

TechTopics Topic: 7.2kV 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 between the ratings of equipment exist because the equipment standards are created in different organizations. However, the major reason that insulation levels differ between 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).

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

Insulation Levels for Equipment
 System Voltage (or voltage rating of winding) = 6.9kV

Type of equipment	Reference Standard	Lightning Impulse Withstand Voltage (BIL) kV, peak	Power Frequency Withstand Voltage kV, rms
Power Transformers (liquid) (8.7kV class)	IEEE C57.12.10	95kV	26kV
Outdoor Dist Circuit Breakers (15.5kV class)	ANSI C37.06	110kV	36kV
Metal-Clad Switchgear (8.25kV class)	IEEE C37.20.2	95kV	36kV
Dry Type Transformers (8.7kV class)	IEEE C57.12.01	45kV	19kV
Medium Voltage Motor Control (MVC)	NEMA ICS3	60kV	17.5kV (note 1)
Medium Voltage Motors	NEMA MG1	26.2kV (note 3)	14.8kV (note 2)
Note 1: $2000V + (2.25 \times \text{nominal voltage rating}) = 2000 + (2.25 \times 6900) = 17.5kV$			
Note 2: $1000V + (2 \times \text{nominal voltage rating}) = 1000 + (2 \times 6900) = 14.8kV$			
Note 3: See discussion. $14.8kV \times \sqrt{2} \times 1.25 = 26.2kV$			

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. 6.9kV metal-clad switchgear has the same dielectric capability as 15kV class metal-clad switchgear (95kV BIL). Liquid filled power transformers usually have 95kV BIL at 6.9kV. Outdoor distribution type 15.5kV circuit breakers (e.g., the Siemens type SDV4a), are rated 110kV BIL.

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 (i.e., as you move closer to the utility source).

Much 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 transformer was less than that of liquid-filled power transformers. As shown in the table, a dry type transformer has a standard rated BIL of 45kV for 8.7kV 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 that it is becoming much more common to require a "power class" BIL (95kV) on dry type transformers.

Now, we turn to medium voltage motor control equipment. MVC equipment became popular in the late 1940's and early 1950's, and predominantly was used to feed 2300V and 4000V 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% of the peak-value of the power-frequency withstand voltage. In our example, the power-frequency withstand voltage is 14.8kV, with a peak value of 20.9kV and a corresponding "impulse strength" of 26.2kV. 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 contactor. Even so, the makers of the contactors in the early years were essentially conservative, and many had backgrounds in circuit breaker type equipment. Accordingly, the contactors came to be designed for 60kV BIL, which is the BIL level of 4.76kV switchgear.

Contactors also employ a control power transformer (CPT) to supply power for the contactor main coil. With drawout designs, the CPT is on the 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 (autotransformer, reactor, CPT, surge arresters, 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 MVC's are intended to feed machines that have low dielectric capabilities. Also, it is rare for MVC's to have direct exposure to lightning. For MVC installations that have exposure to voltage surges, surge arresters should be specified.

Philosophically, my perspective on lightning is this. When a lightning surge comes bopping 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 30kV, 45kV, 60kV, 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 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.

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