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Application of Integrated Wind Energy Conversion System (WECS) and Photovoltaic (PV) Solar Farm as STATCOM to Regulate Grid Voltage During Night Time

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Abstract

This paper presents the integration of wind energy conversion system (WECS) with photovoltaic (PV) solar farm (SF) which acts as flexible ac transmission system controller-static synchronous compensator during night time, to regulate the point of common coupling voltage and to rectify faults when SF is not producing any active power. The proposed control will enable increased connections of WECS. MATLAB/Simulink based simulation results are presented for validation of the system.

Keywords: Wind energy conversion system (WECS); Distributed generation (DG), Photovoltaic (PV); Solar farm (SF); voltage-source inverters (VSI); Doubly-fed induction generator (DFIG); Wind energy conversion system (WECS); Static synchronous compensator (STATCOM); Voltage regulation.

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1. Introduction

Utilities are presently facing a major challenge of grid integrating an increasing number of renewable-energy-based distributed generators (DGs) while ensuring stability, voltage regulation, and power quality. During the night time, feeder loads are usually much lower compared to daytime, while the wind farms (WFs) produce more power due to increased wind speeds. This potentially causes reverse power to flow

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from the point of common coupling (PCC) toward the main grid resulting in feeder voltages to rise above allowable limits. To allow further DG connections, utilities need to install expensive voltage regulating devices. Voltage-source inverters are essential components of PV solar farms (SFs), which provide solar power conversion during daytime (normal operation). However, PV SFs are practically inactive during night time and do not produce any real power output. The proposed concept is to use the existing SF inverter as a STATCOM during night time to regulate voltage variations at the PCC due to increased and intermittent WF power and/or by load variations.

With the development of distributed generation systems, the renewable electricity from PV sources became a resource of energy in great demand. The current control scheme is mainly used in PV inverter applications for real power and reactive power control schemes. The emergence of wind generation is the leading source of renewable energy in the power industry, Wind farms totalling hundreds, even thousands, of MW are now being considered. DFIG is the main type of wind generation currently in use (the other is conventional induction generators) due to their variable speed operation, four-quadrant active and reactive power capability, low-converter cost, and reduced power losses.

2. DG System modelling

Fig. 1 shows the single-line diagram of the wind energy system with battery storage and VSI. A WF modelled as a fully controlled converter–inverter-based doubly-fed induction generator and a PV SF modelled as a voltage-source inverter.

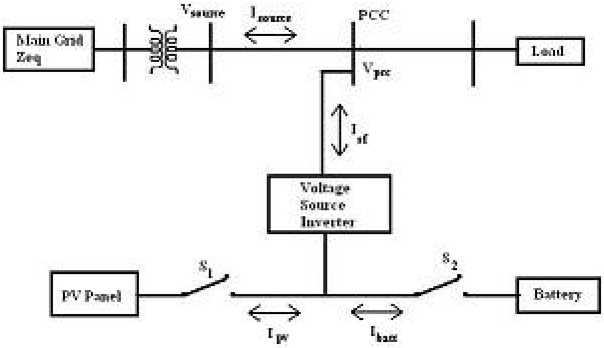

Fig.1 Solar farm inverter as the battery charger system configuration

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3. PV solar farm as battery charger

A typical PV solar farm is basically inactive during night time and the bidirectional inverter used to deliver the PV DC power as three-phase AC power to the grid, remains unutilized as well. Fig. 1 shows the possible operational modes of the solar farm. The point at which the solar farm is connected to the grid is called the point of common coupling (PCC). In Fig.1, v_S and i_S represents the voltage and current at the secondary of the distribution transformer; v_{PCC} and v_L denote voltages at PCC and load terminal respectively; and i_{PV} is the current delivered by the PV solar panels ac current drawn/delivered by the solar farm inverter and the DC current flowing through the storage battery are represented by i_{SF} and i_{Batt}, respectively. Here a storage battery is connected on DC side of the solar farm inverter. Switch “S1” in Fig.1 is utilized to disconnect the PV solar panels especially during night-time and to charge the storage batteries from the main grid [2].

4. SF inverter control

Fig .2 shows the block diagram of the control scheme used to achieve the proposed concept. The controller is composed of two proportional–integral (PI) based voltage-regulation loops. One loop regulates the PCC voltage, while the other maintains the dc-bus voltage across SF inverter capacitor at a constant level. The PCC voltage is regulated by providing leading or lagging reactive power during bus voltage drop and rise, respectively. A phase-locked loop (PLL) based control approach is used to maintain synchronization [5] with PCC voltage. A hysteresis current controller is utilized to perform switching of inverter switches. To facilitate the reactive power exchange, the dc-side capacitor of SF is controlled in self-supporting mode, and thus, eliminates the need of an external dc source (such as battery) [1].

