15840 12420 11730 1525 37950 21530 26190 36225 37950 29760 28100 36225 37950 29760 28100 36225 37950 29760 <t< td=""><td>5380 5380 530 7260 5690 5870 5870 8000 8250 6210 5870 8000 8250 6210 10760 6210 14300 14300 14300 10760 6210 8000 8380 6570 6210 6480 8000 8380 6570 6660 6480 8360 14300 14300 11400 11240 13860 1450 15180 11400 11240 13860 15180 11900 6860 6480 8360 6560 14400 15120 11400 11730 114490 15180 12420 11400 11730 14490 15180 12420 11400 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15840 12420 12420 11730 1525 3</td><td>11000</td><td>11000</td><td></td><td>91.7</td><td>8960</td><td>11 550</td><td>12 100</td><td>9490</td><td>12 100</td></t<> | 5380 5380 530 7260 5690 5870 5870 8000 8250 6210 5870 8000 8250 6210 10760 6210 14300 14300 14300 10760 6210 8000 8380 6570 6210 6480 8000 8380 6570 6660 6480 8360 14300 14300 11400 11240 13860 1450 15180 11400 11240 13860 15180 11900 6860 6480 8360 6560 14400 15120 11400 11730 114490 15180 12420 11400 11730 14490 15180 12420 11400 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15840 12420 12420 11730 1525 3 | 11000 | 11000 | | 91.7 | 8960 | 11 550 | 12 100 | 9490 | 12 100 |
| 10170 14300 14300 10760 5870 5870 8000 8250 6210 5870 600 8250 6210 1760 10170 14300 14300 14300 10760 6210 8000 8380 6570 6210 6480 8000 8380 6560 10760 11240 8000 8380 6560 11400 11240 8360 14490 15180 11400 11240 8350 8760 8860 6860 11730 114490 15120 11400 11900 17730 11730 14490 15126 11400 11730 11730 15120 15180 12420 11730 15120 1580 12420 12420 11730 15120 1580 12420 12420 11730 1550 21910 17180 21530 26190 36255 37950 29760 29760 28100 36225 37950 29760 <t< td=""><td>10170 14300 14300 10760 5870 5870 8000 8250 6210 6800 8000 8380 6570 6210 6480 8000 8380 6570 6210 6480 8000 8380 6570 6210 11240 8000 8380 6560 14400 11240 8360 8760 6860 6860 11240 14490 15180 11900 6860 11730 14490 15180 11400 11900 11730 14490 15180 12420 11400 11730 14490 15180 12420 18975 11730 17920 15180 12420 18975 11730 15120 15180 12420 18975 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15840 12420 12420 11730 15250 21910 17180</td><td>6600/11 430Y</td><td>6600</td><td>1</td><td>55</td><td>5380</td><td>6930</td><td>7260</td><td>5690</td><td>7260</td></t<> | 10170 14300 14300 10760 5870 5870 8000 8250 6210 6800 8000 8380 6570 6210 6480 8000 8380 6570 6210 6480 8000 8380 6570 6210 11240 8000 8380 6560 14400 11240 8360 8760 6860 6860 11240 14490 15180 11900 6860 11730 14490 15180 11400 11900 11730 14490 15180 12420 11400 11730 14490 15180 12420 18975 11730 17920 15180 12420 18975 11730 15120 15180 12420 18975 11730 15120 15180 12420 12420 11730 15120 15180 12420 12420 11730 15120 15840 12420 12420 11730 15250 21910 17180 | 6600/11 430Y | 6600 | 1 | 55 | 5380 | 6930 | 7260 | 5690 | 7260 |
