SCECO PRACTICE IN TESTING MOTORS , TRANSFORMER AND CABLES

Abdulaziz AL-Mahasnah
SCECO-East, GPPD

Abduljalil AL-Helal
SCECO-East, GPPD

Abstract:

SCECO-East continuously evaluates and upgrades its procedures with regard to electrical equipment maintenance. In this paper, SCECO practice in testing motors, transformers and cables will be discussed with projection on some failure cases that were detected throughout testing of equipment.

Introduction:

Insulation degradation is usually initiated by electrical or mechanical stress, chemical attack or environment contamination. The rate of insulation deterioration increases with aging of equipment. Thus, equipment must undergo scheduled maintenance to evaluate the condition of the insulation. As the insulation deteriorates leakage current increases and the dielectric loss characteristics changes. SCECO practice in testing motors, transformers and cables is presented in this paper by listing some recommended tests with reference to GPPD, QPPD and PTD.

MOTORS

1. Insulation Resistance Test (Megger)

It is the first test usually conducted on a machine after visual inspection. A DC Voltage of 500-5000 V is applied between the stator winding and ground for one minute. This test will measure the insulation resistance level from the stator winding to ground. A good insulation should have high resistance reading in order of mega ohms and this value should increase with time.

2. Polarization Index Test (PI)

PI is the ratio of ten minute to one minute insulation resistance. It provides a measure of the winding condition. A PI ratio of 2 or higher indicates good winding conditions while values of 1 and less indicated deteriorated winding conditions.

3. High Pot Test

If the machine has a good PI, then it is ready for High Pot test. High Pot investigates and insures the insulation dielectric strength to ground by stressing the insulation with DC or AC voltages several times higher than the rating of the machine for a period of 1- 5 minutes. The recommended DC and AC maintenance test for stator windings are respectively:

[(2 x rated voltage) +1000] x 1.7x 0.65 V DC

[(2 x rated voltage) +1000] x 0.65 V AC

High Pot is useful in locating weaknesses in the insulation. In GPP and DNAGD , High Pot is performed on main generator every major T&I .However, there is a great deal of contravention in applying High Pot especially on old motors since the life of the motor could be reduced as restricted by manufacturer like the case in QPP.

4. Power Factor Test

Power Factor test is an effective non-destructive method, which can reveal the presence of faulty insulation even if it is surrounded by good insulation. This test allows successful ground-insulation tests on machine individual stator phase windings. The power factor is the ratio of the stator insulation loss (Ws) and volt-amperes at a specified test voltage (Va) irrespective of the amount of insulation under test. It is represented by the formula:

$$PF = \frac{Ws}{Va \times Ia}$$

The ac parameters that are considered in the test include total current, dielectric loss, power factor , resistance and capacitance and are measured at normal power system frequency. Degradation of

insulation will produce changes in one of these parameters.

The evaluation of the test data can be interpreted by comparing with previous test results or similar units.

5. Dissipation Factor Test (DF) (Tan Delta)

Tan Delta is a dimensionless number, which is a measure of the dielectric losses in electrical insulation. It serves as a quality control tool for measurement of the losses in the insulation. The primary function of Tan Delta, however, is in the evaluation of corona discharge in HV machines. This test has been implemented in QPP on some motor. Table 1 shows the result of Megger, PI and Dissipation factor for two motors in two successive years. The trend of change of these values is monitored every time the test is performed to evaluate the winding conditions.

Motor	YR	IR GΩ	PI	CAP μF	%DF
BFP 13.8kV	97	6.50 G	4.6	0.4478	0.338
	98			0.4476	0324
CEP 4.16kV	98	10.0 G	4.62	0.34	0.34
	99			0.338	0.35

Table 1: DF test result for two motors at QPP

6. Partial Discharge Test (PD)

PD is a highly advanced and sensitive non-destructive technique for evaluation of the stator insulation. The long term trending of the PD measurements detects gradually developing insulation problems in winding operating only at voltages above 6 kV. The test on 4 kV and below rated motors, however, shows relatively low PD activity even if the insulation is in advanced state of deterioration. The test can be conducted with equipment on-line or off-line. PD test on unit #3 main generator at QPP is planned to be conducted during 1419T&I.

