ENERGY STORAGE SYSTEM CONTROL STRATEGY TO MINIMIZE THE VOLTAGE AND FREQUENCY FLUCTUATION IN THE MICROGIRD

Qin Lei, Yunpeng Si and Yifu Liu
Electrical, Computer and Energy Engineering
Arizona State University
Tempe, USA
Qin.Lei@asu.edu, yunpengs@asu.edu, yliu457@asu.edu

***Abstract*—The goal of this paper is to solve the voltage and frequency fluctuation problem of microgrid in the standalone operation. The proposed main idea is to use super capacitor to prevent large voltage and frequency fluctuation during the transient and use the battery to maintain the long-term voltage and frequency stability. The control strategies for the renewable energy sources, storage system, load and power quality improvements devices in three different operation modes "grid-connected", "standalone ", and "transient of islanding and reconnection" have been proposed. A sample microgrid system is used to verify the effectiveness of the control strategies.**

Keywords—Energy storage; Microgrid; fluctuation limitation;

I. INTRODUCTION

Compared to large grid the microgrid has a small short circuit capacity and a small inertial. Therefore, when the microgrid is operating at stand-alone mode, the bus voltage has a big fluctuation at the moment of (1) a large load is switched on or switched off; (2) a large source power has a sudden change due to the weather or time; (3) A reconnection of the load or source after a short period of disconnection; (4) hard-start of the large load such as big induction machine or compressor. If the microgrid has no extra energy storage system, the total source power is limited by the maximum power rating of the source and the inverter. The semiconductor-based inverter doesn't have much over-current capability. Therefore, when one big load is switched off, the bus voltage will go high in a big slope. Oppositely, when one big load is switched on, the bus voltage will go low in a big slope. Similarly, those voltage fluctuations happen when the source power has a sudden change due to the weather. If the voltage change slope is very sharp, its effect is similar to the phase to ground or phase to phase short circuit, which can cause power oscillation and can destabilize the system. Therefore, the system needs to have energy storage system to compensate for the voltage fluctuation. In the energy storage device, battery has high energy density but can't react fast enough to pulse current requirement; the super capacitor has low energy density but can provide large transient power. So the best way to flatten the voltage fluctuation is to use hybrid battery and super-capacitor storage system. In addition, when the microgrid is operating in the grid-connected mode, the usage of a large amount of power electronics devices and the large output power fluctuation of the renewable energy sources brings the main-grid significant harmonics. Therefore, the Active Power Filter (APF) and the Var Compensator (VAR) need to be used with the other devices as well. The major idea this proposal proposes is to use super capacitor to prevent large voltage and frequency fluctuation during the transient and use the battery to maintain the long-term voltage and frequency stability, when the microgrid is in standalone mode. The major contents include the control strategies for the renewable energy source, storage system, load, APF, VAR and the charging station, in three different operating modes (1) grid-connected mode (2) standalone mode (3) transient of islanding and reconnection, to overcome to voltage fluctuation problem in standalone mode and the power quality problem in the grid-connected mode. The approach the paper adopts is to simulate the sample microgrid test system as shown in Fig. 1 using