| 5870 5800 8250 6210 10170 14300 14300 10760 6210 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6560 10750 14490 15180 11400 11240 8360 8760 6860 11730 14490 15180 11400 17920 1730 14490 15120 18975 11730 11730 15120 15180 12420 11730 15120 1580 12420 18975 11730 15120 1580 12420 12420 11730 15120 1580 12420 12420 11730 15750 1580 12420 12420 11730 1525 37950 21530 21530 28100 36155 37950 21530 21530 28100 36255 37950 29760 29760 2 | 5870 5800 8250 6210 10170 14300 14300 14300 6210 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6560 10750 14490 14520 11400 11240 8360 8760 6860 11240 8360 8760 6860 11240 14490 15180 11900 11730 14490 15125 11400 11730 14490 15124 12420 11730 15120 15180 12420 11730 15120 15180 12420 11730 15120 15180 12420 11730 15750 1580 12420 11730 15750 1580 12420 11730 15750 1580 12420 11730 15750 1580 12420 11730 15750 1580 12420 11730 15750 21530 21530 | 12 470 | 13 800 | 13 800 | 104 | 10 170 | 14 300 | 14 300 | 10 760 | 14 300 |
| 10170 14300 14300 10760 6210 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6560 11240 800 8360 14500 11240 8360 15180 11400 1730 14490 15120 11400 17730 14490 15125 11400 17730 17730 15120 12420 11730 15120 15180 12420 11730 15120 15840 12420 11730 15120 15840 12420 11730 1550 21910 17180 20330 26190 27435 21530 28100 36225 37950 29760 28100 36225 37950 29760 28100 36225 37950 29760 | 10170 14300 14300 16760 6210 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6570 6480 8000 8380 6560 11240 8360 8760 6860 11240 8360 8760 14400 11730 14490 15180 11900 11730 14490 1512 11400 11730 14490 1512 11400 11730 14490 15120 12420 11730 15120 15180 12420 11730 15120 15180 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 1550 21910 17180 20330 26190 27435 21530 28100 3650 29760 29760 28100 3650 29760 29760 | 7200/12 470Y | 7620 | | 09 | 5870 | 8000 | 8250 | 6210 | 8250 |
| 6210 8380 6570 6480 5800 8380 6560 10750 13 860 14 520 11 400 11 240 13 860 15 180 11 900 6480 8360 8760 6860 11 240 14 490 15 120 11 900 6480 8360 8760 6860 11 730 14 490 15 125 11 400 17 730 14 490 15 120 12 420 11 730 15 120 15 840 12 420 11 730 15 120 15 840 12 420 11 730 15 750 16 500 12 420 11 730 15 750 16 500 12 420 11 730 16 500 21 910 17 180 20 330 26 190 27 435 21 530 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 6210 8380 6570 6480 8300 8380 6560 6480 13 860 14 520 11 400 10 750 13 860 15 180 11 900 11 240 8360 8760 6860 6480 8360 8760 6860 11 240 8360 8760 14 900 11 730 14 490 15 125 11 400 11 730 14 490 15 126 12 420 11 730 15 120 15 180 12 420 11 730 15 120 15 840 12 420 11 730 15 750 16 500 17 180 11 730 15 750 16 500 17 180 16 230 26 190 27 435 21 530 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 7200/12 470Y | 1 | 13 800 | 104 | 10 170 | 14 300 | 14 300 | 10 760 | 14 300 |
| 6480 5480 8000 8330 6860 10750 13 860 14 520 11 400 11 240 5360 8760 6860 6480 8360 8760 6860 11 240 5180 14 90 15 180 11 900 11 730 14 490 15 125 11 400 18 975 11 730 11 730 14 490 15 180 12 420 11 730 11 730 15 120 15 840 12 420 11 730 15 750 15 840 12 420 18 975 11 730 15 750 15 840 12 420 18 975 11 730 20 920 27 435 21 530 28 660 20 330 26 190 27 435 21 530 28 760 28 100 36 225 37 950 29 760 29 760 28 100 36 225 37 950 29 760 29 760 | 6480 6480 8380 6860 10750 13 860 13 860 14 520 11 400 11 240 13 860 15 180 11 900 6860 6480 8360 8760 6860 6860 11 730 11 490 15 125 11 400 11 900 11 730 14 490 15 125 11 400 12 420 11 730 17 920 23 100 24 200 18 975 11 730 15 120 15 180 12 420 18 975 11 730 15 120 15 180 12 420 18 975 11 730 15 120 15 180 12 420 18 975 11 730 15 120 15 180 12 420 18 975 11 730 15 750 15 840 12 420 17 180 16 230 20 920 21 910 17 180 21 530 28 100 36 525 37 950 29 760 29 760 28 100 36 225 37 950 29 760 29 760 | 7620/13 200Y | 7620 |] | 63.5 | 6210 | 8000 | 8380 | 6570 | 8380 |
