American Journal of Electrical and Electronic Engineering, 2018, Vol. 6, No. 1, 28-31
Available online at http://pubs.sciepub.com/ajeee/6/1/4

DOI:10.12691/ajeee-6-1-4

A Contribution to the Insulating System State Estimation for Power Transformers Installed in Amman - Jordan

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Abstract This work focus on observation of the insulating system and analysis of the insulation resistance measurement results in 110kV, 20 and 63 MVA oil-immersed power transformers are presented. The observation was undertaken from the start-up and it includes graphical and numerical values obtained by measurements, the analysis of the state of insulation provides possibilities to undertake remedial action in due time with the aim to extend the transformer life.

Keywords: *contribution, transformer, estimation, insulation, oil transformer*

Cite This Article: khalaf Y. Alzyoud, "A Contribution to the Insulating System State Estimation for Power Transformers Installed in Amman - Jordan." *American Journal of Electrical and Electronic Engineering*, vol. 6, no. 1 (2018): 28-31. doi: 10.12691/ajeee-6-1-4.

1. Introduction

The power transformer represents one of the most important functional components of a power facility, In addition, taking into account the development of electric machines the transformer happens to be among the very first to be developed, Under operating conditions its life extends to about 30 years, Observation of its functional behavior during its life offers important data that may be used as a basis for improvement of its design, technology, for intermediate action under operating conditions all with the aim to extend its life, Generally speaking the transformer represents a complex unit consisting of the following fundamental systems: *conductive system - magnetic system- insulating system -supporting system (structure) - protective system.*

Each of these systems represents an important and inseparable part with respect to the transformer as a whole. Besides, analysis of its component parts proves to be an interesting experience. Each of the complex system mentioned above includes several subsystems that deserve special consideration and attention. ln this paper, the insulation system is presented. This system plays key role in the functioning of the unit and due to its sensitivity and complexity it requires very close consideration as to its design and engineering and technological aspects. Observation of the insulating system by means of selected methods (insulation testing by means of a mega ohmmeter) over a number of years gives a general idea of the insulation state, roughly speaking, the insulating system can be divided into:

Bushings (porcelain) -oil part - cellulose (paper, wood) part - coating-resins (sheet metal, winding.) - Geometry (gaps).

2. Research Method

The following methods have been used for observation of the insulation ageing - Current-voltage measurements (a method)-inductor measurements (mega ohmmeter)-ultrasonic measurements-winding loss angle measurements-chemical analysis, chromatography - capacitance and inductivity measurements. Enclosed in the paper is the figure showing the insulating system observed by a single method over a given period of years. We have selected the inductor measurement method of observation for presentation of the insulating system. This method is known for its adaptability to the operating conditions, fast procurement of results, simple instruments and mobility. This method provides a general idea of the insulation system state. The diagrams and tables show the state of insulating system for five (5), 110/35/10kV, 20 and 63 MVA transformers. These results have been reduced to 20C temperature and they refer to transformers in operation exposed to all conditions that normally happen in a network (over voltages, short-circuits, fluctuation of load, etc.) including all lightning phenomena. Figure 1 illustrates in the best way the behavior of insulation resistance on a transformer in which the insulation level decreased after the commissioning in the factory.

As shown in Figure 2 the permanent decline of insulation, there is no improvement after energizing the transformer either as shown on Figure 3, for MV and LV-

Ground. Experience related to other transformers show that an improvement would normally occur after setting the transformer into operation. This is probably due to the elimination of the residual humidity from the system.

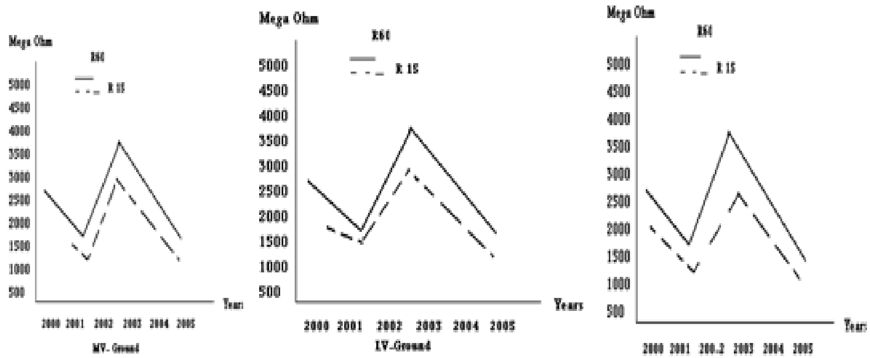

Fig. 1. HV- Ground Fig. 1. MV- Ground Fig.1. LV-Ground

Figure 1.

