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A Control Scheme for Integration of Solar Photovoltaic, And Battery Storage Systems in Hybrid Microgrids

Mahdi Mozaffari Legha[1], Mahdi Soleymani[2], Mostafa Soleimani[1]

[1,2,3]Department of Power Engineering, Institute of Higher Education Javid, Jiroft, Iran.

ABSTRACT

In this article, an operation plan and control method is presented for the integration of photovoltaic (PV), battery (BATT) units, and local AC loads in a hybrid micro grid (MG). The presented control method decreases communication problems between the renewable generators, BATT, and loads. Also, the control method consists of maximum power point tracking (MPPT) control for PV units. A MATLAB/SIMULINK simulation is presented to study the MG behavior and to validate the presented control scheme.

Keywords: *solar photovoltaic; battery; maximum power point tracking; micro grid.*

Corresponding author: Mahdi Mozaffari Legha1

INTRODUCTION

Using nonrenewable energy resources is main reason of environmental pollution and global warming. Renewable energy can decrease CO2 emission, and energy demands from the main grid. Nowadays, nonrenewable energies are main energy resources for human activities and will continue to be a main cause of global warming and other environmental problems; therefore, finding renewable and clean energy resources is necessary. The researches are based on either test-beds or simulations using different MG. Also, the researches present different control strategy. It is attempted to summarize the some new researches about integration of renewable energy generators in MG.Aichi MG is designed by Energy and Industrial Technology Development Organization (NEDO). The Aichi MG consists of fuel cells, PV panels, and a BATT. The fuel is a mixture of biogas, high temperature gasified gas, and town gas. Biogas is produced by methane fermentation system treating garbage onsite. The main challenges to increase rate of using renewable energy generators in power systems are technology evolution and control methods for integration of renewable energy generators in smart grids(Keyhani and et al, 2009). Recently, many studies (Katiraei and et al ,2008; Kroposki and et al, 2008; Loix and et al ,2009; Bossi and et al, 2006; Erge and et al ,2006; Moneta and et al, 2009; Mitra and et al, 2008; Barnes and et al, 2005; Morozumi and et al, 2008; Hirose and et al, 2006; Meiqin and et al, 2008; Jiang and et al, 2008;) about integration of renewable energy generators in MG have been studied. Integration of renewable generators in MG is a topic that has been studying and testing around the world (Aghaein and et al, 2013; Kurohane and et al, 2011; Eghtedarpour and et al, 2012; Karabiber and et al, 2013; Choi and et al, 2011; Nairb and et al, 2013). High temperature gasified gas is produced by a high temperature gasification facility treating PET bottles and waste wood on site. The battery converter controls the voltage and balances the generation and demand. A telecommunication network is used as the medium of communication. The AC integration method is used in the Aichi MG project (Morozumi and et al, 2008; Araki and et al, 2009; Shimakage and et al, 2008; Lidula and et al, 2011).

The Hong Kong MG in (Lidula and et al, 2011). is built attached to a single phase system of 230 V, 50 Hz. It integrates PV, wind and battery storage units. Central controlling strategy is used to balance the power generation and demand in the MG. In grid connected mode sources generate constant P-Q and battery converter lets grid following. In island mode the battery converter operates in voltage control mode. Distributed sources

generate fixed P-Q. To prevent battery over charging the battery converter is set to recognize when battery is fully charged. As soon as the grid frequency increases beyond a threshold, the sources are set to limit their output power according to a set active power versus frequency droop. The AC integration concept and centralized control are used in the Hong Kong MG project (Lidula and et al, 2011; Deependras and et al, 2009). Reference (Paska and et al, 2009) presents information about hybrid power systems. The paper presents a DC MG which integrates WT, PV, BATT and fuel cells units.

The smart site scheme based on domestic renewable power generation is presented in (Elnashar, and et al, 2010). Also, the paper presents site scale integration of renewable power generation with presence of PV and WT units. The proposed method can increase the voltage stability and power quality and isolates the consumer from the main grid faults and voltage instabilities. Reference (Deependras and et al, 2009) presents the test-bed consists of PV, WT, fuel cell, battery bank, ultra capacitor bank, conventional generators, and various loads. The AC integration concept, decentralized control, and centralized control are used in the Hefei University of Technology MG project (Lidula and et al, 2011; Deependras and et al, 2009). A control strategy is presented in [16], for the integration of BATT and PV units in a DC MG. Using one renewable source (PV) in the paper is a weakness

because irradiation condition is variable and it can decrease system efficiency. However, in the control strategy MPPT control is considered.

