MAXIMIZING SOLAR PV INTEGRATION BY ENHANCING HOSTING CAPACITY OF LV NETWORKS USING SMART INVERTERS AND BATTERY ENERGY STORAGE SYSTEMS: A CASE STUDY

Dissanayake Mudiyanselage Krishan Chathuranga Dissanayake

(208671X)

Degree of Master of Science in Electrical Installations

Department of Electrical Engineering

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DECLARATION OF THE CANDIDATE & SUPERVISOR

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

Signature of the supervisor: Date: 28.07.2025

(Prof. W.D.A.S. Wijayapala)

Abstract

The integration of rooftop solar photovoltaic (PV) systems in Sri Lanka, particularly within buildings governed by provincial councils, has been increasing in response to national renewable energy goals. However, the rapid increase of solar PV integration in low-voltage (LV) distribution networks presents considerable technical challenges, notably voltage rise exceeding maximum allowable limits, feeder capacity limitations and transformer capacity limitations. These issues are further compounded by high grid augmentation costs, rendering conventional methods such as feeder upgrades and transformer upgrades economically unfeasible, especially for small to medium-scale PV systems under 42 kVA. As a result, utility providers have imposed restrictions on new PV connections, hindering the full realization of solar energy potential in the region.

This study investigates a cost-effective and technically viable alternative to enhance PV hosting capacity by integrating smart inverters and battery energy storage systems (BESS). A detailed case study was conducted on a 160 kVA transformer located in a solar-rich area in Kotte, where data from actual consumer loads and solar installations were used to model real-world conditions. A series of simulations were developed using MATLAB, exploring different configurations of solar PV system placement, power factor control strategies (Volt-Var and Watt control), and BESS deployment at various feeder locations.

The results indicate that while smart inverters alone can provide limited improvements in voltage regulation, the combined use of smart inverters with BESS—particularly when strategically located at points of maximum voltage—significantly reduces voltage rise and current surges. This facilitates the integration of an additional solar PV without breaching operational voltage limits. Moreover, cost-benefit analysis reveals that the proposed solution offers substantial economic advantages over conventional grid augmentation, with net savings and an acceptable return on investment.

The study concludes that integrating BESS with smart inverter control is a scalable, technically robust, and economically feasible strategy to increase solar PV penetration in

LV distribution networks, thereby supporting the broader transition toward sustainable energy systems in Sri Lanka.

Keywords: Solar PV penetration, Voltage regulation, Grid augmentation, Power factor correction, Battery Energy Storage Systems (BESS), Feeder hosting capacity, Transformer hosting capacity, Smart inverter controls

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D.M.K.C Dissanayake

(208671X)

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List of Abbreviations

Abbreviation	Description
PUCSL	Public Utilities Commission of Sri Lanka
LECO	Lanka Electricity Company Private Limited
CEB	Ceylon Electricity Board
LV	Low Voltage
MV	Medium Voltage
BESS	Battery Energy Storage System
PV	Photovoltaic
DoD	Depth of Discharge
ROI	Return on Investment