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Journal of Engineering and Applied Science (2024) 71:18
https://doi.org/10.1186/s44147-023-00312-7

Journal of Engineering
and Applied Science

REVIEWS Open Access

A review of FACTS device implementation in power systems using optimization techniques

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Abstract

In electrical power systems, FACTS devices effectively control power flow and change bus voltages, 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. The need for more efficient electricity systems management has given rise to innovative technologies in power generation and transmission. The combined cycle power station is a good example of a new development in power generation and flexible AC transmission systems, generally known as FACTS, are controllers that improve transmission systems. Worldwide transmission systems are undergoing continuous changes and restructuring. They are becoming more heavily loaded and are being operated in ways not originally envisioned. Transmission systems must be flexible to react to more diverse generation and load patterns. In addition, the economical utilization of transmission system assets is of vital importance to enable utilities in industrialized countries to remain competitive and to survive. In developing countries, the optimized use of transmission systems investments is also important to support industry, create employment and utilize efficiently scarce economic resources. FACTS controller is a technology that responds to these needs. It significantly alters the way transmission systems are developed and controlled together with improvements in asset utilization, system flexibility and system performance. Several models and techniques suggest that devices can be placed 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. The FACTS controller must be installed in the distribution and transmission lines to maximize the power flow. Various techniques are used for the best placement of FACTS controllers, including analytical methods, arithmetic programming approaches, meta-heuristic optimization approaches, and hybrid approaches—this paper analyses numerous analytical and meta-heuristic optimization techniques to place FACTS controllers in the most advantageous locations. The fundamental problems in intelligent power systems, such as improving stability, power quality, and managing congestion, are discussed in this study, along with several applications of FACTS devices. The cutting-edge power systems of today provide users with constant, high-quality power through smart grids and smart meters.

Keywords: FACTS devices, Optimization techniques, Active and reactive power losses, Voltage profile, Power system security

Introduction

In a power system network, the load increases daily, using the FACTS devices in a network that is very close to thermal capabilities, and improves system capacity and efficiency of the transmission line. They are utilized for the highest power flow to support the voltage increasing the transmission line capacity and stability margins [1]. The author of [2] illustrates FACTS devices' effect on reactive and actual power flow using the tracing power flow approach. These power electronic-based devices may redistribute power in congested lines during high-load situations, controlling the active and reactive flow of power in the system. This increases system stability. For already-existing FACTS controllers in India, a survey on different types of FACTS controllers was conducted. TCSC is the first controller to be installed in India. By enhancing impedance and power quality, FACTS controllers provide voltage stability. The author discusses numerous FACTS controllers, their features, and cost comparisons of various controllers like. Series, Shunt, Series-Series, and Series-Shunt controllers are several FACTS controllers. The power transmission capacity of lines is increased via series controllers.

These FACTS devices must be built with great precision to produce good results due to the compensatory strategies and quick activity.

In recent years, the security of transport networks will become one of the major challenges of the future considering the economic and societal impacts of major incidents. The competitive aspect linked to deregulation as well as the difficulty of building new structures will lead operators to optimize infrastructure and architectural equipment, optimal management of energy transfers, effective real-time monitoring and control, etc.

The principal inspirations and novelties for this survey study are presented below:

- The elements or limits that should be considered the best execution with respect to the accuracy of the solution, the speed of convergence and the effectiveness, with the most elevated achievement rate, while supporting the FACTS devices optimization issue are explored. To take care of the FACTS devices optimization issue, a synopsis of various enhancement strategies that have been broadly utilized, like classical optimization techniques, meta-heuristic methods, sensitive index methods and hybrid methods is viewed as in this work.
- This concentrate additionally presents the benefits and drawbacks of numerous advancement procedures which have been utilized for solving FACTS device optimization issues.
- Outline tables including the strategies applied, the test systems utilized, the types of FACTS devices examined and the helpful goals of each revised document.
- A discussion is investigated toward the finish of this work about the qualities and shortcomings of numerous enhancement strategies that have been utilized for solving FACTS device optimization issues.

Nowadays, FACTS devices, based on power electronics, enable tighter continuous control of power flows with the following benefits: maintaining a voltage that is within acceptable ranges at load buses, controlling the flow of active and reactive electrical power in thermally constrained lines, improving safety measures, and operating electrical systems close to their capacity limits are some of the other improvements. Developing tools that enable us to successfully operate electrical networks, including the use of FACTS controllers, is crucial for all of these reasons. In addition, liberalization will impose defining a division of responsibilities as clearly as possible between the different actors who will use this same resource. To ensure or even improve this security, FACTS devices are based on power. Otherwise, it causes system insecurities that ultimately lead to system failure or a voltage drop [3]. The study on FACTS controllers also reveals promising outcomes when using these tools to increase voltage stability in emergencies such as line outages, as mentioned by [4]. There is a particular urge to use FACTS devices to discover solutions to all issues. Rapid industrialization and lifestyle expansion have increased reliance on the electrical power grid. A few uncertainties have emerged as a result of the rise in demand. Changed technologies are used for transmission setups that have been forced to operate outside the bounds of their sanity to overcome these uncertainties. By improving the power system's regulation, these restrictions can be minimized.

To determine which FACTS device is better for power system stability and which supplies the most power, the article's author [5] provided a survey. FACTS controllers are now one of the finest options for enhancing power system control methods. The firing angle of the thyristor is managed in [6] to maintain frequency management. Advanced static power electronic-based devices called FACTS controllers regulate various transmission system characteristics. These devices improve controllability and boost voltage stability capabilities to control the linked parameters properly. FACTS devices are used to enhance the dynamic and transient behavior of the system and to transmit the most significant amount of power to the consumers in a high-quality manner [7]. discusses another use of autonomous generation control utilizing FACTS devices. These devices are crucial at the transmission level, where load requirements must be met. Transmission lines use the compensators both in series and in parallel. The EHV lines' maximum power transmission mainly uses series compensation. These series capacitors (compensators) are linked throughout the transmission lines at various points. Series compensation hence improves the stability of the system. A parallel L.C. circuit with fixed reactive capacitance and variable reactive inductance makes up TCSC. Shunt compensation adjusts reactive power, which enhances the voltage profile.STATCOM and SVC are utilized in an integrated electrical network to improve dynamic voltage stability [8]. Reactive power is produced when there is a negative inductive reactance and is consumed when there is a positive inductive reactance [9]. For the voltage profile to be improved, reactive power correction is necessary. To regulate the reactive power, STATCOM is one of the shunt controllers used parallel to the transmission line. Combination-type compensators, such as series-shunt compensators, which can control both reactive and active power in the transmission line, are widely used nowadays. Another illustration of a series-shunt controller combo is a U.P.F.C [10]. All of the variables that influence power losses in transmission systems, such as node voltages, voltage magnitudes, phase–angles, and line reactance [11]. 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. Computational methodologies [12] have been used to define some drawbacks. A modern technique includes ANN methods, SA. methods, GA, EP, ACO, and PSO&AIS. These methods effectively solve optimization issues when global rather than local solutions are preferred. We have successfully employed these methods to handle optimization problems like Atom Search - Optimization [13, 14], and metaheuristic - optimization programming algorithms [15]. Literature addresses these issues. Researchers have discussed a fuzzy logic-based strategy for the best positioning and scaling of FACTS controllers in power systems [16] linear optimization programming [17], harmony-search-algorithm [18], and lightning search algorithm [19]. Many researchers have presented sensitivity-based methods in the literature. Fractional Levy light-BatAlgorithm [20], Hybrid Cuckoo-Search-Algorithm [21], Modified-Differential evolution [22], Combined pso-based CPF [23], numerous-sensitivity-based-approaches [24], genetic algorithm [25–32], refined-power-flow-algorithm [33], multiverse optimizer [34], reactive power dispatch problem [35], adaptive grass hooper optimization [36], Heuristic-Techniques [37], MILP-based-OPF [38], AWO-optimization [39], Gravitational-search-assisted algorithm [40–42], whale-optimization-algorithm [43, 44], novel-lightning search-algorithm [45], PSO-adaptive-G.S.A. hybrid-algorithm [46], self-adaptive-DE-algorithm [47], fuzzy-harmony search algorithm [48], imperialistic-competitive-algorithm [49], quasi-oppositional-chemical reaction optimization [50], brain-storm-optimization-algorithm [51], hybrid immune algorithm [52], teaching-learning-based-optimization [53], marine-vessels-analysis [54], optimal-power-flow-problem [55], evolutionary-particle swarm optimization [56], blended-moth flame optimization [57], population-based-evolutionary-optimization [58], MOPSO-algorithm [59], particle-swarm-optimization [60–62], cumulative-gravitational-search-algorithm [63], cat swarm optimization [64], improved-differential-harmony-algorithm [65], brainstorm-search optimization [66], self-adaptive differential evolutionary gravitational search algorithm [67], gravitional-search-algorithm [68], quasi-oppositional-chemical-reaction-optimization [69], hybrid-chemical-reaction-optimization [70], firefly-algorithm [71], modified self slap algorithm [72], self attachment optimization [73], power system security with GA [74], BBO, WIPSO, & PSO algorithm [75], harmony-search-algorithm [76], evolutionary-algorithms [77], cumulative-gravitational-search-algorithm [78], Sin-cosine-algorithm [79], improved-harmony-search-algorithm [80], chaos-embedded-symbiotic-organisms-searchtechniques [81], teaching learning based optimization [82], imperialistic competitive algorithm [83], hybrid techniques [84], brain storm-optimization [85], artificial bee colony optimization [86], hybrid-chemical-reaction-optimization algorithm [87], interior point-solver-optimization [88], metaheuristic-techniques [89], blended mouth-flame-optimization [90], sensitivity-based-coordination [91], adaptive-grasshooper-optimization [92], enhanced leader particle swarm optimization [93], harmony-search-algorithm [94], available transfer-capability [95], meta heuristic optimization evolutionary-based optimization [96], evolotunary-optimization [97], parallel-seek-optimization [98], population-based evolutionary optimization [99], multi-objective-adaptive-cuckoo-search-algorithm [100], MDE-algorithm [101], hybrid soft computing techniques [102], hybrid BOA-GWO-PSO [103], hybrid GWO-PSO [104], penguin optimization algorithm [105], novel meta-heuristic approach [106], hybrid intelligence strategy [107], chaotic hybrid intelligence strategy [108] Response surface methodology [109] PSO-based FLC [110] Fast primary frequency control [111] primary frequency control [112] Monte Carlo simulation (MCS) random sampling approach [113].

