R&D on Insulation Diagnosis Technology in P, R. China

Z,Yan
Xian Jiaotong University
No. 28,Wcst Xianmng Road,710049, Xian, China

1. Introduction

Since 1949, the power industry has been developed rapidly in china, the historical development of energy generation and installed capacity is shown in Tab.l[1]

Table 1. Increase of Power

Year	Installed Capacity(GW)	Electricity Generation(TWH)
1949	1.85	4.31
1957	4.64	19.3
1966	17.0	82.5
1978	57.1	256
1987	101	496
1995	217	1007

Although there is the big growth rate, in order to satisfy the rapid development of industry, many places are still lack of electric power.

As in China, the main energy resources for power generations are stilt the coal and hydropower. But from the geographical point of view, the distribution of these two resources is quite uneven. For instance, most coal reserve is scattered in the North China, while hydropower potential is mainly concentrated in the Southwest, Central and Northwest of China. In order to give full play these resources and supply more power to industrialized areas near the coast, it 35 imperative to expand and interconnect power network by adopting higher voltage AC and DC transmission lines. In 1972, the first 330kV AC line came into operation, and 500kV AC lines were put into operation by 1981, and later the first ±500kV DC link also. In the same time, more and more power plants and substations had been put into operation, and it is very important also how to guarantee the safe operation of installed equipment. Up to now, in many pans of China, the level of operation and maintenance technology is not as high as the developed country, so the insulation diagnosis technology is very interesting to the utilities.

2. Regular Preventive Tests

At the beginning of 1950s, Chinese electrical workers started to introduce the on-site insulation test of power equipment according to the "Regulation of Preventive Tests on Electrical Equipment" (RPTEE), mainly introduced from Soviet Union at that time. The main items of it were measuring the conductor resistance of windings, insulation resistance R, coefficient of absorption $R^{60''}/R^{15''}$, leakage current Ix under HVDC testing voltage, dissipation factor tan , etc., of unenergized equipment every 1-3 years. And a lot of moistened equipment or that with serious defects had been checked out at that years.

With the increase of the capacity of equipment or the rated voltage of it, it was shown that the effectiveness of the mentioned preventive tests will be lower. For instance, using the megohmmeter of 0.5-5kV to measure the insulation resistance R or using the Schering bridge method of 10kV to measure the tan δ of HV insulation will be difficult to detect the void, crack, etc. of the equipment of higher voltage and the larger capacity.

Based on the experience abroad and the

research of local research institutes and universities, many new tests are introduced in many utilities step by step. Some of the new tests or procedures had been accepted to revise the RPTEE of China, and some are still under researching or improving [3].

3. Dissolved Gas Analysis

After popularly used the method of Dissolved Gas Analysis (DGA), a lot of defective power transformers or other equipment of oil-immersed insulation have been checked out, especially with the fault of localized overheating or arcing discharge, so it is very interesting to utilities. As the great role of the DGA has played, so it will cause a big change on the new revision of RPTEE of China.

Up-to-now, the most utilities use the chromaiograph to finish the DGA periodically according the RPTEE of China, for instance each 6 months. If the data will be larger than the "Noticeable Value" as mentioned in Tab.2, the testing period, of course should be shortened. And the increasing rate will be considered also.

Table 2. Noticeable Value of DGA

Equipment	Content	Volume Ratio* 10-6
Transformer	C1+C2	150
or	C2H2	5
Reactor	H2	150
Instrument	CI+C2	100
or	C2H2	3
Transformer	H2	150
	C1+C2	100
Bushing	C2H2	5
	H2	500

In order to finish the DGA on-site, many instruments were developed or still being developed. For instance, some used special semiconductor sensor instead of FID and TCD to measure the quantity of gas contents, so the volume and weight of the chromatograph will be decreased. Some are interesting to detect the H2 or C2H2 only, as it can be finished with a simpler instrument. So several types of portable instrument to detect the H2 content mainly with H2-sensor has been used. Considering the acetylene content is very sensitive to the defect of discharge, some had introduced the method of photoelectric colorimetry, i.e. comparing the incident monochromatic light with the emergent light of a glass tube of chromometer, which consisted with a sort of color solution. It is accurate within the range of 0.5~200*10-6[4]

