REVIEW ON FACTS OPTIMAZATION ALLOCATION ON GRID

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Abstract- **S**ocial impact of new transmission and distribution lines and the growth in environmental requirements has not lead to the expansion of the electric power grid but to the optimization of the existing assets. Flexible AC Transmissions Systems (FACTS), developed during the last decades of the past century, have become one of the most remarkable solutions for the optimization of the electrical power grid. Due to their flexibility, different types of FACTS have been proposed to solve similar transmission system operation problems. This paper reviews the FACTS devices used for solving these problems and the techniques used to optimize their location. In this paper review of different approaches of fact placements by optimization and other approaches and its comparative analysis

Keywords: *Flexible AC Transmission System, Genetic Algorithm, Static Synchronous Compensator*

I. INTRODUCTION

The current power program becomes more technically interconnected program because of worrying upsurge in dynamic pattern of the load and the load demand which usually affect the transmitting lines on extreme basis. They may be operating possibly overloaded or perhaps in under loading conditions. The uneven distribution of load distresses the voltage profile and makes the security of the system vulnerable to the fault. It becomes quite difficult to keep up reliability and security of power system [2]. Conventional strategy adds transmission lines in the machine and build fresh facilities of power generation which usually bounds with certain elements such as for example specialized and cost-effective bounds. Therefore the best and necessary solution left is to create optimal usage of existing transmission and generation network. FACTS technology represents the greatest and successful alternative method intended for the improvement of power such as transfer capability, volts security, and decrease in losses etc. rather than making complex novel transmission passage [9] [12]. The unit could be linked in shunt, series, series-series and series-shunt. It is necessary to choose FACTS devices type based on the reason for need. For the control of voltage control at a certain point, shunt controllers are necessary and line-based power flow could be controlled with the help of series controllers. Power flow could be made controllable or flexible using such units of FACTS. FACTS products really helps to boost load capability of the network through reduced amount of power circulation in overloaded lines and line deficits are also decreased. FACTS devices efficiently tackle the issues of system security and voltage collapse [2, 3]. These devices assist in the issue of managing the congestion part. The optimal position and settings of FACTS gaFACTSets play a significant role intended for enhancement of system overall performance and financial benefits. Previously, several approaches were proposed by researchers to work through the issue of FACTS devices based optimal position. Prevalent techniques of these devices are classified into linear programming, heuristic search, and analytical methods [11] [13]. The issue of optimal area is recognized as combinatorial investigation and heuristic search methods are considered as the best tools to remove such complications because they are strong, fast and suitable for real problems of the energy system. The most commonly built heuristic search techniques projected for optimal location in the research study are Differential Evolution (DE), Genetic Algorithm (GA), Harmony Search Algorithm (HSA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO) [7] [8].

1.1 FACTS Technology

Electric power systems along with some stationary equipment offering controllability of power circulation and volts are referred to as Flexible AC Transmission Systems (FACTS) controllers. FACTS will not make reference to any kind of single gaFACTSet but a bunch of controllers such as for example SVC, UPFC, STATCOM, TCSC, TCPST, etc. Nevertheless, their primary function is usually to regulate electric power by manipulating the parameters such as for example impedance of transmission line, voltage angles and terminal voltage perspectives [1] [9]. The improved interest in FACTS devices is because of the latest development in the technology of power electronics. But FACTS devices are always preferred predicated on their overall efficiency. The FACTS controllers can be classified as: (a) Series connected controllers, (b) Shunt connected controllers, (c) Combined series-shunt, and (d) Combined series-series controllers. The series controllers help in controlling the line-based power flow while shunt controllers can control the bus-based voltage to which they are associated [8]. The FACTS devices used in electric power system consists of the following [4] [9]:

1. Static VAR Compensator (SVC): It controls voltage. The SVC could be operated either as capacitive or inductive compensation. It could be modelled with two switched ideal components in parallel; an inductive and a capacitive. Therefore function from the SVC will either be to put in reactive power to bus or even to absorb reactive power from the bus exactly where it is linked.

2. Thyristor Controlled Series Compensator (TCSC): It controls impedance. By modification of the line reactance. TCSC either act as capacitive or inductive compensator. The capacitance maximum value is fixed at -0.8 XL and the maximum value of the inductance is 0.2XL, where XL is known to be the line reactance.

