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A Transformer Techno Economical Cost Analysis using Modified Object Function using MATLAB

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Abstract— Transformer is one of the important part of electrical engineering. Therefore life cycle of the transformer an emerging topic in electrical industry. In the last decade there are different research work present in the this field, they predict the techno economical cost and life cycle of transformer. In this research work proposed modified objective function based techno economical cost analysis of transformer. The modified objective function is simulated on the matrix laboratory (R -2015b). The simulated outcome shows the better accuracy in life cycle calculation of transformer as compare to other previous methods.

Keywords—Transformer, Total Owning Cost, Life Cycle and Object function.

I. INTRODUCTION

The distribution transformer is the most important single piece of electrical equipment installed in electrical distribution networks with a large impact on the network's overall cost, efficiency and reliability. Selection and acquisition of distribution transformers which are optimized for a particular distribution network, the utility's investment strategy, the network's maintenance policies and local service and loading conditions will provide definite benefits (improved financial and technical performance) for both utilities and their customers. Many electrical distribution utilities claim that they purchase distribution transformers using some type of loss evaluation procedure. Over the past 25 years, these purchasing practices have been established, as the utilities have apparently become aware of the range and the value of distribution transformer losses. On the other hand, very few industrial and commercial customers include evaluation of distribution transformer losses in the purchasing process. proposed an evaluation technique from the industrial and commercial customers' point of view. Moreover, the expected large increases in energy demand and the need to undertake effective measures to protect the environment could be partially solved by improvements in energy efficiency of distribution transformers. Optimized distribution transformers (cost-effective and highly efficient designs) would provide numerous global benefits to the wider public as well as local benefits to electrical distribution companies, their customers and other users of distribution transformers.

The most comprehensive material related to transformers' loss evaluation processes is found in a series of two papers published in 1981, The work refers to a complete loss evaluation method applicable to distribution transformers in vertically-integrated systems. More precisely, the total levelized annual cost method is extended to properly account for conditions of energy cost inflation, load growth and transformer change-out. The reported method may be used only by investor-owned utilities which have their own generation and transmission facilities. Part I refers to the application of the total annual cost method, extended to properly account for energy cost inflation, load growth and transformer change-out when capitalizing for the transformer losses. The methodology provided, also, refers to the occasional need for evaluation and costing of reactive and regulation losses. The discussion in concludes that the effect of regulation and reactive losses is significantly smaller than the cost of power losses, thus in most of the procedures it is neglected. This is mainly due to the time needed to perform the evaluation of reactive and regulation losses in respect to their proportion on the overall transformer losses. Moreover, a detailed derivation of the transformer equivalent levelized annual peak load is provided. This is modified to account for circumstances of energy cost inflation and transformer change-out practices. As a final note, the paper discusses the various loss cost rates obtained in industry (various regulated utilities in different countries).

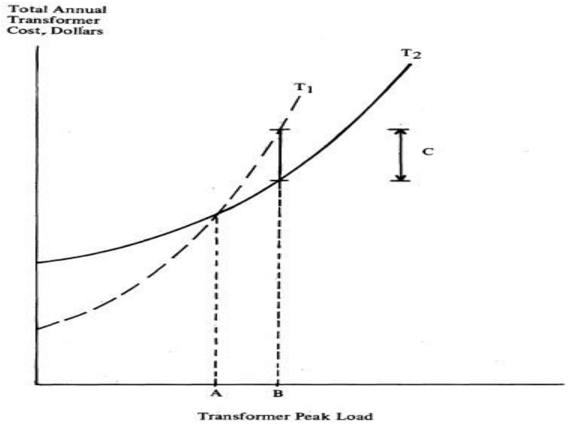


Fig. 1 Determination Of Economic Change-Out Load

II. LITERATURE REVIEW

Niu, Xin,et.al (2023) - Author are presented the predictive maintenance method based on the retrogression analysis of equipment service age can calculate the failure probability before and after maintenance and can be used to flexibly formulate maintenance strategies to reduce operation and maintenance costs and improve long-term benefits. This method comprehensively analyzes the change and cost effectiveness ratio of substation EENS and equipment LCC before and after different maintenance schemes, and then overcomes the contradiction between cost and long-term benefit on the premise of controlling power supply risk, and selects the best maintenance strategy according to the principles of reliability priority, economy priority and cost effectiveness priority. Among them, the service age regression factor can be used to quantitatively describe the repair effect of service age on equipment performance, and th decision results in the example analysis verify that the cost-effectiveness ratio priority strategy can take into account both reliability and economy [01].