| 10750 V 13 860 14 520 11 400 11 240 S360 8760 6680 6480 8360 8760 6860 6480 8360 8760 6860 11 730 14 490 15 125 11 400 11 730 14 490 15 125 11 400 11 730 14 490 15 120 18 975 11 730 15 120 15 840 12 420 11 730 15 120 15 840 12 420 11 730 15 750 16 500 12 420 11 730 16 500 21 910 17 180 20 330 26 190 27 435 21 530 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 10750 V 13 860 14 520 11 400 11 240 51 80 14 490 15 180 11 900 6480 8360 8760 6860 6860 11 730 14 490 15 125 11 400 11 900 11 730 14 490 15 125 11 400 12 420 11 730 14 490 15 120 15 180 12 420 11 730 15 120 15 180 12 420 18 975 11 730 15 120 15 180 12 420 18 975 11 730 15 750 15 840 12 420 17 180 11 730 16 500 17 80 12 420 17 180 11 730 16 500 17 830 21 910 17 180 26 180 26 190 27 435 21 530 28 460 28 460 28 100 36 225 37 950 29 760 29 760 29 760 28 100 36 225 37 950 29 760 29 760 29 760 | 7620/13 200Y | 7620 | 1 | 66.3 | 6480 | 8000 | 8380 | 6860 | 8380 |
| 11 240 14 490 15 180 11 900 6480 8360 8760 6860 6480 8360 8760 6860 10750 14490 15125 11400 11730 14490 1512 12420 11730 11730 12420 18975 11730 11730 12420 18975 11730 11730 12120 15120 15840 12420 11730 11730 15720 16500 12420 12420 11730 12730 15730 12420 12420 11730 15730 27435 21530 12420 16230 26190 27435 21530 28460 28100 36225 37950 29760 29760 28100 36225 37950 29760 29760 28100 36225 37950 29760 29760 | 11 240 14 490 15 180 11 900 6480 8360 8760 6860 6480 8360 8760 6860 10 750 14 490 15 125 11 400 11 730 14 490 15 125 11 400 11 730 14 490 15 120 18 975 11 730 15 120 15 120 18 975 11 730 15 120 15 840 12 420 11 730 15 750 16 500 12 420 11 730 15 750 16 500 17 180 11 730 20 920 21 910 17 180 26 190 27 435 21 530 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 7620/13 200Y | I | 13 200 | 110 | 10 750 | 13 860 | 14 520 | 11 400 | 14 520 |
| 6480 8360 8760 6860 10750 14490 15125 11400 11730 14490 15126 12420 11730 14490 15120 12420 11730 15120 1540 12420 11730 15120 15840 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 15750 16500 12420 11730 20920 21910 17180 16500 26190 27435 21530 20330 26190 27435 21530 28100 36225 37950 29760 28100 36225 37950 29760 | 6480 8360 8760 6860 10750 14490 15125 11400 11730 14490 15125 11400 11730 14490 15120 12420 11730 15120 1540 12420 11730 15120 15840 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 15750 15840 12420 11730 15750 16500 17180 11730 26190 27435 21530 26880 36505 37950 29760 28100 36225 37950 29760 28100 36225 37950 29760 | 7970/13 800Y | | 13 800 | 115 | 11 240 E | 14 490 | 15 180 | 11 900 | 15 180 |
| 10750 14490 15125 11400 11730 14490 15180 12420 17920 23100 24200 18975 17920 15120 15840 12420 1730 15750 15840 12420 11730 15750 15840 12420 11730 15750 16500 12420 11730 20920 21910 17180 20330 26190 27435 21530 26880 36500 27435 21530 26880 36500 27435 21530 28100 36225 37950 29760 28100 36225 37950 29760 | 10750 14490 15125 11400 11730 14490 15180 12420 11730 15120 15180 12420 11730 15120 15840 12420 11730 15750 15840 12420 11730 15750 15500 12420 11730 15750 15500 12420 11730 15750 15500 12420 11730 20920 21910 17180 26880 26190 27435 21530 26880 36500 36300 28460 28100 36225 37950 29760 28100 36225 37950 29760 | 7970/13 800Y | 7970 | 1 | 66.3 | 6480 | 8360 | 8760 | 6860 | 8760 |
