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Paper Authors

*** AMAR KUMAR.**

* Directorate General of Training under Ministry of Skill Development and Entrepreneurship.

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NOVEL UTILIZATION OF A PV SOLAR FARM AS PV-STATCOM FOR IMPROVES THE STABLE TRANSMISSION LIMITS SUBSTANTIALLY IN THE NIGHT AND IN THE DAY

AMAR KUMAR

Assistant Director I.S.D.S. (IES), M.E. (Control Engineering),Directorate General of Training under Ministry of Skill Development and Entrepreneurship.

ABSTRACT

New voltage control has also been proposed on a PV solar farm to act as a STATCOM for improving the power transmission capacity. Although, proposed voltage-control functionality with PV systems, none have utilized the PV system for power transfer limit improvement. A full converter-based wind Turbine generator has recently been provided with FACTS capabilities for improved response during faults and fault ride through capabilities.This paper proposes novel voltage control, together with auxiliary damping control, for a grid-connected PV solar farm inverter to act as a STATCOM both during night and day for increasing transient stability and consequently the power transmission limit. This technology of utilizing a PV solar farm as a STATCOM is called "PV-STATCOM." It utilizes the entire solar farm inverter capacity in the night and the remainder inverter capacity after real power generation during the day, One SMIB system uses only a single PV solar farm as PV-STATCOM connected at the midpoint whereas the other system uses a combination of a PV-STATCOM and another PV-STATCOM or an inverter-based wind distributed generator (DG) with similar STATCOM functionality. Three-phase fault studies are conducted using the electromagnetic transient software EMTDC/PSCAD, and the improvement in the stable power transmission limit is investigated for different combinations of STATCOM controllers on the solar and wind farm inverters, both during night and day.

Index terms : flexible ac transmission systems(FACTS),inverter,photovoltaic solar power systems, reactive power control,STATCOM.

INTRODUCTION :

Photovoltaic's is the field of technology and research related to the devices which directly convert sunlight into electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic effect involves the

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creation of voltage in a material upon exposure to electromagnetic radiation. The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice. For instance, in the fabrication of a photovoltaic solar cell, silicon, which has four valence electrons, is treated to increase its conductivity. On one side of the cell, the impurities, which are phosphorus atoms with five valence electrons (n-donor), donate weakly bound valence electrons to the silicon material, creating excess negative charge carriers. Ohmic metal-semiconductor contacts are made to both the n-type and p-type sides of the solar cell, and the electrodes are ready to be connected to an external load. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo-generated positive charge carriers (holes) from their negative counterpart (electrons). In this way an electrical current is extracted once the circuit is closed on an external load. which is necessary for photovoltaic action and access to the junction for the incident light.

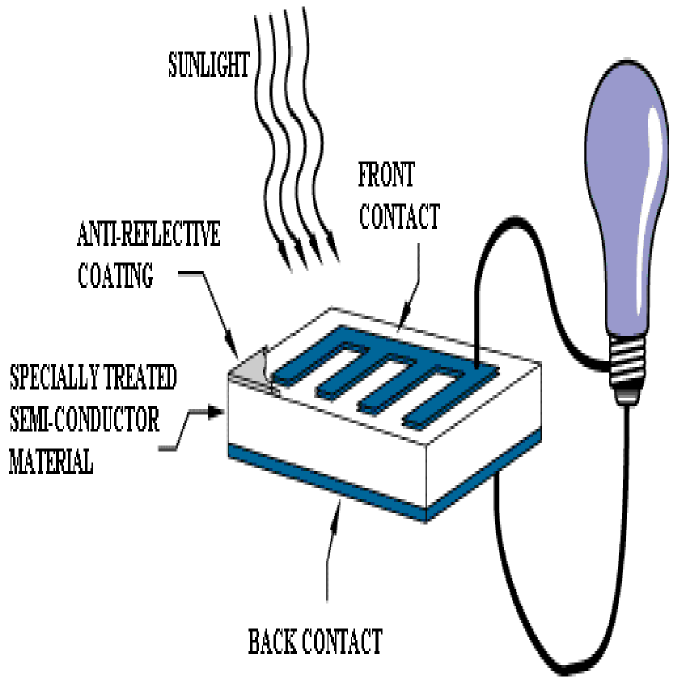

Fig 1. solar cell.

