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Power Quality Improvement in Hybrid Energy Conversion Systems

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Abstract: Solar Photo Voltaic (PV) panels are producing energy during day time to store the energy. Storage batteries are employed and solar inverter with MPPT is used to supply power to the load. The power generated can also be supplied to the grid at times when the load is low. The DC voltage for charging the battery could also be obtained from fuel cells utilizing biogas or hydrogen. Taking the whole system a hybrid system power quality of such a system is investigated in this study. The proposed Interconnected Hybrid Grid Interactive System (IHGIS) works on multiple dc sources which produce energy in different patterns and load itself changes as per consumer's requirement and consumer loads are non linear nature. The MPPT algorithm itself causes fluctuations in voltage fed to the battery. All these factors can cause IHGIS to produce harmonics in the system. The performance of the Battery Energy Storage System (BESS) is important to take care of the fluctuations in power generations from various sources. A mathematical model of the system described and simulated in the MATLAB/Simulink environment

Key words: Hybrid energy conversion, PV cell, average current mode control, point of common coupling, IHGIS converter, producing

INTRODUCTION

Large interconnected power grids are composed of complex combinations of generation plants, substations, transformers and transmission lines which supply electricity to cities, businesses and industry. In addition, there are smaller independent power grids that provide power to far-off. It is difficult and costly to take overhead transmission lines to such places because of difficulty to certain, cost and limited revenue to utility. Hybrid plants can integrate various sources such as photovoltaic, fuel cells and battery. Hybrid plants are outlined as best for such remote areas applications in remote villages.

The vagaries of power generation and rapid fluctuations in load make it difficult to maintain the frequency and hence, the system may remain isolated from the grid.

The objective of this study is to analyze different control strategies in order to study options for improving the operation of PV-battery hybrid plants in stand-alone applications. The studied options focus on reducing the adverse effects of the variations in the load and the power of PV field. Accordingly, the operation cost can be reduced. Therefore, the active power control is analyzed and the effects of the control strategy on the operation and costs of the plant are studied according to four criterions. The criterions are the frequency deviations, fuel consumption and expected lifetime of the batteries. Active power control is analyzed according to primary control which provides regulation in terms of few seconds and secondary control which provides much slower regulation (Li and He, 2011).

In order to analyze the operation of the plant, the dynamic operation is run in the Software MATLAB. Then, a model of battery energy storage system is integrated with the load and then a model of PV field is integrated with the plant. After that, the model is integrated with supplementary components such as lines and transformers. Finally, a model of secondary controller is developed in this study and integrated with the model of the plant.

MATERIALS AND METHODS

System description: The envisaged system consists of a PV/battery hybrid system with the main grid connecting to non-linear and unbalanced loads at the PCC as shown in Fig. 1. The photovoltaic system is modeled as nonlinear voltage sources (Tang *et al.*, 1993). The PV array is connected to HGICB DC-DC converter and bidirectional battery converter is shown in Fig. 1 which is coupled at the dc side of a μG-VSC. The HGICB DC-DC converter is connected to the PV array works as MPPT controller and battery converter is used to regulate the power flow between dc and ac side of the system (Kadri *et al.*, 2011).

