A
PROGRESS PRESENTATION
ON
“OPTIMIZATION ON DESIGN OF THREE PHASE DISTRIBUTION TRANSFORMER USING METAHEURISTIC ALGORITHM”

PRESENTERS

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Overview

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Introduction

Background

- Transformers are vital components in the electric power system, used to transmit electrical energy between voltage levels without changing frequency.
- They are classified into power transformers, distribution transformers, and special purpose transformers based on their use and characteristics.
- The demand to lower the production costs has prompted the search for rigid methods of decision making, such as optimization methods.

Introduction Cont…

Importance of Optimization

- Optimization involves finding conditions that maximize or minimize a function's value, choosing the best alternatives from available options.
- Optimization in transformer can be viewed as exploration of best possible configuration of design parameters which maximizes performance while minimizing resource utilization.

Problem Statement

Losses

- Losses in transformers directly impact the overall power system performance.
- Due to widespread use of distribution transformers even small reductions in losses contribute to substantial energy savings.
- Reduction of losses in transformer can bring down the overall power loss in the system.

Weight

- Conventional design methods often lead to heavier transformers which may result in higher material costs and overall high transformer cost.

Problem Statement Cont.

Challenges in Conventional Design

- Conventional design relies on manual selection of parameters and values based on guidelines and experience. So, exploring new configurations, variations in multiple design variables, and unconventional design spaces is challenging and computationally intensive.

Need for Modern Optimization Algorithms

- Modern optimization algorithms, make use of advanced computer processing power to find the optimal results.
- Optimizing transformers requires multiple iterations, and meta-heuristic algorithms help find near-optimal solutions in complex spaces while minimizing the required computations.

Objective

Main objective

- To identify the optimum design parameters of distribution transformer to achieve reduction of weight and losses.

Specific objectives

- To develop a static model of transformer design
- To use a suitable metaheuristic algorithm to optimize the design

Scope and Limitations

Scope

- Design of distribution transformer by using conventional method (static model) and its implementation on MATLAB.
- Optimization of transformer design with goals to minimize the weight of the transformer and losses on it using metaheuristic algorithm.

