International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

PV Supported Power Quality Improvement in Grid using Static Synchronous Series Compensator (SSSC)

[1]Dr.A.Gowthaman [2] Dr.P.Govindasamy

[1]*Assistant Professor, Dept.of EEE, Government College of Engineering, Erode, Tamilnadu, India*
[2]*Assistant Professor, Dept.of EEE, Government College of Engineering, Erode, Tamilnadu, India*

Date of Submission: 20-07-2023 Date of Acceptance: 31-07-2023

ABSTRACT
Power electronic equipment known as a static synchronous series compensator (SSSC) is used to increase the control and stability of power systems. It uses voltage source converter technology to inject a regulated voltage into a transmission line that is connected to it in series. They can exchange actual power to the power system when coupled with a DC power source on the DC side of an SSSC. Static Synchronous Series Compensator (SSSC) supported by photovoltaic (PV) technology can be used to keep the grid's voltage constant despite variations in the load. To achieve low current ripple, a high-step-up interleaved DC-DC converter made up of two boost converters connected in parallel is used. Particle Swarm technology is used with Photo Voltaic systems.

Keywords — SSSC- Static Synchronous Series Compensator, PV- Photo Voltaic, PSO- Particle Swarm Optimization , MPPT – Maximum Power Point Tracking ,Battery energy storage, Power grid, Renewable energy sources.

I. INTRODUCTION

Power demand has significantly expanded over the past three decades, yet due to resource constraints and environmental concerns, the expansion of power generation and transmission has been severely constrained. Because of this, some transmission lines are excessively laden, and system stability starts to limit the amount of power that can be sent. Areas of generation are discovered to be susceptible to electromechanical oscillation as a result of the power system being interconnected and complicated to overcome this problem. One of the main concerns in operating an electric power system is the suppression of electromechanical oscillation. Uncontrolled oscillation causes a whole or partial suspension or failure of the power supply.

Lack of proper system damping is the main cause of oscillations that are prolonged or growing. The initial method of improving damping may have been the power system stabilizer. The use of flexible ac transmission systems (FACTS) devices in power systems has increased recently in an effort to boost the systems' steady state and dynamic performances.

Dynamic reactive compensation in power systems has been successfully accomplished using the first generation thyristor-controlled FACTS devices, such as the static var compensator (SVC) and thyristor-controlled series capacitor (TCSC). To supply or absorb reactive power, the aforementioned FACTS devices require a fully rated capacitor or reactor bank. However, by using self-commutated voltage-sourced switching converters to generate static synchronous s voltage sources at fundamental frequency, this requirement can be circumvented.The second generation FACTS devices in this category include the synchronous series compensator (SSSC) and the unified power flow controller (UPFC).

II. POWER QUALITY DEFINITION AND ISSUES

Power quality is defined in a variety of ways. Power quality is reliability, according to Utility.

According to the load aspect, it is described as the power given to ensure that all sensitive equipment operates to specification.

This is dependent on the client. It is described as "any power problem manifested in voltage, current, or frequency deviations that results in failure or malfunction of customer equipment" from the perspective of the end user.

According to the IEEE vocabulary, power quality is "the idea of powering and grounding sensitive equipment in a manner that is suitable for that equipment's operation."

It is described as a "set of parameters defining the properties of the power supply as delivered to the user in normal operating

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

conditions" by the IEC (International Electrotechnical Commission).

Problems with power quality (PQ) are currently the most pressing. The extensive usage of electronic devices, such as computing hardware, power electronics, programmable logic controllers (PLC), and energy-efficient lighting, has completely altered the nature of electrical loads. These loads are both the main contributors to and the main recipients of power quality issues. All of these loads disrupt the voltage waveform because they are non-linear. Transient overvoltages (surges/spikes), swells, flickers, unregulated voltages, voltage dips/sags, interruptions, or waveform disturbances (power factor, harmonics, etc.) can occasionally affect electrical equipment. Categories for Power Quality problems are depicted in Fig. 1.

