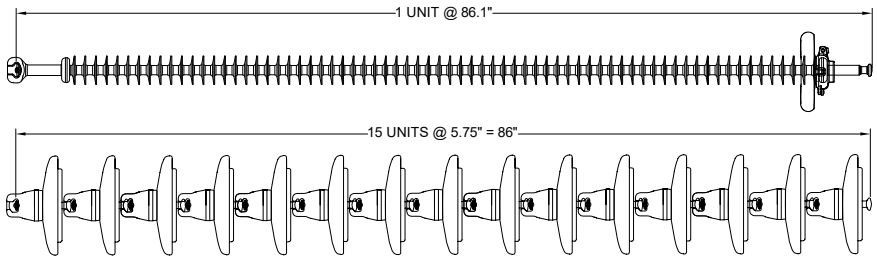
Polymer vs Porcelain Suspension Insulator Equivalence–What to Use?

Several differences in characteristics and application criteria between polymer and porcelain insulation systems lead to the conclusion that polymer insulators are superior. This article examines the various criteria used in selecting insulators and the development of a suitable method for selecting the correct size polymer insulator.



Size difference is apparent when equal strength insulators are side-by-side.

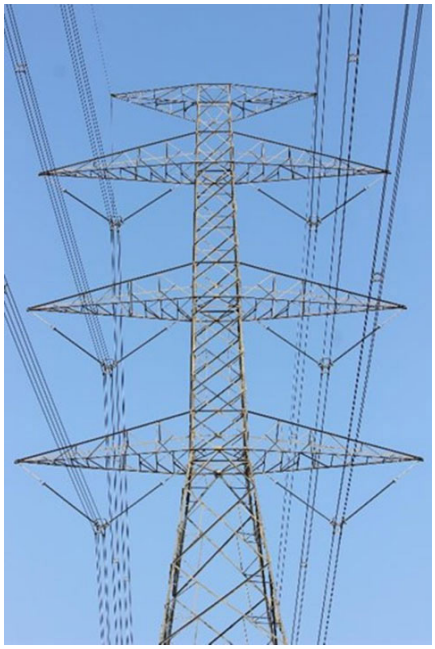
TYPES OF EQUIVALENCE

Several different methods for comparing equivalence come to mind when considering polymer and porcelain insulators. The first broad category is physical equivalences, including the strength rating of the insulators, and the section length (or coupling length) of the porcelain insulator string and the polymer insulator unit. The second broad category is electrical equivalences. Among these are the leakage distance, the 60 Hz wet and dry flashover values, and the positive and negative impulse critical values.

PHYSICAL EQUIVALENCE

The ultimate strength of porcelain suspension insulators is characterized by the porcelain mechanical and electrical (M & E) value. This value is determined from a mechanical strength test performed on individual suspension bells. The applied electrical stress tests the integrity of the relatively thin porcelain section between the cap and pin to indicate the load at which mechanical failure initiates. For Hubbell polymer suspension insulators, the equivalent measure is the specified mechanical load (SML). The SML test is a 90-second tension withstand test up to the SML value. Hubbell polymer insulators are available in strength ratings equal to or exceeding porcelain insulator M & E strengths. Per the standards, porcelain suspension insulators are proof tested at 50% of their M & E value. Similarly, Hubbell polymer insulators are proof tested at a value of 50% of the SML. This routine test load (RTL) is performed on every Hubbell polymer insulator in compliance with the standards.

Therefore, to select the proper strength Hubbell polymer insulator, consider only the porcelain M & E rating used previously. Select a polymer insulator with an SML equal to or greater than this M&E value.



Low profile, high strength polymer insulators

SECTION LENGTH EQUIVALENCE

Based on the design of our Quadri*Sil® transmission insulators, section length can match any desired length within ~2". Often the structure design is far advanced before insulator selections are made, and therefore a defined range for section length is targeted. Hubbell Quadri*Sil polymer insulators are produced in variable 2 shed section lengths to meet this range of length requirement. This allows the section length of porcelain designs to be closely matched.

ELECTRICAL EQUIVALENCE

After the mechanical strength and section length are defined, the electrical characteristics of the polymer insulator must be verified for suitability with the system voltage. In performing this analysis, three voltage stresses are typically considered: 60 Hz power frequency, switching impulse, and lightning impulse voltage.

60 HZ POWER FREQUENCY

A major cause of transmission line flashovers is contamination build-up on the insulator string. These flashovers can occur at nominal system voltage.

