AN ISLANDED MODE PV-BATTERY BASED MICRO GRID CONTROL AND POWER MANAGEMENT SCHEME

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ABSTRACT
Electric power professionals have been motivated to create sustainable ways of power generation by the steadily rising demand for energy and worries about environmental damage. Distributed generation using renewable resources like solar energy is thought to offer a practical way to lessen reliance on traditional power generation while improving the quality and reliability of power systems. Due to its attributes, such as their propensity for producing clean energy from the sun and their availability, photovoltaic (PV) systems have emerged as one of the most promising renewable production technologies. In photovoltaic (PV) systems, battery storage is often used to reduce power oscillations brought on by the nature of PV panels and solar irradiation. Control schemes for PV-battery systems must be able to stabilize the bus voltages as well as to control the power flexibly. This paper proposes a comprehensive control and power management system (CAPMS) for PV-battery-based micro grid with both AC and DC buses in islanded mode. CAPMS is a centralized control system that flexibly and effectively controls power flows among the power sources and loads. CAPMS operates effectively irrespective of fluctuations in irradiance, temperature and change in loads. CAPMS ensures a reliable power supply to the system when PV power fluctuates due to unstable irradiance. CAPMS regulates DC and AC bus voltages and frequency, controlling the voltage and power of each unit flexibly, and balancing the power flows in the system automatically under different operating circumstances, regardless of fluctuations of irradiance and temperature, and change of load.
Keywords: Comprehensive control and power management system (CAPMS), Solar PV System, PV array, Control and Power Management System and Micro Grid.

INTRODUCTION
A micro grid is a collection of interconnected loads and dispersed energy sources that operates as a single, controlled entity in relation to the grid and is contained within well defined electrical limits. In order to function in both grid-connected and island mode, a micro grid may connect to and disengage from the grid. A micro grid needs a generation source in order to satisfy the needs of its consumers for power. As micro grids are a more recent idea, the electricity they get has often come from "behind the meter" fossil fuel sources, such as gas-powered generators. Nevertheless, many of the micro grids being constructed today are solar-powered due to the declining cost of solar energy as well as the environmental advantages of doing supply electricity with a combination of solar plus battery storage. A software-based system, the controller can manage energy supply in many different ways. But here’s one example. An advanced controller can track real-time changes in the power prices on the central grid. (Wholesale electricity prices fluctuate constantly based on electricity supply and demand.) If energy prices are inexpensive at any point, it may choose to buy power from the central grid to serve its customers, rather than use energy from, say, its own solar panels. The micro grid solar panels could instead charge its battery systems. Later in the day, when grid power becomes expensive, the micro grid may discharge its batteries rather than use grid power. PV array is interfaced with the DC bus by a DC/DC boost converter. Battery bank uses a bidirectional

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DC/DC converter to control the changing and discharging processes. A centralized inverter is installed to interconnect the DC and AC networks. DC load block generally represents the loads that are connecting at the DC bus, which can be multiple types of loads. Depending on the PV output power ,state of charge and power limit of battery , AC loads, CAPMS decides the operation modes of PV array & battery (charging, discharge mode) & provides proper reference values to controllers. CAPMS select specific control schemes to be applied tothe converters to ensure a reliably power environment.

PV SYSTEM

A photovoltaic (PV) system is composed of one or more solar panels combined with an inverter, electrical and mechanical hardware that use energy from the Sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. Although PV systems can operate bythemselves as off-grid PV systems, this article focuses on systems connected to the utility grid, or grid-tied PV systems. The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount ofenergy, but can be linked together with other panels to produce higher amounts of energy as a solar array. The electricity produced from a solar panel (or array) is in the form of direct current (DC). It must first be converted from DC to AC using an inverter.This AC electricity from the inverter can then be used to power electronics locally, or besent on to the electrical grid for use.

