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Loss Analysis by Loading Conditions of Distribution Transformers

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***Abstract*—**Efficient use of energy, the increase in demand of energy and also with the reduction of natural energy sources, has improved its importance in recent years. Most of the losses in the system from electricity produced until the point of consumption is mostly composed by the energy distribution system. In this study, analysis of the resulting loss in power distribution transformer and distribution power cable is realized which are most of the losses in the distribution system. Transformer losses in the real distribution system are analyzed by CYME Power Engineering Software program. These losses are disclosed for different voltage levels and different loading conditions.

***Keywords*—**Distribution system, distribution transformer, power cable, technical losses.

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I. Introduction

TODAY's increasing demand for energy and new energy sources on the initiative of environmental awareness of the more efficient energy system has entered the next research objectives. Thus, alleviation of the loss that occur in the power system has gained importance. A large part of the losses in the power distribution system consists of the power distribution line. These losses are examined mainly as technical and non-technical losses. Technical losses occurring due to current are expressed as the loss occurring in cables, lines, transformers, phase imbalance, harmonics, measuring instruments and so on devices [1]. The non-technical losses are non-invoiced electricity use, incorrect energy meters, incorrect billing, and so on. [2]. Technical losses constitute a large part of the transformer losses. As known, transformers have two types of losses which are called no-load and load losses.

In literature there are many studies regarding the identification and estimation of transformer losses. Real system data using the load profile, loading condition and the load factor, etc. for the no load and loaded status of transformer losses, technical losses of the feeder have been analyzed [1]-[6]. In the condition that New-type transformers like amorphous transformer are used in the distribution system, changes of technical losses are explored [7].

In this study, in Bogazici Electricity Distribution Inc. (BEDAS) at the same voltage level in power transformer depends on different balanced loading conditions, no-load and load losses are explored. By CYME Power Engineering Software program and the handled region was modeled and analyzed. Then these transformers losses's changes have been analyzed with different voltage level instead of the same loading conditions and using the distribution transformers which have same powers.

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II. Transformer Losses

In General, balanced three-phase systems it is sufficient to examine the one phase equivalent circuit of a transformer. Equivalent circuit of one phase transformer is given in Fig. 1.

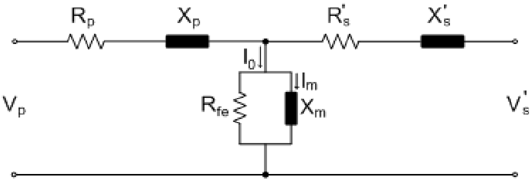

Fig. 1 Equivalent circuit of one phase transformer

Here, respectively R_p and X_p primary winding resistance and leakage of the reactants, R_s' and X_s' primer degrade winding resistance and leakage of reactants, R_{fe} iron loss of resistance, X_m reactance providing magnetization, I_0 no-load current, I_m refers to the current of the magnetization [8].

Transformers total loss is expressed like,

$$P_{TR} = P_0 + P_{LL} \quad (1)$$

where P_0 no-load loss, P_{LL} states load loss.

No-load losses, induced at the core of the transformer, depends the voltage and does not change depending on the load changes, are constant.

Load losses can be expressed like,

$$P_{LL} = I^2R + P_{EC} + P_{OSL} \quad (2)$$

This loss is the total of the "losses that belongs to a current based the joule (ohmic) losses (I^2R), winding with eddy losses (P_{EC}) and leakage losses (P_{OSL})" [8].

Total cable losses (P_L) occurred in the distribution system are taken into account, the total loss in transformer and cable would be;

$$P_T = P_{TR} + P_L \quad (3)$$

found by this relation.

III. Analysis in Distribution Network

In this study, the distribution network of BEDAS at voltage level of 34,5/0,4 kV distribution transformers, which have different powers are explored the open ring network that shown in Fig. 2. The no-load losses and load losses of the system are analyzed for different loading conditions. Investigations are carried out CYME Power Engineering Software program.