3. Unified Power Flow Controller (UPFC): A series inserted phase and voltage position could be patterned for UPFC. The placed voltage gets the maximum magnitude of 0.1Vmax, exactly where Vmax may be the transmitting line maximum voltage. The significant selection of the UPFC position is among -180 level to +180 degree.

*4. Static Synchronous Series Controller (SSSC):*It operates likewise controllable series and capacitor inductor. The principal difference is that the injected voltage isn't linked to the line level and will come to be managed alone. This feature allows the SSSC to utilize high loads along with lower loads satisfactorily.

5. Inter-phase Power Flow Controller (IPFC): It offers advanced solutions for high environments of short-circuit.

6. Static Synchronous Compensator (STATCOM): scontrols voltage of the system

7. Thyristor Controlled Phase Shifting Transformer (TCPST): It controls angle of the system.

1.2 Objectives for placing FACTS Devices

To boost the performance of the electric power system, proper parameter and location setting of FACTS controllers is necessary [6]. Intended for the perfect usage and expense of FACTS controllers, optimization can be carried out based on the following points without violating the constraints of power system [9]:

- Drop in the real power loss of a specific line.
- Drop in altogether program of real power loss.
- Reduction in the full system reactive power reduction.
- Rise in Available Transfer Capability
- Maximum alleviation of blockage in the machine.

1.3 Problem Formulation

1.3.1 Objective of the optimization

As the price of the FACTS devices is great, to be able to accomplish the utmost advantage, the products should be set up at the perfect optimal locations. The target (objective) function offers three conditions; the 1st term signifies the set up cost of the devices, the next and third terms representing the deviations of strain (load) bus voltage and line loadings respectively [8]. The minimization of the suggested objective function must result in an inexpensive protection oriented placement of device. The target function is usually formulated as the following [8]:

$$\text{MinF} = W_1[(C_{FACTS} * \text{S})] + W_2\,[\text{LVD}] + W_3[\text{LL}] \ldots\ldots\ldots (1)$$

Where,

F = objective function,

C_{FACTS} = FACTS device costs in US $/KVar,

S = FACTS device operating range,

LVD = Load voltage deviation

LL = Line loading

W1, W2 &W3 = Weight factors.

*1. Cost (C_{FACTS}):*The primary term of the objective (target) function C_{FACTS}, represents the FACTS devices-based installation cost and are specified by the succeeding equations. C_{SVC} is the SVC device cost in US $/KVar, C_{TCSC}presents the TCSC device cost in US $/KVar, C_{UPFC} is the UPFC device cost in US $/KVar.

$$C_{SVC} = 0.0003\text{s2} - 0.3051\text{s} + 127.38 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$C_{TCSC} = 0.0015\text{s2} - 0.7130\text{s} + 153.75 \ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

$$C_{UPSC} = 0.0003\text{s2} - 0.2691\text{s} + 188.22 \ldots\ldots\ldots.\ldots\ldots\ldots (4)$$

2. Load voltage deviation: Extreme low or high voltages can result in an improper quality of service and may create problems of voltage instability. FACTS products connected in appropriate places play a respected role in improving volts profile therefore avoiding voltage quality collapse in the energy system. The next term considered signifies the strain voltage deviations to be able to avoid the below or higher trouble of voltages at network buses.

$$LVD = \sum_{m=1}^{nb}\left(\frac{V_{mref} - V_m}{V_{mref}}\right)^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

m = Load buses where $V_m < V_{mref}$

V_m= voltage magnitude at bus m

V_{mref}= nominal voltage at bus m and is usually considered as 1.0 p.u

3. Line loading: FACTS devices can be found to be able to take away the overloads and also to distribute the strain (load) flows consistently. To accomplish this, line loading concept is recognized as the 3rd term in the target function.

$$LL = \sum_{l=1}^{nl}\left(\frac{S_l}{S_{lmax}}\right)^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots (6)$$

Here,

S_l= Apparent power in the line

S_{lmax}= Apparent power rating of line *l*.