Figure.1. Residential grid-tied solar PV system diagram

Hybrid system

Hybrid system tries to combine multiple sources of power to maximize availability of power. It may source energy from sun, wind or diesel generator and back it up with battery. Multiple sources of generation allows for complementary sources and backup. For instance, when it is sunny out the PV array will charge the battery; if it is cloudy and windy, a wind turbine can charge the batteries Array size and battery bank capacity can typically be reduced and not having to oversize for periods of no sun More complex system design and installation Multiple power sources can increase upfront expenses Wind turbines and generators require regular maintenance.

Types of battery

Basically, all the electrochemical cells and batteries are classified into two types: Primary (non-rechargeable) Secondary (rechargeable) Even though there are several other classifications within these two types of batteries; these two are the basic types. Simply speaking, Primary Batteries are non-rechargeable batteries i.e., they cannot be recharged electrically while the Secondary Batteries are rechargeable batteries i.e., theycan be recharged electrically.

Common Primary Battery Types

Up until the 1970’s, Zinc anode-based batteries were the predominant primary battery types. During the

1940's, the World War II and after the war, Zinc – Carbon based batteries and they have an average capacity of 50 Wh / kg. Most significant development in the battery technology took place during the period 1970 – 1990. It is during this time, the famous Zinc / Alkaline Manganese Dioxide batteries were developed and they slowly replaced the older Zinc – Carbon types as the main primary battery. Zinc – Mercuric Oxide and Cadmium – Mercuric Oxide batteries were also used during this period but due to the environmental concerns with respect to the usage of Mercury, these battery types slowly phased out. It is during this period, where the development of batteries with Lithium as active anode material has been started and is considered a major accomplishment due to the high specific energy and longer shelf life of Lithium batteries over traditional Zinc batteries. Lithium batteries are manufactured as button and coin cell for a specific range of applications (like watches, memory backup, etc.) while larger cylindrical type batteries are also available.

Common Secondary Battery Types

Two of the oldest batteries are in fact secondary batteries called the Lead – Acid Batteries, which were developed in late 1850's and Nickel – Cadmium Batteries, which were developed in early 1900's. Until recent times, there are only two types of secondary batteries. The first and the most commonly used rechargeable batteries are called Lead – Acid Batteries. They are based on the Lead – Lead Dioxide (Pb – PbO2) electrochemical couple. The electrolyte used in these types of batteries is the very common Sulfuric Acid. The second type of the rechargeable batteries is called Nickel –Cadmium Batteries. They are based on Nickel Ox hydroxide (Nickel Oxide) as the positive electrode and Cadmium metal based negative electrode. Coming to the electrolyte, an alkaline solution of Potassium Hydroxide is used. In the recent decades, two new types of rechargeable batteries have emerged. They are the Nickel – Metal Hydride Battery and the Lithium – Ion Battery. Of these two, the lithium – ion battery came out to be a game changer and became commercially superior with its high specific energy and energy density figures (150 Wh / kg and 400 Wh / L).There are some other types of Secondary Batteries but the four major types are: Lead – Acid Batteries Nickel – Cadmium Batteries Nickel – Metal Hydride Batteries• Lithium-ion (Li-ion) • Lithium-polymer (Li-poly) • Zinc-air.

NICKEL-METAL HYDRIDE

NiMH is an extension of the NiCd technology and offers an improvement in energy density over that in NiCd. The major construction difference is that the anode is made of a metal hydride. This eliminates the environmental concerns of cadmium. Another performance improvement is that it has a negligible memory effect. NiMH, however, is less capable of delivering high peak power, has a high self-discharge rate, and is susceptible to damage due to overcharging. Compared to NiCd, NiMH is expensive at present, although the price is expected to drop significantly in the future. This expectation is based on current development programs targeted for large scale application of this technology in electric vehicles.

LITHIUM-ION

The Li-ion technology is a new development, which offers three times the energy density over that of Pb-acid. Such a large improvement in energy density comes from lithium's low atomic weight of 6.9 vs. 207 for lead. Moreover, Li-ion has a higher cell
voltage, 3.5 V vs. 2.0 V for Pb-acid and 1.2 V for other electro chemistries. This
requires fewer cells in series for a given battery voltage, thus reducing the manufacturing cost. On the negative side, the lithium electrode reacts with any liquid electrolyte, creating a sort of passivation film. Every time the cell is discharged and then charged, the lithium is stripped away, a free metal surface is

exposed to the electrolyte, and a new film is formed. This is compensated for by using thick electrodes or else the battery life would be shortened. For this reason, Li-ion is more expensive than NiCd. In operation, the Li-ion electrochemistry is vulnerable to damage from overcharging or other shortcomings in battery management. Therefore, it requires more elaborate charging circuitry with adequate protection against overcharging.

