Review on Power System Stability by Solar farm as a FACTS Controller

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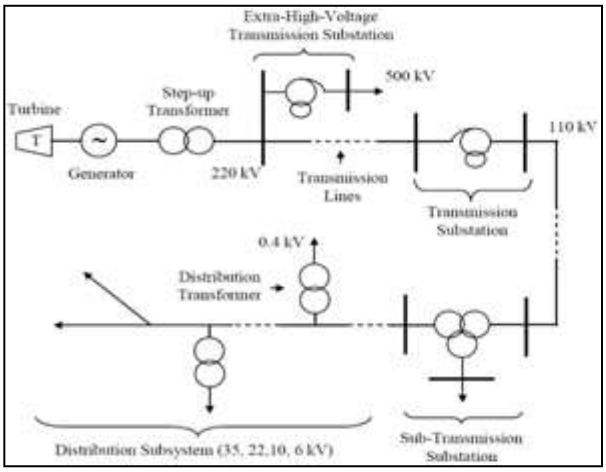
Abstract— The rapid development of power electronics technology provides exciting opportunities to develop new power system equipment for better utilization of existing systems. FACTS devices can be effectively used for power flow control, load sharing among parallel corridor, voltage regulation, and enhancement of transient stability and mitigation of system oscillations. By giving additional flexibility, FACTS controllers can enable a line to carry power closer to its thermal rating. Mechanical switching has to be supplemented by rapid response power electronics. It may be noted that FACTS is an enabling technology, and not a one to one substitute of mechanical switches. FACTS employ high speed thyristors for switching in or out transmission line components such as capacitors, reactors or phase shifting transformers for some desirable performance of the systems. Power system are often subjected to various disturbances such as generator malfunctioning, outage of a transmission line, various types of faults like symmetrical or short circuit faults, asymmetrical faults like line to ground fault, line to line fault, double line to ground fault, various losses in transmission line, thermal issues etc. the protection of power system under these circumstances is a tedious and complicated process. This paper presents utilization of a PV solar farm as a STATCOM controller. According to the switch condition the solar energy is used to improve the stability. This functionality will provide the voltage regulation and improves the stability and transfer limits far beyond minimal incremental benefits.

Keywords: FACTS, TCSC, SVC, STATCOM, UPFC, SSSC, PV

I. INTRODUCTION

The electrical power system consists of three main subsystems: the generation subsystem, the transmission subsystem, and the distribution subsystem. Electricity is generated at the generating station by converting a primary source of energy to electrical energy. The voltage output of the generators is then stepped-up to appropriate transmission levels using a step up transformer. The transmission subsystem then transmits the power close to the load centers. The voltage is then stepped-down to appropriate levels.



A. *Facts Controllers*

The swift development of power electronic technologies provides exciting opportunities to develop new power system equipment for better utilization of enhancing the security, capacity and flexibility of power transmission systems. FACTS solutions empower the power grid owners to increase the existing transmission network capacity keeping in mind of maintaining or improving the operating margins necessary for the stability of grid. Supply of reliable, high quality electrical energy at a reasonable energy at a reasonable cost is at the heart of the nation’s economy.

- Static Var Compensator (SVC)
- Static Synchronous Compensator (STATCOM)
- Static Synchronous Series Controller (SSSC)
- Unified Power Flow Controller (UPFC)
- Thyristor Controlled Series Compensator (TCSC)

Static Var Compensator (SVC), the first generation of FACTS, which was brought to market nearly twenty years ago. The SVC consists of a fast thyristor switch controlling a shunt capacitor bank, which help provide voltage support for heavy loads near the end of a line. It also contributes to system stability but do not control power flow directly.

Static Synchronous Compensator (STATCOM) also named Advanced Static Var Generator (ASVG), the second generation of FACTS, is a new reactive power compensator that overcomes the technical limitations and high cost of the SVC. The development of STATCOM is based on the use of Gate Turnoff (GTO) thyristors which is basically a voltage source inverter that converts the dc voltage at its input terminals into a three phase set of output voltages. The STATCOM that can either generate or absorb reactive power, is superior to SVC in providing the voltage support. It also can respond quickly to damp any big disturbances on the power system.

Static Synchronous Series Compensator (SSSC) which is similar with STATCOM except its output transformer connected in series with the line, is in the design stage and expected to be selected for utility demonstration quit soon.

