ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

SINGLE-PHASE MICROGRID FOR EFFICIENT POWER BALANCE BASED ON POWER CONDITIONING SYSTEM

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***Abstract*— This paper proposes a single-phase microgrid based on a power conditioning system with dual photovoltaic array and an energy storage. A grid-connected inverter and battery charger are adopted for energy conversion from the two arrays of different construction. The power conditioning system 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.**

Index Terms — microgrids, photovoltaic systems, power conditioning.

I. INTRODUCTION

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

Microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A single-phase microgrid based a power conditioning system with dual photovoltaic array and an energy storage system is proposed. A grid-connected inverter and battery charger are adopted for energy conversion from the two arrays of different construction. 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. The power conditioning system 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.

II. MICROGRID MODEL IN AUTONOMOUS OPERATION

A typical characteristic of a microgrid is that it can be operated either in grid connected or in islanded (autonomous) mode. Normally, when a microgrid is 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 while maintaining the voltage and frequency within the allowed limits.

Autonomous operation of a microgrid might be initiated for either of the following two reasons. First, because of preplanned (intentional) islanding due to maintenance or economical reasons. Depending on the market situation the owner of a microgrid can chose between autonomous and grid connected modes. Second, because of unplanned (unintentional) islanding due to the failure of the main grid caused by a network fault.

Autonomous operation is realized by opening the isolating switch (shown in Fig. 1) which disconnects the microgrid from the main grid. Once the microgrid is isolated the micro sources feeding the system are responsible for maintaining the voltage and frequency while sharing the power. During autonomous operation it is important to avoid over-loading of inverters and to ensure that the changes in load are taken by inverters in a well controlled manner. Control techniques based on 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 in close proximity. However, a communication link makes the system more expensive and less reliable

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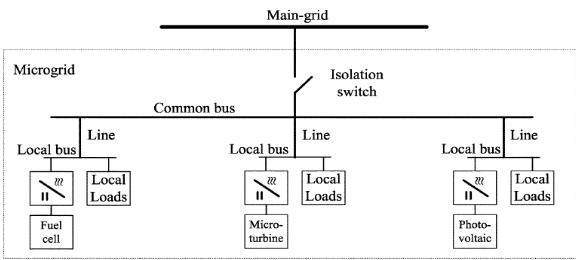

Fig. 1. Typical structure of inverter-based microgrid

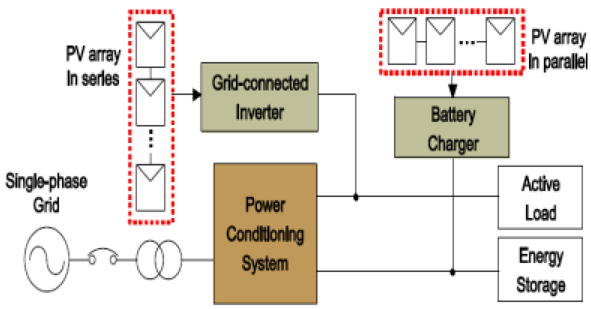

Fig. 2. Single-phase microgrid architecture.

III. MICROGRID

A. Microgrid Architecture

The proposed microgrid is composed of two photovoltaic arrays, a grid-connected inverter, a battery charger, an energy storage system (ESS), and a power conditioning system (PCS) which is capable of the grid-connected or stand-alone operation, as shown in Fig. 2. The two arrays are connected to the load and ESS, respectively, 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. While, 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.

The power conditioning system is connected to the singlephase 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 by the microgrid operations of the power conditioning system. As a result, the microgrid consists of the energy generators by 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 to the 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 is applied to the inverter to determine the reference voltage Vref, and 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 Vref and the input voltage Vpv of the photovoltaic array. The output current is in the same phase of the output voltage for high power factor, by 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 is used to regulate the current. In the controller, $N1$ and $N2$ are used to make the input signals such as voltage and current to be represented using the percent unit. The final gate control signals $S1$ and $S2$ are generated by the pulse width modulation (PWM).

The power stage of the grid-connected inverter is composed of the full-bridge inverter including four power transistors and two inductors. The high-voltage MOSFET is used instead of the IGBT for the power transistors because of the less voltage requirement owing to the full bridge structure. The input capacitor Cin is 10 mF which is large enough to filter the fluctuation by the AC waves and $L1$ and $L2$ are determined as 2.5 mH to limit the output current ripple. The output capacitor is not used because the output voltage Vpcs is dominated by the output of power conditioning system. The DC voltage from the photovoltaic array is inverted to the AC voltage. 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.

