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Review Article

An Overview of Facts Devices with Optimisation Techniques

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ABSTRACT

FACTS devices control power flow and change bus voltages in electrical power systems, leading to lower system losses and excellent system stability. The article discusses the research from the last decade that evaluated various methods for placing FACTS devices using the meta-heuristic approach to address the positioning of FACTS devices to maintain proper bus voltages and control line flow, and improve the overall system efficiency. Several models and techniques suggest that devices allocate in a particular location with different parameter settings. Finally, the optimization problem improved system performance by decreasing power loss, improving the voltage profile and power angle at each bus, raising the L-index, and minimizing generating costs. FACTS devices can increase the transmission line's capacity for transferring power by increasing the voltage at its terminals at both ends and reducing line reactance.

Keywords: Bus voltages; Line reactance; L-index; Optimisation techniques

INTRODUCTION

The motivation for the review

Reducing power losses and increasing the voltage profile in electrical power transmission lines are essential for our country [1-3].

When the power losses are high in standard levels of developing countries, the stability and reliability of the systems correlate with system losses in deregulated markets.

Although this is a problem, several reduction approaches are still employed globally.

The objective of the review

This work aims to discuss in detail the solutions different researchers took to minimize losses. The continued development of the researchers, the experimental challenges they faced, the outcomes they were able to obtain, and the potential severe measures they implemented to minimize power loss. Learn about the future study field that researchers are developing [4-6].

LITERATURE REVIEW

In a power system network, the load have been increasing daily; using the facts, devices in a network are very close to thermal capabilities and improve system capacity and Transmission line efficiency. All of the variables that influence power losses in transmission systems, such as node voltages, voltage magnitudes, phase angles, and line-reactance, can be controlled by precisely FACTS devices. This section briefly presents the fundamentals of PSO and E.P. algorithms and the methods for relating FACTS device variables to PSO and E.P. parameters. A modern technique includes ANN Methods, S.A. methods, G.A., E.P., A.C.O, and P.S.O and A.I.S. These methods effectively solve optimisation issues when global rather than local solutions are preferred. We have successfully employed these methods to handle an optimisation problem [7,8].

Many researchers have presented sensitivity-based methods in the literature, including those based on jacobian analysis, eigenvalue analysis, nodal analysis techniques, and index methods. The numerous sensitivity based approaches literature include the Jacobian matrix based sensitivity-method, eigenvalue analysis-based methods, optimisation techniques, index methods, residue based methods, and a few other approaches like pole placement techniques, frequency response techniques,

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root-locus techniques, projective control method, nonlinear feed control method, lambda-iteration method, and eigen-sensitivity theory of augmented matrix.

Many optimization based methods have been proposed in the literature, including dynamic optimization programming algorithms network contingency, mixedinteger optimization programming techniques, hybrid-optimization programming algorithms, and non-linear optimization programming techniques. Other techniques include linear optimisation programming techniques, immune based optimisation algorithms, and mixed integer linear programming [9].

Genetic-Algorithms (GA) Fuzzy-G.A, are among the various AI-based methods proposed in the literature. Tabu search-Algorithms evolutionary, population-based evolutionary algorithm, approach based on Simulated Annealing (SA), techniques for Particle Swarm Optimization (PSO), Hybrid-P.S.O, enhanced leader P.S.O, Ant Colony Optimization (ACO) algorithms, fuzzy logic-based approach, hybrid T.S.S.A, Artificial Neural Network (ANN) based algorithms, Bacterial Swarming Algorithm (BSA), harmony search algorithm, and bees algorithm A.B.C algorithm. Hybrid chemical reaction optimisation algorithm, binary bat optimisation, grey wolf optimizer, crow search algorithm, hybrid cat firefly algorithm, cat swarm optimisation, firefly algorithm, atom search optimization, dragon fly algorithm, gravitational search algorithm, cummilative gravitational search algorithm whale optimization algorithm, meta heuristic harmony search algorithm, lightning search algorithm, fractional levy light bat algorithm, hybrid cuckoo search algorithm adaptive cuckoo search algorithm, modified differential evolution. Refined power flow algorithm, multi objective multi verse optimizer algorithm, brainstorm optimization, improved differential harmony search algorithm, PSO adaptive G.S.A algorithm, self-adaptive differential volutionary algorithm, quasi oppositional chemical reaction optimisation, min cut algorithm, parallel seeker optimisation algorithm, hybrid chemical reaction optimization algorithm, M.D.E algorithm, adaptive grahooper optimisation [10].

