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SSSC FACTS Controller Based Compensation of Power System: A Survey

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***Abstract*— The fundamentals of series compensation in power systems can be understand by a literature survey. The advantages that this technology tilt to reinforce the steady state and dynamic operation of power systems area unit to be analyzed. The reviews give glimpse about the evolution of the series compensation technologies, from automatically operated power electronic devices, covering management problems, totally different applications, sensible realizations, and case studies. The main drawback of the power electronics circuitries is the generation or main source of the power quality problems such as: harmonics, sag-swell etc. The paper closes with the main challenges that this technology can face within the close to future to realize a completely decarbonized grid.**

Keywords*— Series Compensation, Flexible AC Transmission Systems (FACTS), Distributed-FACTS (D-FACTS) Static Synchronous Series Compensator (SSSC) and Distributed Static Series Compensator (DSSC).

I. INTRODUCTION

This review focuses on series compensation, as well as series capacitors and series FACTS, their technological evolution through the revision of the principal printed literature [1]. The survey is motivated as a result of series capacitors are getting a key part in power transmission systems round the world [2]. This system is characterized by long high-voltage (HV) AC lines connecting major generation and demand areas in an exceedingly meshed fashion, to extend the maximum amount as attainable the system responsibility. In such HV-AC systems, the ability transmission between 2 nodes is primarily restricted by the road series electrical phenomenon [3]. additionally, the ability flows within the meshed network fulfill the G. R. Kirchhoff equations, no matter physical constraints (ampacity or nodal voltage limits) that may cause loop flows or network congestions [4]. the employment of series capacitors might stop these adverse things by part compensating the road electrical phenomenon to either increase the transmittable power or modify the ability flow patterns within the meshed network With the rising power demand, it is important to increase the power transfer capacity of transmission lines. The power transmission system must be able to handle most of the energy supplied to end of consumer by the generating station [1]. The electrical system must provide reliable power to the consumer in general and in particular to the industries. Electricity demand is growing rapidly but the new expansion of generation stations and transmission lines has the financial and environmental problems. To improve reliability by transmitting the power to end users or points of use, several advanced techniques have been introduced in terms of a support system [2]. The capability of a transmission system to transfer the power is compromised by different following stages like ransient stability, thermal limits and dynamic stability. These confines express the electrical power that will be transferred without causing damage to the transmission line system and electrical equipment's. When a small interruption appears in the power network, it leads to low-frequency electromagnetically oscillations. Due to these oscillations, the power system variables like line frequency, Bus voltages, Line currents and generator speeds also becomes oscillatory. For enhancement in the reliability of the power network and to raise the generation capacity, the synchronous generators are interconnected, which resulted in a power system oscillations of around 1-2 Hz [3, 5]. .

The Static Synchronous Series Compensation (SSSC) [8], and therefore the Distributed SSSC (DSSC) [4, 6] are the foremost prominent topologies within this FACTS category. it's been demonstrated that variable series compensation may be a cornerstone of FACTS technology [5], thanks to its effectiveness in both controlling line power flows and improving system stability. The series FACTS allows maximizing the use of transmission assets by controlling the power flow within the lines, preventing loop flows and, with the utilization of fast controllers, minimizing the effect of system disturbances, thereby reducing traditional stability margin requirements [11]. during this regard, this facility transition towards a totally decarbonized paradigm will certainly require the extra flexibility that series FACTS may bring, with the support of power electronics technologies.

