TECHNO-ECONOMIC VIABILITY OF LARGE SCALE SOLAR INTEGRATION WITH BATTERY STORAGE IN SRI LANKA

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DECLARATION

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ABSTRACT

In Sri Lanka, power is generated from fossil fuel, hydro power and other renewable sources while generation from solar power is prominent in non-conventional Renewable Energy Sources (RESs). Over the past few years large scale Solar PV Power plants (SPVPs) are being added to the national grid at Medium Voltage (MV) distribution network. However, the quality of the distribution networks can adversely be affected, if they are connected without the knowledge of optimum sizes and locations.

In the research performed for outlining of SPVPs in the distribution networks, the output power from the SPVPs are assumed dispatchable without considering the variations of solar potential, which affect the output of the PV modules. Besides this, utilization of electricity generated from the weather dependent SPVPs is also affected by the mismatches in the timings of the electrical supply and demand. The difficulties associated with proliferation of SPVPs could be alleviated by the proper use of Battery Energy Storage Systems (BESSs). The use of BESS for SPVPs has been proposed in many studies, however, the impact of installing BESS on the quality of distribution networks during the sizing of battery storage has been ignored in majority of those research. The computational methods in most existing studies for the sizing and placements of SPVPs and Battery connected SPVPs (B-SPVPs) have used different analytical approaches and heuristic techniques. The analytical approaches are favourable for small systems but are not suitable for large and complex networks.

In this research, the optimal planning for SPVPs and B-SPVPs in terms of size and location in the distribution networks is presented. Solar intermittency has also been considered for the output power from PV modules. The main objective of this study is the development of a model to find out the self-sufficiency level of a Grid Substation in terms of energy required to serve the energy demand within the distribution network as much as possible. Models for proposing sizing and placement of SPVPs and B-SPVPs using heuristic optimization technique called Mixed Integer Programming with Genetic Algorithm (MIGA) was developed, preserving power balances and voltage limits before and after either SPVP or B-SPVP is connected to the distribution network.

To building up the basic model and optimization, Backward-Forward Sweep Load flow was carried out on IEEE 33 Bus network. The outcomes from MIGA were verified using Particle Swarm Optimization (PSO). The objective function was taken as minimization of the percentage of loss reduced when SPVP or B-SPVP is installed with respect to neither SPVP nor B-SPVP is present in the distribution network. The built model was then used to assess self-sufficiency level of Tissa 1 Feeder of Hambanthota GSS. The variability of load over a day was also considered in the modelling. In addition to reduction in power losses resulted after installing SPVP and B-SPVP, the improvements in bus voltages were also found significant. A financial evaluation was carried out to inspect the viability of SPVP and B-SPVP in Tissa 1 feeder of Hambanthota GSS using the optimized results with respect to Simple Payback Period and Levelised Cost of Energy for Tissa 1 feeder. At the closure, suggestions have been put forward as future works for any interested researcher.

DEDICATION

This thesis is dedicated to my parents and husband for being my pillars of success.

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ABBREVIATIONS

Abbreviation	*Description*
ADB	Asian Development Bank
BESS	Battery Energy Storage System
BFSF	Backward-Forward Sweep Flow
B-SPVP	Battery energy storage connected solar PV power plant
PDF	Probability Density Function
CEB	Ceylon Electricity Board
DG	Distributed Generator
DER	Distributed Energy Resource
DP	Dynamic Programming
GA	Genetic Algorithm
GSS	Grid Substation
IRR	Internal Rate of Return
IT	Information Technology
LCLTGEP	Least Cost Long Term Generation Expansion Plan
LCOE	Levelized Cost of Energy
LiB	Lithium-ion battery system
MIGA	Mixed Integer Genetic Algorithm for Linear Programming
MV	Medium Voltage
OE	Optimum Energy Level
PPA	Power Purchase Agreement
PSO	Particle Swarm Optimization
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RES	Renewable Energy Sources
RTS	Reliability Test System
SPP	Simple Payback Period
SPVP	Solar PV power plant
TELI	Total Energy Loss Index
UNFCCC	United Nations Framework Convention on Climate Change
US	United States