

LB/DON/69/2017

SIZING OF DISTRIBUTION TRANSFORMERS BASED ON "LIFE-CYCLE - COST"

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

Wellana Gamage Pawithra

(128776N)

Dissertation submitted in partial fulfilment of the requirements for the Degree
Master of Science in Electrical Installations

University of Moratuwa



TH3375

TH 3375+

CD-ROM

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

May 2017

621.3 "IT"


696.6 C0#3

TH3375

DECLARATION OF THE CANDIDATE & SUPERVISOR

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: 

Date: 2017-05-26

W.G. Pawithra

The above candidate has carried out research for the Masters Dissertation under my supervision.

UOM Verified Signature

Signature of the supervisor:

Date 26/05/2017

Prof. J.R. Lucas

DEDICATION

*To my loving parents and husband
who always pick me up on time and encourage me to go on every adventure,
especially this one*

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to my advisor Prof. J. Rohan Lucas for the continuous support of my MSc. study and related research, for his patience, motivation and immense knowledge. His guidance helped me all the time of research and in writing of this thesis. I could not have imagined having a better advisor and mentor for my MSc. study.

Besides my advisor, I would like to thank Dr. Asanka S. Rodrigo and Eng. W.D. Anura S. Wijayapala not only for their insightful comments and encouragement, but also for the hard questions which convinced me to widen my research from various perspectives.

Further, I would like to thank my parents and husband for their encouragement and support.

Lastly, I should thank many individuals, friends and colleagues who have not been mentioned here personally in making this educational process a success.

ABSTRACT

Many energy audits in Sri Lanka have identified the installed presence of oversized transformers and excessive number of transformers. No proper study has been done on the effect of the no load losses added to the system due to oversized transformers. Thus, transformers have not always being properly sized at the design stage.

In this research, a sample of bulk consumers from the North Western Province was selected and their installed capacities were compared with the properly sized transformers. Analysis shows that the no load losses can be reduced, on the average by about 40% with the proper sizing. Having identified the importance of proper sizing of transformers, software has been developed to select the optimum transformer capacity comparing the total owning costs of the transformers. The effect of the load pattern, transformer life time, discounting factor and the tariff rate has been considered in the optimization. Also, the software permits the determination of the optimum transformer for a few different load curves as well. The software tool has been validated in comparison with manual calculations.

This software is a useful tool for the bulk consumer as well as electrical consultants to determine the optimum transformer capacity for a given load curve based on total owning cost. The consumer can select the optimum size at the initial stage of the project so that unnecessary future costs due to losses can be minimized. Moreover, this would not only be a blessing to the consumer, but would mean that the overall distribution loss in the total electrical network will be reduced.

Keywords:

Life Cycle Cost, Transformer, Optimization, Load Losses, No load losses, Total Owning Cost

TABLE OF CONTENTS

| | |
|---|-----------|
| DECLARATION OF THE CANDIDATE & SUPERVISOR..... | I |
| DEDICATION..... | II |
| ACKNOWLEDGEMENT | III |
| ABSTRACT..... | IV |
| LIST OF FIGURES | VII |
| LIST OF TABLES | VII |
| LIST OF ABBREVIATIONS..... | VIII |
| 1 INTRODUCTION | 1 |
| 1.1 BACKGROUND | 1 |
| 1.1.1 Adverse impacts of oversized transformers | 1 |
| 1.1.2 Sri Lankan Scenario | 1 |
| 1.2 POWER SYSTEM TRANSFORMERS..... | 2 |
| 1.2.1 Distribution transformers..... | 4 |
| 1.2.2 Transformer losses | 4 |
| 1.3 TOPIC OF RESEARCH..... | 6 |
| 1.3.1 Research Motivation..... | 6 |
| 1.3.2 Problem Statement | 6 |
| 2 LITERATURE REVIEW | 7 |
| 2.1 BACKGROUND | 7 |
| 2.2 TECHNICAL PAPERS REVIEWED..... | 7 |
| 2.3 RESEARCH GAP | 12 |
| 3 RESEARCH METHODOLOGY | 13 |
| 3.1 INTRODUCTION | 13 |
| 3.2 IDENTIFICATION OF RESEARCH GAP | 13 |
| 3.3 THEORETICAL ANALYSIS..... | 13 |
| 3.4 DEVELOP A MODEL TO CALCULATE THE TOTAL OWNING COST | 14 |
| 3.5 VALIDATE THE MODEL..... | 14 |
| 4 THEORETICAL ANALYSIS OF SIZING OF TRANSFORMERS | 15 |
| 4.1 EFFECT OF THE OVERSIZED TRANSFORMERS TO THE SYSTEM..... | 15 |
| 4.2 FACTORS FOR PROPER SIZING OF TRANSFORMERS (LIFE CYCLE COST) | 16 |
| 4.2.1 Technical factors | 16 |
| 4.2.2 Financial factors | 17 |