TRANSFORMERS

1. High Pot Test

AC High Pot test is applied to evaluate the condition of the transformer windings. For routine maintenance the test voltage should not exceed 65% of factory test voltage. High Pot is usually conducted in the factory as acceptance test before installation and after each repair. PTD does not apply High Pot as its SMS recommends.

2. Transformer Turn Ratio Test (TTR)

TTR test is performed every six years to confirm transformer nameplate ratio and to test transformer ratio at each load tap changer. TTR help to identify troubles in the transformer winding such as open circuit and short circuits of turn to turn sensitivity. The standard states that test result should be within 0.5% of calculated turn ratio. In GPP High Pot and TTR are not performed on l500/1000 KVA dry type transformer due to the unavailability of the test equipment. Most of these transformers were upgraded either after a flashover failure or by visually detected deterioration of insulation under life extension upgrade program.

3. Power Factor Test

Insulation power factor test measures the power loss due to leakage current through the insulation. Acceptable values of transformer power factor are based on comparative power factor values of similar transformers or previous test result. The trend change of transformer insulation parameters is reviewed to determine if a problem is developing in the transformer winding. If the power factor for example increases then this is an indication of possible carbonization of insulation or ionization of voids. The test is performed every major maintinance (every six years). Table 2 shows the results of power factor test on unit#3 oil-filled main transformer rated 440 MVA as obtained by Doble Eng. test instrument at test voltage of 10 kV :

YR	**Energized Winding**	**At 10KV**		**% Power Factor**	
		mA	Ws	**Measured**	**Calcul**
91	**High**	21	0.4	0.19	0.34
	Low	104	6.5	0.63	
99	**High**	20	0.6	0.28	0.45
	Low	100	6	0.50	

Table 2 : Power Factor Test Result on U#3 Main XFRMR at GPP

The results show improving trend although it is supposed to be the opposite. However, since the oil had undergone purification process a year before the last test, the increasing trend is justified.

4. Excitation Current Test

Excitation current is the no-load current of the transformer. The test provides means of detection for short circuited turns, poor joints or contacts or core problems. The test is not conducted in SCECO as a routine maintenance but as an acceptance test after transformer repair.

5. Induced Potential Test

The induced potential test is a proof test and performed at higher level than operating voltages. Under this test, turn-to-turn insulation and phase-to-phase insulation is stressed at 65 % of factory test voltage at higher frequency such as 200-300 Hz. The test is recommended every 6 years however, it is a requirement by SCECO as an acceptance test before installation or after repair and it is not conducted during transformer major maintenance.

6. Insulating Liquid Tests

The insulating liquid used in transformers is subjected to deterioration and contamination over a period of time, which affects its insulating properties. The following are some tests that evaluates the reliability of insulating oil in transformers:

♦0 Dissolved Gasses Analysis (DGA)

A sample of transformer oil is tested monthly in the lab for the presence of dissolved gasses in the oil. Gas chromatography analysis is performed on the sample to identify the gasses present in th oil and their relative percentage. The analysis provides a useful tool in determining the condition of the transformer. If the percent of combustible gases present in the oil exceeds 5 % then the transformer should be out of service for investigation.

♦ Liquid Dielectric Test

This is an ac over voltage test applied to insulating liquids to detect their breakdown strength. High voltage is applied to a sample of the oil and then compared the value of dielectric strength with standard. Table 4 shows Dielectric test result on oil sample of Desal xfrmr at GPP. The difference is obvious since the new oil have higher dielectric strength than the old oil.

♦1 Power Factor Test

The power factor indicates the dielectric loss and heating of the liquid. Good liquid should have a power factor of 0.05 % or less while higher power factor indicates deterioration or contamination of the liquid.

In GPP DESAL 1.5 MVA 13.8/0.48KV transformer, analysis of oil samples reveals increasing percentage of combustible gases namely hydrogen (H2) and methane (CH4) as the DGA test results indicates in Table 3.

YR	**Dielectric Breakdown**		**Min Accptable**	**Remarks**
97	23.0		**22.0**	Old OIL
98	39.0		**22.0**	New Oil
DGA (PPM)				
Date	H2	CH4	**Safe Level**	**Remarks**
9/98	7480	1390	**490**	Old OIL
11/98	53	23	**490**	New Oil

Table 3: Liquid Dielectric test and DGA of Desal xfrmr at GPP

The trend increase of combustible gases could give rise to deteriorated winding. It was decided to replace the transformer as PTD engineering recommendation. However, the field engineer suggested to replace the existing oil with a new one and to put the transformer under observation and until now its working fine.

