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Original Article

Substantial Transformative Control Algorithm Coordinated with Facts Devices Constrained for Optimal Power Flow Control

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Abstract - *By enhancing load capability and improving voltage profile by putting the Flexible AC Transmission System (FACTS) device in the most effective zone, the ultimate goal is to improve power system stability while lowering generation costs and transmission losses. This technique is applied by considering the FACTS operation ranges and their best use in the system. The IEEE30 bus power system is used to simulate varied enhanced load capacities. The primary goal is determining the method's Efficiency based on power generating costs, FACTS investment costs, and reduction of transmission loss. The Substantial Transformative Control (STC) Algorithm executes the system, producing better simulation results. In the power system, the Optimum Power Flow (OPF) control will deliberately meet the demands and compensate for the power fluctuation throughout the transmission system. Usually, OPF will improve power stability and reduces the operation cost. The primary goal of the OPF controller is to stabilize the power demand with less cost and time. The OPF and FACTS controller hybrid devices have been implemented to compensate for the system power. The secondary goal is the minimal cost data with Mega Watt (MW) transactions and auxiliary support voltage through the Mega Volt Ampere Reactive (MVAR) support. The OPF controller will monitor the over and under voltage fluctuations.*

Keywords - *Optimum power flow, Mega volt ampere reactive, Substantial transformative control, Active power, Reactive power.*

1. Introduction

New ways of maximizing power transfer in existing transmission facilities while maintaining the same level of Efficiency, reliability, and stability have emerged as a result of the rapid development of the power system, particularly the increased use of transmission facilities, as well as the demand for higher industrial output and deregulation [1]. The fundamental constraints on power transmission are the substantial reactive power loss under heavily loaded conditions and line disruptions. Adding reactive power sources to the power system network can alleviate voltage instability or collapse.

Shunt capacitors and Flexible AC Transmission System (FACTS) devices are correctly located. Static Compensator (STATCOM), Static Var Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Conditioner (UPFC) are examples of FACTS controllers that can modify network settings quickly and effectively to improve system performance [2-4]. Due to the usage of AC wires, most of these FACTS devices demand a high capacitive charging current, which limits their power transmission capacity over long distances [5].

The electrical and magnetic fields of overhead wires and AC cables are also a source of environmental concern. If these limits can be overcome, direct current transmission is utilized. Losses are decreased while using DC transmission. Furthermore, due to the capacitance of the elimination, the transmission lengths for DC transmission are almost endless [6]. Furthermore, HVDC can shield two coupled systems from each other during a crisis or fault, enhancing reliability. Although HVDC has several technological benefits over FACTS, its use is limited due to the high investment costs.On the other hand, investment utilities are becoming increasingly sensitive to traditional utilities due to current deregulation developments. The efficient utilization of low-cost generation is one of the critical goals of deregulation. However, due to security concerns, power transfer across the transmission system is frequently restricted, producing congestion [7].In this case, the system will require more expensive generators, and as a result, power system economics in terms of operating in a sub-optimal mode will be affected. In many circumstances, the less expensive generation or building of a more competitive power plant is the most cost-effective option in the short term [8].

The transmission system should be improved to allow additional power transfer in FACTS or HVDC. For the FACTS controller with an OPF issue, Substantial Transformative control is proposed in this study. The STC approach assesses the amount of energy to be delivered by every generator that is thought to be connected to the bus. This is where the FACTS controller comes in. This system's entire cost and power consumption were reduced, and the power flow of misfortune was limited due to the buss being the correct configuration of the FACTS controller. The following objectives are motivated in this work to enhance the power quality.

- The primary goal of this study is to devise a new technique for improving voltage profile, increasing voltage stability, and reducing network loss using facts devices.
- To identify precise locations, predict the appropriate FACTS device, and determine optimal parameters to ensure enhanced system performance through a suitable optimization technique.
- To Increase the loading capacity of transmission lines. To improve generation productivity and control the transmission voltage.
- Optimal Location and Sizing of FACTS devices with the aid of the Substantial Transformative Control method.

2. Literature Survey

In today's context, increased electricity consumption leads to voltage instabilities and transmission network losses. Power electronics-based devices known as FACTS effectively limit loss, control power flow, and maintain voltage stability to address this issue [9]. Commonly used FACTs devices include Static Synchronous Compensators (STATCOM), Static Var Compensators (SVC), thyristor-controlled static compensators, thyristor-controlled voltage regulators, interline power flow controllers, unified power flow controllers, and other FACTs devices. The cost of FACTS devices is exorbitant, and their location and size estimates are crucial [10].

Several ways are available in the literature to tackle these FACTS optimization issues, including classical, heuristic, and mixed strategies; however, these methods have certain drawbacks in addition to their benefits. Heuristics methods such as GA, Particle Swarm Optimization (PSO) [11, 12], differential evolution, evolutionary programming, and evolution strategies are frequently used to solve optimization problems. These procedures can calibrate the most significant outcomes with fewer problems [13]. These population-based techniques converge better and are inspired by human behaviour or natural phenomena. They can also converge problems with noncontiguous and no differentiable fitness functions, making them more suitable than other techniques and allowing them to work beyond the limits of function continuity and differentiability [14].