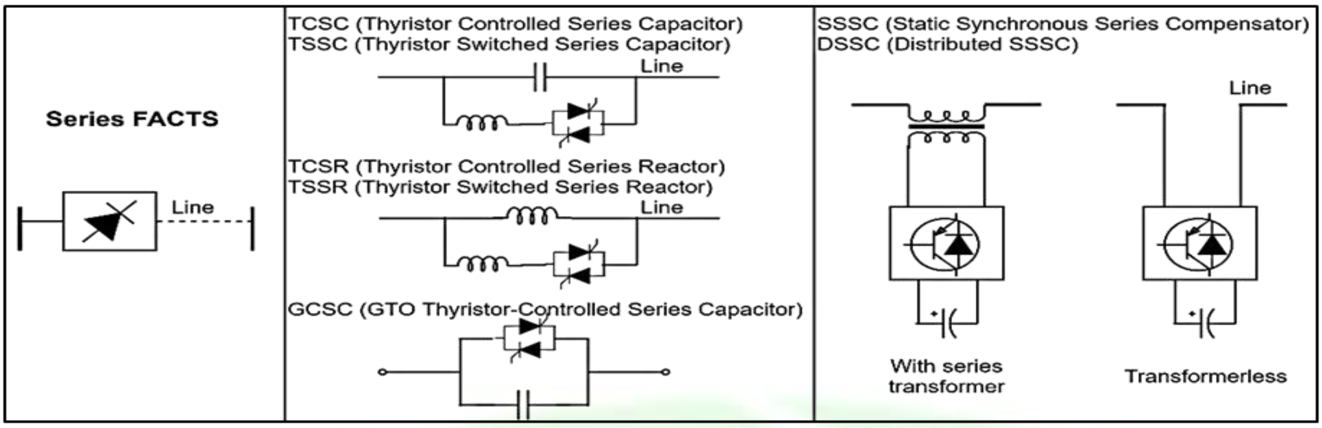

Fig.1. Series Flexible AC Transmission System (FACTS) classification [1]

Research focus on the different criteria:

a. Control strategies to enhance the steady-state and dynamic performance of power systems.
b. Design and modeling issues addressing modifications proposed to the FACTS design, including new features or additional elements, likewise as new models for brand new power systems software tools [13].
c. Operational analysis, assessing the FACTS impact on the ability system, including steady-state simulations, real-time and wide-area control applications [14].
d. Planning studies, addressing location and sizing of FACTS. crucial research is focused on the position of series controllers. that features methodologies to attain an equivalent objective than if it were located in another points [15]. However, it's to be considered that, sometimes, series FACTS could also be located at non-optimal locations if the aim is minimizing costs because the value of lands and every one the environmental.

Similarly transmission lines are also running nearer to their thermal limits. So, the power systems are seemly less sheltered and always carrying the exposure of voltage instability which has led to many major network collapses world-wide. As the electric power system was not so complicated in previous times, the major controversy was to damping the local area oscillations which were simply performed by the aid of AVRs[3].Then PSS appear which associated to the generators which present sizable concurrence towards the oscillations of the network. Hence traditionally PSS was employed for damping the local zones of oscillations in electric network. Different preventive measures as generation and transmission of energy adjourn, carrying reserve generators online, load curtailing and VAR back up by serial or parallel capacitors are followed to conquered voltage instability controversy. However, most of them are electromechanical controller which got the demerits like sluggishness, wear and tear[6]. As an alternate key, intense consideration have been compensated to FACTS (Flexible Alternating Current Transmission System) devices which are directed from present-day components of power electronics, which could give active and reactive power accurately and keep the network stability limit.. In present paper FACTS devices with additional controller is employed for damping the power network oscillations. Thus by employing POD-FACTS the network power oscillations can be quickly damped as related with another commonly devices[8]. Since these controllers impact the driving voltage and thus the current and flow of power directly. For a given MVA size series controllers are manifolds robust than shunt controllers, in order to perform the desire functions such as to control the current/power flow and damping the oscillations.

The Static Synchronous Series Compensator (SSSC), one of the crucial FACTS device, subsists of a voltage-sourced converter (VSC) and a transformer linked in serial with a power line. The SSSC implants a voltage with changing magnitude in quadrature with the line current, hence mirroring an inductive or capacitive reactance. This mirrored changeable reactance in serial with the line hence has leveragence on transmitted electric power. Therefore SSSC control wide range of power through transmission line. The fundamental construction of an SSSC is shown in Fig.2.

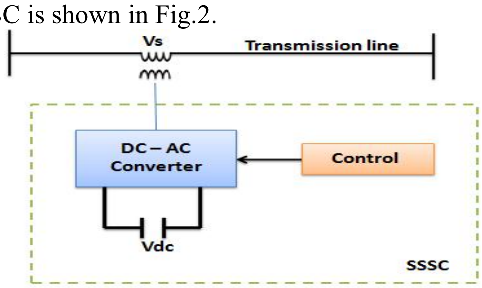

Fig. 2. Basic schematic of an SSSC.

The TCSC (Thyristor Controlled Series Compensator) is another series FACTS controller employed to provide series compensation for transmission line impedance in a regular, rapid, and governable manner. The TCSC is linked in series with transmission lines. The TCSC has immune impact to rising PTC (Power transfer capacity) and ATC (Available transfer capability) over transmission lines. Features alike automatic control of the thyristor has been combined into the TCSC. FACTS significantly alter the technique in which transmission systems are designed, established and controlled together with enhancements in system flexibility, benefit utilization and the system performance [9], [10].

