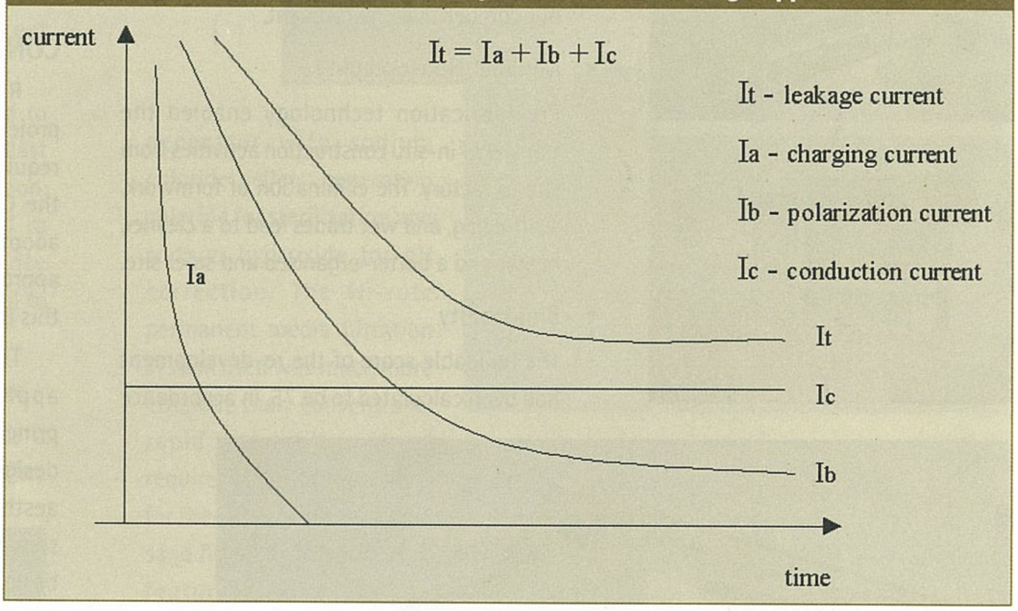
THE DANGERS OF DC HIGH VOLTAGE TEST FOR XLPE CABLES AT SITE

DC high voltage testing of XLPE cables at site has been used because the DC test equipment is small compared to AC test equipment.

At AC power frequency, a cable is a large lumped capacitor, in the order of 300 pF/meter. A 500 meter length of 66 kV cable to be tested at 100 kV AC power frequency will require a capacitive current of 4.7 ampere. The AC tests set will be rated at 470 kVA. Not only is the test set large in size and costly, the demand on the site distribution system will be high. Assuming a single phase 400 volts system, the input current to the test set will be 1175 amperes. A resonant test set could be used and would reduce input power requirements but the systems is almost as large as conventional AC sets, it is heavy and expensive. Hence high voltage AC power frequency test for cable at site is not practical.

However, there are dangers and limitations of high voltage DC test on XLPE cables. High levels of DC Voltage Test on XPLE cables will lead to the unnecessary overstress of localized area of the insulation, and this will decrease the insulation life of the cable, or even lead to failure of the cable insulation. There has been cases of insulation failure of XLPE cables when they were put to operations shortly after successfully tested with high voltage DC.

Figure 1 : Leakage Current Components from DC Voltage Application



BEHAVIOUR OF CABLE UNDER DC TEST

The behaviour of the XLPE cable under the application of DC high voltage and AC high voltage is fundamentally very different.

When DC high voltage is applied to a XLPE cable, the leakage current from the test set will decrease from an initial high value and decay to a fixed value, typically about 15 minutes. **Figure 1** is an illustration. The leakage current is divided into three components; the charging current, polarization current and the conduction current.

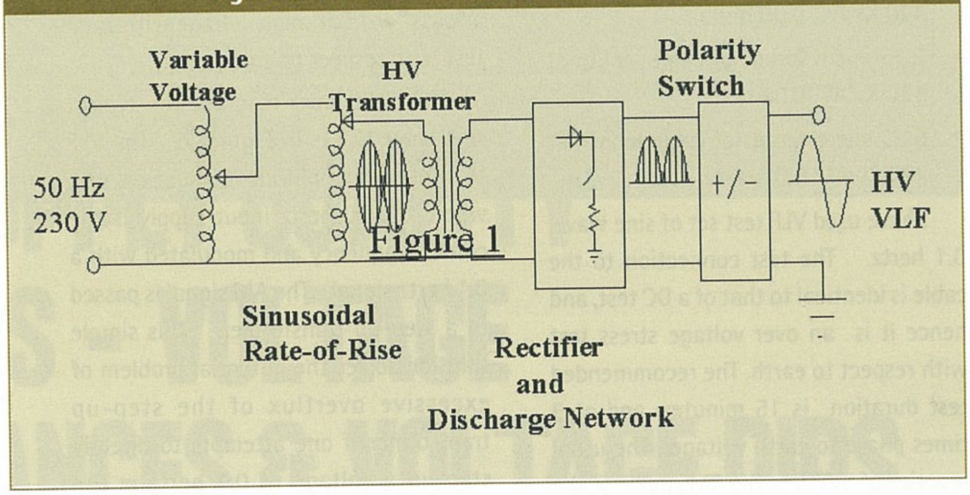
The charging current component is required to charge up the capacitance of the cable, and the value decreases very quickly with time. The measurement of the charging current component is not important to the test except that it distorts the leakage current. The longer the cable length, the larger the charging current and the longer the time for the charging current to recede.

The polarization current component is caused by the polarization and accumulation of electric charges at the XLPE under application of DC voltage. The polarization current is small and will rapidly decrease with time

The leakage current that we are most concerned with will be the conduction current component. The other two components simply serve to mask the true reading of the leakage current. The conduction current component is dependent on the applied DC voltage, the insulation resistance of the XLPE and any other resistance in the test circuit.

