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Artificial Intelligence Techniques for Design of Power Transformers Optimisation and Productivity Assessment

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ABSTRACT

Transformers must be designed to meet all international requirements and customer expectations while also being economically practical, effective, and meeting all international criteria. This is the ultimate goal in transformer design. As AI approaches become more widely used, it is projected that the cost of active components, development, and ownership would decrease while still adhering to international standards and constraints. TDO problems will not be solved using AI technologies now being used in Indian manufacturing. Current research aims to develop AI-based solutions that may be utilised to improve the distribution transformer design. Using this design, the transformer's total ownership costs and manufacture expenses would both be cut in half (TOC). It was shown that while solving TDO problems using GA, PSO, and TLBO techniques, PSO and GA found higher objective feature values than GA. When it comes to percentages, TLBO outperforms PSO and GA hands down. Because of the adoption of NSGA II, the TOPSIS technology allowed DM to choose any solution from the non-dominated solutions.

Keywords: Artificial Intelligence, Transformer Design Optimization, NSGA,

Introduction

When it comes to power grid networks, distribution transformers make up the majority of the overall network's overall size. A transformer is a device that transfers voltage from one level to another by magnetically attaching one or more electric circuits to a standard magnetic field. Transformers come in a variety of shapes and sizes, but distribution transformers are the most common, with networks ranging in size from 50 kVA to 1000 kVA being constructed in Saudi Arabia.

Lower, maximum, and reduce the time it takes for distribution by consumers have all been made possible thanks to computer-aided design businesses. Reduce, maximise, and reduce the time it takes for customers to get your product. The system's design ensures that the user satisfies the criteria in addition to regular design constraints such as performance, loaded and unloaded retrofits, changing temperature, and other restrictions. Finally, we have a number of various transformer prototypes that are fully functional. Despite the fact that both designs adhere to the specifications, the radius of the transformer, the number of laminations, the winding technique, and the number of turns are distinct criteria. The total cost of any transformer layout differs because the two most important cost considerations are the quantity of material utilised and the cumulative failure of the transformer.

Regardless of the kind of power distribution system, transformers are an essential component. The architecture of each transformer is not unique; in particular, the design concepts for all possible capacities are quite similar. Style and formatting modifications can only be made if other structures or components are employed, such as different core styles, or if the winding structure has to be modified. When linking electrical networks with various voltage rates, transformers play a critical role. Most of the ways in which electrical power has been used lately will be impractical without a converter. Consequently, transformers play vital functions in the electrical power grid, which connects power plants and gas stations. In the realm of transformers, more than 400 articles, 50 books, and 65 recommendations have made major contributions to the improvement of transformer quality and efficiency.

1.2 Design Optimization Of The Transformer

Manufacturers need to design the best (optimal) technology for the current adaptation of new legislation involving the use of high-efficiency supply transformers because it would be difficult to ask consumers in today's highly dynamic retail environment to fully pay for the consequent rise in product prices.

With dynamic and discontinuous goal features and constraints that fully identify transformer characteristics in accordance to domestic or external requirements as well as user expectations, Transformer Design Optimization is a non-linear mixed integer programming problem.

This literature describes a variety of trustworthy functions, but the most generally used ones are those that reduce the TOC transformer's manufacturing costs while maintaining its lifetime cost (i.e. the total cost of ownership). Minimizing major content costs, production expenses, and TOC are the three functionality goals offered in the study's package. Tocs are required by rules yet regulatory agencies are urged to continue utilising them since the guidelines merely seek to raise transformational efficiency's minimal minimum level (Global Industry Analysts 2014.). Transmission lines and transformer architectural efficiency are two topics that have received a lot of attention in the literature. First, a review of the literature conducted in 2009 (Amoiralis IE 2014) provided broad outlines of transformer design and optimization progress during the previous 35 years based on more than 420 papers, 50 transformer-related books, and 65 recommendations. The research article might need further investigations on transformer architecture and transformer design optimization (Olivares-Galvan JC 2001, Amoiralis EI 2009, Energy Efficient Transformer Solutions 2014.).