In this article, an operation plan and control method is presented for the integration of photovoltaic (PV), battery (BATT) units, and local AC loads in a hybrid micro grid (MG). In section II, configuration of the hybrid MG is discussed. The presented control strategies are described in section III. A MATLAB/SIMULINK simulation and results are shown in section IV and finally the conclusion is given in section V.

II. CONFIGURATION OF HYBRID DC/AC MICROGRID

The proposed configuration of the hybrid MG consisting of local AC loads, local utility, PV unit with MPPT and BATT unit is shown in Fig.1. PV unit is connected to DC link through a DC/DC boost converter. BATT unit is connected to DC link through a DC/DC bidirectional buck boost converter. Local utility is connected to DC link through an AC/DC bidirectional converter. Local loads are connected to DC link through an AC/DC converter. According to Fig.1, the power flow in BATT unit and local utility is bidirectional, and in different conditions the direction of power flow can be changed to balance generation and consumption.

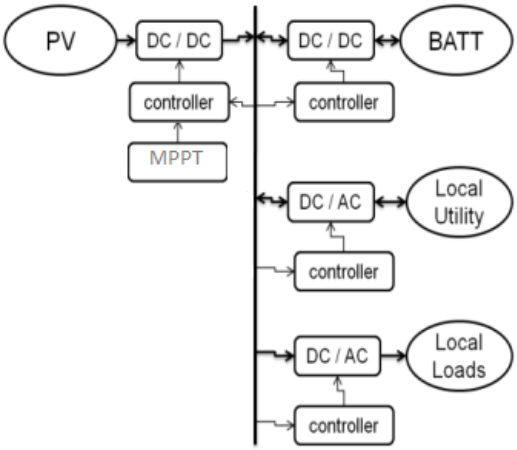

Fig. 1. Configuration of the hybrid micro grid system

In all of the modes, PV work in MPPT and inverter feeds local AC loads. In two modes, the DC MG is not connected to the grid and operates under nominal load condition. Also, in these modes irradiation and wind speed are in normal conditions. The insufficient or surplus power is balanced by discharging or charging of the BATT. The BATT works in charging or off state but the insufficient power is supplied by main grid. In two last modes, the DC bus voltage regulation is controlled by the grid. The MG operates in grid connected and islanding mode. In each of these modes, different operating modes may happen and the control system adjusts the DC bus and local AC loads voltage, frequency, and power oscillations. When load power is less than possible maximum power of the renewable generators, the BATT is fully charged. In order to protect the BATT from over charging the grid should adjust the DC bus voltage. Also, when load power is more than maximum power of the renewable generators in order to avoid DC bus voltage drop and system instability grid should adjust the DC bus voltage by injection of demanded power. Therefore, the controller of the bidirectional DC/AC converter decides to disconnect or connect the MG from/to main grid. In fact, the MG according to condition of generation or consumption of power can work in islanding mode or grid connected mode. In other words, the insufficient or surplus power is balanced by grid or BATT in order to regulate the DC bus voltage respectively in grid connected mode or islanding mode.

III. CONTROL SCHEME

A. The Control Strategy for PV System

For access MPPT and to connect the PV panel to the MG a boost DC / DC converter is used which is illustrated in Fig. 2.

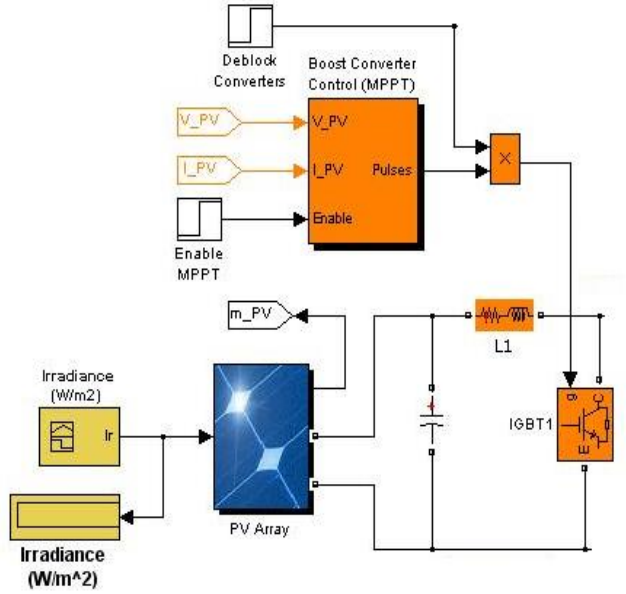

Fig. 2. PV arrays with MPPT to micro grid

The converter for control the PV voltage uses the peak current mode control (PCM) (Eghtedarpour and et al, 2012; Erickson,1997). Block diagram of the control method for PV system is illustrated in Fig. 3. The PCM control has two control loops: voltage and current loops .In the current controller the PV current is compared with its reference value to protect PV against overloading. Reference value for PV current is produced by the voltage loop. In the voltage controller the PV voltage is compared with its reference value to produce reference value for PV current. Reference value for PV voltage is produced by the MPPT controller.