Several researchers from across the world have used soft-computational techniques like the General Regression Neural Network (GRNN) algorithm [15], Particle Swarm Optimization (PSO) [16, 17], and an upgraded version of PSO to study the power flow regulation of a grid-connected MG [18]. The preceding research initiatives aimed to achieve optimal power regulation without using time-consuming and inefficient standard PI tuning processes. The PI coefficients derived by the proposed soft computational optimization approaches resulted in superior transient behaviour of the grid-connected MG systems under investigation compared to traditional PI tuning methodologies. However, the proposed optimization approaches (GA and PSO) have severe limitations [19-22].

For example, GA can get stuck in the local solution and is unsuitable for working with dynamic data sets. Because of these flaws, GA has become an out-of-date optimization strategy in the most recent MG controls [23]. When working with high-dimensional optimization issues, PSO, on the other hand, is prone to become caught in the local minimum (local solution) [24]. Its drawbacks include parameter selection uncertainty and a poor convergence rate [25]. PSO's searching capability is quite good in the early iterations, but it has trouble finding the best solution in certain benchmark functions [26-29]. The transmission system has some drawbacks from the above analysis, like voltage instability, Reactive power loss, and transmission loss. The proposed STC method produces the efficient output that can be determined in the result; the operation and control modules are described below work.

3. Materials and Method

The issue of Optimal Power Flow (OPF) is a subject of extensive discourse within the power systems community. Figure 1 illustrates the operational model of the proposed Flexible Alternating Current Transmission System (FACTS) devices, along with the control procedure of the Substantial Transformative Control Algorithm. This study examines a power generation system, considering multiple parameters such as generation cost, stability of output power demand, and system reliability.Factual control devices, including the Thyristors Controlled Series Capacitor (TCSC), Static Var Compensator (SVC), and Thyristors-Controlled Phase-Shifting Transformer (TCPST), can be utilized to optimize fluctuation issues arising from imbalanced power in the generation unit.

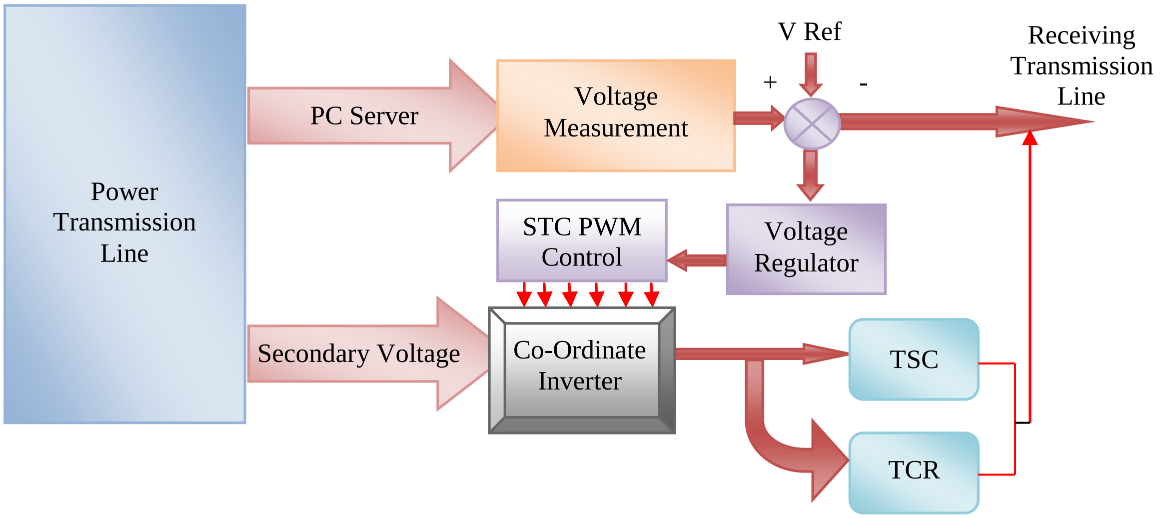


Fig. 1 Block diagram of STC algorithm with optimal power flow

The intended utilization uses the IEEE 30-bus framework and the electrical grid. The STC Algorithm is employed to ascertain the optimal configurations for electrical control components to achieve a harmonious equilibrium between economic considerations and the safety of the overall framework. The primary objective of this project is to facilitate economic power generation by utilizing a voltage stability-based controller. In order to enhance the voltage profile and mitigate congestion within the structure, it is imperative to implement optimization techniques.

3.1. Three-Phase Transformers

Both a 3-phase transformer and a single-phase transformer can alter the Voltage in a 3-phase configuration. The three-phase transformers are constructed using premium materials and engineered to manage substantial power loads effectively. As an illustration, a transformer could possess a 480-volt delta demand and a 120/208-volt auxiliary demand. The three-phase transformer is equipped with a three-phase hub. Each centre’s three legs exhibit a primary and optional torque overlap.