While, the parallel photovoltaic array, generating 10 Kw from 3 series and 12 parallel modules of 300 W, is connected to the energy storage through the battery charger to make nominal 50 V DC voltage. The same MPPT algorithm is applied to the charger to make the reference voltage Vref, 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 Vref and the input voltage Vpv of the photovoltaic array. In the controller, $N1$ is also used to make the input voltage signal to be represented using the percent unit. The final gate control signal $S1$ is generated by the pulse width modulation.

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

C .Energy Storage and Load

The ESS can store and output large amount of electricalenergy using a battery. About 40 kWh capacity was designed but 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 power conditioning system for each microgrid operation mode. The battery has a nominal voltage about 50 V. An active load adopting power factor correction is used instead 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. Christo Ananth et al.[4] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

IV. POWER CONDITIONING SYSTEM

Microgrid Operation Modes

Three microgrid operation modes though the PCS are proposed as shown in Fig. 3. The PCS goes into the island mode when the grid is failed in the protection mode, it 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.

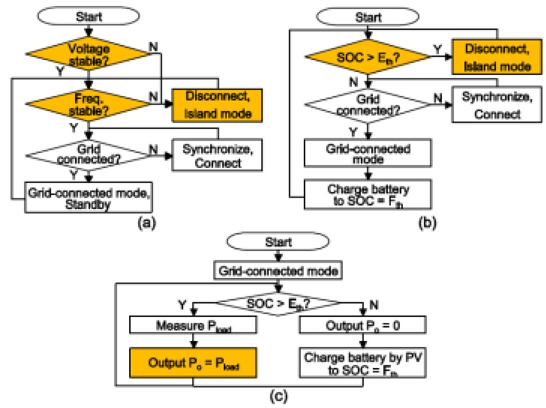

Fig. 3. Flow chart of microgrid operation by power conditioningsystem: (a) protection mode, (b) auto-island mode, and (c) zero-energy mode.

In the protection mode, the utility grid voltage is checked whether 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 to 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 for 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

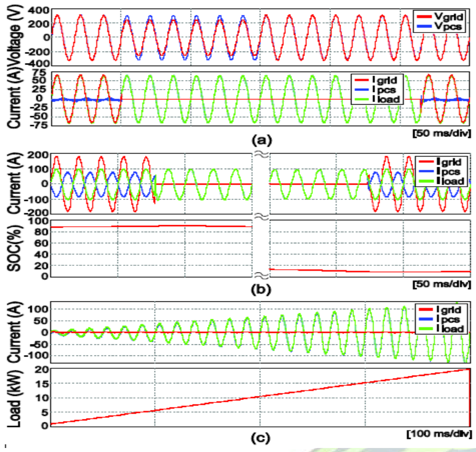

Fig. 4. Simulated waveform of microgrid operation: (a) protect mode, (b) auto-island mode, and (c) zero-energy mode.

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

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.

REFERENCES

[1] Single-phase Microgrid with Dual Photovoltaic Array for Efficient Power Balance based on Power Conditioning System Sewan Heo, Wan-Ki Park, and Ilwoo Lee Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea ©2016 IEEE

[2] P. Basak et al., "A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid," Renewable and Sustainable Energy *Reviews*, vol. 16, no. 8, pp. 5545-5556, 2012

[3] A. G. Tsikalakis et al., "Centralized Control for Optimizing Microgrids Operation," Power and Energy Society General *Meeting*, 2011, p. 1.

[4] Christo Ananth, W.Stalin Jacob, P.Jenifer Darling Rosita. "A Brief Outline On ELECTRONIC DEVICES & CIRCUITS.", ACES Publishers, Tirunelveli, India, ISBN: 978-81-910-747-7-2, Volume 3,April 2016, pp:1-300.

[5] N. Pogaku et al., "Modeling, Analysis and Testing of Autonomous Operation of an Inverter-Based Microgrid," *IEEE Trans. Power Electronics*, vol. 22, no. 2, pp. 613-625, 2007.

[6] S. Dasgupta et al., "Single-Phase Inverter Control Techniques for Interfacing Renewable Energy Sources With Microgrid," *IEEE Trans. Power Electronics*, vol. 26, no. 3, pp. 717-731, 2011.

[7] R. M. S. Filho et al., "Comparison of Three Single-Phase PLL Algorithms for UPS Applications," *IEEE Trans. Industrial Electronics*, vol. 55, no. 8, pp. 2923-2932, 2008.