When an AC high voltage test is applied to a cable, an AC current flows due to the capacitance of the cable. This current is a function of the applied AC voltage, frequency of the voltage and the capacitance of the cable. This current will be constant as long as the applied voltage is there.

Figure 2 : Functional Schematic of the VLF System



PROBLEMS WITH HIGH VOLTAGE DC TEST ON XLPE CABLES

It must be remembered that the application of high voltage DC on a cable will result in a stress distribution very different from the AC service condition. The application of high voltage DC will create space charges within the XLPE insulation, which will remain for a very long time in the XLPE insulation. When the cable is put to AC service condition, the space charges will cause very high levels of localized electrical stress, and will decrease the life of the XLPE insulation.

The typical DC test voltage is about 2 to 3 times the AC breakdown voltage, and such high DC voltage are necessary in order to detect defects within the XLPE insulation. However, the use of such high level of DC voltage will cause localized overstress of the XLPE insulation, and decrease the insulation life of the cables. Old cables may breakdown after a DC high voltage test, when in fact the cable is quite adequate for the intended AC service.

Conversely, it has also been observed that DC test may be ineffective in detecting a serious defect in the cable. For a cable with a defect in the insulation , the DC breakdown voltage is very much higher than the AC breakdown voltage. Most site acceptance test are done at reduced level of DC test voltage as compared to the factory. As such , a DC withstand test at site will pass a cable with defect because the voltage level is not high enough.

For DC test to be effective in detecting defects, the DC voltage level must be high. This use of high level of DC voltage will cause unnecessary overstress of localized area of the insulation.

Hence it is clear that DC test of XLPE cable at site has its dangers and limitations.

AC VLF , VERY LOW FREQUENCY , TESTING AS AN ALTERNATIVE

If the cable is meant for service at AC power frequency, then the most representative test will also be an AC over voltage test at power frequency. However , we have seen that the test set will be very large, and the input power requirements will also be very large.

It is still possible to test at AC power frequency with the series resonant test set. The cable under test will be the capacitance in the resonant circuit. The series resonant test has a high voltage variable reactor whose inductive reactance is adjusted until equal to the capacitive reactance of the cable under test. The series resonant test set will solve the problem of the large input power requirements for a power frequency AC high voltage test. Typically a 230 volts single phase source is all that is needed. However, the size of the reactor will still be large , and this makes site testing using series resonant test set not practical.

However, if the frequency of the AC test voltage is say 0.1 hertz, the KVA size of the test set will be reduced by 500 times as compared to a AC test at 50 hertz. The technology of AC VLF testing has been around a long time for testing of large generators.

VLF testing uses AC signals at frequencies less than one Hertz. In North America, it is very common to have VLF for field testing of service aged and new cables using 0.1 Hertz, sine wave. Other commercially available VLF test sets have frequencies at 0.05 hertz, 0.02 hertz and 0.01 hertz. These frequencies are useful for testing of very long length of cables where the reactive load of the cable system exceeds rating of the test set at 0.1 hertz. Studies have shown that VLF test will produce the same dielectric stress as power frequency test at the same voltage. IEEE is in the process of drafting a guideline for the field testing of cables using VLF.

A USA vendor has a 120 kV peak AC , sine wave VLF test set. The VLF frequencies are selectable at 0.1 hertz, 0.05 hertz , 0.02 hertz and 0.01 hertz.

The capacity of the test set is:

- 0.55 micro farads of cable length at 120 Kv AC, 0.1 hertz.

- 1.10 micro farads of cable length at 120 Kv AC, 0.05 hertz.
- 2.75 micro farads of cable length at 120 Kv AC, 0.02 hertz.
- 5.50 micro farads of cable length at 120 Kv AC, 0.01 hertz.

I have used VLF test set of sine wave, 0.1 hertz. The test connection to the cable is identical to that of a DC test, and hence it is an over voltage stress test with respect to earth. The recommended test duration is 15 minutes, and at 3 times phase to earth voltage. The usual practice of trending the RMS value of the leakage current is not meaningful at VLF because the low frequency will not render any meaningful reading in RMS. Any attempt to measure the leakage current at VLF will give a slowly increasing and decreasing ampere value, mirroring the sine waveform at 0.1 hertz or 10 seconds per period of the sine wave. Hence VLF is a "pass" or " fail" high voltage withstand test with respect to earth.

The basic block diagram of a typical sine wave VLF is in **Figure 2**. The VLF test set uses amplitude modulation, AM, where the 50 hertz input supply is the carrier frequency and modulated with a 0.1 hertz signal. The AM signal is passed to a step-up transformer. This simple solution solves the potential problem of excessive overflux of the step-up transformer if one attempts to directly step-up a voltage of 0.1 hertz. The required 0.1 hertz sine wave is extracted from the AM demodulator.

CONCLUDING REMARK

The use of high voltage DC test for site testing of cables have their dangers and limitation. VLF testing has the following advantages.

- Will not inject harmful space charges into the XLPE insulation. This will eliminate the problems of localized overstress of the XLPE insulation.
- Will detect a defect in the insulation at a much lower voltage than a DC high voltage test.
- Will not cause high voltage transient from a cable failure during a VLF test.
- The size of the VLF tests set is comparable to a DC test set, and hence makes it suitable for site testing of cables.

The VLF technology has immense potential to replace the use of DC voltage for site testing of cables.

Reference

- *Power and communication cables by R. Bartnikas - IEEE Press series on Power Engineering.*

The above information was provided by Lee Wai Meng, J.M. Pang & Seah (Pte) Ltd