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Evaluation of field returned insulators from US Grid through laboratory testing

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Context

The age of the transmission grid in the United States requires an increased focus on the condition of old insulators and many utilities have started testing some of their oldest lines in order to forecast and plan for refurbishment and capex expenditure.

Evaluating the condition of such assets can be done from different angles and CIGRE TB306 shows a statistical approach based mostly on mechanical performance of insulators removed from service. Additionally, flashover, M&E, thermo mechanical and steep front wave evaluations will also provide valuable information and an increased number of utilities are looking at laboratories offering the full scope of ANSI, IEC or CSA test programs for these investigations.

Sediver has established in the USA an assembly factory for glass insulators in 2017 but also, and perhaps more interesting for some engineers, a laboratory capable of performing all the tests required by the world's standards. Large test campaigns have already been conducted in this laboratory for numerous north american utilities from East Coast to West Coast and some of the work is reported in this paper.

1. <u>Meaningful test program</u>

Quantities of units tested clearly help in establishing a statistical diagnostic of the condition of the insulators but often utilities are not in a capacity to dismantle large sections of a line for this work. Therefore, the most pertinent test program should be designed with a customized approach to best fit the environment or the type and age of the samples as well as the application.

Dealing mostly with old porcelain, one may be wondering if it is more beneficial to test the insulators as per the standard which was in place when they were manufactured or if it is wiser to test as per the current version of the standards. A perfect example is the dielectric strength test, which under ANSI is the classical oil puncture test. Today modern versions of standards in IEC and CSA are calling for a steep front wave test which simulates with more consistency a transient overvoltage in air, rather than testing an insulator in oil knowing that the oil characteristics can strongly influence reliable results. Table 1 and Figure 1 show the difference of performance between both tests performed on either glass or porcelain insulators.

Porcelain supplier	A	B	C
Oil puncture test FAILURE rate	0	0	0
Steep front wave FAILURE rate	29%	32%	0%

Glass supplier	A	B	C	D
Oil puncture test FAILURE rate	0	0	0	0
Steep front wave FAILURE rate	25%	12%	20%	0%

Table 1: comparison of oil puncture tests and steep front wave tests on the same insulators (glass and porcelain) from various manufacturers

Figure 1: typical arrangement of steep front wave test with impulse generator and air gap. (Sediver West Memphis laboratory)

The same question stands for the mechanical tests either M&E or thermo mechanical procedures. The most recent versions of the standards are calling for 3 or 4 standard deviations. Should old insulators be measured against standards for which they were not designed? While we have to agree with some who would argue that what was done in the past survived quite well, operating conditions and reliability expectations have changed. Today most service interruptions which were acceptable in the past are no longer tolerated and subsequently when evaluating an old line, the question is less about knowing how they compared to their initial performances but much more to evaluate risks and potential threats. Under this approach, the current test practices should be considered as the only acceptable method, with a detailed examination of the results and their meaning. As an illustration, Figure 2 and Table 2 show M&E test results from insulators which had been in service for approximately 40 years on a 500KV line in the West of the USA.

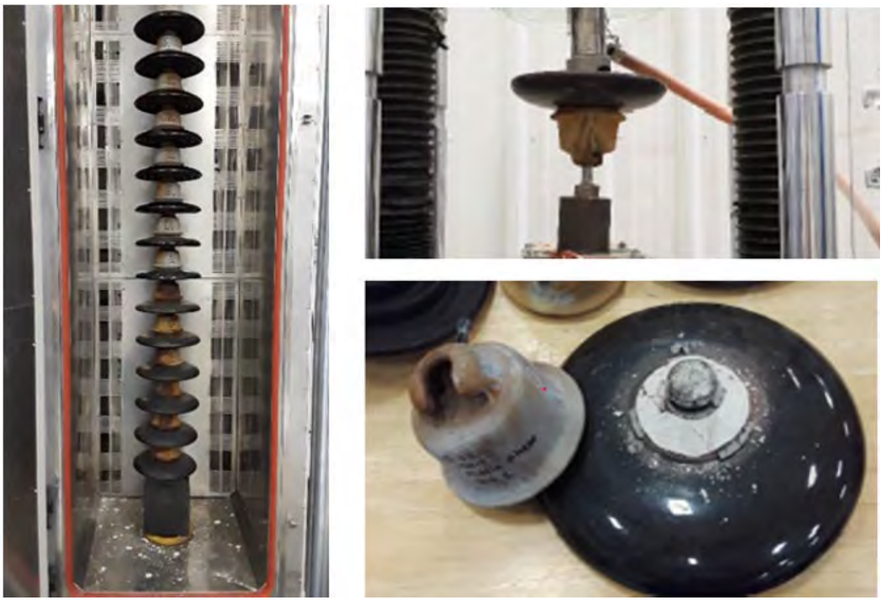
Insulator type/rating (kips)	**30**	**50**
Average M&E (kips)	27	44
Standard deviation (kips)	6	8
Average - 3s	9	20