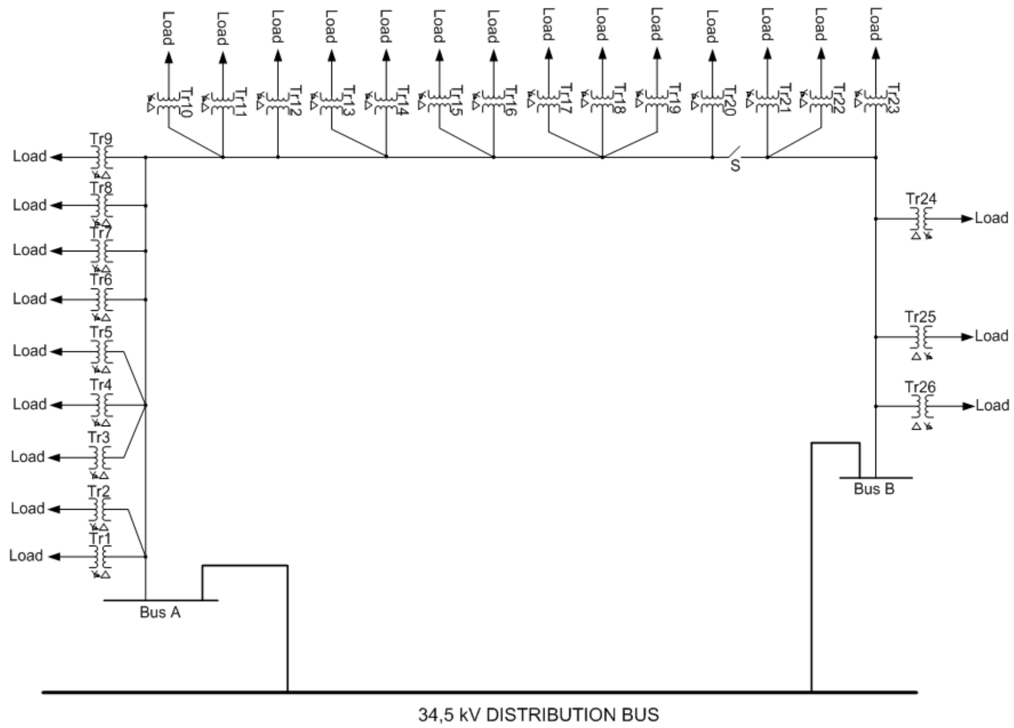

Fig. 2 Analyzed Distribution System

Handled distribution system where different powered for residential and industrial companies, consisting of dry-type transformers, D/Yn (neutral ground) connected 34,5 / are 0.4 kV step-down 26 transformer stations. The closed ring established distribution network is operated as an open ring by the help of switches placed in different locations. The system analyzed in Fig. 2, in the system distribution transformers in open ring divided by S switch in the network is energized from the A and B buses and, technical data of the transformers gained from the manufacturer catalogs are given in Table I.

TABLE I
34,5/0,4 kV Transformers Technical Properties

Transformer Voltage (kV)	Transformer Power (kVA)	Number of Transformer	Impedance Voltage (% U_k)	P_0 (kW)	P_{LL} (kW)
	630	2			
	800	1			
34,5/0,4	1000	2	4,5 - 6	1,4– 2,80	6,65 – 17,00
	1250	2			
	1600	19			

In the study two different conditions are handled. In the first case by using actual system data of different loads (25-100%) cases are analyzed for transformer losses. In the second case the same system by reducing the number of transformers 15,8/0,4 kV and 10,5/0,4 kV voltage level is the case of distribution transformers in the transformer and cable losses are examined.

A. Case A

The analysis are realized for an open ring network which have two 630 kVA, a 800 kVA, two 1000 kVA, two 1250 kVA and nineteen 1600 kVA power transformer. Total transformer losses and the total cable loss (P_L) were analyzed for the case of 25%, 50%, 75% and 100% transformers loading conditions by using CYME software. The data obtained from the simulation shown in Table II.

As seen from the analysis current losses results are increased due to increased loading the transformer.

In the analysis results in 100% loading case of transformers, the losses occur in transformers and the power cable, to installed power capacity ratio has been found to be 2,017518%.