DISCUSSION

Study of F.A.C.T.S devices

Power electronic converters based facts devices can be used in the transmission line, improving the transmission network's overall efficiency (Table 1). A group of Facts devices which their application, installation cost mva, and system dynamic response (Figures 1-4).

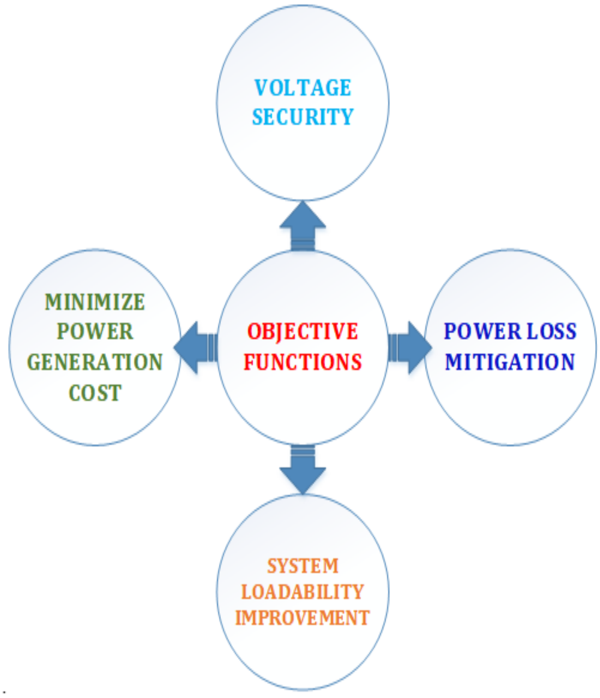

Figure 1: Objective functions of facts devices.

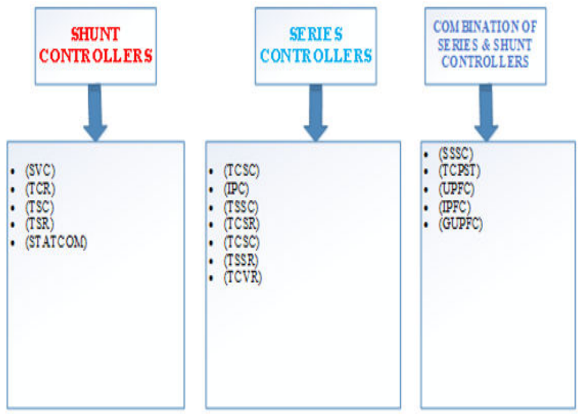

Figure 2: Assessment of facts devices and their works.

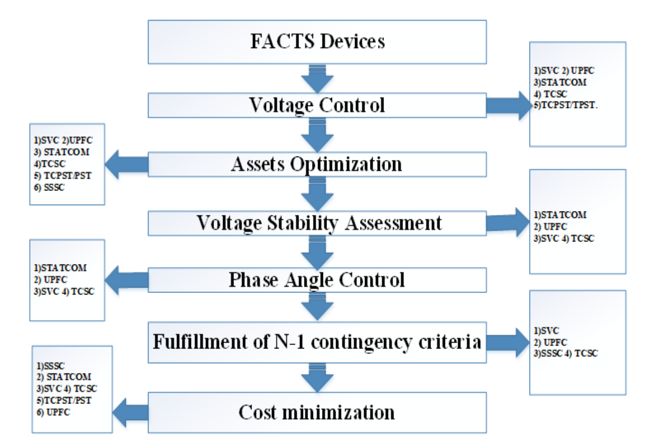

Figure 3: Assessment of facts devices and their works.