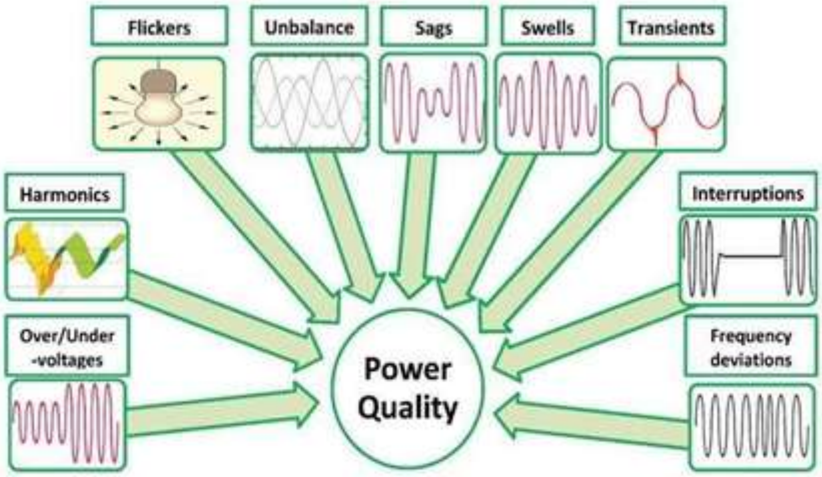


Fig.1. Classification of Power Quality Problems

Following is a summary of the advantages of using FACTS devices in electrical transmission systems:

- More effective use of current transmission system resources.
- Improved availability and dependability of the transmission system.
- Keep the reactive power flowing throughout the entire system network.
- Enhanced grid stability, both dynamically and transiently.
- A higher standard of power supply for industries that require it.
- Environmental advantages.

The technical advantages of the concept for FACTS dynamic applications in tackling transient stability, damping, post contingency voltage regulation, and voltage stability issues. The following categories can be applied to the gadgets used for these things:

- Static Synchronous Compensator (STATCOM) -Controls voltage
- Static VAR Compensator (SVC) -Controls voltage
- Unified Power Flow Controller (UPFC)
- Convertible Series Compensator (CSC)
- Inter-phase Power Flow Controller (IPFC)
- Static Synchronous Series Controller (SSSC)

Each of the above mentioned controllers have impact on voltage, impedance, and/or angle (and power) •

- Thyristor Controlled Series Compensator (TCSC)-Controls impedance
- Thyristor Controlled Phase Shifting Transformer (TCPST)-Controls angle
- Super Conducting Magnetic Energy Storage (SMES)-Controls voltage and power

Only STATCOM, SVC, and UPFC are discussed here from among all of these many FACTS device kinds.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

STATCOM and SVC are devices that control voltage, whereas UPFC is a device that controls voltage, impedance, and angle (or power). These tools are fully capable of minimizing system issues, allowing the system to function effectively. The waveforms of Power Quality issues of voltage sag, voltage swell, outage, harmonics and unbalance are shown in Fig.2. (a), (b), (c), (d) and (e).