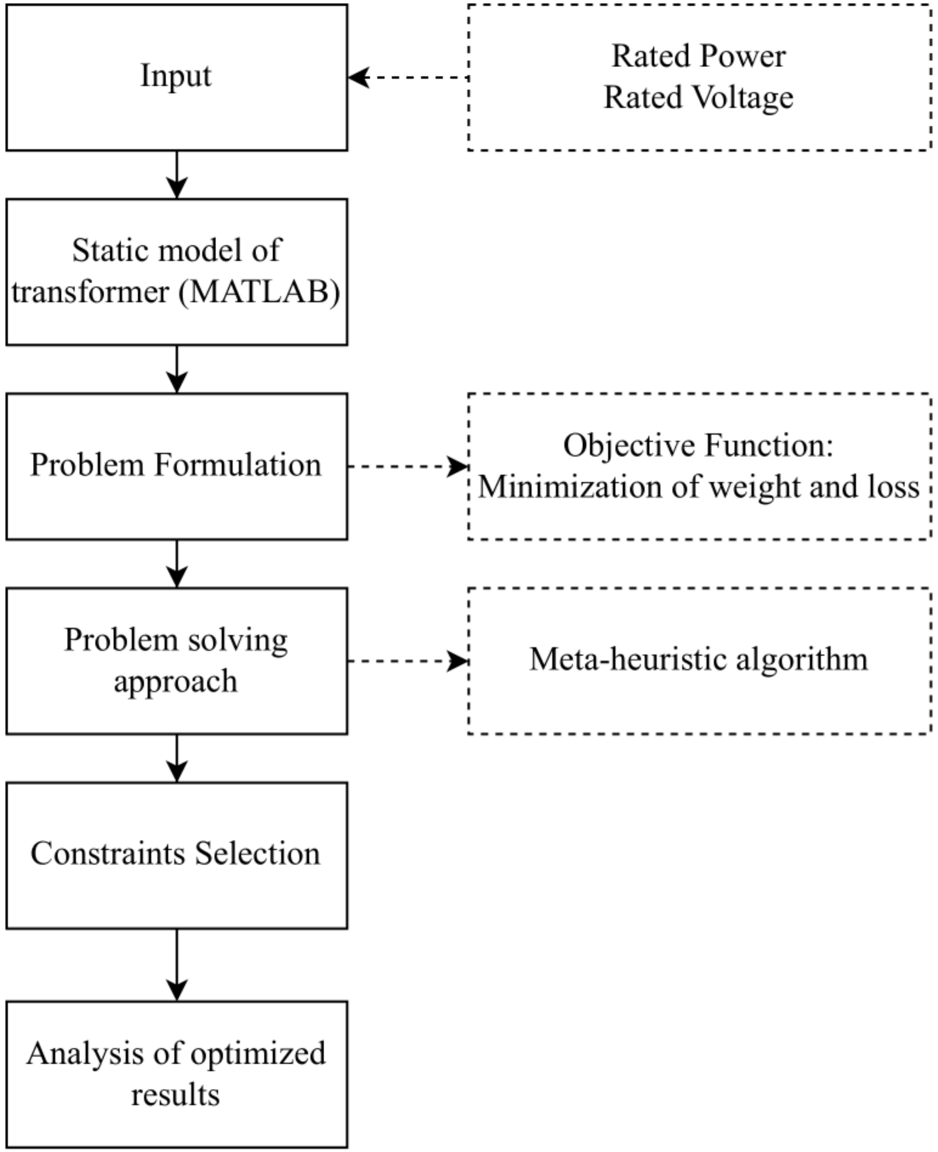
Limitations

- Takes into account a limited number of design variables for optimization.
- Only the weight of active components (limbs, yoke and windings) is considered.
- The design of transformer does not accommodate for non-linear loading conditions.

Methodology

1. **Input to the static model**
   Transformer specifications such as power rating, voltage levels, and frequency are provided as input to the static model.

1. **Transformer Design**
   Based on the power and voltage level; the size, dimensions, materials, etc. are determined by using various calculation techniques along with the implementation in MATLAB.



