IDENTIFICATION OF COHERENT GROUPS OF GENERATORS FOR OUT-OF-STEP PROTECTION: A CASE STUDY OF SRI LANKAN POWER SYSTEM

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Degree of 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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Eng. W.D.A.S. Wijayapala

Signature of the supervisors: Date:

Eng. D.G.R. Fernando

DEDICATION

I dedicate my M.Sc. research dissertation to my beloved parents and my wife for their guidance given throughout my life.

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Abstract

Power systems are operated with tight stability margins, such that when a power system experiences a fault or disturbance, the generator rotors may subject to severe oscillations. These oscillations in the generator rotor angle translate into severe power flow oscillations (or power swings) across the system. Power swings can be categorized as stable swings, for which, the system itself can recover and the unstable swings, where system cannot recover itself, but need some remedial action to gain the stability. During power swings, magnitudes of voltages and currents can oscillate beyond their nominal values across the system. An unstable power swing condition can be identified as an Out-of-Step (OOS) event, which is a condition of angular instability or a state of Asynchronous Operation (AO) of generators. Out-of-Step event cannot be tolerable for a prolonged period of time due to its negative impact on power system equipment and its integrity. These oscillations might trigger distance relays and other backup relays removing key transmission elements leading widespread outages and even blackouts. Controlled islanding of the system is one of the solutions to isolate the systems operating asynchronously during and OOS event. For this purpose, identification of generator coherency would come in handy in this process of control islanding, where the generators with similar rotor dynamic characteristics swing together forming separate clusters in transmission network. Coherency analysis is fundamental for wide area measurement-based control in a power system. Also, it is important that the coherency identification to become online based, as coherent groups may differ in response to various event and operating conditions. This thesis proposes a generalized methodology to identify coherent groups of generators as an online decision-making approach based on real time data. This methodology will identify generators which tend to swing similarly at the initiation of OOS events based on real time rotor angle trajectories and aid to identify possible clusters within transmission network. Simulation results of OOS events on 2 area 4 generator system, IEEE 16 generator 68 bus system and Sri Lankan power system were used for coherency identification using the proposed methodology. The case study considers the identification of the occurrence of OOS event in Sri Lankan power system, as well as the formation of coherent groups of generators. Results indicate that the proposed methodology correctly identifies the number of groups and assigns each generator to its corresponding group. Further, it suggests the requirement of Wide Area Measurement System (WAMS) to ensure wide area information availability in order to facilitate the real time decision making.

Keywords: Power Swing, Out-of-Step, Generator Coherency, Wide Area Measurement System, Sri Lankan Power System

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List of Abbreviations

Abbreviation	Description
OOS	Out of Step
CEB	Ceylon Electricity Board
DFR	Digital Fault Recorder
PSB	Power Swing Blocking
OST	Out of Step Tripping
WAMS	Wide Area Measurement System
NCRE	Non-Conventional Renewable Energy
SCC	System Control Centre
WECC	Western Electricity Coordinating Council
PMU	Phasor Measurement Unit
GPS	Global Positioning System
SCV	Swing Centre Voltage
HHT	Hilbert Haung Transform
CFT	Continuous Fourier Transform
DFT	Discrete Fourier Transform
ICA	Independent Component Analysis
ANN	Artificial Neural Network
RBF	Radial Basis Function
COI	Centre of Inertia
NETS	New England Test System
NYPS	New York Power System
OEM	Original Equipment Manufacturer
GSS	Grid Sub Station
FCB	Fast Cut Back
LVPP	Lak Vijaya Power Plant
LPC	Local Protection Centre
SPC	System Protection Centre
OPGW	Optical Ground Wire
SCADA	Supervisory Control and Data Acquisition
SL	Sri Lankan