After adding FACTS devices, the transmission system would operate highly closely to its temperature and stability constraints. The AC power system has built-in power stability since the transmitting and receiving ends of the lines choose how much power flows between them. From eqn (1), consider voltages V_1 and V_2 at the sending and receiving limitations and θ_1 and θ_2 for the corresponding phase angles at the sending and receiving lines. We examine the power flow equation as follows:

The main aim is to diminish the transmission power loss and to improve the bus voltage profile by acceptable coordination of the optimal control variables in the power transmission network. The real power loss mainly occurs due to highly resistive conductors and this leads to inefficient transportation of power from source to distribution side as shown in eqn (2) with equality constraints. Hence, it is highly essential to reduce real power loss in the networks. To maintain voltage stability, reactive power is an important parameter. Lack of adequate reactive power may lead to voltage collapse in the networks shown in eqn (3). So, there is a pressing need to adjust the voltage magnitudes in the network. Reactive power of generator inequality constraints is shown in eqn (4).

$$P = \frac{V_1 V_2}{X} \mathrm{Sin}(\theta_1 - \theta_2) \tag{1}$$

The function's constraints can meet the real and reactive power limits.

$$P_i = V_i \mid \sum_{k=1}^{n} V_k Y_{ik} \cos\ (\theta_{ik} + \delta_k - \delta_i) \tag{2}$$

$$Q_i = V_i \sum_{k=1}^{n} V_k\ Y_{ik}\ \sin\ (\theta_{ik} + \delta_k - \delta_i) \tag{3}$$

Generator reactive power capability limit:

$$Q_{gi}{}^{min} \leq Q_{gi} \leq Q_{gi}{}^{max} \tag{4}$$

In a deregulated environment, the amount of power generated will depend on various factors, including the availability of fuel, the state of the environment, the state of the economy, and other considerations. At the same time, the load might also change because of the weather, the time of day, and expansion. A situation where the system's security might be questioned would result from the variance in the load and generation. For instance, if the stability or thermal limits of the power system are being approached, a sudden shift in the load or generation, no matter how slight, might result in power swings and cascaded tripping.

The constraints that have to be taken into consideration are the following:

1. Limitation of transient stability

2. Limitation on voltage stability
3. Limitation on dynamic stability
4. Limitation on steady-state power stability
5. Damping oscillations on the power system
6. Therma capacity
7. Limitations on short circuit current

Enhancement of power quality

The power quality can be defined as the system where voltage remains pure sinusoidal continuously with constant magnitude, phase angle, and frequency. Some of the power quality requirements are as follows:

1. The voltage throughout the range must be constant
2. Maintain the frequency within the limits
3. Balancing the phase angle
4. Radio interference is not needed.

There are many causes of power quality problems. Some of them are discussed here.

1. A voltage sag occurs when the voltage drops below the nominal voltage level by less than 10%
2. Power supply interruption in a short-duration
3. A prolonged power outage lasting longer than 1 or 2 s
4. Raise voltage spikes from average to high voltages over a short period. A millisecond-long shift in frequency
5. Harmonic distortion occurs when the voltage and current waveforms are no longer sinusoidal.

Study of FACTS devices

Different industries are working together to get through the global warming challenge: people are paying more attention to renewable energy sources, smart grids are being developed, energy losses are being reduced, energy efficient methods are being explored, and distributed energy resources are being gradually integrated. FACTS devices are commonly employed for this purpose. The power factor becomes close to the accord if proper compensation techniques are applied, as shown in Fig. 1. The increased load could cause congestion and disrupt the electrical system's ability to regulate voltage, as shown in Table 1. If a sufficient supply of reactive power is not in the grid, it produces low voltage levels at the receiving end and, at worst, may even create blackouts, as shown in Table 2. FACTS devices are widely used to avoid this and ensure grid dependability. Hingorani and Gyugyi are attributed. Power electronic converter-based FACTS devices, as shown in Fig. 2 and contributions, as shown in Table 3, can be used in the transmission line, improving the transmission network's overall efficiency, as shown in Fig. 3. A group of FACTS devices whose application, performance, as shown in Table 4 installation, cost mva, and dynamic response of

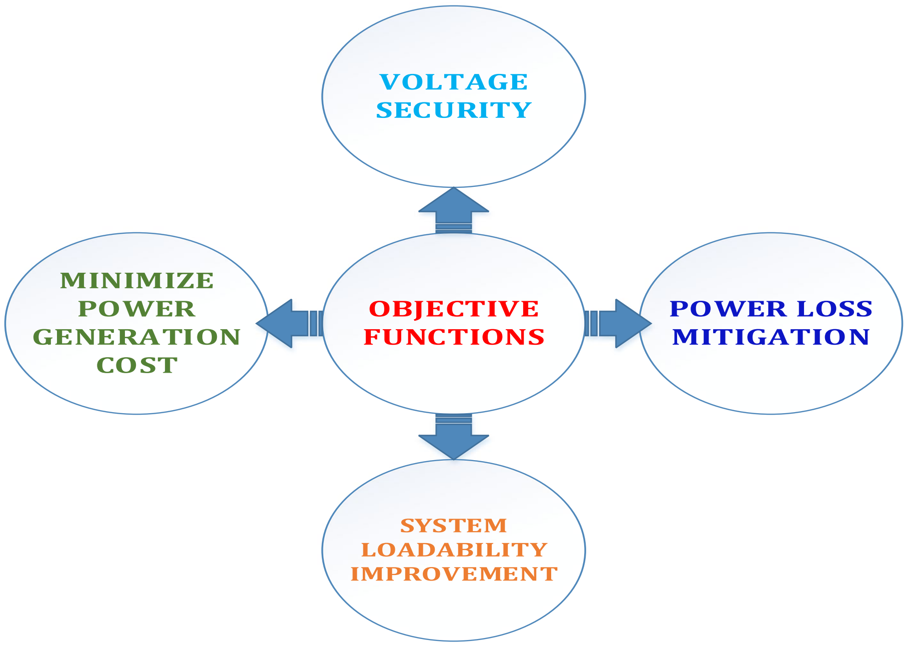

Fig. 1 Objective functions of FACTS devices

the system a shown in Fig. 4. Depending on the circumstances, loads may be resistive, capacitive, or inductive and conventional sources, as shown in Fig. 5. 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 precise FACTS devices in Table 5.

A power grid is a cumulative result of connecting many individual generators, consumers, and regulators. However, while the sources and control circuits are generally predetermined, as shown in Figs. 6 and 7, the loads are constantly shifting and typically unpredictable. When dealing with resistive loads, phase balancing is not critical. However, when operating with inductive or capacitive loads, the current and voltage are out of phase, resulting in a power factor that is less than unity. Improve compensation is necessary.

Series-connected controllers

These controllers are in charge of enhancing the capacity to transmit power. Reduce the sum line impedance from the transmitting end to the receiving end. In the end, series compensation works. Therefore, passing the damping can be used to lessen stability oscillations. One may manage the current flow direction a series controller uses. A variable might be the form of a series controller as variable power, reactor, or capacitor. It is an SSSC serial compensator with a voltage source that regulates the line's voltage drop and is transmittable power. It thus enhances the maximum power transmission they are lining up. The performance of the SSSC is examined by numerous places, such as the line's end, the line's center, etc., when the distance fault occurred relay. An inductive

Table 1 Steady-state issues in power system With FACTS Devices

Challenges	Identification problem	Corrective measures	Traditional approaches	Adding FACTS devices in the circuit
Limiting voltages	At low voltage levels at high load	Reactive power supply	Using series capacitors, shunt capacitors & svc	S.T.A.T.C.O.M., T.C.S.C.
	At high voltage levels at light load	The reactive power supply removed	Using shunt capacitors	T.C.S.C., T.C.P.A.R.
		Reactive power absorbed	Svc, shunt capacitor & shunt reactor	Using S.T.A.T.C.O.M., TCR
	Following outages in a high voltage	Reactive power absorb	Additional reactor used	TCR
		Protecting equipment	Need additional arrestor.	T.C.V.L.
	Following outages in a low voltage	Limiting the overload and supply of reactive Power	Switching shunt capacitor, shunt reactor, using svc & switching series capacitor	T.C.S.C., S.T.A.T.C.O.M.
		Overload prevention	Adding series reactor, Tcpar	T.C.S.C., I.P.F.C., U.P.F.C.
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	Minimize 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	T.C.S.C., U.P.F.C., I.P.C.
		Phase angle adjustment	Adding par	T.C.P.A.R.
	Sharing post-fault condition	Rearranging networks	Using series reactor	T.C.S.C., I.P.C., TCR, T.C.P.A.R.
	Reversal of power flow direction	Phase angle adjustment	Using par	U.P.F.C., I.P.C., T.C.P.A.R.
short circuits levels	Limit circuit breaker current	Reducing short circuit current	Addition of using a fuse, the reactor	U.P.F.C., S.C.C.L., I.P.C., TCR
		They remove the circuit breaker when the fault occurs.	Add up on circuit breaker	
		Rearranging of network	Splitting of bus	I.P.C.

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

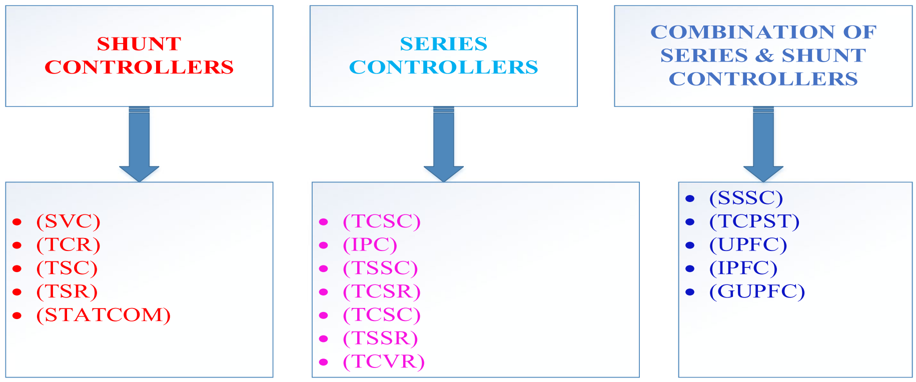

Fig. 2 Types of FACTS Controllers

Table 3 FACTS devices controller's contribution to transmission lines

Technological functions	Implementation FACTS controllers
1. System stability improvement 2. Reducing voltage collapse	T.C.S.C.
1. Controlling reactive power and true power in transmission line 2. Harmonics levels reducing	U.P.F.C.
1. Voltage controls 2. Compensation for reactive power	S.T.A.T.C.O.M.
1. Power flow control in sub-networks 2. Voltage profile maintenance	I.P.F.C.
1. Power quality improvement 2. Voltage regulation	S.V.C.
1. Power system stability enhancement 2. Damping power oscillations	S.S.S.C.

