Ain Shams University
Faculty of Engineering

Out-of-Step Detection using Phasor Measurement Units

By

Eng. Zeinab Gamal Hasan Moussa

A Thesis Submitted for the Requirement of the Degree of Master of Sciences in Electrical Power Engineering

Supervised by

Prof. Dr. Almoataz Youssef Abdelaziz

Dr. Amr Mohammed Ibrahim

Cairo 2013

Supervisors Committee

Name, Title and Affiliation Signature

1. Prof. Dr. Almoataz Youssef Abdelaziz
   Electrical Power and Machines Department,
   Faculty of Engineering,
   Ain Shams University.

2. Dr. Amr Mohammed Ibrahim
   Electrical Power and Machines Department,
   Faculty of Engineering,
   Ain Shams University.

Examiners Committee

Name, Title and Affiliation | Signature

1. Prof. Dr. Moussa Awadallah Abdallah
   Vice-Dean of Graduate Studies & Researches,
   Faculty of Engineering at Shoubra,
   Benha University, Egypt.

2. Prof. Dr. Salem Mahmoud Elkhodry
   Electrical Power and Machines Department,
   Faculty of Engineering,
   Ain Shams University.

3. Prof. Dr. Almoataz Youssef Abdelaziz
   Electrical Power and Machines Department
   Faculty of Engineering,
   Ain Shams University.

Statement

This dissertation is submitted to Ain Shams University in partial fulfillment of the requirements for the degree of Master of Sciences in Electrical Engineering.

The work included in the thesis is carried out by the author at the department of Electrical Power and Machines, Ain Shams University.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

Name: Zeinab Gamal Hasan Moussa
Signature:
Date:

Acknowledgement

I would like to thank **Prof. Dr. Almoataz Youssef Abdelaziz,** one of my two thesis supervisors, for his valuable help in seeing this thesis through to its successful completion. Prof. Almoataz has always shown professionalism, dedication and enthusiasm. I am grateful for having had the opportunity to study and to work under his supervision. I would like to thank him for suggesting the research topic, helpful advices, patience, encouragement, reviewing the drafts of the thesis and the time he offered me during supervision.

Also, I would like to thank **Dr. Amr Mohammed Ibrahim**, my other thesis supervisor, for the guidance and advices during the research and for his continuous patience in reviewing the drafts during the preparation of this thesis.

To my parents, my brothers and my family, thanks a lot for your continuous support and encouragement during the research period. To my friend, Riham, your kindness and presence is always my motivation. Finally, to my fiancé, thank you is perhaps not enough. Your patience, support and encouragement have meant a lot to me. I could have not done this thesis without you.

Table of Contents

List of Abbreviations

PMU	Phasor Measurement Unit
GPS	Global positioning system
DFT	Discrete Fourier Transform
TDS	Time Domain Simulation
EAC	Equal-Area Criterion
SMIB	Single Machine Infinite Bus
SCV	Swing Centre Voltage
NN	Neural Network
TSA	Transient Stability Assessment
SVCs	Static VAR Compensators
EMS	Energy Management System
SE	State Estimator
WLS	Weighted Least Square
DFRs	Disturbance Fault Recorders
DSR	Dynamic Swing Recorder
RMS	Root Mean Square
SCADA	Supervisory Control and Data Acquisition
PAs	Parallel Algorithms
SMEB	Single Machine to Equivalent Bus
LEB	Load Equivalent Bus

List of Symbols

A	Accelerating area
B	Decelerating area
t_f	Time of fault inception
D_f	Duration of fault
α_j	Voltage angle of bus-j
ρ_{ij}	Angle of line admittance between bus-i and bus-j
ρ_{ii}	Angle of self-admittance of bus-i from the bus admittance matrix
α_{eqi}	Voltage angle of the equivalent artificial bus connected to machine-i
ρ_{eqi}	Angle of line admittance connected to machine-i
V_j	Voltage of bus-j
Y_{ij}	Magnitude of line admittance between bus-i and bus-j
Y_{ii}	Magnitude of self-admittance of bus-i from the bus admittance matrix
V_{eqi}	Voltage magnitude of the equivalent artificial bus connected to machine-i
Y_{eqi}	Admittance magnitude of the equivalent artificial bus connected to machine-i

List of Tables:

List of Figures

Abstract

The electrical power systems have a huge interconnected network dispersed over a large area. A balance exist between generated and consumed power, any disturbance to this balance in the system caused due to change in load as well as faults and their clearance often results in electromechanical oscillations. As a result there is variation in power flow between two areas (accelerating area and decelerating area). This phenomenon is referred as Power Swing. This thesis presents a transmission line protection scheme that uses measured values of the currents and voltages of the three phases of two buses (equivalent to Phasor Measurement Unit (PMU) data). The measurement in time domain data is transformed into phasor domain using Discrete Fourier Transform to predict whether the swing is stable or not. The performance of the method has been tested on a simulated system using PSCAD and MATLAB software. The proposed scheme can be used for the detection of out of step condition using equal-area criterion with different types of faults at different locations and different models of transmission lines.

The scheme is developed to design power system transient stability assessment using direct methods of reduction for a multi-machine system. The multi-machine system is reduced to groups denoted as Single Machine to Equivalent Bus (SMEB) models and another groups denoted as Load Equivalent Bus (LEB) using Parallel Algorithms (PAs) or it is reduced to a single machine infinite bus (SMIB) system using system reduction. The proposed scheme can be used for the detection of out of step condition using an extension of the equal-area criterion. A three phase fault is simulated at different test systems for different durations.

This thesis deals with Out-Of-Step conditions in a network, how to detect the events and how to make improvements on the protection devices that are being used today. Power systems and stability analysis are studied in general and Out-Of-Step conditions are reviewed in detail.