EPRI

Survey of Utility Experiences with Composite/Polymer Components in Transmission Class (69 – 765 kV class) Substations

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REPORT SUMMARY

This report covers the results and analysis of a North American utility survey on the experience of polymer-based / composite products and apparatus used in transmission class (69 - 765 kV) substations. The survey addresses many topics that are of general interest to utilities such as:

- Standards (internal or industry) that may have been used to purchase these apparatus.
- Laboratory and field trial investigations undertaken by utilities to determine whether the apparatus was suitable for their use.
- Identification of the various polymer / composite products and apparatus installed in their systems.
- Brand names, years installed, kV class of lines where installed, specific problems, failure modes, etc. of the various polymer / composite products and apparatus available for use in transmission class (69 - 765 kV) substations.
- Reasons for using and not using these polymer / composite products and apparatus.
- Usage of corona rings or electrical field grading devices.
- Field potential inspection and diagnostic techniques.
- Utility's lifetime expectancy for each polymer / composite products and apparatus.
- Criteria for removal for each polymer / composite products and apparatus.
- Cleaning / washing techniques used on each polymer / composite products and apparatus.
- Utility's interest for future R&D that could be conducted by EPRI.

Background

The use of substation polymer / composite based utility products and apparatus has grown in the last 10 years with the advent of new materials, new product applications, lower costs, new designs, technology upgrades in manufacturing, standards and application guides, introduction of inspection and condition assessment tools, etc. The list of polymer / composite products and apparatus continues to grow from the already large list that today includes insulators, mechanical supports, transformer and circuit bushings, arresters, coatings, etc. Many of the well-established polymer / composite and newly developed products are applicable for transmission class (69 – 765 kV class) substation use. EPRI member utilities are interested in many technical aspects that need to be addressed with the introduction of different polymer products in their substations. Thus, this utility survey study is focused on the experience of those polymer / composite based products and apparatus used in transmission class substation applications.

Results & Findings

The quality of polymer / composite based products and apparatus used by the various North American utilities today has translated into high expectations of 25+ years of service life. However, utilities still have concerns to install polymer / composite based apparatus in substations and thus hesitate to purchase larger quantities. These concerns include lack of experience with polymers, expected aging and reduced life expectancy compared to what they are using today, and past problems with other polymer / composite products.

The information gathered regarding substation polymer / composite based product design, manufacturing, inspections, user experiences, etc. lends itself well to have EPRI formulate application guides for polymer-based products to help utilities decide how to specify and purchase, handle, store, install, inspect, test, establish criteria to repair or remove products from service, etc. Utilities have expressed an interest for future R&D investigations that can be used to formulate application guides to overcome their specific concerns when factoring in their own or other utility's experiences with field failures and problems of other polymer / composite based substation products. Approximately 2/3 of the North American utilities surveyed indicated that more R&D was needed for polymer / composite based transmission class substation products and apparatus.

There is a general lack of knowledge by utilities in the potential field and laboratory diagnostic and testing techniques. Thus, it is recommended that any future R&D proposed by EPRI to their utility members include diagnostic inspection techniques (IR camera, visual, UV camera, etc.), criteria for field removal, potential failure mechanisms, modes of failure, etc. This R&D should focus on substation polymer / composite products such as insulators (suspension, post), mechanical support (disconnect switches), arresters, and bushings (transformers, switchgear, breakers, wall).

Challenges & Objectives

The survey focuses on experiences of North American utilities regarding the application of polymer / composite based products and apparatus used in transmission class (69 - 765 kV class) substations. The project objective is to gain specific information with respect to brands, vintages, good and poor performance, failure modes and mechanisms, diagnostic and inspection techniques, etc., and need for future R&D.

EPRI Perspective

This is a first time investigation for EPRI members into the large variety of transmission class substation polymer / composite based products and apparatus related to service experiences of both EPRI and non-EPRI utilities. This analysis complements the more detailed investigation completed by EPRI into the large variety of substation polymer / composite based apparatus with respect to technical specifications, design, manufacturing techniques, potential field inspection and laboratory test techniques, etc. There is a high level of technical expertise required for further R&D investigations that the utility participants have a desire to see undertake. EPRI can best fill this technical need and provide the value-added R&D information for their EPRI members to help them feel confident in their present and future use of transmission class substation polymer / composite based equipment.

Approach

The following activities were planned to complete the above objectives:

- Determine a breakdown of present-day products that can be categorized as transmission class substation polymer / composite based apparatus.
- Formulate a questionnaire and conduct a utility survey regarding their service experiences.
- Compile and analyze the utility replies to help EPRI and their members learn from present-day polymer / composite based apparatus transmission class substation installations.

Keywords

Polymer Composite
Suspension Insulators
Arresters
Circuit breaker bushings
Wall bushings
NCI
Station post insulators
Transformer bushings
RTV coatings
Disconnect switches

ABSTRACT

A questionnaire was completed by 31 utilities and the responses analyzed to help ascertain their service environment with respect to climate and pollution, common voltage classes, usage of substation polymer / composite based products and apparatus, brands, kV classes, problems, failures, reasons for using and not using polymer-based products, need and products for future EPRI R&D activities, etc. The polymer / composite based products that were the focus of this utility survey included:

Suspension Insulators	Station post insulators (solid and hollow core)
Arresters	Transformer bushings
Circuit breaker bushings	RTV coatings

Approximately 2/3 of the surveyed utility's had a positive reply and opinion as to the need for further R&D related to transmission class substation polymer / composite based apparatus. Thus, EPRI should formulate proposals for EPRI member sponsored R&D investigations with the aim to address diagnostic inspection techniques (IR camera, visual, UV camera, etc.), criteria for field removal, potential failure mechanisms, modes of failure, etc. all with the focus on polymer insulators (suspension, station post), arresters, bushings (transformers, switchgear, wall), RTV coatings, and disconnect switches.

CONTENTS

1 INTRODUCTION

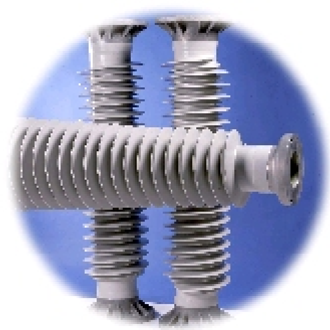
The use of polymer / composite based utility products and apparatus for Transmission Class (69 – 765 kV) substation applications has grown in the last 10 years with the advent of new materials, new product applications, lower costs, new designs, technology upgrades in manufacturing, standards and application guides, introduction of inspection and condition assessment tools, etc. The list of polymer / composite substation equipment continues to grow from the already large list that today includes insulators, mechanical supports, bushings for circuit breakers and transformers bushings, arresters, and coatings. Many of these well-established polymer / composite and newly developed products are applicable transmission class (69 – 765 kV class) substation use.

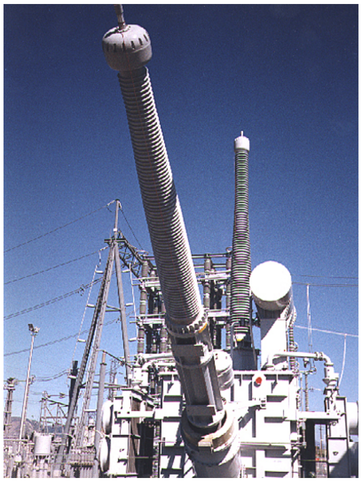
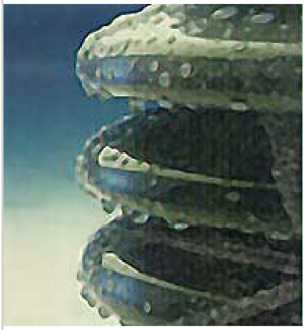
With the expected increase in usage of polymer-based utility products and products specifically designed for substation applications, EPRI member utilities are interested in many technical aspects that need to be addressed with the introduction of different polymer products in their substations. Thus, this study was focused on supplementing other EPRI technical investigations into those polymer / composite based products and equipment with respect to design, construction, manufacturing techniques, technical ratings, diagnostic techniques, etc. that are presently used in transmission class substation applications.

The project objective was to gain an understanding of North American utility's service experience for polymer / composite based products and apparatus with respect to brands, vintages, good and poor performance, failure modes and mechanisms, diagnostic and inspection techniques, etc., and need for future R&D. Formulating an extensive questionnaire and conducting a utility survey regarding their service experiences accomplished this objective.

For the purposes of this utility survey, Table 1.1 (see below) illustrates the Transmission Class polymer / composite based substation products and apparatus that were investigated:

Table 1-1
Polymer / Composite based Transmission Class Substation Products & Apparatus

Polymer / Composite based Transmission Class Substation Products & Apparatus	**Photos**
Suspension / dead-end insulators	
Station post insulators (solid & hollow core) - Solid core will be constructed from a 3.5+ inch diameter composite rod - Hollow core with typically an insulating gas or a vacuum to provide the inner HV insulation / dielectric strength	 
Transformers bushings – Typically hollow core and filled with an insulating gas (i.e. SF_6) or insulating oil - This technology also applies to current transformers (CT) and CVTs	

Circuit breaker bushings - Typically hollow core and filled with an insulating gas (i.e. SF_6) or insulating oil. - This technology also applies to gas insulated switchgear (GIS)	
Lightning arrestors	 
RTV coatings	 

2 ANALYSIS OF UTILITY SURVEY RESPONSES

2.1 List of Participating North American Utilities

The 31 utilities that responded to the survey include (unless otherwise indicated, utilities are from USA) the following. Most of the participating utilities participating in this survey are present or past EPRI members:

BC Hydro (Canada)	BPA	Centerpoint Energy
DTE Energy	Electricity de France	Exelon (Com Ed)
Entergy	First Energy Corp.	Grant County PUD
Hawaiian Electric	Hydro Quebec (Canada)	Lincoln Electric
Kansas City P&L	Keyspan Energy	Nashville Electric
Nambia Power Corp (Nambia)	Northeast Utilities	National Grid Transco (UK)
National Grid	Oklahoma G&E	PG&E
Progress Energy – Carolinas	Salt River Project	San Diego G&E
Seattle City & Light	Snohomish County PUD	SCE
TXU	United Illuminating	WAPA
Xcel Energy		

2.2 Survey Results Analysis

The following is a summary analysis of replies from the 31 utilities that participated in this survey. Also included in the analysis were answers from 4 other utilities, which only answered questions 1, 2, 3, 8, 9, 10, 11, & 16. This was helpful to compile and analyze the service experience of transmission class polymer / composite based substation products and equipment.