Figure and table 2: Mechanical results and standard deviations of 40 year old porcelain discs removed for testing from a 500KV line. The results do not show very low average values but huge variations and large standard deviations. The dispersion of the results was enough to consider that these units should be replaced rapidly.

2. <u>**Mechanical and thermo mechanical tests**</u>

These tests are the most commonly used, either in the type test sequence of new insulators or in the investigation performed on old units. Between these two tests, the thermo mechanical goes beyond establishing the condition of insulators since it uses a 96 hour pre-stress sequence of hot and cold variations to stimulate potential flaws and weaknesses. The example below from a US utility which sent units to our laboratory are quite interesting in this regard. The units are old (1920), rated 11kips and still in operation. The M&E testing shows still good results as described in Figure 3 but the thermo mechanical shows clear evidence of the ageing as shown in figure 4.

<u>Figure 3</u>: M&E test results on old porcelain from 1920 still passing the rated value; Average strength is at 13.4 kips with a standard deviation of 800 lbs. With 3 standard deviations the insulators are still good. The reason is mostly because of stable climatic conditions and an early 20th century over-designed product compared to the actual application.



<u>Figure 4</u>: the M&E (right) of the same batch of insulators fails after a thermo mechanical test (left) as per ANSI 29 2B. Average failing load is at 10 kips (for a 11kips rating) with a standard deviation of 1500 lbs.

3. <u>**Case study on aged units from storage & in-service**</u>

An interesting situation arose from insulators of the same vintage and manufacturer which came from both warehouse storage (never installed) and from decades of service. The utility was wondering what to do about these 1971/1972 units and significant results came from the laboratory. For the stored insulators, 42% of the units tested in M&E failed with some values as low as 60% of their rating. Under steep front wave test conditions (figure 5), 90% of the 36kip model failed and 50% of the 25kip model failed. For the insulators removed from service, the M&E test result were almost identical to the stored units and less than 5% passed steep front wave testing.

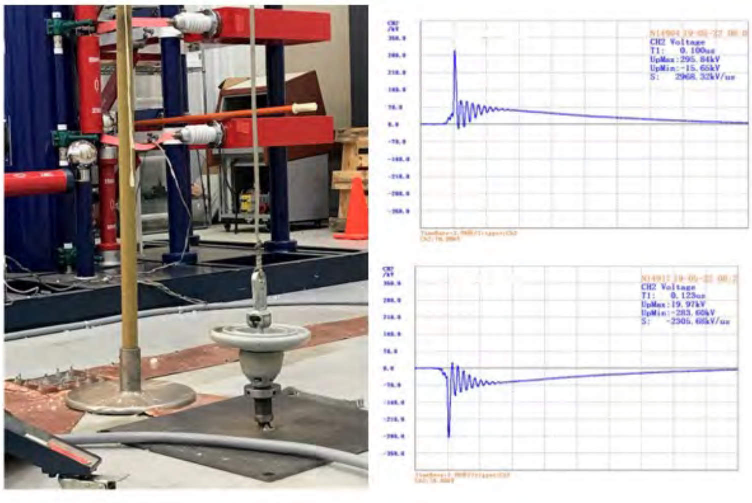


Figure 5: Steep front wave test on porcelain units taken from stock

These insulators were made by a major US manufacturer approximately 45 years ago and there are millions of such units still in service, not to mention the countless number of insulators still in various warehouses throughout the country. What this study has pointed out is the risk to install insulators today which are apparently new (meaning not used) but no longer capable of meeting current requirements. One may wonder what is the real stock asset value? Perhaps the best way to answer this question is producing detailed test programs to help make such assessments.