| 11 730 14 490 15 180 12 420 17 920 23 100 24 200 18 975 11 730 15 120 15 840 12 420 11 730 15 750 15 840 12 420 11 730 15 750 15 500 12 420 11 730 15 750 15 500 12 420 11 730 20 920 21 910 17 180 16 500 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 11 730 14 490 15 180 12 420 17 920 23 100 24 200 18 975 11 730 15 120 15 840 12 420 11 730 15 750 16 500 12 420 11 730 15 750 16 500 12 420 11 730 20 920 21 910 17 180 16 230 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 13 200 | 13 800 | 13 800 | 110 | 10 750 | 14 490 | 15 125 | 11 400 | 15 125 |
| 17920 17920 23100 24200 18975 11730 15120 15840 12420 11730 15750 16500 12420 11730 20920 21910 17180 20330 26190 27435 21530 20880 34.650 36.300 28460 28100 36.225 37950 29760 28100 36.225 37950 29760 | 17920 17920 18975 1730 15120 15840 18975 11730 15750 15840 12420 11730 15750 16500 12420 11730 20920 21910 17180 20330 26190 27435 21530 26880 34650 36300 28460 28100 3625 37950 29760 28100 36225 37950 29760 | 14 400 | 13 800 | 13 800 | 120 | 11 730 | 14 490 | 15 180 | 12 420 | 15 180 |
| 11 730 15 120 15 840 12 420 11 730 15 750 15 50 15 750 16 500 11 730 16 230 20 920 21 910 17 180 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 11 730 15 120 15 840 12 420 11 730 15 750 16 500 12 420 16 230 20 920 21 910 17 180 26 880 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 22 000 | 22 000 | | 183.3 | 17 920 | 23 100 | 24 200 | 18 975 | 24 200 |
| 11 730 15 750 16 500 12 420 16 230 20 920 21 910 17 180 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 11 730 15 750 16 500 12 420 16 230 20 920 21 910 17 180 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 14 400/24 940Y | 14 400 | Ι | 120 | 11 730 | 15 120 | 15 840 | 12 420 | 15 840 |
| 16 230 10 17 180 20 330 26 190 27 435 21 530 26 880 34 650 27 435 21 530 28 100 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 16 230 10 17 180 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 15 000/25 980Y | 15 000 | Ĩ | 120 | D 11 730 | 15 750 | 16 500 | 12 420 | 16 500 |
| 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 20 330 26 190 27 435 21 530 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 19 920/34 500Y | 19 920 | I. | 166 | 16 230 | 20 920 | 21 910 | 17 180 | 21 910 |
| 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 26 880 34 650 36 300 28 460 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 14 400/24 940Y | | 24 940 | 208 | 20 330 | 26 190 | 27 435 | 21 530 | 27 435 |
| 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 28 100 36 225 37 950 29 760 28 100 36 225 37 950 29 760 | 33 000 | 33 000 | Ì | 275 | 26 880 | 34 650 | 36 300 | 28 460 | 36300 |
| 28 100 36 225 37 950 29 760 | 28 100 C 36 225 37 950 29 760 XH | 19 920/34 500Y | | 34 500 | 287.5 | 28 100 | 36 225 | 37 950 | 29 760 | 37 950 |
| 0 | 01 | 34 500 | 34 500 | 22 <u>-</u> 22 | 287.5 | 28 100 C | 36 225 | 37 950 | 29 760 | 37 950 |
| | 1 | | values are derived u | ising procedures o | fs.s. | NTE | 35 | | | |
| | | ^a Where the listed voltas | re ratio is provided, an | ancillary transformer | may be required. | X | | | | |