Several methods to its attainment have still to be investigated, as noted in the literature, when it comes to global optimization of disruptive architecture, European Copper Institute (2014).

Objectives

- To investigate transformer design optimization using conventional methods
- To use swarm and intelligent evolutionary algorithms to figure out the best transformer design.
- To use evolutionary algorithms to investigate transformer design with multiple objectives.
- To study the Transformer selection, performance analysis, and owning cost calculation

Scope of the Study

A power supply network's transformers are often seen as a liability. Transformators go through the same design process regardless of what they are intended to do. In order to deal with the significant task of enhancing the transformer architecture, a hybrid, non-linear programme called Transformer design optimization (TDO) was developed with a sophisticated, discontinuous objective feature and restrictions that have both been widely employed. Reduced transformer installation costs and maintenance and operating expenses have been achieved by the usage of GAs. GAs are often used to automate the construction of delivery transformer cooling systems. Analysis of computer systems through mutual intelligence is known as Swarm Intelligence. Many homogenous agents interact in the system, creating collective knowledge. This multi-objective design uses GA in high-frequency transformers, thus efficiency and cost savings may be improved by optimising the particle swarm. Transformer layout characteristics have also been approximately measured using multi-target simulation for transformer design.

Review Of Literature

According to Chandan Chakraborty et al. (2002), a performance optimization technique that relies heavily on the DC link power dimension should be used. Optimizing induction motor performance can be accomplished using loss model controls and seeks control algorithms.

Yadav et al. (2011) In the electric grid, the converter is a key piece of equipment. It's important to know the design restrictions of a power transformer while it's being tweaked to meet a number of requirements to get the best layout. Power transformer configuration is optimised using Simulated Annealing (SA) in this work (OPTD). The reduction objective is to lower the centre and copper mass to its highest possible value. A worldwide ideal seems to have been created, according to the results of this method. Inverse and natural building effects reduce calculation time and complicated content mass dramatically. Using this approach, the transformer's efficiency may be improved.

Ali Soldoozy et al. (2018) There have been several improvement equations and approaches proposed over the previous few decades, most of which are impacted by design and regular situations in some way or another, particularly those that may be fundamentally explored and articulated. We want to present a new streamlining technique, based on the development and fertility of plants, that allows researchers to swiftly scan the whole study area while only having to deal with the problematic parts of the plant or tree (i.e., the portions that don't satisfy the issue's restrictions). By working together, we'll reduce the scope of the improvement problem's shooting region, remove the obnoxious components that don't meet the criteria of the query, and make the investigation flow more smoothly. We intend to reduce the risk of being shot to a bare minimum by improving the quality of our shooting. To enhance a tree's variety, you prune it. To increase measurement performance, you shorten the shooting range to address a construction problem. It is necessary to employ JMAG-Designer technology to conduct finite part research.

Sudha et al. (2019) Large-scale strategy and operations engineers encounter several challenges, including scenario planning. A contingency model is used by power grid engineers to assess the network's architecture and evaluate if further transmission expansions are needed as demand changes or as the network becomes older. Variables such as AC load flow analysis or decreased load flow or responsiveness are employed in different ways to analyse such scenarios. There are no on-line applications in wide power frameworks suitable for such strategies since they need an enormous quantity of computer resources regardless of the circumstance. When the faster approach and the consistency of the arrangement differ, it's impossible to do current on-line contingency research utilising conventional methods. As a result, using a synthetic neural system, this work proposes a computationally efficient method for conducting contingency research.

Method and Material

Conventional Method for Transformer Design Optimization

This chapter will present a typical approach to the problem of transformer configuration optimization. There are numerous common design variables assigned to many distinct designs using this heuristic approach. When everything is said and done, choose a design that addresses all problems while using the least amount of active materials (aluminium and CRGO pricing).