Unified Power Flow Controller (UPFC), the third generation of FACTS and the most versatile FACTS device consists of one STATCOM and one SSSC connected by a common dc link that includes a storage capacitor. UPFC will be the first FACTS device having the unique ability to simultaneously control all three parameters of power flow voltage, line impedance and phase angle. This combination of functions gives the UPFC a unique capability to control simultaneously both real and line reactive power flows on a transmission corridor.

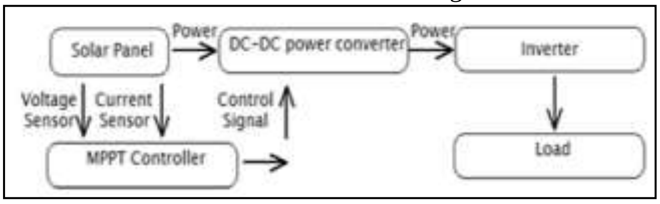
Thyristor Controlled Series Capacitor (TCSC) is a capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor controlled reactor in order to provide a smoothly variable series capacitive reactance. TCSC's are an excellent tool to introduce if increased damping is required when interconnecting large electrical systems. They can overcome the problem of subsynchronous resonance, a phenomenon that involves an interaction between large thermal generating units and series compensated transmission systems.

B. Comparison between FACTS Devices for Power System Stability Enhancement

S. No.	FACTS Device	Power System Stability Enhancement	Load flow control	Voltage stability	Transient stability	Dynamic stability	Time (sec)
1	UPFC	YES	High	High	Medium	Medium	0.6
2	TCSC	YES	Medium	Low	High	Medium	1.5
3	SVC	YES	Low	high	Low	Medium	7
4	SSSC	YES	Low	High	Medium	Medium	11

II. PV-BASED SOLAR FARM

PV-based solar farm uses PV-panels to generate clean and green electricity locally at large scale which is then feed into the grid. The area occupied by solar farm may be anything between 1 acre and 100 acres. Figure 2 represents a simple block diagram of solar farm which shows main components of solar farm. Other components of solar farm are cabling network, step-up transformer and power lines to evacuate power. Solar panel is a collection of solar cells connected together for desired power generation. Cabling network is used to link solar panels. It consists of thin cables from each panel which are then connected to form bigger size cables. These are connected to charge controller and battery system to collect the entire DC power from the panels. As output of solar panel is DC so it is required to convert it into AC before feeding into the grid. For this purpose, DC-AC power converter is used. It is also known as inverter and constitutes the main component of solar farm. Step-up transformer is used to increase the voltage level up to the grid voltage level. Depending upon the power rating, the size and type of conductors are chosen to connect it to the grid line.



1) This paper describes about a technology which utilizes PV solar farm as a STATCOM during night time. As voltage source inverter is an important component which is common to solar as well as STATCOM and solar plant usually remains ideal in case of bad sunlight hence this ideal time can be utilized to improve power factor and voltage regulation, by using solar power plant as a STATCOM. In this paper a simple open-loop control method has been presented such that PV solar plant could be used as STATCOM, in dark periods without sunlight, to control the voltage or for load reactive power compensation and voltage control. This work improves the power factor, which enhances the efficiency of the line and reduces the losses of the line due to reduction in load current. This paper also presents the comparative simulation study of STATCOM with PI controller and PID controllers and hence shows that performance of STATCOM is better with PID controller in comparison with PI controller.
2) This paper presents the usage of utilizing Photovoltaic (PV) Solar Farm (SF) during idle conditions as Static Synchronous Compensator (STATCOM), to regulate the point of common coupling voltage when the wind farm supply the power to the grid. In this paper study has been carried out on 25KV bus. The MATLAB/Simulation fault analysis has been carried out with and without STATCOM.PV array has been used as DC capacitor for the STATCOM and is interfaced to the system at the 25kv bus. There proposed control enables increased connections of WECS (Wind energy conversion system) to the grid.
3) This paper describes in a novel utilization of an existing solar farm as a STATCOM to improve power transmission limits during night as well as day time, which would have otherwise required expensive additional FACTS devices. In this paper transient study has been carried out for SMIB (single machine infinite bus) with EMTDC/PSCAD simulation software while PV solar farm is located at the midpoint. Fault studies has been conducted by applying LLLG fault at the 400kV terminal of the generator transformer (bus 1) for 5 cycles and maximum generator power output has been obtained for the system using PSCAD/EMTDC simulation software for both cases with and without proposed solar farm controller. Maximum power flow limit has been obtained by considering post-fault clearance settling time has and it is within 10 seconds for the rotor mode oscillations. The proposed system has damping ratio higher than 5% and peak over shoot of the voltage at the point of common connection limited to 10%.