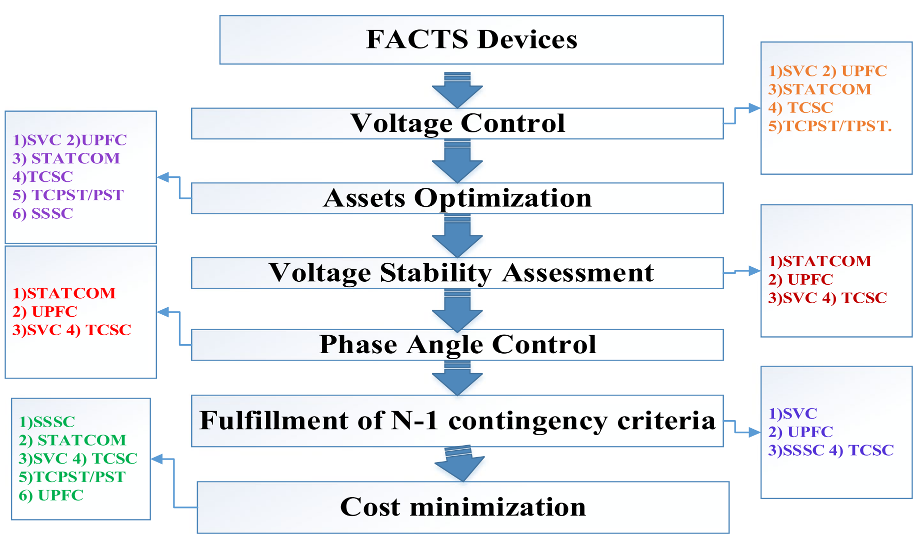

Fig. 3 Assessment of FACTS devices and their works

Table 4 Comparison between different FACTS devices

Devices	Technical performance	Working principle	Advantage
1. U.P.F.C	Power flow optimization	Control the inserted voltage, current & line impedance	Optimize power flow in the system
2. S.V.C	Reactive power compensation	Change in parallel capacitance	Simple and cheap
3. S.S.S.C.	Active power regulation	Control the equivalent line impedance	No resonance problem
4. S.T.A.T.C.O.M.	Dynamic voltage regulation	Controlled the inserted reactive current	Fast response speed

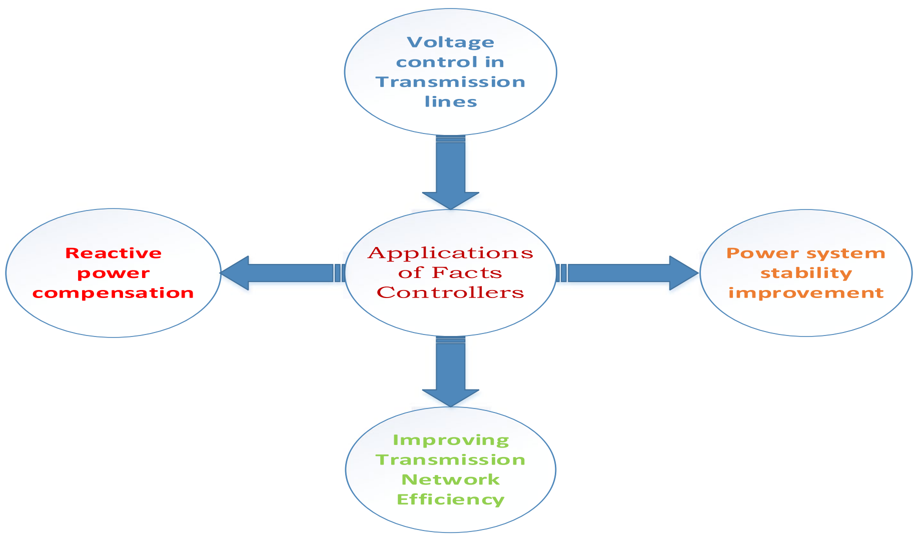

Fig. 4 FACTS controllers applications in power systems

reactance compensator offers a step-by-step command controller for series-shunting etc. Increasing series controllers the power-transfer capacity of lines.

Shunt-connected controllers

The transmission line's shunt controllers may be variable sources, variable impedances, or both. The system receives variable currents from the shunt controllers. Reactive power changes depending on whether the current and voltage lines are in phase quadrature. These controllers with shunt connections can be positioned in the center of the transmission lines. One of the shunt controllers that control reactive power in lines is STATCOM.

A detailed analysis of STATCOM, deployed in a 5-bus power system, is provided. The shunt controller injects electricity into the transmission line after installing STATCOM to achieve the desired power flow via the lines of 0.43 P.U. and 0.154 P.U., respectively. The compensating approaches also demonstrate a lessening of the transmission cables' burden. A shunt compensator is further placed at bus 4 to enhance voltage control. All bus voltages are within the voltage limitations in these

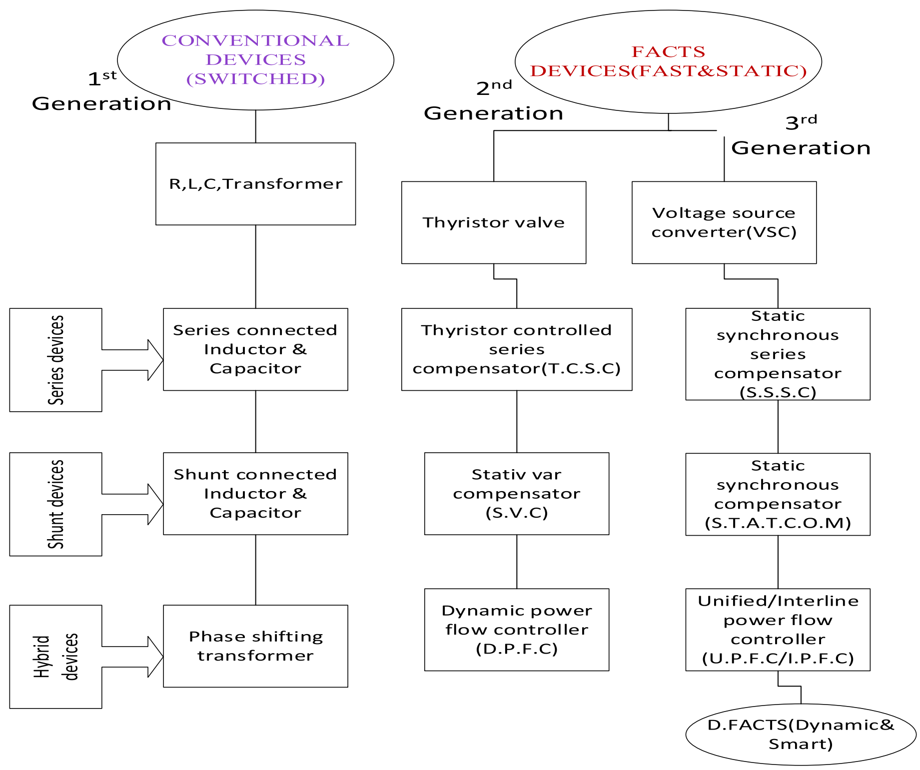

Fig. 5 Diagram for conventional devices and FACTS devices

circumstances goes into great detail about using two control techniques to improve transmission stability utilizing shunt-connected FACTS controllers. A S.T.A.T.C.O.M. shunt controller was taken and approached for the traditional cascade controller, consisting of an inner vector-current controller and several outside control loops.

Combined series-shunt controllers

Both series and shunt controllers are employed in the combination of series-shunt controllers. The series-shunt controller's fundamental working concept utilizes the shunt controller to manage voltage and the series controller to supply current to the lines. The actual power is exchanged between the controllers when assembled in the system. Real and reactive power is regulated using series-shunt controllers, which improve system performance. A type of series-shunt controller is the U.P.F.C. The specific constructional elements of U.P.F.C. are covered in how S.S.S.C. and S.T.A.T.C.O.M. were combined to create U.P.F.C. The author talked about U.P.F.C. and how it may improve power quality by managing both active and reactive power and the use of U.P.F.C. to regulate power flow in transmission lines by adjusting the impedance of the lines, the magnitude of the voltage, and the phase angle with wind energy generation. These two components are connected by a D.C. connection to provide a two-way power flow for the line's reactive and actual power adjustment. One G.U.P.F.C. device, two in series, and one in parallel with the line regulates the intelligent power system characteristics of the line, such as power flows, bus voltage, actual power, and reactive power.

Table 5 Survey on FACTS devices with optimization techniques

FACTS devices	Algorithms	References	Features
1. UPFC	1. Genetic algorithm, 2 real-coded genetic algorithm,3. daptive particle swarm optimization,4. particle swarm optimization.5.cat-swarm optimization,6.atom search optimization 7.biography-base optimization,8.whale optimization, 9.gui-based genetic algorithm,10. Ptsbalgoithm,1 1grasshooperalgorithm,12.adaptive grass hooper optimization,13. Sensitivity-based coordination,14. hybrid chemical reaction optimization 15.Evolutionary algorithm16.self-adaptive-differentiall evolutionary-algorithm, 17.Imperialisticcompetitivealgorithm,18. sqp&eptechniques19.simulated annealing,20. Metaheauristic techniques,21. Optimization techniques	[1,3 ,4 ,6 ,14 –17,25 ,35 –37,44 ,47 ,49 ,64 ,67 ,70 ,77 ,87 ,91 ,92 ,95]	1) Controlling of active and reactive power. 2) Voltage stability improvement 3) Maintain phase angle margin
2.TCSC	1. Optimization techniques,2.n-1 security contingency analysis,3. Hybrid cat firefly algorithm,4. Atom search optimization 5.Biography-based optimization,6. Whale optimization,7. Lightning search algorithm,8. Hybrid cuckoo search algorithm,9. Sensitivity analysis,10. Gui-basedgeneticalgorithm,11.propabalistic multiobjective optimization,12. Momvo algorithm,13. Adaptive whale optimization, 14. Genetic algorithm,15. Neural computing applications,16. Population-based evolutionary algorithm,17. Particle swarm optimization,18. Gso algorithm,19. Improved differential harmony search algorithm,20. Network contingency,21. Parallel seeker optimization, 22Adaptive cuckoo search algorithm, 23.Population-based evolutionary algorithm,24. Parallel seeker optimization algorithm,25. Gravitational search-assisted algorithm,26. Enhanced leader pso,27. Qazi oppositional chemical reaction algorithm,28. Mde algorithm	[4,8 ,12 ,14 ,16 ,17 ,19 ,21 ,22 ,24 ,25 ,28 ,33 ,34 ,36 ,39 ,42 ,56 ,58 ,63 ,65 ,69 ,73 ,93 ,98 –101]	1) Reactive power compensation 2) Power loss reduction 3) Sub-synchronous resonance elimination.