1. Identify your typical **environmental** and **climatic conditions** where transmission class substation polymer-based products are installed.

Analysis: The lowest temperature identified was –40 °F (-40°C) and the highest temperature identified was 122 °F (50°C).

The lowest annual precipitation rate identified was 12 inches/year (300 mm/year) and highest identified was 72 inches/year (1,800 mm/year).

A Temperate climate was the most common utility reply where transmission class substation equipment is installed. A Temperate climate can be classifiable as an area with cool or cold winter and warm summer with an average temperature during the warmest month above 50°F. A few installations were installed in a desert and arctic environment. This information illustrates that utilities are open to installing transmission class polymer / composite based substation products and equipment in both high and low temperature, and in both dry and wet environments.

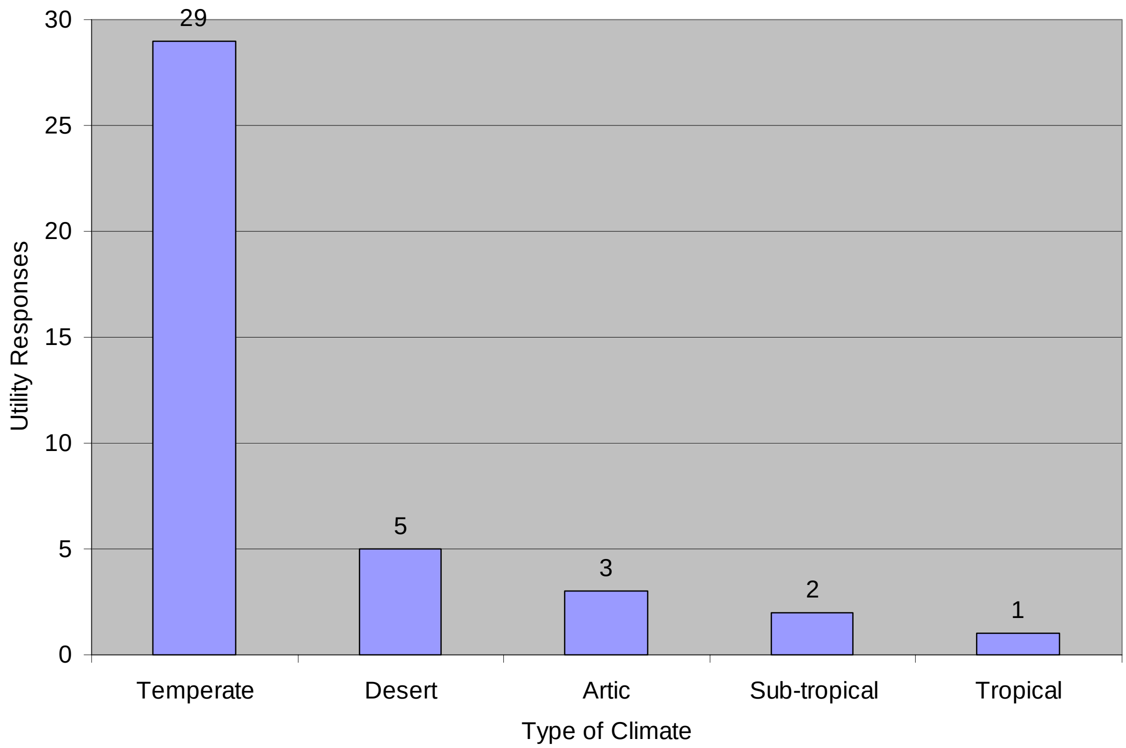


Figure 2-1 Utilities with Climate Type

2. Identify your **polluted service environment** for substation where polymer-based products are installed.

Analysis: 27 of the 35 utilities indicated that they had some form of pollution and/or contamination in the proximity of their substations where transmission class polymer / composite based products and equipment are installed. A breakdown of the utility replies is shown below:

Industrial = 22 (Chemical = 16; Cement = 13; Mining = 7)

Agricultural: = 18 (Fertilizers = 17; Pesticides = 15)

Coastal = 17 Moss or Algae = 6 Road Salt = 13

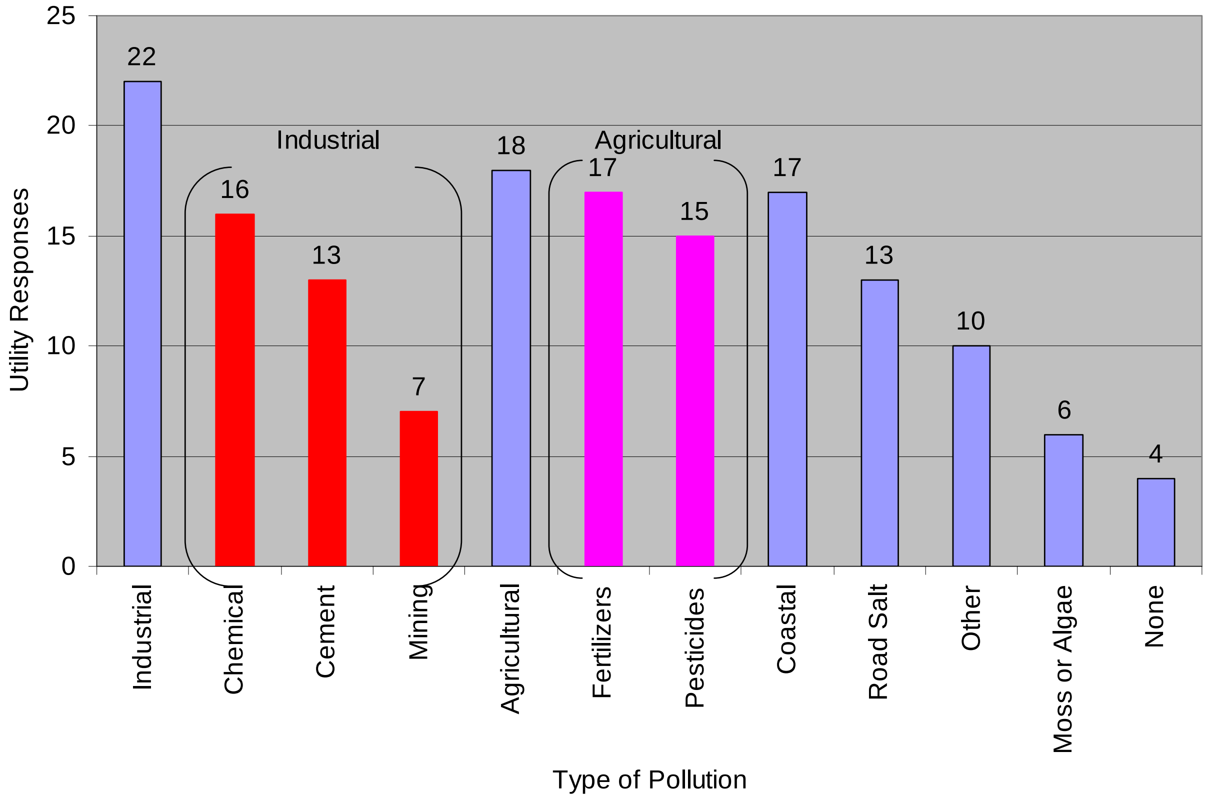


Figure 2-2 Utilities with Pollution Type

The percentage of man-influenced industrial and agricultural contamination was quite high with 63% and 52% of utilities indicating that they have transmission class substation installed in these environments. Industrial pollution included chemical, cement, and mining deposits. Agricultural contamination consisted of fertilizers and pesticides.

Another man-influenced pollution that was common is the use of road salt where 37% of utilities indicating a use of road salt near substations. This indicates that their transmission class substations are likely installed within city limits and in climatic environments where cold weather and snow is common during the winter months.

Weather related contamination in the form of salt fog (coastal) was identified by 49% of the utilities indicating that their transmission class substations are likely installed close to the East, West, and Southern coasts of USA. Moss or algae was identified by those utilities that likely have substations located in a humid and/or rainy environment.

Other types of contamination described by the utilities included tropical rain forest (1), general agricultural dust (1), concrete dust (1), paper mill dust (1), petrochemical airborne release (1), coal dust (2), grain dust (2), and iron dust (1).

It should be noted that although the above results indicate the percentage of utilities that have to account for contamination in their substations, it does not indicate how many of their substations are affected by contamination. For example, if a utility had one substation out of one hundred that was affected by contamination, a positive reply was obtained.

3. Identify the different transmission **voltage classes** for your substations where polymer-based products are installed.

Analysis: The most common substation voltage class used by the utilities participants is 115 / 138 KV which was used by 100% of the utility participants. The 69 kV and 345 / 400 kV class substations were a close second and third. The breakdown of voltage classes used by utilities is shown below:

69 kV= 24	115 / 138 kV= 31	161 kV= 10	230 kV = 19
345 / 400kV = 21	500 kV = 14	765 kV= 2	

Figure 2-3 through Figure 2-6 show the number of utilities with substations at each voltage class and how many are using the particular polymer component in their substation at that voltage class. These charts are a snapshot of the more popular products used. Table 3-2 shows the raw data for polymers used in substations at the voltages applied.