B. The Control Strategy for BATT System

For access most efficiency and to connect the BATT to the MG a bidirectional buck boost DC/DC converter is used which is illustrated in Fig. 3 (Eghtedarpour and et al, 2012; Jiang Wei and et al, 2010). The buck boost converter for control the BATT voltage uses the peak current mode control (PCM) (Erickson ,1997). In the voltage controller the DC bus voltage is compared with its reference value to produce reference value for BATT current. Voltage controller consists of three sections, the dead zone, the compensator, and the limiter. The BATT according to the DC bus voltage level can operate at charging, discharging, or floating modes(Eghtedarpour and et al, 2012).

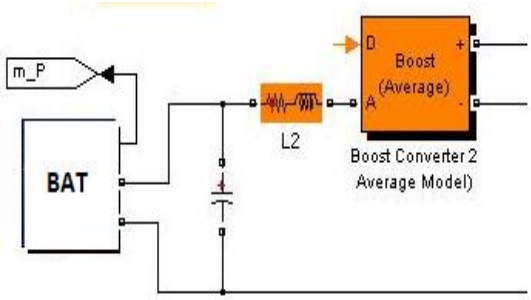

Fig. 3. Battery used to micro grid

C. The Control Strategy for DC/AC Converter System

The power converter system used in this section consists of a three phase PWM voltage inverter with LC output filter and a Δ-Y transformer (Keyhani and et al, 2009). The VSC converter equivalent circuit is illustrated in Fig. 4. The transformer turns a three wire power system of the inverter to a four wire system for the load. Small capacitors are located at the load side to filter more harmonics and regulate the load voltages. A controller system controls the power converter by generation required PWM gating signals. Voltages and currents measured by the controller.

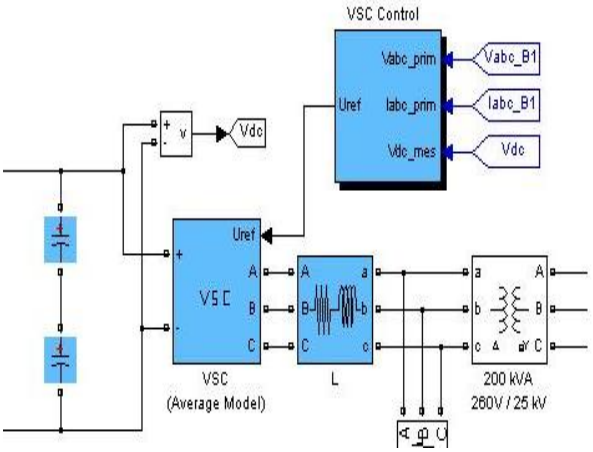

Fig. 4. Power converter system used to micro grid

IV. MATLAB/SIMULINK SIMULATION RESULT

For study the stability of the system and to validate the proposed control strategies a MATLAB/SIMULINK simulation test-bed have been constructed. For this purpose a test operating scenario is simulated. Operations happening during the test are presented in Fig. 5.