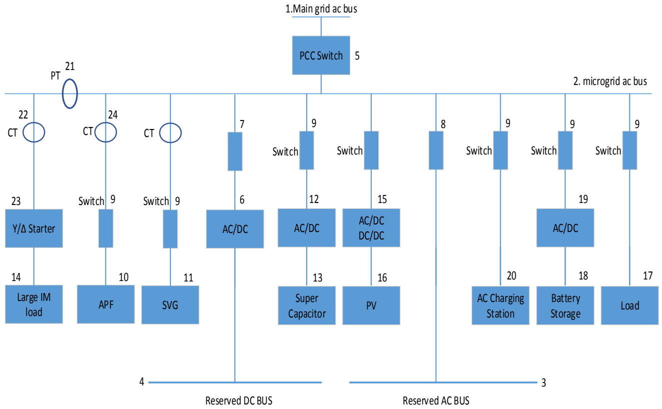

Fig.1. Proposed microgrid test system

978-1-5386-1180-7/18/$31.00 ©2018 IEEE

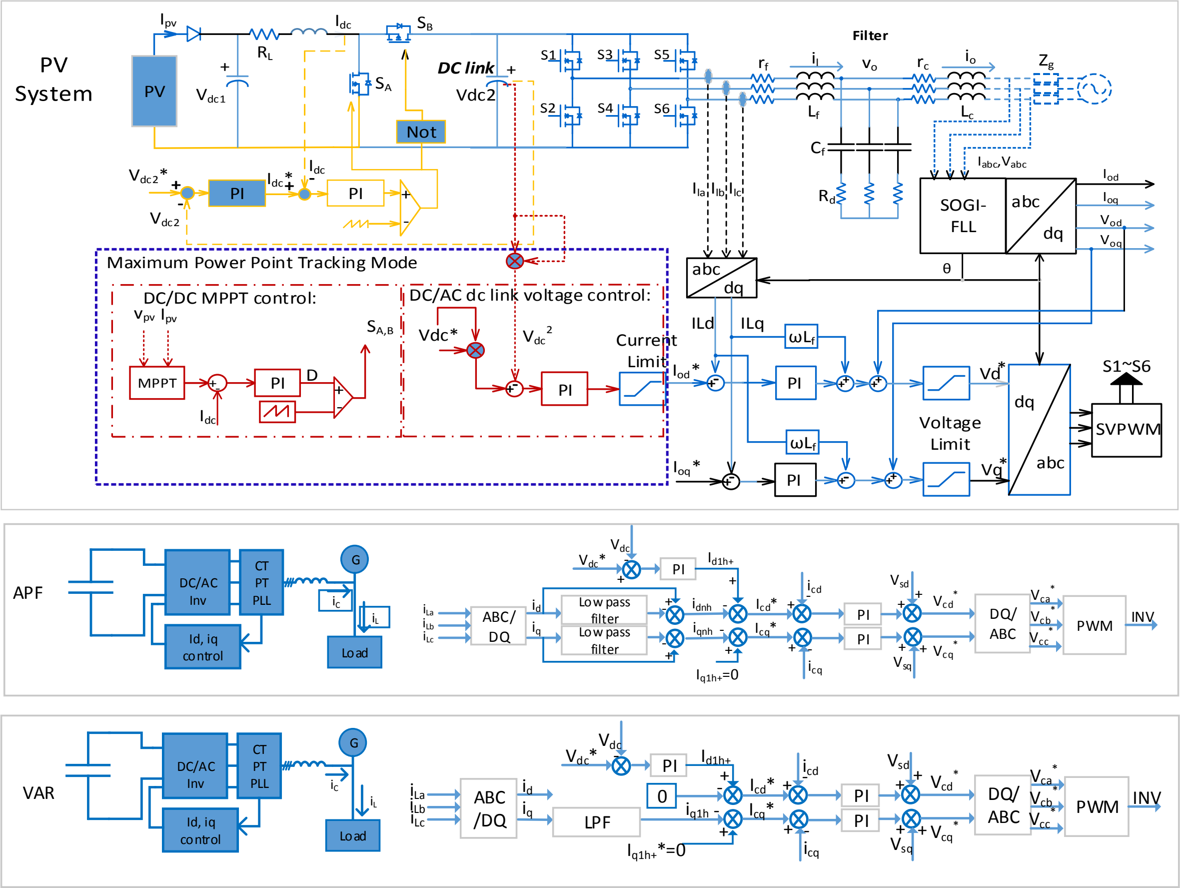

Fig. 2. PV, APF and SVG control for microgrid with no energy storage system operating in grid-connected