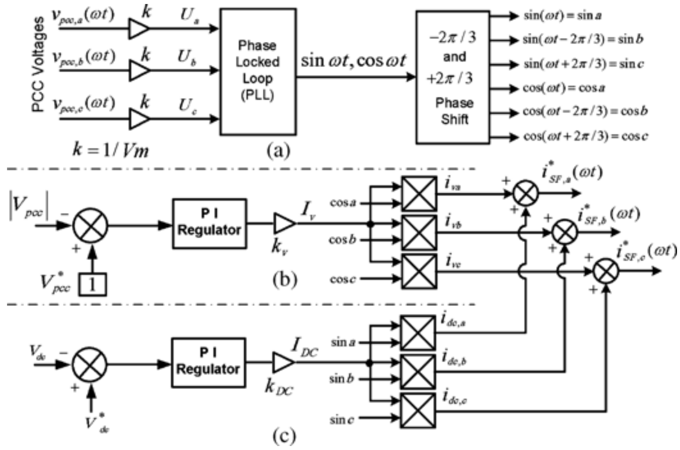
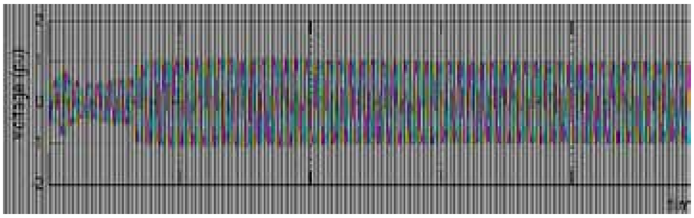


Fig .2 SF as STATCOM—controller diagrams. (a)Synchronization. (b) PCC voltage regulation loop. (c) DC bus voltage regulation loop.

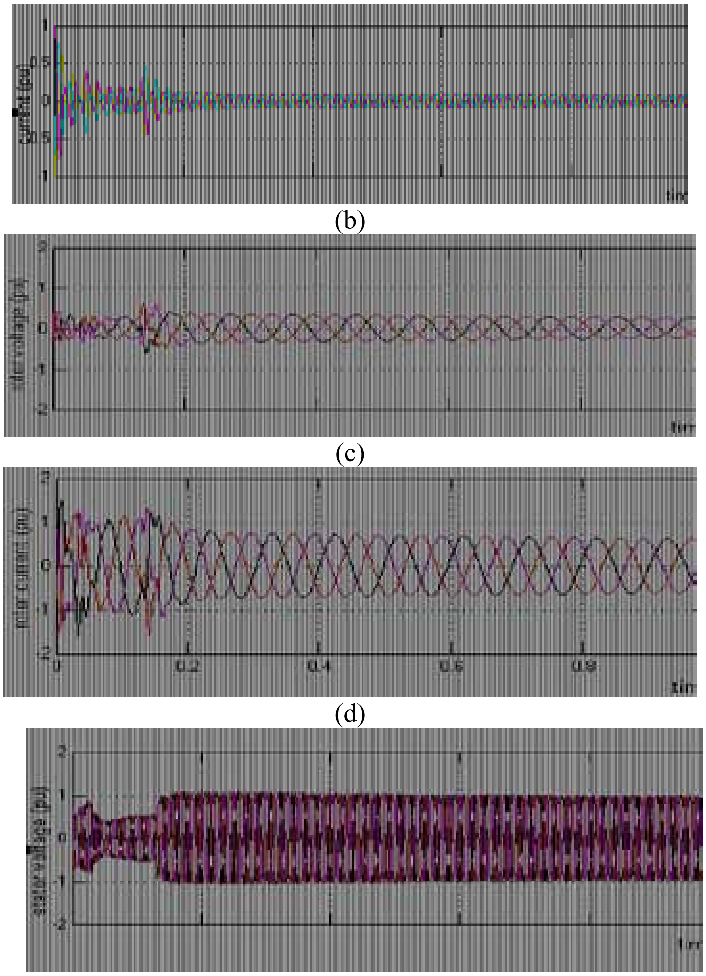
5. Simulation study and results

To validate the concept presented in the paper, MATLAB/ SIMULINK based simulation study is carried out. A Test system consists of integration of both wind energy system and PV Array system.

Wind turbines using a doubly-fed induction generator (DFIG) consist of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter modeled by voltage sources. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind.



(a)



(b)

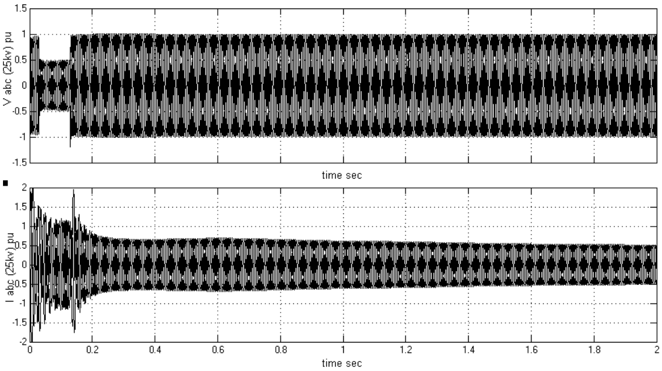
(c)

(d)

(e)

Fig.3(a) grid voltage,(b) current,(c) rotor voltage,(d) current,(e) stator voltage of the turbine
PV array is made to act as DC capacitor for the STATCOM designed and is interfaced to the system at the 25kv bus as in fig 2.