Table 5 (continued)

FACTS devices	Algorithms	References	Features
3.SVC	1. Optimization techniques 2.n-1 security contingency 3. Atom search optimization,4. Hybrid cat firefly optimization,5. Biography-based optimization,6. Whale optimization,7. Particle swarm optimization.8. Gui-based genetic algorithm,9. Momvo algorithm10. Genetic algorithm,11. Epson algorithm,12. Symbiotic search algorithm,13. Hybrid pso algorithm14. G.s.o algorithm,15. Hybrid tssa algorithm	[4,7 ,8 ,12 ,14 –17,23 ,25 ,28 ,34 ,56 ,61 –63,90 ,97]	1) Reactive power absorbs or generates 2) Correction of power factor 3) Voltage regulation 4) Mitigation of harmonic levels
4.SSSC	1. Hybrid cuckoo search algorithm, 2. Improved harmony search algorithm, 3. Spef techniques	[21,80 ,85]	1) Without changing the line current 2) Withstand the reactance value from capacitive to inductive load.
5.STATCOM	1. ireflyalgorithm, 2.Harmony-search algorithm 3.sensitivity analysis, 4.probabilisticm Multiobjectiveoptimization, 5.improved differential harmony search algorithm 6. teaching learning-based ptimization algorithm	[9,18 ,24 ,33 ,65 ,76 ,82]	1) Supplying inductive and capacitive reactive power 2) Harmonics elimination 3) Power factor improvement
6.DSTATCOM	1.Particleswarm optimization, 2. Novel lightning search algorithm, 3.Mopso -algorithm	[45,59 ,94]	1) Improve power factor & voltage regulation
7. I.P.F.C.	1.optimisationtechniques 2.atom.search optimiza-tion. 3. Firefly –algorithm	[13,14 ,71]	1) Minimizing power loss and generating cost 2) Maintain voltage stability margin

Table 5 (continued)

FACTS devices	Algorithms	References	Features
8. Multitype-FACTS	**1.Hybrid meta mouth flame optimization,2. Particle swarm optimization,3. Hybrid particle swarm optimization.** **4.Artificial bee colony optimization,5.Optimization techniques,6. Fractional leavy light algorithm,7. Genetic algorithm,8. Milp algorithm,9. Newton raphson method** **10. Whale optimization,11. Gravitational search algorithm** **12. Pso-ga,13. Harmony search algorithm,14. Fuzzy-ga** **15. Genetic algorithm,16. Interior point solver,17. Meta heuristic optimization techniques,18. Abc algorithm,19. Hybrid techniques,20. Imperialistic competitive algorithm** **21. Boulter chaos embedded symbiotic organisms search technique,22. Cumulative gravitational search algorithm** **23. Evolutionary programming & differential evolution** **24. Optimal power flow,25. B.b.o, p.s.o, w.i.p.s.o** **26.Immune-algorithm,27.Bsoa0-algorithm,28.Jaya algorithm,29.Modellingoflines,30.Marine-vessels algorith31. Teaching learning-based algorithm**	[2,3 ,5 ,10 ,13 ,20 ,26 ,27 ,29 ,31 ,32 ,38 ,40 ,41 ,43 ,46 ,48 ,50 –54,57 ,66 ,68 ,74 ,75 ,78 ,79 ,81 ,83 ,84 ,86 ,88 ,89 ,96]	**The power balance between the transmission system.** **1) Real & reactive power monitoring.** **2) Power loss and cost minimization.** **3) Maximize the system loadability** **4) Power transfer for heavy-loaded to light-loaded lines**

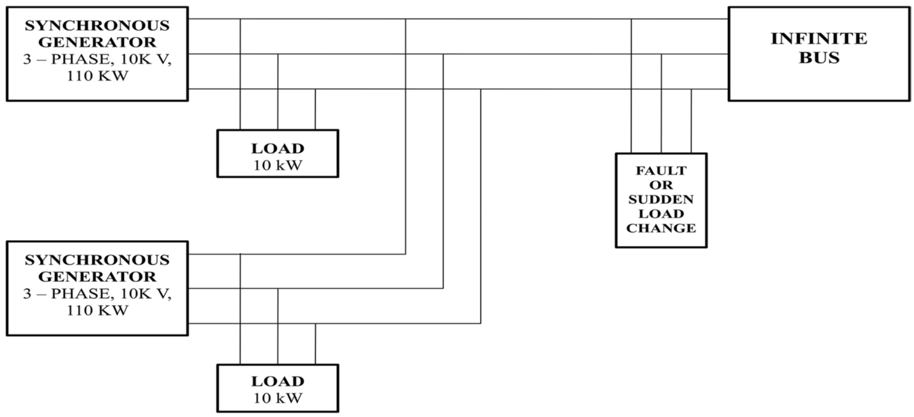

Fig. 6 Block diagram for power system without FACTS devices

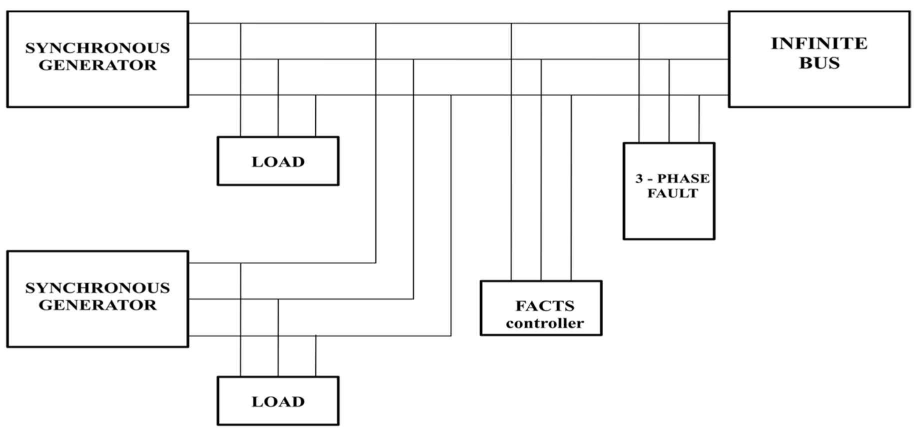

Fig. 7 Block diagram for power system with FACTS devices

Integrating the shunt and series compensators allows for effective system parameter changes, such as the improvement of the power transfer capabilities.

Combined series-series controller

The formation of this combination occurs when two or more series controllers are joined. The primary function of a series controller is to compensate for reactive power imbalances across lines, but these controllers may also handle actual power differences by using power connections. This power transfer feature enables the controller to balance reactive and real power flow. An integrated series-series controller is the I.P.F.C. This converter, which regulates the flow of electricity in systems with many transmission lines, is one of the voltage source converters. They are typically positioned on hazardous transmission lines.

Analytical approach

Finding the best location for FACTS controllers in deregulated electric power systems is a primary goal addressed by many writers. S.T.A.T.C.O.M. and S.S.S.C. are ideally positioned to clear the congestion. The power system network utilizes several FACTS devices strategically to reduce the generation cost with the integration of wind power as renewable energy resources are added to the grid. Save costs using an ideal power flow program employing T.C.S.C. FACTS devices were also added where they belonged allocated T.C.S.C. and U.P.F.C. using a sensitivity-based method to increase system security. Similar to the optimal location of T.C.S.C. and S.S.S.C. was determined using a sensitivity factor based on line outage distribution to improve system security. For the U.P.F.C. and the T.C.S.C. ideal site respectively applied the sensitivity-based technique. The effectiveness of the FACTS device was also examined in contingency instances by both authors using T.C.S.C. to enhance the state of the power system network. Additionally, the power flow-based sensitivity factor was examined.

A survey on FACTS devices

Using the simulated-annealing technique and the IEEE 14-bus system, the author of this research established the ideal position for U.P.F.C. Using the differential evolution method, some of the authors have researched the best part and size for the T.C.S.C. and S.V.C. controllers to decrease line losses and increase voltage stability. L.O.S.F. is employed to find the line that will allow T.C.S.C. to be placed in the most advantageous location. Systems utilizing the IEEE 14-bus and 57-bus use this PSO approach.

Locating S.T.A.T.C.O.M., a shunt controller, in the right place may make congestion issues worse artificially. If one line experiences a fault, I.P.F.C. is still relevant and will use other lines to supply electricity. The author determines where the I.P.F.C. controller should be placed to reduce congestion and describes how the S.T.A.T.C.O.M. controller in a P.V. solar farm works with power system stabilizers to reduce system oscillations. As a result, the system's transient and dynamic behavior is enhanced to reduce the cost of FACTS controller investment and power plant generation, and a GA-based strategy was explored. According to the authors, the multi-type FACTS controllers were positioned in the system optimally using the G.A. technique. The IEEE 30-bus system was used by the authors, and they explored how better congestion management may result from putting S.T.A.T.C.O.M. at an ideal position and lowering the system's running costs and decreasing production costs in the transmission system utilizing FACTS controllers, increasing the power system's capacity, and enabling yearly savings. Results show that S.V.C. and S.T.A.T.C.O.M. may reduce voltage failure and fall during emergencies and function as quick-response devices to maintain the power system's stability. Using FACTS devices, the D.E. algorithm suggested reducing the generator fuel cost. The controller U.P.F.C. is employed to manage congestion in a linked power system network by choosing the best position. FACTS are also utilized in A.C. transmission networks to increase stability and control the power delivered over the transmission line. The C.S.A. algorithm and two controllers, S.V.C. and T.C.S.C., are employed to regulate the dispatch of reactive power across the transmission line at the best possible efficiency. Following deregulation, the strain on transmission lines rose. FACTS devices are employed to lessen this stress on A.C. transmission lines. These gadgets decrease losses, generate costs, balance reactive demand and supply, and enhance voltage profiles. These advantages are achievable only when FACTS controllers are placed in the ideal location.