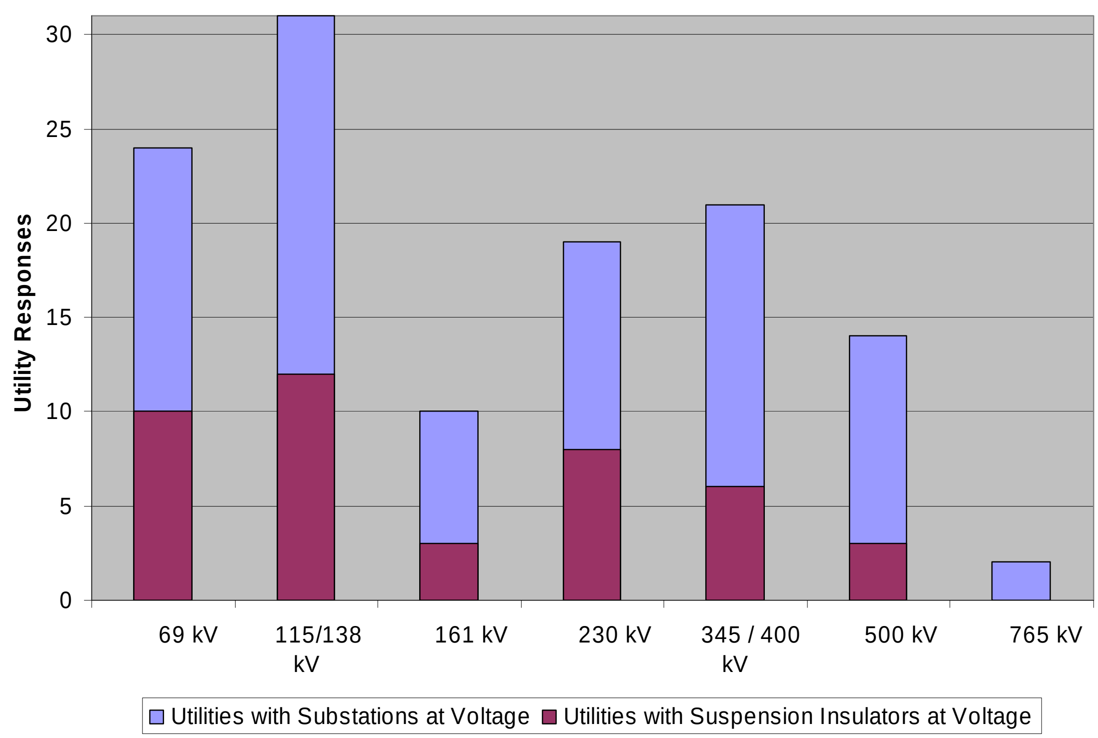


Figure 2-3 Utilities Using Polymer Suspension Insulators at Voltage

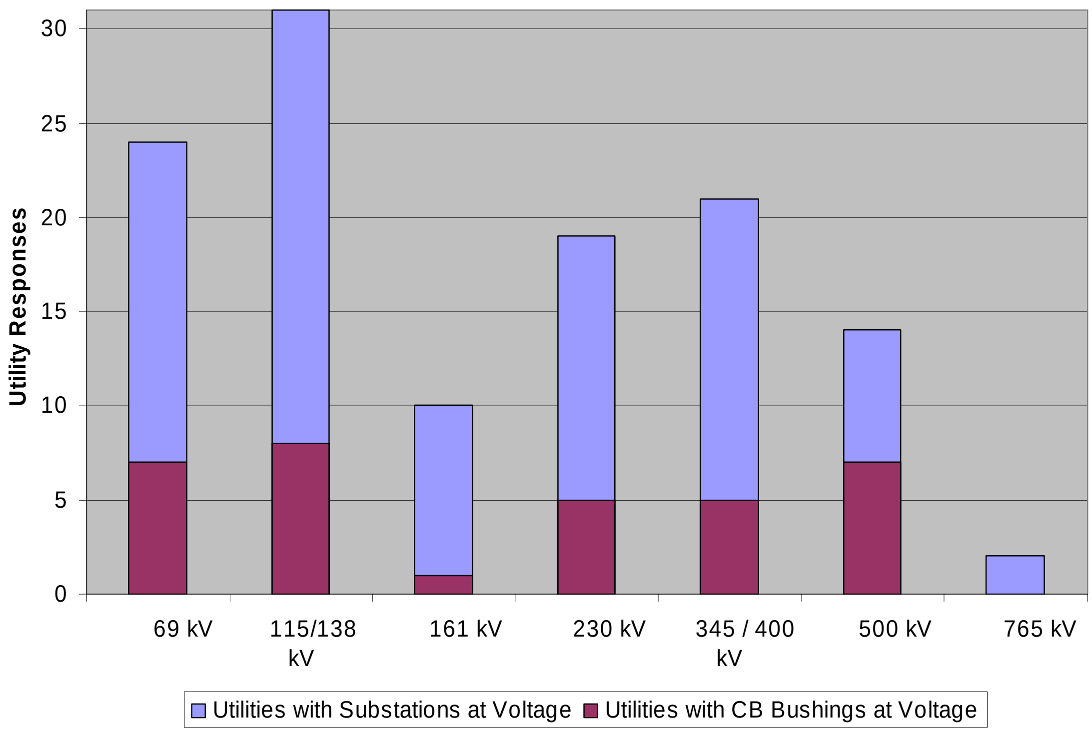


Figure 2-4 Utilities Using CB Polymer Bushings at Voltage

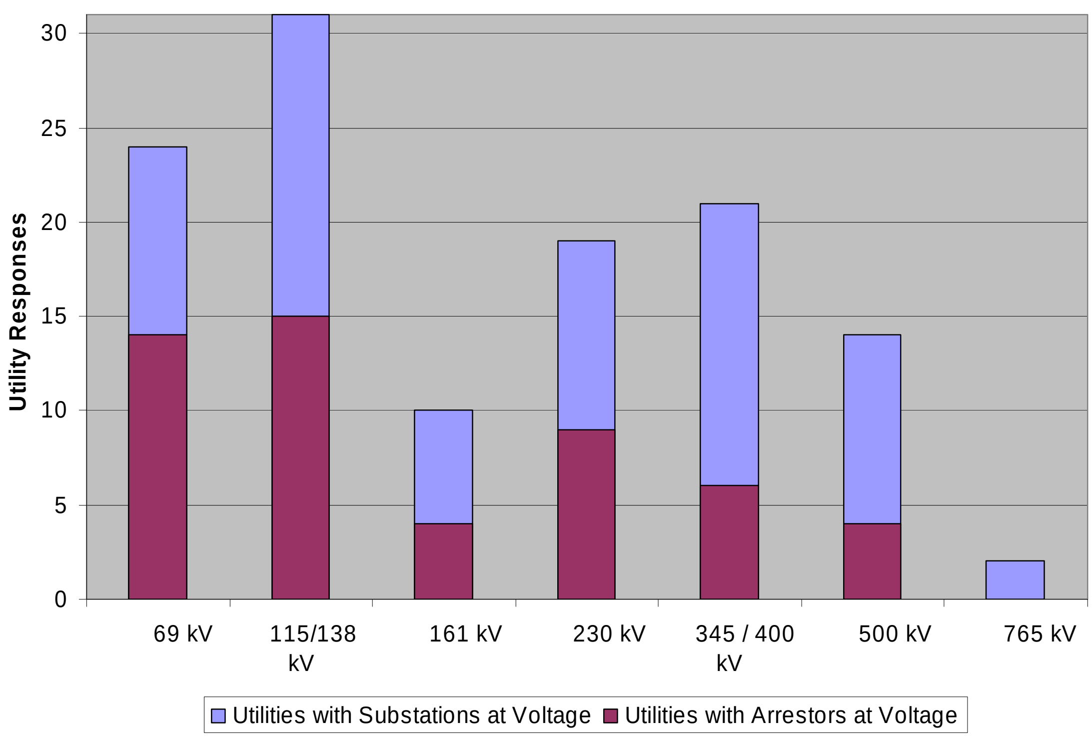


Figure 2-5 Utilities Using Polymer Arrestors at Voltage

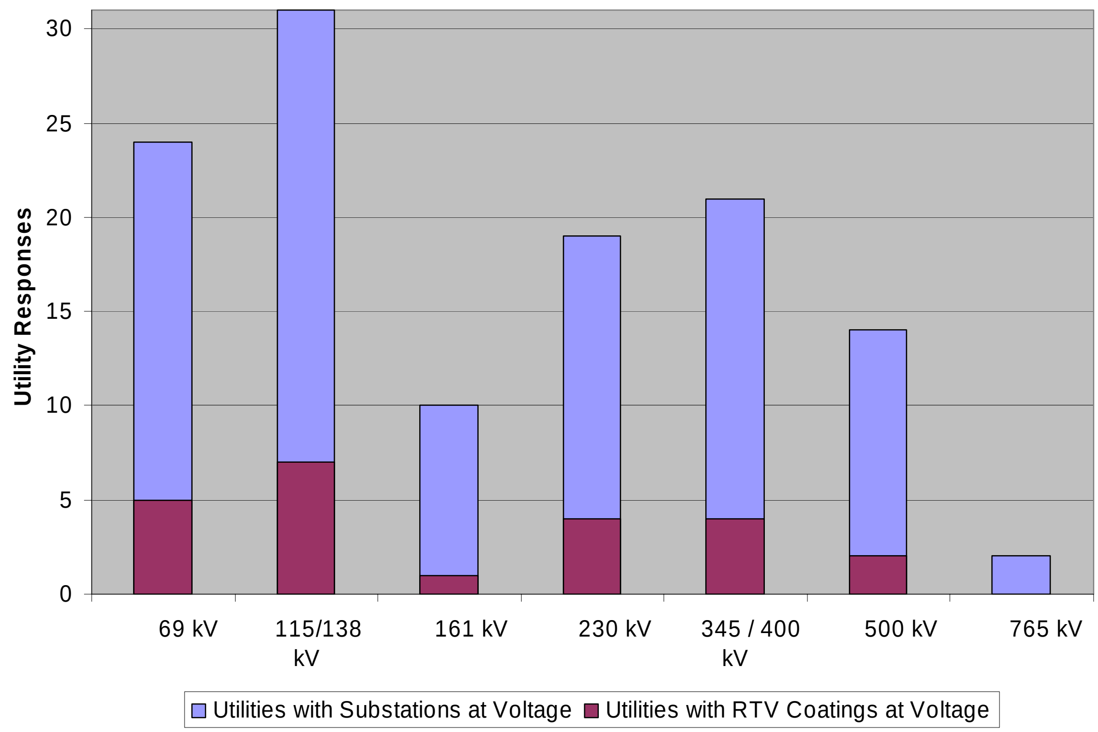


Figure 2-6 Utilities Using RTV Coatings at Voltage

4. Did you purchase the polymer-based substation products to a **Purchase Standard** or **Specification**?

Analysis: 13 of the 31 (42%) utilities indicated that they did use some form of purchase standard or specification to purchase transmission class polymer / composite based substation products and equipment. Those utilities that did reply indicated a use of Standard class 3 (1), IEC 137 (1), internal specification or standards (4), use Manufacturer's / vender's catalogs (3), applicable IEC standards or based upon IEC requirements (2), and ANSI C62.11 (1).

The other 18 (58%) utilities that use some form of transmission class polymer / composite based substation products and equipment did not use any type of purchase specification or standard.

5. Did your company perform any **laboratory evaluation** or **performance based testing** before purchasing the polymer-based substation products?