1.3.2 The optimization variables

The optimization variables considered in this ongoing work are as follows [8]:

- The amount of FACTS devices to be set up is accepted as the 1st variable.
- The positioning of the devices is recognized as the next variable to be enhanced/optimized. TCSC is positioned in a line, SVC is put into load bus and UPFC is linked between a bus and a line.
- Type of devices to become installed is recognized as the 3rd variable.
- The device rating is recognized as the fourth variable.

1.4 Optimal Siting of FACTS Devices

The choice of placing a FACTS gaFACTSet is basically determined by the required impact and the features of the precise system. Static VAr Compensators (SVCs) are mainly suitable once reactive flow of power or perhaps voltage support is essential. TCSC devices aren't suitable in line with large flow of reactive power [10]. Also the expenses of the devices play a significant role for the decision of FACTS device. Having made a choice to set up a FACTS device in the machine, one will find three primary conditions that should be considered: location, capacity and type of device.

One will find two unique method of placing FACTS devices in the machine system for the intended purpose of raising the system's capability to transfer power, thereby enabling the usage of more economic generating units. This is why FACTS devices are put in even more heavily loaded lines to restrict the energy flow in the line. This kind causes even more capacity to be sent through the rest of the servings of the machine while shielding the line with these devices to be inundated. This technique which usually sites the devices inside the heavily packed line may be the most reliable [10, 12]. In the event if the flow of reactive power is usually a substantial part of the full total circulation on the restricting transmission collection, then either a TCSC device inside the line or possibly a SVC system located by the end of the range gets the reactive power, enabling to decrease the reactive power movement, increasing the capacity of active power flow. Once again it really is discovered that UPFC may be the most effective and flexible FACTS unit due the fact that line impedance, phase ange and voltage magnitude could be transformed by the similar device.

II. RELATED WORK

S.Kundu, et.al [1] presented a great iterative research in Mi-power software intended for IEEE 57 bus check system. The severe nature of the line has been recognized using FVSI i.e. Fast Voltage Stability Index and afterwards SVC was positioned on the recognized critical buses distinctly to save lots of computation as well as the searching space. Using additional aspects based on technical concepts and other aspects i.e. environmental and economic issues were also reflected in this paper while placing SVC at the perfect location. Dipesh Gaur, et.al [2] considered distinct methods of optimization such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) etc. These methods were debated and compared for optimal placement, rating and type of devices. FACTS devices like Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC) were taken into consideration. It also revealed the effects of FACTS controllers on different parameters of IEEE bus network like the cost of generation, voltage stability, active power loss, etc. have been compared and analysed among the other devices. K. Kavitha, et.al [3] investigated and proposed a novel solution approaches for the optimal FACTS devices placement, for the improvement of system protection under differing system weight (load). The potency of the perfect installing SVC, TCSC, combined TCSC-SVC and UPFC in advancement of the security of power systems, when it comes to minimizing load voltage deviations and the line loading were inspected. The algorithms developed for the perfect placement of numerous FACTS devices was authenticated by performing case research on regular IEEE test systems. The analysis shows that after the placement of optimal FACTS device, both line loadings and load bus voltage deviations were minimized henceforth enhancing the machine security. Even more analysis discloses that Biogeography Optimization (BBO) technique displays best overall performance contrasted with PSO and Weight Increased PSO (WIPSO) approaches. Saurav Raj, et.al [4] studied the minimization of both active power reduction and total system working cost like the cost of FACTS devices were believed while sustaining volts profile inside the permitted limit. Showing the potency of the suggested work, IEEE-57 and IEEE-30 bus check system were analysed. The effect obtained by proposed strategy was weighed against the outcomes obtained simply by Grey wolf optimisation (GWO), Whale optimization algorithm (WOA), Differential Evolution (DE). GWO and Quasi-oppositional based DE were also implemented to progress the solution. The implementation of GWO and quasi-oppositional in DE was primarily completed to expand the searching space which escalates the robustness and exploitability from the algorithm. It was observed the proposed form of WOA provides better and dependable guidance for optimised management of FACTS devices with other sources of reactive power within the energy network. O. Ziaee, et.al [5] formulated the issues related to TCSC location-allocation as a combined integer non-linear program, and proposed a new decomposition process of deciding the perfect area of TCSCs and their own size for the respective network. The strain (load) uncertainty, transmission lines AC characteristics, and of TCSCs non-linear cost explicitly were considered. The full total results of applying the task to the IEEE 118-bus test system were reported, and perceptions related to TCSC location-allocation problem were provided. Sai Ram Inkollu, et.al [6] presented a novel way of optimizing the devices of FACTS technology, in order to keep up with the voltage stability in the energy transmission systems. Right here, the PSO (particle swarm optimization) algorithm and the adaptable form of GSA (gravitational search algorithm) technique was proposed and intended for refining the voltage balance of the energy-based transmission devices. In the suggested approach, the PSO formula can be used to get optimized gravitational constant and enhances the overall GSA searching performance. Using the recommended technique, the optimised settings of the FACTS-based devices were determined. The offered algorithm presents an efficient technique for learning the perfect area and the dimension of the FACTS controllers. The perfect locations and the energy rankings of these devices were actually determined predicated on the voltage-based collapse ranking along with the loss of electrical power system. Mithilesh Singh, et.al [7] explained the technical expansion with modelling of FACTS products proven to boost line load ability and decrease the transmission blockage by improvement of volts profile. This methodology shows the solutions of load circulation equations intended for power devices with UPFC flexible ac transmissions gaFACTSets for the typical IEEE 14 bus to validate the effectiveness from the proposed technique.

