Modeling of Solar Farm as a Facts Device for Power System Stability

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Abstract— The increase in power demand and use of various types of electrical equipment has a great impact on the stability of the system. Whenever there is switching, loss of load line or any type of fault there is a change in the behavior of the system and these phenomena affects the stability of the system. For the stability analysis of a system two kinds of stability analysis is performed small signal stability study (Steady State Stability and Dynamic Stability) and large signal stability (Transient Stability) study. In this work we will improve the transient behavior of the Grid with the help of Photovoltaic based Solar Farm which will act as FACTS device. The output of PV cell is DC which is an important part of storage system of FACTS device / controllers. In this work we will make an array of PV cell which will act as DC source to the converters and by applying suitable control algorithm we will control the output of converter.

Key words: Power Factor; Apparent Power; Active Power; Reactive Power; Solar Farm; Converters; MPPT; MLI; ANFIS; MATLAB

I. Introduction

At present, many countries are mostly dependent on fossil fuels to meet their requirement for power but the major problems associated with the fossil fuels are long term availability and global warming. From availability, commercial and technical aspects among different available renewable energy resources, solar energy are the choice of most countries of world. Efficient conversion of solar energy into power is a major concern. This is a fascinating and research area for the scientists. Commercially its installation requires lesser of manpower, area and time as compared to other renewable energy resources.

[1] This paper proposes a straightforward and powerful MPPT model-based system, the control procedure of which depends on IOL (information output linearization) controller. The two feedback loops in the cascaded structure resulting MPPT causes to compensate for sudden irradiance drops. [4] In this paper UPQC has been used to improve the power quality. Voltage sag has been compensated by active power control approach. Power angle control approach has been used to compensate for load reactive power sharing. UPQC uses solar power to compensate for the voltage sag. [6] This paper presents the standalone three phase PV generation system. By using the required power tracking scheme instead of conventional MPPT scheme the battery have long life because of not having overcharge and deep discharge. [10] In this paper an adaptive fuzzy logic controller (FLC) design technique for photovoltaic (PV) inverters has been presented in which differential search algorithm (DSA) has been used. [13] In this paper real time simulation and analysis as well as comparison of different maximum power point tracking techniques have been carried out by authors. Five MPPT algorithms perturb and observe incremental conductance, fuzzy logic, neural network and adaptive neuro-fuzzy inference system (ANFIS) based have been explained and the results have been compared.

II. Power System Stability

Power system stability may be defined as the ability of the system to return or regain its steady state operating condition after the occurrence of transients or certain kind of disturbances. Sometimes the power system stability is also termed as synchronous stability, frequently in case of multi machine system. In terms of synchronous stability, it can be defined as the ability of the system to return to its synchronous operating condition after having undergone through disturbances caused by switching on and off of load or due to line transients. Reactive power is an important component in the power system network, variation of which could lead to imbalance in the network is aspect of losses, voltage and frequency. A definite amount of reactive power is always required in the power system. But an increase in the amount of the reactive power in the system above the limit can cause the frequency collapse and also decrease in the reactive power below a certain limit can cause voltage collapse. So we need a balance in the flow of reactive power in the system. Power factor plays a vital role in reactive power flow in the system.

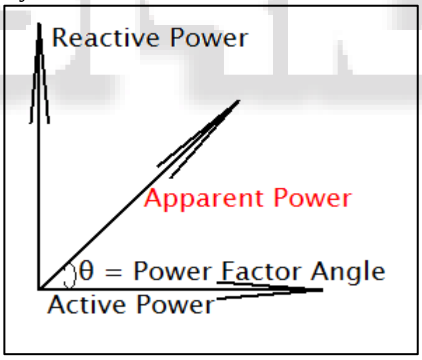

Fig. 1: Power Factor angle, Apparent Power, Active Power and Reactive power

III. Solar Farm

Solar panels, MPP tracker, host controller, Boost converter, PWM controller and inverter are major components of solar farm. Solar panels convert incident solar radiation into electrical DC. Boost converter is used to boost the output of the solar panel as the output of solar panel is low to meet the load demand. MPP tracker ensures the operation of system at maximum power point. PWM contoller contorls the duty cycle of switches of boost converter and inverter. Inverter converts DC to AC.