Boost DC/DC Converter

A boost converter (dc-dc) is shown in Figure. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is usedin series with the load. Switch, S (i.e., the device) is put ON (or turned ON) during the period, $T_{ON} \geq t \geq 0$, the ON period being T_{ON} . The output voltage is zero ($v_o = 0$
), if no battery (back emf) is connected in series with the load, and also as stated earlier, the load inductance is small. The value of current increases linearly with time in this interval, with (di/dt) being positive. As the current through L increases, the polarity of the induced emf is taken as say, positive, the left hand side of L being Positive.

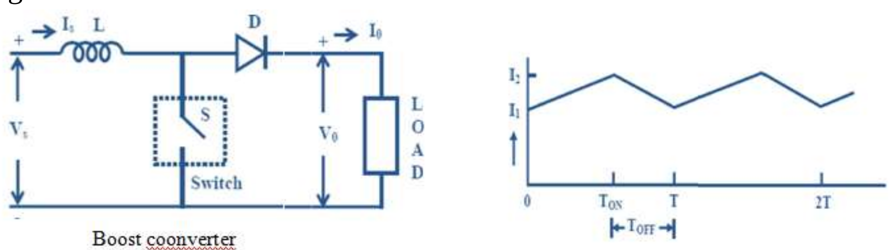

Figure.2. Boost DC/DC converter and its wave form

PWM INVERTER

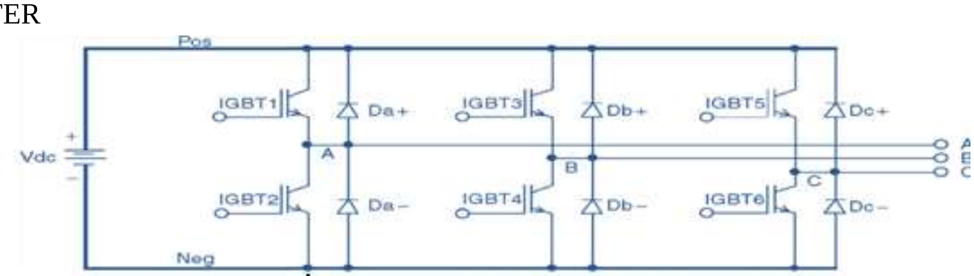

Figure.3. PWM Two Level Inverter

SINUSOIDAL PULSE WIDTH MODULATION:

This control technique is widely used in industrial applications. In this method, the reference signal is a square wave signal. In this method, the reference signal is a sine wave signal.

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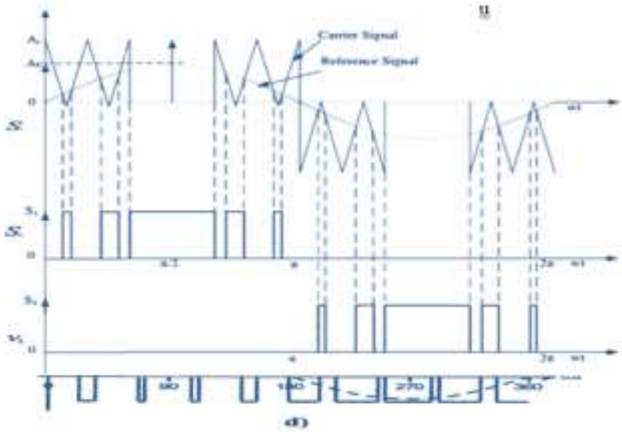

Figure.4. Switching Pulse generation by using SPWM

The gate pulse for the switches is generated by comparing the sine wave reference signal with the triangular carrier wave. The width of each pulse varies with variation of amplitude of the sine wave. The frequency of output waveform is the same as the frequency of the reference signal. The output voltage is a sine wave and the RMS voltage can be controlled by Modulation index.