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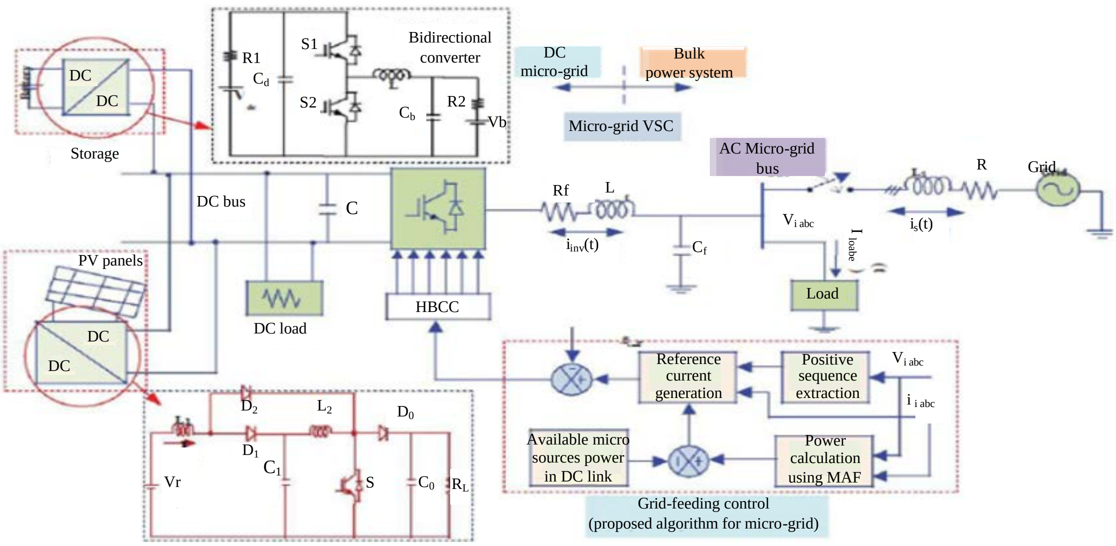

Fig. 1: Block diagram for hybrid energy conversion

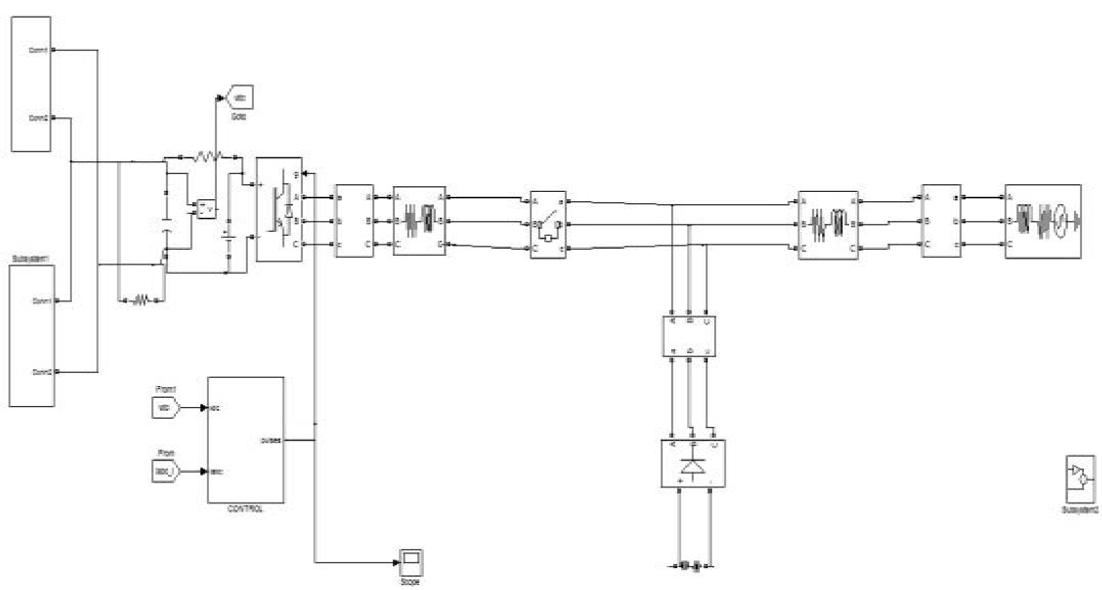

Fig. 2: Simulink model

Simulink model and software description: Voltage output of the photo voltaic panel and that of battery is connected in parallel normally the battery under charging condition. After the battery in fully charged, power flows to the load through the inverter. The inverter follows MPPT algorithm to maximize the overall efficiency of the system. Load is connected to the hybrid system as well as to the rest of power generation system comprising the micro grid. Measurements blocks are connected approximately to measure voltages, currents, real and reactive power flows, etc. (Fig. 2).