The FACTS are the static device used for the AC transmission of electrical power to improve controllability and enhance power transfer capability. The main role of FACTS is to manage the congestion, increasing power transfer capability, reliability, controlled the power flow, enhancing security, and other system performance. The FACTS devices are capable to control the different electrical parameters in the transmission system. Due to minimum installation cost, fast active power, better optimum location, controllability and security of power system, the FACTS are installed on ultra-high voltage [11]

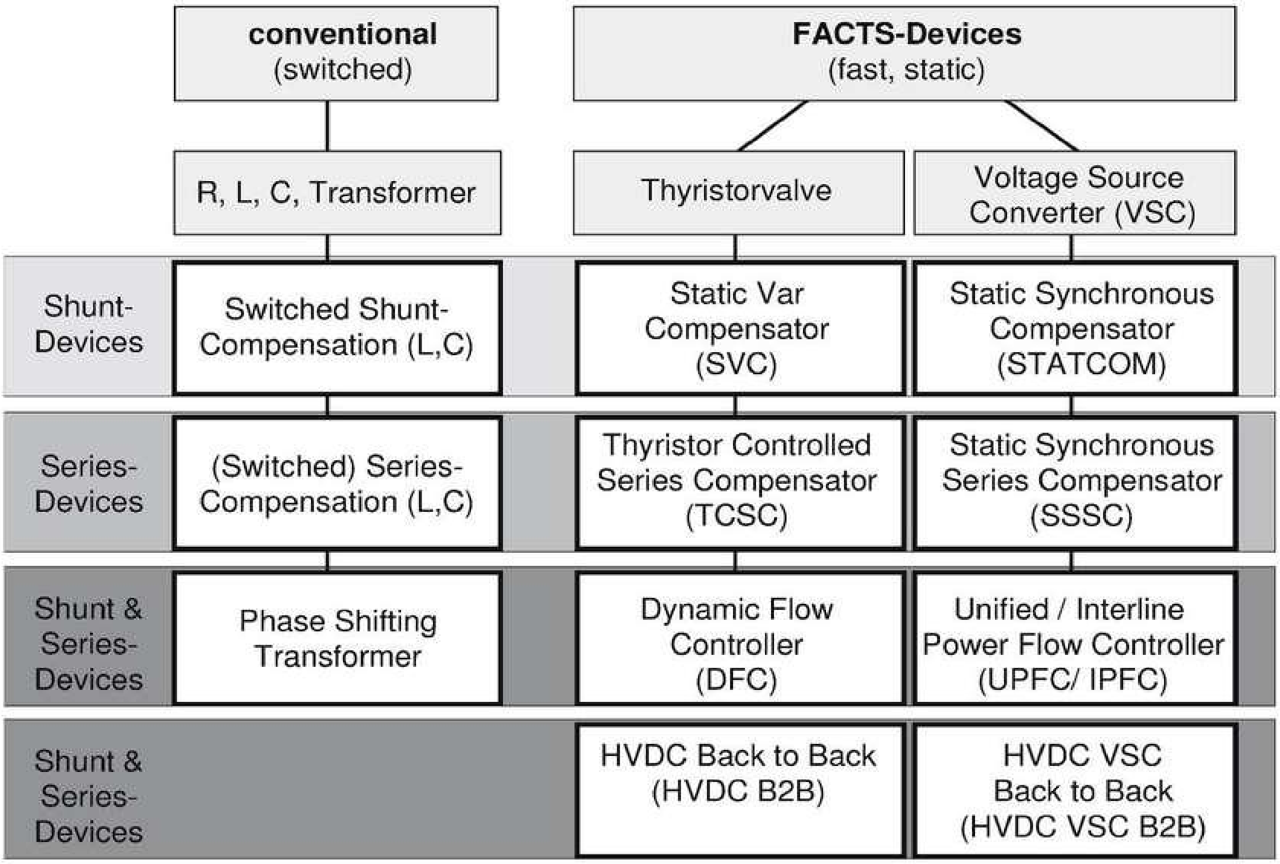

Fig. 3. Basic Types Of FACTS Compensation

In the next section II discuss the literature survey of SSSC FACTS controller. Section III discuss the SSSC basic concept of its. In the last the conclusion of the this survey and reference are illustrated in this literature survey.