| | | |
|----------|---|-----------|
| 4.2.3 | <i>Production/business related factors</i> | 17 |
| 4.3 | TYPICAL LOAD PATTERNS CONSIDERED | 19 |
| 4.3.1 | <i>Type A Load Curve: Distribution Load Curve</i> | 19 |
| 4.3.2 | <i>Type B Load Curve:</i> | 20 |
| 4.3.3 | <i>Type C Load Curve:</i> | 20 |
| 4.3.4 | <i>Type D Load Curve:</i> | 21 |
| 4.4 | ASSUMPTIONS AND STANDARDS | 22 |
| 5 | TOTAL OWNING COST OF TRANSFORMERS | 24 |
| 5.1 | BACKGROUND | 24 |
| 5.2 | TOTAL OWNING COST CALCULATION SOFTWARE | 25 |
| 6 | RESULTS | 28 |
| 6.1 | RESULTS OF THE THEORETICAL ANALYSIS | 28 |
| 6.1.1 | <i>Scenario 1 - Effect of Load Pattern</i> | 28 |
| 6.1.2 | <i>Scenario 2- Effect of discounting factor</i> | 29 |
| 6.1.3 | <i>Scenario 3 : Effect of Transformer Life time</i> | 29 |
| 6.1.4 | <i>Scenario 4: Effect of Tariff</i> | 30 |
| 6.2 | RESULTS OF THE SOFTWARE ANALYSIS | 30 |
| 6.2.1 | <i>Scenario 1 - Effect of Load Pattern</i> | 30 |
| 6.2.2 | <i>Scenario 2- Effect of discounting factor</i> | 31 |
| 6.2.3 | <i>Scenario 3: Effect of Transformer Life time</i> | 31 |
| 6.2.4 | <i>Scenario 4: Effect of Tariff</i> | 31 |
| 7 | CONCLUSIONS AND RECOMMENDATIONS | 32 |
| 7.1 | LIMITATIONS | 33 |
| 7.2 | RECOMMENDATIONS AND FURTHER WORK | 33 |
| | LIST OF REFERENCES' | 34 |
| | ANNEXURE | 36 |
| | SOFTWARE CODE | 36 |
| | <i>Main User Form</i> | 36 |
| | <i>Load Curve Method User Form</i> | 36 |
| | <i>Load Pattern User Form</i> | 37 |
| | <i>Variable Confirmation User Form</i> | 46 |
| | <i>Output Display Form</i> | 47 |



LIST OF FIGURES

| | |
|---|----|
| Figure 4-1: Type A load curve | 19 |
| Figure 4-2: Type B load curve..... | 20 |
| Figure 4-3: Type C load curve..... | 20 |
| Figure 4-4: Type D load curve | 21 |
| Figure 4-5: Equivalent two step load curve according to IEC 60354 | 22 |
| Figure 4-6: Overload curve according to IEC 60354 | 23 |
| Figure 5-1: Software development algorithm..... | 25 |
| Figure 5-2: Interface of the software | 26 |
| Figure 5-3: Variable inputs..... | 27 |
| Figure 5-4: Results–Evaluated best transformers..... | 27 |

LIST OF TABLES

| | |
|--|----|
| Table 2-1: Total Owning Cost Calculation Comparison..... | 8 |
| Table 2-2: Monthly Energy Loss of Total Transformer Circuit..... | 10 |
| Table 2-3: Rating Wise Transformer Losses for 1 Month | 10 |
| Table 4-1: Tariff Rates | 17 |
| Table 5-1: Cost of no load and load losses of 75 kVA transformer | 24 |
| Table 6-1: Total owning cost for different load curves..... | 28 |
| Table 6-2: Total owning cost for different discounting factors..... | 29 |
| Table 6-3: Total owning cost for different transformer life times..... | 29 |
| Table 6-4: Total owning cost for different tariffs..... | 30 |
| Table 6-5: Total owning cost from Software for different discounting factors | 30 |
| Table 6-6: Total owning cost from software for different discounting factors | 31 |
| Table 6-7: Total owning cost for different transformer life times..... | 31 |
| Table 6-4: Total owning cost for different tariffs..... | 31 |

LIST OF FIGURES

| | |
|---|----|
| Figure 4-1: Type A load curve | 19 |
| Figure 4-2: Type B load curve..... | 20 |
| Figure 4-3: Type C load curve..... | 20 |
| Figure 4-4: Type D load curve | 21 |
| Figure 4-5: Equivalent two step load curve according to IEC 60354 | 22 |
| Figure 4-6: Overload curve according to IEC 60354 | 23 |
| Figure 5-1: Software development algorithm..... | 25 |
| Figure 5-2: Interface of the software | 26 |
| Figure 5-3: Variable inputs..... | 27 |
| Figure 5-4: Results–Evaluated best transformers..... | 27 |

LIST OF TABLES

| | |
|--|----|
| Table 2-1: Total Owning Cost Calculation Comparison..... | 8 |
| Table 2-2: Monthly Energy Loss of Total Transformer Circuit..... | 10 |
| Table 2-3: Rating Wise Transformer Losses for 1 Month | 10 |
| Table 4-1: Tariff Rates | 17 |
| Table 5-1: Cost of no load and load losses of 75 kVA transformer | 24 |
| Table 6-1: Total owning cost for different load curves..... | 28 |
| Table 6-2: Total owning cost for different discounting factors..... | 29 |
| Table 6-3: Total owning cost for different transformer life times..... | 29 |
| Table 6-4: Total owning cost for different tariffs..... | 30 |
| Table 6-5: Total owning cost from Software for different discounting factors | 30 |
| Table 6-6: Total owning cost from software for different discounting factors | 31 |
| Table 6-7: Total owning cost for different transformer life times..... | 31 |
| Table 6-4: Total owning cost for different tariffs..... | 31 |

LIST OF ABBREVIATIONS

- CEB : Ceylon Electricity Board
- IEC : International Electrotechnical Commission
- LKR : Sri Lankan Rupees
- TOC : Total Owning Cost
- DF : Discounting Factor
- Tf : Transformer
- Distn : Distribution