



**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**

**AMR MOHAMED IBRAHIM HASSAN**

B. Sc. in Elect. Eng., M. Sc. in Elect. Eng., Ain Shams University

***SUPERVISED BY***

**Prof. MOHAMED MOHAMED MANSOUR**

**Dr. SAID FOUAD MEKHAMER**

**Dr. MOSTAFA IBRAHIM MAREI**

Electrical Power and Machines Department  
Faculty of Engineering  
Ain Shams University  
Egypt

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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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Approval Sheet  
for the Thesis Entitled

**Protection for Flexible Alternating-Current  
Transmission Systems**

Prepared By

**Eng.\ Amr Mohamed Ibrahim Hassan**

B.Sc. Electrical Power Engineering

Submitted in partial fulfillment of the requirements for the  
Ph.D. degree in electrical engineering.

Approved By

| <b>Name</b>   | <b>Signature</b> |
|---|------------------|
| <b>Prof. Dr. Mohamed Abd El-Alim El-Hadidy</b><br>Consultant of Egyptian Electricity Transmission Company |                  |
| <b>Prof. Dr. Ahmed Abd El-Sattar Abd El-Fattah</b><br>Faculty of Engineering – Ain Shams University       |                  |
| <b>Prof. Dr. Mohamed Mohamed Mansour</b><br>Faculty of Engineering – Ain Shams University                 |                  |

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جامعة عين شمس – كلية الهندسة

قسم هندسة القوى والآلات الكهربائية

## تقرير موافقه على رسالة لدرجة الدكتوراة

اسم الطالب

عمرو محمد ابراهيم حسن

عنوان الرسالة

وقاية نظم النقل الكهربى المرن

### لجنة الحكم على الرسالة

1- أ.د. محمد عبد العليم على الحديدي

مستشار بالشركة القابضة لنقل الكهرباء.

2- أ.د. أحمد عبد الستار عبد الفتاح

الأستاذ بقسم هندسة القوى والآلات الكهربائية جامعة عين شمس.

### وعن لجنة الإشراف على الرسالة

3- أ.د. محمد محمد سيد منصور

الأستاذ بقسم هندسة القوى والآلات الكهربائية جامعة عين شمس.

### لدراسات العليا

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ختم الإدارة

بتاريخ / /

موافقة مجلس الجامعة

موافقة مجلس الكلية

## **Approval Sheet**

For The thesis:

### **Protection for Flexible Alternating-Current Transmission Systems**

Presented by

**Eng. AMR MOHAMED IBRAHIM HASSAN**

Submitted in partial fulfillment of the requirements for the  
Ph.D degree in electrical engineering