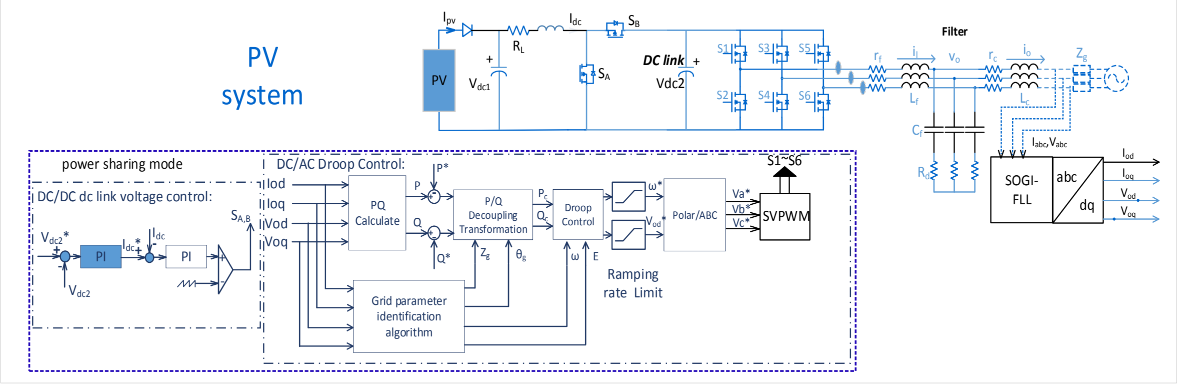

Fig. 3. PV system control for microgrid with no energy storage system operating in standalone

PLECS software and the OPAL-RT real time simulator to demonstrate the proposed control strategy.

II. SYSTEM CONTROL STRATEGIES

A. System without energy storage at grid-connected and standalone modes

In grid-connected mode, all the renewables, the APF and the SVG are controlled as the current source and work at Maximum Power Point Tracking (MPPT) mode, as shown in Fig. 2.

In standalone mode, the single PV in Fig. 1 is controlled as a voltage source in the droop manner, with the current limit. The APF and SVG are doing the same thing as in the grid-connected mode. The control diagram for the PV system is