The proposed control strategies for PV hybrid generating system are developed and simulated using MATLAB/Simulink under different solar insulation levels. In order to capture the transient response of the proposed control system, PV insulation is assumed to increase from 200-1000 W/m^2 at 0.3 sec and decreases from 1000-200 W/m^2 at 0.5 sec. This abrupt increase or decrease is assumed in this research in order to test the robustness of the proposed control algorithm. As a result, the inductor current of the HGICB converter is varied to track the maximum power accordingly and the power flow between the micro grid-VSC, grid and load is also varied under above the operating conditions (Radwan and Mohamed, 2012)

The model of the hybrid PV-battery plant which is built in MATLAB can be used as a base for further analysis with dispatch control. A model of dispatch control must be integrated in order to be able to run a one year simulation if the required input data is available.

A one year simulation is useful to study the effects of different dispatch strategies on the operation and cost of the plant. Moreover, the simulation results of one year can be used for more accurate analysis of the fuel consumption of the plant and the lifetime of the battery bank. In addition, it can provide a better economical evaluation compared to one day simulation. Based on one year simulation results, an economical comparison between the control strategies according to the different fuel consumption and different expected lifetime of the batteries can be performed (Zhang *et al*., 2011).

Battery banks are susceptible to performance degradation according to the aging effect. The capacity and the DC voltage of the battery decrease by the time which can negatively affect the performance of the BESS. However, in this study it is assumed that the capacity and the voltage are not affected by age because the simulation is only for one day. For a longer simulation, integrating the model of the BESS with the effect of aging can provide more accurate results which can be used for better analysis of the lifetime and optimum sizing of battery banks.

In this study, the dynamic operation of a hybrid PV-battery plant in off grid power supply is simulated in MATLAB. The primary and secondary control of active power is considered to compensate the active power fluctuations which result from the variations of the load and PV field power. Four control strategies are proposed to represent different contribution to the primary and secondary control between the Battery Energy Storage System (BESS) and the PV (Chatterjee *et al*., 2011).

Control scheme: The primary control is provided by the BESS in parallel and the secondary control is provided only by the BESS.

Control scheme: The primary and secondary control is provided by the BESS in parallel.

Control scheme: The primary control is provided mainly by the BESS while the secondary control is provided by the PV in parallel.

The control strategies are compared according to four criterions; The frequency deviations, fuel consumption, the expected lifetime of the batteries and the performance of the diesel generators.

The results show that each control strategy leads to a different level of variations in the output power of the BESS. Control strategy leads to more constant output power close to the nominal value of the diesel generators whereas control strategy leads to a higher level of variations in the output power of the while control strategy and lead to the second and third higher levels of the variations in the loading of the BESS, respectively.

In general when the primary and secondary control covers the power fluctuations from the BESS, the output power of the PV becomes more constant and close to the nominal value.

The frequency deviations are lower when the BESS mainly provides the primary and secondary control of active power to cover the power fluctuations.

The fuel consumption is lower when the output power of the battery is constant and close to the nominal value which means that the power fluctuations are compensated by the BESS. As a result, CO_2 emission is lower in this control strategy. In this case, the fuel consumption is 3.5% lower than in the case in which power fluctuations are covered by the BESS and the PV in parallel.

The lifetime of the batteries is expected to be lower when the BESS mainly covers the power fluctuations whereas it is expected to be higher when the fluctuations are covered by the BESS and the PV in parallel.

The performance of the diesel generators is better when the output power of the PV is constant and close to the nominal value which means that the BESS mainly covers the power fluctuations of the grid.

RESULTS AND DISCUSSION

An economical overview is performed by considering the difference in the fuel consumption for each control strategy. The results show that a lower cost of energy is achieved when the power fluctuations are mainly covered by the BESS. The cost of energy for the corresponding control strategy is approximately 1% less compared to the control strategy when the power fluctuations are covered by the BESS and the PV in parallel. However, the cost saving can be higher if the fuel price increases (Fig. 3-8).

