

SINGLE-PHASE MICROGRID FOR EFFICIENT POWER BALANCE

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Abstract— Microgrid is interconnected loads and distributed energy resources defined electrical boundaries. That acts as a single controllable with respect to the grid. The proposed single phase microgrid based PCS with double PV array and an energy storage system. Grid-connected inverter and a battery charger are adopted for energy conversion. One array is connected in series then high voltage and delivers AC power fed through a grid-connected inverter. The another array connected in parallel then low voltage and delivers DC power through a battery charger. The separate arrays for different construction lower the power load of the PCS by supplying power directly to the actual load and storage. The power conditioning system on a bidirectional inverter delivers power through grid, load, and storage using the grid-connected mode and island mode. This proposed system is analyzed and simulated using MATLAB/SIMULINK.

IndexTerms— microgrids, photovoltaic systems, power conditioning.

I. INTRODUCTION

In the present situation we are facing so many energy crisis. For power generation use so many energy resources; renewable and non renewable energy resources. But in most widely used in a non renewable energy resources. In future the availability of a non renewable energy resources may be a big problem. The renewable energy resources are widely studied in microgrid networks. Power balancing based on PCS is used to improve the efficiency of a microgrid.

Single-phase microgrid based PCS with double photovoltaic array and an energy storage system is proposed. A grid-connected inverter and battery charger used in energy conversion from the two arrays of operation. One array connected in series for high voltage and supplied AC power deliver through a grid-connected inverter. The other array is connected in parallel for low voltage and provides DC power through a battery charger. These separate arrays for different construction lower the power load of the power conditioning system provide power directly to the actual load and storage. The PCS based on a bidirectional inverter delivers power among grid, load, and storage using the grid-connected mode and island mode. The performance of the microgrid was verified by simulation of three microgrid operations modes.

II. MICROGRID MODEL IN AUTONOMOUS OPERATION

A typical characteristic on a microgrid is that it can be operated either in grid connected or in islanded (autonomous) mode. Normally, when a microgrid operated in grid connected mode the micro sources act as constant power sources which means that they are controlled to inject the demanded power in to the network. In autonomous mode the micro sources are controlled to supply all the power needed by the local loads then maintaining the voltage and frequency within the allowed limits.

Autonomous operation on a microgrid to be initiated for either of the following two reasons. First because of pre-planned islanding due to maintenance or economical reasons. Depending on the market situation of the owner of a microgrid can choose between autonomous and grid-connected modes. Second of unplanned islanding due to the failure of the main grid caused by a network fault.

In autonomous operation realized by opening the isolating switch (shown in Fig.1) which will be disconnects the microgrid from the main grid. Once the microgrid is isolated the micro sources to the system are responsible for maintaining the voltage and frequency while sharing the power. During the autonomous operation it is important to avoid over-loading of inverters and to confirm that the changes in load are taken by inverters in controlled. Control techniques based in a communication link, such as the master-slave approach, can be adapted in systems where micro sources are connected to a common bus or located. However the communication link makes the system such expensive and less reliable

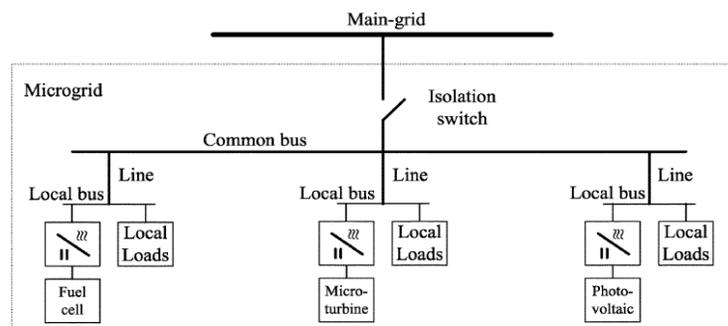


Fig. 1. Typical structure of inverter-based microgrid

III. MICROGRID

A. MICROGRID ARCHITECTURE

The proposed microgrid is composed of two photovoltaic arrays, an energy storage system (ESS), a grid-connected inverter, a battery charger, and a power conditioning system (PCS) which connections are shown in Fig.2. The two arrays are connected to the ESS and load for efficient power balance considering the power limit of the power conditioning system. One array is connected in series for high voltage and delivers AC power through a grid-connected inverter. The other array is connected in parallel for low voltage and delivers DC power through a battery charger. These separate arrays of different construction lower the power load of the power conditioning system by supplying power directly to the actual load and storage.