As shown in Table III, the rate of increase in the load of transformer, increases the rate of increase in losses. For example, when the load increase from 25% to 50% the total loss of the transformer is 5,0288%, in the case that when

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loading ratio increase from 75% to 100% then increase of loss is greater 12,1388%.

TABLE II
CHANGE OF THE LOSS DEPENDING ON THE LOAD OF TRANSFORMER

Transformer Voltage (kV)	Loading Rate (%)	P_0+P_{LL} (kW)	P_L (kW)	P_T (kW)	P_T (%)
34,5/0,4	25	87,53	14,50	102,03	1,104331
	50	169,54	58,21	227,75	1,233011
	75	308,50	132,13	440,63	1,591423
	100	506,65	237,45	744,10	2,017518

B. Case B

Examined in open ring distribution network in the condition that instead of 34,5/0,4 kV same power, but at 10,5/0,4 kV and 15,8/0,4 kV voltage level distribution transformers used and analyzed for changes in losses. In the analysis, the current value is increased due to voltage reduction for the same power. The number of 1600 kVA transformers is reduced in inability of power due to the cable section with increased current. Analysis was performed by system model shown in Fig. 3. In this system there are 2x630 kVA, 1x800 kVA, 2x1000 kVA, 2x1600 kVA, 4x1250 kVA transformers are used in the simulation model.

TABLE III
THE RATE OF INCREASING LOSSES, DEPENDS ON THE TRANSFORMER LOAD

Transformer Loading Rate (%)		Increase Rate (%)		
First Value	Last Value	P_{TR}	P_L	P_T
0	25	3,5012	0,5800	4,0812
25	50	3,2804	1,7484	5,0288
50	75	5,5584	2,9568	8,5152
75	100	7,9260	4,2128	12,1388

