ON SOME ASPECTS OF OPTIMAL DISTRIBUTION SYSTEM PLANNING

A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

By

M. PONNAVAIKKO

DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, D E L H I
March, 1983

D E D I C A T E D

T O

M Y P A R E N T S

CERTIFICATE

Certified that this work, 'On Some Aspects of Optimal Distribution System Planning', by Mr. Murugesan Ponnavaikko has been carried out under our supervision and that this work has not been submitted elsewhere for a degree.

R.D. Jain
Chief (Monitoring)
Rural Electrification
Corporation Limited
New Delhi 110 019

Dr. K.S. Prakasa Rao
Associate Professor
Department of Electrical Engineering
Indian Institute of Technology, Delhi
New Delhi 110 016

ACKNOWLEDGEMENT

I acknowledge with great pleasure my deep sense of gratitude to Professor K.S. Prakasa Rao, for his constant encouragement, valuable guidance and inspiring suggestions throughout the course of this work. I deem it as my unique privilege to have worked with Professor Prakasa Rao, who has been the motive force behind this work. But for his untiring persuasion and unbounded patience it would not have been possible for me to make this effort a success.

I gratefully acknowledge my sincere thanks to Mr. R.D. Jain, Chief Engineer, Rural Electrification Corporation for his encouragement and valuable advice during the course of this work.

I thank with gratitude Prof. V. Rajamani, Head of the Department of Electrical Engineering for his encouragement, and Prof. P.S.Satsangi and Dr. Suresh Chandra for the useful discussions I had with them during the course of this work. I also thank my friends, colleagues and well-wishers, with particular reference to Prof. K. Parthasarathy and Dr. R. Raghavan, for their advice and encouragement.

I sincerely thank Mr. N. Sriram, Director (Finance) and Mr. S.V.R. Rao, Chief (Consultancy) of Rural Electrification Corporation for their support and encouragement during the course of this work.

I acknowledge my sincere thanks to Mr. P.M. Padmanabhan Nambiar, for his excellent work in typing the manuscript of this thesis. I also thank and appreciate M/s. S.K. Pandit and M.K. Malik, for their help in preparing the drawings.

I am happy to acknowledge the facilities provided to me by the authorities of the Indian Institute of Technology, Delhi, and the Rural Electrification Corporation, New Delhi, during the course of this work.

Finally, I wish to thank my wife Booma and my sons Poongovan and Kovendhan, for their continued patience, tolerance and understanding, making many sacrifices during the course of this work. Without their moral and physical support, this work would never have been accomplished.

M. PONNAVAIKKO

ABSTRACT

This thesis presents the results of the investigation on certain important aspects of optimal distribution system planning. The problems considered are

(a) distribution system parameter optimization,

(b) optimal grading of conductor cross-sections for radial distribution feeders,

(c) optimal sizing and siting of substations and network routing for a specific distribution system, and

(d) optimal choice of fixed and/or switched on-line shunt capacitors along the radial distributors.

The main contributions of this investigation include

(i) development of new concepts for modelling non-uniform loading in a distribution system,

(ii) formulation of mathematical models considering growth factors for the various distribution system components, costs and problems,

(iii) development of simple solution methods and procedures for solving the above problems subject to voltage drop/rise and network constraints, and

(iv) development of simple planning aids for the practicing engineers.

The effect of growth factors such as growth in load factor and increase in cost of energy with time is incorporated in the

parameter optimization problem and a two level optimization technique is suggested for its solution. Simple planning aids in the form of nomograms are also developed for obtaining the feeder power losses, substation feed-areas and the feeder main lengths, to serve the practicing engineer as ready reckoners for his regular system expansion planning. The effect of a variation in the system cost components on the optimal distribution system parameters is demonstrated through the results of a system study using the proposed method. The conductor gradation problem is studied considering the effect of growth factors and the feeder voltage drop constraint using two direct search solution techniques, namely the dynamic programming (DP) and the method of local variations (MLV). Results are presented to clearly demonstrate the effects of growth factors on optimal conductor grading. Nomograms are also developed for obtaining readily the optimal conductor gradation of a given radial distribution feeder. The optimal sizing and siting of substations and network routing problem is formulated as a Quadratic Mixed Integer Programming (QMIP) problem. The solution to this QMIP problem is obtained in two stages using, in the first stage, the procedure developed by Wolfe for solving quadratic programming problems. In the second stage, an integerization procedure is adopted for obtaining the integer values of the integer variables associated with the substation locations and feeder branch elements. The optimization procedure suggested, here, is very effective in obtaining the optimal network solutions without the need for linearizing the non-linear loss cost functions. The optimal capacitor allocation

problem is studied considering the effect of growth factors and the constraint on the nodal voltage rise during off-peak hours due to over-compensation of fixed shunt capacitor banks along the feeder mains. The solution to the problem is obtained using the DP and the MLV. The effect of growth factors and the influence of the cost of capacity release in the feeders on the optimal allocation of fixed and switched shunt capacitors are clearly demonstrated through the results of the sample systems studied.

CONTENTS