Approved by

Name

Signature

Prof. Dr. MOHAMED MOHAMED MANSOUR

Dr. SAID FOUAD MEKHAMER

Dr. MOSTAFA IBRAHIM MAREI

Date:     /     / 2008

# **CONTENTS**

| <b>Subject</b>  | <b>Page</b> |
|---|-------------|
| <b>CHAPTER (1): INTRODUCTION</b>  |             |
| 1.1 GENERAL   | 1           |
| 1.2 THESIS OBJECTIVE  | 1           |
| 1.3 THESIS CONTENTS   | 2           |
| <b>CHAPTER (2): PROTECTION FOR FLEXIBLE ALTERNATING-CURRENT TRANSMISSION SYSTEMS: BASIC CONCEPTS AND LITERATURE</b> |             |
| 2.1 GENERAL   | 4           |
| 2.2 Thyristor Controlled Series Capacitor (TCSC)  | 5           |
| 2.3 Static Synchronous Compensator (STATCOM)  | 7           |
| 2.4 THE IMPACT OF TCSC ON PROTECTION  | 8           |
| 2.5 THE IMPACT OF STATCOM ON PROTECTION   | 8           |
| 2.6 DIGITAL RELAYING ALGORITHMS   | 10          |
| 2.7 PROTECTION OF TRANSMISSION LINES  | 10          |
| 2.7.1 TECHNIQUES BASED ON TRAVELING WAVE  | 11          |
| 2.7.2 PHASE COMPARISON TECHNIQUES   | 11          |
| 2.7.3 DIRECTIONAL COMPARISON RELAY  | 12          |
| 2.8 ADAPTIVE PROTECTION: CONCEPT AND RELATED ISSUES   | 12          |
| 2.9 ANN BASED FAULT DIAGNOSIS: A REVIEW   | 17          |
| 2.10 A SURVEY ON APPLICATION OF SWARM INTELLIGENCE COMPUTATION TO ELECTRIC POWER SYSTEM                             | 22          |
| 2.10.1 SWARM INTELLIGENCE COMPUTATION   | 23          |
| 2.10.2 APPLICATIONS OF SWARM INTELLIGENCE IN POWER SYSTEM   | 25          |
| 2.11 THE TOTAL LEAST SQUARES ESPRIT ALGORITHM   | 26          |
| <b>CHAPTER (3): THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)</b>  |             |
| 3.1 INTRODUCTION  | 28          |
| 3.2 CONVENTIONAL SERIES COMPENSATION SCHEME   | 29          |
| 3.3 OVER-VOLTAGE PROTECTION OF SERIES CAPACITORS (METAL OXIDE VARISTOR)   | 30          |
| 3.3.1 NUMERICAL SIMULATION OF MOV-PROTECTED SERIES CAPACITORS   | 32          |
| 3.4 THYRISTOR CONTROLLED SERIES COMPENSATION  | 36          |



|  |    |
|--|----|
| 3.4.1 TCSC Mode  | 36 |
| 3.4.2 Thyristor Switched Reactor Mode (TSR)                        | 36 |
| 3.4.3 Waiting Mode   | 37 |
| 3.5 DESCRIPTION OF THE STUDY SYSTEM                                | 37 |
| 3.5.1 Metal Oxide Varistor Chosen                                  | 39 |
| 3.6 FAULT-INDUCED SIGNALS  | 39 |
| 3.7 SIMULATION RESULTS   | 40 |
| <br><b>CHAPTER (4): THE STATIC COMPENSATOR (STATCOM)</b>           |    |
| 4.1 INTRODUCTION   | 46 |
| 4.2 DESCRIPTION OF THE STUDY SYSTEM                                | 47 |
| 4.3 SIMULATION RESULTS   | 48 |
| <br><b>CHAPTER (5): TLS-ESPRIT</b>                                 |    |
| 5.1 INTRODUCTION   | 56 |
| 5.2 FAULT TRANSIENT MODEL  | 56 |
| 5.3 PROPOSED SYSTEM ARCHITECTURE                                   | 57 |
| 5.4 TLS-ESPRIT ALGORITHM   | 58 |
| 5.5 MATLAB NUMERICAL EXAMPLES                                      | 65 |
| 5.6 TEST SYSTEM SIMULATION RESULTS                                 | 66 |
| <br><b>CHAPTER (6): THE PARTICLE SWARM OPTIMIZER : AN OVERVIEW</b> |    |
| 6.1 GENERAL  | 71 |
| 6.2 INTRODUCTION   | 71 |
| 6.3 SOFT COMPUTING   | 73 |
| 6.4 EVOLUTIONARY COMPUTATION                                       | 74 |
| 6.5 THE EVOLUTIONARY PROCESS                                       | 75 |
| 6.6 EVOLUTIOANRY ALGORITHMS  | 75 |
| 6.6.1 Evolutionary Programming                                     | 77 |
| 6.6.2 Evolution Strategies   | 78 |
| 6.6.3 Genetic Algorithms   | 79 |
| 6.6.4 Genetic Programming  | 80 |
| 6.7 PARTICLE SWARM OPTIMIZER                                       | 82 |
| 6.7.1 Biological and Social behavior                               | 83 |
| 6.7.2 PSO Language and Terminology                                 | 84 |
| 6.7.3 The Standard PSO Algorithm                                   | 88 |
| 6.7.4 The Relation between PSO and EA                              | 93 |
| 6.8 APPLICATIONS OF PSO  | 94 |
| 6.9 NEURAL NETWORK LEARNING USING PARTICLE SWARM OPTIMIZERS        | 95 |
| 6.9.1 Particle Swarm Parameters                                    | 96 |

