Chapter 1

Introduction

1.1 BACKGROUND

The world's electrical supply sector is going through careful transition. Among the elements causing such remarkable shift are market forces, a lack of natural resources, and a rising need for electricity. A range of legitimate environmental, land-use, and supervisory concerns that hinder the licensing and building of new transmission lines and power plants are impeding many utilities' development plans against this backdrop of rapid evolution.

Transmission lines, transformers, and other auxiliary devices connect generating sources and consumer loads to form a power system. Due to prior economic, political, engineering, and environmental choices, it has a complex structural makeup. Power systems are separated into mesh and longitudinal systems based on their structural characteristics. Power plants can be located close to load centers in densely populated areas to create mesh systems. When a lot of electricity needs to be transported over long distances from power plants to load demand centers, longitudinal systems are typically used.

Regardless of the system's form, the distribution of power flows depends mainly on the impedance of the transmission lines; a transmission line with a low impedance may carry more power than one with a high impedance. The system operator's role is to interfere to achieve power flow redistribution, although with little success. This is not always the greatest outcome because it frequently results in a plethora of operational concerns. Uncontrolled active and reactive power flows can result in several operational problems, such as loss of system stability, power flow loops, high transmission losses, voltage limit violations, the inability to use the thermal limit of transmission lines, cascade tripping, and high transmission losses.

Building of new power plants and transmission lines has historically been a long-term solution to such issues, but it is also an expensive one with slow construction times and opposition from interest groups. The most cutting-edge power electronic tools and techniques, also known as FACTS, or flexible alternating current transmission systems, are projected to be used to upgrade existing transmission corridors to address these operating challenges.

1.2 FLEXIBLE AC TRANSMISSION SYSTEMS

The foundation of the FACTS idea, in its most basic form, is the significant integration of power electronic devices and procedures into the high-voltage side of the network to make it electronically controlled (IEEE/CIGRE', 1995).

Over many years, many of the ideas that form the foundation of FACTS developed. FACTS was nonetheless created in the 1980s at the Electric Power Research Institute (EPRI), the utility division of North American utilities (Hingorani and Gyugyi, 2000). To better regulate power flows on the high-voltage side of the network under both steady-state and transient situations, FACTS looks into ways to take use of the various advancements in high-voltage and high-current power electronics. The process of designing and building power plant equipment, as well as how people see power plants and how transmission and distribution networks are planned and run, have all started to alter because of the new reality of making the power network electronically programmable.

Given that the energy flow channel can now be controlled at high speed, these developments could also influence how energy transactions are carried out. Due to the various economic and technological advantages it offered, FACTS garnered the unwavering backing of electrical equipment makers, utilities, and research organizations across the world (Song and Johns, 1999).

Around the world, many FACTS controller types have been implemented. The most popular types of controllers are load tap changers, phase-angle regulators, static VAR compensators, thyristor-controlled series compensators, interphase power controllers, static compensators, and unified power flow controllers (IEEE/CIGRE, 1995).

The goals of FACTS devices have been threefold:

- To improve transmission networks' capacity for electricity transfer,
- To keep electricity flowing over authorized pathways and boost power transfer effectiveness.
- To achieve total system optimization control.

After more than ten years of development, there are already quite a few members of the FACTS family. Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC)., Static Var Compensator (SVC), Static Synchronous Compensator (SATCOM), Static Synchronous Series Compensator (SSSC), Thyristor-Controlled Series Capacitor (TCSC).

1.2.1 FACTS controllers' function in the management of the power system

Operational problem	Disciplinary action	FACTS controller
Low voltage at a significant load	Supply Q	STATCOM, SVC,
high voltage with a light load	Absorb Q	STATCOM, SVC, TCR
high voltage after an interruption	Absorb Q; prevent overload	STATCOM, SVC, TCR
Low voltage after a failure	Supply reactive power to prevent overload	STATCOM, SVC
Thermal limits: Transmission circuit overload	Reduce overload	TCSC, SSSC, UPFC, IPC, PS
Tripping of parallel circuits	Limit circuit loading	TCSC, SSSC, UPFC, IPC, PS
Loop flows Parallel line load sharing	Adjust series reactance	IPC, SSSC, UPFC, TCSC, PS

Postfault power flow sharing	Rearrange the network or use thermal limit actions	IPC, TCSC, SSSC, UPFC, PS
Reversing the flow of power	Adjust phase angle	IPC, SSSC, UPFC, PS

Table-1.1 FACTS controller's function

1.3 MODELLING PHILOSOPHY

"Power flows" refers to the three most popular iterations of the power system application tool: three-phase power flow, positive sequence power flow, and optimum power flow (Stagg and El-Abiad, 1968). Arrellaga and Arnold (1990). Instances of balanced operations with, respectively, non-optimal and optimum solutions are the subject of the first two examples. The third application focuses on operating inequities caused by imbalances in system load or plant components.