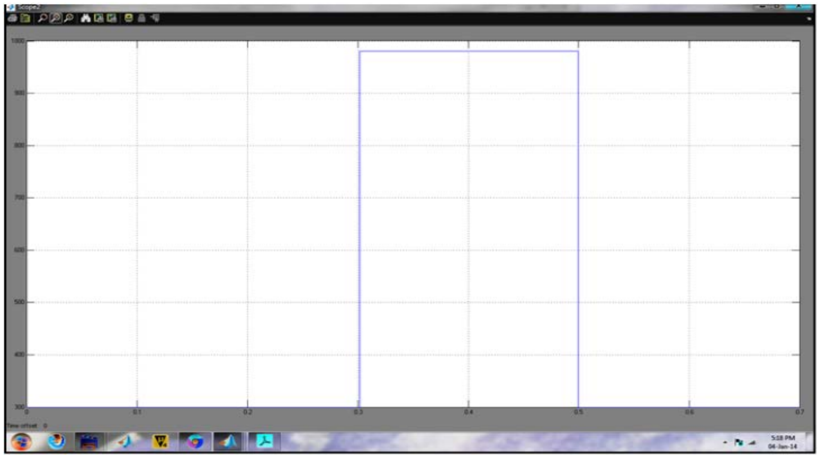

Fig. 3: Irradiance

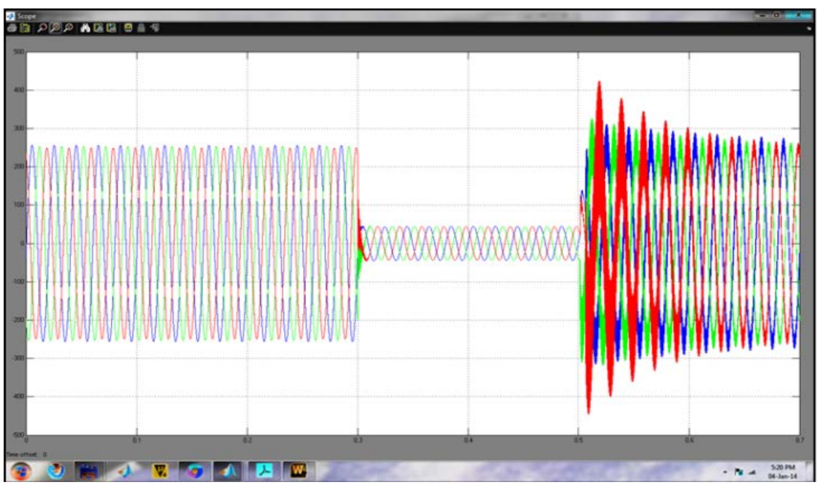

Fig. 4: Simulation results using proposed control approach for micro-grid side voltage

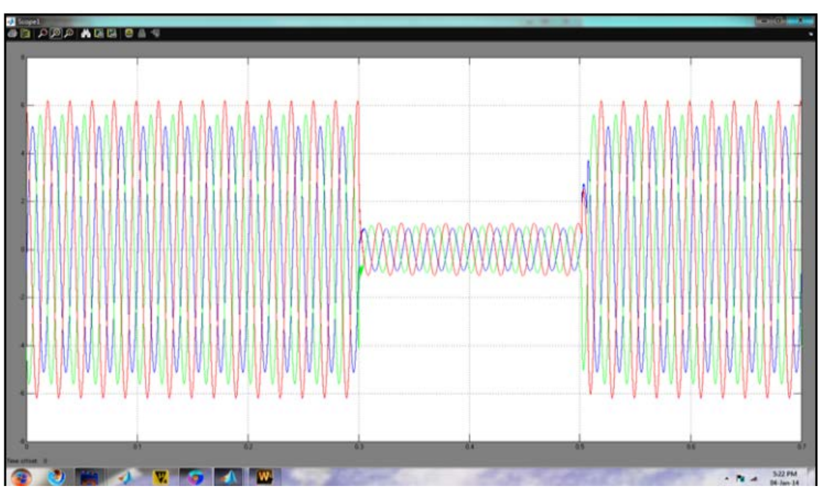

Fig. 5: Simulation results using proposed control approach for micro-grid side current