|                      |    |
|----------------------|----|
| 6.9.2 Swarm Behavior | 97 |
|----------------------|----|

## **CHAPTER (7): Adaptive Protection for FACTS using an Approach Based on Artificial Neural Networks using TLS\_ESPRIT**

|   |     |
|---|-----|
| 7.1 INTRODUCTION  | 98  |
| 7.2 TRANSMISSION LINE WITH TCSC SYSTEM  | 98  |
| 7.3 TRANSMISSION LINE WITH STATCOM SYSTEM   | 100 |
| 7.4 ADAPTIVE PROTECTION SCHEME  | 100 |
| 7.4.1 Neural Network  | 100 |
| 7.4.2 Neural Network Learning using Particle Swarm Optimizers                             | 101 |
| 7.4.3 Neural Network Architectures  | 102 |
| 7.4.4 Feature Extraction  | 102 |
| 7.5 ARTIFICIAL NEURAL NETWORKS  | 103 |
| 7.5.1 The Network Topology  | 104 |
| 7.6 NETWORK TRAINING USING BACK-PROPAGATION ALGORITHM FOR THE PROTECTION OF (TCSC) SYSTEM | 106 |
| 7.6.1 Artificial Neural Network-F (ANNF)  | 106 |
| 7.6.1.1 Test Results  | 108 |
| 7.6.2 Artificial Neural Networks (ANNA, ANNB, ANNC and ANNG)                              | 109 |
| 7.6.2.1 Test Results  | 110 |
| 7.7 NETWORK TRAINING USING BACK-PROPAGATION ALGORITHM APPLIED FOR STATCOM POWER SYSTEM    | 111 |
| 7.7.1 Artificial Neural Network-F (ANNF)  | 111 |
| 7.7.1.1 Test Results  | 111 |
| 7.7.2 Artificial Neural Networks (ANNA, ANNB, ANNC and ANNG)                              | 112 |
| 7.7.2.1 Test Results  | 113 |
| 7.8 NETWORK TRAINING USING PARTICLE SWARM OPTIMIZER TECHNIQUES                            | 114 |
| 7.8.1 Training Phase  | 114 |
| 7.8.2 Testing Phase   | 115 |
| 7.9 CONCLUSION  | 116 |

## **CHAPTER (8): CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK**

|                                     |            |
|-------------------------------------|------------|
| 8.1 CONCLUSIONS                     | 133        |
| 8.2 RECOMMENDATIONS FOR FUTURE WORK | 134        |
| <b>REFERENCES</b>                   | <b>135</b> |