4. On-site Partial Discharge Monitoring

It was shown, that partial discharge (PD) is one of the main reason causing the aging and defect of the insulation. So it is very necessary to introduce the PD monitoring system on-site or on-line. The former means to measure the PD parameters of unenergized power equipment on site, but the substation is still in operation. The latter means to detect PD parameters of operating equipment, so it is so called on-line monitoring system,

A set of additional corona-free testing HV source, for instance, a car with the mounted M-G set, testing transformer, etc., will be the source for the on-site PD measurement

During the PD measurement on-site or on-line, as the noise level in the substation is very high, for instance, order of 10^ pC, so it is very important to suppress the interference and discriminate PD signal from the interference. So combined the acoustic method with the electrical method as shown in Fig. I, has been used widely in China.[5]

Based on comparing the signals from different branches, the pulse discrimination system as shown in Fig.2 is effective to reduce the pulse interference with

The digital filter technique can play the same role of analog filter. For example, the data acquitted in time domain are transformed by FFT to frequency domain, and the periodic narrow band signals will appear as discrete spectrum lines. After clearing these spectrum lines and

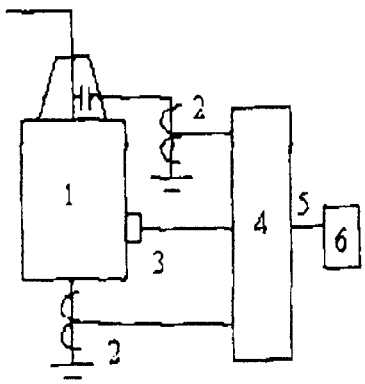

Fig.1 On-line PD monitoring system I-Tested transformer; 3-Current transducers; 3-Acoustic transducers; 4-Data acquisition unit; 5-Optical fiber; 6-Microcomputer

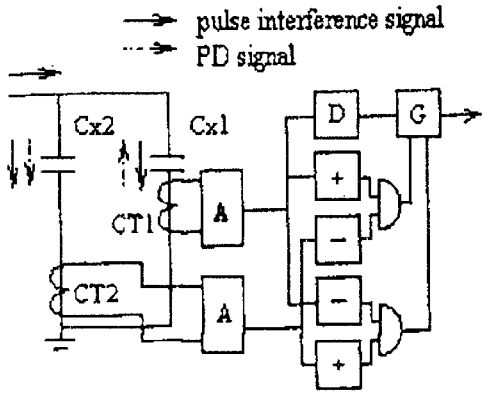

Fig. 2. Diagram of pulse discrimination system
A-Amplifier; + -Pulse positive formation;
Cx-Test sample; —Pulse negative formation;
D-Time delay unit; G - Electronic switch
CT-Current transducer

making inverse transformation IFFT to time domain, the PD pulse signals will be obtained [6].

5. Detection of Transformer Winding Deformation

In China, some insulation faults are caused by the winding deformation, i.e. there will be the change of position due to the large force during the short circuit accident, but it is difficult to detect the deformation from the outside of transformer.

Although the impedance method, frequency response analysis (FRA) and low voltage impulse (LVI) method all can be used for the deformation detection, most utilities are prefer to use the method of ERA and LVI.

During LVI test, a series of stable low voltage impulses, for instance, 0.5/51^ are applied to a terminal of winding and comparing the waveform of the import and the output and calculated the transfer function by FFT, then the winding deformation can be diagnosed. 'An example of it is shown in FigJ. And this method will be helpful for the fault location.

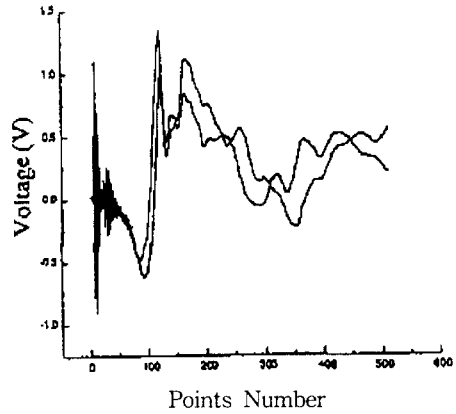

Fig. 3. LVI waveform in time domain of a transformer with fault

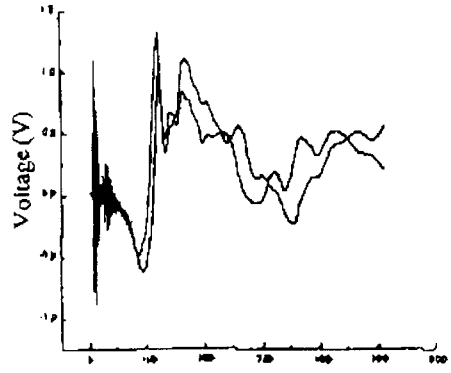

Fig. 4. Frequency response of a 3-phase faulted transformer
— Phase A; - - - - Phase B, ...Phase C