The simulation results are given in Figs 4 to 6. Case1: under normal condition the voltage and current profile in the 25kv bus is as shown in figure 4(a) here after an initial fluctuation for about 0.2 sec the voltages and currents profile is well within the ±5% pu value criteria. The reason for the fluctuation is due to change over of speed from 8m/s to 14m/s. The simulation is conducted for duration of 2 sec. Also the zoomed view of the voltages and currents is shown in fig 3(b)



(a)

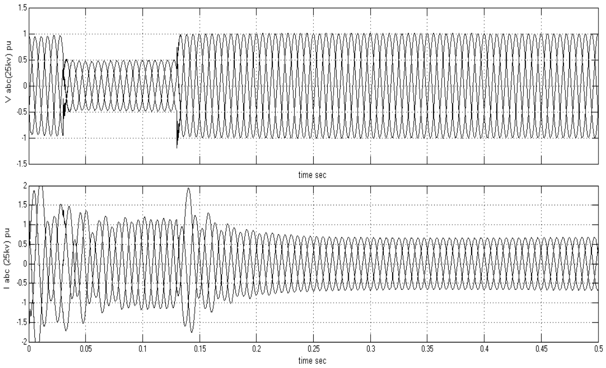


Fig.4 (b) voltage and current at 25kv bus under normal condition

Case2: when the system in acting under normal condition single phase short circuit fault is set on the "phase A" line at the 25kv bus at the instant of 0.8 sec. The voltage decreases and current increases after the instant at 0.8 as shown in the fig 4 and propagates till the complete cycle of the simulation.

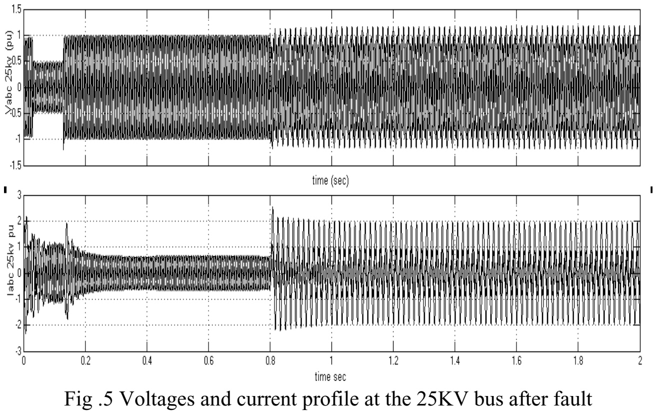


Fig .5 Voltages and current profile at the 25KV bus after fault

Case3: In this case the fault is implemented at 25kv bus at about 0.8 sec and is allowed to propagate. At 1 sec PV array STATCOM is brought into action and after 1.2 sec system is compensated and system is restored to normal condition after 1.2 sec as shown in fig

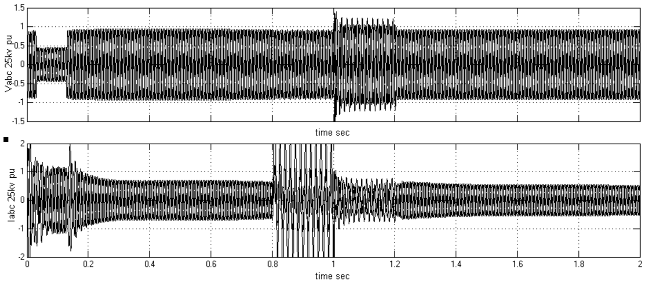


Fig .6 Voltage and current profile at 25KV bus after STATCOM action

6. Conclusion

A novel concept of optimal utilization of a PV SF as a STATCOM has been proposed and validated through MATLAB/SIMULINK simulation. The proposed strategy of PV SF control will facilitate integration of more wind plants in the system without needing additional voltage-regulating devices. PV Solar farm virtually inactive during night time in terms of active power generation is used to regulate the distribution voltage at PCC within utility specified limits even during wide variations in WF output and rectifies the fault. This novel strategy implies operating PV solar plant as a generator during the day [providing megawatts (MW)] and ancillary services provider at night [providing mega volt amperes (MVARs)]. This may pose interesting questions on ownership/partnership/lease options, license to operate, etc., and possible code changes by the regulator. These aspects are outside the scope of the paper. The technical aspects, however, warrant a look at such mixed usages.

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