

TechTopics No. 47

7.2 kV equipment basic insulation levels (BIL)

The differences in insulation levels, or withstand voltages, of differing types of electrical equipment can be quite puzzling. The differences do make sense, and relate to the application of the equipment. To a minor degree, differences among the ratings of equipment exist because the equipment standards are created in different organizations. However, the major reason that insulation levels differ among different types of equipment relates to the equipment's role in the distribution system.

Insulation levels in electrical equipment are characterized by the withstand voltages used during the design tests.

There are two basic classifications of insulation strength: basic insulation level (BIL) or lightning-impulse withstand voltage, and power-frequency withstand voltage (often called "hipot" voltage).

Consider the most extreme situation with respect to insulation levels, for equipment used on 6.9 kV systems. Since most users commonly think of insulation strength in terms of the rated BIL, the discussion will focus on BIL.

Metal-clad switchgear is often the main service equipment for the facility, supplied directly from the utility system. The utility system is often an overhead line system, with direct exposure to lightning, or only slightly shielded from lightning surges. Thus, the BIL requirements for switchgear are relatively high, but not as high as for outdoor power transformers and outdoor circuit breakers exposed to lightning.

6.9 kV metal-clad switchgear has the same dielectric capability as 15 kV class metal-clad switchgear (95 kV BIL). Liquid-filled power transformers usually have 95 kV BIL at 6.9 kV. Outdoor distribution type 15.5 kV circuit breakers (e.g., the Siemens type SDV7), are rated 110 kV BIL.

Insulation levels for equipment system voltage (or voltage rating of winding) = 6.9 kV

Type of equipment	Reference standard	Lightning-impulse withstand voltage (BIL) kV, peak	Power-frequency withstand voltage kV, rms
Power transformers (liquid) (8.7 kV class)	IEEE C57.12.10	95 kV	26 kV
Outdoor distribution circuit breakers (15.5 kV class)	ANSI/IEEE C37.06	110 kV	36 kV
Metal-clad switchgear (8.25 kV class)	ANSI/IEEE C37.20.2	95 kV	36 kV
Dry-type transformers (8.7 kV class)	ANSI/IEEE C57.12.01	45 kV	19 kV
Medium-voltage motor control (MVC)	UL 347	60 kV	17.5 kV ¹
Medium-voltage motors	NEMA MG1	26.2 kV ³	14.8 kV ²

Footnotes:

¹ $2,000\text{ V} + (2.25 \times \text{nominal voltage rating}) = 2,000 + (2.25 \times 6,900) = 17.5\text{ kV}$

² $1,000\text{ V} + (2 \times \text{nominal voltage rating}) = 1,000 + (2 \times 6,900) = 14.8\text{ kV}$

³ Refer to discussion. $14.8\text{ kV} \times \sqrt{2} \times 1.25 = 26.2\text{ kV}$

Switchgear and circuit breakers most often feed transformers and other circuit breakers, both relatively “robust” from the dielectric standpoint. The BIL of the upstream equipment is coordinated with that of the served equipment, as the insulation capability (BIL rating) of the equipment increases as the exposure to lightning increases (e.g., as you move closer to the utility source).

Well after this basic concept was embodied in the standards, dry-type transformers were introduced. Since air is used as the insulating medium, of course, the insulation level of the dry-type transformer is less than that of liquid-filled power transformers. As shown in the table, a dry-type transformer has a standard rated BIL of 45 kV for 8.7 kV class windings. This is considerably less than the BIL level of liquid-filled transformers, so use of surge arresters was very common in the early years. In recent years, insulation in dry-type transformers has improved, but conservative engineers still often specify surge arresters for “standard BIL” dry-type transformers. More recently, VPI, VPE and cast epoxy windings have become available on dry-type transformers, so it is becoming much more common to require a “power class” BIL (95 kV) on dry-type transformers.

Now, we turn to medium-voltage motor control (MVC) equipment. MVC equipment became popular in the late 1940s and early 1950s, and predominantly was used to feed 2.3 kV and 4.0 kV machines. A motor has no BIL capability, strictly speaking. IEEE 141-1992 (the “Red Book”) shows a value for “impulse strength” in table 6-4, based on a proposal from a working group. The proposed impulse strength value was 125 percent of the peak value of the power-frequency withstand voltage. In our example, the power-frequency withstand voltage is 14.8 kV, with a peak value of 20.9 kV and a corresponding “impulse strength” of 26.2 kV.

This proposed “impulse strength” has not been incorporated in the motor standards, and is mentioned solely to illustrate that motor insulation levels are considerably lower than the insulation levels of the equipment used to supply power for the motors.

Since the motor starting contactor feeds a machine with a very low impulse capability, there is little value to requiring a high BIL of the vacuum contactor. Even so, the makers of the vacuum contactors in the early years were relatively conservative, and many had backgrounds in circuit breaker type equipment. Accordingly, the vacuum contactors came to be designed for 60 kV BIL, which is the BIL level of 4.76 kV switchgear.

Vacuum contactors also employ a control power transformer (CPT) to supply power for the contactor main coil. With drawout designs, the CPT is often on the drawout carriage. The CPT is usually of open, dry-type construction for cost reasons and for space considerations. This led to an exclusion of the CPT from the BIL requirement (impulse test) in the standard for MVC equipment.

Essentially, all transformers and a number of other voltage-sensitive devices (such as, autotransformers, reactors, CPTs, surge arresters and surge capacitors) are disconnected from the MVC when the impulse test is performed. This may sound like “cheating,” but really isn’t. These devices all would take very high currents when the voltage rises, preventing the voltage from rising to the level required for the test. Therefore, they are disconnected from the MVC equipment for dielectric testing. They are also disconnected from switchgear during dielectric testing.

It is recognized that machines have very poor insulation, and therefore, CPTs, autotransformers and reactors in MVCs are allowed to have the BIL capability allowed by their respective standards.

All of this reflects the fact that MVCs are intended to feed machines that have low dielectric capabilities. Also, it is rare for MVCs to have direct exposure to lightning. For MVC installations that have exposure to voltage surges, surge arresters should be specified.

Philosophically, when a lightning surge comes down the line, it doesn’t stop just before it reaches the connected equipment to ask, “What BIL are you?” It doesn’t change its voltage level to suit the BIL of the equipment it is about to hit. Lightning surges don’t come in 30 kV, 45 kV, 60 kV or similar values. A lightning strike is millions of volts and tens of kA. Accordingly, if the application involves direct lightning exposure, surge protection in accordance with the applicable standards (primarily ANSI/IEEE C62.21) must be specified when the equipment is purchased.

In summary, the differences in BIL requirements arise primarily from differences in the dielectric capabilities of the served equipment and exposure levels.

The information provided in this document contains merely general descriptions or characteristics of performance which in case of actual use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of contract.

All product designations may be trademarks or product names of Siemens AG or supplier companies whose use by third parties for their own purposes could violate the rights of the owners.

Siemens Industry, Inc.
7000 Siemens Road
Wendell, NC 27591

Subject to change without prior notice.
Order No.: E50001-F710-A336-X-4A00
All rights reserved.
© 2012 Siemens Industry, Inc.

For more information, contact: +1 (800) 347-6659

www.usa.siemens.com/techttopics