Table.1 Existing Scheduling Model

Author's Name	Year	Methodology Used	Proposed Work
Dipesh Gaur, et.al [2]	2018	FACTS devices like Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC)	Considered distinct methods of optimization such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) etc.
O. Ziaee, et.al [5]		Thyristor Controlled Series Compensator (TCSC)	Formulated the issues related to TCSC location-allocation as a combined integer non-linear program, and proposed a new decomposition process of deciding the perfect area of TCSCs and their own size for the respective network.
Pooja Prasad Kulkarni, et.al [9]	2013	TCSC, UPFC, and SVC	Provides brief overview of fast and versatile control of transmission line-based power flow.
A. B. Bhattacharyya, et.al [10]	2011	GA-based FACTS	Revealed the approach of Genetic Algorithm (GA) intended for the allowance of FACTS devices to get the improvement of capacity of power transfer within an interrelated Electric power System.
K. Kavitha, et.al [14]		TCSC-SVC Facts	The potency of the perfect installing SVC, TCSC, combined TCSC-SVC and UPFC in advancement of the security of power systems, when it comes to minimizing load voltage deviations and the line loading were inspected. The algorithms developed for the perfect placement of numerous FACTS devices was authenticated by performing case research on regular IEEE test systems. The analysis shows that after the placement of optimal FACTS device, both line loadings and load bus voltage deviations were minimized henceforth enhancing the machine security.

Saurav Raj, et.al [15]		GWO base Facts	The effect obtained by proposed strategy was weighed against the outcomes obtained simply by Grey wolf optimisation (GWO), Whale optimization algorithm (WOA), Differential Evolution (DE). GWO and Quasi-oppositional based DE were also implemented to progress the solution. The implementation of GWO and quasi-oppositional in DE was primarily completed to expand the searching space which escalates the robustness and exploitability from the algorithm. It was observed the proposed form of WOA provides better and dependable guidance for optimised management of FACTS devices with other sources of reactive power within the energy network.
Alex Corredor, et.al [16]		D-Facts	addition of Distributed Flexible AC Transmission System (D-FACTS) devices on specific transmission lines to reduce line loading and eliminate potential bottlenecks under contingency conditions as a study for a utility. The D-FACTS devices potentially have reduced costs compared to re-conductoring an existing line or installing a new line. The main objective of this paper is to study the effect of installing a limited number of these devices on selecting lines to improve system performance under N-1 contingency, N-2 contingency and N-1 contingency at conditions occurring on a neighboring system.
R.K.Verma, et.al [17]		Bus-Facts	voltage limits taken into consideration. Various conditions of loading in the power system are taken into account during this method. The exploration of the proposed approach is accomplished on the IEEE 40-bus system
O. Ziaee, et.al [18]		TCSC -Facts	TCSC location-allocation as a combined integer non-linear program, and proposed a new decomposition process of deciding the perfect area of TCSCs and their own size for the respective network. The strain (load) uncertainty, transmission lines AC characteristics, and of TCSCs non-linear cost explicitly were considered
Sai Ram Inkollu, et.al [19]		GSA-FACTS	devices of FACTS technology, in order to keep up with the voltage stability in the energy transmission systems. Right here, the PSO (particle swarm optimization) algorithm and the adaptable form of GSA (gravitational search algorithm) technique was proposed and intended for refining the voltage balance of the energy-based transmission devices
Jadhao, et.al [13]	2015	MATLAB software	Explained that the FACTS devices location has been a great challenge. This problem was conquered through the use of sensitivity-based Indices evaluation method.