3.2. Inverter

The term ‘inverter’ pertains to a specific category of power electronics circuits that convert energy from one form to another, explicitly converting DC voltage into AC supply. The inverter circuit can be considered a contribution to the DC source, assuming it is derived from the DC source utilized as the AC utility. The Alternating Current (AC) power voltage undergoes repeated transformations, transitioning from an AC to a Direct Current (DC) converter and subsequently to an AC inverter due to the utilization of information. The alternating frequency and magnitude can serve as a viable alternative input for the application, replacing the conventional AC distribution. Typical applications include Uninterruptible Power Supplies (UPS), industrial drivers, traction systems, and High-Voltage Direct Current (HVDC).

3.3. Interline Power Flow Controller

A distributed power flow controller is employed. At least two distributed interline power flow controllers are linked to the DC connector. The IPFC is acknowledged for its ability to regulate power flow and manage compensation in a multi-line transmission system, in contrast to individual devices dependent on controlling a single transmission line parameter. Each converter can provide project response compensation, as evidenced by its comparison with a Static Synchronous Series Compensator (SSSC). Converters can transfer dynamic energy through their fundamental DC interface, providing the current frequency.

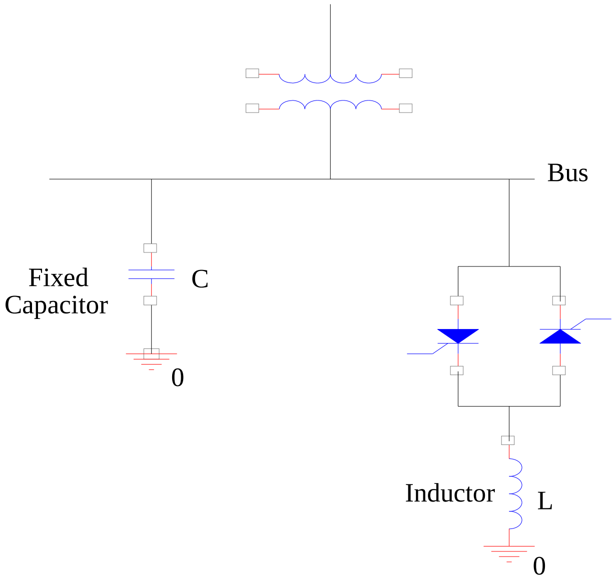


Fig. 2 One-line diagram of a typical SVC configuration

3.4. Static Var Compensator

The most likely architecture of the Static Variable Compensator (SVC) is seen in Figure 2. It had previously served a different purpose as a drive-related device. Every one of these identifiably replaceable modules has its name. The pack is a focal point for comparative susceptance, where the compasses are halted. It provides a description of the angle and a recognition of the conclusion of the condenser voltage. The first thing to do is eliminate the effects of the past in the here and now using harmonics of equal frequency.

$$Beg = Bl(\propto) + Bc \qquad (1)$$

3.5. Thyristor Controlled Series Capacitor (TCSC)

Comparable to SVC, TCSC is made up of a series of modules that are fitted in a capacitive settling trigger and thyristors. These components are combined to form the TCSC. A configuration analogous to that shown in Figure 3 is connected to the thyristor-controlled series capacitor, as shown here. Altering the capacitive or the inductive reactive transfer line of the DCSC allows for independently charging the compensation. In this study, the TCSC is used as the sole instrument for adjusting the reaction of the transmission line.

On the other hand, the series capacitor needs to behave like a capacitor when the power frequency (either 50 Hz or 60 Hz) is being used. This is necessary in order to convert the sub-resonance frequency of the DCSC virtual response into the initial capacitance of the excitation. A reactive controller offers a capacitive reaction that can be controlled concerning the power frequency. A portion of the transmission line was discovered in the reaction of TCSC, and its estimated value is as follows.

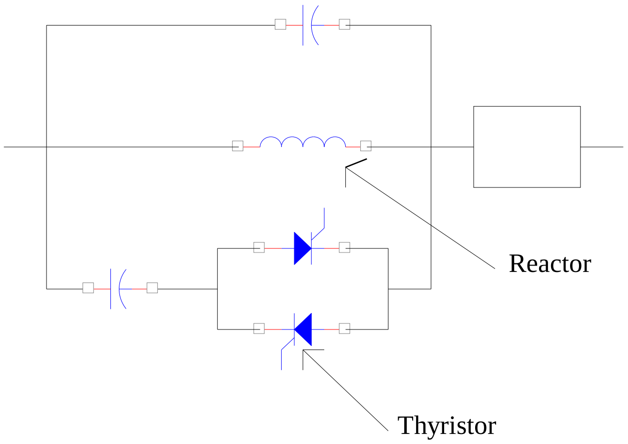


Fig. 3 Structure of a TCSC

3.6. Thyristor - Controlled Phase - Shifting Transformer (TCPST)

The structure of a TCPST is depicted here in Figure 4. The accompanying shunt takes advantage of the arrangement of the transformer. It adds several connectors to control the action taken regarding a specific Transformer Voltage (TV); compared to a conventional transformer, a proportionally regulated thyristor is used in its place of the moving phase. The power can be controlled by adjusting the angle at which the transmission thrust is applied to the TCPST.