Every model is made with an emphasis on the machinery's actual physical design. This technique has the benefit of providing a flexible modelling methodology that can be applied to assess the performance of plant components in network-wide applications while considering equipment design imbalances that exist in all power plant equipment. If such imbalances are minor and can be ignored in the inquiry, simpler models of plant components, such as sequence domain models, are easier to access.

At the fundamental frequency, steady-state analysis takes this into account, and models are built accordingly. They are ineffective for evaluating both the power systems' dynamic or transient behavior, as well as their periodic steady-state functioning (Acha and Madrigal, 2001). (1994, Kundur).

1.3.1 SVC modeling

SVC is used to inject or absorb reactive power to control a transmission line system's end voltage. The reactive power restrictions of the generator play a major role in determining its stability. For this reason, the reactive power range is shown as follows:

The voltage level is kept between 0.95 and 1.05 PU and is maintained at -100 MVAR QSVC 100 MVAR. When the voltage decreases to 0.95 PU, the assessed 100 MVAR will thus supply 90 MVAR, but 110 MVAR when the voltage increases to 1.05 PU. These data are helpful after inductors are employed to calculate voltage deviation. The reactive power capacity level, which corresponds to the system's maximum loading limit, is 1.795 when the generator's reactive power capabilities are approximated by the constant.

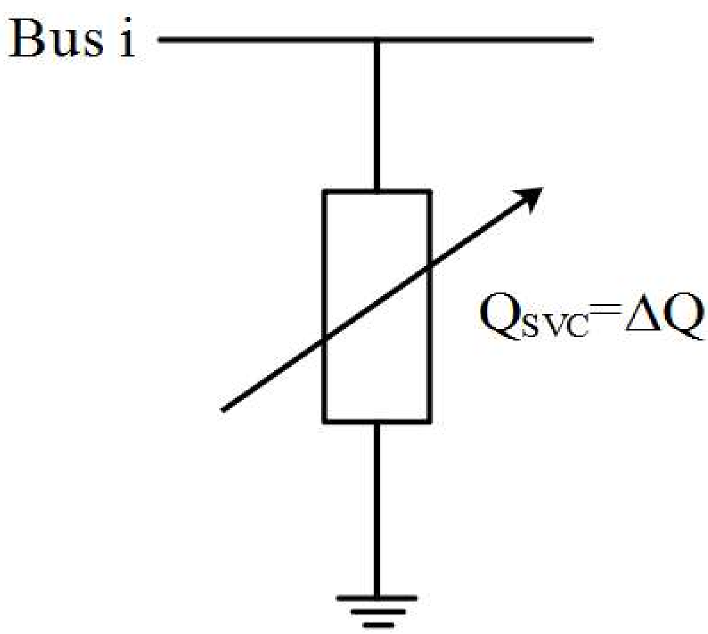

Figure 1.1 Model of SVC

The location of the SVC in a node is expressed in the following equation (6).

$$\Delta Q = Q_{SVC} \quad (6)$$

where the size of SVC is represented as ΔQ. The Reactive Power Dispatch (RPD) issue with SVC placementis given as follows:

The cost function of SVC:

The SVC cost function is specified in equation (7).

$$Cost - svc = 0.0003 \times s^2 - 0.305 \times s + 127.38 \quad (7)$$

where the functional limit of the FACTS device is represented as s.

1.3.2 TCSC modeling

To alter the effective series reactance of the transmission line, the TCSC has capacitive or inductive reactance. The TCSC also improves transient stability and reduces oscillations in inter-area power.

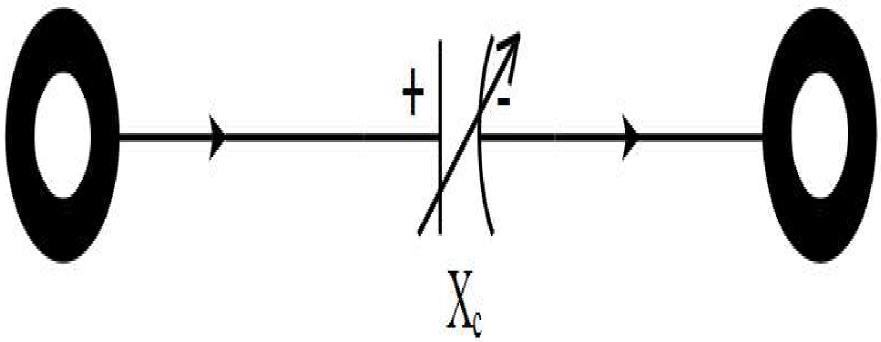

Figure 1.2. Model of TCSC

The location of the TCSC in a node is expressed in the following equation (8).