The photovoltaic effect was first reported by Edmund Becquerel in 1839 when he observed that the action of light on a silver coated platinum electrode immersed in electrolyte produced an electric current. Forty years later the first solid state photovoltaic devices were constructed by workers investigating the recently discovered photoconductivity of selenium. In 1876 William Adams and Richard Day found that a photocurrent could be produced in a sample of selenium when contacted by two heated platinum contacts. The photovoltaic action of the selenium differed from its photoconductive action in that a current was produced spontaneously by the action of light.

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1.System Model :

The synchronous generator is represented by a detailed six thorder model and a DC1A-typeexcite.Thetransmission-line segments TL1, TL2, TL11, TL12, and TL22, shown in Fig. 1, are represented by lumped pi-circuits. The PV solar DG, is model edasane quivalent voltage-source inverter along with a controlled current source as the dc source which follows the - characteristics of PV panels. The wind DG is likewise modeled as an equivalent voltage-source inverter. In the solar DG, dc power is provided by the solar panels,where as in the full-converter-based wind DG, dc power comes out of ac controlled ac–dc rectifier connected to the PMSG wind turbines, depicted as "wind Turbine-Generator-Rectifier (T-G-R)." The dc power produced by each DG is fed into the dc bus of the corresponding inverter, as illustrated in Fig. 2. A maximum power point tracking(MPPT) algorithm based on an incremental conductance algorithm is used to operate the solarDGsatitsmaximumpowerpointallofthetimeandisintegrated with the inverter controller The wind DG is also assumed to operateat its maximum powerpoint, since this proposed control utilizes only the inverter capacity left after the maximum power point operation of the solar DG and wind DG The voltage-source inverter in each DG is composed of six insulated-gate bi polar transistors (IGBTs) and associated snubber circuits as showninFig.2

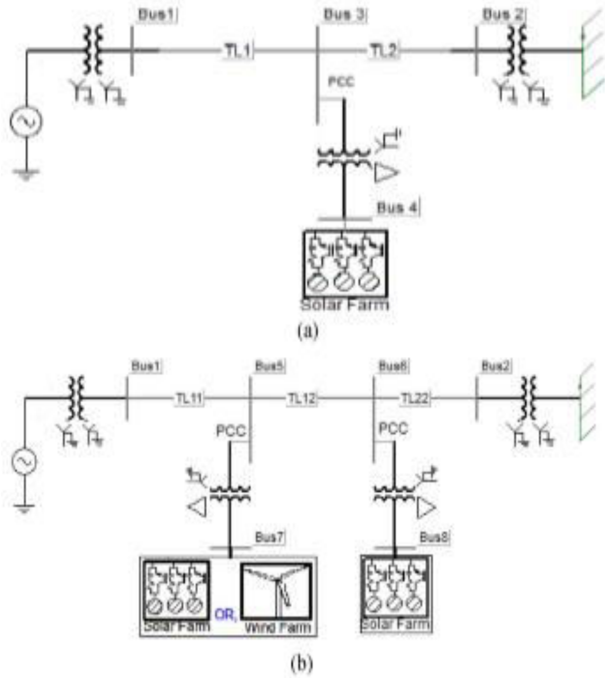

Fig.2. Single- line diagram of (a) study system I with a single solar farm(DG) and (b) study system II with a solar farm(DG) and a solar/wind farm(DG).

The single-line diagrams of two study systems: Study System 1 and Study System 2 are depicted in Fig.2 respectively. Both systems are single-machine infinite bus (SMIB) systems where a large equivalent synchronous generator (1110 MVA) supplies power to the infinite bus over a 200-km, 400-kV transmission line. This line length is typical of a long line carrying bulk power in Ontario. In Study System 1, a 100-MW PV solar farm (DG) as STATCOM (PV-

STATCOM) is connected at the midpoint of the transmission line. In Study System 2, two 100-MVA inverter-based distributed generators (DGs) are connected at 1/3 (bus 5) and 2/3 (bus 6) of the line length from the synchronous generator. The DG connected at bus 6 is a PV-STATCOM and the other DG at bus 5 is either a PV-STATCOM or a wind farm with STATCOM functionality. In this case, the wind farm employs permanent-magnet synchronous generator (PMSG)-based wind turbine generators with a full ac-dc-ac converter. It is understood that the solar DG and wind DG employ several inverters. However, for this analysis, each DG is considered to have a single equivalent inverter with the rating equal to the total rating of solar DG or wind DG, respectively. The wind DG and solar DG are considered to be of the same rating, hence, they can be interchanged in terms of location depending upon the studies being performed. Fig. presents the block diagrams of various subsystems of two equivalent DGs.