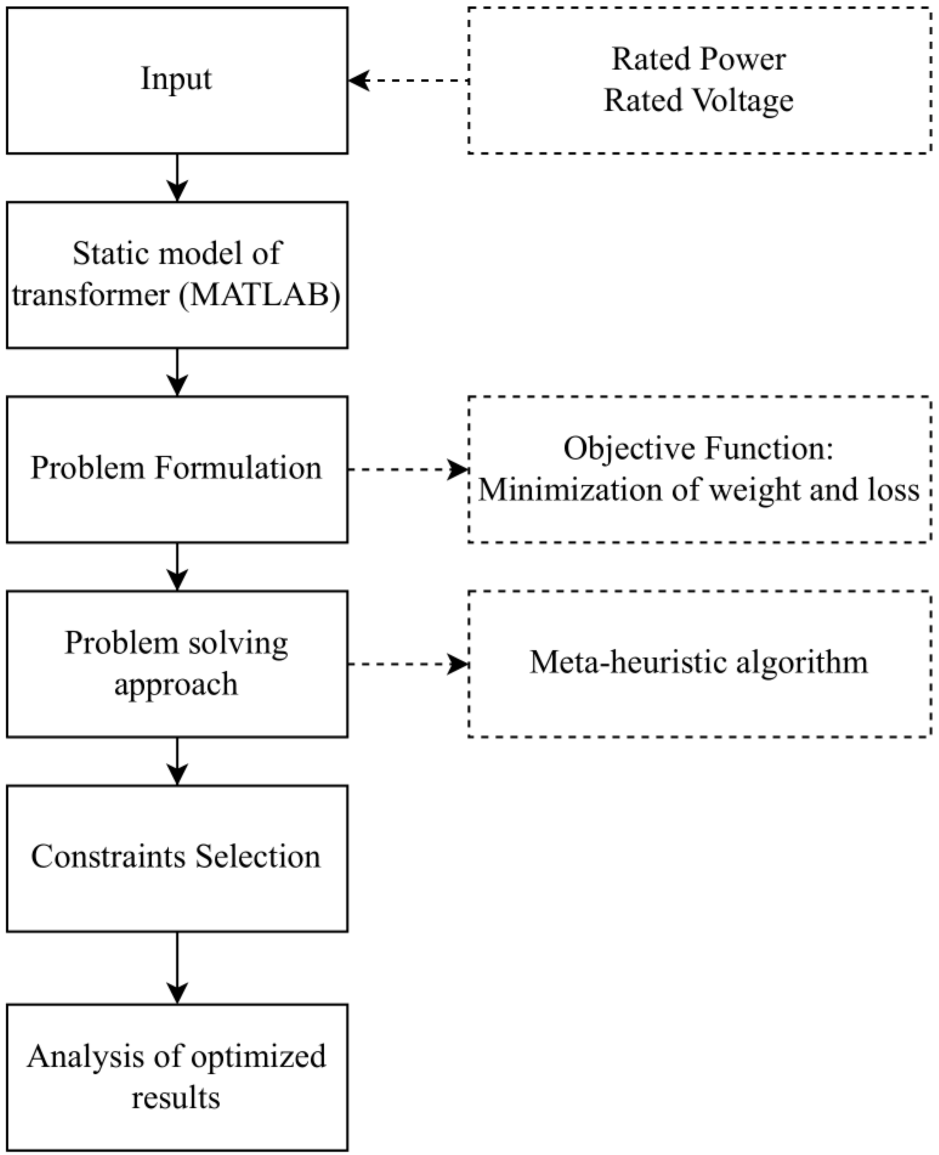
Methodology

3. **Problem formulation**

   Problem formulation is done by the selection of parameters and formulating objective function which minimizes weight, and losses. And suitable constraints are selected such as flux density, current density, etc.

4. **Optimization approach**

   A suitable metaheuristic algorithm; Teaching Learning Based Optimization is used as the optimization technique.



Transformer Design

- Choice of current density
- Choice of flux density
- Design of frame
  - Limbs
  - Yokes
  - Windows
- Design of windings
- Operating Characteristics
- Determination of weight
- Determination of losses

**All formulas and tables used in the design process are taken from [1-3].*

Problem Formulation

- The objective function for optimization is determined by taking the function of transformer weight and power loss.
- The constraints and decision variables impact the objective function.

Decision Variables

Variable	**Permissible Value**	**Unit**
Flux density (B_m)	0.9 - 1.4	Wb/m^2
Current density (δ)	1.5 - 6.0	A/mm^2
No of core steps	[3, 5, 7, 9, 11]	-
Ratio window height to width ($R_{H\text{-}W}$)	2.5 - 3.5	-
Loading factor	0.5 - 0.8	-

Problem Formulation Cont.

Optimization Problem

$$OF = min\left[\sum_{i=0}^{n} x \cdot W + y \cdot P_l\right]$$

Subject to:

$$0.9 \leq B_m \leq 1.4$$

$$1.5 \leq \delta \leq 6.0$$

$$Nc \in \{3,5,7,9,11\}$$

$$2.5 \leq R_{H-W} \leq 3.5$$

$$0.5 \leq lf \leq 0.8$$

$$Clearance_{primary}, Clearance_{secondary} > 0$$

$$Clearance_{limbs} > 0$$

Where,

$$W = \frac{Wi + Wc}{W_{base}}$$

$$P_l = \frac{P_i + lf^2 \cdot P_c}{P_b ase}$$

x and y determine the influence of weight and loss in objective function respectively.

