Pitri Bhakta Adhikari Journal of Engineering Research and Application *www.ijera.com*
ISSN : 2248-9622 Vol. 9,Issue 3 (Series -VI) March 2019, pp 94-99

RESEARCH ARTICLE OPEN ACCESS

Asset Management of an Electricity Distribution System up to 132KV

Abdullah Alsultan[(1)], Adnan ALhares[(2)]
Electrical Networks Department, High Institute of Energy, Public Authority of Applied Education and Training, KUWAIT

ABSTRACT
This paper discuss change in policy of electrical network maintenance program from a time-based maintenance program to a condition based strategy maintenance program. Also the paper will discuss the reason of such change in program. Also, will list transformer tests that aid such maintenance changes.

Date of Submission: 30-03-2019 Date of acceptance: 13-04-2019

I. INTRODUCTION

If there is an intention to change a maintenance program for any electrical network system, the main aspect for the management is to state the reason of their choices and how the new program will affect positively the contentious network services for the customers. We will suppose that a current maintenance program for our electrical network is a time-based maintenance program and the management want to change it to a conditional-based maintenance program as such program is more beneficial economically to the electrical network.

The paper explain the reasons why optimizing the policy are important and detail the short and long term drivers. Also, we will list the transformer tests which are available to aid determination of condition for each voltage level. In the paper we will discuss the merits of applying our chosen tests and will include corrosion atmospheres, 'routine' and 'special tests' with the cost benefit of each test.

1. A shift in policy: From time-based to condition-based maintenance

Performing maintenance works on the assets of business is an essential activity needed for keeping that business running. A traditional maintenance policy that was widely spread worldwide and relevant particularly to power utilities was carrying out the maintenance at pre-scheduled intervals. This Time-Based Maintenance (TBM) policy is also considered a preventive procedure. However, a growingtendency to apply a Condition-Based Maintenance (CBM) policy on power systems has more recently been observed. This shift from the TBM to CBM policy is meant to reduce maintenance costs without compromising system reliability and keeping it in a good working condition.

The TBM policy is not only a costly choice but also seen sometimes not to be sufficiently efficientin having the power to determine the asset life time. Such an inefficiency in the TBM policy has led to looking for a more flexible maintenance approach. The CBM strategy allows for performing the maintenance works only when there is a need for it. In this case, maintenance is performed when any signs of faults arise rather than at pre-scheduled fixed times. Thus, the focus is the condition of the asset on which the maintenances is carried out.

The following tables summarize the advantages and disadvantages of different maintenance approaches.

Corrective Maintenance	
Advantages	**Disadvantages**
"over maintenance" of machines does not occur	Secondary failure is highly possible
There are no costs related to 'condition monitoring'	Production downtime is high
	The cost of spare parts is high
	It involves extra costs for labour overtime
	There are workforce safety concerns

Predetermined Maintenance	
Advantages	**Disadvantages**
The maintenance is controlled	Repair of machines occurs when there is no need
Catastrophic breakdowns are less likely	Repair is often harmful
Stored parts and costs are better controlled	“unscheduled breakdowns” still exist
Possibility of unexpected failures of machines is minimized	

Predictive Maintenance	
Advantages	**Disadvantages**
Possibility of breakdowns is minimized	Investment costs too much
Parts are bought when there is a need	There is a need for additional skills
Performing maintenance occurs in when convenient	
Life time of equipment is maximized	

1.1 Advantages of using a condition-based strategy

I. Avoiding disastrous breakdowns

- The safety of the workforce is improved (in advance warning of dangers and problems)
- The likelihood of disastrous breakdowns, which might lead to fatal incidents, is minimized due to in advance warning of the problems in the asset.
- Asset serious damage can be avoided through CBM
- Data on the working condition of important assets can be obtained.
- The business can be protected against potential fines that might be arise from failures in asset maintenance.
- Potential business losses can be avoided.
- The reputation of the organisation can be improved.

II. Maximising the asset availability

- The asset condition and its operating efficiency are monitored regularly and, therefore, the time between repairs might maximize. This would, in turn, affect the availability of the plant in a positive way.
- The breakdown likelihood is minimized and, hence, reliability and availability are improved.
- The efficiency is increased.
- Unforeseen breakdowns are minimized.
- The forced outage that might be caused by a breakdown is minimized.
- Actual time data about the condition of the asset can be obtained.