Leakage distance is the primary factor which determines an insulator's performance under contaminated

conditions. When a Hubbell polymer insulator is selected with a section length equal to the porcelain strings that were previously used, the specific leakage distance of the polymer insulator will be greater than the specific leakage distance of the standard porcelain bell insulator (leakage divided by dry arc).
For example, at 230 kV, one typical porcelain bell string used is 15 units.

For ANSI class 52-5-L rated M&E at 25,000 lbs., a standard profile has a leakage distance of 165 inches. The Quadri*Sil insulator with equivalent section length, Catalog No. S025075S301A, has a leakage distance of 192 inches. In this case, the Quadri*Sil insulator offers >15% more leakage distance over the same section length (~86 inches).

SWITCHING IMPULSE AND TRANSIENT PERFORMANCE

Due to improvements in breaker technology, switching transients have been greatly reduced over the past 75 years. For example, switching transients in the 1930's were measured as high as 5.5 per unit, while today's breakers will limit the voltages to three per unit or less. Therefore, for the 230 kV system, the maximum switching surge voltage to which the insulators would be subjected is 563 kV.

$$\left(\frac{230\ kV}{\sqrt{3}} \times \sqrt{2} \times 3.0\right) = 563\ kV$$

Table 1. Characteristics of Equivalent Insulators

Insulator	Section Length	Leakage Distance	60 Hz Dry Flashover	60 Hz Wet Flashover	Critical Impulse Flashover +	Critical Impulse Flashover -
S025075S301A	86.1 in	192 in	745 kV	690 kV	1220 kV	1235 kV
15 units 52-5L	86 in	165 in	830 kV	600 kV	1345 kV	1360 kV
13 units 52-5L	74.5 in.	143 in	735 kV	525 kV	1185 kV	1190 kV

The simplest way to coordinate insulation levels with expected switching surge voltages is by using the 60 Hz wet and dry values. There is some debate as to whether this value should be used. We will assume that switching will occur in the worse of the two conditions such as during a storm when the insulators are wet.

The 15 porcelain bells will have a 60 Hz wet flashover of 600 kV, while the equivalent Quadri*Sil insulator has a 60 Hz wet flashover of 690 kV. Again, this is a 15% increase. However, in both cases, the values exceed the 563 kV expected switching surge voltage. Therefore, a Quadri*Sil insulator chosen with section length equal to porcelain string length will have equal or better switching impulse voltage performance.

LIGHTNING IMPULSE VOLTAGES

Lightning impulse voltages are the most challenging to insulate against. Even manufacturers' literature indicates that a major design criteria of high voltage insulators is that they should not flashover under any condition except lightning.

Because lightning is such an unpredictable phenomenon, few utilities know the stroke currents for which they have designed. They may only know the impulse critical positive and negative values listed for the porcelain insulator strings currently in use.

An often-overlooked detail, porcelain insulator strings frequently include one to two "insurance units." These extra bells are sometimes included in the string in case units are damaged during shipment or installation or punctured in service.

For example, in the 230 kV case, the 15 bells would have positive and negative impulse critical values of 1345 and 1360 kV, respectively. However, if two damaged insulators are assumed in the string, these values are reduced to 1185 and 1190 kV respectively. By contrast the Quadri*Sil insulator is not prone to damage; therefore, the positive and negative impulse critical voltages for the polymer insulator are higher at 1220 and 1235 kV, respectively.

Therefore, the lightning impulse performance of the equivalent section

Equivalent polymer insulators provide multiple advantages when used as a direct replacement for porcelain.

length Quadri*Sil insulator will be equal to or greater than the porcelain insulator string.

CONCLUSION

All the various electrical equivalences indicate that selecting a Hubbell Quadri*Sil polymer insulator with a section length equal to that previously used in porcelain insulators will result in an assembly with equivalent or superior electrical performance. The following table summarizes the selection process.

Table 2. Steps to selecting a Quadri*Sil replacement for a porcelain string

Mechanical	1. Choose Quadri*Sil specified mechanical load (SML) equal to or greater than porcelain M & E.
Section Length	2. Choose Quadri*Sil section length equal to (or greater than) porcelain section length.
Switching Surge	3. If step 2 is followed, Quadri*Sil specific leakage distance will most likely be greater than the porcelain string.
Impulse (Lightning)	4. If step 2 is followed, Quadri*Sil performance (60 Hz wet flash-over) will be greater than porcelain.
Leakage Distance	5. If step 2 is followed and allowances made for “insurance units,” Quadri*Sil values are greater than porcelain.

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