

# **An Efficient Method for the Practical Planning of Radial Distribution Network**

*A thesis  
submitted towards the partial fulfillment for  
the requirements of the degree of*

**Master of Engineering  
in  
Power Systems & Electric Drives**



**Thapar University, Patiala**

Submitted By

**Ashutosh Kumar Tiwari**  
(80741004)

Under the Esteemed Guidance of

**Ms. Aabha**  
Lecturer, EIED

JUNE 2009

**DEPARTMENT OF ELECTRICAL AND INSTRUMENTATION ENGINEERING  
THAPAR UNIVERSITY  
PATIALA –147004**

**DEDICATED**  
**TO**  
**MY PARENTS**

## ACKNOWLEDGEMENT

### CERTIFICATE

This is to certify that my work presented in this thesis entitled "**An Efficient Method for the Practical Planning of Radial Distribution Network**" submitted in partial fulfillment of the requirement for the award of the degree of **Master of Engineering in Power Systems & Electric Drives** at **Thapar University, Patiala**, is an original record under supervision and guidance of **Ms. Aabha**.


The matter embodied in this report has not been submitted anywhere for the award of any degree.

Date: 10/07/09

  
(Ashutosh Kumar Tiwari)

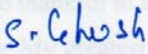
Roll No. - 80741004

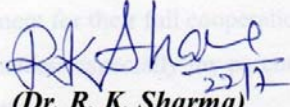
It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

  
10/7/09  
(Ms. Aabha)  
Lecturer, EIED  
(Supervisor)

Thapar University, Patiala

Countersigned By:

  
(Dr. Smarajit Ghosh)  
Professor & Head, EIED  
Thapar University, Patiala

  
22/7  
(Dr. R. K. Sharma)  
Dean of Academic Affairs  
Thapar University, Patiala

## *ACKNOWLEDGEMENT*

The real spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

First of all, I render my gratitude to the ALMIGHTY who bestowed self-confidence, ability and strength in me to complete this work. Without his grace this would never come to be today's reality.

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy Supervisor **Ms. Aabha** in the Department of Electrical and Instrumentation Engineering for her valuable guidance in carrying out this work under her effective supervision, encouragement, enlightenment and cooperation. Most of the novel ideas and solutions found in this thesis are the result of our numerous stimulating discussions. Her feedback and editorial comments were also invaluable for writing of this thesis.

I shall be failing in my duties if I do not express my deep sense of gratitude towards **Dr. Smarajit Ghosh**, Professor and Head of Electrical and Instrumentation Department who has been a constant source of inspiration for me throughout this work.

I am grateful to **Dr. R.K. Sharma**, Dean of Academic Affairs for his constant encouragement that was of great importance in the completion of the thesis.

I extend my thanks to **Dr. K.K. Raina**, Deputy Director, **Dr. Abhijit Mukherjee**, Director Thapar University, for their valuable support that made me a consistent performer.

I am also thankful to all the staff members of the Department for their full cooperation and help. My greatest thanks are to all who wished me success especially my parents, my friends whose support and care makes me stay on earth.

**Ashutosh Kumar Tiwari**

**Roll No. 80741004**

## *ABSTRACT*

The close propinquity of distribution network to the consumers of electricity, it has become necessity to explore the area of practical planning of distribution system. In this work the practical planning of distribution system include the selection of optimal conductor size selection and capacitor placement in radial distribution network.

The optimal conductor size selection, in this work, is based on a practical method which combines the current density based method and a heuristic index directed method. The load flow analysis is carried out to the distributed system power flow. The capacitor placement includes the voltage constraint and load variation. This is done by coggin method. Coggin method is search technique in which quadratic convergence is used. The problem capacitor placement has been represented by a objective function and minimal of the objective function is found using coggin method.

# TABLE OF CONTENT

|   | <b>Page No.</b> |
|---|-----------------|
| <i>CERTIFICATE</i>  | ii              |
| <i>ACKNOWLEDGEMENT</i>                                      | iii             |
| <i>ABSTRACT</i>   | iv              |
| <i>TABLE OF CONTENTS</i>                                    | v               |
| <i>LIST OF FIGURES</i>                                      | vii             |
| <i>LIST OF TABLES</i>                                       | viii            |
| <b>1. INTRODUCTION</b>                                      | <b>1-18</b>     |
| 1.1 Introduction to Electrical Power System                 | 1               |
| 1.1.1 Generation Systems                                    | 2               |
| 1.1.2 Transmission Systems                                  | 3               |
| 1.1.3 Distribution Systems                                  | 5               |
| 1.2 Brief Overview of Distribution System                   | 5               |
| 1.3 Distribution System Configuration                       | 7               |
| 1.4 Primary Distribution Systems                            | 7               |
| 1.4.1 Typical Configurations of Primary Distribution System | 10              |
| 1.5 Secondary Distribution System                           | 11              |
| 1.6 Literature Review                                       | 12              |
| 1.6.1 Load Flow Analysis                                    | 12              |
| 1.6.2 Allocation of Shunt Capacitors                        | 15              |
| 1.6.3 Conductor Sizing                                      | 17              |
| 1.7 Objective of the Thesis                                 | 17              |
| 1.8 Organisation of Thesis                                  | 18              |
| <b>2. DISTRIBUTION SYSTEM PLANNING</b>                      | <b>19-24</b>    |
| 2.1 Planning of Distribution Network                        | 19              |
| 2.2 Different Methods for Planning of Distribution Network  | 21              |
| 2.2.1 Branch and Bound Method                               | 21              |
| 2.2.2 Branch-Exchange Algorithm                             | 22              |
| 2.2.3 Evolutionary Algorithms                               | 23              |
| <b>3. LOAD FLOW ANALYSIS</b>                                | <b>25-33</b>    |