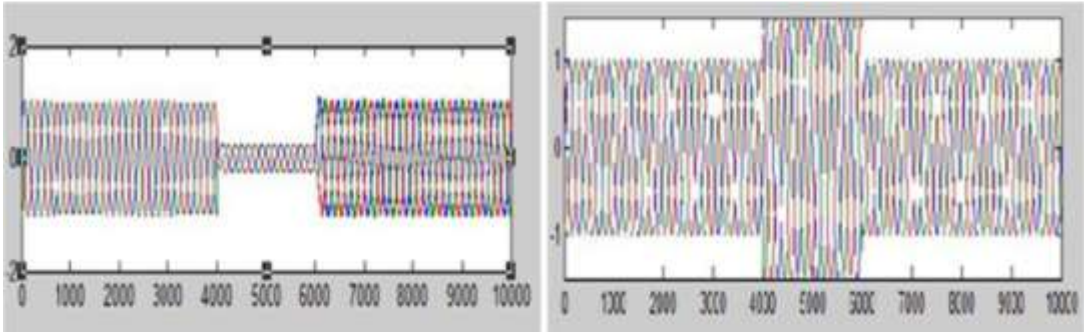


Fig.2. (a) Voltage Sag (b) Voltage Swell

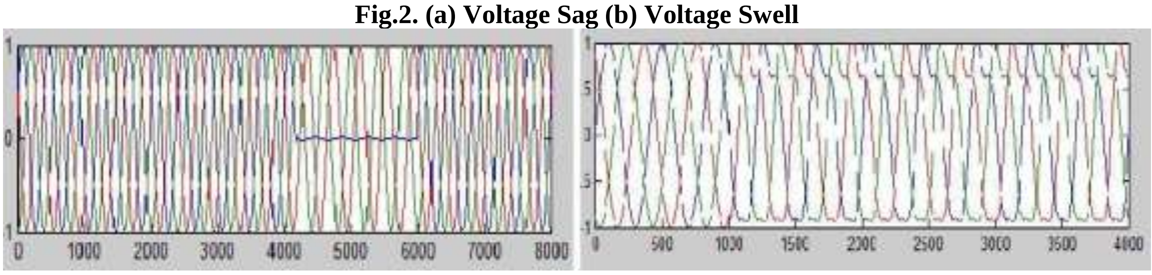


Fig.2. (c) Outage (d) Harmonics

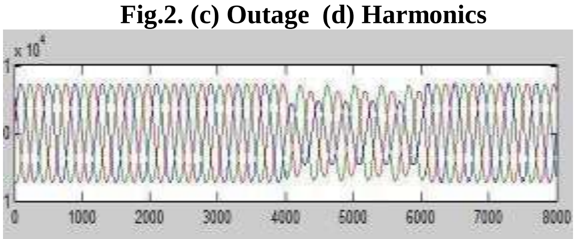


Fig.2. (e) Unbalance

The effectiveness of SSSC to compensate load voltage is examined in this paper. It is a series compensating device that aids in improving system dependability by controlling system voltage. The focus of the entire project is on SSSC and its different control strategies.

III. LITERATURE REVIEW

S. Panda, N. P. Padhy and R. N. Patel, "Power-system Stability Improvement by PSO Optimized SSSC-based Damping Controller", Taylor & Francis Electric Power Components and Systems, pp. 468-489, 2008 [1]. Rajendra Kumar Pande and Deepak Kumar Gupta, "Performance Evaluation of Power Oscillation Damping Controller—Firefly Algorithm Based Parameter Tuning", Taylor & Francis Electric Power Components and Systems, 2017 [2]. Lionel Leroy Sonfack, Godpromesse Kenné and Andrew Muluh Fombu, "A New Static Synchronous Series Compensator Control Strategy Based on RBF Neuro-Sliding Mode Technique for Power Flow Control and DC Voltage Regulation", Taylor & Francis Electric Power Components and Systems, 2018 [3]. M H Haque, "Use of SSSC to improve first swing stability limit and damping of a power system", Taylor & Francis Australian Journal of Electrical and Electronics Engineering, pp. 17-26, 2015 [4]. Eskandar Gholipour and Seyyed Mostafa Nosratabadi, "A new coordination strategy of SSSC and PSS controllers in power system using SOA algorithm based on Pareto method", Elsevier Electrical Power and Energy system, pp. 462-471, 2015 [5]. Vicky T. Kullarkar and Vinod K. Chandrakar, "Power Quality Improvement in Power System by using Static Synchronous Series

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

Compensator", 2nd International Conference for Convergence in Technology (I2CT), 2017 [6].

IV. SIGNIFICANCE OF STUDY

The SSSC can be used to alter the equivalent line impedance and improve the line's capacity for active power transmission. The SSSCs are also very controllable and can provide the energy system additional functionality and services.

V. SCOPE OF STUDY

An SSSC is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode.

VI. OBJECTIVE

- Our suggested work's main contribution is to improve power efficiency.
- Sharing inverter power based on load requirements
- Integrating renewable energy sources.
- Charger with an alternative option for EB.

VII. PROPOSED METHODOLOGY

The effectiveness of SSSC to correct for load voltages was examined in this paper. It is a series compensating device that, by controlling the system's voltage, aids in boosting the system's dependability and equipment immunity. The focus of the entire project is on SSSC and its different control strategies.

