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# ANALYSIS OF DISTIRIBUTION TRANSFORMER LOSSES IN FEEDER CIRCUIT

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***Abstract*—efficient use of electrical energy includes all the technical and non-technical measures to reduce the electrical energy demand of an electrical distribution system. In this paper an assessment and minimization of distribution transformer losses is carried out in detail with the help of simulation using ETAP software. Statistical data of one year on 11kv Alaiamman Koil feeder of 33kv substation has been analyzed and the results were presented. Month wise cumulative percentage of no load and full load losses of distribution transformer were taken into consideration for analysis. The simulation result obtained shows the maximum distribution transformer losses in feeder circuit and based on this simulation result, suggestion were given for further improvement of efficiency of the system and reduction of losses based on simulation studies carried out.**

***Index Terms*—Feeder circuit, Loss calculation, Loss factor, Transformer losses.**

## I. INTRODUCTION

Electrical energy is the cleanest form of energy. Electrical energy is converted from various forms of conventional and non- conventional energy source at suitable location. Transmitted at high voltage over long distance and distributed to the consumers at a medium or low voltage. The electric power system includes a generation, transmission and distribution system. Total system loss indicates how effectively and efficiently a power system is delivering a power to its customers. Hence became one of the controlling factor while planning and operating strategies. Most of the power utilities have high transmission and distribution losses which occur due to technical and non- technical losses. As the non – technical transmission losses are negligible, total system losses consist of technical transmission loss and technical and non -technical distribution losses. A distribution system is that of power system which distributes power to the consumer for local use. It consists of a large number of distribution transformer, feeder, and service mains. The distribution system losses have two components namely technical and non - technical together are called "total distribution loss".

## II. SUBSTATION (SS) FEEDER CIRCUIT

Energy is supplied from the substation to the end users (consumers) by feeder circuit. It can be divided into two parts as:

- HT feeder line which is a conductor overhead or underground (ACSR or HT cable) and
- Distribution transformer.

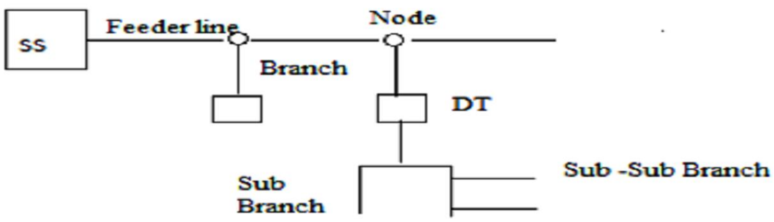


Fig.1. Typical Feeder Circuit

*Fig 2.1 shows a typical feeder circuit indicating the deployment of DTs in branches and sub branches.*

## III. DISTRIBUTION SUBSTATION

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution. The input for a distribution substation is typically at least two transmission or sub-transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltage, between 2.4 kV and 33 kV depending on the size of the area served and the practices of the local utility. The feeders run along streets overhead (or underground, in some cases) and power the distribution transformers at or near the customer premises. In addition to transforming voltage, distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometers), voltage regulation equipment may also be installed along the line. The downtown areas of large cities feature complicated distribution substations, with high-voltage switching, and switching and backup systems on the low-voltage side.

## IV. DISTRIBUTION TRANSFORMER LOSSES

Transformers are inductive in nature they consume the power with lagging power factor. But the key input for estimating distribution transformer energy loss is the transformer load that determines the power factor and energy consumed. The distribution transformer rated capacity does not reflect their actual consumption. Therefore, there is no measured load record for distribution transformers when the feeder is supplying the energy. The loss due to DT is of significance as it contributes to some percentage of total input units. Attempts may be made to minimize these losses.

### *A. NO LOAD LOSSES ($W_i$)*

Taking place in iron/core part comprising of hysteresis losses and eddy current losses in the core considered to be constant irrespective of load.