Ξ -TAB 1 2 1 Ë

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IS 2026 (Part 21) : 2018 IEC 60076-21 : 2011 IEEE Std C57.15 : 2009

IS 2026 (Part 21) : 2018 IEC 60076-21 : 2011 IEEE Std C57.15 : 2009

5.6 Voltage supply ratios

Values of voltage supply ratios are given in Table 11. When a voltage supply ratio is specified that is not a preferred value shown in Table 11, an ancillary transformer may be furnished in the unit or control to modify the preferred ratio.

TABLE 11 MAY BE CHANGED TO VOLTAGES IN INDIAN CONTEXT Table 11—Values of voltage supply ratios & 3.3 KV ALSO TO APEAF

| Voltage regula | tor rating (V) | Values of valtage supply paties |
|----------------|----------------|---------------------------------|
| Single phase | Three phase | Values of voltage supply ratios |
| 2500 | | 20, 20.8 |
| | 4330 | 34.6, 36.1 |
| 5000 | 5000 | 40, 41.7 |
| 6600 | | 55 |
| 7620 | | 60, 63.5 |
| 7970 | | 66.4 |
| | 8660 | 69.3, 72.2 |
| 11 000 | | 91.7 |
| | 13 200 | 110, 104 |
| 13 800 | 13 800 | 115, 110 |
| 14 400 | | 120 |
| 15 000 | | 120 |
| 19 920 | | 166 |
| 22 000 | | 183.3 |
| | 24 940 | 208 |
| 33 000 | | 275 |
| 34 500 | 34 500 | 287.5 |

5.7 Insulation levels

200

70

Voltage regulators shall be designed to provide coordinated applied-voltage and lightning impulse insulation levels on line terminals, and applied-voltage insulation levels on neutral terminals. The identity of a set of coordinated levels shall be its basic impulse insulation level (BIL), as shown in Table 12.

NOTE—When single-phase voltage regulators are connected in wye, the neutral of the voltage regulator bank shall be connected to the neutral of the system. A closed or open delta connection of the voltage regulators is recommended when the system is three-wire ungrounded.

| | | | mpulse levels | |
|--------|-------------------------------------|------------|---------------|-------------------------------|
| BIL kV | Applied-voltage insulation level | Full wave | Chopp | ed wave |
| DIL KV | (kV rms) | (kV crest) | (kV crest) | Min time to flashover (µs) |
| 60 | 19 | 60 | 66 | 1.5 |
| 75 | 26 | 75 | 83 | 1.5 |
| 95 | 34 | 95 | 105 | 1.8 |
| 110 | 34 | 110 | 120 | 2,0 |
| 150 | 50 | 150 | 165 | 3.0 |
| 170 | 70 | 170 | 187 | 3.0 |

200

220

3.0

Table 12—Interrelationships of dielectric insulation levels for voltage regulators used on systems with BIL ratings of 200 kV and below

5.9 Short-circuit requirements

5.9.1 General

Step-voltage regulators shall be designed and constructed to withstand the mechanical and thermal stresses produced by external short circuits of a maximum value of 25 times the base rms symmetrical rated load current to a maximum requirement of 16 kA rms symmetrical.

a) The first-cycle asymmetrical peak current that the voltage regulator is required to withstand shall be determined as shown in Equation (1) and Table 13.

ISC(pk asym) = KISC(rms sym)

(1)

60 Hz MAY BE DLETED IN INDIAN CONTEXT Table 13—Values of K

| | K | | |
|---|-------------------|-------------------|--|
| Base rated kVA | 60 Hz | 50 Hz | |
| < 165 (single phase) | 2.26 ^a | 2.19 ^a | |
| \geq 165 (single phase) \geq 500 (three phase) | 2.60 ^b | 2.55 ^b | |

^a Value of the first-cycle asymmetrical peak current is based on an X/R ratio of 6 and 5, 60 and 50 Hz, respectively, which are common for distribution circuits.

^h Value of the first-cycle asymmetrical peak current is based on an X/R ratio of 17 and 14, 60 and 50 Hz, respectively, which are common for substation circuits.

b) The short-circuit current shall be assumed to be a duration of 2 s to determine the thermal stresses.

It is recognized that short-circuit withstand capability can be adversely affected by the cumulative effects of repeated mechanical and thermal overstressing, as produced by short circuits and loads above the nameplate rating. Since means are not available to continuously monitor and quantitatively evaluate the degrading effects of such duty, short-circuit tests, when required, should be performed prior to placing the voltage regulator in service.