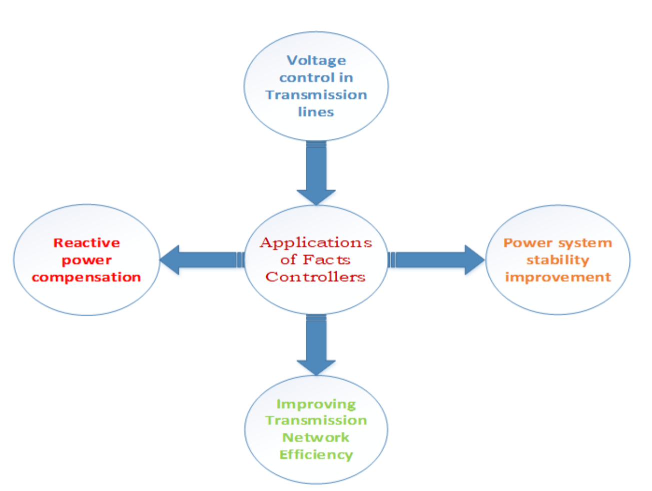

Figure 4: Facts controllers Applications in power systems.

Table 1: Steady-state issues in power system operation.

Challenges	Identification problem	Corrective measures	Traditional approaches	Adding FACTS devices in the circuit
Limiting voltages	At low voltages level at high load	Reactive power supply	Using series capacitors, shunt capacitors and svc	Using S.T.A.T.C.O.M., T.C.S.C.
	At high voltages level at light load	The reactive power supply removed	Using shunt capacitors	Using T.C.S.C., T.C.P.A.R.
		Reactive power absorbed	Svc, shunt capacitor and shunt reactor	Using S.T.A.T.C.O.M., TCR
	Following outages in high voltage	Reactive power absorb	Additional reactor used	TCR
		Protecting equipment	Need additional arrestor.	T.C.V.L.
	Following outages in low voltage	Limiting the overload and supply of reactive power	Switching shunt capacitor, shunt reactor, using svc and switching series capacitor	T.C.S.C., S.T.A.T.C.O.M.
		Overload prevention	Adding series reactor, Tcpar	TCSC,IPFC,UPFC
Physical limits	Overload transformer/line	Overload reduction	Adding transformers/line	U.P.F.C., T.C.P.A.R.
			Addition of a series reactor	I.P.C., TCR
	Trip of parallel circuit	Minimise circuit loadability	Addition of series capacitor, reactor	TCR, U.P.F.C.
Power flow loops	Line load sharing in parallel	Series reactance adjustment	Adding additional series rector/capacitor	TCSC,UPFC,IPC
		Phase angle adjustment	Adding par	T.C.P.A.R.
	Sharing post-fault condition	Rearranging networks	Using series reactor	TCSC,IPC,TCR,TCPAR
	Reversal of power flow direction	Phase angle adjustment	Using par	UPFC,IPC,TCPAR
Level of short circuits	Limit circuit breaker current	Reducing short circuit current	Addition of using a fuse, the reactor	UPFC,SCCL,IPC,TCR

	They remove the circuit breaker when the fault occurs.	Add up on circuit breaker	
	Rearranging of network	Splitting of bus	I.P.C.

Optimisation techniques

Artificial intelligence based techniques, sensitivity based, and optimization based, are used to determine the best location of facts devices in the transmission system (Figure 5) [11].

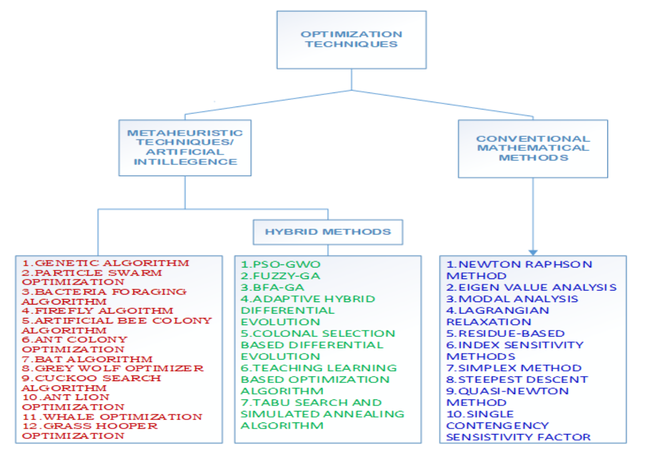

Figure 5: Optimisation techniques.