$$X_{TCSC} = r_{TCSC} . X_{Line} \quad (8)$$

where the transmission line reactance is specified as X_{Line} and $rTCSC$ represents the coefficient that specifiesthe degree of composition by TCSC. The operating range of the TCSC is selected between -0.8X_{Line} and 0.2X_{Line} for avoiding overcompensation.

The cost function of TCSC:

The TCSC cost function is specified in equation (9).

$$Cost - \text{TCSC} = 0.0015 \times s^2 - 0.7130 \times s + 153.75 \quad (9)$$

1.3.3 UPFC modeling

The UPFC modelling is a combination of TCSC, and SVC coupled with the bus, and equation (10) expresses the UPFC power flow.

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin{(\delta_i - \delta_j)}$$

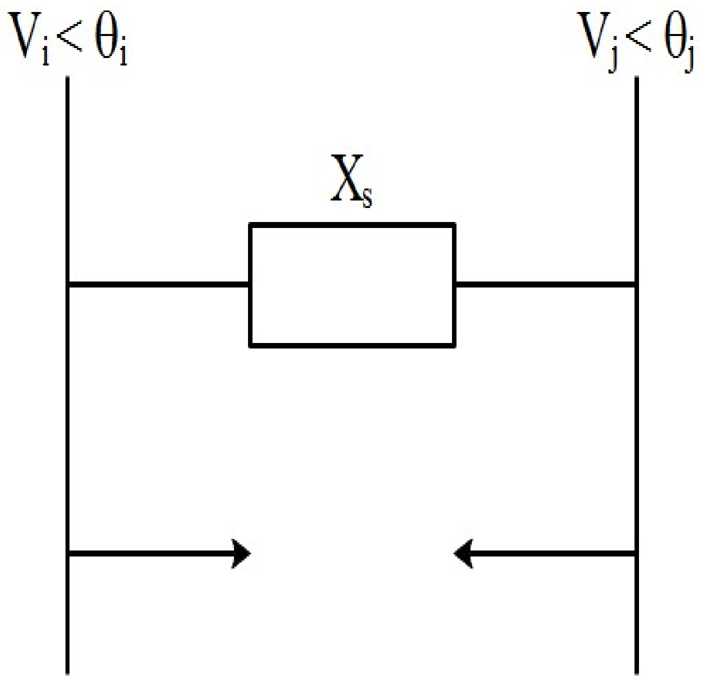

Figure 1.3. Schematic representation of the UPFC

If the UPFC is located between nodes i and j, the admittance matrix between i and j is denoted as Xij, and it is used to adjust the reactance. The Jacobian matrix changes because of the reactance value.

Cost function of UPFC:

The UPFC cost function is specified as

$$Cost\text{−UPFC}=0.0003\times s^2-0.2691\times s+188.22 \quad (11)$$

1.4 Integration of FACT controllers into power system

Three main categories may be used to categories FACTS controller placement in power systems under different operating conditions: sensitivity-based approaches, optimization-based methods, and artificial intelligence-based strategies (Bansal 2005).

1.4.1 Sensitivity Based Methods

Modal, eigen-value, and index analysis are approaches for sensitivity analysis. The Extended Voltage Phasors Strategy (EVPA), suggested by Sharma et al. (2003), the residues-based approach, proposed by Pilotto et al. (1997), and the sensitivity-based approach for positioning FACTS controllers in power systems have all drawn attention.

1.4.2 Optimization Based Methods

The placement of FACTS controllers is optimised using artificial intelligence techniques such as a genetic algorithm (GA), expert system (ES), artificial neural network (ANN), tabu search optimization (TSO), ant colony optimization (ACO), simulated annealing (SA), particle swarm optimization (PSO), and fuzzy logic-based methods. The primary areas of debate have been a static variable compensator, as in Mustafa and Chiew (2008), a genetic algorithm for selecting the optimal phase shifter location, and FACTS controllers, as in Pateni et al. (1999). (2001).