4. Case study of catastrophic situation

It should be mentioned that prior to any test on porcelain insulators, the integrity of the dielectric is checked through a power frequency flashover test (figure 6). The following case describes a situation where more than 200 units rated 20 kips were received from a utility on the East Coast and tested. None of these units were found to be punctured when they arrived at the Sediver laboratory in West Memphis.

Figure 6: Power frequency verification prior to implementation of an investigation program

While the M&E test was already showing values below rating, the decision was made to also go through a thermo mechanical 96 hour test as per ANSI C29 2B. The M&E results (table 7) show that values were relatively in line with expectations from old porcelain insulators with a standard deviation close to 4000 lbs. However during the second test, a string separation occurred after 12 hours at 60% of the rating (figure 7) with a collateral damage on the parallel string tested simultaneously.

Breakage value (lbs)		Type of breakage
Electrical	Mechanical	
--	25,471	Porcelain Head Breakage
17,535	22,414	Porcelain Head Breakage
24,302	26,550	Porcelain Head Breakage
20,458	21,694	Porcelain Head Breakage
--	31,811	Pin Break
24,302	24,931	Porcelain Head Breakage
--	29,180	Porcelain Head Breakage
22,256	29,765	Porcelain Head Breakage
20,907	21,312	Porcelain Head Breakage
22,706	23,178	Porcelain Head Breakage
19,446	20,323	Porcelain Head Breakage
19,221	19,873	Porcelain Head Breakage
11,937	15,422	Porcelain Head Breakage
17,063	17,063	Porcelain Head Breakage
14,388	15,917	Porcelain Head Breakage
21,357	22,661	Porcelain Head Breakage
--	18,210	Porcelain Head Breakage
16,411	17,580	Porcelain Head Breakage
15,062	18,097	Porcelain Head Breakage
15,962	24,707	Porcelain Head Breakage
--	18,592	Porcelain Head Breakage
--	24,392	Porcelain Head Breakage
--	27,539	Pin Break
16,636	20,008	Porcelain Head Breakage

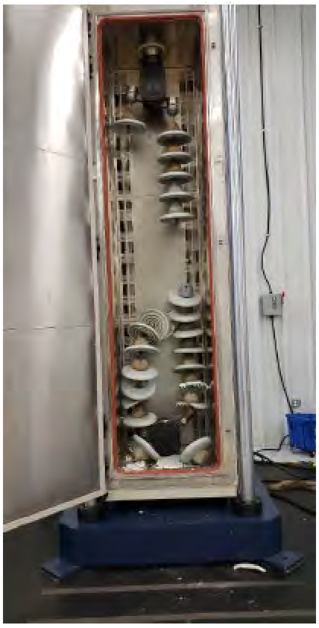


Table and Figure 7: M&E test on a batch showing values below rating and catastrophic failure in TM (right) after 12 hours at 60% of the rating.

This combination of results urged the utility to plan for a refurbishment of the line. It can be noted also that the M&E test shows first an electrical puncture while the mechanical failure occurs at higher loads. The fact that the thermo mechanical test shows a separation at an early stage of the test indicates that these units, while not yet punctured, are nevertheless close to their end of life.

5. Bringing tools to the market

There are very important conversations in the US market and abroad about strengthening specifications and standards to prevent low quality products from being used on transmission lines. Reliability and resiliency have become key words used among asset managers and line engineering ahead of, more and more, pure procurement cost. To this effect ANSI is currently revising ANSI C29-2B to be reinforced. The same process is engaged in IEC. We are reaching the point today where utilities recognize again that insulators are one of the most critical components of the line, and therefore need to be properly evaluated.

Beyond this evolution, we see a growing need for utilities to have access to laboratories having the full set of testing equipment required to produce such tests on old insulators.
Sediver offers this service in its West Memphis facility, which has capabilities to perform all the tests described in ANSI, IEC and CSA. Besides having access to the test equipment and results, utilities can draw upon Sediver's unique expertise in the evaluation of the results, helping making sense out of the raw data collected from these test campaigns.