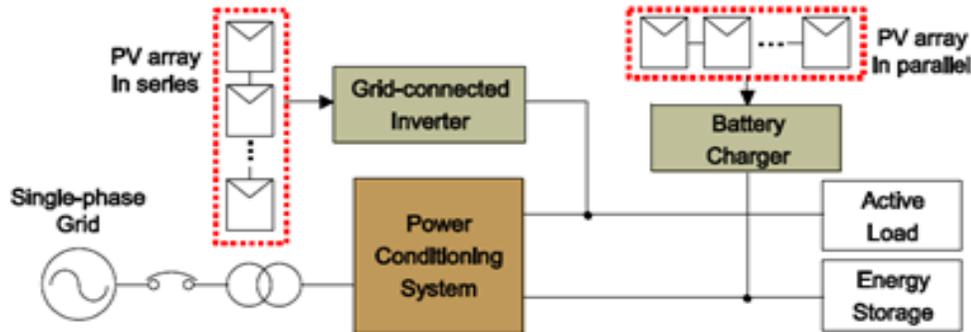


Fig. 2. Single-phase microgrid architecture.

The PCS is connected to the single phase utility grid through a circuit breaker and isolated by the transformer for stability. It is an interface between the utility grid and load. The load cannot catch the variations of the utility grid of the microgrid operations of the PCS. As a result, the microgrid consists of the energy generators by of the photovoltaic array, the energy converters such as the grid-connected inverter and battery charger. The energy storage for storing excess energy and utilizing it effectively and the load which consuming the energy.

B. DUAL PHOTOVOLTAIC ARRAY AND ENERGY CONVERTERS

The series photovoltaic array, generating 10 kW from 12 series and 3 parallel modules of 300 W, is connected on power conditioning system through the grid-connected inverter to make 220 Vrms AC voltage. The Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm applied the inverter to determine the reference voltage V_{ref} , and the amount of output current of the inverter is determined by a proportion-integration (PI) control to regulate the array voltage, by comparing the reference voltage V_{ref} and the input voltage V_{pv} of the photovoltaic array. The output current in same phase and output voltage for high power factor. Multiplying the reference output current level and the output voltage. The negative output current is limited to prevent reverse current. Finally the reference output current signal is compared to the output current. Another PI controller used to regulate current. In the controllers $N1$ and $N2$ used to make the input signals.

The power stage of the grid-connected inverter is compose full-bridge inverter including two inductors and four power transistors. The high-voltage MOSFET is used IGBT for the power transistors because of the less voltage requirement to the full bridge structure. The input capacitor C_{in} is 10 mF which is large enough to filter the fluctuation by the AC waves and $L1$ and $L2$ determined as 2.5 mH to limit the output current ripple. The output capacitor is not used because the output voltage V_{pcs} is dominated by the output of PCS. Since the input voltage is high enough to make 220 Vrms, The inverter does not require a prior boost converter or a transformer which has a different turn ratio.

The parallel photovoltaic array, generating 10 Kw of 3 series and 12 parallel modules of 300 W connected to the energy storage on the battery charger to make nominal 50 V DC voltage. The same MPPT algorithm is applied to the reference voltage V_{ref} , and amount of output current of the battery charger is determined by the proportion-integration control to regulate the array voltage, by comparing the reference voltage V_{ref} and the input voltage V_{pv} of the photovoltaic array. The final gate control signal $S1$ by the pulse width modulation.

The power stage of the battery charger has a buck topology which is composed of a diode, a single transistor and an inductor. The MOSFET is used instead IGBT for the power transistors because the input voltage and output voltage are low. The input capacitor C_{in} is 2.5 mF is large enough to filter the large discontinuous current and L is determined as 1 mH to limit the output current ripple. The output capacitor C_{out} and a damping resistor R_d are used and determined as 1 mF and 20 mF, respectively. The DC voltage from photovoltaic array may be converted to another lower DC voltage. But it acts like a current source to the current regulation. Since the input voltage low enough by the parallel construction of the array battery charger does not require the transformer

C. ENERGY STORAGE AND LOAD

The ESS can store and output large amount of electrical energy using a battery. About 40 kWh capacity was designed it was reduced for fast simulation so that 1 hour is Corresponding to 1 second. The energy storage provides the state of charge (SOC) information to the power conditioning system. The information is used to determine the operation mode of the PCS for each operation mode. The battery has a nominal voltage about 50 V. An active load adopting power factor correction of a passive load and consumes maximum 20 Kw considering an office microgrid. It is designed using a fullbridge structure and inductors without input capacitor because the input voltage is dominated by the output voltage of the power conditioning system. In the model, an ideal DC voltage sink is used. The design is similar to the grid-connected inverter but the current direction is reversed. By using the active load instead of a passive load such as resistor, more actual situation is applied to this microgrid architecture and operations.

IV. POWER CONDITIONING SYSTEM

A. MICROGRID OPERATION MODES

Three microgrid operation modes through the PCS are proposed as shown in Fig. 3. The PCS goes into the island mode when grid failed in the protection mode determines mode between grid-connected mode and island mode according to the SOC from the ESS in the auto-island mode, and it minimizes the grid power in the grid-connected mode of the PCS in the zero-energy mode of the microgrid.