2.1. System Model

The synchronous generator is represented by a detailed sixth order model and a DC1A-type exciter. The transmission-line segments TL1, TL2, TL11, TL12, and TL22, shown in Fig.5.1, are represented by lumped pi-circuits. The PV solar DG, as shown in Fig.5.2, is modeled as an equivalent voltage-source inverter along with a controlled current source as the dc source which follows the -characteristics of PV panels. The wind DG is likewise modeled as an equivalent voltage-source inverter. In the solar DG, dc power is provided by the solar panels, whereas in the full-converter-based wind DG, dc power comes out of a controlled ac–dc rectifier connected to the PMSG wind turbines, depicted as “wind Turbine-Generator-Rectifier (T-G-R).” The dc power produced by each DG is fed into the dc bus of the corresponding inverter, as illustrated in Fig.5.2. A maximum power point tracking (MPPT) algorithm based on an incremental conductance algorithm is used to operate the solar DGs at its maximum power point all of the time and is integrated with the inverter controller. The wind DG is also assumed to operate at its maximum power point, since this proposed control utilizes only the inverter capacity left after the maximum power point operation of the solar DG and wind DG. For PV-STATCOM operation during nighttime, the solar panels are disconnected from the inverter and a small amount of real power is drawn from the grid to charge the dc capacitor. The voltage-source inverter in each DG is composed of six insulated- gate bipolar transistors (IGBTs) and associated snubber circuits as shown in Fig.5.2. An appropriately large dc capacitor of size 200 Farad is selected to reduce the dc side ripple. Each

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phase has a pair of IGBT devices which converts the dc voltage into a series of variable-width pulsating voltages, using the sinusoidal pulse width modulation (SPWM) technique . An L-C-L filter [13] is also connected at the inverter ac side.

