DEVELOPMENT OF COORDINATED VOLTAGE CONTROL MECHANISM FOR MV NETWORKS WITH LARGE SCALE SOLAR PENETRATION

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Degree of Master of Science

Department of Electrical Engineering

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science

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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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M. K. D. Peiris

The above candidate has carried out research for the Masters thesis under my supervision.

Signature of the supervisor:

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Dr. J. V. U. P. Jayatunga

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Dr. D. P. Chandima

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Dr. H. M. Wijekoon

ABSTRACT

With the rapidly increasing solar PV penetration to the Utility Distribution Network (UDN) over the past decade, numerous operational challenges including Power Quality (PQ) problems have become substantial compared with the conventional UDN globally. Primarily, solar photovoltaic (PV) systems were connected to the UDN via Low Voltage (LV) side, however, global trend has been advanced to extract solar energy through Medium Voltage (MV) networks up to date via large scale solar farm integration.

Steady state voltage rise in the distribution feeders is reported as one of the main constraining factors for limiting solar PV deployment in LV and MV networks. In Sri Lankan context, recent studies proved that over voltages stay unavoidable in LV networks with high solar PV penetration. Further, preliminary system studies has shown that over voltages will give rise due to the connection of proposed 1 MW Solar Farms at MV level under the "Battle for Solar Energy" program.

This thesis is a comprehensive study to identify the PQ issues correlated to such MV networks, especially asses the over voltage occurrences during the day time where solar penetration at its maximum. A coordinated decentralized control mechanism is adapted to control the over voltages and maintain the voltage levels within its stipulated limits. Coordination between two decentralized voltage controllers; reactive power control of solar PV inverter and distribution static compensator (DSTATCOM), is proposed to harness the maximum amount of clean energy into the UDN avoiding voltage violations, splitting the MV network into multiple controllable zones.

The coordinated voltage control mechanism was modeled using DIgSILENT PowerFactory simulation platform for IEEE 33-bus radial network, which was further extended to the Mauara feeder of the Embilipitiya Grid Substation of Sri Lanka in order to verify the mitigation of over voltages due to large scale solar penetrations. Finally, the influence of the DSTATCOM location and the dead band voltage of the PV inverter on the voltage profile of the Mauara feeder were analyzed.

Index Terms – Solar penetration, coordinated voltage control, IEEE 33 bus network, DSTATCOM

DEDICATION

To my parents, beloved wife and our daughter.

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M. K. D. Peiris
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LIST OF ABBREVIATIONS

Abbreviation	Description
AC	Alternating current
CEB	Ceylon electricity board
CSD	Current synchronous detection
CSP	Concentrating solar thermal power
DC	Direct current
DER	Distributed energy resource
DG	Distributed generation
DMS	Distribution management system
DSL	DIgSILENT-PowerFactory simulation language
DSTATCOM	Distribution static compensator
DVR	Dynamic voltage restorer
EMD	Empirical decomposition
EPLL	Enhanced phase locked loop
FACTS	Flexible alternative current transmission system
GSS	Grid substation
GW	Giga watt
HV	High voltage
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated-gate bipolar transistor
IO	Input output
ISCT	Instantaneous symmetrical component theory
LCZ	Local controllable zone
LECO	Lanka Electricity Company (Pvt) Ltd
LV	Low voltage
MLC	Minimum mid-day load condition
MOSFET	Metal oxide semiconductor field effect transistor
MV	Medium voltage

MW	Mega watt
OLTC	On-load tap changer
PBT	Power balance theory
PCC	Point of common coupling
PI	Proportional integral
PLL	Phase locked loop
PV	Photovoltaic
PQ	Power quality
RE	Renewable energy
SLSEA	Sri Lanka sustainable energy authority
SRF	Synchronous reference frame
SVC	Static var compensator
TCR	Thyristor-controlled reactor
TLC	Typical mid-day load condition
TSC	Thyristor-switched capacitor
UDN	Utility distribution network
UNFCCC	United Nations Framework Convention on Climate Change

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