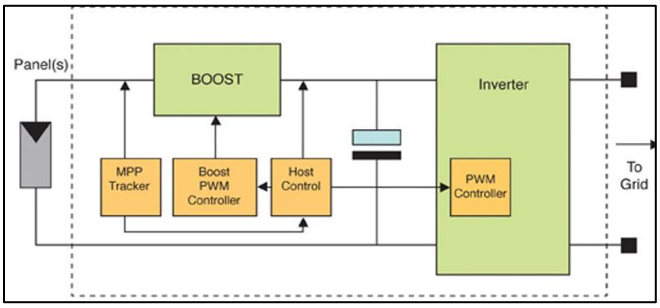

Fig. 2: Schematic diagram of Solar Farm

IV. FACTS CONTROLLERS

FACTS stand for Flexible Alternating Current Transmission System. The word flexible in its definition indicates its functionality and importance in the power system. Its use in the power system aids to the flexible behavior of the power system and thus enhances the controllability and power quality delivered by the power system during different abnormal operating conditions. Revolutions in power electronics led to the evolution of FACTS and its application in power system transmission and distribution. It involves conversion and/or switching power electronics in the range of a few tens to a few hundred megawatts. FACTS technology revealed the large potential opportunity for power electronics technology to enhance the value of power systems. The FACTS technology includes a collection of controllers applied individually or in coordination with others to control one or more interrelated system parameters like series impedance, shunt impedance, current, voltage, phase angle, and the damping of oscillations at various frequencies below the rated frequency. FACTS controllers mostly uses voltage-source converters with gate turn-off thyristors due to their reactive power supply capability.

V. MODELING OF PV CELL

Modeling of PV cell in MATLAB/Simulink environment with the help of single diode characteristic equation of PV cell.

$$I = I_{lg} - I_{os} * \left[\exp\left\{q * \frac{V+I*R_s}{A*k*T}\right\} - 1\right] - \frac{V+I*R_s}{R_{sh}}$$

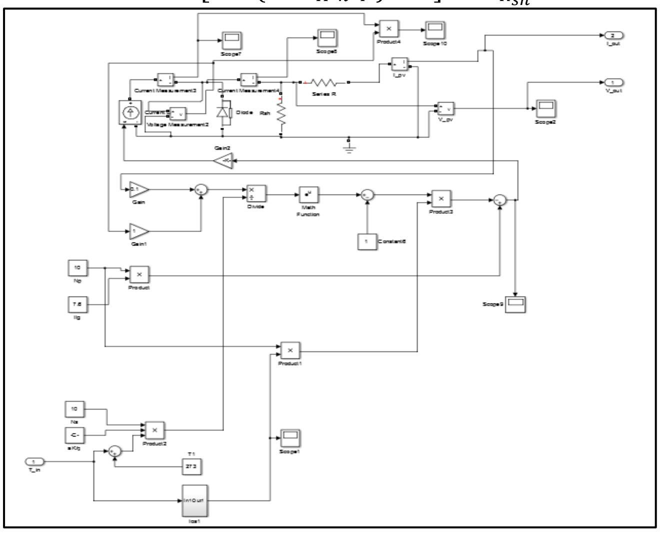

Fig. 3: Single diode MATLAB/ SIMULINK Model of PV cell

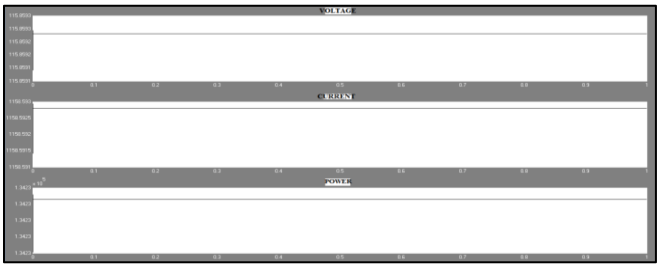

Fig. 4: Voltage, Current and Power of PV cell

Simulation results of Single Diode Model of PV cell are:
Output Voltage: 115.86 V (approximately)
Current: 1158.6 A (approximately)
Power: 1.3423 x 10^5 W (approximately)

VI. MODELING OF BOOST CONVERTER

Modeling of boost converter to boost the output of the PV cell in MATLAB / Simulink.