III. Reducing the downtime and outage occurrences through CBM

- Failures can be predicted so that maintenance workers can plan repairs beforehand.
- Many repairs that could potentially occur in maintenance outage can be avoided through the CBM.
- The resultant CBM data helps in controlling when outages occur.
- Maintenance activities can be effectively pre-determined and planned.
- The time it takes for repairing the asset (repair downtime) can be reduced.

IV. Saving the costs of asset maintenance

- Costs of repairs can be saved.
- Energy can be saved.
- Money spent through paying premium overtime can be saved.
- A reduction of the inventory requirements of parts can be achieved.
- Capacity of the production can be improved.
- Maintenance labour can be minimized and parts can be reduced.
- Profits can be increased.

V. Improving the quality of the product

- The inspection of technical quality could prevent technical problems that might arise in the future.
- The equipment and plant condition can be evaluated in the course of the Site Acceptance Test through using the techniques of the CBM. This procedure helps in ensuring that the new equipment condition is up to expectations before accepting its purchase.
- The morals of the workers can be raised up.
- Quality deficits can be avoided.

II. TESTS OF TRANSFORMERS

Transformers are essential tools operating on electricity networks and they are known to be expensive. These tools are used to regulate the current and voltage of the AC/DC through raising it up or lowering it down to match consumers’ needs. Similar to other electrical equipment, transformers are subject to breakdown. This might occur due to a breakdown in one of their components. For example, an excessive flow of current within the transformer could result in the coil being overheated, which would in turn lead the insulator to expand and decompose. The coil could, consequently, be covered with flammable gasses, the matter of which might cause tragic incidents.

A variety of equipment tests can be identified, including routine as well as special tests. While the former type of testing is performed periodically in the aim of checking the performance and condition of the equipment and spotting breakdowns at early stages, the latter type is carried out on request when an unusual occurrence arises in order to diagnose and evaluate the performance of the equipment.

Controlling the availability of systems and the suspension of operation of the equipment is an important step for owner companies. Accordingly, a number of field tests has been advanced to verify the sound operation of the equipment. Some of these tests are presented below in the following sections.

2.1 Magnetic/Electric Circuit Tests

Easy-to-carry instruments and measurement parameters of the transformer are used to carry out this type of testing. This test is performed offline, but the actual time status is relied on to carry out a diagnosis and parameter trending values are used to execute the planned tasks. This type of tests is considered ‘no load’ and ‘load’ methods of testing.

2.1.1 No Load Tests (Turn ratio, excitation current)

This type of testing requires for every phase involving low voltage side open an alternate voltage to be inserted in a transformer high voltage winding. This would allow obtaining the transformers basic parameters.

A) Transformer Turn Ratio (TTR)

Transformer Turns Ratio (TTR) means the proportion of the turns in a winding of high voltage to that of low voltage. The Three-phase Automatic TTR, which is known to be able to measure the ratio of turns in transformers of most types, is one example of a TTR Test Set. Many factors can cause the ratio of the transformer to change. Among these factors are contamination, the deterioration of insulation and faults that arise from physical or shipping damage. However, the resultant figure of the TTR should be similar to the value shown on the transformer nameplate. This type of testing can determine if the turns contain any short circuits.

The accuracy rate of the TTR is 0.1% and this is why it is a preferred ratio method for testing new transformers and relocated or overhauled ones. New transformers of high-voltage (e.g., 132KV) or medium voltage (e.g., 33KV or 11KV) are supposed to undergo a TTR test when they are installed. The accuracy of the TTR makes it a good method to detect faults or short circuits in winding. It is also advisable that this type of testing should be performed on transformers after overhauling or relocating. The data that come from the TTR work as a diagnostic base that can be used during the maintenance process of transformers.

B) Excitation Current Test

In this type of testing, while the low voltage side open, the current flows to the winding of high voltage. The test is carried out in the aim of spotting any problems in winding, inter-turn shorts, electrical connections or any damage in the core of the transformer. It is performed in the course of operation of the transformer, during prevention maintenance works and after fault occurrences. It also results in data relevant to the transformer mechanical evaluation. When it is applied on transformers with three phases, comparisons between the phases are implemented and it is supposed that the shorted turns phase magnetising current be of a higher value.

