# AIN SHAMS UNIVERSITY
# FACULTY OF ENGINEERING

ELECTRICAL POWER AND MACHINES DEPARTMENT

# Protection for Flexible Alternating-Current Transmission Systems

A Thesis submitted for the Requirements of the

Degree of DOCTOR OF PHILOSOPHY
In

**Electrical Engineering (POWER AND MACHINES)**

**By**


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# Abstract

FACTS is a new technology using power electronics for controlling the parameters and structures of power systems for improving the power transfer capability of the system.

Thyristor-Controlled Series Capacitor (TCSC) is a series FACTS device which allows rapid and continuous changes of the transmission line impedance. However, this in turn introduces problems in conventional distance protection.

The Static Synchronous Compensator (STATCOM) is introduced as a powerful FACTS tool for reactive power compensation. The measured impedance by distance relay at the relaying point in the presence of a STATCOM on the transmission line depends on the controlling parameters of STATCOM and on its installation location. The conventional distance relay characteristics are greatly subjected to mal-operation in the form of over-reaching or under-reaching the fault point.

This thesis proposes an approach based on Artificial Neural Networks (ANN) using the Total Least Square-Estimation of Signal Parameters via Rotational Invariance Technique (TLS-ESPRIT) for fault type classification and faulted phase selection to be used in the protection of series compensated (TCSC) transmission lines and also for the protection of a transmission line employing STATCOM. The required features for the proposed algorithm are extracted from transient currents and voltages waveforms measured at the substation using TLS-ESPRIT. Since these transient waveforms are considered as a summation of damped sinusoids, TLS-ESPRIT is used to estimate different signal parameters mainly damping factors and frequencies of different modes contained in the signal. Those features can then be employed for fault type classification and faulted phase selection.

Two different learning algorithms are used for training the neural network: Back propagation (BP) and Particle Swarm Optimization techniques (PSO).

System simulation and results which are presented and analyzed in this thesis indicate the feasibility of using neural networks with TLS-ESPRIT in the protection of series compensated (TCSC) transmission lines and for the transmission lines which using STATCOM.

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# Chapter 1

# INTRODUCTION

## 1.1 GENERAL

The use of power electronic devices in AC power systems to improve the power transfer capability of the system forms the basis of the concept of Flexible AC Transmission Systems (FACTS). While the use of FACTS controller aids in the power transfer capability and control of the power system, certain other problems emerge in the field of power system protection, in particular the line protection.

There is a need for an adaptive relay characteristic since the system parameters and configuration are rapidly changed by the FACTS devices.

## 1.2 THESIS OBECTIVE

The objective of this research is to develop an adaptive protection scheme based on the artificial neural network algorithm using Total Least Square- Estimation of Signal Parameters via Rotational Invariance Technique (TLS-ESPRIT) for two different types of FACTS one of them is fixed series in the transmission lines: Thyristor Controlled Series Capacitor (TCSC) and the other is fixed in shunt in transmission line: Static Synchronous Compensator (STATCOM). TLS-ESPRIT extracts the transient voltage and current modal information which is functions in the fault parameters. Then, a Feed Forward-Artificial Neural Network (FF-ANN) is employed to classify the fault type and select the faulted phase by using the extracted modal information. Using two different learning algorithms for training the neural network: Back propagation (BP) and Particle Swarm Optimization techniques (PSO).