|  |              |
|--|--------------|
| 3.1 Introduction   | 25           |
| 3.2 Distribution System Load Flow  | 25           |
| 3.3 General Case   | 29           |
| 3.3.1 Solution of Dist Flow Equations                                      | 29           |
| 3.3.2 Reduction of Dist Flow Equation                                      | 30           |
| 3.4 Algorithm for the solution of Dist Flow Equations                      | 30           |
| 3.5 Flow Chart for Load Flow   | 33           |
| <b>4. OPTIMAL CONDUCTOR SIZE SELECTION AND CAPACITOR ALLOCATION</b>        | <b>34-45</b> |
| 4.1 Introduction   | 34           |
| 4.2 Problem Formulation  | 34           |
| 4.2.1 Optimization Problem of Conductor Size Selection                     | 35           |
| 4.2.2 Formulation of the Optimization Problem                              | 35           |
| 4.2.2.1 Objective Function   | 35           |
| 4.2.2.2 Constraints  | 36           |
| 4.2.3 Solution Methodology   | 37           |
| 4.2.3.1 Economical Current Density Based Method                            | 37           |
| 4.2.3.2 RCV Index Method   | 38           |
| 4.2.3.3 Flow Chart of RCV Method   | 39           |
| 4.2.3.4 Algorithm for RCV Index Method                                     | 39           |
| 4.3 Allocation of Shunt Capacitor  | 40           |
| 4.4 Single Variable Unconstrained Optimization Approach (Coggin Algorithm) | 43           |
| 4.4.1 Flow Chart for Optimum Size (Coggin Approach)                        | 44           |
| 4.4.2 Algorithm for Optimum Size (Coggin Approach)                         | 45           |
| <b>5. RESULT</b>   | <b>46</b>    |
| 5.1 Results for capacitor placement  | 46           |
| 5.2 Results for conductor gradation  | 53           |
| <b>6. CONCLUSIONS AND SCOPE OF FUTURE WORK</b>                             | <b>54</b>    |
| 6.1 Conclusions  | 54           |
| 6.2 Scope of future work   | 54           |
| <b>REFERENCES</b>  | <b>55-57</b> |
| <b>APPENDIX</b>  | <b>58-59</b> |

# LIST OF FIGURES

| <b>Figure No.</b> | <b>Name of Figure</b>  | <b>Page No.</b> |
|-------------------|--|-----------------|
| Figure 1.1        | Different Parts of Power Systems                                 | 4               |
| Figure 1.2        | A single-line diagram of a distribution substation               | 6               |
| Figure 1.3        | A Primary Distribution Feeder Showing Major Components           | 8               |
| Figure 1.4        | Typical Primary Distribution Systems                             | 10              |
| Figure 1.5        | Service Drops in Distribution System                             | 11              |
| Figure 2.1        | A Loop Interconnection Branch-Exchange and Optimal Flow Pattern  | 22              |
| Figure 2.2        | Urban Distribution Network Configuration                         | 23              |
| Figure 3.1        | One Line Diagram of Radial Distribution Network                  | 26              |
| Figure 3.2        | Flow Chart for Load Flow   | 33              |
| Figure 4.1        | A 33-Bus Radial Distribution Feeder                              | 35              |
| Figure 4.2        | RCV Index Method   | 39              |
| Figure 4.3        | Load Duration Curve  | 41              |
| Figure 4.4        | Typical Distribution Feeder                                      | 41              |
| Figure 4.5        | Flow Chart for Optimum Capacitor Placement Using Coggin Approach | 44              |
| Figure 5.1        | Active Power at Each Node (Without Capacitor Placement)          | 49              |
| Figure 5.2        | Active Power at Each Node (With Capacitor Placement)             | 49              |
| Figure 5.3        | Reactive Power at Each Node (Without Capacitor Placement)        | 50              |
| Figure 5.4        | Reactive Power at Each Node (With Capacitor Placement)           | 50              |
| Figure 5.5        | Path Loss at Each Node (Without Capacitor Placement)             | 51              |
| Figure 5.6        | Path Loss at Each Node (With Capacitor Placement)                | 51              |
| Figure 5.7        | Voltage at Each Node (Without Capacitor Placement)               | 52              |
| Figure 5.8        | Voltage at Each Node (With Capacitor Placement)                  | 52              |



## *LIST OF TABLE*

| <b>Figure No.</b> | <b>Name of Table</b>  | <b>Page No.</b> |
|-------------------|---|-----------------|
| Table 1.1         | Common types of overhead lines                                      | 9               |
| Table 5.1         | Load Flow Results without Capacitor Placement                       | 47              |
| Table 5.2         | Load Flow Results without Capacitor Placement Using<br>Coggin Logic | 48              |
| Table 5.3         | Initial and Final Cross-Section Area of the Conductor               | 53              |
| Table A.1         | Segment Data for 33-Segment Feeder                                  | 58              |
| Table A.2         | Node Load Data of the 33- Segment Feeder                            | 59              |