Ain Shams University
Faculty of Engineering
Engineering Physics and Mathematics Department

Use of Optimization Techniques to Enhance Power System Performance

By

Ibrahim Mohamed Diaa El-Din Ibrahim Elsayed

B.Sc. Electrical Engineering, Ain Shams University, 2014

A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Engineering Mathematics

Supervised by

Prof. Dr. / Niveen Mohamed Khalil Badra

Faculty of Engineering, Ain Shams University

Dr. / Mahmoud Abdallah Attia Ibrahim

Faculty of Engineering, Ain Shams University

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Examiners Committee

Title, Name & Affiliation	**Signature**
Prof. Dr. / **Fahmy Metwali Ahmed Bendary** Faculty of Engineering, Shoubra, Benha University	……………………..
Prof. Dr. / **Almoataz Youssef Abdelaziz** Faculty of Engineering, Ain Shams University	……………………..
Prof. Dr. / **Niveen Mohamed Khalil Badra** Faculty of Engineering, Ain Shams University	……………………..

Date: 7 / 8 / 2017

Researcher Data

Name : Ibrahim Mohamed Diaa El-Din Ibrahim Elsayed

Date of birth : 1/3/1993

Place of birth : Giza

Academic Degree : B.Sc. in Electrical Engineering.

Field of Specialization : Electrical Power and Machines

University issued the degree: Faculty of Engineering, Ain-Shams University.

Date of issued degree : 2014

Current job : Demonstrator in Faculty of Engineering, Ain-Shams University.

STATEMENT

This thesis is submitted as partial fulfillment of M.Sc. degree in Engineering Mathematics, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

Ibrahim Mohamed Diaa El-Din Ibrahim Elsayed

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ABBREVIATIONS

FACTS	Flexible AC Transmission Systems
TCSC	Thyristor-Controlled Series Capacitor
HS	Harmony Search Algorithm
TLBO	Teaching-Learning-Based Optimization
WOA	Whale Optimization Algorithm
NLP	Nonlinear Programming
HS-NLP	Harmony Search Algorithm and Nonlinear Programming hybrid approach
MINLP	Mixed-Integer Nonlinear Programming
AI	Artificial Intelligence
IP	Interior Point
LP	Linear Programming
Max	Maximum
Min	Minimum
PSO	Practical Swarm Optimization
QP	Quadratic Programming
TCR	Thyristor Controlled Reactor
C range	Capacitive Range
L-C range	Inductive – Capacitive range
KKT	Karush–Kuhn–Tucker
HM	Harmony Memory
HMS	Harmony Memory Size
HMCR	Harmony Memory Consideration Rate
PAR	Pitch Adjustment Rate
MaxImp	Maximum Number of Improvisations

Thesis Summary

Recently meta-heuristic optimization techniques were widely used to solve optimization problems to avoid the long time taken by classical techniques. The main objective of this thesis is to discuss a new hybrid optimization technique that combines between the accuracy of the classical techniques and the speediness of the meta-heuristic optimization techniques.

The new hybrid technique was tested on a very complex optimization problem and compared with other artificial and classical techniques. The problem is to find the best location and sizing of Flexible AC Transmission Systems (FACTS) to enhance power system performance. The optimization techniques were tested on two different case studies.

In the first case study, the IEEE 30 bus system suffers from the outage of a transmission line and the increase of the load. Two methodologies were proposed to find the optimal location and sizing using various optimization techniques.

In the second case study, the IEEE 9 bus system suffers from the presence of a wind generator. The two best optimization techniques from the previous case study were used to find the optimal siting and sizing of FACTS devices.

Results proved the effectiveness of the new hybrid technique. The new hybrid technique combined the speedy criteria of the artificial techniques and the accuracy of the classical techniques.

Keywords:

Transmission line losses minimization, Flexible AC Transmission Systems, Meta-Heuristic Optimization Techniques, Classical Optimization Techniques, Hybrid Optimization Techniques.

CHAPTER ONE
INTRODUCTION

Transmission networks are nowadays suffering from the increase of the loads which pushes the transmitted power towards the thermal limits. Transmission networks expansion is a proposed approach towards solving this problem, but it has a political, and environmental issues. Another approach is also proposed which is to increase the efficiency of the transmission systems operation.

The insertion of Flexible Alternating Current Transmission Systems (FACTS) devices is proposed as a solution to enhance power system transmission capability, and also to increase system loadability. These devices are power electronic devices which act on transmission system parameters in order to provide power system controllability where the power system security and operational cost increased.

FACTS consist of Series, Shunt types and combined series-shunt FACTS devices. The most effective type used in previous researches is Series and Shunt FACTS. It was widely used due to its effectiveness in the restoration of the system to its stable state. Therefore this type is used in the thesis and specifically the Thyristor-Controlled Series Capacitor (TCSC) devices. The insertion of (TCSC) devices in series with the transmission line allows the control of line reactance in order to decrease line losses and allows more power to be transmitted increasing the utilization of transmission lines. TCSCs insertion may deal with wind power penetration. The optimal location of TCSCs and sizing has a great effect on minimizing power system losses.

The main concern of this thesis is to achieve a new hybrid technique between classical and artificial intellegence optimization techniques in order to take the best accuracy achieved by classical techniques and the speedy criteria of the artificial ones. The goal is achieved through the application of different optimization techniques. Those techniques are classical optimization techniques, meta-heuristic techniques of optimization and the new hybrid technique. These optimization techniques are applied in two cases of power system instability to optimally locate and size TCSC devices in order to restore system stability.

1.1 Transmission Networks

Transmission networks were designed to withstand specific power flow limits. The increase in the load all over the world requires expansion of the transmission network. The connection of renewable energy sources to the grid is proposed as a solution to the increase of load, but it results in great effects in the transmission systems operation. Renewable power requires the availability of primary resources, and they are also located in remote places, showing up the weakness of the transmission infrastructures.

Consequently, some of the transmission lines are overloaded, as they are operated near their stability limit and also thermal limits. As a result of this problem, increasing transmission lines capacity is proposed as a solution; however, this solution has political and environmental issues. So there is no doubt that improving transmission lines efficiency is a good proposed solution in order to solve this problem.

1.2 FACTS devices

FACTS devices are power electronic devices that provide controllability of power system parameters. There are various types of FACTS controllers. FACTS devices are proposed as a solution towards transmission line expansion due to its ability to vary system operation conditions in order to restore system stability which delays the requirements of transmission line expansion. FACTS devices have many advantages such as controlling the power flow, voltage improvement, restoring system's stability margins, and also compensating the reactive power.

FACTS devices have many advantages against mechanical conventional devices which require a lot of maintenance. FACTS devices are categorized into three types, those types are the series, shunt, and the combined series-shunt FACTS devices. Both conventional and FACTS controllers have the same basic principle. The main type used in this study is the TCSC devices and will be discussed in the next section due to its techno-economic benefits than other types.

1.2.1 Thyristor-Controlled Series Capacitor (TCSC)

Thyristor-controlled series compensation (TCSC) has much beneficial importance. Its importance arises in many applications like sub synchronous resonance risks mitigation, active power oscillations damping, and dynamic power flow control. The main concern in this thesis is the power flow control.

TCSC has a great advantage in the applications concerned with the power flow control. The power flows through line doesn't take an intended routes due to the dependence of the power flow on the line impedance. The insertion of TCSC devices in series with transmission lines provides the controllability of the power flowing through lines which have many advantages arising from the minimization of system losses, loop flows reduction, line overloads elimination, and load sharing optimization between parallel circuits.