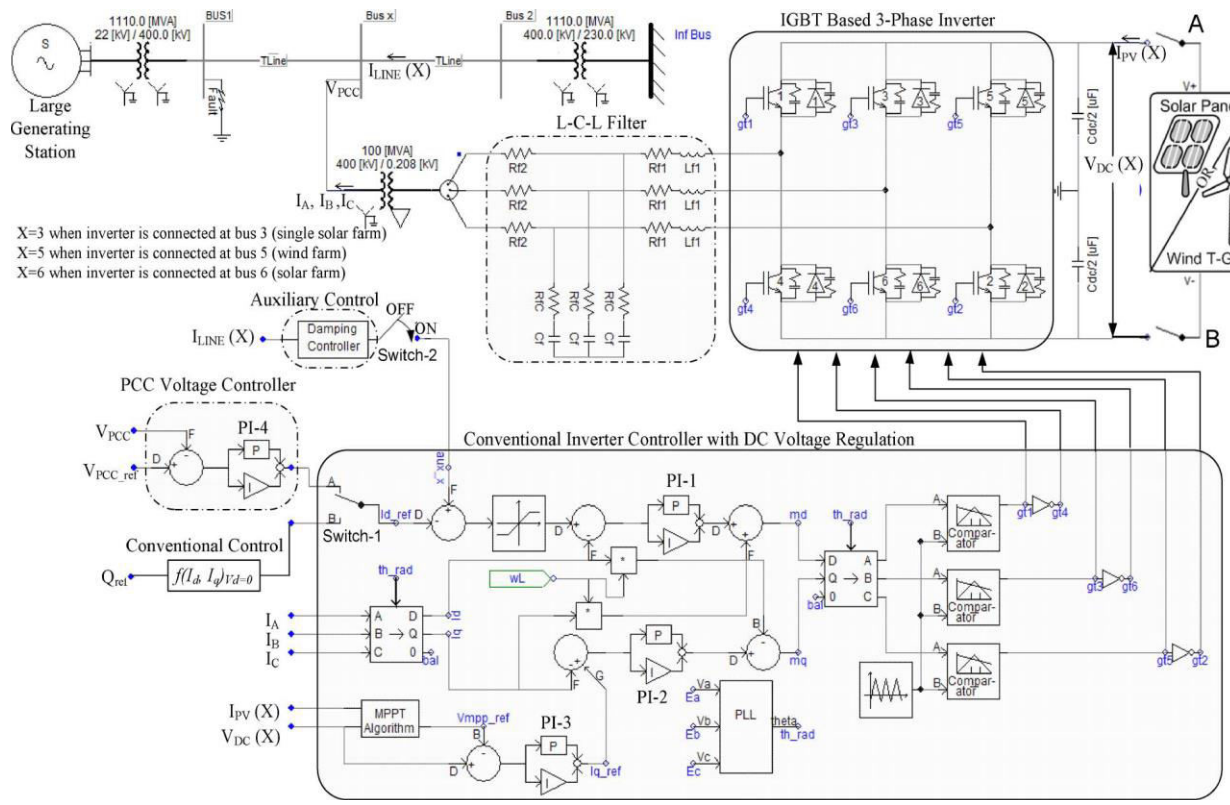

Fig. 3.0. Complete DG (solar/wind) system model with a damping controller and PCC voltage-control system

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3.1 Control System :

The conventional reactive power control only regulates the reactive power output of the inverter such that it can perform unity power factor operation along with dc-link voltage control.The switching signals for the inverter switching are generated through two current control loops in - -0 coordinate system.The inverter operates in a conventional controller mode only provided that “Switch-2” is in the “OFF” position. . It is understood that the solar DG and wind DG employ several inverters. However, for this analysis, each DG is considered to have a single equivalent inverter with the rating equal to the total rating of solar DG or wind DG, respectively.

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MATLAB/SIMULINK RESULTS

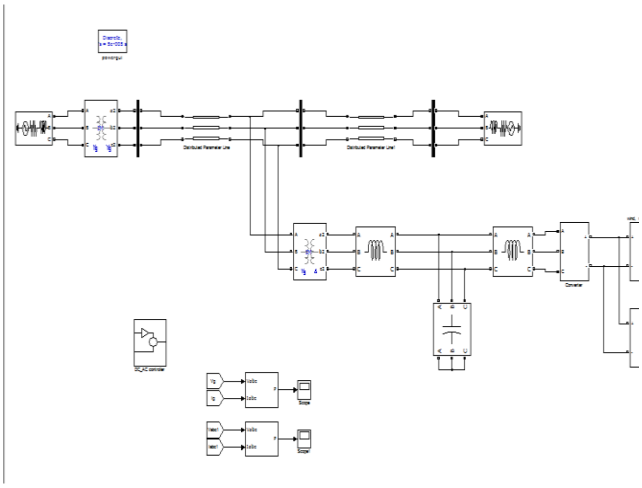


Fig 3.1 MATLAB/SIMULINK Diagram of Complete DG (solar/wind) system model with a damping controller and PCC voltage-control system.