Paper Implementation steps:

1. In this project PV array is interfaced with the DC bus by a DC/DC boostconverter.
2. Battery bank uses a bidirectional DC/DC converter to control the changing and discharging processes.
3. A centralized inverter is installed to interconnect the DC and AC networks.
4. DC load block generally represents the loads that are connecting at the DC bus, which can be multiple types of loads.
5. Depending on the PV output power, state of charge and power limit of battery, AC loads.
6. CAPMS decides the operation modes of PV array & battery (charging, discharge mode) & provides proper reference values to controllers.
7. CAPMS select specific control schemes to be applied to the converters to ensure a reliably power environment.

Simulation:

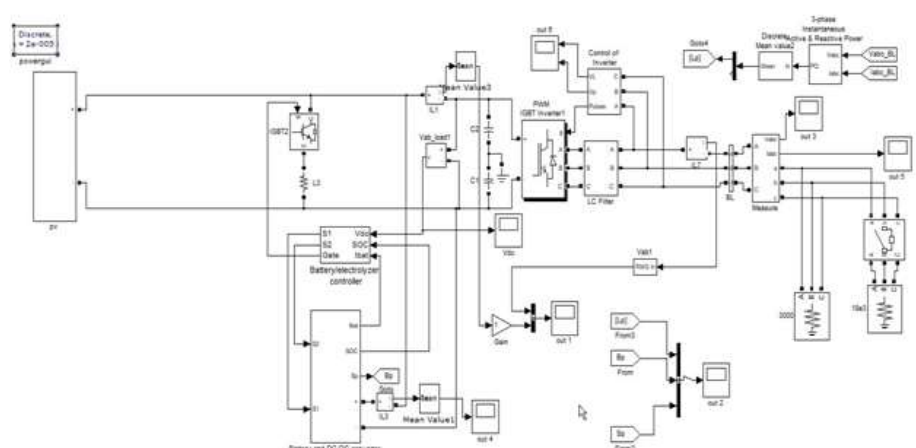

Figure.5. Simulation Block diagram

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Simulation Results:

Case 1:

Initial load: 10000 watts. Extra load: 4000 watts. Battery Specifications: 200V, 2.6.5AH and Nickel-Metal Hydrate Battery.