Artificial intelligence methods such as a genetic algorithm (GA), expert system (ES), artificial neural network (ANN), tabu search optimization (TSO), ant colony optimization (ACO), simulated annealing (SA), particle swarm optimization (PSO), and fuzzy logic-based techniques are used to optimise the placement of FACTS controllers. The main points of contention have been a static variable compensator, as proposed by Mustafa and Chiew (2008), a genetic method for choosing the best placement for the phase shifter, and FACTS controllers, as proposed by Pateni et al (1999). (2001).

An information processing paradigm called ANN uses symbols to depict the workings of the human brain. Analyzing ANN-based optimization improves the performance of the entire system. Instead of competing, intelligent strategies can enhance one another. The system is trained to deliver the bus solution with the least amount of power loss based on the tests, prior experiences, and knowledge of the bus. To reach this solution in a way that is both considerably more ideal and practical, optimization techniques are applied.

They have the subsequent advantages:

- They are relatively adaptable in dealing with various qualitative constraints.
- They aid in completing multiple objectives in a single run.
- They can be applied to large-scale power system problems as well as nonlinear mathematical problems.

1.5 Distribution Systems Utilizing FACTS Controllers

Although the FACTS concept was originally developed for transmission networks, it has now been adapted to enhance power quality (PQ) in distribution systems that operate at low or medium voltages.

Initially, "power quality" meant that the power supply would remain consistent at a suitable voltage and frequency. On the other hand, concerns with power quality involving transient disruptions in voltage magnitude, waveform, and frequency have been brought on by the growing use of computers, microprocessors, and power electronic devices. In addition to causing PQ problems, nonlinear loads are also very vulnerable to voltage changes.

Optimal Allocation of SVC, TCSC and UPFC using Kinetic Gas Molecular Optimization and Cuckoo Search Algorithm

The contemporary definition of a PQ issue is "any flaw exhibited in voltage, current, or frequency changes that results in failure or mis operation."

Advantages of Power System Control

The advantages of the extra power system control must be established once the limitations of the power system have been identified and workable solutions have been discovered through system research. Here is a list of some of these benefits:

- More effective use of transmission halls and increased loading
- Flow Control for Additional Power
- Improvements in Power System Stability
- Additional System Security
- Boosted System Reliability
- More Options for Placing New Generation
- Removing or postponing the requirement for a different transmission line

To achieve in the overall design and operation of power systems, the benefits indicated in this list are essential. More precise measures of the advantages to the power system are frequently needed, nevertheless, to compare FACTS controllers to conventional methods and to justify the expenses of adding more power system control. These benefits are frequently related to a particular area or region for a particular season, year, and dispatch (usually given by an ISO or equivalent).

The primary goals are to:

- Identify conventional and FACTS solution options, as well as combinations of these options; and
- Assess the effectiveness of available solution options.
- Keep in mind other issues Location and the economics of the alternatives - Deficiencies -Compatibility with other devices

REQUIREMENTS, BENEFITS, AND LIMITATIONS

Installing FACTS controllers has a number of benefits, including dynamic reactive power compensation, improved steady-state and transient stability, voltage regulation, increased power transfer capacity, three-phase voltage balancing, lower transmission losses, flicker reduction, and oscillation damping. For the needs of the power system, the benefits stimulate the use of FACTS controllers, which results in less expensive expenses than the use of extra generation or new transmission lines (6).

The transmission system requires FACTS Controllers for these overall advantages because

- Regulation and control of steady-state voltage
- managing a transmission line's steady-state power flow
- Improvements in transient stability
- Damping at transmission system oscillation frequencies (0.2-2 Hz)

Stable-state voltage regulation and control are advantageous to the electrical system.

- Shunt capacitor switching, and reduced transformer tap changes.
- Better voltage profiles for consumers; and a system that is better equipped to resist emergencies.

Advantages of

- Unscheduled line flow can be reduced while rising contract flow is allowed using steady-state management of power flow on a transmission line.
- Load regulation, which enables more system mobility
- To avoid ice formation in cold conditions, force current flow.
- Increase voltage control by forcing current flow Benefits of Increasing Transient Stability
- Permit a higher steady state loading
- Lessen the requirement for load shedding or other unique safety measures.
- Lessen the possibility of several contingency events leading to system failure. Benefits of Better Dynamic Stability
- Reduces the requirement for specialized protective systems and permits system operation across a wider variety of loading profiles without power or voltage fluctuations. Just more expensive than substitutes for many uses.