By and large, when a core type transformer is free of any faults, similar magnatising currents appear in the core external limbs, but marginally less currents arise in the central limb. This method is supposed to be used for TTR result confirmation and it is highly sensitive in case of shorted turns. Moreover, this method is easy to apply, which makes it an appropriate choice to be used with the voltage of different levels and particularly with HV transformers on which a TTR has been performed. The measured values are expected to differ in case of the presence of a disconnection in the magnetic shunt, loose core, heated point or a magnetic package degradation. However, when the transformer is operating normally, the difference might be ignored.

2.1.2 Load testing (short circuit test, impedance measurement)

C) Frequency response analysis (FRA) testing

This testing method uses the frequency response analysis (FRA) measurement, which allows for checking transformers winding movement that are caused by short circuit faults or other types of faults that might lead to a change in the inductance and capacitance of the transformer winding. Compared to other similar testing methods, this is considered more reliable because of its accuracy in measuring transformers life time. It also has the power to spot any early signs of faults. This method can be used to test different voltage level transformers and it is considered a preventive procedure as it can be relied on to evaluate the condition of the winding in the transformer so that it can spot any slackness.

Transformers that require testing at site such as 132 KV transformers can also be tested by this method and results have been confirmed to be accurate. In the course of short circuits, great electromagnetic forces might take place, which would cause mechanical damage to the transformer. The FRA testing method is known for its efficiency in evaluating the condition of the transformer electrically and mechanically. The FRA results in a unique fingerprint in fixed electromechanical systems such as that of large power transformers (e.g., 132 KV) or medium voltage ones (e.g., 11/66 KV). This fingerprint, in turn, is useful to evaluate the transformer mechanical and electrical condition. This test can also be used to check transformer mechanical damages for which high current is held to be accountable.

Performing the FRA requires disconnecting the transformer connections. A sensual voltage should be applied on terminal winding and this is supposed to be at different frequencies. After that, a measurement of the voltage of one of one side of the winding is taken and the value registered is between 5HZ and 10MHZ. In normal conditions, considering the responses of the amplitude is satisfactory.

D) Short Circuit Test

The short circuit test is performed through the voltage application on one side with a high voltage when the other side is of low voltage and has short circuits. The required voltage amount for the process is minimal, relative to the nominal voltage. Thus, this method is appropriate for testing 132 KV transformers because of the low voltage it needed to perform the test. Due to the small amount of the voltage needed in the process, the core losses are very tiny and, therefore, can be ignored. Performing this test on a transformer goes into a number of stages. In the first stage, the power transformer should be disconnected to put it out of services as the test is carried out offline. As for HV transformers, because of the use of this method, the reliability of the system is not compromised. The second step involves removing the HV and LV jumps and disconnecting the neutral one from ground. Then, a shortening of the LV phases should occur and, after that, these need to be connected to neutral. In the following stage, the LV supply is used to feed the HV side. Next, the current in different voltage lines is measured. Finally, the loss of copper from the transformer is demonstrated in Wattmeter. Other forms of this type of testing are also available

E) Winding resistance

The winding resistance testing method is performed in the aim of checking the presence of faults such as tap changers high contact resistance or loose connections. The occurrence of such faults might be indicated by ethylene, ethane or methane production. To check the presence of high resistance, in a type of transformers such as the star connected ones, different phases can be compared with each other. In delta connected transformers, the results from different terminal pairs are compared for the same purpose. Moreover, the relevant data provided by the factory is also a useful indicator in this matter. A 5% difference in the test result would be within the acceptable value. The micro-ohmmeter is the equipment that is used for measuring the winding resistance. To get reliable results from the temperature measurement, which is needed to determine the winding resistance, an important procedure to follow is to leave the transformer until the temperature of different parts of the transformer equalizes. What follows is a formula that can be used to calculate the winding resistance:

= resistance at the factory reference temperature
= measured resistance
= factory reference temperature
= temperature at which measurement where taken
= a constant for the metal the winding is made from.234.5 for copper and 225 for aluminium.