VIII. BLOCK DIAGRAM

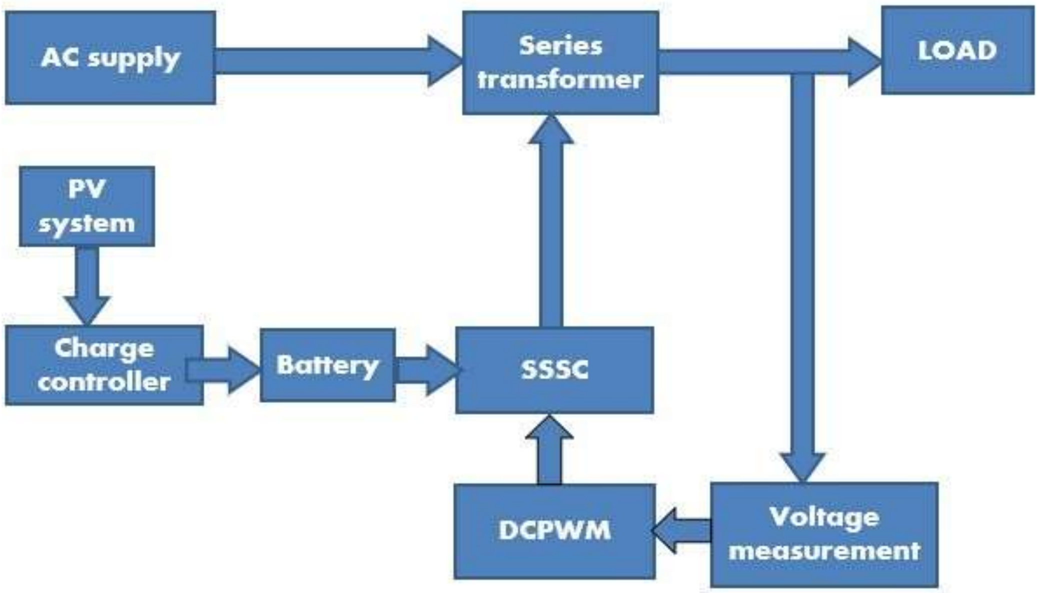


Fig.3. Block representation of the proposed system

IX. DESCRIPTION OF BLOCK DIAGRAM

The proposed system of a Static Synchronous Series Compensator with PV support is shown in Fig.3. Between the load and the AC transmission line is a series transformer. The SSSC, which employs voltage source inverters (VSI), will change the voltage whenever the transmission line voltage varies for a variety of causes. VSI receives its input voltage from battery sources. The PV system supplies power to the battery sources. DCPWM(Double Carrier Pulse Width Modulation) is a popular choice in power electronics due to its straightforward circuit design and reliable control. Industrial applications frequently employ the DCPWM switching technology. Using DCPWM, a constant-amplitude pulse is delivered with a changing duty cycle for each interval. Harmonics are reduced since we may alter the pulse width to manage the output voltage. The DCPWM approaches strengthen the basic principles of current. The fundamental is improved and harmonics are reduced through DCPWM methods. Additionally, it lowers voltage THD.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

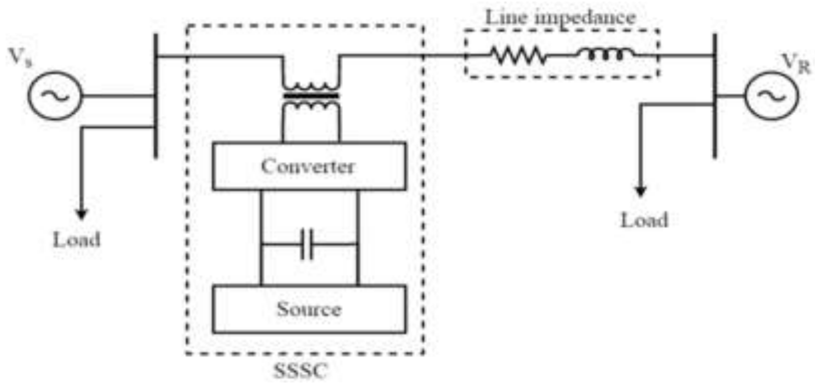


Fig.4. Static Synchronous Series Compensator (SSSC)