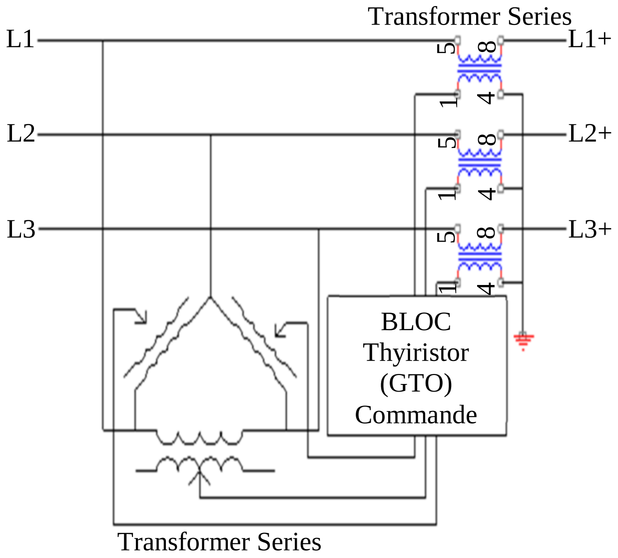


Fig. 4 Structure of a TCPST

3.7. Mathematical Model of STC for Solving Optimal Power Flow Problem

The STC is a dependable population-based progress calculation that considers challenges. STC is activated by top-secret standards that reveal the system's integrity. Calculations performed by the STC suggest the differential progression and harmonic genesis of a compound to elevate the DE's level of coherence. The proposed method is a carbon copy of the existing STC population, which uses the Interline Power Flow Controller process to provide new people with STC development. An OPF controller can be utilized between the power and the reactive power to transition from loaded to low-laden lines. The more general form of linearly constrained optimization is characterized by the equation which follows,

$$MinimizeF(x) forx = (x_1, x_2 \ldots\ldots x_n) \qquad (2)$$

$$\begin{gathered} subject\ to\ g(x) > 0 forj = 1,2 \ldots\ldots j\ and \\ h(x) = 0\ for\ k = 1,2, \ldots.k \end{gathered} \qquad (3)$$

Where, X : Variables (a set of design parameters)
F(x) : Objective functions to be minimized
g(x) : Inequality constraints
h(x) : Equality constraints

According to preliminary calculations, it is possible to influence the parameters' values by manipulating the quadratic errors.

$$\mathrm{F(x)} = \sum[\mathrm{y} - \mathrm{f(x, \theta)2}] \quad (4)$$

Where, y : Test data at the test condition
f(x, θ) : Predicted value at the test condition θ

$$\nabla F(x) - \sum_{j=1}^{j} u_f \nabla_{gj} f(x) - \sum_{k=1}^{k} v_f \nabla h_k(x) = 1 \quad (5)$$

$\mathrm{U_{jgi}(x)}$: Lagrangian multiplier corresponding to constraint g(x)
$\mathrm{V_k}$: Lagrangian multiplier corresponding to constraint h(x)

The OPF issue is referred to as a growing process that features several jobs that are now ongoing in addition to frequency issues. It is possible to file a complaint regarding the OPF in general.

$$\text{Minimize F(X)} \quad (6)$$

$$\text{Subject to } \mathrm{g(x)} = 0 \quad (7)$$

$$\mathrm{h(x)} \leq 0$$

Where, F(X) corresponds to the correspondence function, g(x) discusses the different constraints and the control where a control centre leader replaces x. The best power stream problem entails minimizing actual labour while meeting heap conditions and avoiding hurting irregular obstructions.

The power generation cost is given by,

$$F(x) = \sum_{i-1}^{n} NG(a_i + b_i p_{Gi} + c_i p_{Gi}^2 \quad (8)$$

Where NG is the size of the generation, including the load bus, PG is the dynamic power provided by the bus (i), b (i), and c (i) are the unit costs for i ^ th generator. The valve point loading of the supplying units is provided by the smooth quadratic fuel cost (8), where the valve point impacts are ignored. Manufacturing units with multiple valves are the most apparent classification in fuel cost ranges. As valve point swells are felt, there is a greater need for a cost job. Similarly, condition (9) must be changed to consider valve-point impacts. Sinusoidal skills are combined in these ways into quadratic costing jobs.

$$F_i(p_i) = a_i + b_i p_i + c_i p2_i + |e_i \times \sin(f_i \times \left(p_{i,min} - p_i\right) \quad (9)$$

Where, a_i , $b_i + c_i$ are the fuel cost coefficients of the ith unit. e_i *and* f_i is the fuel cost coefficient of the $\mathrm{i^{th}}$ unit.

Even while it is important to keep labour costs down, it is necessary to ensure that the generation of load demands is still more significant than any accidents that may occur on the transmission lines. In most cases, stock limits are determined by the parameters of the electric flow.

$$\begin{bmatrix} \Delta p_i \\ \Delta Q_I \end{bmatrix} = \begin{bmatrix} p_i(V,\theta) - (P_{Gi} - P_{Di}) \\ Q_i(V,\theta) - (Q_{Gi} - Q_{Di}) \end{bmatrix} = 0 \quad (10)$$

Where active and reactive power injection at bus i is defined in the following equation

$$P_i(V,\theta) = \sum_{j=1}^{NB} V_i V_J (G_{ij} cos\theta_{ij} + B_{ij} sin\theta_{ij}) \quad (11)$$

$$Q_i(V,\theta) = \sum_{j=1}^{NB} V_i V_J (G_{ij} sin\theta_{ij} + cosB_{ij}\theta_{ij}) \quad (12)$$

The limitations placed on guaranteeing the structural integrity of the building are reflected in the restrictions placed on the OPF, which mirror the objectives of repressing the physical contradictions within the power system. A handful of people are working on the top bus voltage limitations on generation and load buses.

