VOLTAGE SWELL MITIGATION USING ADVANCED FLEXIBLE AC TRANSMISSION SYSTEMS BASED ON EVOLUTIONARY COMPUTATIONAL TECHNIQUES

By

Yasser Mamdouh El-Sayed Mohammed

A thesis submitted in partial fulfillment
Of
The requirement for the degree of

Doctor of Philosophy

In
Department of Electrical Engineering
(Electrical Power and Machines)

Department of Electrical Engineering
Faculty of Engineering, Fayoum

Fayoum University, Fayoum, Egypt
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Approval Sheet

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Date of Examination: ٣ / ١٠ / ٢٠١٩

ABSTRACT

In order to demonstrate and understand many operational and electrical power issues, "Power Quality" term is identified. Power quality studies become more important because of the impacts of economic, operation and safety.

The motivation behind this work is that many industrial consumers may be economically affected by the quality of power. More automation and intelligent equipments have lately been heavily inserted in industry. This means appearance of new electronically devices that are much more affected by any big changes or deviations in power supplies' voltages, currents or frequencies than the previous electromechanically equipments.

From sensitive equipments point of view, quality of the voltage is the most important part of power quality. Voltage disturbances mainly include voltage sags, voltage swells, voltage flickers and voltage harmonics. The definition of "Swell" is the rise of Root Mean Square value of voltage or current, at power frequency, to between ١١٠% and ١٨٠% of their nominal value for a period of time between half cycle and one minute. Voltage swell can blow fuses and trip the circuit breakers due to the creation of large unbalance current, also can damage transformers, or even make malfunction or completely shutdown of sensitive equipment in plants.

One of the most efficient techniques used to mitigate voltage swells is Flexible AC Transmission Systems (FACTS). FACTS forming a modern trend in control engineering linked to power system, using the more recent automatic control theories and technologies and the power electronic circuits and equipments.

The main objective of this research is to give as complete as possible analysis of voltage swell and their mitigation in power systems. There are various mathematical models of FACTS devices developed to study different functions that they can perform in a power system. Studies in the past focused on making models and estimate the optimum place of FACTS devices in order to mitigate voltage swell problem. In this approach the effect of FACTS on the whole network and on the nearby buses is neglected. So the analysis should be extended to the system level so that to accurately estimate the involvement of FACTS devices to system swell performance. This thesis deeply studies the steady state and dynamic

performance of the power systems with application of traditional FACTS controllers and also proposed Advanced FACTS controllers.

For every voltage swell magnitude, evolutionary computing methods will be used to determine the parameters of the traditional FACTS like inductor and capacitor values and also to get the best values of PI controller gains connected to the traditional FACTS. So by formation of the variable inductance and capacitance FACTS with variable controller gains for each swell magnitude, we can introduce a new idea namely Advanced Flexible AC Transmission System (AFACTS). Hence, AFACTS applied with various power system networks to deeply study their affects on the steady state and transient performance of the network during any magnitude of voltage swell. Results were compared to traditional FACTS, showing that the performance of the proposed AFACTS is better than the traditional one.

The thesis is organized in six Chapters.

Chapter ١: Introduction

This Chapter takes about general overview of the work as well as the objectives.

Chapter ٢: Flexible AC Transmission Systems

This Chapter explains the steady state characteristics, operation, and the structure of Thyristor Controlled Reactor (TCR) and the Synchronous Voltage Source (SVS) based FACTS devices. Also this Chapter presents a survey of previous published papers about Voltage Swell mitigation with FACTS devices.

Chapter ٣: Evolutionary Computation Technologies

This Chapter introduces optimization technology used in proposed AFACTS devices like, Particle Swarm Optimization (PSO); Adaptive Weighted Particle Swarm Optimization (AWPSO); Adaptive Accelerated Coefficient Particle Swarm Optimization (AACPSO); Modified Adaptive Accelerated Coefficient Particle Swarm Optimization (MAACPSO); Whale Optimization Algorithm (WOA), and Gray Wolf Optimization (GWO).

Chapter ٤: Procedure of Voltage Swell Mitigation

This Chapter presents a comprehensive analysis of swell mitigating solution. The Chapter also describes developed software for voltage swell assessment. The main target in this Chapter is reaching the fitness function to be optimized by previously mentioned Evolutionary Computing methods to achieve real criteria on a real world transmission networks and the structures of the software are briefly discussed.

Chapter ٥: Simulation and Result

This Chapter presents the use of Power Systems Computer Aided Design (PSCAD) package to simulate the system under study to mitigate voltage swell by AFACTS based on PSO, AWPSO, AACPSO, MAACPSO, WOA, and GWO. Also in this Chapter, the results of the proposed AFACTS were compared to those of Traditional FACTS showing superiority of proposed AFACTS over the Traditional FACTS to mitigate several magnitudes of swell. This Chapter indicates also achievements of the research.

Chapter ٦: Conclusion and Future Work

This Chapter gives a summary of the introduced research and highlights the major conclusion of this work. It also introduces where additional work is required and suggests possible approaches.

The thesis contains also an updated list of References as well as Appendices.