A step is defined as a change in the firing from one thyristor to the next in appropriate sequence. A three phase VSI is a six step bridge inverter that employs a minimum of six thyristors. A six step inverter has steps that are each 60 degrees for a 360 degree cycle. The system receives voltage boost and electrical isolation via the series injection transformer. For the purpose of injecting electricity into a three-phase system, either three single-phase isolating transformer units or a three-phase isolating transformer can be used. The estimation of the predicted maximum output voltage is of utmost importance when choosing the injection transformer, both economically & technically. The turn ratio of the series injection transformer is determined prior to the level of the distribution system being corrected by SSSC and the maximum sag to be compensated by VSI at the minimum Dc-link voltage. Electronic circuits called filters are made up of several passive components like resistors, inductors, and capacitors. In order to improve the desired signal output, they undertake signal processing operations to eliminate the undesirable frequency signals.In order to offer compensation in the necessary phase of the three-phase system that has been strengthened by SSSC, LC type filters correct the harmonic output from VSI. Energy storage devices are designed to safeguard delicate equipment from shutdowns brought on by voltage sags or interruptions. Through a dc link, they supply the VSI with the energy it needs to produce injected voltages. There are numerous types of storage systems, including DC batteries, flywheel energy storage systems, battery energy storage systems (BESS), superconducting magnetic energy storage systems (SMES), etc. Among the aforementioned storage devices, batteries are the most prevalent and, when utilized in high voltage configuration, are quite effective. There are various battery energy storage technologies, including lead-acid batteries, flooded batteries, valve-regulated lead acid batteries (VRLA), and lithium-ion batteries.

X. CONTROL CIRCUIT

A number of methods including the SSSC's control philosophy have been put into practice to improve the distribution system's power quality. A control mechanism is installed in the SSSC to reduce voltage sags and swells. The control of the SSSC is crucial since it requires the start, end, and depth of voltage sags being detected by the proper detection algorithm. The linked load type may affect the control technique. Its major objective is to maintain constant voltage magnitude during system disruptions at the location where the sensitive load is connected. The following three SSSC control principles can be stated:

1. Pre Sag Compensation Method

Both magnitude and phase angle must be adjusted using this method. As shown in Fig. 5, the supply voltage is continually monitored, and the load voltage is adjusted to the pre-sag state by injecting voltage equal to the difference between the voltages under those conditions. Although it provides a nearly unaltered load voltage, it has the downside of exceeding the SSSC's rating.

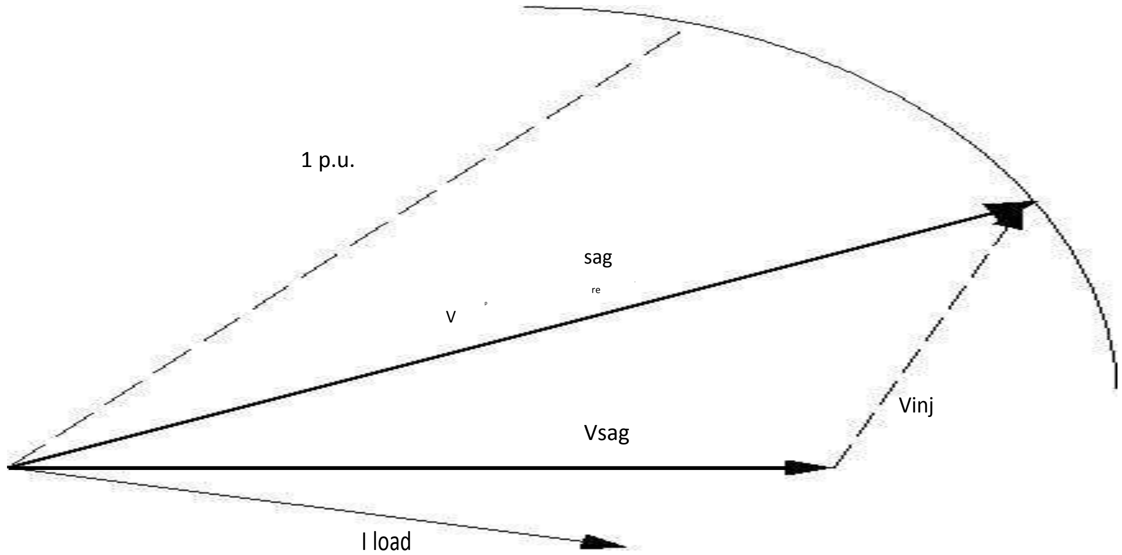


Fig.5. Pre-Sag Compensation Method

2. In-phase Compensation Method

According to this method, the VSI injects a voltage known as a missing voltage dependent on the size of the voltage loss, as shown in Fig. 6. Regardless of the load current and the pre-sag voltage, the generated voltage of the SSSC is always in phase with the measured supply voltage.