1) *Hysteresis losses:*

Each time the magnetic field is reversed, a small amount of energy is lost due to hysteresis within the core. According to Steinmetz's formula, the heat energy due to hysteresis is given by

$$W_h \approx \eta \beta_{max}^{1.6}$$

And hysteresis loss is thus given by

$$P_h \approx W_h f \approx \eta f \beta_{max}^{1.6}$$

Where f is the frequency, η is the hysteresis coefficient and βmax is the maximum flux density, the empirical exponent of which varies from about 1.4 to 1 .8 but is often given as 1.6 for iron.

2) *Eddy current loss:*

The eddy current loss is a complex function of the square of supply frequency and square inverse of the material thickness. Eddy current losses can be reduced by making the core of a stack of plates electrically insulated from each other, rather than a solid block; all transformers operating at low frequencies use laminated or similar cores.

### *B. WINDING LOSSES OR LOAD LOSS (Wwdg)*

Takes place in the winding part. As a function of load current, can be divided into ($I^2R$) loss and stray losses. The stray losses are caused by eddy currents that produce stray electromagnetic flux in the windings, core, core clamps, magnetic shield and other parts of the transformer.

3) *Stray loss:*

Leakage inductance is by itself largely lossless, since energy supplied to its magnetic fields is returned to the supply with the next half-cycle. However, any leakage flux that intercepts nearby conductive materials such as the transformer's support structure will give rise to eddy currents and be converted to heat. There are also radioactive losses due to the oscillating magnetic field but these are usually small. Mechanical vibration and audible noise transmission In addition to magnetostriction the alternating magnetic field causes fluctuating forces between the primary and secondary windings. This energy incites vibration transmission in interconnected metalwork, thus amplifying audible transformer hum.

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*C. OTHER LOSSES (Wother*)

Dielectric loss ( due to electrostatic reversal in insulation and circulating currents), load unbalance, oil leakage, loss of life, lack of maintenance, improper up keep of distribution boxes, and joints loose connections. Generally the value is less than 1% of total energy input to the system. The most important losses are Wi and Wwdg. The other losses are described mainly to give a complete picture on losses.

## V. LOSS CALCULATION APPROACH

After replacing the High rating transformer with low rating value, by using the past data collected the loss calculation is carried out. T = period of consideration (day/month/year,

KVAavg = average of recorded KVA from load curve = $\sum_{i=1}^{T} KVA/T$

*D. LOAD FACTOR (Ld*)

It is the ratio of the average KVA consumed during a designed period, to the maximum demand MDKVA occurring in that same period. A system load factor measures the degree of utilization of the power supply system. By increasing the system load factor, the need to provide larger building transformer capacity may be avoided and the construction of new generating and transmission plant may be delayed.

LOAD FACTOR = Ld F = (KVAavg / (MDKVA)

*E.LOSS FACTOR (Ls Factor)*

It describes the average electrical energy losses for electricity transmitted through T. Ideally, to calculate the load losses it would be necessary to integrate the square of all momentary ratio of actual load to the rated load. This is practically difficult.

LOSS FACTOR = LsFactor = $LdF^2 + (0.273)(LdF - K)^2$

Where K = (KVA min) / (KVA max) (as per load curve)

Now, Wwdg = Wc $[(MDKVA) / (Tr\ KVA\ total)]^2$ ( Ls Factor)

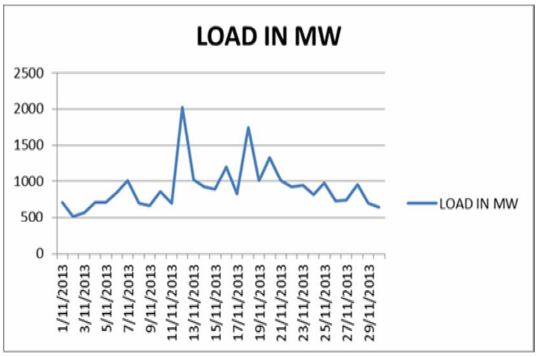
Where Wc = full load copper loss Wi and Wc can be obtained from the standard losses table available,
Tr KVA total = total rating of all transformer KVA.
Transformer energy losses are given by TRenloss = (Wi + Wwdg +Wother)

Total losses for all distribution transformers can then be calculated by summing the losses for individual transformer as below: Total transformer energy losses = $\sum_{i=1}^{n} TRenloss(i)$

## VI. SAMPLE CASE STUDY

11KV alaiamman feeder of MAMBALAM SUBSTATION is considered as a sample case study. The substation is located in main part of the city comprising of many number of houses and medium industries. Working voltage of SS is 33KV/11KV having many feeders. Alaiamman feeder is selected for sample study. The period of study was for one month (for 30 days) in November 2013. The feeder is drawn through a distance of 15 km. This feeder circuit consists of 6 quantities of 250 KVA transformers and 5 quantities of 500 KVA transformers.