Congestion management using FACTS devices

The technological solution relies on the utilization of FACTS devices to regulate congestion FACTS controller, assist in managing the transmission line impedance, and the magnitude and angle of the bus voltage in increasing the flow of the line, as well as the system's reliability and security. Once these devices have been implemented, the transmission line loading limitations can be adjusted without infringing on any other requirements. The violation of transmission limit limits and the reduction of contracted power flow across transmission lines are caused by congestion. After deregulatory measures were taken, an increase in generator competition led to a rise in transmission line congestion, which caused difficulties for the system operator. The ideal placement and size of the FACTS controllers T.C.S.C. and S.S.S.C. are calculated by evaluating the magnitude and reactive power fluctuations in a congested environment. This helps ensure that the controllers are placed in the best possible locations. Under loading conditions, the ideal size and position of FACTS devices are determined by the magnitude of the voltage on the load buses and the needed reactive power of those buses. In an IEEE 14-bus system, T.C.S.C. and S.S.S.C. are utilized to determine the best position by analyzing the voltage magnitude and necessary reactive power of load buses. The ideal location of FACTS controllers is examined in a crowded environment. Congestion control is handled with the help of T.C.S.C. The U.P.F.C. is proposed to ease congestion while simultaneously reducing the cost of generating.

The supplier's objective is to supply its clients with reliable and uninterrupted access to the electrical grid at all times. For three-phase activities to be carried out, the steady supply must have a voltage waveform that is entirely sinusoidal and has a constant amplitude, frequency, and balance between the phase angles. On the other hand, a typical stable operation is not always achievable because of variations in the magnitude and angle of the voltage when a substantial reactive load is present in the circuit. Under certain circumstances, such as fault conditions or emergencies, a system may become unstable. Controlling the magnitude and angle of the voltage in diseases of the solid reactive load is made more accessible by developing semiconductor switch-based FACTS devices. Most of the time, S.T.A.T.C.O.M. is utilized for stability research. Controlling power flow over transmission lines is another function of the U.P.F.C., another device used for stability analysis that examines the ideal placement of the FACTS devices concerning enhancing the system's stability.

U.P.F.C

The U.P.F.C. is the most adaptable factor controller within the family of FACTS controllers Gyugyi proposed for controlling voltage and power flow in a particular conductor. One shunt device and one series device make up its two voltage supply devices (VSC). Furthermore, the two converters' D.C. capacitors are linked in parallel in Fig. 8. The dc voltage for both converters is provided by a common capacitor bank. In this process, the

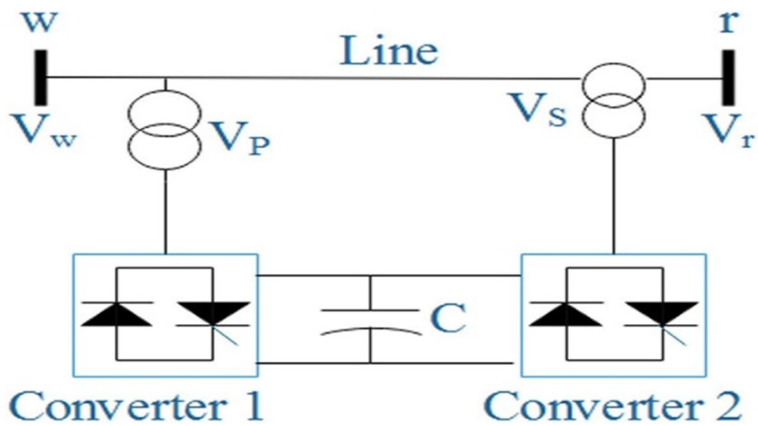

Fig. 8 UPFC equivalent diagram

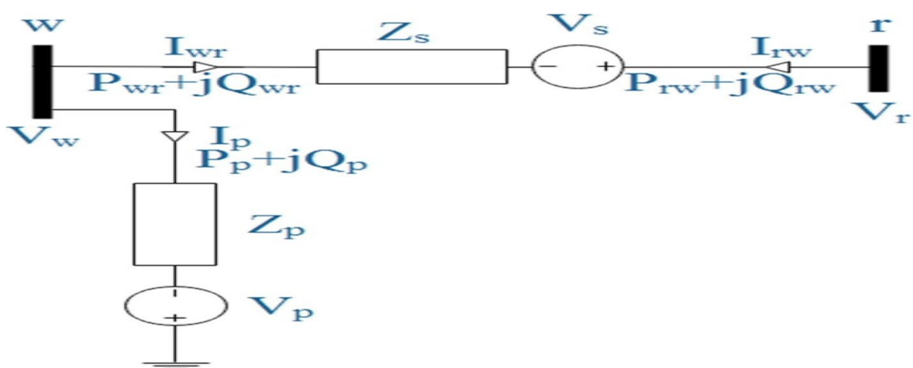

Fig. 9 UPFC equivalent diagram

series converter exchanges both real and reactive power with the transmission line. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains the constant voltage of the dc bus. The reactive current can be achieved by the shunt converter performing the function of S.T.A.T.C.O.M. and injecting the reactive voltage into the line. The series device performs the function of S.S.S.C in Fig. 9.

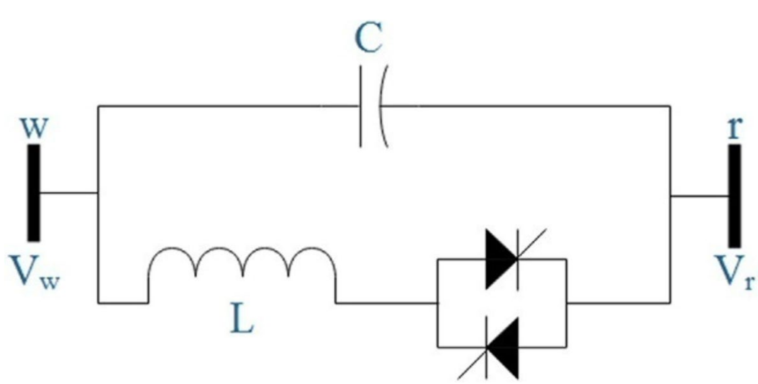

Fig. 10 T.C.S.C schematic diagram

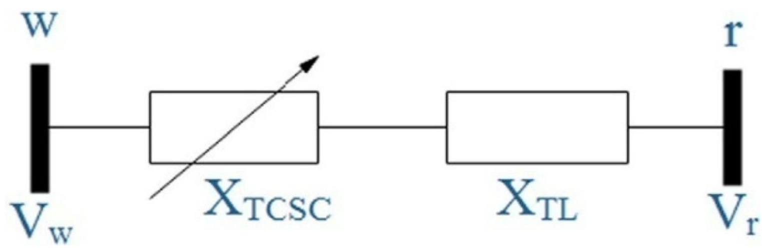

Fig. 11 T.C.S.C equivalent diagram

TCSC

Thyristor controlled series capacitor (T.C.S.C.) offers practical ways to regulate and boost the power transfer level of a system by altering the apparent impedance of a particular transmission line in Fig. 10. To improve power system stability during emergencies, a T.C.SC. might be used in a planned manner. It is feasible to function steadily at 75 power levels, much more than the system's initial design intent, without affecting its stability. Additionally, T.C.S.C. is employed to lessen S.S.R. in Fig. 11 (sub-synchronous resonance)

SVC

A static V.A.R. generator is shown in Fig. 12 or absorbent material that is shunt-connected and whose output is modified to exchange capacitive or inductive current while maintaining or regulating particular power system characteristics (typically bus voltage)as shown in Fig. 13.

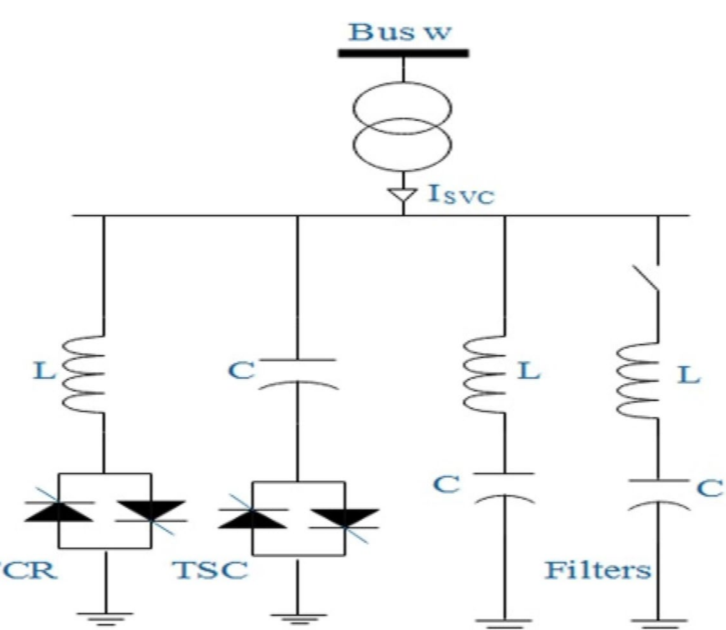

Fig. 12 S.V.C schematic diagram

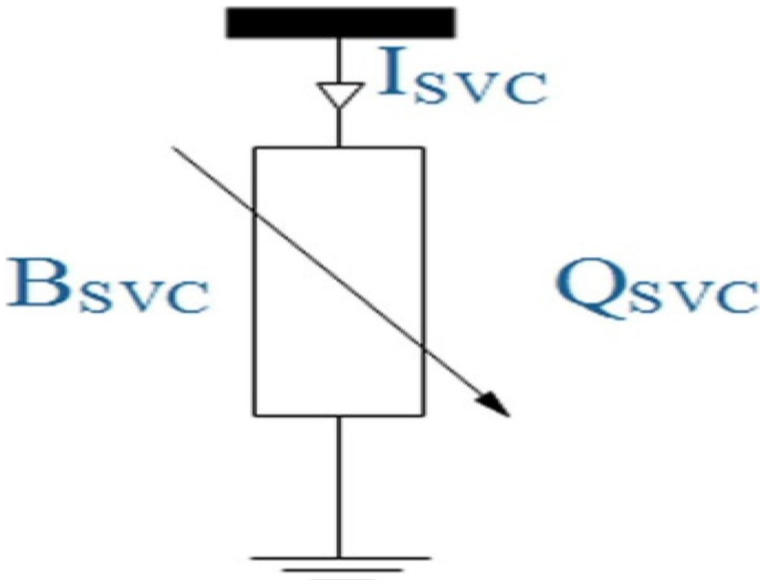

Fig. 13 S.V.C equivalent circuit

STATCOM

The ac system voltage of the static synchronous generator, as shown in Fig. 14, which is used as a shunt-connected static power unit compensator, controls the capacitive or inductive output current as shown in Fig. 15.

SSSC

A static synchronous generator in Fig. 16 that is run without the need for an external power source acts as a series compensator with an output voltage that is built into and controllable separately from the line current to speed or decelerates the overall reactive fall over the line and, as a result, dominating the transmitted electrical power in Fig. 17. The S.S.S.C. may include transiently rated energy storage or engrossing energy devices to increase temporary real power compensation, lengthen or lower the overall real (resistive) fall briefly over the line, and support the facility system's dynamic behavior.