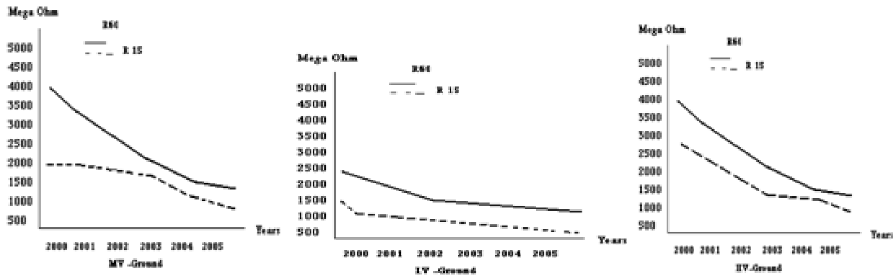

Fig.2. HV – Ground Fig.2. MV –Ground Fig.2. LV –Ground

Figure 2.

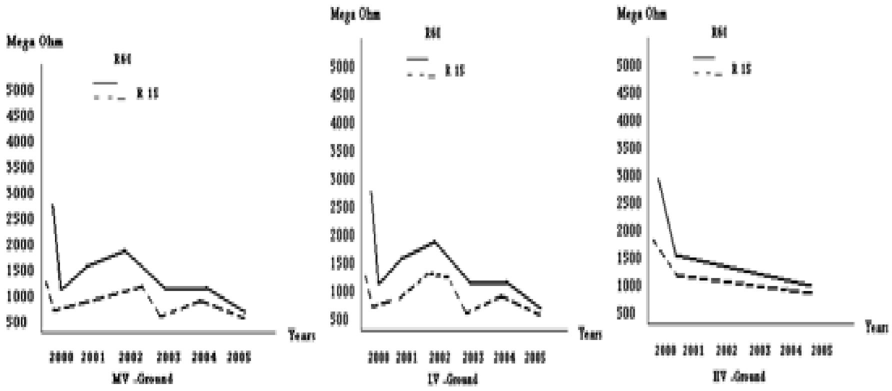

Fig.3. HV –Ground Fig.3. MV –Ground Fig.3. LV –Ground

Figure 3.

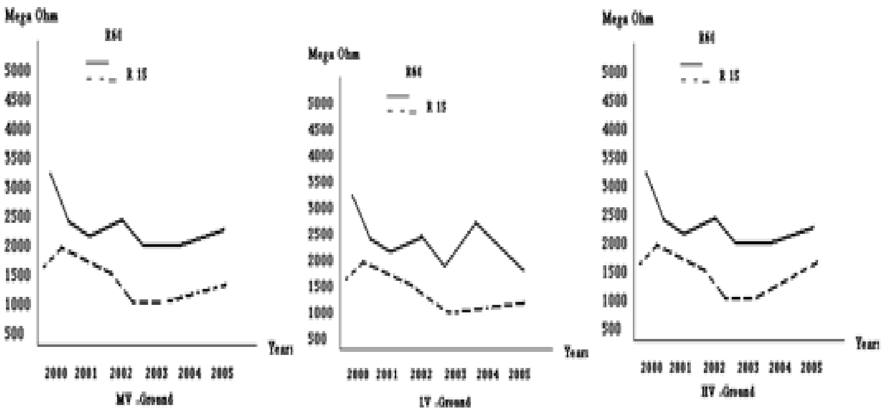

Fig.4. MV – Ground Fig.4. LV – Ground Fig.4. HV – Ground

Figure 4.

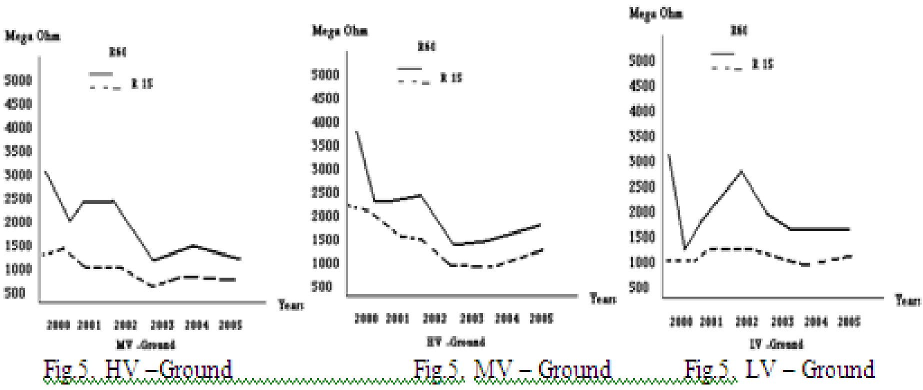

Figure 5.