Analysis: 10 of 31 utilities (32%) did perform some form of laboratory evaluation or performance based testing before purchasing the polymer-based substation products. However, none of the utility respondents were able to share this information. Those utilities that did reply indicated that they used Electric Field Analysis (4), Electrical Performance & Aging Testing (7), Mechanical Testing (5), Seismic Testing (2), Heavy wet testing (1), Thermal cycling x 50 dips using 1 dip per day (1), Corona testing under wet conditions (1), Visual only (1), and Ice testing (1).

The formulation of a future specification and/or application guide would serve well for this need by either the utilities or manufacturers, which should also address some form of laboratory evaluation or performance based testing before purchasing or selling the polymer-based substation products.

6. Did your company perform any **field evaluation testing** or **trials** before purchasing the polymer-based substation products?

Analysis: 14 of 31 utilities (45%) indicated that they did perform field evaluation testing or trials before purchasing the polymer-based substation products. The field evaluation investigations were installed in coastal test stations (3), general field trials (2), natural coastal pollution areas (3), industrial pollution areas (2), use field experience of arresters from distribution class substation installations (1), trial test area then sent back to manufacturer for analysis (2), pilot project in 115 kV substation (1), and in general outdoor test stations (2).

The other 17 utilities did not feel a need to undertake field trials perhaps to due reasons that could include:

- They have had good experience to date with polymer / composite products.
- They performed laboratory testing (see question # 5).
- They have no other option given their situation (i.e. coastal environment).
- They have a specification from which to purchase polymer / composite equipment.
- They have a high confidence level in the polymer / composite equipment technology.
- They do not have an outdoor test station or area to perform trial testing, etc.

7. Identify the **polymer / composite based products** used in your transmission class substations and answer questions related to brands, vintages, voltage class installation, problems, and annual failure rates.

Analysis: Of the 31 utilities that answered this survey question, a breakdown of the various polymer / composite products and equipment is shown in Table 2-1 below.

Table 2-1
Utility Usage of Various Polymer / Composite based Transmission Class Substation Products & Apparatus

Suspension Insulator	Station Post Solid Core Insulator	Station Post Hollow Core Insulator	Circuit Breaker Hollow Core Bushing	Transformer Hollow Core Bushing	Composite Arresters	RTV Coatings	Other
18 Utilities	8 Utilities	NONE	11 Utilities	7 Utilities	21 Utilities	11 Utilities	4 Utilities GIS Bushing = 1 CVT = 2 Other = 1

The question regarding the “common mode of failure” and “failure mechanism” seemed to be confusing to many of the utilities, so their answers seemed to be similar. A quick summary for their replies include:

- Housing puncture & rupture
- Base rupture
- Tracking & server erosion
- Moisture ingress
- Internal flash-through
- Pressure seal failure (SF_6 gas escape)
- Cutting corona activity (improper ring install, no ring)
- Shed split
- Brittle fracture
- Core exposure
- Improper selection of product or apparatus
- Polymer / core interface adhesion problems and failure

The utility replies for annual failure rates of the different substation polymer / composite apparatus was not well answered to indicate that there is no significant problem, only isolated cases that appear to occur more often with suspension insulators.

The table “Comparison Table for Number of Polymer-based Products Installed Vs. Substation Voltage for Each Type of Substation Apparatus / Products” in Chapter 3 on Pages 3-6 & 3-7 provides detailed information regarding specific equipment and brands installed in the various substation voltages.

The table “Comparison Table of Each Polymer-based Product Brand Vs. the Number of Years Installed in Service” in Chapter 3 on Pages 3-8 & 3-9 provides detailed information regarding years installed in service for the various equipment and brands. The more popular brands used by the utilities that answered this survey question include:

- For suspension and station post (solid core) insulators = MP, OB, NGK and Sediver.
- Usage of CB and transformer bushings was scattered amongst many brands with no dominating brand.
- For polymer arresters = ABB, Siemens and Hubbell.
- For RTV silicone coatings = Dow (Sylgard) and Midsun.
- Usage of CVTs was scattered amongst several brands with no dominating brand.

8. Identify your **reasons** for **using** polymer-based transmission class substation products over traditional products.

Analysis: 32 of the 35 utilities surveyed replied to this survey question. The main reasons identified for using polymer / composite based transmission substation products were (in order of the most votes):

Less Damage to Other Equipment during Failure = 20

Cost Effective = 18

Expected Improved Pollution performance = 16

Expect Less Installation Problems & Personnel Safety = 13

Expected Less Flashovers / Outages = 11

Expected Less Maintenance = 10

Availability / Timely Delivery = 9

Improved Seismic / Earthquake Performance = 6

Expected Longer Service Life = 1

These higher rated reasons centered on reduced damage that can occur from less violent explosions (if they should occur), better-cost effectiveness (installation at remote sites, life cycle cost, maintenance, less outages, etc.) flashover performance in polluted and regular climates, and safety to substation personnel and the public.

Other reasons offered by the utilities included use in only coastal areas (1), less vandalism compared to porcelain (1), weight reduction / lighter (4), smaller profile (1), easier to handle / install (2), and reduced animal outages (1).

9. Identify your **reasons** for **NOT using** polymer-based transmission class substation products.

Analysis: 27 or the 35 utilities replied to this survey question. The main reasons identified for NOT using polymer / composite based transmission substation products were (in order of the most votes):

Lack of Experience with Polymers = 15

Aging & Reduced Life Expectancy = 12

Past Problems with Other Polymer Products = 10

Lack of Product Standardization = 9

Higher Cost = 6 | Lack of Inspection & Diagnostic Techniques= 5

Live Working Concerns = 5 | Inability to Assess Condition of Equipment= 4

These higher rated reasons for not using them centered on the utility's lack of experience with or poor experience with polymer / composite products in general, premature aging concerns, and lack of existing purchase specifications and application guides.

Other reasons offered by the utilities included not priced competitively (1), cleaning issues / concerns (1), disconnect switches (deflection concerns, not rated for use with disconnect switches, problems with disconnect switches) (4), strength concerns compared to porcelain (2), lack of design for bus work (1), and equipment ratings not high enough for application (1).

10. Identify how your utility selects **electric field stress relief** and/or **corona rings** for transmission class substation polymer / composite **suspension and post insulators, and bushings**.

Analysis: 29 of 35 utilities replied to this survey question. 83% of the respondents indicated the use of manufacturer's guidelines (24). The other reasons used to a much lesser extent were calculations / modeling (5), use of corona rings from transmission lines (4), use of corona rings from substations (4), and undertake testing and/or R&D (4).

These results indicate the importance of the electric field distribution on composite components. This is the type of work that could be best developed and more importantly confirmed through R&D, testing and investigations generated by independent organizations such as EPRI.

11. Does your utility use any **unique configurations** for suspension composite insulators in transmission class substations?

Analysis: 29 of the 35 utilities replied to this survey question. The majority (27 or 77%) answered that they did **not** use any unique configurations for suspension composite insulators in substations.

12. Identify the **specific problems** with transmission class substation polymer-based products that your utility has experienced to date.

Analysis: 20 of the 31 utilities replied to this survey question. The purpose of this question was to obtain more specific information provided in question #7 regarding problems and failure modes experienced with polymer / composite substation products and apparatus. Not all utilities that replied in question #7 offered to elaborate in this survey question #12.

For the purposes of this survey question, the following apply:

- **Surface aging** and **deterioration** includes weathering, light erosion, discoloring, and chalking. **Surface damage** includes severe erosion, burning, tracking, torn sheds, and punctured sheds. This polymer surface degradation and damage was noted most often for polymer suspension insulators (7) and RTV coatings (5).

- **Exposure of the core** consists of removal of the polymer housing from the underlying composite (fiberglass / resin) core. This core exposure would ultimately lead to the destruction of the polymer / composite equipment. This damage was noted most often for polymer suspension insulators (5) even though it can occur on any of the polymer / composite substation equipment.
- **Pollution induced flashovers** is multiple electrical flashovers caused by contamination related problems (industrial, agricultural, coastal, road salt, etc.). This problem was noted only for polymer suspension insulators (2) and RTV coatings (2).
- **Mechanical degradation or failure** means a breech of the structural integrity of the product, component, or equipment in the form of brittle fracture, cracked core, etc. Mechanical failure was noted most often for suspension insulators (6), but there were also isolated occurrences for a station post insulator, arrester, and CB bushing.
- **Damage during installation** would occur as a result of using improper handling, storage, transportation, installation, etc. procedures employed by the utilities that may be their own ignorance, inadequate training, or from inaccurate information given to them by manufacturers. Utilities reported this to occur mainly to suspension insulators (6) with occurrences also for CB bushings (2).
- **Excessive Corona** using specialized diagnostic tools is typically measured in the form of audible noise, radio noise (RN) and/or TV interference (TVI). Excessive corona was noted by 4 utilities to occur on suspension insulators with 2 cases when the corona ring was incorrectly installed. With the larger diameter hardware used with bushings, station posts, CVTs, and arresters, corona is not expected to be a major problem.
- **Other** specific types of problems reported by a few utilities include water ingress into the polymer / composite equipment, deformed or damaged during storage, corrosion of metal, mildew formation on polymer housing, separation of the housing from the core, rupture at the base (arrester), loss of hydrophobicity (RTV), and an internal explosive failure.

13. Identify those **field diagnostic techniques** that you have tried with respect to each transmission class substation polymer-based product by grading their effectiveness for each polymer-based product. **NOTE:** (Apply using the following Legend: **1** Very Effective, **2** Effective, **3** Average, **4** Below Average, **5** Ineffective)

Analysis: 19 of the 31 utilities replied that they have undertaken some form of field diagnostic or condition assessment analysis. Visual inspections were the most common form of field diagnostic technique employed with their effectiveness rated as good (rating from 1 – 3) with respect to the detection of polymer surface degradation or damages. Visual inspections can be performed close up, close proximity, and remotely (depending on the apparatus). This technique was reported to be more commonly used by utilities for the inspection of polymer / composite arresters (17), suspension insulators (13), RTV coatings (9), and circuit breaker (CB) bushings (9). This technique has also been used on CVTs and GIS (gas insulated switchgear).