Sensitivity based methods

Optimal Power Flow (OPF) determines the best possible location for F.A.C.T.S components like T.C.S.C. in Ref. Sensitivity-based methods have addressed the optimal site and regulation of shunt F.A.C.T.S devices for controlling renewable energy resources in power systems (Table 2).

Table 2: Compensation technique for finding objective functions.

Objective functions	Shunt compensation technique	Series compensation technique
Power factor improvement	Major	Minor
Power losses	Minor	Major
Voltage level improvement	Minor	Major
Reduction of voltage fluctuations	Till now, no used	Major

Optimisation programming techniques

The best location of F.A.C.T.S devices used to examine the various techniques, including linear and quadratic programming, nonlinear optimisation programming, integer and mixed integer optimisation programming, and dynamic optimization programming (Table 3).

Table 3: FACTS devices controller's contribution to transmission lines.

Technological functions	Implementation facts controllers
System stability improvement,	T.C.S.C.
Reducing voltage collapse	
Controlling reactive power and true power in transmission line	U.P.F.C.
Harmonics levels reducing	
Voltage controls	S.T.A.T.C.O.M.
Compensation for reactive power	
Power flow control in sub-networks	I.P.F.C.

Voltage profile maintenance	
Power quality improvement	S.V.C.
Voltage regulation	
Power system stability enhancement	S.S.S.C.
Damping power oscillations	

Nonlinear Optimisation Programming (N.L.P.)

In uses a nonlinear optimisation approach to evaluate controlling parameters. Eissa MM, et al. suggests a non-linear interior point O.P.F. method for accessing the devices like G.U.P.F.C [12].

Integer and Mixed Integer optimization Programming (I.P. and M.I.P.) techniques

In a power system transmission network, the integer and mixed integer optimisation programme, the T.C.P.C.S.T, is used to control the actual power loss as well as generation limits and shifting phase angle constraints.

Dynamic Programming (D.P.) Techniques

The Differential Evolution (D.E.) method is employed to solve optimal power flow in power systems using the Unified Power Flow Controller (U.P.F.C.), an efficient and adaptable Flexible A.C. Transmission Systems (FACTS) device, to reduce the generation cost and maintain the power flows within their security limitations [13].

Artificial Intelligence (A.I) Techniques

The best placement of F.A.C.T.S controllers is discussed in this part using a variety of artificial intelligence based methodologies, including a Genetic Algorithm (G.A.). Artificial Neural Network (ANN), Tabu Search Optimisation (TSO), Ant Colony Optimisation (A.C.O.) methodology, Simulated Annealing (S.A.) approach, Particle Swarm Optimisation (PSO) algorithm, and Fuzzy Logic-based approach.

Genetic Algorithm (G.A.)

The ideal placement and U.P.F.C. parameter values are determined using G.A. and PSO to enhance the goal of strengthening power system security under single contingencies. Adopting a hybrid G.A. method for O.P.F. with FACTS devices is recommended. For the best placement of FACTS devices, multi-objective optimal power flow in G.A. G.A. regulates power flow through any transmission line, to enhance system capabilities, the perfect location to place phase shifters and the best quantity to use has addressed using a genetic algorithm. A multi objective evolutionary algorithm selects the Location of FACTS devices for power system security in for enhancing power system load ability. G.A. is to be used to locate upfc in Singh SN, et al. A genetic algorithm determines the best placement of phase shifters in the network to reduce power flows, increase network load ability, and reduce production costs.

Evolution strategies (E.P.)

Evolutionary techniques suggest locating FACTS controllers in power systems in the best possible locations. Optimal allocation of FACTS devices using the evolutionary Algorithm in Reference enhances overall transfer capability. In Reference, Somebody has proposed a hybrid-meta heuristic technique based on evolutionary computing and sequential quadratic programming for the best placement of FACTS Devices like U.P.F.C. in the power system. The ideal location and FACTS device settings are determined in while considering the power loss in transmission lines and voltage deviation buses. A multi-objective evolutionary method is applied.