Figure 3 shows continuous decline of insulation resistance which can be explained by insufficient loading and oil heating (drying) after the start-up which did not allow any significant improvement to occur. A transformer which managed to maintain its insulating properties on a permanent level over a 17-year period of operation because it functioned under nearly nominal conditions as shown in Figure 4

Figure 5 shows a transformer in which a deviation from its characteristics of R15 and R60 for HV and MD-Ground took place. These deviations could be most probably attributed to measurement errors. After one year, the transformer was energized immediately after the installation and over a period of. four subsequent years continuous improvement of the insulation resistance took place, After these, there. came a period of expected decline of insulation properties as a result of the normal ageing process It must be emphasized that measurement method provides approximate results that night serve for the insulation state estimation although it has been strongly influenced by wither conditions, by the fact , , that different measuring instruments were used, by the precision of readings, etc. The observation carried out provides interesting data which proved that such observations are useful and important. In order to obtain a general state estimation it is required to carry out the observations during the entire life of the transformer, This approach enables procurement of data which can be used as a guide for necessary steps that are needed to slow down the ageing process and extension of the transformer useful life.

3. Results and Analysis

Table 1 illustrate the Transformer: o1 "Amman, 110/33/11KV 20 MVA, the insulation resistance has been reduced to 20c0 temperature.

Table 1. Transformer: "Jo1" Amman

	TEST 2015			TEST 2016		
measurement	R15 M	R60 M	R60 / R15	R15 M	R60 M	R60 / R15
hv-ground mv, lv	2100	2800	1.3	1300	1750	1.7
mv-ground, hv, lv	1200	1650	1.3	800	1230	1.5
lv-ground, hv, lv	1000	1420	1.4	700	1020	1.3

Table 2 shows the Transformer: "Jo2" Amman, 110/33/11KV 63 MVA, insulation resistance has been reduced to 20c0 temperature

Table 2. Transformer: "Jo2" Amman

	TEST 2015			TEST 2016		
measurement	R15 M	R60 M	R60 / R15	R15 M	R60 M	R60 / R15
hv-ground, mv, lv	485	730	1.50	500	850	1.70
mv-ground, hv, lv	325	650	2.00	350	800	2.28
lv-ground, hv, lv	360	845	2.45	300	850	2.80

Table 3. Transformer: "Jo 3" Amman

	TEST 2015			TEST 2016		
measurement	R15 M	R60 M	R60 / R15	R15 M	R60 M	R60 / R15
hv-ground, mv, lv	340	425	1.2	215	330	1.5
mv-ground, hv, lv	950	1700	1.8	265	1000	3.7
lv-ground, hv, lv	850	1550	1.8	230	850	3.7

Table 4. Transformer: "Jo 4" Amman TDRN3XC _16000/110, 110/2X10/10KV 20 MVA

	TEST 2015			TEST 2016		
measurement	R15 M	R60 M	R60 / R15	R15 M	R60 M	R60 / R15
hv-ground mv, lv	1275	2400	1.8	920	1845	2.0
mv-ground hv, lv	900	2100	2.3	675	1535	2.2
lv-ground, hv, lv	1050	2250	2.1	740	1720	2.3

Table 5. Transformer: "Jo 5" _ Amman TDR 3XC _16000/110, 110/10/10KV 20 MVA

	TEST 2015			TEST 2016		
measurement	R15 M	R60 M	R60 / R15	R15 M	R60 M	R60 / R15
hv-ground, mv, lv	1360	2380	1.7	735	1010	1.3
mv-ground, hv, lv	1190	2250	1.6	550	1190	2.1
lvgroundhv, lv	1360	2890	1.7	1190	2300	1.9

4. Conclusion

The observation and analysis of insulation under operating conditions is of utmost importance. The observation results allow to carry out insulation state estimation and to predict future tendencies in its behavior. They also provide basis for defining necessary steps and remedial action aimed at extension of transformer useful life. Among other things, the results reflect the quality of insulating materials used; The following advantage is the possibility to plan auxiliary transformer requirements in cases when accelerated decline of insulation becomes evident. The data concerning the state of insulation may become important background data for new transformer developments.

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