Other people are working on bus voltage limits on load buses, responsive power limits on producing buses, and the most critical dynamic power limits associated with the cut-off. Several factors are to consider, including generators, outrageous line loading restrictions, and pipe system constraints. Many different kinds of circumstances can be issue factors.

Command of the generation: Their maximum and minimum values determine generator voltages and honest and responsive power outputs.

$$\mathrm{P_{Gi,min}} \leq \mathrm{P_{Gi,max}} \mathrm{Fori} = 1,2 \ldots \ldots \mathrm{N_G} \quad (13)$$

$$\mathrm{Q_{Gi,min}} \leq \mathrm{Q_{Gi}} \leq \mathrm{Q_{Gi,max}} \mathrm{Fori} = 1,2 \ldots \ldots \mathrm{N_G} \quad (14)$$

$$\mathrm{V_{Gi,min}} \leq \mathrm{V_{Gi}} \leq \mathrm{V_{Gi,max}} \mathrm{Fori} = 1,2 \ldots \ldots \mathrm{N_G} \quad (15)$$

Shunt VAR control: their upper and lower limits control shunt VAR compensation,

$$\mathrm{Q_{Gi,min}} \leq \mathrm{Q_{Gi}} \leq \mathrm{Q_{Gi,max}} \mathrm{Fori} = 1,2 \ldots \ldots \mathrm{N_G} \quad (16)$$

Where $\mathrm{N_C}$ is the number of shunt compensators.

Transformer arrangement and transformer tap settings are controlled by their upper and lower limits as follows,

$$\mathrm{T_{i,min}} \leq \mathrm{T_i} \leq \mathrm{T_{i,max}} \mathrm{Fori} = 1,2 \ldots \ldots \mathrm{N_T} \quad (17)$$

Where $\mathrm{N_T}$ is the number of transformer taps.

3.7.1. Safety Constraint

Their upper and lower limits control the voltages on the load bus.

$$v_{Li,min} \le V_{Li} \le V_{Li,max} \text{Fori} = 1,2 \ldots\ldots N_L \tag{18}$$

Where N_L is the number of load buses.

3.8. Apply Substantial Transformative Control Algorithm

This method relies on two parameters, such as voltage angle, output power, and power losses, to achieve the desired tuning. Provides solutions to optimization issues by carrying out three essential duties: mutation, determination, and stability. The following diagram illustrates the operations of the STC:

Step 1 : Mutation

Select the target vector X_ (i, g) (= x0, g) and the base vector X (0, g) (= x2, g) and select two vector elements randomly X_ (ri, g) (= x3, g) and X_ (r2, g) (= xN_ (p-2), g)

Compute the Value for a Mutant Vector:

$$V_{i,g} = x_{r0,g} + F.(x_{r1,g} - x_{r2,g}) \tag{19}$$

Step 2 : Crossover

Select the original vector from the target vector and the mutant vector according to the following rules:

$$u_{i,g} = u_{j,i,g} = \begin{cases} v_{j,i,g} \text{ if } \operatorname{randj}(0,1) \le \text{cr or } j = j_{randj} \\ x_{j,i,g} \text{ otherwise} \end{cases} \tag{20}$$

Step 3 : Selection

To determine whether or not the initial vector should be selected, it is necessary first to calculate the value of the new vector's goal function and then evaluate how that value stacks up against the value of the target vector's objective function.

$$x_{i,g+1} = \begin{cases} u_{i,g} \text{ if } f(ui, g \le f(xi, g)) \\ x_{i,g} \text{ otherwise} \end{cases} \tag{21}$$

3.9. Apply STC for Optimal Power Flow Problem

The introduction of disclosed systems is, in the first place, in the functional space of storing all of the available vectors. This is of the utmost importance. The number of posterior vectors is based on the determination made by the Substantial Transformative Control. The Harmonized System (HS) will prevent anyone from using the STC, utilizing the Pitch Adjustment Rate (PAR), selecting an incentive rating from the STC, and selecting an arbitrary reward with compatible memory regarding the ratio. The steps involved in the algorithm are as follows:

- As input data, read the data on the energy production and its co-efficient, on the active energy resources and their restrictions, load needs, voltage limits, and lower and upper limits, devices related to FACTS.
- Generate a random sample of the total number of particles depending on the limits of each unit, which may include search locations, dimensions, and velocities. These fundamental particles need to be workable solutions that can circumvent the limitations imposed by particle motion.
- Determine the CT cost ratio for every Pg included in the population.
- Set the price of each particle such that it is at its most profitable level. If the differential
- value cost for Pg is lower than that produced with pbest, replace pbest with the integrals of the Pgest Contemporary. Gather the Pbest beach values of all the particles and the best particle coordinates to define the Gbest particles.
- Change the velocity of each cell's members to the equation below:

$$V_{id}^{k+1} = wV_{id}^{k} + C_1 * \text{rand1} * \left(P_{id} - x_{id}^{k}\right) + C_2 * \text{rand2} * \left(P_{gd} - x_{id}^{k}\right) \tag{22}$$

Where,

$$w = w_{max} - [\frac{w_{max} - w_{min}}{iter_{max}}]$$

- Change each particle member's current position (search point) using the equation below.