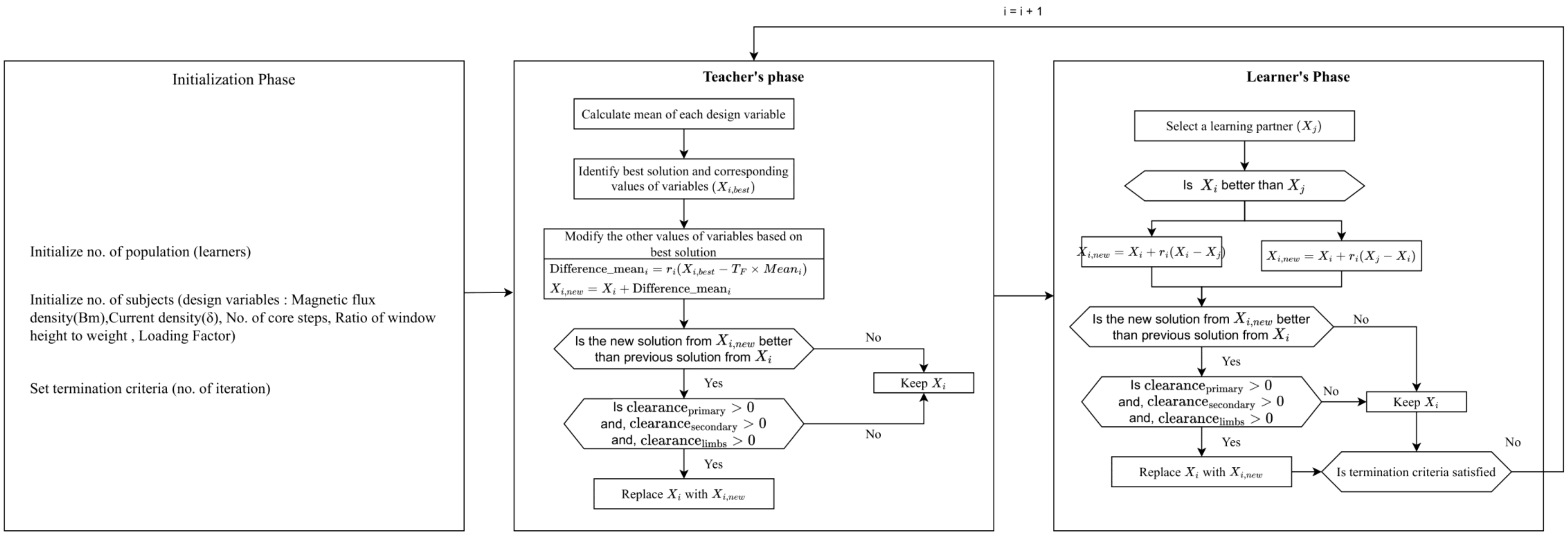
Problem Solving Approach

- To solve the optimization problem of minimizing the weight and loss in transformer, a metaheuristic optimization technique is required.
- Teaching Learning Based Optimization (TLBO) was chosen as a problem solving approach.

Optimization Algorithm

- The Teaching Learning Based Optimization (TLBO) algorithm is a teaching-learning process-inspired algorithm based on the influence of a teacher on the output of learners in a class. [4]
- Two phases:
    - Teacher phase
    - Learner phase
- No algorithm specific parameters.
- Depends only on population size and maximum number of iterations.
- Rapid convergence.

