FEASIBLE STUDY ON THE POWER QUALITY ISSUES OF VOLTAGE VARIATION AND HARMONICS DUE TO PV PENETRATION IN LVDN: A CASE STUDY IN NEGOMBO LVDN, SRI LANKA

Sareka Saravanapavan

178634B

Degree of Master of Science

Department of Electrical Engineering

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Sareka Saravanapavan

178634B

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DECLARATION

I, Sareka Saravanapavan declare that this is my own work and this thesis/dissertation 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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Name of the supervisor: Prof. W.D. Asanka S Rodrigo

Signature of the supervisor: Date: 04/02/2024

Abstract

Renewable energy resources are encouraged all over the world to have a green power generation to avoid global warming due to conventional energy sources. As one of a sustainable power source, solar photovoltaic system is considered in micro grid and domestic solar system. Domestic solar systems have a rapid growth in Sri Lanka since last decade and they are connected with the existing low voltage distribution network. Therefore, it causes power quality issues with increasing PV penetration in LVDN.

The common PQ issue arising from PV penetration is the voltage rise. Therefore, a LVDN with voltage rise issue in Negombo, Sri Lanka was selected for the case study of this research. This research focused on a LVDN with low active power existence and high feeder resistance where the voltage rise is due to feeder resistance with increasing PV penetration. This study considered power quality issues of voltage violation, harmonic analysis and power factor violation in the selected LVDN. Analysis of another LVDN with different transformer capacity was also summarized in this study.

The mitigation techniques of active network management and network reinforcement were applied to the LVDN and the response was analyzed. The harmonic results were insignificant with voltage violation. And when the voltage rise was mitigated with tap settings, the harmonic results were more insignificant compared to the previous. Therefore, harmonic analysis was not carried out for further analysis.

The enhancement of hosting capacity with different mitigation techniques was analyzed while considering voltage violation and power factor violation. The mitigation technique of active network management with balancing loads, tap settings and increasing the loading of the network, increased the hosting capacity from 50kW (31% w.r.t t/f capacity) to 108kW (68%) at no cost. Reactive power compensation schemes did not provide solution as it violates the power factor of the network while mitigating the voltage variation and vice versa. Because, the required reactive power to mitigate the voltage rise becomes significant compared to the active power existence in the network. Mitigation technique of energy storage system also did not provide solution for the low load demand LVDN.

The mitigation techniques of network reinforcement methods were applied. It increased the hosting capacity up to 144kW (90%) with upgrading conductor, 153kW (96%) with the installation of OLTC with AVR and the installation of separate PV feeder did not increase the hosting capacity. The cost estimation was done for the mitigation techniques. And it is concluded that the techno economic feasible solution as upgrading conductor with 95sqmm conductor size is selected as the mitigation technique for this existing system.

The conclusions of this study are as follow. The network reinforcement mitigation techniques are more suitable than the reactive power compensation schemes, for a PV penetrated LVDN with low active power existence and high feeder resistance, in order to increase the PV penetration, when the voltage rise is due to the feeder resistance. Reactive power compensation methods are suitable for the network with high active power existence and/or high reactive power existence, otherwise it would violate the power factor and/or voltage. Installation of solar PV system in the LVDN will make the system better, to overcome from the effect of the high feeder resistance and it will increase the loading capability of the network while maintaining PQ standards. The increase in the day time loading of the network, increases the PV penetration. Mitigation techniques of active network management of balancing loads and tap settings also increases PV penetration at no cost in such LVDN. Feeder resistance and loading of the network give more impact in deciding the hosting capacity of such LVDN. Therefore, the network reinforcement techniques are more suitable for LVDN with low active power existence and high feeder resistance. Future analysis can be extended for a small scale LVDN with PV systems including significant nonlinear loads and reactive loads.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
DN	Distribution network
DG	Distribution generators
ESS	Energy storage system
HC	Hosting capacity
LV	Low Voltage
LVDN	Low voltage distribution network
Max	Maximum
Min	Minimum
MV	Medium voltage
MVDN	Medium voltage distribution network
PQ	Power quality
t/f	Transformer
VVC	Volt VAR Control
w.r.t	with respect to