IR temperature camera diagnostic analysis was performed by 13 of the 19 utilities that answered to the survey question. This technique was used most often for the polymer / composite arresters (13) and suspension insulators (11). This technique has also been used on GIS (gas insulated switchgear) by 1 utility. A higher success rate for arresters was reported by the users, which is likely due to the metal oxide varistor / blocks reaching the end of their life (high leakage current) with a noticeable internal temperature increase. Depending on the arrester design, it is possible that the high voltage potting material (silicone grease, polymer, composite, etc.) may be deteriorating and generating heat internally. Thus, this diagnostic tool may be more of a condition assessment tool for the arrester internal components.

Only 3 of the 19 utilities that answered to the survey question have tried using one of the different types of daytime corona or UV amplification cameras (DayCor, CoroCam, etc.) to detect corona or electrical discharge associated with polymer / composite apparatus internal and/or external damages. This was most often tried with suspension insulators (3). No conclusions can be drawn from these few experiences.

Only 1 of the 19 utilities that answered to the survey question has attempted to employ an E-Field measurement device on the suspension insulators (Positron, etc.) to detect anomalies in the electrical field profile that may be indicative of internal damage. No conclusions can be drawn from these few experiences.

Only 3 of the 19 utilities that answered to the survey question have tried to use a parabolic ultrasonic emission dish on the suspension insulators to detect electrical discharges that may be indicative of internal damage. No conclusions can be drawn from these few experiences.

Only 3 of the 19 utilities that answered to the survey question have tried to use a HVAC resistance device (used when equipment de-energized) that would help ascertain the condition (insulating or conductive) of the polymer surface. No conclusions can be drawn from these few experiences.

Only 1 of the 19 utilities that answered to the survey question has tried to implement a Vibrational Frequency Response technique to detect internal defects and damages. No conclusions can be drawn from these few experiences.

Other in-service diagnostic techniques used by a few utilities include Doble testing for circuit breakers, and Power Factor testing for transformers.

Utilities reported that polymer arresters (8) were inspected most often for regular maintenance / inspection in their substations. The other substation apparatus identified for regular or semi-regular inspections include suspension insulators (5), CB bushings (4), and transformer bushings (3).

14. What is your **expected service lifetime** for polymer-based transmission class substation products in your service environment?

Analysis: 25 of the 31 utilities replied to this survey question. Depending on their service environment, most utilities expect to realize a life expectancy for their polymer-based transmission substation products of more than 20 years. For RTV coatings, this is usually less than 10 years. For a detailed breakdown, see Chapter 3 (page 3-16).

15. Identify and elaborate where applicable on your utility's **criteria for removal / replacement** for each transmission class substation polymer-based product.

Analysis: 19 of 31 utilities surveyed replied to this question. The 12 utilities that did not reply may not have a removal criterion, may not have experienced any problems to date, may still be experimenting with them, may not perform any scheduled inspections, etc.

For the purposes of this survey question, the following apply:

- **Surface aging** includes light erosion, discoloring, chalking, and loss of hydrophobicity. Surface aging was cited as the most used criteria for the removal of substation polymer / composite products and equipment except for CB and transformer bushings, and station post insulators.
- **Surface damage** includes severe erosion, burning, tracking, torn sheds, punctured sheds, exposed core, and interfacial separation. Surface damage was cited as the most used criteria for the removal of substation polymer / composite products and equipment except for station post insulators.
- **Poor flashover performance** is multiple electrical flashovers that may cause outages. Poor flashover was cited as the most used criteria for the removal of substation polymer / composite products and equipment except for CB and transformer bushings, and station post insulators.
- **Mechanical failure** means a breech of the structural integrity of the product, component or equipment. Mechanical failure was cited as the most used criteria for the removal of substation polymer / composite products and equipment except for station post insulators.
- **High failure rate** implies failure of the component / equipment to operate any further. High failure rate was cited as the most used criteria for the removal of substation polymer / composite products and equipment except for station post insulators.

Other criteria for removal identified by one or two utilities each included poor Doble and High Power Factor measurements, loss of hydrophobicity, and excessive corona.

16. Identify the **washing or cleaning techniques** used too date and elaborate where applicable for each transmission class substation polymer-based product.

Analysis: Less than 25% of the utilities indicated that they had attempted any washing or cleaning of their substation polymer / composite products and equipment.

Pressurized washing was the most common cleaning technique used. Those utilities that used this technique, attempted this on all substation polymer / composite products and equipment including CVT's except hollow core station post insulators.

Hand washing was used by only a few utilities. Those utilities that used this technique, attempted this technique on all substation polymer / composite products and equipment including CVT's except station post insulators.

The abrasive cleaning technique (e.g. corncobs, walnut shells) was used by only 3 utilities on suspension and station post (solid core) insulators, and a transformer hollow core bushing.

No results or details were offered by the utilities as to the success of the washing / cleaning techniques, but this was not part of the question asked of utilities.

17. In your opinion, is further R&D needed on polymeric / composite components for substations? **<u>NOTE:</u>** (Prioritize R&D suggestions in brackets: **1** Very High, **2** High, **3** Average, **4** Low, **5** Very Low)

<u>Analysis:</u> 23 of the 35 utilities (66%) replied that they felt that some form of further R&D is needed on polymeric / composite components and equipment used in substations. Of the 23 utilities that provided a positive reply, 5 utilities did not provide any details as to prioritizing which equipment is most important to their needs. There were 9 utilities that provided a negative reply, and 3 utilities that had no reply to this question.

The breakdown of polymer / composite substation products and apparatus that utilities felt required future R&D with the highest priority (Level 1, 2 & 3 from survey) included: Station post solid core (13), Station post hollow core (13), Circuit breaker hollow core bushing (15), Transformer hollow core bushing (12), and Arresters. See the detailed breakdown in Chapter 3 (page 3-19).

Comments and ideas from utilities for future R&D activities specific to substation polymer / composite products and equipment include:

- Design an ID marker that a polymer / composite apparatus had sustained a flashover.
- Determine porcelain equivalency for polymer / composite station posts, and supports used in disconnect switches.
- Determine permissible movement during operation of polymer / composite station posts, and supports used in disconnect switches.
- Formulate live line condition assessment of substation polymer / composite products and equipment.
- Formulate live line mechanical testing of polymer / composite suspension and station post insulators.
- Investigate possibility of using fiber optic implants for internal temperature measurement of CVT, GIS, and CB and transformer hollow core bushings.
- Design an inexpensive but effective field-test techniques for arresters.
- Develop standards for station post solid and hollow core post insulators, and CB and transformer hollow core bushings.

- Formulate guidelines for combined M&E testing for substation polymer / composite hollow core station equipment.
- Formulate end-of-life assessment for substation polymer / composite products and equipment.
- Determine sensitivity of polymer/composite products to Electric fields and the resulting surface degradation.
- Formulate life cycle analysis (LCA) to help justify and confirm the use of some polymer / composite products in place of tradition substation components.

3
RAW DATA RESULTS OF UTILITY RESPONSES

<u>NOTE:</u> Raw useable data from **31** utilities plus **4** utilities that did not qualify by not providing any useable technical information regarding the use of Polymer / Composite Products & Equipment in Transmission Class (69 – 765 kV Class) Substations. Some of these provided only data for polymer suspension insulators for Transmission O/H lines, which was not applicable for this survey.

1. Identify your typical **environmental** and **climatic conditions** where Transmission class Substation Polymer-based products are installed.

Annual temperature range (°C): Lowest Temp. = **-40** Highest Temp. = **50**
Annual temperature range (°F): Lowest Temp. = **-40** Highest Temp. = **122**

Annual Precipitation rate: Lowest = **300** mm/year Highest = **1,800** mm/year
Annual Precipitation rate: Lowest = **12** inches/year Highest = **72** inches/year
Utilities that did NOT reply = **6**

Type of climate: Arctic **= 3** Temperate **= 29** Sub-tropical **= 2** Tropical = **1** Desert = **5**

2. Identify your **polluted service environment** if applicable. (Answer ALL that apply)

<u>Industrial:</u> = **22** Chemical **= 16** Cement **= 13** Mining = **7**
<u>Agricultural:</u> = **18** Fertilizers **= 17** Pesticides **= 15**
Coastal = **17**
Moss or Algae **= 6**
Road Salt **= 13**
Utilities with NO identified pollution in substation areas = 4

<u>Other:</u>
Tropical rain forest = **1** General Agricultural dust = **1** Concrete dust = **1**
Paper mill = **1** Petrochemical =**1** Coal dust = **2**
Grain dust = **2** Iron dust = **1**

3. Identify the different transmission **voltage classes** for your substations. (Answer ALL that apply)

69 kV **= 24** 115 / 138 kV **= 31** 161 kV **= 10** 230 kV **= 19**
345 / 400kV **= 21** 500 kV **= 14** 765 kV **= 2**

4. Did you purchase the polymer-based substation products to a **Purchase Standard** or **Specification**?

Yes **= 13** No **= 21** Utilities that did NOT reply = **1**

If **yes**, please identify the standard or purchase specification:

- Standard class 3 = **1**
- IEC 137 = **1**
- Internal specification or standards = **4**
- Use Manufacturer's and Vender's catalogs = **3**
- Applicable IEC standards or based upon IEC requirements = **2**
- ANSI C62.11 = **1**

If an internal or supplier specification was used, can you share this? Yes **= 2** No **= 7**

5. Did your company perform any **laboratory evaluation** or **performance based testing** before purchasing the polymer-based substation products? Yes **= 10** No **= 25**

If **yes**, answer ALL that apply:

Electric Field Analysis **= 4** Electrical Performance & Aging Testing = **7**

Mechanical Testing = **5** Seismic Testing **= 2**

Describe **other** testing conducted:

- Heavy wet testing = **1**
- Thermal cycling x 50 dips (1 dip per day) = **1**
- Corona testing under wet conditions = 1
- Visual only = **1**
- Ice testing = **1**

Can you share the results? Yes **= 0** No = **8**

6. Did your company perform any **field evaluation testing** or **trials** before purchasing the polymer-based substation products? Yes **= 14** No = **17**

If **yes**, describe testing conducted and results:

- Installed in coastal test station = **3**
- General field trials = **2**
- Installed in natural coastal pollution areas = **3**
- Installed in industrial pollution areas = **2**
- Use field experience of arresters from distribution class substation installations = **1**
- Installed in trial test area then sent back to manufacturer for analysis = **2**
- Pilot project in 115 kV substation = **1**
- Installed in general outdoor test stations = **2**

If **yes**, can you share the detailed results? Yes **= 4** No **= 8** No replies **= 5**