R.Srinivasa Rao, et.al [8] revealed a general method intended for determining optimal places for placement of FACTS devices in the energy system with a target of reducing actual (real) power reduction and also to decrease the lines-based overloading process. A target (objective) function including above goals was developed and an in depth mathematical unit for every goal was offered when it comes to program-based parameters. Three of the FACT gaFACTSets, namely, UPFC (Unified Power Flow Controller), IPFC (Interline Power Flow Controller), and OUPFC (Optimal Unified Power Flow Controller) which can handle controlling the two active and reactive powers were believed in the process of analysis and simulation in the networks. Chetan W. Jadhao, et.al [9] explained that the FACTS devices location has been a great challenge. This problem was conquered through the use of sensitivity-based Indices evaluation method. Right here two sensitivity-based Indices research methods were being used and they are; reduced amount of total system reactive power reduction and actual (real) power flow performance index sensitivity-based indices. The 'MATLAB' software can be used to create a development code intended for learning the sensitivity directories for the two methods. IEEE-14bus system can be used here for the analysis purpose.Kavitha, et.al [10] disclosed the potential difficulties of alternative (renewable) energy on the smartly built grid system along with the improvement of system protection with the use of FACTS devices. The optimal placement of the device was performed using algorithm based on Biogeography Optimization (BBO). SVC and TCSC devices of FACTS were considered in this work. The suggested work was usually verified upon typical IEEE 14 bus system. The proposed technique optimizes the positioning of FACTS devices, with the aim of minimizing the load voltage deviation and line loading, in order to improve the security of the system under several conditions of loading with inconsistent integration of wind power.Pooja Prasad Kulkarni, et.al [11] provides brief overview of fast and versatile control of transmission line-based power flow. Exceptional highlighting was based upon TCSC, UPFC, and SVC considering their benefits for refining the power system operation. A comparison based on the performance of the known FACTS controllers has been discussed. Additionally, a few of the utility experiences have already been summarized and reviewed. The study based on FACTS applications to power system has already been discussed in the working methodology. A. B. Bhattacharyya, et.al [12] revealed the approach of Genetic Algorithm (GA) intended for the allowance of FACTS devices to get the improvement of capacity of power transfer within an interrelated Electric power System. The GA structured approach is usually applied on IEEE 30 Bus System. The device is reactively loaded beginning with base to 200% of base weight (load). FACTS products were installed inside the different places of the electric power system and system overall performance was observed either in absence or presence of FACTS devices. Firstly, the positions, in which the FACTS gaFACTSets to be positioned was determined by determining active and reactive power flows inside the lines. GA was then applied to discover the amount of variation of the all the FACTS devices. This method of GA-based FACTS products was huge beneficial in terms of economy and performance.Zuwei Yu, et.al [13] analysed the existing position on the optimised placement of versatile flexible AC transmitting systems and reasoned that the use of one-shot (instant) models can lead to sub-optimal alternatives. The researchers have proposed an alternative solution model that help in optimizing the FACTS devices placement predicated on multiple schedules with considered deficits. Needs were generally modelled as features of prices in order to reflect the operating theory of deregulated power places. Numerous interpretations were suggested to lessen the problem size deprived of considerable degradation of the quality-based solution. Statistical results displayed that the gain obtained from multiple period model was usually very significant.

IV. CONCLUSION

Several technical issues related to FACTS installations have been highlighted and performance comparison of different FACTS controllers has been discussed. In addition, some of the utility experience, real-world installations, and semiconductor technology development have been reviewed and summarized. Applications of FACTS to other power system studies have also been discussed. About two hundred twenty seven research publications have been classified and appended for a quick reference.

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