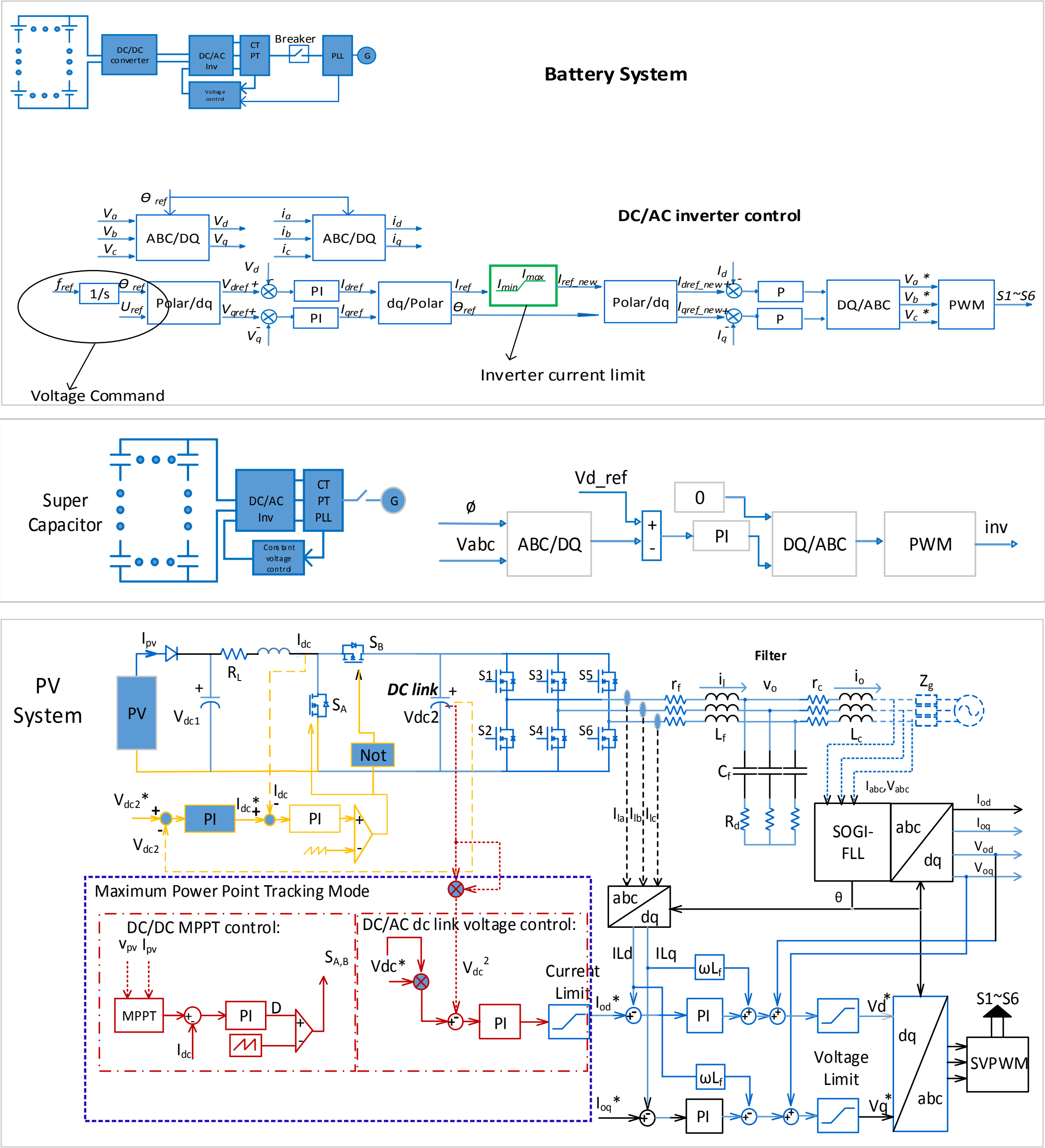

Fig. 4. Super Capacitor, battery, PV control for microgrid standalone mode

shown in Fig. 3. The control diagram for APF and VAR are the same as Fig. 2.

B. System with energy storage at grid-connected and standalone modes

In standalone mode, the super capacitor and the battery both are controlled as the master voltage source, but the renewables, APF and SVG are all controlled as a current source, to follow the voltage of the energy storage system. In this way, the bus voltage fluctuation caused by load sudden change can be significantly reduced.

In standalone mode, the coordination between battery and super capacitor is implemented by setting a current limit for the inverter of the battery system. Because of this current limit, the excessive transient current can't be produced by the battery system, and only the super capacitor is responding to the