Flowchart of TLBO



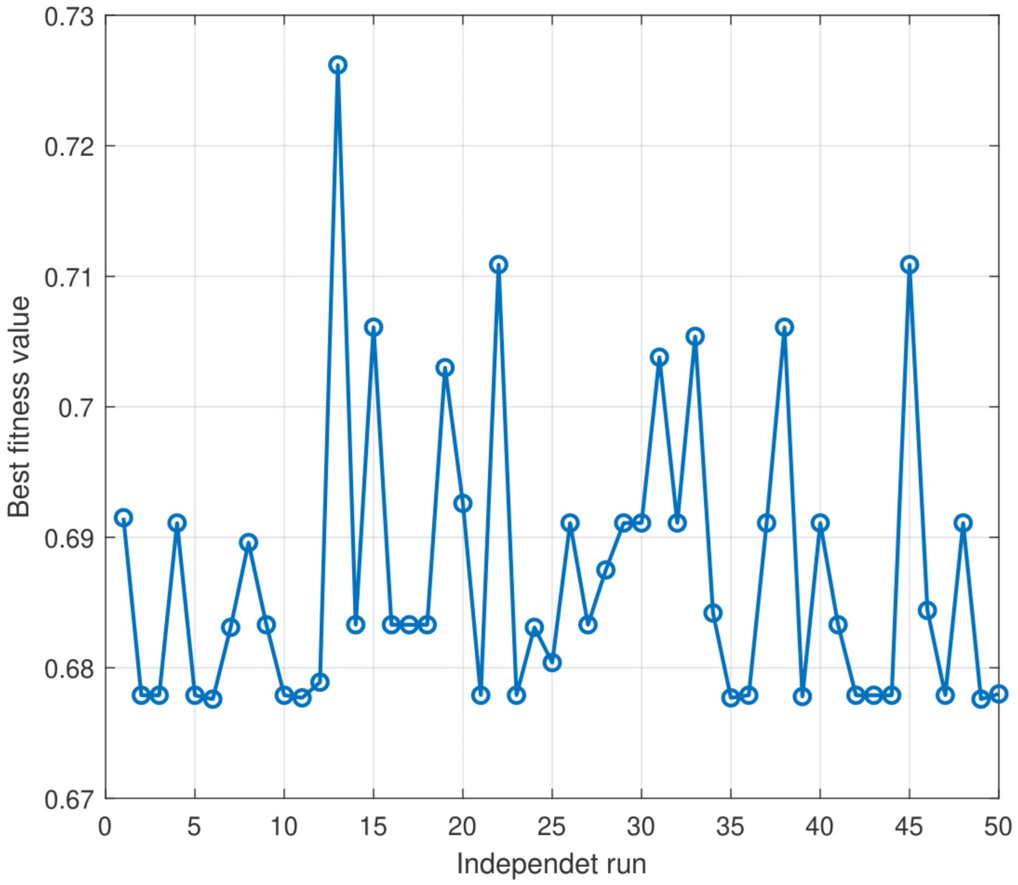
Result & Discussion

- The problem formulated was solved using TLBO.
- The input parameters for the optimization algorithm are:
  - No. of learners : 5 (design variables)
  - No. of population : 20 (learners)
  - No. of iterations : 100
- With these parameters, the algorithm was run for 50 independent runs.

Result & Discussion

Best fitness values for different independent runs

- The values for best fitness in each independent run are shown in the figure.
- The best fitness value from 50 independent runs was 0.6776 in 6th run.



Result & Discussion

Measure of Central Tendency

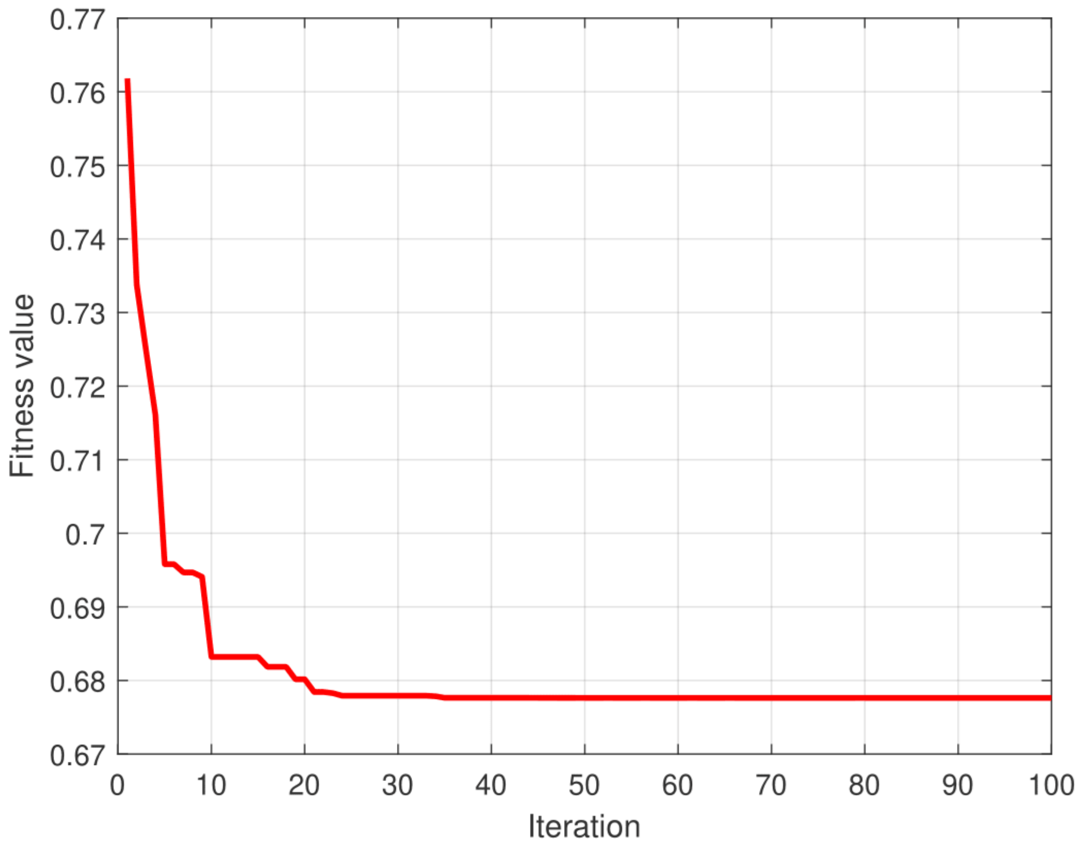
- To measure the central tendency, mean , median, mode and standard deviation(SD) were calculated and presented in the table.
- The solutions are clustered with less standard deviation(SD). So , the solution obtained can be regarded as optimal solution.