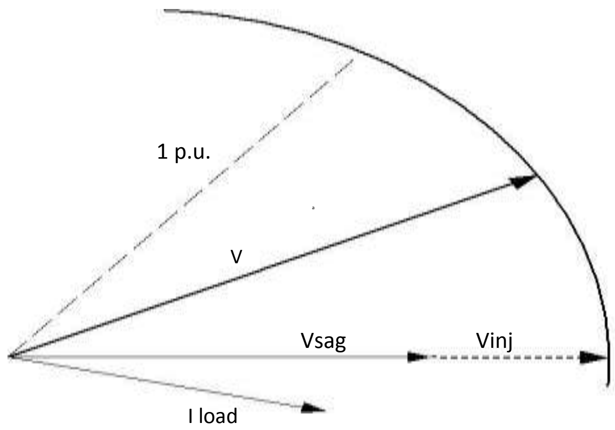


Fig.6. In-Phase Compensation Method

3. Reactive Power Compensation

This is also referred to as the minimum energy injection and relies on maximizing the active power supplied by the network while minimizing the active power supplied by the compensator and increasing the reactive power supplied by the compensator. This maintains apparent power while reducing network reactive power. The injected voltage in this injection technique is in quadrature with the load current.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

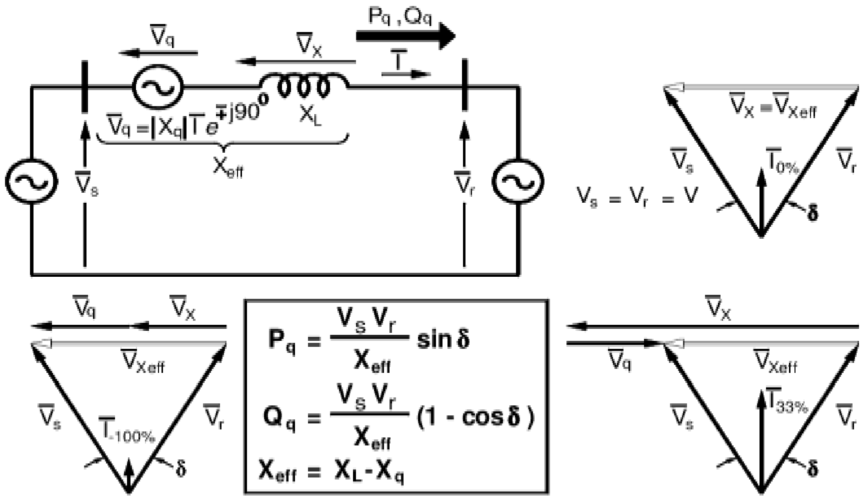


Fig.7. An Inductive and Capacitive Operated SSSC and Related Phasor Diagrams

XI. APPLICATIONS OF SSSC

In 1996, a 12.47 kV system in Anderson, South Carolina, became the first SSSC to be erected in North America. Practically speaking, the SSSC system can inject voltage up to 50% of the nominal voltage. Because of this, SSSCs may successfully offer 50% sag protection for up to 0.1 seconds. Furthermore, the majority of voltage sags hardly ever go below 50%. Additionally utilized to lessen the negative impacts of voltage swells, voltage imbalance, and other waveform distortions is the static synchronous series compensator. SSSCs with up to 50 MVA of capacity have been used for critical loads in the semiconductor, utility supply, and food processing industries. These can only be used when there is a clear necessity for consistent voltage supply due to cost and installation limitations.