Firstly, the power system SS, its components like feeder and distribution transformer are discussed. Various losses in distribution transformers are discussed. Next approach for estimating the losses of DT circuit is presented using actual readings available and analytical method. A load profile based on the consumer's data, is described. The approach is implemented for the loss calculations. Results and conclusions are drawn on the basis of calculation.




Period in days, fig 2.load curve

*F. REPLACING THE EXISTING TRANSFORMER*

Although the transformer capacity is loaded to recorded value up to collectively but considering the low values of the factor, it can be noted that in terms of loading, the utility of transformer is very less.

G. *NEED FOR REPLACING*

Losses are more for high rated transformer groups. This is because they are connected to bulk LT consumers. The network is large and covers many versatile type of machinery. Hence the losses are expected to be more. Transformers of high ratings are connected to LT consumers. Compared to LT consumers, HT consumers are less in number. In the alaiamman feeder circuit load connected is large but the load consumed is very less. In this feeder circuit higher rated transformer is not all needed. Due to the excess of load more losses occurs and it reduces the efficiency of the system. The 250 KVA transformers is replaced with 100 KVA transformer and 500 KVA transformer is replaced with 250 KVA transformer to minimize the loss.By replacing the transformer the load is connected according to the requirement. Thus the amount of load connected is utilized fully and losses can be reduced to some extent. Energy conservation in HT sector is comparatively wide and easy.

| SI.NO | TRANSFORMER RATING KVA | Wi (W) | Wc (W) |
|---|---|---|---|
| 1 | 100 | 350 | 2500 |
| 2 | 200 | 570 | 3300 |
| 3 | 250 | 748 | 3163 |
| 4 | 315 | 800 | 4600 |
| 5 | 500 | 1030 | 6860 |
| 6 | 1000 | 1800 | 11000 |
| 7 | 2000 | 3000 | 20000 |

TABLE 1 STANDARD TRANSFORMER LOSS TABLE

| SL. NO | TRANSFORMER RATING KVA | QTY | TOTAL KVA | PERCENTAGE (%) OF OVERALL TOTAL CAPACITY |
|---|---|---|---|---|
| 1. | 100 | 6 | 600 | 32.43 |
| 2. | 250 | 5 | 1250 | 67.56 |
| | TOTAL OVERALL Tr KVA | 11 | 1850 | |

TABLE 2 DETAILS OF TRANSFORMER USED

As per the load curve data, total consumption (SS import) is 27368000 units, 55500 KVA per month.

After replacing the transformer the KVA overall KVA value to reduce to 1850 KVA. We have reduced 2150 KVA when compared to the existing system. The load is connected according to the need and the utility of transformer is better, which obliviously reduces losses and improves the system efficiency.

*F. DAILY ENERGY LOSS OF TOTAL TRANSFORMER CIRCUIT*

| SL.NO | TRANSFORMER TYPE KVA | QTY | ENERGY LOSSES IN WATTS (K WH) | | | TOTAL UNITS (KWH) |
|---|---|---|---|---|---|---|
| | | | $W_i$ | $W_{wdg}$ | $W_{other}$ | |
| 1. | 100 | 6 | 108 | 147 | 27 | 282 |
| 2. | 250 | 5 | 106.6 | 156.2 | 36.3 | 299.1 |
| | Total | | 214.6 | 303.2 | 63.3 | 581.1 |