Voltage regulator components such as leads, bushings, and load tap changers that carry current continuously shall comply with all the requirements of 5.9.1. Load tap changers are not required to change tap position coincident with a short-circuit condition.

It is recommended that current-limiting reactors be installed by the user, where necessary, to limit the short-circuit current to a maximum of 25 times the base rated full-load current or 16 000 A, whichever is less.

NOTE 1—Larger kVA sizes for the same voltage rating should be considered if the available fault current exceeds the 25 times base rated current.

NOTE 2—User may specify a larger short-circuit withstand value due to unique system parameters. An example as such is a short-circuit withstand of 40 times the base rated load current or 20 000 A whichever is less. Application, limitations, design, and resulting cost are to be agreed upon by the user and the manufacturer.

5.9.2 Mechanical capability demonstration

It is not the intent of this subclause that every voltage regulator design is short-circuit tested to demonstrate adequate construction. When specified, tests of short-circuit mechanical capability shall be performed as described in 8.8.

Bushings for use in voltage regulators shall have impulse and applied-voltage insulation levels as listed in Table 14. Unless otherwise specified, the color of the bushings shall match Light Gray Number 70, Munsell Notation 5BG7.0/0.4, as described in IEEE Std C57.12.31.

| Regulator BIL (kV) | Creep distance (minimum) | Applied-voltage withstand | | Impulse full- wave dry withstand |
|-----------------------|-----------------------------|------------------------------|-----------------------------------|--|
| (KV) | mm (in) | 1 min dry (kV rms) | 10 s wet ^a (kV rms) | kV crest (1.2 × 50 μs) |
| 60 | 90 (3.5) | 21 | 20 | 60 |
| 75 | 150 (6) | 27 | 24 | 75 |
| 95 | 255 (10) | 35 | 30 | 95 |
| 110 | 280 (11) | 50 | 45 | 110 |
| 150 | 435 (17) | 60 | 50 | 150 |
| 170 | 660 (26) | 70 | 65 | 170 |
| 200 | 660 (26) | 80 | 75 | 200 |

| Table 14—Electrical characteristics of voltage regul | ator bushings (kV) |
|--|---------------------|
| Tuble IT Electrical characteriotice of Foltage rega | ator saoringo (itt) |

^a Wet withstand values are based on water resistivity of 180 Ω ·m (7000 Ω ·in) and precipitation rate of 0.085 mm/s (0.2 in/min).

6.2 Terminal markings

6.2.1 Terminal markings for step-voltage regulators

Voltage regulator terminals that are connected to the load shall be designated by an L, and those that are connected to the source shall be designated by an S. For example, in the case of a single-phase voltage regulator, the terminals shall be identified by S, L, and SL. In the case of a three-phase voltage regulator, the terminals shall be identified S_1 , S_2 , S_3 , L_1 , L_2 , L_3 , and, if a neutral is provided, S_0L_0 .

Single-phase voltage regulators, when viewed from the top, shall have the *S* terminal on the left, followed in sequence in a clockwise direction by the *L* terminal and the common terminal *SL*, as shown in Figure 3.

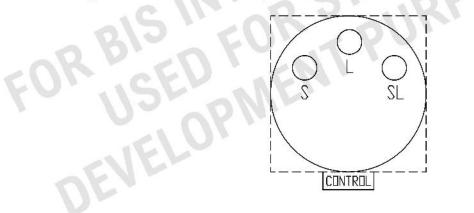


Figure 3—Single-phase voltage regulators

For three-phase voltage regulators, when facing the voltage regulator on the source side, the S_I terminal shall be in front on the right, and the L_I terminal shall be directly behind the S_I terminal, as shown in Figure 4(a), or the S_I terminal shall be in front on the right, and the L_I terminal shall be directly to the left of the S_I terminal, as shown in Figure 4(b). The other terminals shall be located as shown in Figure 4.