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1}$$

- If the number of iterations is high, go to step 9 and go to step 3.
- The Gbest solution to a given problem is the latest G_{best} Generating Particle.

The focus systems automatically switch from using the primary parameter vector to the applicant vector once the work of this kind is slowed down. The work proceeded even if the exhibition attendees were not the same. In step 4, the process stops when one of the stopping conditions has been met; if not, the process continues to step 2.

4. Simulation Results and Discussion

When demonstrating the efficacy of the Substantial Transformation Control Algorithm in optimal power flow with SVC, IEEE30 bus systems are considered a potential candidate. An OPF program using the STCA methodology and SVC within MATLAB has been built.

This software can classify different line voltage levels and the cost and Efficiency of data creation and line losses. A MATLAB program has been coded to perform the test, and the results can be found further down.

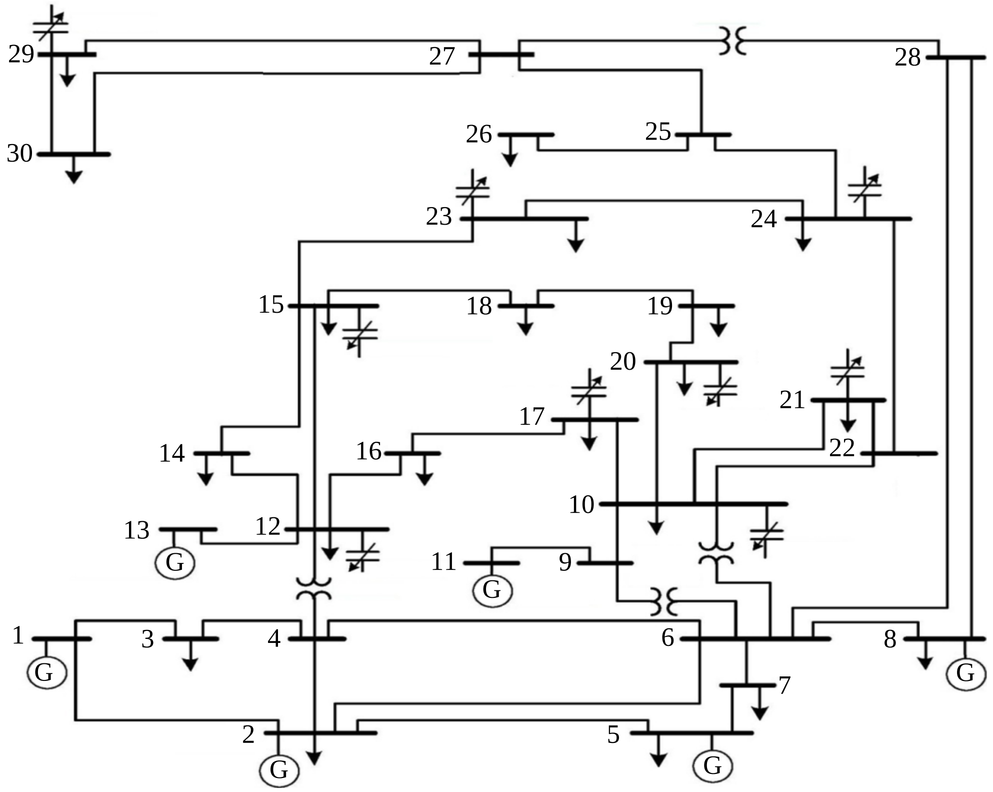
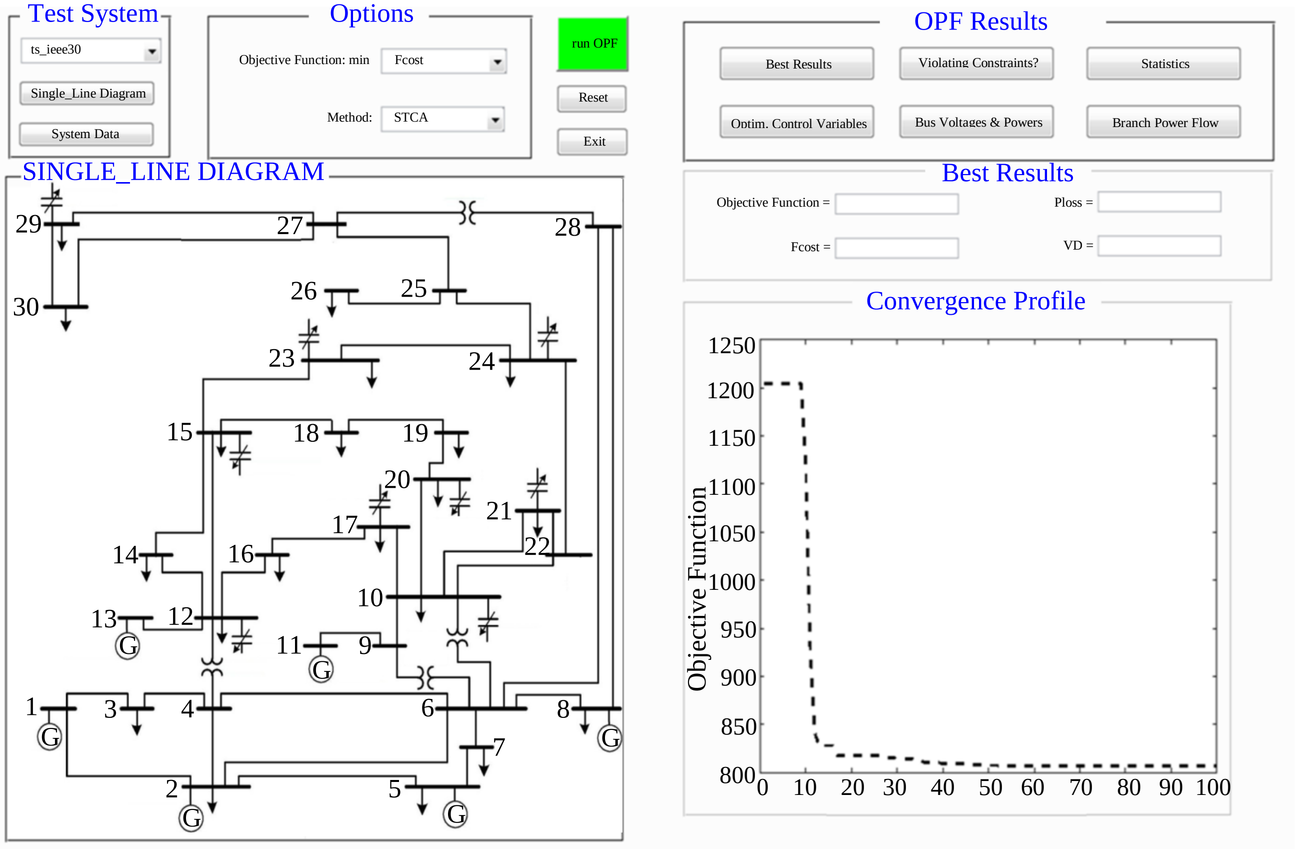