## **LIST OF FIGURES**

| <b>Subject</b>  | <b>Page</b> |
|---|-------------|
| Fig (3.1) Midpoint series compensation  | 31          |
| Fig (3.2) Line ends series compensation   | 31          |
| Fig (3.3) MOV protected series capacitor  | 33          |
| Fig (3.4) A reduced single phase circuit used in calculating the<br>fundamental impedance of the MOV/series capacitor | 35          |
| Fig (3.5) Equivalent series impedance   | 35          |
| Fig (3.6) Thyristor control series capacitor  | 36          |
| Fig (3.7) Study system  | 38          |
| Fig (3.8) A Phase Current (kA), for line to line to ground<br>fault “A-B- G” at 30 % of line                          | 41          |
| Fig (3.9) A Phase Current (kA), for line to line to ground<br>fault “A-B- G” at 70 % of line                          | 41          |
| Fig (3.10) A Phase Current (kA), for line to ground<br>fault “A-G” at 30 % of line                                    | 42          |
| Fig (3.11) A Phase Current (kA), for line to ground<br>fault “A-G” at 70 % of line                                    | 42          |
| Fig (3.12) A Phase Voltage (kV), for line to ground<br>fault “A-G” at 70 % of line                                    | 43          |
| Fig (3.13) A Phase Voltage (kV), for line to ground<br>fault “A-G” at 30 % of line                                    | 43          |
| Fig (3.14) A Phase Voltage (kV), for line to line to<br>ground fault “A-B-G” at 70 % of line                          | 44          |
| Fig (3.15) A Phase Voltage (kV), for line to line to<br>ground fault “A-B-G” at 30 % of line                          | 44          |
| Fig (3.16) B Phase Voltage (kV), for line to line to<br>ground fault “A-B-G” at 30 % of line                          | 45          |
| Fig (3.17) B Phase Current (kA), for line to line to<br>ground fault “A-B-G” at 70 % of line                          | 45          |
| Fig (4.1) Static compensator (STATCOM) system   | 46          |
| Fig (4.2) Power system under study  | 47          |
| Fig (4.3) B Phase Voltage (kV), for line to line to<br>ground fault “A-B-G” at 70 % of line                           | 49          |
| Fig (4.4) A Phase Voltage (kV), for 3 Phase to<br>ground fault “A-B-C-G” at 30 % of line                              | 49          |
| Fig (4.5) A Phase Voltage (kV), for 3 Phase to<br>ground fault “A-B-C-G” at 70 % of line                              | 50          |

|            |  |    |
|------------|--|----|
| Fig (4.6)  | A Phase Voltage (kV), for line to line to ground fault “A-B-G” at 30 % of line               | 50 |
| Fig (4.7)  | A Phase Voltage (kV), for line to line to ground fault “A-B-G” at 70 % of line               | 51 |
| Fig (4.8)  | A Phase Voltage (kV), for line to ground fault “A-G” at 30 % of line                         | 51 |
| Fig (4.9)  | A Phase Voltage (kV), for line to ground fault “A-G” at 70 % of line                         | 52 |
| Fig (4.10) | A Phase Current (kA), for line to ground fault “A-G” at 70 % of line                         | 52 |
| Fig (4.11) | A Phase Current (kA), for line to ground fault “A-G” at 30 % of line                         | 53 |
| Fig (4.12) | A Phase Current (kA), for line to line to ground fault “A-B-G” at 70 % of line               | 53 |
| Fig (4.13) | A Phase Current (kA), for line to line to ground fault “A-B-G” at 30 % of line               | 54 |
| Fig (4.14) | A Phase Current (kA), for 3 Phase to ground fault “A-B-C-G” at 70 % of line                  | 54 |
| Fig (4.15) | A Phase Current (kA), for 3 Phase to ground fault “A-B-C-G” at 30 % of line                  | 55 |
| Fig (4.16) | B Phase Voltage (kV), for line to line to ground fault “A-B- G” at 70 % of line              | 55 |
| Fig (5.1)  | Fault classification algorithm   | 58 |
| Fig (5.2)  | Phase (A) current poles for line to line to ground fault at 30 % of transmission line length | 67 |
| Fig (5.3)  | Phase (A) current poles for line to line to ground fault at 70 % of transmission line length | 67 |
| Fig (5.4)  | Phase (A) voltage poles for line to ground fault at 70 % of transmission line length         | 68 |
| Fig (5.5)  | Phase (A) voltage poles for line to ground fault at 30 % of transmission line length         | 68 |
| Fig (5.6)  | Phase (A) current poles for line to line to ground fault at 70 % of transmission line length | 69 |
| Fig (5.7)  | Phase (A) voltage poles for line to ground fault at 70% of transmission line length          | 69 |
| Fig (5.8)  | Phase (A) voltage poles for line to line to ground fault at 30 % of transmission line length | 70 |
| Fig (5.9)  | Phase (A) current poles for three line to ground fault at 30 % of transmission line length   | 70 |
| Fig (6.1)  | Natural analogy of the PSO search mechanism  |    |