4) This paper presents a solar energy with FACTS controller in their paper. The work of this paper introduces a new way to increase the penetration of renewable energy into the distribution systems. This paper proposes a new concept of multilevel inverter to use it as a FACTS controllers for smallto-mid-size solar installations. This inverter is placed between the PV panel and the grid to regulate active and reactive power transfer to the grid. The results of this paper shows that to regulate the power factor of the gird, the proposed inverter can replace traditional renewable energy inverters and hence can be used as STATCOM.
5) This paper describes a new control method to maintain the STATCOM DC link voltage to a minimum value in their paper. The additional PV cell acts as a backup to the STATCOM DC link voltage source. It serves as a source to the STATCOM DC link capacitor when the capacitor voltage is below a particular limit. This control method along with STATCOM improves the output waveform quality and improves the reliability of the system. The control algorithm described in this paper has been used to control capacitor voltage and solar cell voltage control. This paper presents an improved quality of output waveform and reliability of system with the proposed control method.
6) This paper proposes configurations of PV system that can act as Inter Line Power Flow controller (IPFC), Static Synchronous Compensator (STATCOM), or Unified Power Flow Controller (UPFC) in multi-feeder systems in their paper. In this paper inverters used in Photo Voltaic plant has been reconfigured to interconnect two or more distribution networks/feeders and inverters are connected n back to back manner to get Inter line photo voltaic system. Three different topologies shunt interline photovoltaic, series interline photovoltaic and shunt-series interline photo voltaic has been configured from the proposed photo voltaic system configuration. The result of this paper shows that all three configurations have the real power exchange capability and among these series interline photo voltaic configuration has greater capability to control the power flow in the system and regulate the voltage at the point of common connection. The limitation with the series configuration is the requirement of high rating of series coupled transformer. The results of this paper presents a noble approach to control the real and reactive power, voltage regulation and management of real power flow by expansion of large scale photo voltaic power plants.
7) This paper presents the mathematical modeling and the control screams having MPPT control and provided for the three converters, which are the dc-dc boost converter, battery converter and inverter. In the stand-alone PV system, both dc bus voltage and ac output voltage are kept stable even when the source and load are changing. The inverter is used to supply nonlinear load which is represented by a single phase diode rectifier with a capacitor and resistor connected in parallel at the dc terminal of the rectifier. The current is intermittent, but the voltage is kept stable and has a good quality. The result shows of the modeling in Matlab/Simulink that boost converter can track the maximum power point of the solar panel, the battery converter have a constant dc bus voltage , and the inverter have high quality sinusoidal ac voltage with the nonlinear load.
8) In this paper the Monte Carlo approach is used for analyzing the behavior of electrical load and for taking into account the stochastic variability of electrical energy demand. This approach is also used for the calculating the power production of standalone PV generation system as a function of hourly solar irradiation of the installation site. The Monte Carlo method is a computational algorithm that relies on repeated random sampling to compute its results.
9) The near-Maximum-Power-Point-Operation (nMPPO) design is used instead of maximum power point technique (MPPT) method in this paper the reason behind it is to reduce the conversion loss of MPPT at non full load operation. For the PV generation system lead acid battery are widely used. The result shows of this paper that the loss of load probability for full night lighting in the lighter (50W) solar system is zero in a particular interval (more than two months) while for the higher load (100W) solar LED system , the loss of load probability is increased (3.6%) in spring.

III. Conclusion

In this review, the current status of power system stability enhancement using soalr farm as FACTS controllers was discussed and scrutinized. The essential features of FACTS controllers and their potential to enhance system stability was addressed. The location and feedback signals used for design of FACTS-based damping controllers were discussed. The coordination problem among different control schemes was also considered. Performance comparison of different FACTS controllers has been reviewed. A brief review of FACTS applications to optimal power flow and deregulated electricity market has been presented. About two hundred twenty seven research publications have been classified, discussed, and appended for a quick reference. The solar system and the MPPT techniques are also well discussed in this paper. The main issue of FACTS controller is the storage system which is replaced by solar system and use of solar system for stability enhancement of power system as FACTS controller in this paper.

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