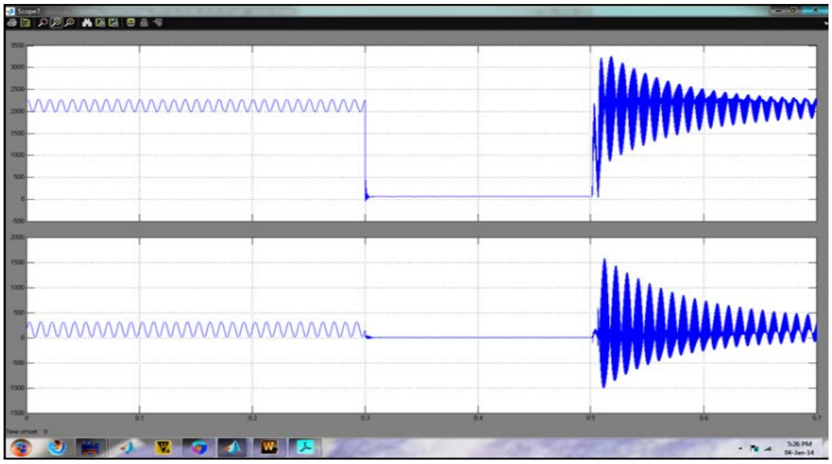

Fig. 6: Active power and reactive power

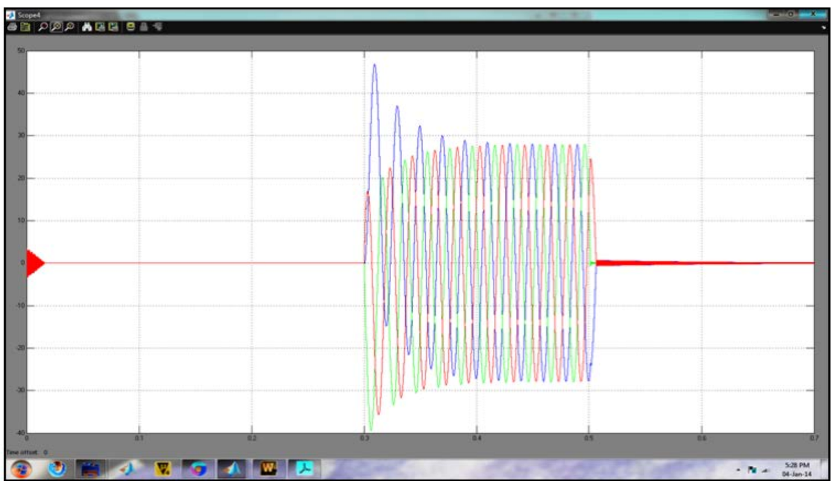

Fig. 7: Inverter currents

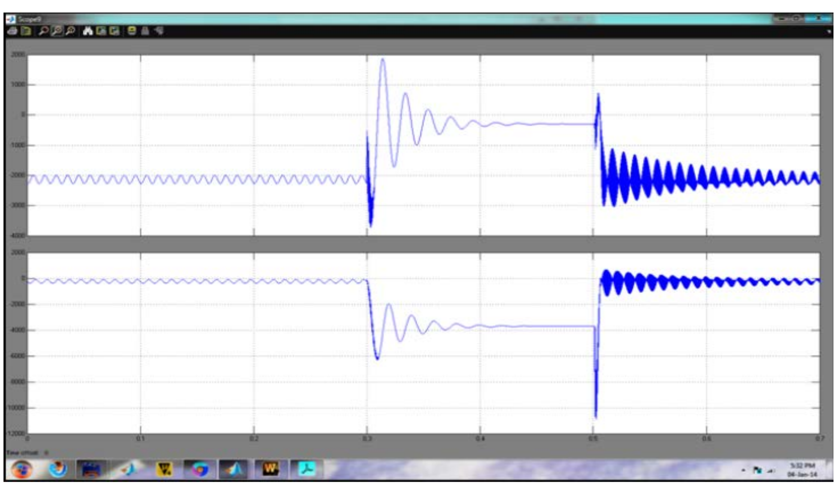

Fig. 8: Grid currents

CONCLUSION

In this study, it is demonstrated that the control strategy in which the primary and secondary control of active power is mainly provided by the BESS, leads to preferable operation of the plant and lower cost of energy compared to the other analyzed control strategies.

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