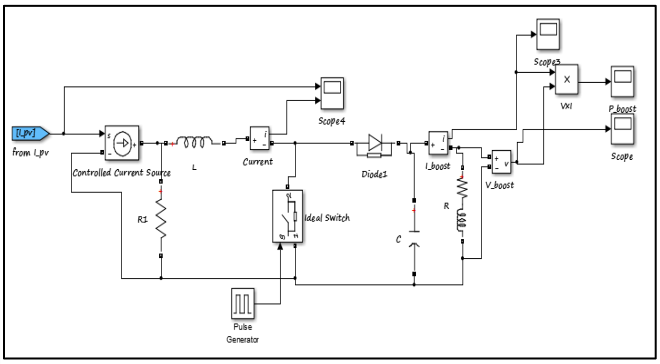

Fig. 5: MATLAB/ SIMULINK Model of boost converter

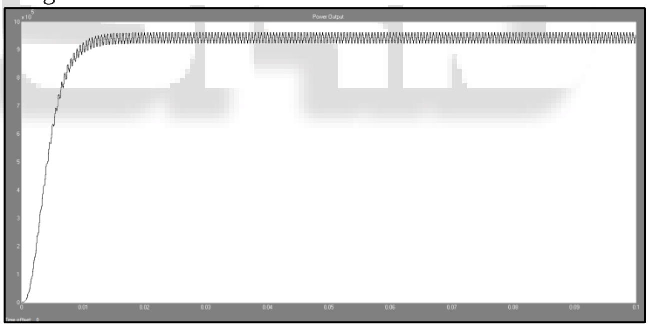

Fig. 6: Power output with normal gating pulse

From above simulation output from the boost converter with normal gating signal we observe that Response time with normal gating signal is approximately 0.01 second and the power output with normal gating sequence is near to 10 x 10^5 Watt.

VII. MPPT CONTROL

Application and comparison of Perturbation & Observation MPPT algorithm and FLC based MPPT algorithm and control the duty cycle of Boost Converter to get maximum power output from the PV cell.