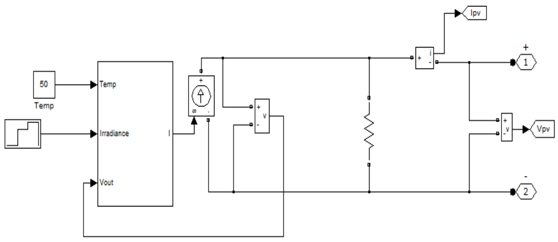


Fig 3.2 pv subsystem

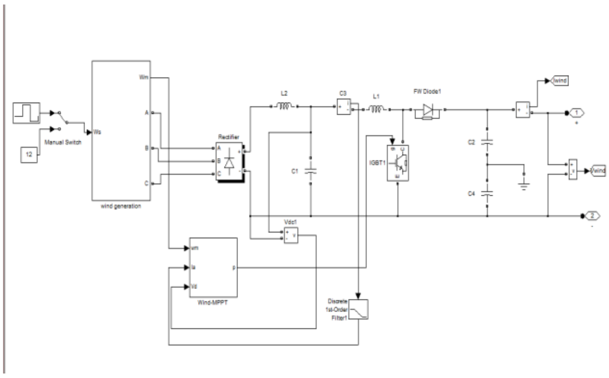
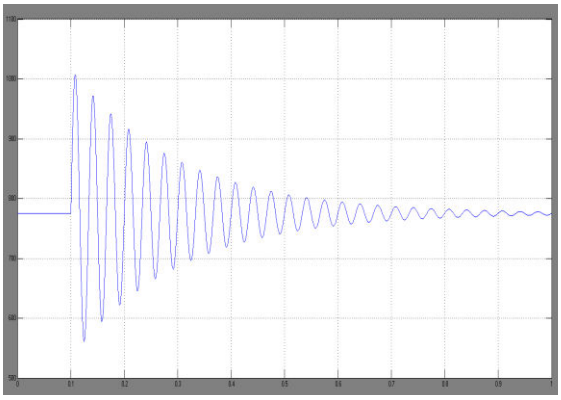
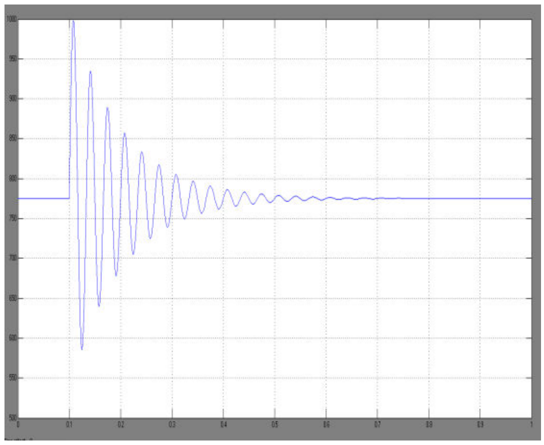


Fig 3.3 wind subsystem

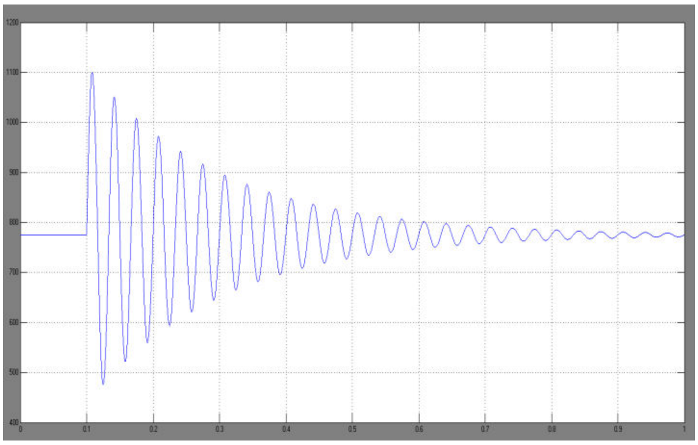


(a)



(b)

Fig 3.4 Night time (a) generator power Pg (B) infinite bus power Pinf



(a)

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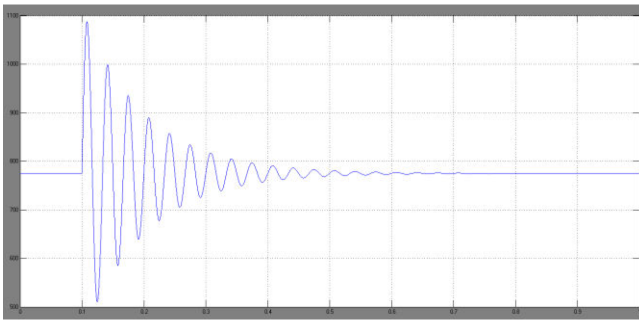

(b)

Fig 3.5 Day time (a) generator power Pg (B) infinite bus power Pinf

CONCLUSION

Solar farms are idle during nights. A novel patent-pending control paradigm of PV solar farms is presented where they can operate during the night as a STATCOM with full inverter capacity and during the day with inverter capacity remaining after real power generation, for providing significant improvements in the power transfer limits of transmission systems This new control of PV solar system as STATCOM is called PV-STATCOM. The effectiveness of the proposed controls is demonstrated on two study SMIB systems: System I has one 100-MW PV-STATCOM and System II has one 100-MW PV-STATCOM and another 100-MW PV-STATCOM or 100-MW wind farm controlled as STATCOM. Three different types of STATCOM controls are proposed for the PV solar DG and inverter-based wind DG. These are pure voltage control, pure damping control, and a combination of voltage control and damping control. This study thus makes a strong case for relaxing the present grid codes to allow selected inverter-based renewable generators (solar and wind) to exercise damping control, thereby increasing much needed power transmission capability.

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