Optimisation techniques

As a result of its effectiveness, FACTS devices may be used to address issues in the electrical grid. However, their high price and installation costs typically outweigh the savings on energy bills they produce. Because of this, a proper balance of devices is difficult. Many respected scientists and engineers have presented solutions to this problem over the past few decades. Optimization provides an unbiased evaluation of relevant elements.

Optimization methods come in two flavors: single-objective and multiobjective, each tailored to different goals. The benefits of using single objective approaches are that they are quick, cheap, and only produce one possible answer. However, a multiobjective optimization strategy considers several competing goals. It generates a collection

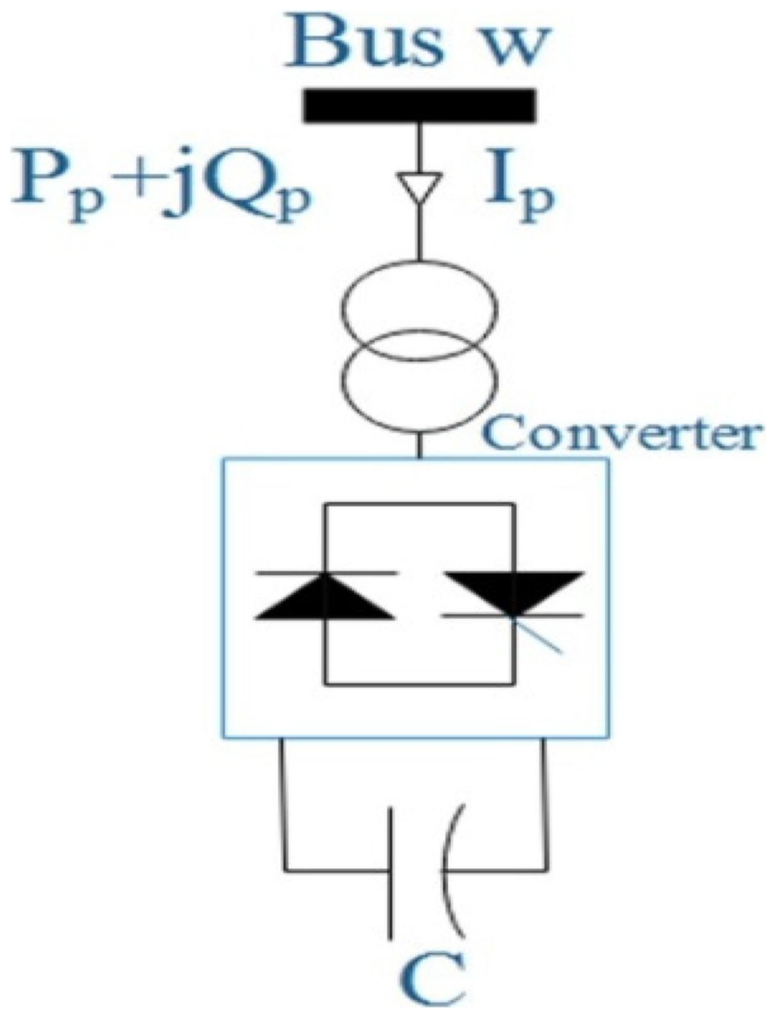

Fig. 14 STATCOM schematic diagram

of middle-ground options, or a pareto-optimal front of parallel solutions, that are more practical and feasible for use in challenging real-world scenarios. This review work motivates the researchers to do further research to improve the size and the location of the FACTS devices as in order to reduce the loss in power and maintain a voltage level. Figure 18 shows Clasification of optimal size and location.

Due to the growing renewable energy penetration, deploying FACTS devices with distributed energy has attracted more attention in recent years. The development decisions on series FACTS employing a deduced shifting factor model in a market environment with significant penetration of renewable energy sources were also identified using the stochastic mixed integer program bi-level model.

Additionally, because of its reduced model size, the proposed shift factor formulation is thought to perform better than a comparable Bq formulation in terms of computational speed. An essential setback for optimal power flow analysis is its restricted use in D.C. power flow. The co-optimization approach was alternatively reformed for transmission expansion planning with the T.C.S.C. site by two mixed integers linear programmed suggested to address the multi-optimization challenge more effectively.

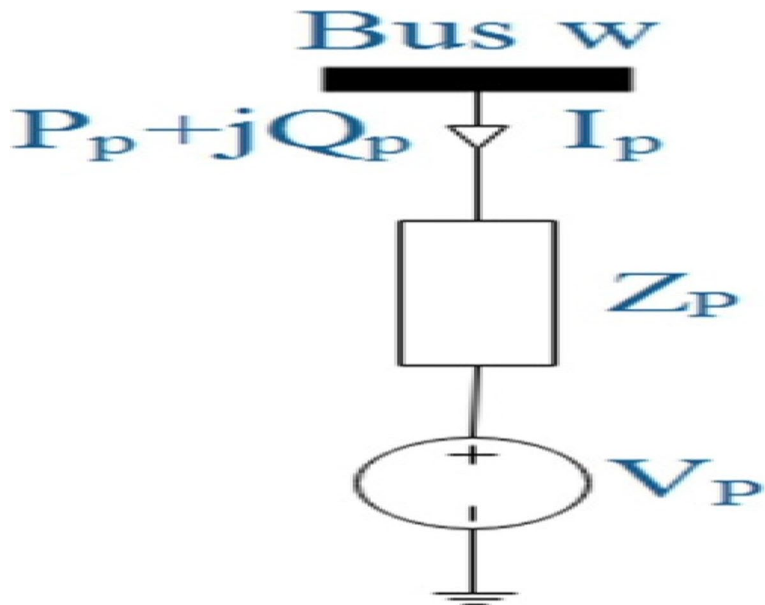

Fig. 15 STATCOM equivalent circuit

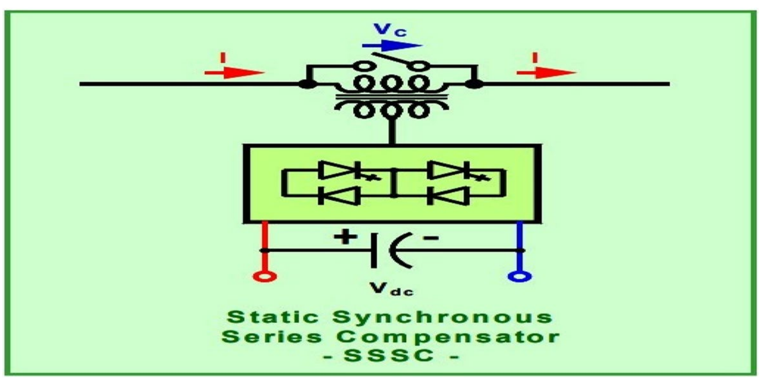

Fig. 16 SSSC schematic diagram

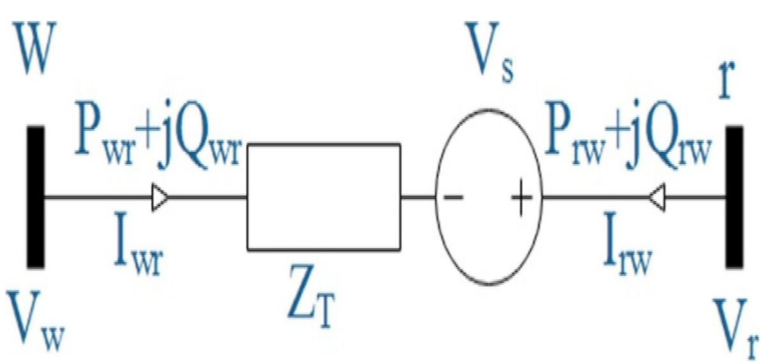

Fig. 17 SSSC equivalent circuit

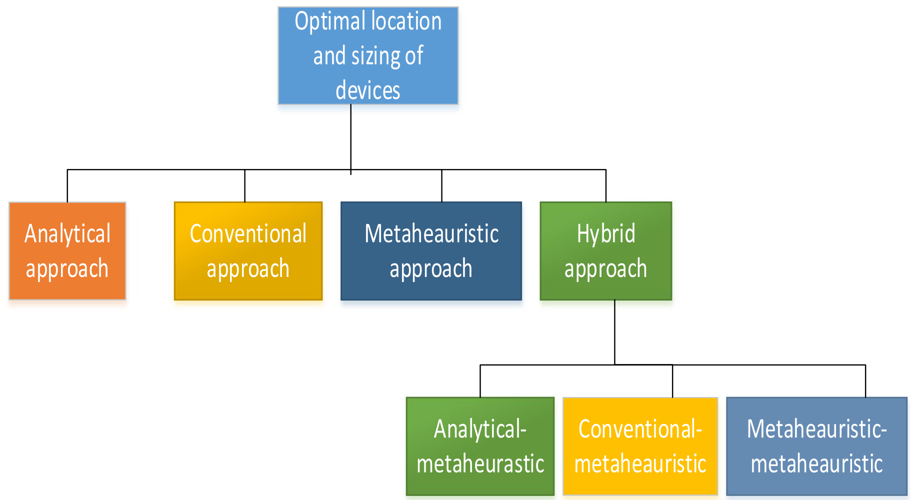

Fig. 18 Classification of optimal sizing and locations

The best location for the generalized unified power flow controller (G.U.P.F.C.) and integrated power flow controller (I.P.F.C.) integrated with the wind farm and fuel cell was found using an improved squirrel search method. The model was influenced by the way flying squirrels move between trees in nature by gliding.

The various scenario-aware models that have been suggested perform well. When allocating S.V.C.s and T.C.S.C.s in a deregulated network, the accompanying uncertainty of wind power penetration is taken into account with dynamic line rating using a probabilistic approach. It was found that S.V.C. enhanced the maximum loadability limit of dynamic line rating more effectively than T.C.S.C. or other FACTS devices.

The correct placement and size of the FACTS devices are critical, especially from an economic standpoint. Additionally crucial to the technical advancement of the entire power system is the optimal functioning and control of these devices. As a result, research has focused on the best operating and controlling FACTS devices to enhance the power system's quality, dependability, and security. A nonlinear controller for a unified power quality conditioner (U.P.Q.C.) was designed using sliding mode control and instantaneous active and reactive power theories. It turned out to be more effective at compensating current and voltage distortion than the traditional proportional-integral controller—the model with U.P.F.C. parameter settings.

Using a self-adaptive differential evolutionary algorithm, they consider transmission losses in U.P.F.C., coupling transformers, and failures of both converters. Utilizing the U.P.F.C. increased power flow while reducing line losses simultaneously. The first of its kind in Canada, the application of photovoltaic solar-based FACTS devices for stabilizing crucial induction motors. Such induction motor stabilization reduces disturbance in a power system. The new PV-STATCOM costs roughly 50 times less than a standard S.T.A.T.C.O.M. of comparable size.