II LITERATURE SURVEY

Agrawal, H. P., et. Al (2020, September),In this research work, an optimization of SSSC FACT controller device is provided to achieve the system stability and higher gain ratio. The model is here optimized using differential evolution method. The model is designed with inclusion of three phase fault. These faults increased the voltage fluctuation and disturb the power outcome from the system. The proposed differential evolution integrated SSSC Fact control first evaluate the degree of fluctuation exist in the system respective to the power system parameter. Later on, the differential evaluation applied the vectors to adjust the voltage, current and load to reduce the fluctuation and to improve the stability in the system. The proposed model is implemented as the Simulink model. The results obtained shows that the overall fluctuation is reduced and the stability over the system is achieved. The comparative evaluation shows that the method has optimized the stability and the stability gain is achieved more effectively. The results show that the higher stability in the system is achieved in existence of three phase fault**[02]**.

kumar Patra, A., et. al (2020, July).In this research work presents the main purpose here is to damp power system oscillation and to enhance system performance under disturbance. In this study, the GSA optimization technique has been used in parameter tuning for the coordinated design PI types lead-lag in SSSC based controllers with PSS in both SMIB and multi machine power system. The performance of transient stability improvement by purpose controller has been validated in the MATLAB simulation platform. at three type of loading and disturbance condition. The damping performance is compared between the propose controllers and it shows that the coordinated controller of SSSC based PI Types lead-lag with PSS of damping performance is better. A special advantage is that it can be used a robust multimachine power system network with very easily and cheaply**[03].**

Movahedi, A., et. al (2019),In this research work , the power system stability enhancement via PI controllers and PSS and FACTS-based stabilizers when applied through coordinated application was discussed and investigated for a multimachine power system in the presence of PV and wind farms. Parameters of the proposed FACTS, PSS, and PI controllers were optimized using AVURPSO, GSA and GA. The effectiveness of the proposed control schemes in improving the power system transient stability has been verified through eigenvalue analysis and nonlinear time-domain simulations under a three-phase line-to-ground fault. The system has become unstable following the three-phase line-toground fault; however, by the simultaneous application of TCSC and PSS controllers and STATCOM and PSS controllers, the stability of the system improves and its oscillations are damped. Using SSSC and PSS simultaneous controllers, oscillation and time damping have been decreased compared to STATCOM and TCSC. Furthermore, the comparison of the simulated methods indicated that SSSC and PI controllers are the most reliable and effective LVRT capability-enhancement methods for wind and PV farms. Moreover, using the AVURPSO algorithm, oscillation and time damping have been decreased in comparison to GSA and GA. As a result, the performance of the AVURPSO algorithm is superior to that of GSA and GA**[04]**.

Sahu, P. R., Hota, P. K., & Panda, S. (2018).In this research work , enhancement of power system stability with the help of a fractional order MISO-SSSC based damping controller is studied in detail. The design task is considered as an optimization problem and whale optimization technique is applied for the estimation of controller parameters. The feasibility of the proposed FO MISO SSSC based damping controller in enhancing the power system stability is shown for both single machine infinite bus and three-machine six bus power systems under different severe contingencies. The superiority of the proposed controller structure and optimization method is shown by comparing results of some recently proposed methodologies like DE and PSO based SISO SSSC controller. It is observed that superior damping performance is obtained with proposed MISO controller compared to SISO controllers**[05].**

Siddique, A., et. al (2018, May), This research work presents the electric power network with different loads linked at distinct buses as a test network with FACTSPOD controller by accomplishing a time domain simulation in MATLAB/Simulink software. The enforced POD gives stabilizing signals to the FACTS devices. For the investigation of series FACTS-POD, a 3-phase fault is activated at time 1.33 sec having fault duration is 0.166 sec. Results revealed that SSSC with POD has superior potential for damping the network oscillations as compared to TCSC controller. In addition SSSC-POD rises real and reactive power of the system, hence improving load capacity of the network. Thus it can be concluded that power oscillation damping and PTC of the power network with various loads at distinct buses increased by employing SSSC and TCSC with additional POD controlle**r[06]**.

III. Static Synchronous Series Compensator (SSSC)

The SSSC was proposed by Dr. Laszlo Gyugyi [14] and consists of a line asynchronous voltage-sourced converter (VSC), as illustrated in Figure 4.

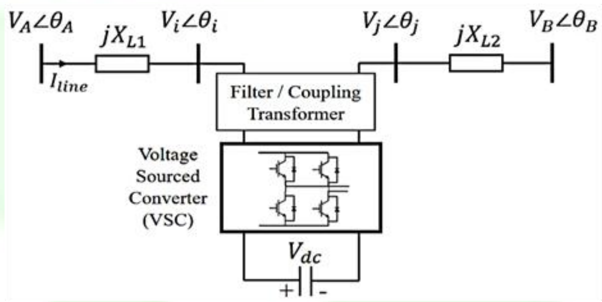

Fig.4. Static Synchronous Series Compensation (SSSC) [1]

Device The SSSC provides a wider control range compared to the previous topologies because it injects a series voltage instead of a series impedance. Therefore, the series compensation is independent of the system line current.

$$P = \frac{V^2}{X_L \pm V_q/I}\sin\delta = \frac{V^2}{X_L}\sin\delta \pm \frac{VV_q}{X_L}\cos(\delta/2) = P_0 \pm \frac{VV_q}{X_L}\cos(\delta/2) = P_0 \pm \Delta P, \quad (1)$$

Where, Po is the active power of the uncompensated line.