XII. MATLAB AND RESULTS

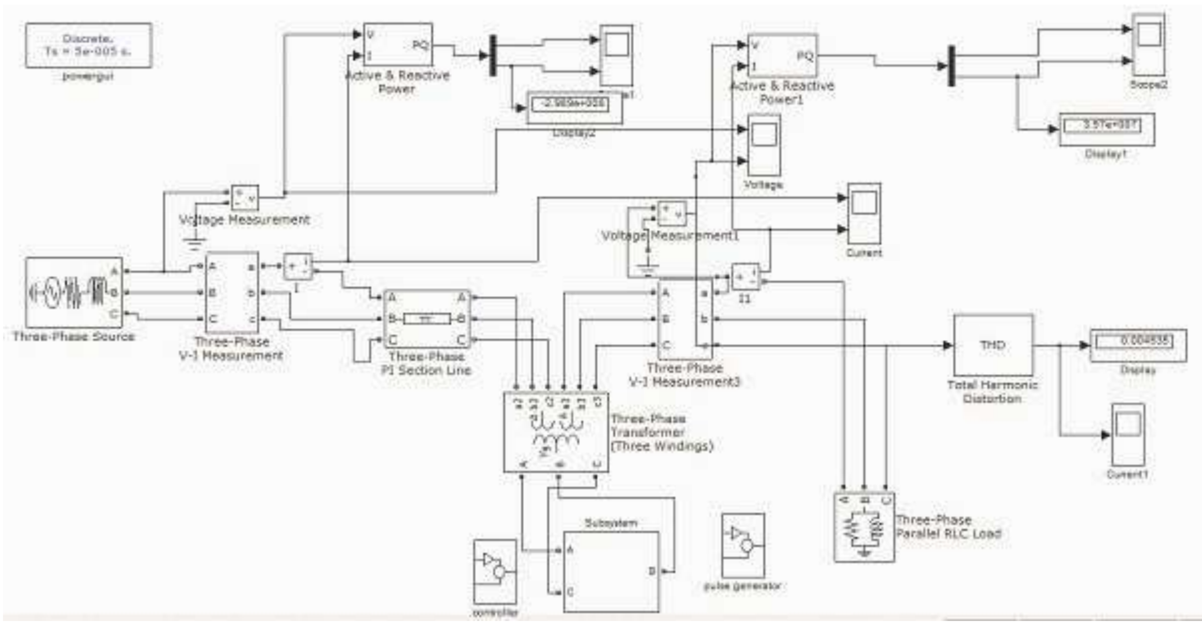


Fig.8. MATLAB SIMULINK Model with SSSC

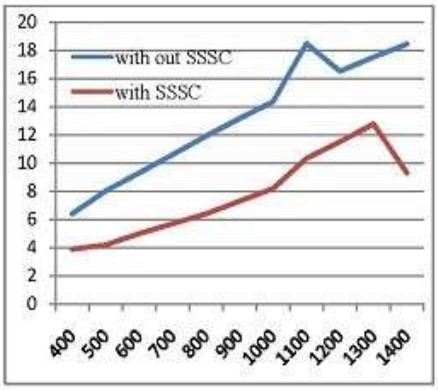


Fig.9. Voltage Regulation with distance

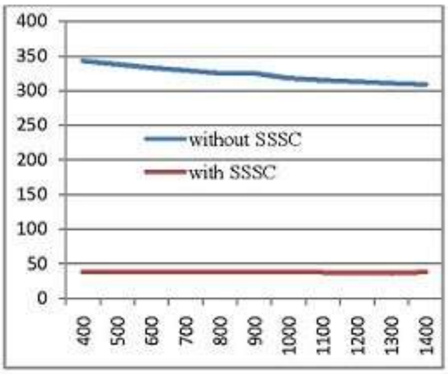
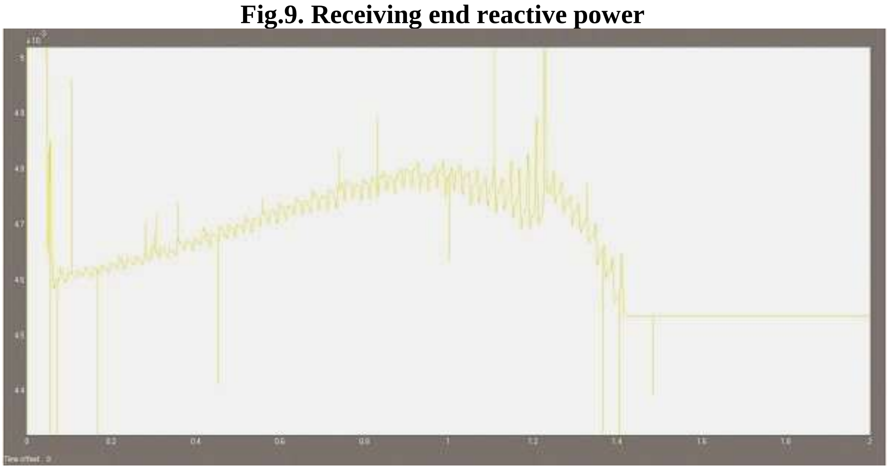


Fig.9. Receiving end reactive power



International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 839-848 www.ijaem.net ISSN: 2395-5252

Table 1: Comparison of different FACT controllers...