Parameter	Value
Minimum	0.6776
Mean	0.6873
Median	0.6833
Mode	0.6779
SD	1.11%

Result & Discussion

Convergence Curve

- Convergence curve for 6th independent run in which the fitness value obtained was 0.6776 is shown in the figure.
- The result was converged before 40th iteration.



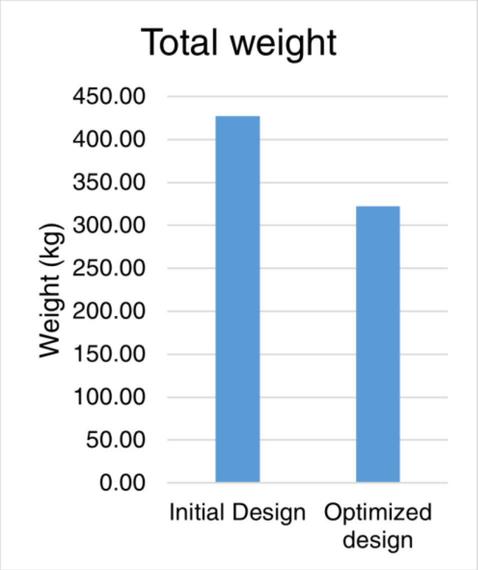
Result & Discussion

Comparison between design variable in initial design and optimized design

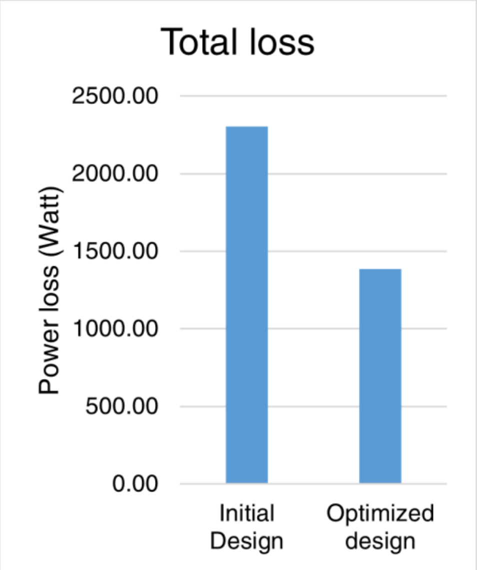
Design variable	Initial	Optimized
Flux density (B_m)	1.35	1.4
Current density (δ)	2.3	4.29
No of core steps (Nc)	2	11
Ratio window height to width ($R_{H\text{-}W}$)	3.5	2.5
Loading factor	1	0.5

Result & Discussion

Parameter	Initial Design	Optimized design	%Improvement
Depth of frame(D)	0.2866 m	0.2534 m	11.58%
Width of frame(W)	0.7124 m	0.6511 m	8.60%
Height of frame(H)	0.7176 m	0.5481 m	23.62%
Weight of core(Wi)	373.54 kg	296.93 kg	20.51%
Core loss(Pi)	1017.8 W	888.53 W	12.70%
Weight of copper(Wc)	53.43 kg	25.11 kg	53.00%
Copper loss(Pc)	1236.2 W	495.77 W	59.90%
clearance(LV)	46.23 mm	4.7138 mm	89.80%
clearance(HV)	300.28 mm	193.01 mm	35.72%
Total weight	426.9789 kg	322.04 kg	24.58%
Total loss	2303.2 W	1384.3 W	39.90%



24.58% reduction in total weight



39.90% reduction in total loss

References

[1] A. Sawhney, “A course in electrical machine design, dhanpat rai & co,” in ed: Publications, 1999.

[2] V. Rajini and V. Nagarajan, Electrical machine design. Pearson Education India, 2018.

[3] K. Nair, Power and Distribution transformers: Practical design guide. CRC press, 2021.

[4] R. V. Rao and R. V. Rao, “Applications of tlbo algorithm and its modifications to different engineering and science disciplines,” Teaching Learning Based Optimization Algorithm: And Its Engineering Applications, 2016.

Thank You