ACHIEVING FREQUENCY STABILITY THROUGH CONTROLLED ACTIVE POWER INJECTION USING ENERGY STORAGE SYSTEMS

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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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Name of the supervisor: Prof. K T M U Hemapala

Signature of the supervisor: Date

Name of the supervisor: Prof. J R Lucas

Signature of the supervisor: Date

Abstract

As solar Photovoltaic solar generation increases in the power system the conventional generators are being replaced or lose their dominance. Therefore, the resultant inertia of the system reduces. Due to this reason, in case of a large machine tripping in the system, or a line being tripped, the frequency deviation in a unit time increases compared to the fequency deviation in a system without high solar pentration. By using a fast active power injector to the system, such frequency deviation could be mitigated in a high solar power pentrated system. An energy storage system of such magnitude is not economically possible in the Sri Lankan context.

During a fault in the system, Under Frequency Load Shedding (UFLS) occurs in the feeders and 33 kV feeders are diconected from the grid. A control mechanism has been developed to be used as an Uniterrupted Power Supply for the feeder. so that the feeder's voltage and frequency are kept intact until the system is restored. By incorporating the said method, the selected feeder will not undergo any power interruptions during UFLS, as the fast active power injector which has been developed will cater to supplying the required power to the feeder. The fast active power injection method has been developed by combining both the virtual synchronous generator concept and the indirect current control pulse width modulation technique.

Further, the research also addresses the selection criteria of the Battery Energy Storage System (BESS) to be implemented when developing the fast active power injector.

The study has shown that a unity power factor 50 MW BESS can stop UFLS occurring in case of the tripping of a medium scale power plant or line tripping. and other common system faults. As such a BESS would not be economical, it also shows that a 13.7 MW, 3.88 MWh of BESS would be sufficient to prevent UFLS operating 90% of the time at night peak and day peak, with the UFLS operating probability during the off peak being less than 0.1%. Thus, the study has also shown that depleting the energy storage during the day to account for solar fluctuations would be to great advantage, with building up the battery energy reserves before night time.

Keywords: Battery Energy Storage System, Solar power penetration, Fast active power injection, Under frequency load shedding, Low inertia power system, Virtual synchronous generator.

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Content

List of Figures

List of Tables

List of Abbreviations

BESS	:	Battery Energy System Storage
CEB	:	Ceylon Electricity Board
DoD	:	Depth of Discharge
DFT	:	Discrete Fourier Transformation
ESS	:	Energy System Storage
FFT	:	Fast Fourier Transformation
PV	:	Photovoltaic
PWM	:	Pulse Width Modulation
SoC	:	State of Charge
UFLS	:	Under Frequency Load Shedding
VSG	:	Virtual Synchronous Generator