Name	Type	Main Function	Controller Used	Comments
SVC(Static VAR Compensator)	Shunt	Voltage control	Thyristor	Variable impedance device
TCSC(Thyristor Controlled Series Compensation)	Series	Power flow control	Thyristor	Variable impedance device
TCPAR(Thyristor Controlled Phase Angle Regulator)	Series and Shunt	Power flow control	Thyristor	Phase control using series(quadrature) voltage injection
STATCOM(Static condenser)	Shunt	Voltage control	GTO	Variable voltage source
SSSC(Static Synchronous Series Compensator)	Series	Power flow control	GTO source	Variable voltage
UPFC(Unified Power Flow Controller)	Shunt and Series	Voltage and power flow control	GTO	Variable impedance device

Fig.10. THD with SSSC

Table 2: Results of simulation...

Distance (km)	Without SSSC			With SSSC (%)		
	Voltage Regulation (%)	Receiving end Reactive Power (MVAr)	THD	Voltage Regulation (%)	Receiving end Reactive Power (MVar)	THD
400	6.4	343	0.56	3.9	37.8	0.0048
500	8.02	338	0.55	4.2	37.9	0.0045
600	9.30	333	0.56	5.0	38.1	0.0047
700	10.6	329	0.56	5.7	38.21	0.0047
800	11.9	325	0.56	6.4	38.27	0.004535
900	13.15	325	0.56	7.3	38.26	0.004535
1000	14.34	318	0.56	8.2	38.16	0.004535
1100	18.47	315	0.562	10.33	37.61	0.004535
120	16.51	313	0.56	11.5	37.15	0.004535
1300	17.50	310.7	0.566	12.77	36.54	0.004535
1400	18.43	308.9	0.565	9.3	37.9	0.004535

XIII. ADVANTAGES

- The sag rectification's transient stability time is less than 1 millisecond
- A separate dc source is used as a compensation voltage source, or alternatively, renewable energy sources can be utilised.
- Particle swarm optimization has been implemented, and the result is constant

XIV. CONCLUSION

An inventive application using a PV solar system as SSSC is advised for voltage sag/swell and outage reducing at companies or homes. The suggested interleaved high stepup DC-DC converter with PSO controller and P&O MPPT algorithm is achieved to track the PV array's highest power point. The suggested PV-SSSC is built to lower the power consumption from the utility grid by means of disconnecting the utility grid from the load via semiconductor switches, even while the PV array produce the same or more real power to meet the required load. Additionally, it lowers panel costs and eliminates the need for UPS and stabilizer for various tools in a home, factory, or business. The outcomes of the simulation show how PV SSSC can support voltage changes.

REFERENCES

[1]. Y.Mohamadrezapour, M.B.Bana Sharifian, M.R. Feyzi and S.H.Hosseini "Design and Simulation of SSSC by

Synchronous Reference Frame Theory Considering Loading of Series and Shunt Inverters" Journal of Applied Sciences, Vol. 9, No.14, pp2599-2605, 2009.

[2]. H. Akagi, Y. Kanazawa, and A. Nabae, "Instantaneous reactive power compensators comprising switching devices without energy storage components," IEEE Trans. Ind. Applications, vol. IA-20, pp. 625-630, May/June1984.

[3]. Basu, M.,S.P.Das and G.K.Dubey, "Comparative evaluation of two models of SSSC for suitable interface to enhance power quality". Electrical Power Systems Research, Vol 77, No.7, pp821-830, May 2007.

[4]. Y. Chen; X. Zha; J. Wang; H. Liu; J. Sun; H.Tang; "Unified Power Quality Conditioner (SSSC): the theory, modeling and application ", Power System Technology Proceedings. 4-7 Dec. 2000, vol.3, pp. 1329 -1333.

[5]. Ghosh,A. and G.Ledwich, "A unified power quality conditioner (SSSC) for simultaneous voltag4e and current compensation", Electrical Power Systems Research, Vol 59, No.1, pp55-63, August 2001.

[6]. L. Xun , Z. Guorong , D. Shanxu and C. J. Chen, "Control Scheme for Three- Phase Four-Wire SSSC in a Three-Phase Stationary Frame," in Proc. 2007 IEEE/IECON, pp.1732-1736, 2007.

[7]. B. Singh and Venkateswarlu, "A Simplified Control Algorithm for Three-Phase Four-Wire Unified Power Quality Conditioner," Journal of Power Electronics, vol.10, No.1, January2010.