Swarm and Intelligent Evolutionary Algorithms for Optimal Transformer Design

In order to tackle the Transformer Design Optimization (TDO) issue, "Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Teaching Learning Based Optimization (TLBO)" have all been used. According to the No-Free Lunch Theorem, no one metaheuristic can solve all optimization problems perfectly. To put it another way, although multiple meta-heurists may have excellent results on certain issues, the same approach may have bad results on others tasks. For want of a better term. There will be a comparison of three different artificial intelligence (AI) approaches to solving TDO issues in this part (i.e. GA, PSO, and TLBO).

Multi-target, optimum transformations are built using evolutionary algorithms.

A multi-objective optimum design of a distribution transformer will be used in this chapter by NSGA-II. To decrease the cost of the active portion, as well as the transformer's no-load errors and load losses, a multi-objective optimization approach is used. An advantage of the strategy is that it saves time since the decision-maker (DM) may pick from a number of ideal options instead of just one. a design that is tailored to a certain use case The NSGA-derived diversity features of pareto-front might provide DM additional options when making a solution decision (design). To assist DM choose between several pareto-optimal solutions, the TOPSIS approach will recommend which helps to choose the best compromise alternatives in order of preference for DM to use. Effectiveness will be shown on 100 kVA distribution transformer by using the suggested approach.

Result and Findings

This paper explores the effects of the Transformer Interface Optimization (TDO) issue by Exhaustive Search Process (ESM). The shortcomings of no load failure, loss of loads, loss of percent, and total losses for half load transformers for the 1st and 2stars as well as other software parameters were set out in Table 3.1 according to the Energy Efficiency Office (78).

Table 3.1 Input Parameters for 1-Star and 2-Star Rated Transformers

Sr. No.	Parameter	1-star	2•star	Units
1	Rated power	100	1 00	kVA
2	Max. Total Losses permitted	2020	1910	W
3	Max. Losses permitted at half load	700	610	W
4	Max. No load losses permitted	220	200	W
5	Max. Percentage impedance permitted	4.7	4.7	%
6	Rated low voltage	433	433	H
7	Rated high voyage	11000	11000	H
8	Permitted Temperature rise	S0	50	"C

Tables 3.2 and 3.3 Exemplify 100kVA11/0.433kV, Transmission Transformer, output of 1-star and 2-star.

Table 3.2 Sample of Acceptable Solutions Pertaining to 1-Star Rating

Active Part Cost (INR)	No-load losses (W)	Load losses (W)	%Z	Efficiency
59608	187.19	1760.67	4.27	98.089
61632	189.61	1675.74	4.53	98.168
59564	187.19	1767.69	4.27	98.082
61351	188.70	1683.01	4.55	98.162
59284	186.29	1774.71	4.29	98.076
61307	188.70	1690.27	4.55	98.155
59242	186.29	1781.72	4.29	98.069
61263	188.70	1697.54	4.55	98.148
61263	188.70	1697.54	4.55	98.148
59199	186.29	1788.74	4.30	98.063
61208	190.88	1664.51	4.51	98.178
59146	188.45	1756.26	4.26	98.092
58825	187.53	1770.27	4.28	98.079
67707	216.64	1505.61	3.55	98.306
69698	219.65	1427.22	3.75	98.379
68741	212.63	1531.47	3.57	98.285

Total number of designs = 20400

Rejected cumulative designs for infringement of restrictions= 13403

Accepted cumulative prototypes = 6997

Design no. from all prototypes picked = 1178

Design no. selected from all shortlisted designs = 15

If the manufacturer needs a minor change in the measurements of the software configuration of the transformers, the software should join alternate values of the allowable no load and lack of load as long as the restriction referred to in Table 3.1 is not violated.

CONCLUSION

This segment explores systematically all application choices by dismissing all applicant alternatives (designs) that breach consumer limitations. The software then proposes all acceptable choices and offers the best design and output parameters of the transformer. The presented approach is useful for delivery transformer manufacturers since it saves significant design time. However, it should be noted that it is not possible to go below step size of 0.01 for design variables, as it would increase the execution time tremendously.

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