Campanhola et.al,(2023) - They are presented it can be concluded that the article fulfilled its objective by proposing a methodology for analysing the costs of the unavailability of large power transformers due to the overload caused to the other transformers in the network. This methodology presented can be used as a tool to aid decision-making in the management of equipment by the power utilities. Likewise, it helps to bring to light financial data that, together with the power utilities' technical and strategic parameters, can form an important decision making tool for proper prioritization when replacing equipment or reconfiguring the system. As a limitation, this case study was carried out in a single power utility, and it can be expanded to th complete network through the availability of data and computational capacity to perform the simulations **[02].**

Cossutta, et.al,(2022) - Author are study trade-offs exist between electricity supply costs, peak reduction and life cycle GHG reductions. PV generation provides a significant reduction in GHG emissions, but makes little contribution to reducing peak demand from the grid. Community energy storage in batteries are effective at reducing peak demand, but at significant additional sts, and may result in a modest increase in GHG emissions due to emissions associated with battery manufacture. GHG emissions reductions with community-level energy storage would be possible, provided that they are charged with renewable (or low carbon) electricity sources and discharged at times where fossil fuel generation can thereby be avoided, but analysis of such a management strategy is outside of the scope of the current paper. Anticipated cost reductions for PV and battery, and longer battery cycle life, will considerably reduce the cost of community electricity generation and storage for managing peak grid demand **[03].**

Chen,et.al,(2023) - They are presented a techno-economic framework for the evaluation and comparison of different power distribution architectures in large-scale data centres. The technicalindicators such as LOLE, equipment damage risk, and system efficiency are calculated and mapped to the economic metrics. Numerical results show that using a DC system at the mediu voltage level can substantially reduce the costs of data centers as compared with the conventiona AC architectures. It is concluded that the LVDC and MVDC architectures enhance the system efficiency at a lower cost. The highest overall performance is observed in the MVDC architecture that employs WBG devices **[04].**

Beltran,et.al - (2020) After analyzing the power and energy capacity requirements for an ESS implemented at a wind turbine or at a wind farm level to provide IR and FS services, this paper reviewed and discussed the different technologies available in the industry that could comply with these requirements. As well as identifying prospective storage technologies, two control strategies were identified that are capable of providing the specific inertial response characteristics, but may require further adjustment depending on the final technology choice e.g., considering state-of-charge of the storage system. Out of the multiple ES technologies compelle in the literature and taking into account various constraints (location-dependence, maturity, technical characteristics), three are considered as potential candidates: flywheels, super capacitors, and three chemistries out of the Li-ion battery family (NMC, LFP, and LTO) **[05].**

Cai, G., & Kong, L. (2017). Wind curtailment supplying energy for hydrogen fuel cell vehicles is described in this paper. Based on actual measurement data of curtailment obtained from a wind farm in the Jilin area in northeast China and by applying the HOMER software, a techno-economic analysis of WCHPFCVS is conducted. The conclusions are as follows: 1) Curtailment power cannot be fully absorbed by hydrogen production equipment because it is no economical. The optimal capacity of the hydrogen production equipment can be calculated through simulations and optimization. 2)

Different initial investments in the WCHPFCVS and different load levels of fuel cell vehicles have strong impact on WCHPFCVS's economic benefits. At present technical conditions, the higher the load level of fuel cell vehicles is, the worse the economic efficiency, even entailing negative profit **[06].**

Marchi, B., Zanoni, S., Mazzoldi, L., & Reboldi, R. (2016) - Steel industry is one of the largest energy consumers in the manufacturing sector, even though many improvements in the energy efficiency have already been introduced in the Electric Arc Furnace (EAF) process. Consequently, further developments in the energy performance are still requested. However, additional technical and technological progresses are now uneconomical, i.e. high costs for few benefits. The main opportunity consists, thus, in the improvement of the EAF transformer's performance, as its relevance due to the fact that all the melting energy passes trough it. Recent EAF transformers have become indistinctly well performing in terms of rated performances. As a consequence, the basis of the competition has been shifted from the single product to a customized solution, consisting of tangible products and intangible services designed and combined to fulfill specific customer needs in an economical and sustainable manner (PSS). The intangible value is currently the key to obtain competitive advantages and to overcome the competitors' performances. These extra services take into account the real energy losses obtained during the operation of the furnace in order to design a tailor-made transformer, the provider consultancy on the efficient operation of the product and the integration of maintenance initiatives. To perform the economical analysis of the solution, it is thus necessary to calculate the EAF transformer's life cycle cost (LCC) taking into account the purchasing price, the costs of energy losses (no load, load, LV terminals and auxiliary losses) and the cost due to maintenance. At the present, no works have been conducted on the EAF transformers, which are exposed to more critical conditions than power/distribution transformers **[07]**.