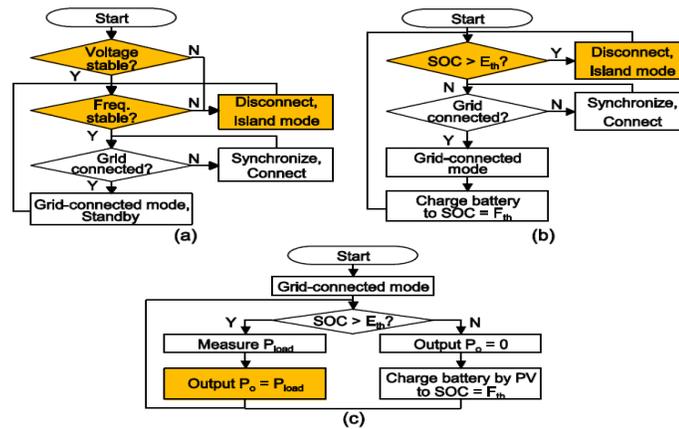


Fig. 3. Flow chart of microgrid operation by power conditioning system: (a) protection mode, (b) auto-island mode, and (c) zero-energy mode.

In the protection mode, The grid voltage is checked it is stable. The frequency is also checked. If one of the two is not normal, the microgrid is disconnected from the utility grid and changes mode the island mode. If the voltage and frequency are normal the microgrid tries to connect to the utility grid. If they are not connected, they become connected with the help of the synchronizer using the slew rate control for smooth connection. If they are connected, the mode is changed to the grid-connected mode and the microgrid becomes standby waiting until the grid is failed.

In auto-island mode, the state-of-charge is checked, first. When the SOC is larger than the lower threshold E_{th} , the microgrid is disconnected and changes mode to the island mode. If it is less than the threshold, it tries to connect to the utility grid. If the microgrid is not connected to the grid, the synchronizer helps the connection. When they are connected, the mode is changed to the grid-connected mode. Then the microgrid charges the battery of the energy storage until the state-of-charge becomes to the upper threshold F_{th} . Finally the microgrid is disconnected from the utility grid and changes the mode to the island mode in the auto-island operation.

In the zero-energy mode, the utility grid is always connected to the microgrid. When the state-of-charge is less than the lower threshold E_{th} , the microgrid stops output power and charge the battery using the series-connected photovoltaic Array until the state-of-charge becomes to the upper limit F_{th} . Otherwise, when the state-of-charge is larger than the lower threshold, the power consumption of the load is measured and the PCS outputs the same amount of power measured from the load. Because of this, the net power from the grid is almost zero

V. SIMULATION RESULTS

The single-phase microgrid adopting the dual photovoltaic array was designed and simulated using the PSIM software. The PCS mode change between the grid-connected mode and island mode for each microgrid operation mode was shown in Fig. 4. In Fig. 4(a) and 4(b), the PCS went into the island mode at the time of the grid failure and at the SOC is equal to 90% by charging, respectively. Then, the PCS went into the grid-connected mode at the grid return and at the SOC is equal to 10% by discharging, respectively. In Fig. 4(c), the PCS supplied power to the load so that the grid current is maintained as nearly zero regardless of amount of load current

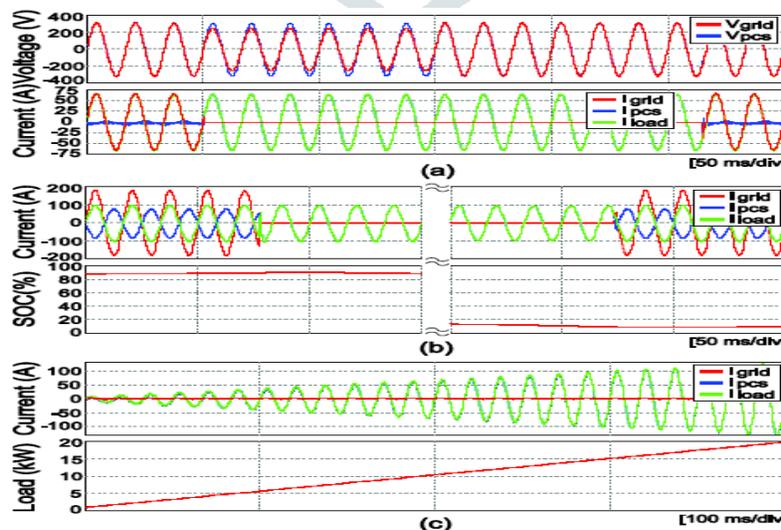


Fig. 4 Simulated waveform of microgrid operation: (a) protect mode, (b) auto-island mode, and (c) zero-energy mode.

VI. CONCLUSION

The single-phase microgrid based on the PCS with dual photovoltaic array was proposed. A grid-connected inverter and battery charger were utilized for the arrays and the stable microgrid operation was verified by the bidirectional PCS changing the mode properly according to the three microgrid operation modes.

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