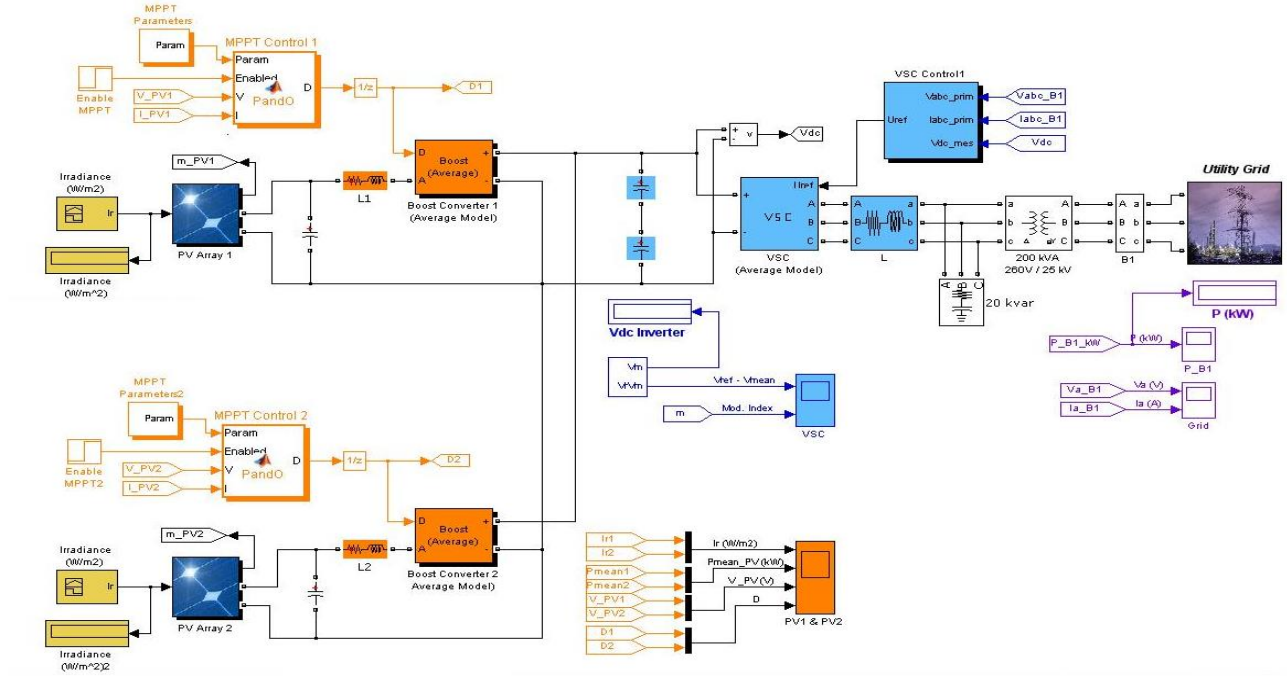

Fig. 5. Simulation test

In this scenario irradiation conditions and load changes are variable. This studies effect of irradiation changes, switch between grid connection mode and island mode and load changes on DC link voltage, battery current and load voltages.

Simulation results are illustrated in Fig. 6. Results show the effective operation of the MG during various conditions.

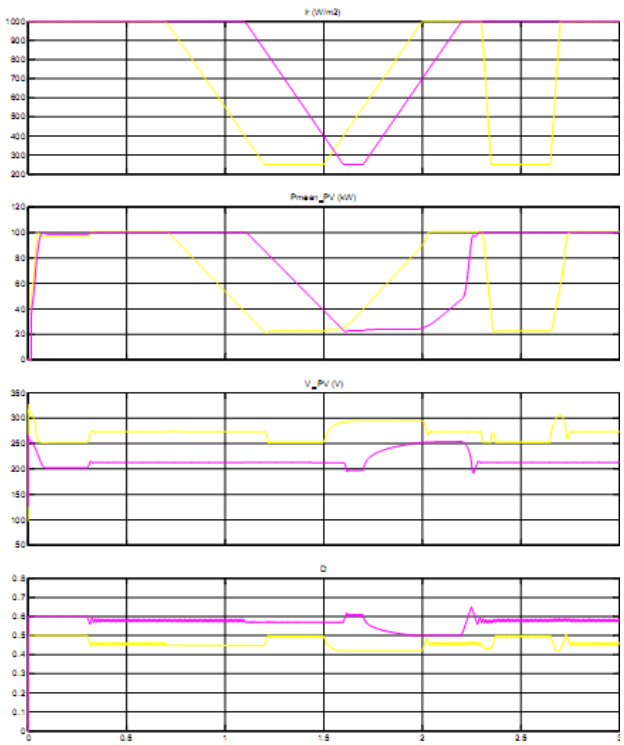

Fig. 6. Results of simulation.

V. CONCLUSION

This paper, presents an an operation plan and control method is presented for the integration of photovoltaic (PV), battery (BATT) units, and local AC loads in a hybrid micro grid (MG). The control schemes presented in this article including the MPPT control for WT and PV systems, and combine discrete time sliding mode current control and robust servomechanism voltage control for inverter (DC/AC), to supply the loads and to adjust voltage, frequency, and power oscillations. A MATLAB/SIMULINK simulation test-bed have been constructed to study the stability of the system and to validate the proposed control strategies. Results show the effective operation of the MG during various conditions, and validate the presented control scheme for integration of renewable generators in MG.

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