Fig. 5 Modelling of IEEE 30 bus systems



Objective Function: min Fcost

Method: STCA

Fig. 6 Simulation gain of 30 bus system

Table 1. Voltage magnitudes between various buses

S. No.	Bus Number	GA Method V(Pu)	GA Method Angle (Degree)	CDP-CEA V(Pu)	CDP – CEA Angle (Degree)	PCDPO V(Pu)	PCDPO Angle (Degree)	STC (Pu)	STC Angle (Degree)
1	2	0.985	-18.146	1.043	-5.43	1.0600	0.0000	1.080	0.0000
2	6	0.989	-18.110	1.012	-11.088	1.0431	-5.3500	1.0612	-4.6100
3	8	0.991	-17.532	1.010	-11.804	1.0207	-7.5300	1.0463	-6.8912
4	12	0.994	-16.853	1.058	-14.94	1.0118	-9.2800	1.0352	-7.6931
5	15	0.998	-15.105	1.038	-15.49	1.0100	-14.1700	1.0351	-11.7214
6	20	1.053	-14.763	1.029	-16.536	1.0102	-11.0600	1.0324	-9.06425
7	30	1.016	-9.31	0.995	-17.655	1.0024	-12.8600	1.0075	-9.6578

Table 2. Comparison of FACTS devices with different control algorithms

Control Variables	GA with SVC	GA with TCSC	GA with TCPST	CDP–CEA with SVC	CDP–CEA with TCSC	CDP – CEA with TCPST	PCDPO with SVC	PCDPO with TCSC	PCDPO with TCPST	STC with SVC	STC with TCSC	STC with TCPST
PG1(MW)	176.30	176.03	180.15	185.26	185.91	1 75.12	186.10	184.64	176.05	188.26	184.52	178.36
PG2(MW)	31.253	32.22	32.105	34.183	33.43	32.623	34.215	33.05	32.569	35.051	33.68	33.269
PG3(MW)	28.105	27.01	27.88	29.763	28.42	6.55	29.856	8.14	6.45	30.215	28.65	6.12
PG4(MW)	10.179	11.03	12.54	11.536	12.71	15.832	11.056	12.56	14.058	11.698	12.32	14.024
PG5(MW)	12.56	13.01	13.96	13.103	13.17	14.745	13.03	13.96	14.056	13.436	13.79	14.023
VG1(pu)	1.04	1.03	1.02	1.01	1.03	1.00	1.01	1.03	1.04	1.01	1.03	1.02
VG2(pu)	1.02	1.01	1.01	1.01	1.01	1.04	1.01	1.01	1.02	1.01	1.01	1.01
VG3(pu)	0.99	1.00	1.01	1.02	0.97	1.023	1.02	1.00	0.99	1.02	1.00	0.986
VG4(pu)	1.02	0.96	0.95	1.02	0.96	0.946	1.02	0.96	1.02	1.02	0.96	1.02
VG5(pu)	0.99	1.01	1.02	1.02	1.01	0.945	1.02	1.01	0.99	1.02	1.01	0.995
T1(pu)	0.98	1.00	0.987	0.987	1.00	0.987	0.987	1.00	0.98	0.987	1.00	0.99
T2(pu)	0.945	0.998	0.965	0.949	0.942	0.943	0.949	0.998	0.945	0.949	0.998	0.953