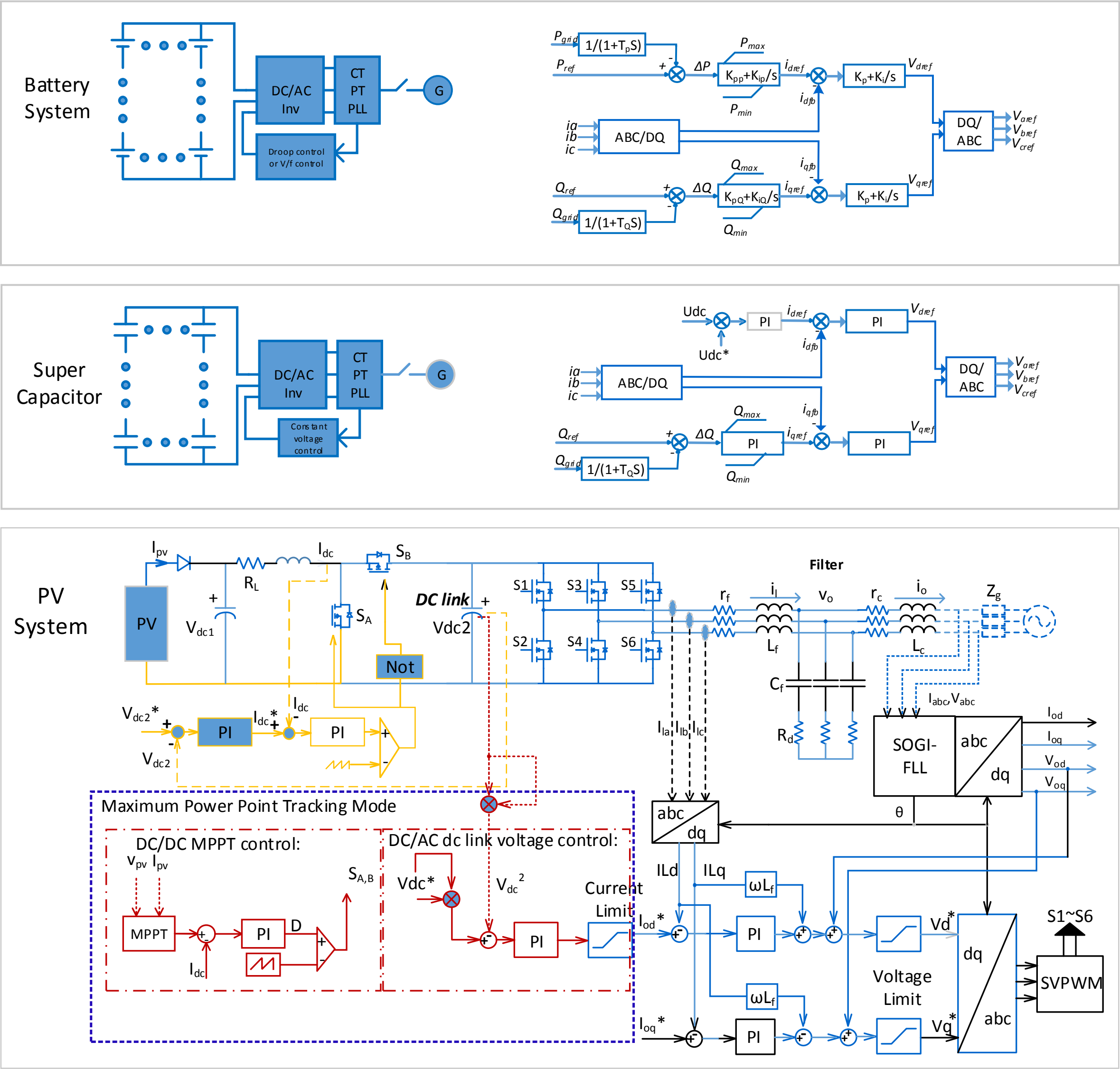

Fig. 5. Super Capacitor, battery, PV control for microgrid grid-connected mode

transient. This also takes advantage of the "fast dynamic response" feature of the super capacitor system. The control diagram for each component is shown in Fig. 4. The control diagram for APF and SVG are the same as Fig. 2.

In grid-connected mode, PV, APF, VAR, Battery and Super-cap all works at current source mode. PV is under MPPT control; APF and VAR are compensating the harmonics and the var according to the upper-level supervisory command; battery and super-cap are either being charged or providing real and reactive power to the grid, according to their State Of Charge. The control diagram for each component is shown in Fig. 5. The diagram for APF and VAR are the same as Fig. 2.

III. SIMULATION RESULTS

Figure 6 shows simulation results with three inverters connected in series with different power ratings. At time equals to 2s, another branch of load has been added to the network to intentionally simulate grid load change. The first two figures show the per unit value of each inverter. It can be seen that power sharing has been achieved among inverters even after the load change. The two figures to the left bottom show the fluctuation of the grid voltage and frequency. The results show that the fluctuation has been reduced with supervisory control. The right four figures show that the feedback of grid frequency and grid voltage can be maintain within an acceptable range. Additionally, different directions of frequency and grid voltage change have been observed. This is mainly due the principle of supervisory control which adds difference between feedback and reference back to the original reference and send them to the individual inverters:

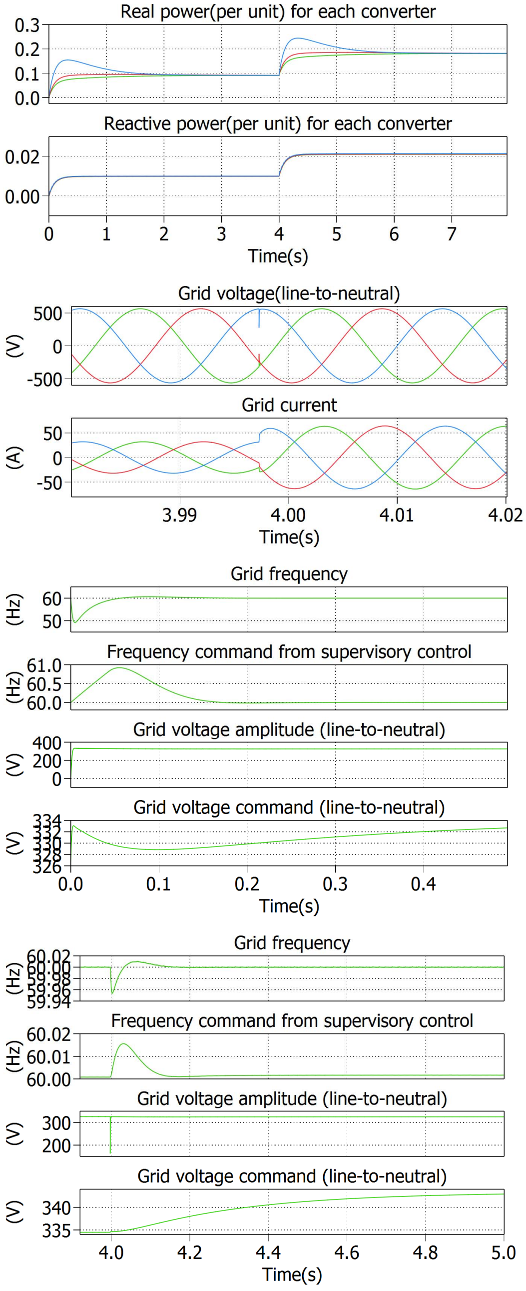

Figure 6. Simulation Results for Paralleled Inverters

Figure 7 shows the simulation results for PV inverter and energy storage combined system. The PV cell is manually controlled to change its output power to create an unbalanced situation between PV sources and the load. In this case, pure resistive load is considered. During some time period, the PV output power is greater than the load power. As a result, the extra energy will be absorbed by energy storage devices in order to maintain a constant bus voltage. During some time period, the PV output power is not sufficient so that the energy storage device will provide the power difference. The first figure shows the DC link current reference for supercapacitors and batteries. The polarity of the current is changing between positive and negative which means the power is flow into and out from the energy storage devices. The lower two figures show the current feedback and reference for supercapacitors and batteries. Since supercapacitors have high power density, they can only take high frequency component current (green line). Batteries have high energy density which indicates they can only take low frequency component current (red line). The control strategy mentioned before has been verified.

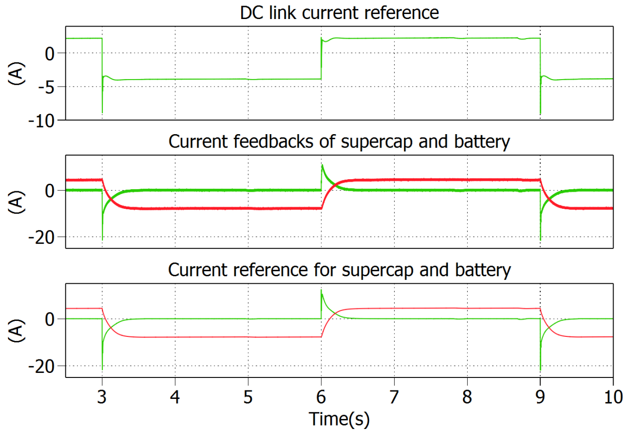

Figure 7. Simulation Results for PV and Energy Storage Combined System

IV. CONCLUSIONS

The objective of this paper is to address the issue of the voltage and frequency fluctuation problem of microgrid in the standalone operation. The proposed approach is to use supercapacitor to prevent large voltage and frequency fluctuation during the transient and use the battery to maintain the long term voltage and frequency stability. The control strategies for the renewable energy sources, storage system, load and power quality improvements devices in three different operation modes "grid-connected", "standalone ", and "transient of islanding and reconnection" have been proposed. A simple simulation of three paralleled inverter with different power ratings has been established. The simulation results show that three inverters are able to achieve power sharing under supervisory control. In addition, grid voltage and frequency can be regulated after a sudden load change. Another simulation combining PV inverter with energy storage devices has also been investigated. The results show the promising future of supercapacitors and batteries. They help to stable the bus voltage and current by continuously absorbing and providing power difference between the PV source and the load.

REFERENCE

[1] Mariam, Lubna, Malabika Basu, and Michael F. Conlon. "A review of existing microgrid architectures." Journal of Engineering 2013

[2] Piagi, Paolo, and Robert H. Lasseter. "Autonomous control of microgrids." Power Engineering Society General Meeting, 2006. IEEE.

[3] “Advanced control for onsite energy optimization”, Siemens.

[4] “ Microgrids under perfect control, Controlling and monitoring microgrids in a reliable, cost-optimized, and environmentally friendly manner with the SICAM Microgrid Manager”, Siemens.

[5] “ Advanced Microgrid Management System, Spectrum PowerTM MGMS”, Siemens.

[6] “U90Plus, Microgrid Generation Optimization”, GE digital energy