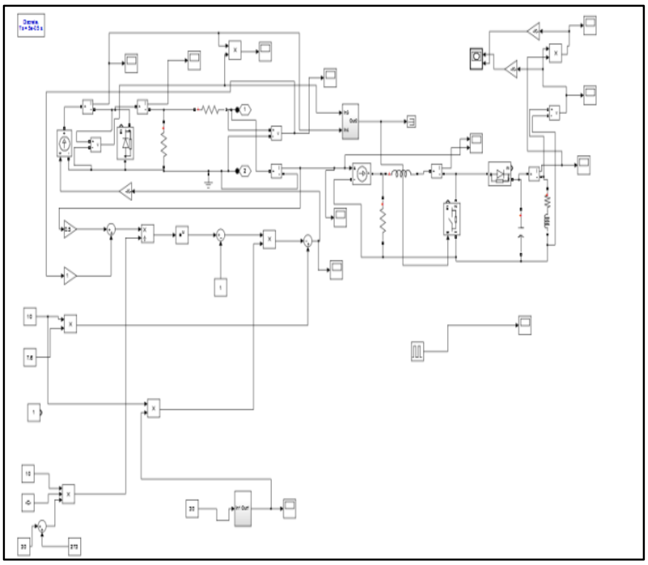

Fig. 7: MATLAB/ SIMULINK Model for P&O based MPPT

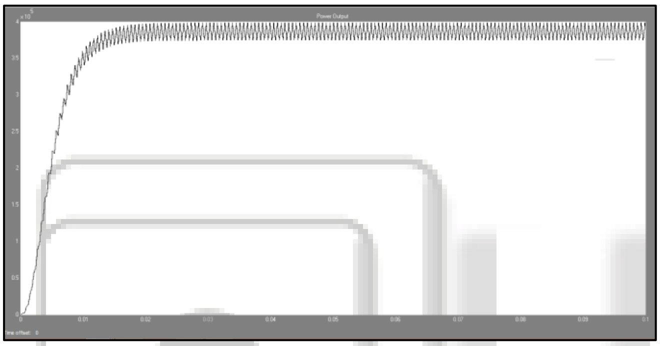

Fig. 8: Power output with Perturbation and Observation based MPPT

From above simulation result from the boost converter with Perturbation and observation MPPT, response time is 0.02 second and power output is near to 4 x 105 watt.

VIII. Modeling of Cascaded MLI

Modeling of cascaded MLI and hence to get AC from DC output of boost converter.

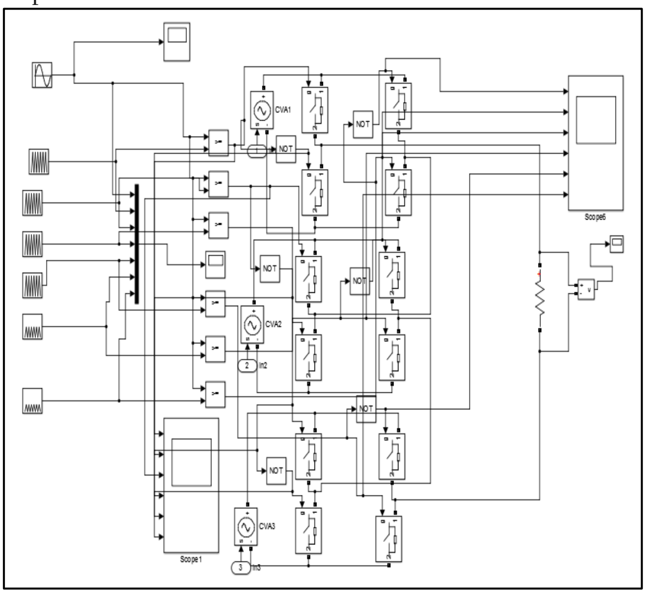

Fig. 9: MATLAB / Simulink model of 7 level cascaded MLI

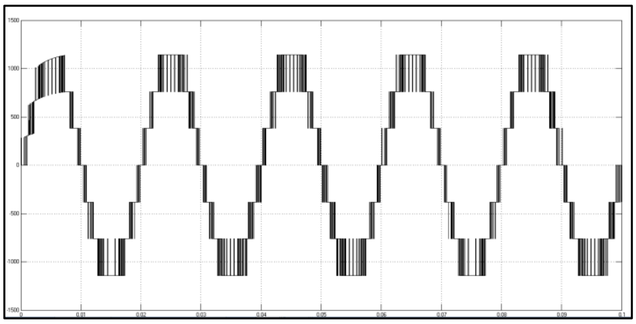

Fig. 10: AC Voltage output of 7 level cascaded MLI

IX. Synchronization with Grid

Synchronization and control the output of MLI according to the power factor of system and improve voltage and current profile at the load during transient in the form of fault and hence improve the transient stability of the system.