Table 3. Performance analysis of generation and injected voltage using STC controller

Bus No.	Voltage Magnitude	Load (Power)		Generation (Power)		Injected (Power)
		MW	MVAR	MW	MVAR	MVAR
1 - 5	1.032	26.53	6.75	60.40	7.31	1.41
6 - 10	1.046	28.36	8.63	59.43	6.35	2.92
11 - 15	1.09	5.71	2.65	59.26	5.312	2.75
16 - 20	1.046	5.49	2.36	60.42	7.41	0.71
21 - 25	1.025	10.09	1.95	60.23	7.24	1.63
26 – 30	1.016	1.28	1.06	60.12	7.21	1.93

Table 4. Line losses analysis using PCDPO and other algorithms

Control Technique	Line Losses CDP-CEA	Line Loss GA	Line Losses PCDPO	Line Loss STC
SVC	5.3	6.5	5.1	4.02
TCSC	4.5	5.1	4.2	3.65
TCPST	2.5	2.9	1.9	1.64

Table 5. Performance of OPF based on various algorithm

Parameters	GA	CDP & CEA	PCDPO	STC
Efficiency (%)	79	85	91.56	96.52
Average Load Voltage (V)	410	440	440	440
Line Losses (%)	10	7.05	4.4	3.02

The operational model of the IEEE 30 bus system is depicted in Figure 5. This model can be carried out on the proposed sophisticated STC. The power produced by the six generators is transported via bus numbers 1, 2, 5, 8, 11, and 13, and 13 of those generators supply the active power voltage for the system. Combining these factors determines the system’s power output with 30 buses.

Figure 6 depicts the 80 transmission lines that are a part of the conventional IEEE 30-bus system, as well as the six generators that are a part of buses 1, 2, 5, 8, 11, and 13 located underneath the load tap changing transformer branches. Reactive power sources are considered in buses 17, 20, and 24.

We consider the minimum and maximum limitations of the system line data, bus data, generator data, and control variables. The top and lower limitations of transparent power sources and transformer pipeline systems are taken from various transformer buses. Within the scope of this study, 72 separate test cases are carried out to answer the OPF problem using a variety of objective functions.

Table 1 presents the findings of comparing voltage magnitude with different buses, which may be correlated with a voltage angle obtained from the data system. This research makes it abundantly evident that the proposed STC approach produces favourable results compared to other methodologies.

The preceding Table 2 provides a description of the power generation as well as the related power load on the grid. The proposed STCA technique, which outperforms other popular methods, estimates losses on all lines near this line. These lines all have SVC, TCSC, and TCPST. The suggested STC method was used to compare voltage levels, load, generation, and injection in the IEEE 30 bus (see Table 3).

The Line Losses Analysis of the FACTS devices is presented in Table 4, and it uses the GA, CDP & CE, and PCDPO in conjunction with the STC Controller. The loss is a 1.64 percentage point reduction when several parameters are considered. According to the findings, the FACTS-based controller performs significantly better than conventional controllers like the GA and CDP approaches regarding response overshoot.

Table 5 compares the action taken by the FACTS Controller with several different parameters, including Loss reduction, Power loss, Efficiency, and so on. According to the findings, the controller based on the STC algorithm works better than conventional controllers like CDP & CEA and GA regarding response overshoot.

5. Conclusion

This research presents the development of a comprehensive evaluation code system for analyzing various comparisons involving different Flexible Alternating Current Transmission System (FACTS) devices. The primary indicator of the index power is its control over flow control, while complementary indicators include loss reduction, improvement in static voltage stability, and reduction in load shear. Irrespective of whether a singular or comprehensive evaluation index is considered, Thyristor Controlled Switched Capacitor (TCSC) and Thyristor Controlled Reactor (TCR) exhibit notable superiority among the various Flexible Alternating Current Transmission System (FACTS) devices. This observation holds crucial research significance in the context of Thyristor control-based reactors.

The simulation shows that the transmission framework has improved exchangeability, decreased optimal power flow issue, decreased optimal power flow issue, voltage change, stability control, and Efficiency of 96.52%. SVCs are accountable for the components dealing with the Voltage and the active power losses, whereas TCSCs and TCPST are accountable for the component dealing with line loadings. The FACTS devices are vital to alleviate congestion while improving the system’s overall security.

However, deploying such devices without proper coordination may result in conflicting scenarios that put the safe operation of the transmission grid at risk. This effort has resulted in the development a substantial transformative control algorithm based on the most efficient power flow. Finally, simulations demonstrating the advantages of the control developed from the Substantial Transformative Control Algorithm were shown. Congestions were cleared up, voltage profiles were more balanced, and active power losses decreased by 3.02%.

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