6.5.5.2 Maximum continuous rating 300 A or greater

Tank grounding provision shall consist, at a minimum, of one unpainted copper-faced steel or stainlesssteel pad, 50 mm \times 90 mm (2.0 in \times 3.5 in), with two holes horizontally spaced on 44.5 mm (1.75 in) centers, tapped for 0.5 inch 13 NC thread and located near the bottom of the tank. Minimum thread depth of each hole shall be 13 mm (0.5 in). Minimum thickness of the copper facing, when used, shall be 0.4 mm (0.015 in).

6.6 Components and accessories

6.6.1 Components for full automatic control and operation

- a) Control system.
- b) Current and voltage transformers or the equivalent for supplying the control system.
- c) Load tap changer equipment shall consist of a liquid-immersed arcing tap switch, a tap selector, and an arcing switch, or a tap selector with vacuum switch or other current interrupting facility, and motor mechanism. Equipment shall meet the requirements of either IEEE Std C57.131 or IEC 60214-1 as specified.
- d) Internal power supply for tap changer motor.
- e) Provision for disconnecting control power supply.
- f) Position indicator for the load tap changer with maximum and minimum indicating hands and provision for resetting shall be provided. Adjustable range of regulation for the *raise* and *lower* ranges is to be provided for supplementary current ratings per 5.3. Mechanically actuated electric limit switches shall be provided to prevent travel beyond the maximum raise and lower positions.

6.6.2 Accessories for single-phase step-voltage regulators

- a) Combination drain and lower filter valve with sampling device.
- b) Fill plug located at the top of the tank above fluid level.
- c) Liquid level indicator.
- d) Bushing terminals shall be either clamp-type or threaded stud, depending on the nameplate line current ratings as shown in Table 15. The clamp-type terminals shall have at least the conductor range stated and shall be capable of accepting an aluminum or copper conductor. Spade terminals shall have a pad with a minimum dimension of 101.6 mm × 101.6 mm (4.0 in × 4.0 in), with four 14.2 mm (0.5625 in) holes horizontally and vertically spaced on 44.5 mm (1.75 in) centers. Thickness of the pad is shown in Table 15. The user has the responsibility of selecting the proper conductor size for use with the clamp-type or spade terminals. When selecting the conductor size, the user should consider factors such as additional current carrying capability with reduced regulation (see 5.3), supplementary voltage ratings (see 5.2.3) and loading at other than rated conditions (see 4.2).

SPADE SIZE SHALL BE AS PER INDIAN CONTEXT & RLEAVNT IS

SPADE SIZE SHALL BE AS PER INDIA Table 15—Bushing terminal apploandre XT & RLEAVNT IS

| Nameplate line current rating (A) | Conductor size range or 4-hole spade |
|-----------------------------------|---|
| 150 or less | #8-4/0 |
| 151 to 300 | #2–477 kCM |
| 301 to 668 | #2–800 kCM |
| 669 to 1200 | 1-1/8–12 UNF-2A with 4-hole spade— 9.5 mm (0.375 in) minimum thickness |
| 1201 to 2000 | 1-1/2—12 UNF-2A with 4-hole spade— 12.7 mm (0.5 in) minimum thickness |

6.6.3 Accessories for three-phase step-voltage regulators

- a) Combination drain and lower filter valve with sampling device.
- b) Fill plug located at the top of the tank.
- c) Liquid level indicator.
- d) Clamp-type terminals in accordance with single-phase criteria [see item d) in 6.6.2].
- e) Provision for thermometer.
- f) Handholes or openings to permit inspection of core and coil and load tap changer.

7. Other requirements

Certain specific applications have voltage regulator requirements not covered in Clause 4, Clause 5, or Clause 6. Clause 7 comprises descriptions of the most frequently used requirements for such voltage regulators. They shall be provided only when specified in conjunction with the requirements of Clause 4 through Clause 6. Information in the following subclauses may be specified for some applications.