Both HV and LV transformers can be tested by the winding resistance test. However, the reliability and redundancy of the network is supposed to be considered prior to applying the test on transformers of medium and high voltage. This is because this is an offline test. Transformers that require testing at site such as 132 KV transformers can be tested by this method because the test equipment can be easily carried.

2.2 Dielectric System Tests

These tests are very useful in the power transformer for determining its useful life. They are classified as liquid dielectric, which is usually mineral oil and solid dielectric (paper insulation in the winding).

There are several detection methods that have been discussed. Some of the tests are done in laboratory and related to oil sampling. What comes next is about some of the usual field test performed on the power transformer dielectric system.

Some of the dielectric circuit tests are as follows:

F) Core Insulation Resistance.

Core insulation resistance is used incase an additional core ground is suspected. It can be indicated by the DGA.This test can be done only when the winding resistance test shows all the connection and tap changer are in good condition.Then, this test needs to be conducted.

The disadvantage of this test is that the intention core ground must first be disconnected and to do this oil needs to be drained off.

Some of the small transformers or dry-type may not have this ground. A DC Megger is then attached between the core ground lead or the top of the core itself and the tank (ground). In case of a new transformer, the reading should be more than 1000MΩ; a service aged transformer should read greater than 100MΩ. 10-100MΩ is indicative of the deteriorating insulation between the core and ground. Less than10MΩ is sufficient to cause destructive circulating currents and should be investigatedfurther.This test is easy to apply and the equipment is simple and can be used for different transformers in different voltage levels.

G) Polarisation Spectrum :(Recovery Voltage Measurement (RVM))

This test was developed in the 1950s and became common in 1990s. It is used for determining the moisture content in the paper. This test uses the measurement of the spectrum of polarization time constant of the transformer dielectric. In this test, the dielectric is charged by a 2000V, DC voltage for a particular charge time, discharged for half that time and then the peak and initial slope and the recovery voltage are measured. The dielectric is then fully discharged before a new measurement is made for a different charge time.Measurement can be made for charge time from 20 ms to 5000s. The condition of dielectric is characterised by the dominant time constant for the peak recovery voltage and by the characteristic slope of the initial slope versus peak recovery voltage plot.

On the other hand, old transformers with excessive oil acidity or other paper degradation product need a different method. RVM diagnostic method has effective way for testing general state of insulation in large transformers for many years. Then, it is a proven approach to test 132KV transformers and medium voltage ones. Other advantages of this method are indicated below:

i. It provides non-destructive diagnosis of the state of paper-oil insulation systems.

ii. It can be used easily and it measures power transformers without any knowledge about geometrical or electrical configurations.

iii. It provides a clear results indications, as water content in paper and recommended maximum temperature on the transformer.

All of above make it the best choice to test oil-paper insulation transformers at different voltage levels such as 132 KV, 11KV, 66KV and 415V.

H) Power factor test

Power factor test is used to determine the dielectric condition of the winding.Power factor is the ratio of the capacitive or charging current to resistive current. It is a means of measuring insulation condition. It means that the smaller the power factor, the better the insulator.

Insulation makes it impossible to determine whether the causes of the problem contamination by sludge or carbon deposits or other seriouslocalised fault. The result can be done by comparing phase to phase results and can be greatly enhanced. Otherwise, it is necessary to rely upon trend analysis or comparison with results from similar transformers.

The power factor test can be applied on medium and high voltage transformers and circuit breakers such as 132KV, 66 KV and 11KV transformers.Furthermore, this test is not expensive to apply for low voltage level.

The disadvantage of this test is the difficulty in getting information about the winding. Therefore, it is practically impossible to determine which exact area of winding has the fault.

I) Partial Discharge test

Partial discharge is an electrical discharge that does not completely bridge the space between the two conducting electrodes. This phenomena appears as a result of an increase in the electric field in small gaseous voids inside the oil. In case partial discharge occurs in gas, it is called corona. Also,partial discharge can normally happen in liquids Solid insulation.

This test can provide indicator of transformer condition by dielectric degeneration. The effects of partial discharge on insulations are the following:

- Thermal instability due to heating by partial discharge
- Chemical changes in the dielectric when they conduct due to carbon formation
- Generation of channels into insulation which can make tracks especially

There are two usual detection systems for partial discharge, which are acoustic and electric. Acoustic systemsuses sound mechanic manifestation with ultrasonic range of discharges even enabling echolocation. This test can be done online or offline if a source apart is used to energize the machine, which is difficult to be done in field. Then, for 132 KV transformers it is a good option to test asset because it does not cause disruption in high voltage equipment.