- Power semiconductors need to be larger.
- Costs for semiconductors have not fallen as anticipated
- Generators and other transmission equipment have more transient overload capacity than these devices.
- There is little research on equipment durability and long-term dependability. Technology is always changing and being researched.
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1.6 Optimal Power Flow:

To operate and design power systems, optimal power flow (OPF) has been frequently employed. It is becoming more crucial for the setting of energy pricing as well as the control of traffic in the deregulated environment of the power industry. When analyzing several power plants, transmission links, and demands, OPF is a computationally intensive instrument. Finally, the optimal power flow issue is formulated and solved to integrate the engineering limitations with the economic goals for system operations. OPF is employed in the power system's economic analysis as well.

To maintain acceptable system performance in terms of limits on a generator's real and reactive powers, line flow limits, the output of various compensating devices, etc., one method is to use optimal power flow (OPF), which seeks out a steady state operation point that minimizes generation cost, loss, etc., or maximizes social welfare, loadability, etc.

Reactive power generation dispatch and active power generation dispatch are further formulations of the OPF issue that may exist. The primary objective of the EDP is to identify the generation schedule for the electrical energy system that minimizes overall generation and operation costs while abiding by all system operational limitations, including line overloading, bus voltage profiles, and deviations.

Reactive power dispatch aims to minimize active power transmission losses in an electrical system while meeting all operational requirements. Other than reducing the cost of production and transmission system losses, the goal function of the OPF might take numerous shapes. the control variable settings for the power system's steady-state operations. Among these control factors are those for the transmission system and the generator. Generator MW output may be used as a control variable for generators. The bus voltages of the generator buses, the tap ratio or phase shift angle for transformers, or the settings of switching shunt or flexible ac transmission system (FACTS) devices can all be considered control variables for the transmission system.

Reducing the cost of fuel for power systems is the goal of economic dispatch, sometimes referred to as optimum dispatch. Economic load scheduling of the various producing units or plants in the power system results in the lowest possible fuel costs. Economic load scheduling refers to determining the production of the various generators or plants in a way that minimises overall fuel costs while also ensuring that the whole demand and losses at any one time are fulfilled by the total generation.

Because there are so many different energy sources (coal, oil, or gas; river water; sea tides; solar energy), the decision to choose one over the other is based on economic, technological, or geographic considerations. Due to the lack of facilities for electrical energy storage, a utility's net production (generation plus inflows across its ties) must precisely match its entire load. The primary challenge for a linked system is minimising the source costs. The goal of the economic dispatch issue is to determine each plant's output level such that the overall cost of generation and transmission is as low as possible for a given load schedule.

1.6.1 Features of OPF

Consequently, the key components of ideal power flow are:

- OPF Reduce costs while taking into consideration reasonable equality and inequality limits, such as operational costs.
- OPF essentially combines losses with economic dispatch.
- Bus actual and reactive power balance, generator voltage set points, area MW exchange, and other equality limitations are taken into consideration while constructing OPF.

- The generator MW limitations, the bus voltage magnitudes, the generator reactive power capability curves, and the transmission line transformer interface flow limits are the inequality restrictions.
- Generator MW outputs, transformer taps, phase angles, and other controls are offered.

1.6.2 OPF applications

The OPF has a wide range of uses, such as: -

1. In planning studies, the OPF is frequently used to calculate the highest stress that a proposed transmission system can bear.
2. If the security restrictions are taken into consideration, the OPF can be configured to offer a preventative dispatch.
3. The OPF can offer a corrective dispatch in an emergency, that is, when a system component is overloaded or a bus is experiencing a voltage violation, which informs the system's operators what type of modifications can be done to reduce the overload or voltage violation problems.
4. To obtain the lowest generation cost while still adhering to the transmission system constraints, the optimal generation pattern and all control variables must be calculated.
5. Optimal settings for generating voltages, transformer taps, switchable capacitors, or static VAR components can also be determined regularly using the OPF (called "Voltage-VAR" optimization).

1.7 Organization of the Thesis

This thesis is divided into four chapters that cover the entire research process. The results are then discussed and analyzed. The first chapter is a brief background that describes the philosophy behind the work. This chapter also contains information on how to organize thesis.

Chapter 2 provides a literature survey on essential topics of research in the field. It starts with a general overview of FACTS devices and intelligent techniques. And it also covers various Meta heuristic optimizations techniques. objective and scope also mentioned in the section.

Chapter 3 explains Applicability of optimization algorithm. Hybrid KGMO-CSA approach is proposed and the proposed approach is tested with IEEE 14, 30, and 57 bus test networks and this is highlighted in this chapter.

Chapter 4 discusses the implementation of proposed method on various scenario and comparative analysis is mentation with various objective function with IEEE 14,30 and 57 bus test networks. summarizes the concluding remarks of the research with suggestions to carry out future work.