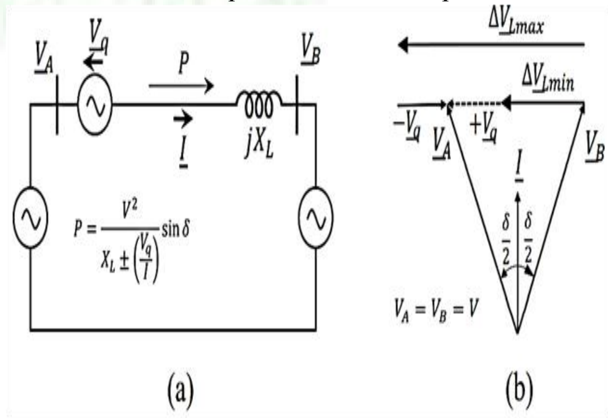

Fig. 5 (a) Single-phase equivalent circuit. (b) Phase diagram.

The SSSC is optimally synchronized with the system line current, I, and injects a required series voltage

Vq which is orthogonal to it, lagging or leading. SSSC has two operation modes: (a) series voltage control,(b) reactance control, Assuming VA = VB = V and neglecting the active power losses. The transmitted active power compensated by SSSC can be expressed as [16]: Variable series compensation is very effective in both controlling line power flows and improving stability. It is often applied in many applications: to realize full utilization f transmission assets by controlling the facility flow across the lines, preventing loop flows and reducing stability margin requirements, voltage controlling and stability enhancement. More applications and benefits of this FACTS should still be investigated, but more importantly, the research and development of university and research centers will continue to fall down to the commercial development of cost-efficient technologies for his or her installation and proliferation in power transmission systems. Particularly, future research might be focused on new protection schemes for SSSC and DSSC considering that these new technologies may be massively deployed within the installation, therefore requiring a smooth integration with legacy power grid protection strategies. additionally, more control approaches to seek out additional applications for DSSC and GCSC are of utmost importance in order to widen the possible economic incomes thanks to the supply of latest services to the power system operator. These new control methodologies together with new planning strategies (i.e., location and sizing of series devices) may facilitate the business plan of those technologies characterized by large investment costs. during this regard, it's key to maximize their capabilities once installed by applying convenient wide area coordinated control techniques aiming at optimizing their operation. during this way, grid operators will be able to achieve the desired flexibility to cut back the strain within the complex operation of an increasingly renewable-based power grid pursuing its fully decarbonization.

IV.CONCLUSION

As discussed in this paper, different technologies for series compensation have been developed over almost the last decade of the previous century, some of them effectively installed in power transmission grids, and some still at the theoretical or concept stage. After the proliferation of FSC in the power transmission systems, two approaches to power electronics-based series compensators (series FACTS) have been proposed and investigated. Employing a switching power converter to realizea controllable synchronous voltage source (VSC) in series with the line (SSSC and DSSC belong to that approach). the introduction of different FACTS devices TCSC, SSSC, SVC, STATCOM and UPFC for operation and controls the essential features and comparison performance of various FACTS devices has been addressed. The operating principles and applications of the main five FACTS controller for transient as well as steady state stability enhancement are also presented. A FACT raises the reliability of AC grids and decreases the power delivery costs. It is also seen that UPFC is excellent for stability enhancement as compared to other FACTS devices discussed in the below table 1. In the future, going to implement the fuzzy adaptive and adaptive neuro-fuzzy (ANFIS) control approach based FACTS devices for better power stability and reliability improvements.

TABLE -I COMPARISON OF DIFFERENT FACTS DEVICES

FACTS DEVICES	Load Flow Control	Voltage Control	Transient Stability	Dynamic Stability
SVC	LESS	HIGH	LOW	MEDIUM
TCSC	LESS	HIGH	MEDIUM	MEDIUM
STATCOM	MEDIUM	LESS	HIGH	MEDIUM
UPFC	HIGH	HIGH	MEDIUM	MEDIUM

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