III. ALGORITHM FORMULATION OF OBJECTIVE FUNCTION

above said points. And a comparative study of results obtained will be considered in this work.

The objective function for the Techno-Economic Evaluation of useful life of Transformer will includes

$$OF = C_{TO} + C_M + C_{NSE} \qquad [1]$$

OF = Objective Function.
CTO = Cost of Total Owning
CNSE = *Cost of Interruption.*
CM = Cost of Annual Repair & Maintenance.

Step 1 Calculation of Total Owning Cost (C_{TO})

The total owning cost (*CTO*) method provides an effective way to evaluate various transformer initial purchase prices and cost of losses. The goal is to choose a transformer that meets specifications and simultaneously has the lowest CTO. The A and B values include the cost of no-load and load losses in the CTO formula:

$$C_{TO} = IC + A\times (P_0 + P_{00}) + B\times (P_k + P_{cs} - P_{00}) \qquad [2]$$

Where,
P0 = No Load Losses (NLL)
Pco = Power Consumption of cooling equipment at no load operation
Pk = Load Losses (LL)
Pcs = Rated Power Operation
IC = Initial Cost

Estimate

$$A = t\times \frac{Cn}{2}\times\frac{1\left(\frac{1}{1+i}\right)^n}{i} \qquad [3]$$

$$B = K^2\times\frac{Cn}{2}\times t\times \qquad [4]$$

$$\frac{Cn}{2} = \frac{c+(cx\,(1+j)n)}{2} \qquad [5]$$

Where,
t = Operating Time in Hour per year
i = Discount factor for investment (Cost of Money in percentage)
n = No. of Year for lifetime of the transformer in Year
2 */C*= Cost of Energy at the mid-life of the transformer
C = Initial Cost of Energy (in Rs/kWh)
j = Annual Increases of Energy Price (in Percentage)
k = Average Loading of the Transformer during its Life time

Step 2 Calculation of Interruption Cost

The interruption cost [30] can be measured in terms of non-supplied energy cost. Thus

the objective is to formulate the annual cost of interruption which depends upon

failure rate of transformer in its three different life stages (infant, normal and wear out

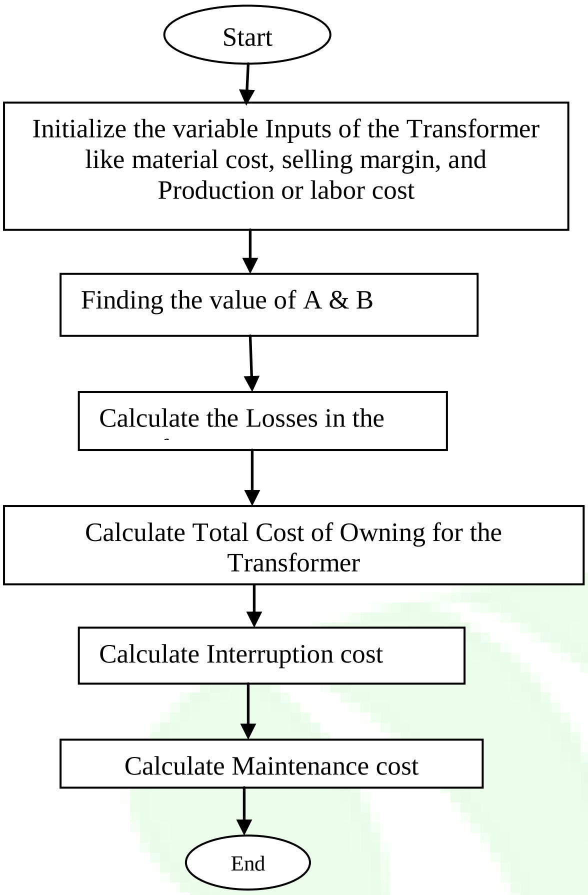
region). Mathematically the cost of non supplied energy can be modeled as follows:

$$C_{NSE}\ AIC = \lambda \times P \times r \qquad [6]$$

Where,
λ: Variable Failure rate of transformer
P: Average load on the transformer
r: Average outage time

Step 3 Calculation of Maintenance Cost

$$C_M = 0.03\times\text{Initial Investment cost }(\text{IC}) \qquad [7]$$



Flow Chart of the Estimated Cost of the Power Transformer.