During FRA test, the stable screening voltage is applied to a terminal of winding, and record the amplitude and phase angle at the different terminals. . If there is [he winding deformation, it will be diagnosed according the frequency response characteristics. And a example of it is shown in Fig.4. And the advantage of FRA is its result will be not very sensitive to the circumstance.

The criteria of deformation in detail for FRA and LVA methods and the detection of energized transformer are still under research in China.

6. Testing of XLPE Cable

Due to better characteristics, lower price and easier maintenance of XLPE insulation, more and more XLPE cable has been installed. Using the preventive testing items and standard of the oil-impregnated cable for it had caused many problems. Some XLPE cable had passed the HVDC withstand test but it was breakdown under normal AC working voltage only several hours after passed the DC test.

It was found that is, perhaps, caused by the residual charges, which was formed during the HVDC test. And higher the resistance of the XLPE insulation and larger the length and number of the treeing, bigger the -problem of distortion of AC field due to the residual charges will be.

So some utilities prefer to use the very low frequency test, for instance O.I Hz test, and some utilities are interesting to introduce the on-line monitoring of the XLPE cables, such as the DC' superposition method or DC-component method.

It was shown, using the on-line DC-superposition method, it will be easier to eliminate the interference, especially by changing the polarity of imposed DC source. An example is shown in Tab.3 [2] .

Table 3. An Example of On-line DC-superposition Method

No. of Cable		1#	2#	3#
Shelth Resistance (M)	DC Superposition Method	75	0.1	60
	Megohmmeter	70	0.5	50
XLPE Insulation (103 M)	DC Superposition Method	34.5	55.9	2*103
	Off-line DC Leakage Method	35.7	41.7	103

7. Discussion

Although the residual strength of insulation is the most important for utilities, it cannot be gotten directly from the measured insulation parameters, Synthetical analysis the data both just measured and [hat of the past will be helpful for giving out the conclusion.

Using expert system ES, the synthetical analysis of data will be finished more quickly and effectively. For instance, correct diagnosing the insulation condition of an oil-impregnated equipment must base on all the data measured, i.e. form electrical test, DGA, oil test, etc, and the conclusion of diagnosis will be given out not only based on the data measured but also its changing tendency and the comparison with equipment of other phases. At that time, using ES will be very useful.

Additionally, some universities and research institutes have combined the fuzzy logic, artificial intelligence, etc. with the ES to improve the accuracy of insulation diagnosis. And it will be used more widely in China.

So, in general, with the experience abroad and local, the method of measurement and diagnosis has been developed quickly in China. And sincerely hope there will be more chance for information changing and collaboration with other countries.

Reference

[1] Z.Yan, Recent Progress in the Technology on Insulation Diagnosis in China, Proceedings of 1994 International Joint Conference, Sept,

26-30,1994. Osaka, p.235-242.

[2] Cai Danzhou et al, A Research on Live-line . Diagnostic Methods for Cable in China, ibid., p.351- 354

[3] Ministry of Power, Regulation of Preventive Tests on Electrical Equipment (In Chinese), 1985.

[4] Xue Wilde et al. Monitoring of Oil-Dissolved Gas and Transformer Faults Diagnosis on Site, Proceeding of Joint Conference: 96' AICDEI & 4th-JCCEID, 0ct8-1 1.1996, Xian , p.401-404.

[5] Zhu Deheng et al. On-line Monitoring Partial Discharge in Electrical equipment, ibid., p.329-332.

[6] Wang Changchang, et al, A Digital Filter Technique Used for On-line Monitoring Partial Discharge, 2nd Sino-Japanese Conference on Electric Insulation Diagnosis,

< This paper was also published on Proceedings of 5th ICPADM, pp.45-48, May 25-30, 1997 >