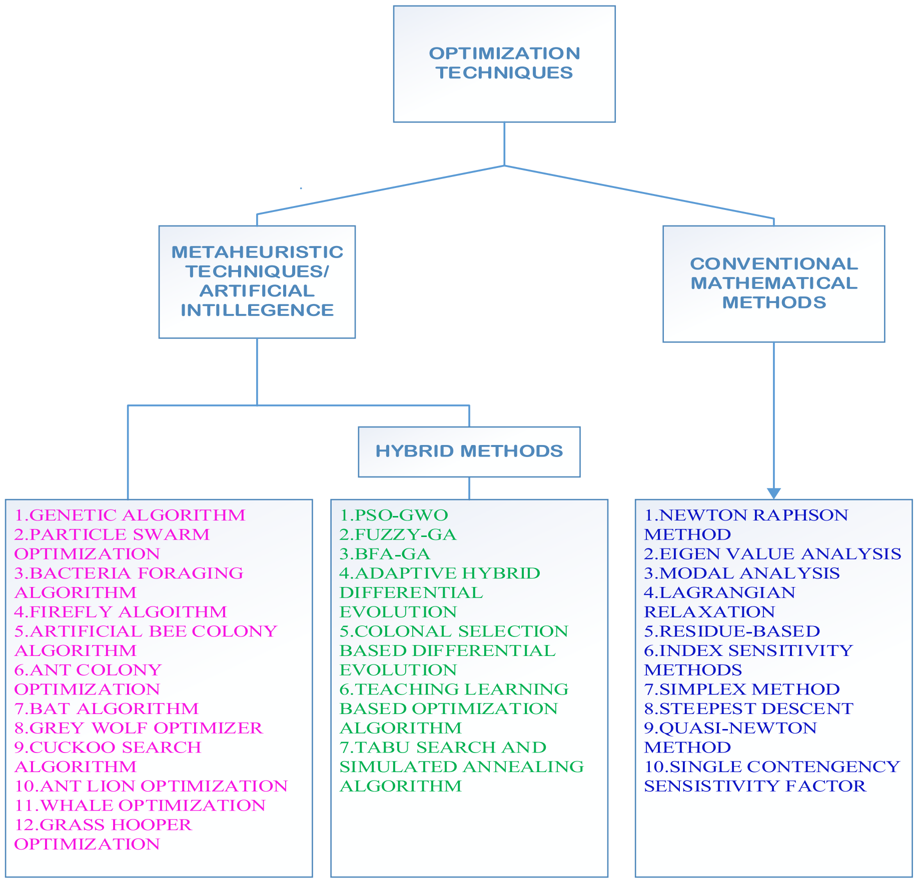

Fig. 19 Methods of optimization techniques

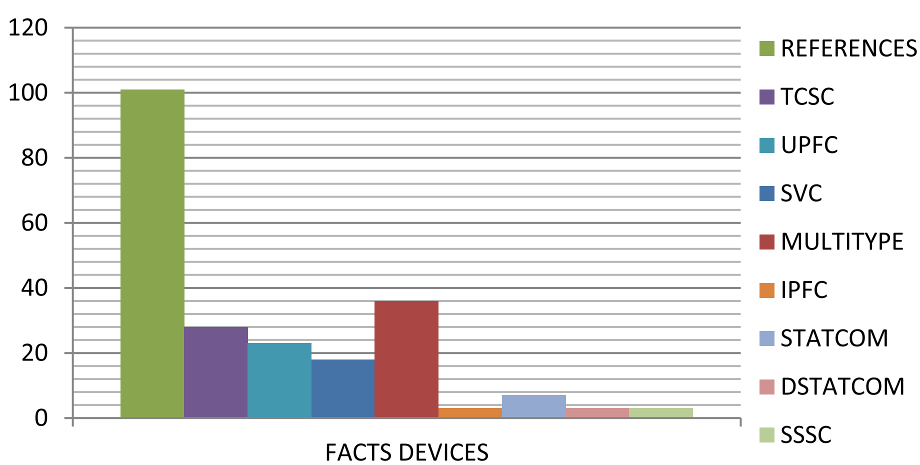

Fig. 20 FACTS devices using in references

Methods of optimization techniques shown in Fig. 19 such as sensitivity-based, optimization-based, and artificial intelligence-based techniques are used to determine the best location of FACTS devices in the transmission system in Fig. 20.

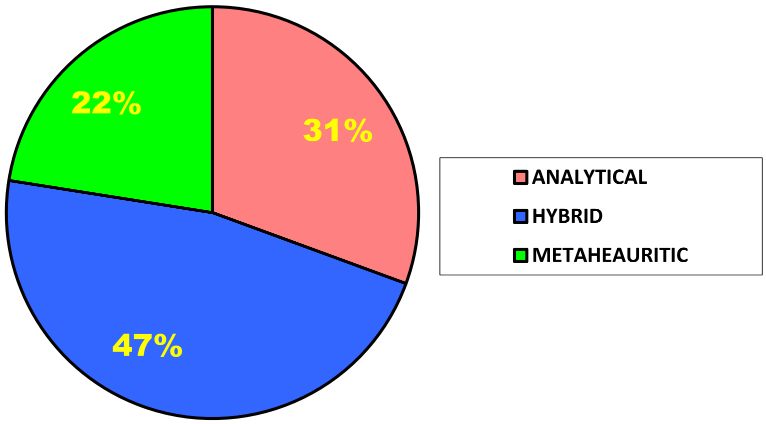

Fig. 21 Optimal location and sizing of FACTS devices to solve optimized techniques

Sensitivity-based methods

Optimal power flow (O.P.F.) determines the best location for FACTS components like T.C.S.C and S.V.C. Sensitivity-based methods have addressed the optimal site and regulation of shunt FACTS devices for controlling renewable energy resources in power systems.

Optimization programming techniques

The best location of FACTS devices is used to examine the various techniques, including linear and quadratic programming, nonlinear optimization programming, integer and mixed–integer optimization programming, and dynamic optimization programming.

Nonlinear optimization programming (N.L.P.)

The nonlinear optimization approach to evaluate controlling parameters suggests a non-linear-interior-point-O.P.F. method for accessing the devices like G.U.P.F.C.

Integer and mixed integer optimization programming (I.P. & M.I.P.) techniques

In a power system transmission network, the integer and mixed–integer–optimization 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.

Artificial intelligence (AI) techniques

The best placement of FACTS 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-optimization (TSO), ant–colony-optimisation

(A.C.O.) methodology, simulated annealing (S.A.) approach, particle- swarm -optimization (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, multiobjective optimal power flow in GA regulates power flow through any transmission line. To enhance system capabilities, the perfect location to place phase shifters and the best quantity to use have been addressed using a genetic algorithm. A multiobjective evolutionary algorithm selects the location of FACTS devices for the power system security for enhancing power system load ability G.A. is used to locate upfc. 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. Some authors have 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 while considering the power loss in transmission lines and voltage deviation buses. A multiobjective evolutionary method is applied.

Tabu search algorithm

The tabu-search algorithm is used to select the appropriate location for FACTS controllers in power systems. The ideal location of FACTS devices in the transmission network can be optimized with the help of a proposed hybrid-meta heuristic technique based on tabu search and nonlinear programming methods.

Simulated-annealing algorithm

Power loss minimization can be adopted with the help of simulated annealing and particle swarm optimization techniques. The location of FACTS devices can be dealt with with the help of tabu search and simulated annealing techniques are used. Suggests a hybrid-meta heuristic approach based on S.A. and PSO for loss minimization

Particle swarm-optimization (PSO) algorithms

The control parameters of FACTS devices can be investigated with the help of a particle swarm -optimization (PSO). The installation cost of T.C.S.C. and U.P.F.C. to find power-system loadability can be calculated with the help of PSO techniques and the plan is to allocate FACTS based on anticipated security costs using a hybrid PSO. The best position for FACTS devices was determined using the PSO technique, considering installation costs and power system security.

Particle swarm optimization uses U.P.F.C. to find the line outage in the power system network suggesting optimal locations of multiple S.T.A.T.C.O.M. for improving voltage stability and loadability.

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.

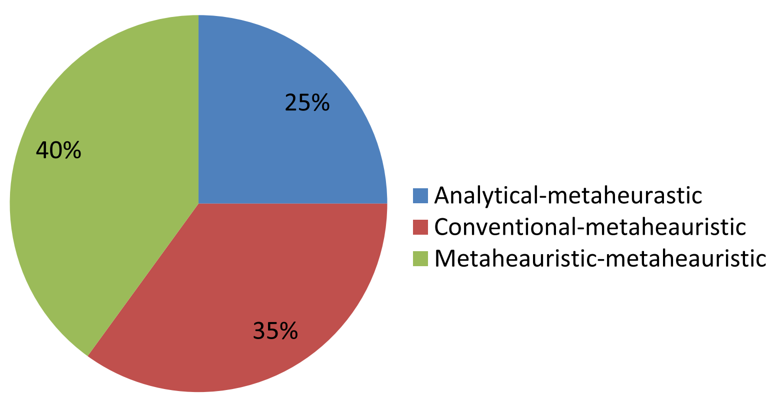

Fig. 22 FACTS devices using in references with optimization techniques

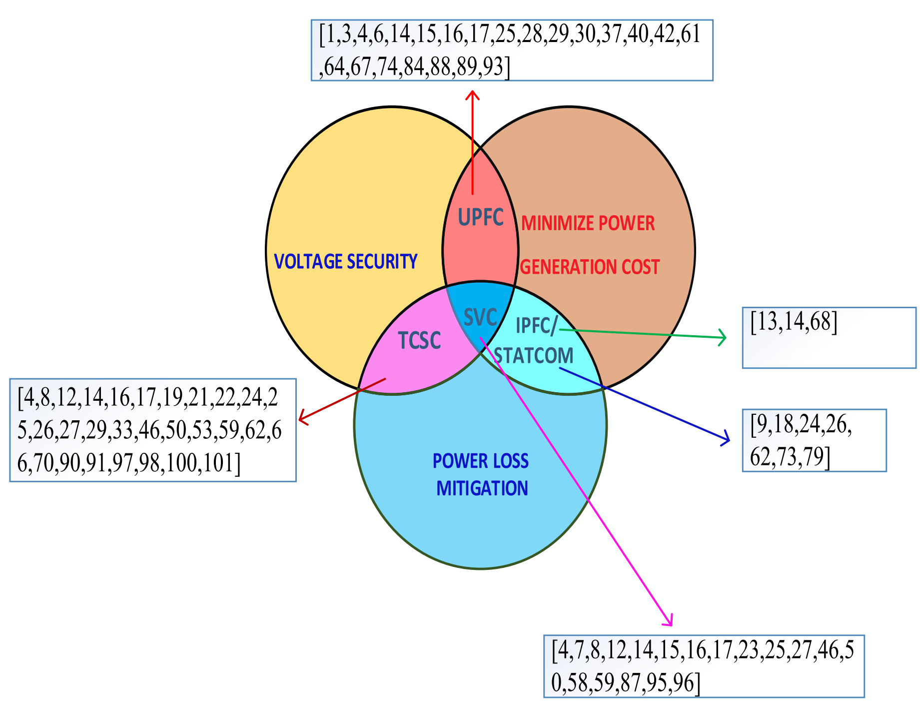

Fig. 23 FACTS devices with objective functions

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.