|  |     |
|--|-----|
| (a) Bees searching a field for the location of the most flowers  |     |
| (b) All the bees swarm around the best location over-flying it only to be pulled back in after failing to find a higher concentration of flowers elsewhere | 84  |
| Fig (6.2) The three components of the velocity update equation in a 2-D space  | 91  |
| Fig (6.3) The position update of agents in a 2-D space   | 92  |
| Fig (7.1) Phase A-to-ground fault  | 99  |
| Fig (7.2) Architecture of the neural networks (ANN <sub>f</sub> , ANN <sub>A</sub> , ANN <sub>B</sub> , ANN <sub>C</sub> and ANN <sub>G</sub> )            | 104 |
| Fig (7.3) The ANN proposed scheme  | 106 |
| Fig (7.4) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A- G” at 30 % of line (TCSC) (BP)                                | 125 |
| Fig (7.5) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A- G” at 70 % of line (TCSC) (BP)                                | 126 |
| Fig (7.6) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-B- G” at 30 % of line (TCSC) (PSO)                             | 127 |
| Fig (7.7) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-B- G” at 70 % of line (TCSC) (PSO)                             | 128 |
| Fig (7.8) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-G” at 30 % of line (STATCOM) (BP)                              | 129 |
| Fig (7.9) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-B-G” at 70 % of line (STATCOM) (BP)                            | 130 |
| Fig (7.10) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-B-G” at 70 % of line (STATCOM) (PSO)                          | 131 |
| Fig (7.11) 3-Ph. Voltages (kV), 3-Ph. Currents (kA), ANNs output for line to ground fault “A-B-G” at 70 % of line (STATCOM) (PSO)                          | 132 |

## **LIST OF TABLES**

| <b>Subject</b>   | <b>Page</b> |
|--|-------------|
| Table (2-1) Adaptive transmission system protection techniques | 16          |
| Table (6-1) Some Keywords Used to Describe the PSO Algorithm   | 87          |
| Table (7-9) Training phase (using PSO)                         | 115         |
| Table (7-1) TCSC/BP Results of training ANN-F                  | 117         |
| Table (7-3) TCSC/BP Results of training ANN (A,B,C&G)          | 117         |
| Table (7-2) TCSC/BP Results of testing ANN-F                   | 118         |
| Table (7-4) TCSC/BP Results of testing ANN(A,B,C&G)            | 118         |
| Table (7-5) STATCOM/BP Results of training ANN-F               | 119         |
| Table (7-7) STATCOM/BP Results of training ANN(A,B,C&G)        | 119         |
| Table (7-6) STATCOM/BP Results of testing ANN-F                | 120         |
| Table (7-8) STATCOM/BP Results of testing ANN(A,B,C&G)         | 120         |
| Table (7-10) TCSC/PSO Results of training ANN-F                | 121         |
| Table (7-11) TCSC/PSO Results of training ANN(A,B,C&G)         | 121         |
| Table (7-12) TCSC/PSO Results of testing ANN-F                 | 122         |
| Table (7-13) TCSC/PSO Results of testing ANN(A,B,C&G)          | 122         |
| Table (7-14) STATCOM/PSO Results of training ANN-F             | 123         |
| Table (7-15) STATCOM/PSO Results of training ANN(A,B,C&G)      | 123         |
| Table (7-16) STATCOM/PSO Results of testing ANN-F              | 124         |
| Table (7-17) STATCOM/PSO Results of testing ANN(A,B,C&G)       | 124         |

# **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 OBJECTIVE**

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).