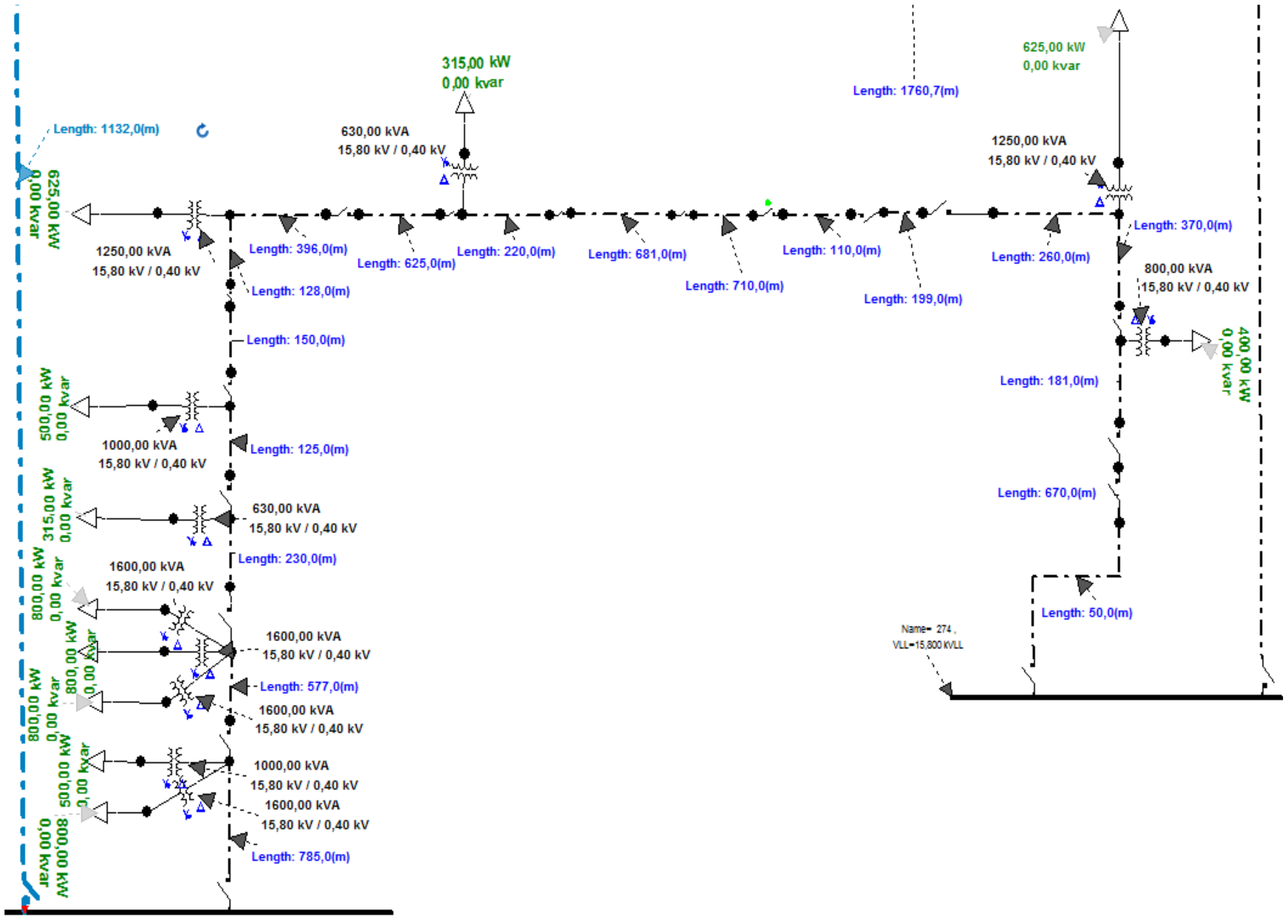

Fig. 3 The examined system section for different transformer voltage levels

The values obtained from the simulation are given in Table IV.

The analysis for three different voltage levels, when transformer voltage level increases there is not a significant change in the total loss. 10,5/0,4 kV voltage level, the analysis of the distribution system where the transformer cable losses 139,52 kW to 100% load condition, whereat 34,5/0,4 kV transformer, the value obtained as 33,47 kW. Total losses occurring in the cable and transformer (P_T) is decreased by about 30,9%.

In Table V, Changes in loss ratios of transformers are given for different voltage levels and different loading conditions.

IV. CONCLUSION

Voltage level at 34,5/0,4 kV, in the analysis for different loading conditions in a real distribution system, when load

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increases result is the total losses increased. Total transformer loss generally climbing when load ratio is 50% and over.

In the analysis performed for 3 different voltage levels, for different voltage levels and different load conditions we see that P_{TR} does not have much change. When Voltage increases and loading decreases, P_L decreases. P_T increase rate increases, when voltage decreases and the loading increases.

TABLE IV
THE RATE OF LOSSES RELATED TO THE TRANSFORMER LOAD AND VOLTAGE LEVELS

Transformer Voltage (kV)	Loading Rate (%)	P_0+P_{LL} (kW)	P_L (kW)	P_T (kW)
10,5/0,4	25	30,43	8,46	38,89
	50	56,69	34,05	90,74
	75	101,36	77,46	178,82
	100	165,27	139,52	304,79
15,8/0,4	25	30,48	3,72	34,2
	50	56,61	14,94	71,55
	75	100,8	33,85	134,65
	100	163,62	60,71	224,33
34,5/0,4	25	31,68	2,07	33,75
	50	60,25	8,25	68,5
	75	108,5	18,68	127,18
	100	177,02	33,47	210,49

TABLE V
THE RATE OF INCREASE IN LOSSES DUE TO THE RATE OF POWER CAPACITY OF DIFFERENT VOLTAGE LEVEL

Transformer Loading Rate (%)		Transformer Voltage (kV)	Increase Rate (%)		
First Value	Last Value		P_{TR}	P_L	P_T
0	25	10,5	1,2171	0,3384	1,5556
		15,8	1,2192	0,1488	1,3680
		34,5	1,2672	0,0828	1,3500
25	50	10,5	1,0504	1,0236	2,0740
		15,8	1,0452	0,4488	1,4940
		34,5	1,1428	0,2472	1,3900
50	75	10,5	1,7868	1,7364	3,5232
		15,8	1,7676	0,7564	2,5240
		34,5	1,9300	0,4172	2,3472
75	100	10,5	2,5564	2,4824	5,0388
		15,8	2,5128	1,0744	3,5872
		34,5	2,7408	0,6716	3,3324

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