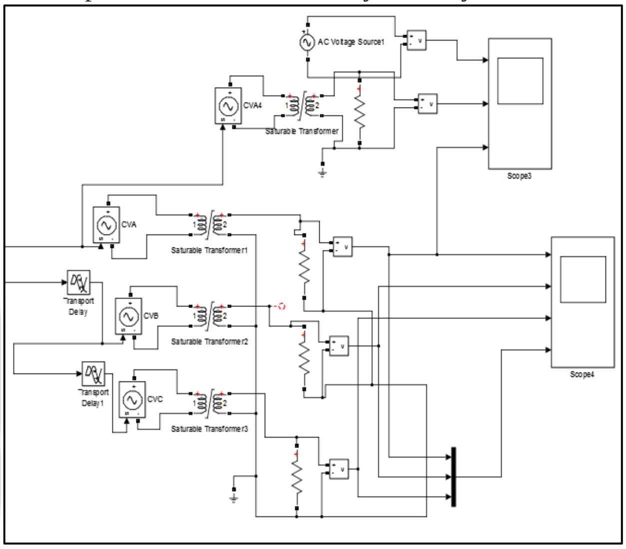

Fig. 11. Schematic diagram for synchronization with Grid

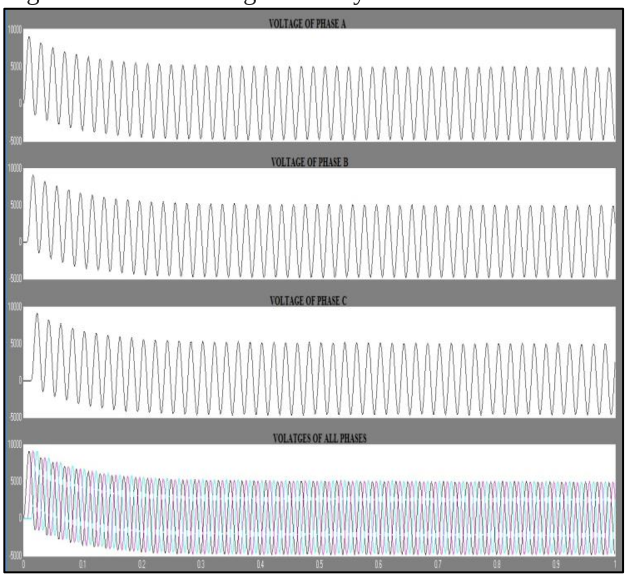

Fig. 12: Voltage outputs at solar farm terminals

Figure 38 shows the schematic diagram used to get sinusoidal voltage output from the MLI. To reduce the effect of harmonics due to switching devices a step-up transformer has been used. This step-up transformer isolates the Grid system from the switching devices of MLI and thus prevents the system from harmonics introduced by these switching devices. Along with this, it also step-ups the low voltage output of the MLI. This enables the voltage magnitude matching capability of the designed system with the grid. A controlled voltage source has been used between the output terminals of MLI and input of this transformer so reduce the THD in the voltage output waveform.

Figure 39 shows the voltages at the output terminals of the designed solar farm. This is sinusoidal in nature. To apply the phase difference of 120° in phases, the time delayer has been used for each phase. From the waveform it is clear that the designed system 0.2 second for synchronization.