7.1 Other supplementary continuous-current ratings

When specified, other supplementary continuous-current ratings, 668 A maximum, for three-phase voltage regulators rated 8660 V and 13 200 V shall be provided as shown in Table 16 (see 5.3).

| Range of voltage regulation (%) | Continuous-current ratings (%) |
|---------------------------------|-----------------------------------|
| 10.0 | 100 |
| 8.75 | 110 |
| 7.5 | 120 |
| 6.25 | 135 |
| 5.0 | 160 |

Table 16—Other supplementary continuous-current ratings for three-phase voltage regulators

7.2 Other components and accessories

When specified, the other components and accessories listed in 7.2.1 and 7.2.2 may be provided.

associated turn insulation. T_f shall not exceed the limiting temperature in 5.9.3. All temperatures are in degrees Celsius.

$$T_f = (T_k + T_s)m(1 + E + 0.6m) + T_s$$
(26)

where

$$m = \frac{\left(W_s t\right)}{\left[C\left(T_k + T_s\right)\right]}$$

These equations are approximate formulas, and their use *should* be restricted to values of m = 0.6 or less.

For values of *m* in excess of 0.6, the following more nearly exact equation *should* be used:

$$T_f = \left(T_k + T_s\right)\left[\sqrt{\varepsilon^{2m} + E\left(\varepsilon^{2m} - 1\right)} - 1\right] + T_s$$

where

- T_f is final winding temperature
- T_k is 234.5 °C (copper) and 225 °C (aluminum)

Tk = 235 C in line with other parts of IS : 2026

NOTE—225 °C applies for pure or EC aluminum. T_k may be as high as 230 °C for alloyed aluminum. Where copper and aluminum windings are employed in the same voltage regulator, a value for T_k of 229 °C should be applied for the correction of losses.

- T_s is the starting temperature equal to
 - a) A 30 °C ambient temperature plus the average winding rise plus the manufacturer's recommended hottest-spot allowance, or
 - b) A 30 °C ambient temperature plus the limiting winding hottest-spot temperature rise specified for the appropriate type of voltage regulator
- ε is the base of natural logarithm, 2.718
- E is the per unit eddy-current loss, based on resistance loss, W_s , at the starting temperature

where



is the per-unit eddy-current loss at reference temperature

is the reference temperature, which is 20 °C ambient temperature plus rated average winding rise is the short-circuit resistance loss of the winding at the starting temperature, in watts per weight of conductor material

78

(27)

(28)

Annex C

(informative)

RELEVANT INDIAN STANDARDS SHALL BE INCORPORATED

Bibliography

[B1] Accredited Standards Committee C2-2007, National Electrical Safety Code[®] (NESC[®]).^c

[B2] ANSI C84.1, American National Standard Voltage Ratings (60 Hz) for Electric Power Systems and Equipment.^d

[B3] ASTM D 117, Standard Methods of Testing and Specifications for Electrical Insulating Oils of Petroleum Origin.^e

[B4] ASTM D 3487, Specifications for Mineral Insulating Oil Used in Electrical Apparatus.

[B5] IEC 60076-4, Power transformers—Part 4: Guide to the lightning impulse and switching impulse testing—Power transformers and reactors.¹

[B6] IEC 60214-2, Tap Changers-Part 2: Application Guide.

[B7] IEC 61000-4-8, Electromagnetic compatibility (EMC)—Part 4-8: Testing and measurement techniques—Power frequency magnetic field immunity test.

[B8] IEC 61000-4-9, Electromagnetic compatibility (EMC)—Part 4-9: Testing and measurement techniques—Pulse magnetic field immunity test.

[B9] IEC 61000-4-10, Electromagnetic compatibility (EMC)—Part 4-10: Testing and measurement techniques—Damped oscillatory magnetic field immunity test.

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[B11] IEEE Std 62[™], IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus—Part 1: Oil Filled Power Transformers, Regulators, and Reactors.^{g, h}

[B12] IEEE Std 315[™], IEEE Standard Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters).

[B13] IEEE Std C57.12.00TM, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

[B14] IEEE Std C57.12.20[™], IEEE Standard for Overhead Type Distribution Transformers, 500 kVA and Smaller: High Voltage, 34 500 V and below; Low Voltage, 7970/13 800y V and below.

[B15] IEEE Std C57.12.80[™], IEEE Standard Terminology for Power and Distribution Transformers.

[°] The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

^d ANSI publications are available from the Customer Service Department, American National Standards Institute, 25 W. 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

^e ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

^f IEC publications are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

⁸ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

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