7. Identify the **polymer / composite based products** used in your transmission substation and answer the questions on the left hand margin. (Answer ALL that apply)

Number of utilities that do **no**t use polymer / composite apparatus in Substations = **4**

Table 3-1
Comparison Table for Sumamry of Replies regarding Usage of Various Polymer / Composite based Transmission Class Substation Products & Apparatus

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
# of Utilities using Polymer-based Products	YES = 18	YES = 8	NONE	YES = 11	YES = 7	YES = 21	YES = 11	YES = 4 GIS Bushing = 1 CVT = 2 Other = 1
Brand Names and Voltage Classes (kV)								
Years Installed								
Type of Field Problems	Adhesion of rubber to rod =1					Rupture of base = 1	- Collection of lots of dirt / pollution = 1 - Loss of Hydrophobicity = 4	

Common Mode of Failure	- Tracking = 2 - Brittle Fracture = 3 - Shed split = 1 - Internal flash through = 2			SF6 gas escape = 1		- Housing rupture = 1 - Base rupture = 1 - Housing puncture = 1 - Internal flash through = 1	Coating does not perform properly = 1 External flashover = 1	Mechanical failure (CVT) = 1
Common Reason for Failure	- Moisture ingress = 1 - Improper corona ring install = 1 - Improper ring selection = 1 - Rod failure / exposure = 3 - Handling / application = 2 - Thin sheath = 1 - Corona Cutting = 1 - Seal failure = 1			Pressure seal failure = 1		Excessive heat dissipation = 1 Lightning strike = 1 Moisture ingress = 1	Surface pollution = 1	FRP / Fitting interface (CVT) = 1
Annual Failure Rate (# / Year)	<1 / yr = 3 2 / yr = 1 3 / yr = 2 10-15 / yr = 1			1 / yr = 1		< 1 / yr = 1 2-4 / yr = 1 Very few = 1	20 / yr = 1	2 in Year 2000
Most Problematic Brands	LAPP = 3 Sediver = 2 MP = 4 OB = 5 1970 & 80 vintages = 1 EDPM brands = 1							

Table 3-2
Comparison Table of Number of Utilities using Polymer / Composite based Product & Equipment Vs. Voltage Class of Substations

Voltage Class (kV)	**69 kV**	**115/138 kV**	**161 kV**	**230 kV**	**345 / 400 kV**	**500 kV**	**735 kV**	**Unknown**
Number of Utilities With Substations in Each Voltage Class	24 Utilities	31 Utilities	10 Utilities	19 Utilities	21 Utilities	14 Utilities	2 Utilities	??
Number of Utilities With Polymer Suspension Insulators Installed	10 / 24 Utilities	12 / 31 Utilities	3 / 10 Utilities	8 / 19 Utilities	6 / 21Utilities	3 / 14Utilities	0 / 2 Utilities	1 Utility
Number of Utilities With Polymer Station Post Insulators Installed	3 / 24Utilities	4 / 31Utilities	1 / 10 Utilities	1 / 19 Utilities	0 / 21Utilities	2 / 14Utilities	0 / 2 Utilities	1 Utility
Number of Utilities With Circuit Breaker Polymer Bushings Installed	7 / 24Utilities	8 / 31Utilities	1 / 10 Utilities	5 / 19 Utilities	5 / 21Utilities	7 / 14Utilities	0 / 2 Utilities	0 Utilities
Number of Utilities With Transformer Polymer Bushings Installed	1 / 24 Utilities	3 / 31Utilities	1 / 10 Utilities	5 / 19 Utilities	1 / 21Utilities	4 / 14Utilities	0 / 2 Utilities	1 Utility
Number of Utilities With Polymer Arresters Installed	14 / 24Utilities	15 / 31Utilities	4 / 10 Utilities	9 / 19 Utilities	6 / 21Utilities	4 / 14Utilities	0 / 2 Utilities	2 Utilities
Number of Utilities With RTV Coatings Applied	5 / 24 Utilities	7 / 31Utilities	1 /10 Utilities	4 / 19 Utilities	4 / 21Utilities	2 / 14Utilities	0 / 2 Utilities	2 Utilities

Number of Utilities With CT / CVT Polymer Bushings Installed		3 / 31Utilities		3 / 19 Utilities	1 / 21Utilities	2 / 14Utilities	0 / 2 Utilities	2 Utilities
Number of Utilities With Polymer Wall Bushings Installed						1 / 14 Utilities		

NOTE: All “Various Voltage” replies by utilities were assumed to be ALL the voltage classes they listed in question #3 of the survey.

Table 3-3
Comparison Table for Number of Polymer-based Products Installed Vs. Substation Voltage for Each Type of Substation Apparatus / Products

Voltage Class (kV) Apparatus & Brand	Number Installed at 69 kV	at 115 / 138 kV	Number Installed at 161 kV	Number Installed at 230 kV	Number Installed at 345 / 400 kV	Number Installed at 500 kV	Number Installed at Various ? Voltages
Suspension (# Utilities using them)							
Old TL 1970 /80's (1)		1		1		1	
Sediver (6)	4	5	1	5	2	1	1
LAPP (4)	1	2	1	1	1		
OB (10)	7	8	4	3	5	1	
MP (12)	8	8	2	4	4	2	1
NGK (8)	5	7	1	4	3	2	
Locke (1)	1		1	1	1		
Station Post Solid Core (# Utilities using them)							
LAPP (1)		1					
NGK (2)	1	2					
Sediver (3)	1	3		1	1		
OB (4)	1	3	1				
MP (4)	2	3		1			
Unknown (1)						1	
Station Post Hollow Core (# Utilities using them)							
Circuit Breaker Hollow Core Bushing (# Utilities using them)							

Electro-composite (1)	1						
OB (2)							2
ABB (1)							1
Axicom (1)							1
Sediver (3)	1	2		1	1	1	
ABB Platt (1)							1
Mitsubishi (1)						1	
Westinghouse (1)	1						
NGK (2)	1	1		1		2	
Cellpack (2)	1	1		1		2	
Unknown (4)	2	2		2	1	1	
Transformer Hollow Core Bushing (# Utilities using them)							
Mitsubishi (1)						1	
Piedmont (1)	1						
HSP (3)							
Trench (1)						1	
ABB (2)		1		2			
Siemens (1)						1	
Sediver (1)				1	1		
Arresters (# Utilities using them)							
GE (3)	2	1	2		1	1	1
Sediver (1)	1						
OB (10)	6	7	2	3	1	1	
Siemens (7)	5	4	1	4	1	3	
Cooper (2)	2	1		1			1
ABB (10)	7	8	2	6	2	4	
Joslyn (3)	3	3		1	1		
Tyco (1)		1			1		
Unknown (3)	1	2	1				
RTV Coatings (# Utilities using them)							
CSL (1)	1			1			
Dow / Sylgard (7)	3	3		2	2	1	3
Midsun (4)	3	2		2	1	1	
Wacker (1)	1	1			1		1

Unknown (5)	1	3		1	1		1
Other (# Utilities using them)							
GIS Wall Bushing - HSP(1)						1	
CVT / CT – Siemens (1)		1		1		1	
CVT / CT – Sediver (1)		1		1		1	
CVT / CT – Trench (2)		1		1	1		1
CVT / CT – Khulman (1)							1

Table 3-4
Comparison Table of Each Polymer-based Product Brand Vs. the Number of Years Installed in Service

Polymer-Based Apparatus Brands **Legend**: OB = Ohio Brass MP = MacLean Power (Reliable)	Suspension Insulator (Yrs Installed)	Station Post Solid Core Insulator (Yrs Installed)	Station Post Hollow Core Insulator (Yrs Installed)	Circuit Breaker Hollow Core Bushing (Yrs Installed)	Transformer Hollow Core Bushing (Yrs Installed)	Composite Arresters (Yrs Installed)	RTV Coatings (Yrs Installed)	Other (Yrs Installed)
ABB				15	1	6 / 1 / 10 / 5 / 4 / 10 / 15 / 5 / 3 / 6 / 6		
Axicom				15				
ABB Platt				15				
Cellpack				4				
Cooper						6 / 6		
CSL							19	
Dow / Sylgard							1 / 15 / 10 / 19 / 20 / 16	
Electro-composite				1				
GE						6 / 4 / 15		
HSP					1 / 1/ 6			GIS - 5
Joslyn						1 / 10 / 6		

Khulman								CVT - 1
LAPP	? / 10/	10 / 20 / ?						
Locke	20							
Mitsubishi				?	?			
MacLean Power (MP)	10 / 10 / 8 / 17 / 15 / 15 / 15 / 15 / 20 / 20	10 / 10 / 10 / 5 / ?						
Midsun							19 / 15 / 15 / 16	
NGK	10 / 10 / 5 / 15 / 15 / 15/ 15/	10 / 10 / 20		4				
OB	10/ 10/ 15/ 15/ 15 / 15 / 20 / 8	10 / 10 / 10 / 10 / 20		10 / 15		10 / 10 / 10 / 6 / 6 / 5 / 6 / 10 / 3 / 2 /		
Piedmont					1			
Sediver	23 / 17 / 10 / 10 / 17 / ? / 15	10 / 10 / 5		15 / 7 / 5	1	14		CVT - 4
Siemens					1	5 / 1 / 10 / 6 / 6 / 5 / 4 / 3 /		CVT - 4
Trench					4			CVT – 1 / 7
Tyco						6		
Wacker							20	
Westinghouse				20				
Unknown Brands	4	11		7 / 10 / ? / 6		3 / ? / 7 / ? / 7	13 / 10 / 10 / ? / 4	

8. Identify your **reasons** for **using** of polymer-based transmission substation products over traditional products.
   (Answer ALL that apply)
   - Cost Effective **= 18**
   - Improved Seismic / Earthquake Performance **= 6**
   - Expect Less Installation Problems = **13**
   - Expected Improved Pollution performance **= 16**
   - Availability / Timely Delivery **= 9**
   - Expected Less Flashovers / Outages **= 11**
   - Expected Longer Service Life **= 1**
   - Less Damage to Other Equipment during Failure **= 20**
   - Personnel Safety **= 13**
   - Expected Less Maintenance **= 10**
   - Utilities that did NOT reply = **3**

   Other:
- Only coastal areas = **1**
- Less vandalism compared to porcelain = **1**
- Weight reduction / lighter = **4**
- Smaller profile = **1**
- Easier to handle / install = **2**
- Reduced animal outages = **1**