CABLES

1. Insulation Resistance Test (Megger)

It is recommended to Megger cables initially to determine the condition of the cable insulation in terms of contamination due to moisture, dirt or carbonization. The results of each test is kept as a record for

comparison with the next test to determine the trend of insulation conditions.

2. DC High Pot Test

This test can be used for identification of weakness in the cable insulation and can also be used to break down an incipient fault. Table4 shows the IEC standard test voltage for old cables. The test voltage for new cables is obtained by omitting the factor 0.7 :

Rated Voltage (U)	**DC Test Voltage (Kv)**
3.6- 6 kV	(2.5x U+2) x 2.4 x 0.7
Above 6 kV	2.5 x U x 2.4 x 0.7

Table 4: IEC Standard High Pot Test Voltage

There is, however, much hesitation in SCECO for the application of this test on old cable because it could shorten the life of the cable.

3. Teleflex Test

Teleflex operates on pulse reflection principle. When the transmitted pulse meet with inhomogeneties part of its energy is reflected and sent back to transmitter where it is fed to a receiver. The shape and size of the reflection depend on the nature and size of the inhomogeneties.

In testing unit 1&2 4160V cables, Teleflex was conducted on the feeder cables during T&I. The picture has been taken and stored for future reference. However, it could not detect any major inhomogeneties in the cables which is probably due to cables being short and hence not enough change in the cable impedance. Fig 1 shows the output of Teleflex test on Fuel Oil Pump motor cable, it does not show significant indication of deterioration.

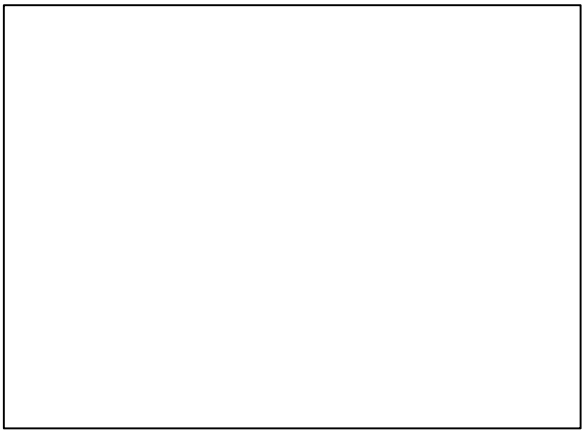

Fig 1: Teleflex Test on FOP Cable

Megger test was conducted at 5Kv to confirm the healthiness of the cables. Most of the cables showed good IR values except 5 out of 6 fuel oil pump feeders showed deterioration when Megger reading started swinging instead of steadily increasing. Table 5 shows results of megger test on a Fuel Oil Pump motor cable.

Time	PH-1	PH-2	PH-3
30sec	30 G	30 G	30 G
1 min	50 G	50 G	50 G
2	70 G	100 G	100 G
3	100 G	150 G	190 G
4	120 G	150 G	30 G-
5	30 G-	30 G-	30 G-
6	↓	↓	↓
7	↓	↓	↓
8	↓	↓	↓
9	↓	↓	↓
10	30 G-	30 G-	30 G-

Table 5 : Megger Test on FOP Cable

Although the Megger readings are good the swinging behavior of reading during the test is questionable. Swinging of Megger reading indicates charging and discharging due to possible deterioration in metallic shield which indicates a leakage in the electric field within the cable. This leakage can produce partial discharge and eventual break down of cable insulation. It was decided to replace the deteriorated cables since they affect the reliability of the pumps as well as the units.

CONCLOUSION

Maintenance practice at SCECO differs from one department to another , however , the minimum requirements called by the standards are practiced. Indeed, Some of the tests are controversial like High Pot, which is treated with some reluctance from some department. The trend now is toward upgrading test facilities with latest advancement in the world

of predictive maintenance of electrical equipment.

References

(1) IEEE standard #43 Recommended Practice for Testing Insulation Resistance of Rotating Machinary.
(2) Electrical Equipment Testing and Maintenance, A.S. Gill
(3) Substation Maintenance Standard
(4) IEC standard#502 Extruded solid dielectric insulated power cables