IV. SIMULATION AND RESULT

For the simulation of proposed objective function use MATLAB (R2015a) software. That is shown in below figure 2.

Fig. 2. Shows MATLAB GUI Window

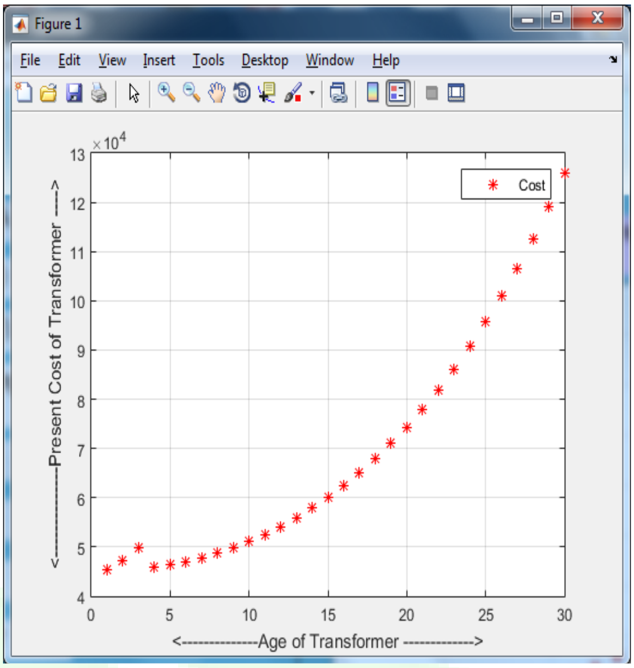
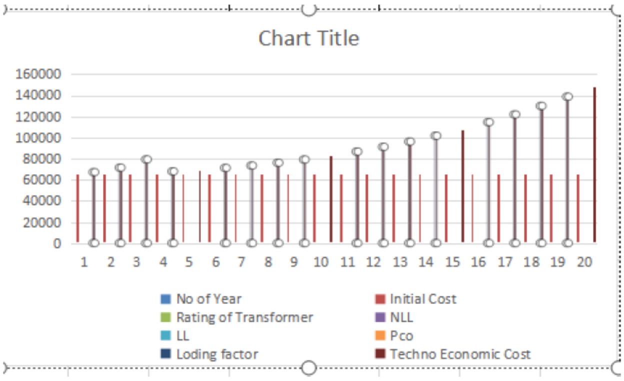


Fig. 3 Transformer Cost Analysis

Transformer is one of the most important equipment in both transmission and distribution systems. And as regards many available documentations and papers, it is necessary that in transformers simulation (particular in transient and unbalance states), three-phase core to b modeled as monolithic. Matlab/Simulink transformer model is a good model which engaging saturation effect but it has a big weakness namely non-ability in perspective of monolithic core. Particularly, in unbalance and transient conditions this weakness will be caused to fail in simulations. So a new Matlab/Simulink model is proposed in this paper for consideration of both magnetic saturation and monolithic core.



No of Year	Initial Cost	Rating of Transformer	NLL	LL	Pco	Loading factor	Techno Economic Cost
1	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	67246.1752
2	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	71505.0059
3	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	79304.3545
4	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	67938.8396
5	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	69409.7137
6	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	71250.979
7	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	73480.5458
8	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	76117.3655
9	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	79181.4888
10	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	82694.1275
11	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	86677.7194
12	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	91155.9966
13	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	96154.0572
14	65500	75kVA	0.05kW	0.125kW	0.125kW	0.125kW	101698.4411

V. CONCLUSION AND FUTURE SCOPE

Finally it can be summarized, that the Life-Cycle-Cost Analysis is a useful instrument to identify the main cost drivers of a network and to take up there appropriate actions to reduce the costs. Because it is possible to examine the present value of each component, these set screws still can be refined. The calculation of the outage costs plays a crucial part, if the system operator intends to change the maintenance strategy, for example a transition from a time based to a condition based maintenance strategy. Due to the low failure rate of modern system components the benefit for additional condition assessment devices has to be calculated very carefully.

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