9. Identify your **reasons** for **NOT using** polymer-based transmission substation products. (Answer ALL that apply)
   - Aging & Reduced Life Expectancy **= 12**
   - Past Problems with Other Polymer Products **= 10**
   - Lack of Product Standardization **= 9**
   - Lack of Inspection & Diagnostic Techniques **= 5**
   - Live Working Concerns **= 5**
   - Inability to Assess Condition of Equipment **= 4**
   - Lack of Experience with Polymers **= 15**
   - Higher Cost **= 6**
   - Number utilities with no reason or no replies as to why not to use = **8**

   Other:
- Not priced competitively = **1**
- Cleaning issues / concerns = **1**
- Deflection concerns for Disconnects switches, not rated for use with disconnect switches, problems with Disconnect switches = **4**
- Strength concerns compared to porcelain = **2**
- Lack of design for buswork = **1**
- Equipment ratings not high enough for application = **1**

10. Identify how your utility selects **electric field stress relief** and/or **corona rings** for substation polymer / composite **suspension and post insulators, and bushings**. (Answer ALL that apply)
   - Calculations / Modeling **= 5**
   - Use Corona Rings from Transmission Lines **= 4**
   - Use Manufacturer's Guidelines **= 24**
   - Use Corona Rings from Substations **= 4**
   - Undertake Testing and/or R&D **= 4**

Number utilities that deemed this noon-applicable for their substation use or no replies = **6**

<u>Other:</u>

- Spark gap adapted to voltage level = **1**
- Only use at EHV levels = **3** (138 = 1; 230 = 2)
- Manufacturer supplies corona rings = **1**
- None used for bushings = **1**

11. Does your utility use any **unique configurations** for suspension composite insulators in substations?

Yes **= 1** No = **27** No utility replies = **6**

12. Identify the **specific problems** with transmission substation polymer-based products that your utility has experienced to date. (Answer ALL that apply with **X** and where possible write a 1 – 3 word description for clarification; Example: Surface Damage = tracking & burning)

No problems OR No utility replies = 11

	Surface Aging or Deterioration or Damage	**Exposure of Fiberglass Core**	**Frequent Outages**	**Pollution Induced Flashovers**	**Mechanical Degradation or Failure**	**Damage During Installation**	**Excessive Corona (Audible Noise, RN & TVI)**	**Other Types of Specific Problems**
Suspension Insulator OB = Ohio Brass MP = MacLean Power (Reliable)	Sediver = 1 MP = 1 OB = 2 YES = 7 Corona induced = 4	YES = 5 OB = 3		YES = 2 Coastal = 2	YES = 6 Brittle Fracture = 1 End fitting seal = 1	YES = 6 Corona ring = 1	YES = 4 230 kV Apply = 1 Misapply corona ring = 2	Poor adhesion of rubber = 1 Water ingress = 1 Animal induced =1 Internal explode = 1 Corrosion = 1 OB = 1
Station Post Solid Core Insulator						YES = 1		
Station Post Hollow Core Insulator					YES = 1 Internal Failure =1			
Circuit Breaker Hollow Core Bushing	YES = 1 Erosion & Cracking =1				YES = 1 Cooling tower vapor = 1	YES = 2		
Transformer Hollow Core Bushing								YES = 1 Deformed on storage = 1
Composite Arresters	YES = 2 Flaking (Joslyn) = 1 Tracking = 1	YES = 1 Terminal cap = 1			YES = 1			YES = 2 Water ingress = 1 Deformed on storage = 1

RTV Coatings	YES = 5 Peeling = 1 Loss of Hydrophobocity = 1			YES = 2 Coastal = 1				
Other								YES = 1 Mildew =1

13. Identify those **field diagnostic techniques** that you have tried with respect to each transmission substation polymer-based product by grading their effectiveness for every polymer-based product. **<u>NOTE:</u>** (Answer ALL that apply using the following legend: **1** Very Effective, **2** Effective, **3** Average, **4** Below Average, **5** Ineffective, **N/A** Not Attempted)

No diagnostic analysis or techniques conducted OR No utility replies = 12

Diagnostic Technique	Suspension Insulator	Station Post Solid Core Insulator	Station Post Hollow Core Insulator	Circuit Breaker Hollow Core Bushing	Transformer Hollow Core Bushing	Composite Arresters	RTV Coatings	Other
Visual Inspections	1 = 1 2 = 4 3 = 6 4 = 1 5 = 1	1 = 2 = 3 3 = 1 4 = 5 =		1 = 2 = 4 3 = 2 4 = 3 5 =	1 = 2 = 3 3 = 2 4 = 5 =	1 = 1 2 = 5 3 = 6 4 = 3 5 = 2	1 = 1 2 = 6 3 = 2 4 = 5 =	CVT = 2 GIS = 2
Temperature Profile (IR)	1 = 2 2 = 3 = 2 4 = 2 5 = 5			1 = 1 2 = 1 3 = 1 4 = 1 5 =	1 = 1 2 = 1 3 = 1 4 = 5 =	1 = 1 2 = 4 3 = 5 4 = 2 5 = 1	1 = 2 = 3 = 2 4 = 5 = 1	GIS = 3
Daytime UV Light Amplification	1 = 1 2 = 3 = 4 = 5 = 2					1 = 2 = 3 = 1 4 = 5 =		
E-field Measurement	1 = 2 = 1 3 = 4 = 5 =							

Parabolic Dish (Acoustic Emission)	1 = 1 2 = 3 = 4 = 1 5 = 1	1 = 2 = 1 3 = 4 = 5 =				1 = 2 = 1 3 = 4 = 5 =		
Portable X-ray								
HVAC Resistance	1 = 2 = 1 3 = 4 = 5 =	1 = 2 = 1 3 = 4 = 5 =		1 = 2 = 1 3 = 4 = 5 =	1 = 2 = 1 3 = 4 = 5 =	1 = 1 2 = 1 3 = 4 = 5 =	1 = 2 = 1 3 = 4 = 5 =	CVT = 2
Vibrational Frequency Response	1 = 2 = 3 = 4 = 5 = 1							
Inspection Cycle (years)	1 yr. = 3 2 yr. = 1 7 yr. = 1	Monthly = 1 (Visual) 7 yr. = 1		Monthly = 1 (Visual) 0.5 yr. = 1 3 yr. = 1 4 r. = 1	Monthly = 1 (Visual) 0.5 yr. = 1 4 r. = 1	Monthly = 1 (Visual) 0.5 yr. = 2 1 yr. = 2 5 yr. = 1 7 r. = 1 Doble Test (4 yr) = 1	0.5 yr. = 1 1 yr. = 1 3 yr. = 1	GIS (0.5 yr.) = 1
Other				Doble Test (3 yr) = 1	Power factor = 1			

Describe any successes for diagnostic techniques applied: **NO REPLIES**

14. What is your **expected service lifetime** for polymer-based transmission substation products in your service environment? (Answer ALL that apply)

No utility replies = 6

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Expected Service Lifetime (Years)	No expectations = 1 Same as porcelain = 1 15 yr. = 1 20 – 40 yr. = 1 25 yr. = 3 30 yr. = 5 40 yr. = 1 50 yr. = 4 60 yr. = 1	25 yr. = 1 20 – 40 yr. = 1 30 yr. = 5 40 yr. = 1		20 – 40 yr. = 1 30 yr. = 5 >40 yr. = 1 50 yr. = 3 >30 yr. = 3	20 – 40 yr. = 1 25 yr. = 1 30 yr. = 3 >40 yr. = 1 >30 yr. = 2	Same as porcelain =1 15 yr. = 1 20 yr. = 1 20 – 40 yr. = 1 25 yr. = 3 30 yr. = 1 >30 yr. = 5 40 yr. = 2 50 yr. = 2 60 yr. = 1	5 yr. = 1 7-10 yr. = 2 10 yr. = 2 15 yr. = 3 20 yr. = 1 10 –20 yr. = 1 30 yr. = 1	20 – 40 yr (CVT) = 1 20 –25 yr. (GIS) = 1

15. Identify and elaborate where applicable on your utility's **criteria for removal / replacement** for each transmission substation polymer-based product. (Answer ALL that apply).

No utility replies = 12

	Suspension Insulator	Station Post Solid Core Insulator	Station Post Hollow Core Insulator	Circuit Breaker Hollow Core Bushing	Transformer Hollow Core Bushing	Composite Arresters	RTV Coatings	Other
Surface Aging	YES = 5	YES = 2		YES = 3	YES = 1	YES = 6	YES = 5 Loss of hydrophobicity = 2 Flaking = 2	CVT = 1
Surface Damage	YES = 10	YES = 2		YES = 5	YES = 4	YES = 7	YES = 6	CVT = 1 GIS = 1
Poor Flashover Performance	YES = 7	YES = 1		YES = 3	YES = 3	YES = 5	YES = 5	CVT = 1 GIS = 1
Mechanical Failures	YES = 13	YES = 2		YES = 5	YES = 4	YES = 11	YES = 4 Peeling off = 3	CVT = 1 GIS = 1
High Failure Rate	YES = 10 LAPP = 1	YES = 2		YES = 4	YES = 2	YES = 8	YES = 5	CVT = 1 GIS = 1
Others	YES = 1 Excessive corona = 1			Poor Doble results = 1 High Power Factor = 1	Poor Doble results = 1	Fail to operate = 1 Arrester fail = 1		

16. Identify the **washing or cleaning techniques** used too date and elaborate where applicable for each transmission substation polymer-based product. (Answer ALL that apply)

	Suspension Insulator	Station Post Solid Core Insulator	Station Post Hollow Core Insulator	Circuit Breaker Hollow Core Bushing	Transformer Hollow Core Bushing	Composite Arresters	RTV Coatings	Other
Pressurized Water (energized or de-energized)	YES = 7 De-energized = 1 Energized = 0	YES = 2 De-energized = 1 Energized = 0		YES = 3 De-energized = 0 Energized = 0	YES = 2 De-energized = 1 Energized = 0	YES = 3 De-energized = 0 Energized = 0	YES = 6 De-energized = 1 Energized = 0	CVT = 1
Hand Washing or Wiping (Water or chemicals)	YES = 1 Chemical = 1 Water = 0			YES = 3 Chemical = 0 Water = 0 Soap = 3	YES = 1 Chemical = 0 Water = 0	YES = 1 Chemical = 1 Water = 0	YES = 4 Chemical = 0 Water = 0	CVT = 1 (Soap)
Abrasive (energized or de-energized)	YES = 1 De-energized = 1 Energized = 0	YES = 1 De-energized = 1 Energized = 0			YES = 1 De-energized = 1 Energized = 0		YES = 2 De-energized = 0 Energized = 0 Silica = 1	
Other: **Self-cleaning**						Yes = 1		