In addition, optimization techniques with FACTS devices used in power systems are analyzed, Optimal Location And Sizing of Facts Devices to Solve Optimized Techniques in Fig. 21. Facts Devices Using In References With Optimization Techniques in Fig. 22. Facts devices with objective functions as shown in Fig. 23.

- ➢ The main objective function of UPFC as shown in the above figure with references offers system stability, improved voltage profile, relief from congestion problems and better safety of the electrical network
- ➢ The objective function of IPFC with references as shown in the above figure, it minimizes the cost of energy generation and reduces the power losses that occur in electrical networks by adjusting the parameters via compensation techniques. In addition to these, it can also enhance the voltage profile of the power system.
- ➢ The objective function of SVC which consists of references as shown in the above figure can effectively monitor reactive power and is commonly employed for maintaining the voltage within prescribed limits and also for reducing frequency distortions. SVC can absorb as well as generate reactive power in its two different modes of operation. It can be used as a source of ideal reactive power when connected to the bus, and as variable admittance if connected to transmission lines. SVCs are also deployed to smooth flicker voltage in industries. They are widely used to ameliorate power losses, as well as to maintain reactive power, voltage levels and frequencies of the electrical networks at their desired levels.
- ➢ The objective function of TCSC as shown in the above figure with references is based on series compensation techniques. TCSC can support inductive as well as capacitive compensation of the transmission lines. The power system becomes less prone to frequency disturbances and loadability enhancement is also facilitated by the use of TCSC.
- ➢ The objective function of STATCOM references as shown in the above figure supply as well as consume the reactive power, to and from the electric circuit. It can successfully regulate the power factor and voltage of the power system. Additionally, it can be deployed to mitigate fluctuations in the system frequency, compensate for the reactive power when it changes rapidly, and also to maintain the voltage within prescribed safe limits.

Conclusions

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 optimization techniques. As essential guidelines for adequately positioning and sizing FACTS devices, the publication includes a thorough literature analysis and a list of published sources. System studies are very important for the implementation of FACTS controllers to determine the requirements for the relevant installation. Experienced network planning engineers have to evaluate the system including future developments. Right controllers of the right size at the right place have the right cost. The reliable operation of FACTS controllers requires regular maintenance in addition to using equipment of the highest quality standards. Maintenance requirements are minimal but important. According to the literature research, various FACTS devices, as seen in Fig. 2, may regulate a variety of power system characteristics. Additionally, numerous optimization methods are explored, and Table 3 provides an overview of their results. The types of FACTS controllers and their applications are discussed in this review study and are shown in Table 5. Twelve distinct types of controllers are investigated to assess the FACTS best position and use in the power system, and a total of 99 research publications are analyzed. Six of the total number of research publications are reviews, 14 are reviewed to describe the various types of FACTS controllers, and 16 are reviewed to control and optimize FACTS controllers. Thirty-six research articles are examined using the meta-heuristic and analytical methodology to determine the best locations for FACTS devices. The most suitable FACTS controller is to manage reactive and actual power with bus voltage using U.P.F.C. and I.P.F.C. However, S.V.C. and S.T.A.T.C.O.M. are the most used tools for reactive power correction. The best controller for changing the transmission line's impedance is the T.C.S.C., while the S.S.S.C. controller offers active power regulation. Most researchers have employed modern metaheuristic optimization techniques to determine the best location and size for FACTS controllers. The optimal use of FACTS Controllers depends upon well-trained operators. Since most utility operators are unfamiliar with FACTS Controllers compared with for example switched reactors or capacitors), training on the operation of FACTS Controllers is therefore very important, which helps to learn what is important for the operators to know is are the appropriate settings of FACTS Controllers, especially the speed of response to changing phase angle and voltage conditions as well as operating modes.

Future outlook

The IEEE, the World Bank, and other organizations have published several papers indicating that there would be an increase in both the need for and production of energy in the future. Electric vehicles (E.V.) are anticipated to eventually replace traditional diesel and gasoline-powered automobiles. Numerous studies are being conducted to improve the interface between E.V. batteries and the power grid to facilitate quick battery charging and use batteries as energy sources during times of high demand. The future is predicted to see a growth in this tendency. Rooftop solar panel utilization is a different concept already gaining popularity; a sharp increase in its use is anticipated. Renewable energy generation is expected to increase significantly in the upcoming decades, and several forecasts have been produced to reduce global warming through zero carbon emissions. In this way, a paradigm change in the linkage of dispersed energy resources and renewable energy usage is foreshadowed.

Because of their enhanced efficacy, versatility, and ability to act quickly in various situations, non-dominated sorting multiobjective optimization approaches and hybrid techniques are predicted to become increasingly prevalent in the future of optimization techniques. Regarding cutting-edge FACTS devices, due to their adaptability in automatically and selectively managing many power system characteristics, utilization of more general FACTS devices like U.P.F.C. and other variations is anticipated to increase in the future decades.

FACTS devices are necessary in the underground part of the coal mine power supply system for the reactive power compensation consumed by mining equipment. In China, research is actively being conducted on the development of an explosion-proof FACTS device in particular, it is necessary to note the patent for the construction of explosion-proof STATCOM [Explosion-proof Statcom Reactive Compensation Device, URL: http://www.lens.org], which can be placed in the underground part of a coal mine. Two generations of FACTS devices are considered, as a result, it was found that in coal mines it is advisable to use FACTS devices of the APF, PF, SVC and STATCOM types. FACTS devices of the D-FACTS and CPD types are very promising for use in coal mine conditions. The product line of the company FGI Science and Technology Co. (China) was analyzed. It was established that the volume of space occupied by STATCOM is in the range of 10 to 20 m^3 with rated unit power of 1 to 12 MVAr.

Future developments will include the combination of existing devices, e.g. combining a STATCOM with a TSC (Thyristor Switched Capacitor) to extend the operational range. In addition, more sophisticated control systems will improve the operation of FACTS Controller. Improvements in semiconductor technology (e.g. higher current carrying capability, higher blocking voltages) could reduce the costs of FACTS Controllers and extend their operation ranges. Finally, developments in superconductor technology open the door to new Controllers like SCCL (Super Conducting Current Limiter) and SMES (Super Conducting Magnetic Energy Storage). There is a vision for a high voltage transmission system around the world to generate electrical energy economically and environmentally friendly and provide electrical energy where it's needed. FACTS are the key to make this vision live.

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.

Observation

Particle swarm optimization is a technique for solving optimization problems discussed in many articles.

Some authors proposed an optimization 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 optimization to place FACTS devices, reducing the installment 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 minimize 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 minimization. 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 the FACTS device to decrease cost and system loadability withstand limits.

Abbreviations

SVC	Static var compensator
TCR	Thyristor-controlled reactor
T.S.C.	Thyristor-switched capacitor
T.S.R.	Thyristor-switched reactance
STATCOM	Static synchronous compensator
TCSC.	Thyristor-controlled series compensator
IPC	Interphase power controller
TSSC	Thyristor-switched series capacitor
T.C.S.R.	Thyristor-controlled series reactor
TCSC	Thyristor-controlled series capacitor
T.S.S.R.	Thyristor-switched series reactor
T.C.V.R.	Thyristor-controlled voltage regulator
SSSC	Static synchronous series compensator
T.C.P.S.T.	Thyristor-controlled phase shift transformer
UPFC	Unified power flow controller
IPFC	Interlink power flow controller
G.UPFC	Generalized unified power flow controller
B.B.O.	Biography-based optimization
W.I.P.S.O.	Weight improved particle swarm optimization
PSO	Particle swarm optimization
E.P.S.O.	Evolutionary particle swarm optimization
I.P.S.O.	Improved particle swarm optimization
E.L.P.S.O.	Enhanced leader particle swarm optimization
N.S.P.S.O.	Non-dominated sorting particle swarm optimization
PSO-TVAC	Particle swarm optimization with time varying acceleration coefficient techniques
F.A.	Firefly algorithm
TS	Tabu search
C.S.A.	Cuckoo search algorithm
G.S.A.	Gravitational search algorithm
I.G.A.	Improved genetic algorithm
A.B.C.A.	Artificial bees colony algorithm
CPVEIHBMO	Chaotic parallel vector evaluated interactive honey bee mating optimization
G.A.	Genetic algorithm
R.C.G.A.	Real coded genetic algorithm
G.U.I.B.G.A.	Graphical user interface-based genetic algorithm
I.A.	Immune algorithm
S.Q.P.	Sequential quadratic programming-based OPF
BAT	BAT algorithm
M.I.N.L.P.	Mixed integer nonlinear programming
NM	Newton method optimization technique
I.P.	Interior point optimization technique

G.M.	Gradient method optimization technique
M.C.A.	Min cut algorithm
TVT	Tangent vector technique
NR	Newton's Raphson
CE	Cross entropy approach
C.P.F.	Continuation power flow
S.A.	Sensitivity analysis
D.L.U.F.	Disparity line utilization factor
L.F.I.	Line flow index
AIS	Artificial immune system
V.C.P.I.	Voltage collapse proximity indication
PO	Petrubation and observation

Acknowledgements
I would like to thank my Guide Dr. Ravi. K. for their guidance and support throughout this project.

Authors' contributions
We declare that this manuscript is original and has not been published before. It is not currently being considered for publication elsewhere. As the only author, we conceived the presented idea, developed the theory, performed the computations, and verified the analytical methods. We have approved the final version of the manuscript and agree to be accountable for all aspects of this work.

Funding
No financial support was received for this study.

Availability of data and materials
Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

Declarations

Competing interests
The authors declare that they have no competing interests.

Received: 14 March 2023 Accepted: 3 November 2023
Published online: 18 January 2024

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