Some of the advantages of this method are:

i. It can identify single or localized void-type defects.

ii. It is applicable on all transformer.
iii. Offline techniques allow for the detection of PD at voltage above system"s nominal
voltage.
iv. Basic results can be available at end of test.
v. Test can be stopped if unacceptable PD is observed.

2.3 Oil sampling

There are several tests done based on an oil sample on/off line in certain operating cases of the transformer. There are four tests as follows:

J) Furfuraldehyde Analysis.

The purpose of this test is measuring the mount of Furfuraldehyde in an insulating oil sample. This test is done by using High Performance Liquid Chromatography (HPLC) for analysing the Furfuraldehyde content of an oil sample. The theory indicates that Furfuraldehydeis exists only in paper degeneration inside the transformer and does not exist in oil. FFA is oil soluble, which makes it sampled and analysed easily, particularly as oil samples are routinely taken for DGA. However, the exact relationship between the generation of these 25products and the degradation of paper is not yet fully established.

K) Moisture content

Dissolving moisture in oil was a difficult task. But, nowadays, Megger device is an available andeasy to carry unit, which can make the test in field or plant a handy way. The implemented system is Karl-Fischer. It is laboratory regulated and has good repeatability and accuracy. Also this system need a small oil sample (1ml) and the system executes the complete control of the chemical process eliminating dissolved moisture and indicating quantity in ppm, %. Then this method is a widely used test approach for HV, LV and medium voltage transformers to check their oil dryness and chemical content.

L) Dissolved Gas Analysis

This testwas discovered in the 1920s. It depends on the principle that gases are formed in transformer oil created in thermal and electrical stresses. The Buchholzrelay helpscollecting gases from the transformer head space for laboratoryanalysis. It is a field combustible gas detector that gives the gas level expressed as a percentage.

Furthermore, transformer oils can contain dissolved gases produced duringregular operating conditions and local faults. Each fault can produce different gases in the oil. The gases caused by fault can be different according to the manufacturer and model of transformer, whether it is free breathing or sealed. Transformer faults associated with the generation of gases are usually classified as follows: arcing, sparking,partial discharge and overheating.

The ratio of concentration of the dissolved gases is used as an indication of the type of fault. It can be seen by the table below:

No	Key Ratio	Value of ratio	Suspected indication
1	C_2H_2/C_2H_6	>1	Electrical discharge
2	H_2/CH_4	>10	Partial discharge
3	C_2H_4/C_2H_6	>1	Thermal fault in oil
4	C_2H_2/H_2	>/= 2 if C_2H_2 >/= 30 ppm	Arcing in in-tank tapchanger
5	CO_2/CO	>10 <3	Overheating of cellulose Degradation of cellulose by electrical fault

The gases are analysed using gas chromatography by extracting gas to the level of partsper million. There are two detectors.1) The Flame ionisation: this is used to detect hydrocarbons including carbonmonoxide, CO, and carbon dioxide, CO2. 2) A thermal conductivity detector: this is usedto measure air and hydrogen, H2.

The decomposition of oil at temperatures in the range of 150C to500 C produce big quantity of hydrogen and methane, CH4, and small quantitiesof ethylene, C2H4, and ethane, C2H6. When temperature increases, the hydrogen quantity increases more than methane. After getting temperate more than 500 C, ethane and ethylene will be produced. Ethane concentration is usuallyhigher than ethylene.

The thermal decomposition of both paper and oil may produce carbon monoxide, but

paper is the less stable, producing CO at lower temperatures than oil. Consequently,the ratio of CO2/CO can be used as an indication of paper decomposition.

M) Breakdown voltage

The breakdown voltage for the transformer oil is very important. It has been available since 1920s .The benefit of this test is finding the Oil degradation. The test uses increased alternating voltage between two electrodes put inside the oil. It is found that the spherical electrodes are more sensitive to moisture and measurement is better in modern transformers because they use metallic parts rather than sharp edges.