17. In your opinion, is further R&D needed on polymeric / composite components for substations? Yes **= 24** No **= 8** No utility replies = **3**

If **yes**, identify any areas that you believe require further **investigations or R&D** to improve the performance / use of polymer-based substation products.
<u>NOTE:</u> (Prioritize R&D suggestions in brackets: **1** Very High, **2** High, **3** Average, **4** Low, **5** Very Low)

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Ideas for Future R&D Investigations (Assigned Priority)	1 = 1 2 = 3 3 = 2 4 = 4 5 = 1	1 = 4 2 = 5 3 = 4 4 = 5 =	1 = 3 2 = 7 3 = 3 4 = 5 =	1 = 2 2 = 7 3 = 6 4 = 1 5 =	1 = 2 2 = 9 3 = 1 4 = 5 = 1	1 = 1 2 = 4 3 = 5 4 = 1 5 = 1	1 = 2 = 5 3 = 3 4 = 2 5 = 2	1 = 2 = GIS & CVT 3 = CVT 4 = 5 =

Number of utilities that indicated YES to this question but did not complete the above table = **5**

4
APPENDIX - UTILITY QUESTIONNAIRE

EPRI Utility Survey Regarding Usage & Experience with Polymer / Composite Products & Equipment in Transmission Class (69 – 765 kV Class) Substations

On behalf of EPRI (www.epri.com), it would be appreciated if you could complete this survey. The purpose of this questionnaire is to collect information from North American utility's regarding their usage and experience with respect to Polymer / Composite based products used in Transmission Class Substations (S*uspension* ***Insulators, Solid Core Station Post Insulators; Hollow Core Station Post Insulators; Circuit Breaker and Transformer Hollow Core Bushings; Arrestors; and RTV Coatings)***. The general results of the questionnaire / survey will be shared with **ONLY** those utilities that have completed this survey. The names of the utilities will be kept CONFIDENTIAL. Please answer all questions that are applicable to your utility's experiences. We would very much appreciate your response before **Friday, 16 August 2004**.

Please reply to: Erich Gnandt, P.Eng.
IEEE & CIGRE Member, T&D High Voltage Consulting, Vancouver, BC, Canada
EGnandt@IEEE.ORG ; Office Tel: 604-535-6936 (PST) ; Office Fax: 604-538-4540

Utility: ________________________________ Contact Person: ________________________________
Tel / Fax: ______________________________ E-mail:
____
Address:
____

1. Identify your typical **environmental** and **climatic conditions** where Transmission class Polymer / Composite based substation product and apparatus are installed.
   Annual temperature range _______°C _______ °F
   Annual Precipitation rate _______ mm/year _______ inches/year
   Type of climate Arctic ☐ Temperate ☐ Sub-tropical ☐ Tropical ☐
   Other information: ____

2. Identify your **polluted service environment** if applicable. (Answer ALL that apply)
   Industrial: Chemical ☐ Cement ☐ Mining ☐
   Agricultural: Fertilizers ☐ Pesticides ☐
   Coastal ☐
   Moss or Algae ☐
   Road Salt ☐
   Other: ________________________________-
   ____

3. Identify the different transmission **voltage classes** for your substations. (Answer ALL that apply)
   69 kV ☐ 115 / 138 kV ☐ 161 kV ☐ 230 kV ☐
   345 kV ☐ 500 kV ☐ 765 kV ☐ Other:
   ____

4. Did you purchase the transmission class Polymer / Composite based substation product and apparatus to a **Purchase Standard** or **Specification**? Yes ☐ No ☐

If **yes**, please identify the standard or purchase specification: ____

If an internal or supplier specification was used, can you share this? Yes ☐ No ☐ **If yes, please fax.**

5. Did your company perform any **laboratory evaluation** or **performance based testing** before purchasing transmission class Polymer / Composite based substation product and apparatus? Yes ☐ No ☐

If **yes**, answer ALL that apply.

Electric Field Analysis ☐ Electrical Performance & Aging Testing ☐

Mechanical Testing ☐ Seismic Testing ☐

Other ☐ Describe testing conducted: ____

____

If **yes**, can you share the results? Yes ☐ No ☐ **If yes, please fax.**

6. Did your company perform any **field evaluation testing** or **trials** before purchasing the transmission class Polymer / Composite based substation product and apparatus?

Yes ☐ No ☐

If **yes**, describe testing conducted and results: ____

____

If **yes**, can you share the detailed results? Yes ☐ No ☐ **If yes, please fax.**

7. Identify the **polymer / composite based products and apparatus** used in your transmission substations and answer the questions on the left hand margin. (Answer ALL that apply)

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Widespread Use (Yes / No)								
Brand Names and Voltage Classes (kV)								
Years Installed								
Type of Field Problems								
Common Mode of Failure								
Common Reason for Failure								
Annual Failure Rate (# / Year)								

Most Problematic Brands								

8. Identify your **reasons** for **using** of transmission class Polymer / Composite based substation product and apparatus
over traditional ones. (Answer ALL that apply)

Cost Effective ☐ Improved Seismic / Earthquake Performance ☐
Expect Less Installation Problems ☐ Expected Improved Pollution performance ☐
Availability / Timely Delivery ☐ Expected Less Flashovers / Outages ☐
Expected Longer Service Life ☐ Less Damage to Other Equipment during Failure ☐
Personnel Safety ☐ Expected Less Maintenance ☐
Other ☐ ____

9. Identify your **reasons** for **NOT using** transmission class Polymer / Composite based substation product and apparatus.
(Answer ALL that apply)

Aging & Reduced Life Expectancy ☐ Past Problems with Other Polymer Products ☐
Lack of Product Standardization ☐ Lack of Inspection & Diagnostic Techniques ☐
Live Working Concerns ☐ Inability to Assess Condition of Equipment ☐
Lack of Experience with Polymers ☐ Higher Cost ☐
Other ☐ ____

10. Identify how your utility selects **electric field stress relief** and/or **corona rings** for substation polymer / composite **suspension and post insulators, and bushings**. (Answer ALL that apply)

Calculations / Modeling ☐ Use Corona Rings from Transmission Lines ☐
Use Manufacturer's Guidelines ☐ Use Corona Rings from Substations ☐
Undertake Testing and/or R&D ☐ Other ☐ ____________________

11. Does your utility use any **unique configurations** for suspension composite insulators in substations? Yes ☐ No ☐

If **yes**, can you provide a diagram / photo in the box below or separately by e-mail or fax?

12. Identify the **specific problems** with transmission class Polymer / Composite based substation product and apparatus that your utility has experienced to date. (Answer ALL that apply with **X** and where possible write a 1 – 3 word description for clarification; Example: Surface Damage = tracking & burning)

	Surface Aging or Deterioration or Damage	**Exposure of Fiberglass Core**	**Frequent Outages**	**Pollution Induced Flashovers**	**Mechanical Degradation or Failure**	**Damage During Installation**	**Excessive Corona (Audible Noise, RN & TVI)**	**Other Types of Specific Problems**
Suspension Insulator								
Station Post Solid Core Insulator								
Station Post Hollow Core Insulator								
Circuit Breaker Hollow Core Bushing								
Transformer Hollow Core Bushing								
Composite Arresters								
RTV Coatings								
Other								

13. Identify those **field diagnostic techniques** that you have tried with respect to each transmission class Polymer / Composite based substation product and apparatus by grading their effectiveness for every Polymer / Composite based product and apparatus. **NOTE:** (Answer ALL that apply using the following legend: **1** Very Effective, **2** Effective, **3** Average, **4** Below Average, **5** Ineffective, **N/A** Not Attempted)

Diagnostic Technique	Suspension Insulator	Station Post Solid Core Insulator	Station Post Hollow Core Insulator	Circuit Breaker Hollow Core Bushing	Transformer Hollow Core Bushing	Composite Arresters	RTV Coatings	Other
Visual Inspections								
Temperature Profile (IR)								
Daytime UV Light Amplification								
E-field Measurement								
Parabolic Dish (Acoustic Emission)								
Portable X-ray								
HVAC Resistance								

Vibrational Frequency Response								
Inspection Cycle (years)								
Other								

Describe any successes for diagnostic techniques applied: ____

____-

____

14. What is your **expected service lifetime** for transmission class Polymer / Composite based substation product and apparatus in your service environment? (Answer ALL that apply)

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**O th er**
Expected Service Lifetime (Years)								

15. Identify and elaborate where applicable on your utility's **criteria for removal / replacement** for each transmission class Polymer / Composite based substation product and apparatus. (Answer ALL that apply).

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Surface Aging								
Surface Damage								
Poor Flashover Performance								
Mechanical Failures								
High Failure Rate								
Others								

16. Identify the **washing or cleaning techniques** used too date and elaborate where applicable for each transmission class Polymer / Composite based substation product and apparatus. (Answer ALL that apply)

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Pressurized Water (energized or de-energized)								
Hand Washing or Wiping (Water or chemicals)								
Abrasive (energized or de-energized)								
Other								

17. In your opinion, is further R&D needed on transmission class Polymer / Composite based substation product and apparatus? Yes ☐ No ☐

If **yes**, identify any areas that you believe require further **investigations or R&D** to improve the performance / use of polymer-based substation products.
NOTE: (Prioritize R&D suggestions in brackets: **1** Very High, **2** High, **3** Average, **4** Low, **5** Very Low)

	Suspension Insulator	**Station Post Solid Core Insulator**	**Station Post Hollow Core Insulator**	**Circuit Breaker Hollow Core Bushing**	**Transformer Hollow Core Bushing**	**Composite Arresters**	**RTV Coatings**	**Other**
Ideas for Future R&D Investigations (Assigned Priority)								

Please reply to:
Erich Gnandt, Tel: 604-535-6936 (PST) ; Fax: 604-538-4540 ; E-mail: egnandt@ieee.org
Note: If you have any questions regarding research that EPRI is investigating regarding the performance of polymers/composites in overhead transmission lines or substations please contact: Dr. Andrew Phillips, Tel: 704-717-6438 ; E-mail: aphillip@epri.com

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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