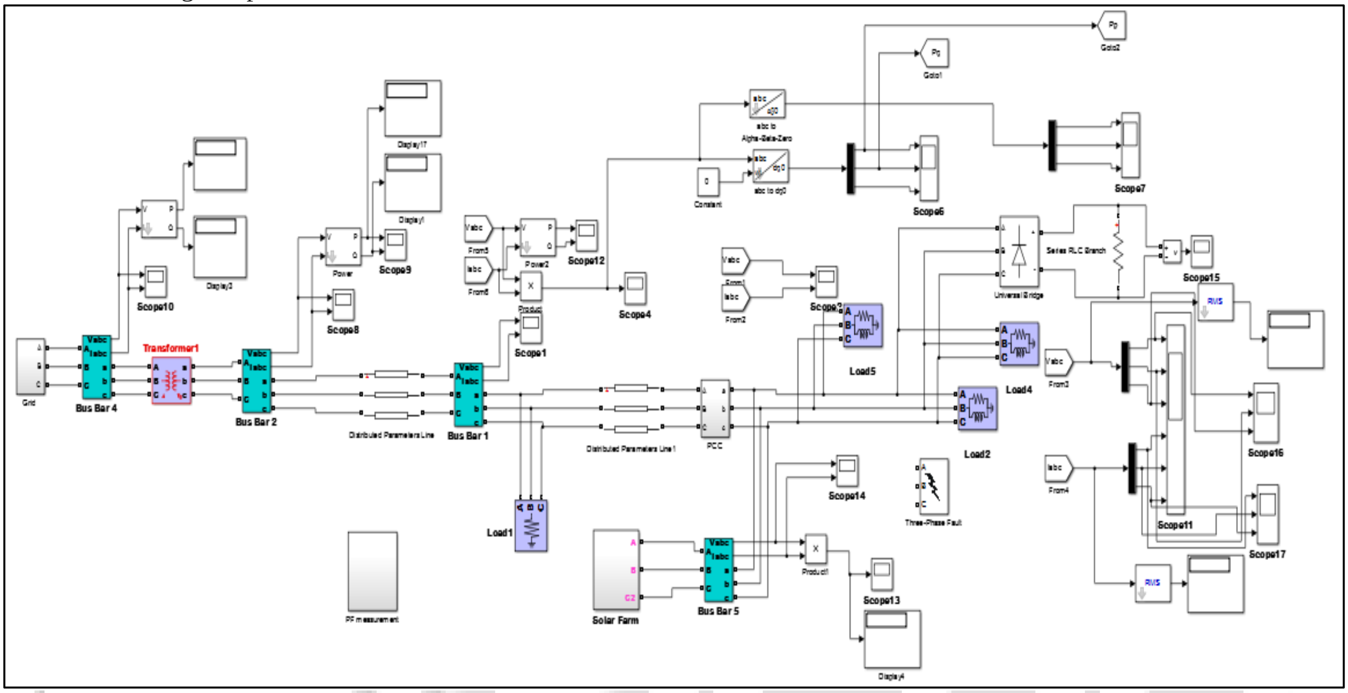

Fig. 13: Overall System model

X. CONCLUSION

This Paper presents such utilization of solar farm which improves the power quality. Power factor and the voltage profile improvement and system reinforcement during different transient conditions are the desired functions of the FACTS device. In this paper solar farm has been utilized as a FACTS controller which improves the power factor by injecting voltage in quadrature with the system voltage depending upon the power factor of the system. The modeling of the solar farm is performed in this paper for utilizing it as a FACTS device for being improvement of various factor of the power system. The overall system model connected with grid is designed.

REFERENCES

[1] Diego R. Espinoza-Trejo, Ernesto Bárcenas-Bárcenas, Daniel U. Campos-Delgado, and Cristian H. De Angelo, Voltage-Oriented Input–Output Linearization Controller as Maximum Power Point Tracking Technique for Photovoltaic Systems, *IEEE Transactions on Industrial Electronics*, Vol. 62, No. 6, 2015.

[2] Dr.C.Nagarajan, 2R.Srinivasan, 3V.R.Anand, Analysis and Design of Series Inverter Based

[3] Load Reactive Power Compensation, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4, 2015.

[4] Moumita Das and Vivek Agarwal, Novel High Performance Stand Alone Solar PV System with High Gain, High Efficiency DC-DC Converter Power Stages, *0093-9994 (c)* 2015 IEEE.

[5] Ammar Hussein Mutlag, Hussain Shareef, Azah Mohamed, M. A. Hannan and Jamal Abd Ali, An Improved Fuzzy Logic Controller Design for PV Inverters, Utilizing Differential Search Optimization, Hindawi Publishing Corporation, International Journal of Photo Energy, 2014.

[6] D. S. Karanjkar, S. Chatterji and Shimi S. L. and Amod Kumar, Real Time Simulation and Analysis of Maximum Power Point Tracking (MPPT) Techniques for Solar Photo-Voltaic System Proceedings of 2014 RAECS UIET ,Punjab University Chandigarh, March, 2014.

[7] V.Srimaheswaran, R.Uthirasamy, Cascaded Multilevel Inverter for PV Cell Application Using PIC Microcontroller, International Journal of Innovative Technology and Exploring Engineering, Volume-2, Issue-3, Feb. 2013.

[8] Srushti R. Chafle, Uttam B. Vaidya, Incremental Conductance MPPT Technique FOR PV System, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 6, June 2013.

[9] Burri Ankaiah and Jalakanuru Nageswararao, MPPT Algorithm for Solar Photovotaic Cell by Incremental Conductance Method, International Journal of Innovations in Engineering and Technology (IJIET) ,February 2013.

[10] S. Reshma Kiran1, CH. Rajesh2, Harmonic and Reactive Power Compensation in a Grid Connected PV System with Source Side Control Technique, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 9, September 2013