OPTIMAL PLACEMENT, SIZING AND DISPATCH OF BATTERY ENERGY STORAGE SYSTEM INTEGRATED DISTRIBUTED GENERATION

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Degree of Master of Science by Research

Department of Electrical Engineering

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DECLARATION

I declare that this is my own work and this thesis 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.

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The above candidate has carried out research for the Masters/~~MPhil~~/~~PhD~~ thesis/ ~~Dissertation~~ under my supervision.

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ABSTRACT

Distributed Generation (DG) has become a key component in modern power industry due its significant advantages over the traditional power generation methods. Nevertheless, it is required to integrate them for distribution networks in such a way that their best expected outcomes can be achieved as inappropriate allocation may impose power system stability, protection and quality issues. This thesis presents novel analytical approaches for optimizing the DG location, size and power dispatch. Analytical methodologies based on formulating objective functions using loss and voltage sensitivities are presented for optimizing the DG location and size. An alternative method for determining the optimal DG sizes which is solved by Lagrange Multiplier Method (LMM) is also presented for better comparison. Moreover, the values obtained for optimal DG sizes from the novel analytical methods are compared with the results obtained by Genetic Algorithm (GA). A novel approach for determining the Battery Energy Storage System (BESS) capacities is presented as a part of developing an optimal power dispatch schedule for BESS units. The time varying nature of loads and DG output are also taken into consideration in this approach. Raw data obtained from a Solar Photovoltaic (SPV) farm in Hambantota area and typical three load profile data (i.e. mix load, residential load and commercial load) obtained from Long Term Generation Expansion Plan (LTGEP) of Ceylon Electricity Board (CEB) are used for modelling the SPV generation and load patterns respectively. The BESS capacities are determined in terms of Load Proportionality Factor (LPF), State of Charge limits (SOC) of battery storages and proportion of off-peak solar period energy consumption expected to be served by each BESS unit. An optimal BESS dispatch algorithm is also presented in this thesis for minimizing the energy losses and voltage deviations. The applicability of the proposed methodologies are tested using standard IEEE-6 and IEEE-33 test bus systems. Simulation results obtained for active power loss variations, voltage profile variations, SOC variations of BESS units and charging/discharging rates of BESS units suggest the acceptability and the appropriateness of the proposed methodologies.

Keywords- *Distributed generation, optimal DG allocation, loss sensitivity index (LSI), voltage sensitivity index (VSI), loss-voltage sensitivity index (LVSI), load proportionality factor (LPF), loss minimization, voltage deviations,*

ACKNOWLEDGEMENT

There were so many officials and non-officials who gave their full contribution and commitment towards the successful completion of my M.Sc. First of all, I would like to acknowledge my supervisors Dr. J.V.U.P. Jayatunga and Prof. H.Y.R. Perera of Department of Electrical Engineering, University of Moratuwa for their constant guidance, supervision and encouragement granted towards me from beginning to the end. Furthermore, I would like to grant my gratitude towards Prof. W.D.A.S. Wijayapala and Dr. Lidula N. Widanagama Arachchige for providing me with valuable advises and suggestions towards the successful completion of my M.Sc. I would also like to appreciate the valuable comments and assistance given by all the other academic staff members which were helpful in achieving the research objectives.

I express my sincere appreciation to the Senate Research Committee (SRC) of University of Moratuwa for providing me with financial support (SRC/LT/2018/23) towards the conduct of this research. Moreover, the support given by the non-academic staff of Department of Electrical Engineering is also commendable.

Finally, I would like to grant my heartfelt thanks to my beloved parents, my research mates and all the others who provided their support and dedication in numerous ways towards the successful completion of my M.Sc.

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LIST OF ABBREVIATIONS

ABCO	:	Artificial Bee Colony Optimization
ACO	:	Ant Colony Optimization
BESS	:	Battery Energy Storage System
BPDF	:	Beta Probability Density Function
CEB	:	Ceylon electricity Board
CSP	:	Concentrated Solar Power
DE	:	Differential Evolution
DER	:	Distributed Energy Resources
DG	:	Distributed Generation
DNO	:	Distribution Network Operator
DP	:	Dynamic Programming
DSO	:	Distribution System Operator
ELF	:	Exact Loss Formula
EV	:	Electric Vehicles
FF	:	Fill Factor
GA	:	Genetic Algorithm
GHG	:	Green House Gases
IA	:	Improved Analytical
IPP	:	Independent Power Producers
LMM	:	Lagrange Multiplier Method
LP	:	Linear Programming
LPF	:	Load Proportionality Factor
LSF	:	Loss Sensitivity Factor
LTGEP	:	Long Term Generation Expansion Plan
MCS	:	Monte Carlo Simulation
MINLP	:	Mixed Integer Non-Linear Programming
MIP	:	Mixed Integer Programming
MPPT	:	Maximum Power Point Tracking
NLP	:	Non-Linear Programming
OP	:	Ordinal Programming
OPF	:	Optimal Power Flow

PSO	:	Particle Swarm Optimization
RES	:	Renewable Energy Sources
SA	:	Simulated Annealing
SBM	:	Sensitivity Based Methods
SCL	:	Short Circuit Level
SOC	:	State of Charge
SPV	:	Solar Photo-Voltaic
SQP	:	Sequential Quadratic Programming
TS	:	Tabu Search
VI	:	Voltage Index
VPP	:	Virtual Power Plant