Life Cycle Cost Analysis Approach in Selection of Transformer Rating

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Abstract

The improving efficiency in transformers represents a significant gain as almost one third of network losses are caused by inefficient transformers. In addition reduced energy losses, high efficiency transformer provides benefits of reduced greenhouse gas emission, increased reliability and longer service life of the equipment. The energy-efficient transformer technology has been available for decades, but its high upfront costs deterred wide-scale penetration. Given this, most major economies across the world have established and introduced minimum energy performance standards for distribution transformers.

1 INTRODUCTION

A transformer is unique equipment, where efficiency improves with decreased loading, up to a certain loading. This is because the load losses in a transformer vary as a square of the load current. However, this will hold good only up a certain loading. This is the loading where iron losses become equal to copper losses.

The case study below is based on this principle.

Case Study

Consideration for analysis

The life of transformer is considered as 25 Years(1]

The losses as per IS1180 are considered for loss cost calculation (for energy efficiency Level 1). The same are calculated as below:

i.1.6MVA- Total loss at 100 per cent load =14.51Kw [2].

ii.Total loss at50 per cent load=4.84kW [2].

iii. Sample calculation for no load loss and full load loss calculations for 1.6 MVA transformer P_{Total} =P no load+ (load percentage / 100) 2× P load [3]

Calculated no load loss-1.61 KW

Calculated full load loss-12.9 KW

Similarly, for a 2 MVA transformer, calculated no load loss-1.65 kW and calculated full load loss-16.62 kW

Transformer running cost (loss lost) is calculated for three shifts working, considering350 days of yearly operation and eight working hours per shifts.

For the first year of operation, the per unit cost is considered as Rs 10 per kWh.Increase in utility company tariff is considered@ 5 per cent annum over the next 25 years.

Payback period is calculated with interest loading on saving in capex/opex and it will vary based on:

i.Hours of operation

ii. Actual loading

iii. Per unit(kWh) power cost

iv. Interest rate

For an option with a higher rating of transformer, as a different cost in initial investment, only the increased cost of a higher rating transformer is considered.

The cost towards its 415 V power control centre income, associated bus dust and outgoing feeders will remain unchanged since the load to be distributed remainas same in any of the option.

Load cycle for 1.5 MVA demand over a span of 24 hours is considered as mentioned in Table1.

TABLE -1

MD(%)	40	50	60	70	90	100
Work hours	6	3	4	8	2	1
Total hours	24					

Operation and maintenance costs are not considered in the analysis since they are considered to be almost the same for both the options.

(1) Life cycle cost comprises the initials investment and the running cost due to energy losses in the transformer.

2 ANALYSIS OF LIFE CYCLE COST ANALYSIS TRANSFORMER RATING

The transformer sizing is analyzed considering the following configurations:

(1) Option1-1×1.6MVA,33/0.415KV
(2) Option2-1 ×2MVA, 33/0.415KV

OPTION1 For a demand variation between 40 percent and 100 percent during a 24- hour cycle, the loading on transformer will vary from 38 percent to 94 percent and according to the loading, the load loss will also vary. A sample calculated of the life cycle cost is as follows:

Step1: Calculations of initial investment

Cost of 1.6MVA transformer =Rs2.31million

Total cost of initial investment =Rs2.31 million

Step2: Calculation of running cost

Step2a: Calculation of the percentage loading of a transformer as per the actual demand is an mentioned in Table2

Step2b: The losses for the different percentage loading of transformers are as mentioned in table 3.

Step2c: Sample calculated for annual loss cost for 56 percent loading of transformers

Loss cost = Total losses for 56 percent loading × Annual working hours for 56 percent loading× power tariff rate

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TABLE-2

MD(%)	40	50	60	70	90	100
Demand during these working hours(MVA)	0.60	0.75	0.90	1.05	1.35	1.50
% Loading oftransformer(%)	38	47	56	66	84	94

Table -3

% loading oftransformer	38	47	56	66	84	94
No load loss (Kw)	1.61	1.61	1.61	1.61	1.61	1.61
Full load loss (Kw)	1.81	2.83	4.09	5.57	9.21	11.35
Total loss (Kw)	3.42	4.45	5.71	7.19	10.81	12.97

Equation 1

Loss cost for the first years =5.69 ×(4 ×350) × 10 =Rs 79,000

Loss cost for the second years =5.69 × (4× 350) × 10.5 =84,000

So, consideration a 5 percent increase in tariff rate per years, for period of 25 years, the loss cost for the 25th years =5.69× (4 × 350) × 32.3 = Rs 256,000.

Total loss cost for 25 years = Rs 3.8 million

Similar to equation 1, the total loss cost for the first years = ∑{ Total losses for (38% / 47% /56% / 66% / 84% / 94 %) loading × Annual working hours [(6/3/4/8/2/1) × 350] × power tariff rate for the first years } = Rs 520,000

Based of these calculation the summary of the annual loss cost for option 1 is mentioned in table 4.

Table-4

% loading of tran	38	47	56	66	84	94
Cores. loss cost for 25 years(Rs million)	3.43	2.22	3.80	9.57	3.60	2.16
Total loss cost for 25 years(Rs	24.81					

million)	

Step 3 : Calculation of life cycle cost

Life cycle cost = cost of initial investment+ load loss cost = Rs 2.31 million + 24.8 million = Rs 27.11 million

OPTION 2

Similar working is carried out for 2MVA transformers.

Comparison of option 1 and 2

A comparison of option 1 and 2 indicated in table 5

Table -5

COST (Rs million)	Option 1	Option 2	Difference
Capital cost	2.311	2.480	-0.175
Operational loss cost for 25 years (Rs million)	24.806	21.745	+3.059
Life cycle cost	27.117	24.2321	

The lifecycle cost mentioned in table 5 is without interest rate consideration on initial saving in the capital cost as well as without any interest loading on the loss cost saving (due to option for higher size,that is 2MVAtransformer istead of 1.6MVA transformer)

3 CALCULATION WITH INTEREST LOADING

Calculation for total saving in the initial investment in option 1: saving =P×(1+R/100)N where ,P = Principal amount (saving of Rs 17,5000) R, Rate of interest @ 8 percent annun , N= no. of years =25 years , saving= Rs = 1.198 million

4 CALCULATIONS FOR TOTAL SAVING IN THE LOSS COST FOR OPTION2

Saving at the end of the first years = Loss cost of 1.6 MVA- Loss cost of 2.0 MVA= Rs 520,000-Rs 456,000= Rs 64,000 saving at the end of the second years = (Loss cost of 1.6 MVA-Loss cost of2.0 MVA)+ Interest on the first year's savings =(546,000-478,000)+ (64,000×1.08)= Rs 137,000.

On a similar basis, the years wise cash flow scenario, consideration interest components is mentioned in table 6

As the end of the25 th years, there will be net saving of Rs 6.2 million (7.398-1.198 = 6.20)

5 CONCLUSION

If the transformer size calculated for a maximum demand (MD) of 1.5MVA is 1.6MVA, on a life cycle cost analysis basis, a 2 MVA transformer will be advantageous. The payback period will be a 3.5 years .The analysis will not be applicable for a group of transformers selected on the redundancy philosophy. The accuracy in the load estimation and load pattern will play a key role in the analysis.

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