TABLE 3 DAILY ENERGY LOSS OF TOTAL TRANSFORMER

*G. MONTHLY ENERGY LOSS OF TOTAL TRANSFORMER CIRCUIT*

| SL.NO | TRANSFORMER TYPE KVA | QTY | ENERGY LOSSES IN WATTS (KWH) | | | TOTAL UNITS (KWH) |
|---|---|---|---|---|---|---|
| | | | $W_i$ | $W_{wdg}$ | $W_{other}$ | |
| 1. | 100 | 6 | 3240 | 4410 | 810 | 8460 |
| 2. | 250 | 5 | 3198 | 4686 | 1089 | 8973 |
| | Total | | 6438 | 9096 | 1899 | 17433 |

*TABLE 4 MONTHLY ENERGY LOSS OF TOTAL TRANSFORMER CIRCUIT*

*H. RATING WISE TRANSFORMER LOSSES FOR ONE MONTH*

| SL.NO | TRANSFORMER RATING (KVA) | PERCENTAGE (%) OF TOTAL INPUT (IMPORT) UNITS KWH |
|---|---|---|
| 1. | 100 | 0.18 |
| 2. | 250 | 0.39 |
| | TOTAL | 0.57 |

*TABLE 5 RATING WISE TRANSFORMER LOSSES FOR ONE MONTH*

The table 5 shows losses of each group as percentage of total import units in the feeder.

## VII. HT REGULATION OF PROPOSED SYSTEM

A HT REGULATION CHART OF 11KV M FEEDER FED BY 33/11 KV MAMBALAM SS IN CIT NAGAR II SECTION

| 11KV CABLE SIZE | DISTANCE IN KM | DISTRIBUTION TRANSFORMER | CAPACITY | CUMULATIVE LOAD | MOMENTUM | REGULATION |
|---|---|---|---|---|---|---|
| 3*120 | 0.100 | CRESENT PARK SS-II TP - 250 KVA | 100 | 1850 | 185.00 | 0.0478 |
| 3*120 | 0.950 | CRESENT PARK SS-I- TP - 250 KVA | 100 | 1750 | 1662.50 | 0.04298 |
| 3*120 | 0.100 | HINDI PRACHAR SABHA RMU-500 KVA | 250 | 1650 | 165.00 | 0.0427 |
| 3*120 | 0.100 | THANICKACHALAM ST RMU | 500 | 1400 | 140.00 | 0.0362 |
| 3*120 | 0.300 | BURKIT RD SS-I- 500 KVA BURKIT RD SS-II- 500 KVA (PROPOSED) | 500 | 900 | 270.00 | 0.0698 |
| 3*120 | 0.100 | SARAVANA RMU – 250 KVA | 100 | 400 | 40.00 | 0.0103 |
| 3*120 | 0.100 | LOTUS RING – 250 KVA | 100 | 300 | 30.00 | 0.0078 |
| 3*120 | 0.100 | CANARA BANK TP-250 KVA | 100 | 200 | 20.00 | 0.0052 |
| 3*120 | 0.050 | BURKIT ROAD RMU- 250 KVA | 100 | 100 | 5.00 | 0.0013 |
| | | | | | | 0.6508 |

TABLE 6 SHOWS A HT REGULATION CHART OF 11KV M FEEDER FED BY 33/11 KV MAMBALAM SS IN CIT NAGAR II SECTION

The HT Regulation of 11 KV MHU feeder fed by 33/11 KV Mambalam SS works out 0.6508% with Diversity factor. Hence Satisfactory

## VIII **CONCLUSION**

The method used in this project makes use of the past data of the feeder circuit. By calculating the factors, the losses can be easily calculated. A total loss due to transformer in feeder circuit is 0.71% of the total input to the substation. This quantity of loss is seemingly little high as compared to normal losses of 0.5% in a feeder circuit. More losses in present case can be attributed to poor maintenance and environmental aspects. If maintenance work is done with planning at least 6000 units (0.14%) can be saved. It can be noted that losses are more for high rated transformer groups. This is because they are connected to bulk LT consumers. The network is large and covers many versatile types of machinery. Hence the losses are expected to be moretransformers of higher rating are connected to LT consumers. Compared to HT consumers LT consumers are more and are cautious about energy saving activities. Energy conservation in HT sector is comparatively wide and easy. If the entire higher rated transformer is replaced with lower KVA value we could save 6000 units per month. The output is verified with the Etap software.

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