Tabu search algorithm

The tabu search algorithm is discussed in ref to select the appropriate location for FACTS controllers in power systems. About, the ideal location of facts devices in the transmission network is optimised with the help of a proposed hybrid-meta heuristic technique based on tabu search and nonlinear programming methods.

Simulated annealing algorithm

Reference, Majumdar S, et al. that power loss minimisation with the help of simulated annealing and particle swarm-optimisation techniques. From, Bhasaputra P, et al. the tabu-search, simulated annealing techniques. Suggesting a hybrid-meta heuristic approach based on S.A. and PSO for loss minimization.

Particle Swarm Optimization (P.S.O) algorithms

In ref, Ahmad AA, et al., the control parameters of facts devices with the help of a Particle Swarm Optimisation (P.S.O) from. The P.S.O. technique calculates the installation cost of T.C.S.C and U.P.F.C to find power-system loadability with the help of P.S.O techniques. In, the plan is to allocate F.A.C.T.S based on anticipated security costs using a hybrid PSO. In, the best position for F.A.C.T.S devices is determined using the P.S.O technique, considering installation costs and power system security [14-18].

In, particle swarm optimisation uses U.P.F.C. to find the line outage in the power system network. Suggests optimal locations of multiple S.T.A.T.C.O.M. for improving voltage stability and loadability [19,20].

Fuzzy Logic (F.L. algorithms)

Due to the increasing load on the existing power transmission lines, voltage stability and voltage collapse have become crucial challenges in the design and operation of power systems. Literature addresses these issues. Researchers have discussed a fuzzy logic-based strategy for the best positioning and scaling of FACTS controllers in power systems.

Harmony Search (H.S. algorithm)

The H.S. algorithm determines the ideal location for FACTS devices, including U.P.F.C., T.C.S.C., and S.V.C. Another method for locating multi-type FACTS devices is using the H.S. algorithm incorporating S.V.C., T.C.P.A.R.s, and U.P.F.C.

Key points and observations

Key points

- Many authors contributed their works as the facts devices placed in the bu systems to improve voltage profiles and reduce power loss with the help of bio-inspired algorithms.
- Some papers classified losses as real and reactive power losses. Active power generates heat, light, torque, and other effects.
- Reactive power losses occur because of measuring power factors from inductive load due to causing magnetic flux, failure of motor coils, and heating types of equipment.
- Many authors are looking at the reason for power losses of the existing system, lines, unbalanced phases, poor equipment quality, inadequate conductor size, low power factor, and improper arrangement of protection devices.

Observations

- Particle swarm optimisation is a technique for solving problems discussed in many articles.
- Some authors proposed an optimisation technique like harmony search algorithms based on the performance of musical instruments, which are highly compatible with inserting a few parameters.
- Grey wolf algorithm, the cuckoo search algorithm, and the brainstorm optimisation to place facts devices, reducing the instalment cost and system loadability.
- Generally, some authors have composed a paper with a genetic algorithm, and the newton Rapson method is a primary method to compare voltage stability by incorporating facts devices.
- Some authors have shown that high power losses contribute to increased energy loss in distribution networks. Utilities must minimise power loss in the system to reduce resultant energy loss.
- Many authors raise the issues of other factors that contribute to increased power loss in Transmission systems are as reducing resistance, power factor improvement, reduction of skin effect use, and wrong sizing of conductors.
- Others have only considered absolute power loss minimisation. They are not working with reactive power loss.
- Some authors work only on improving voltage profile and power system stability, not reducing power loss. They are not considering.
- Some authors proposed the location of facts device to decrease cost and system loadaibility withstand limits.

CONCLUSION

This research provides a bibliographical survey of published work on the proper positioning and sizing of FACTS devices in power systems. To investigate the subject, researchers used a variety of heuristic optimisation techniques. As essential guidelines for adequately positioning and sizing FACTS devices, the publication includes a thorough literature analysis and a list of published sources.

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