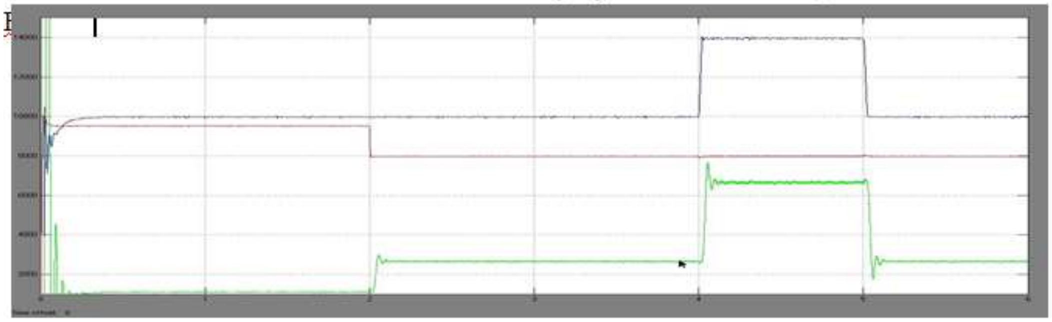

Figure.6. Power Flow of PV –Battery System

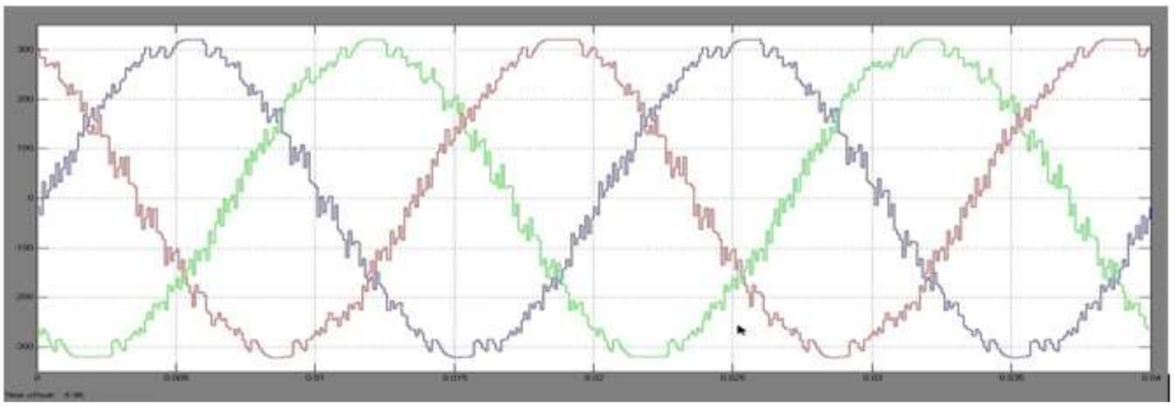

Figure.7. Variation in current waveform

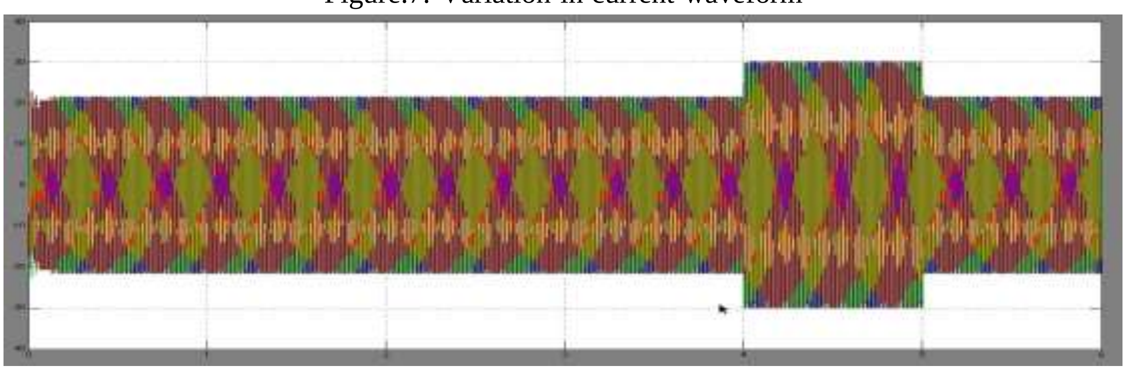

Figure.8. Variation in Voltage waveform

Case 2: (Power flow of PV-battery system when PV input is changed)

Figure.9. Power flow of PV –Battery system

Case-3: (Power flow of PV-battery system when both PV input & load ischanged):

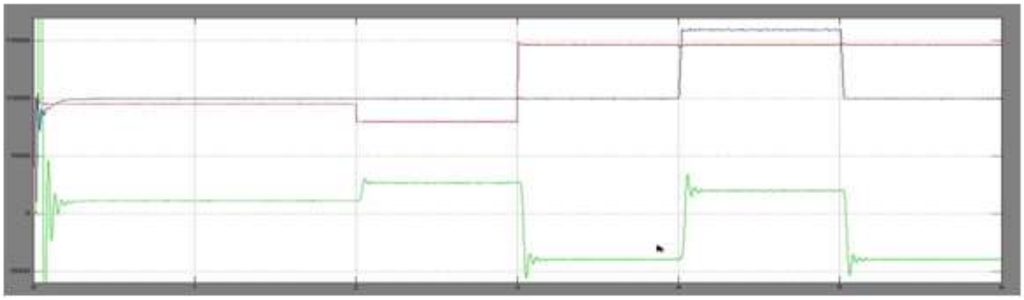

Figure.10. Power Flow of PV-Battery System

Case-4

(Power flow of PV-system when there is change in transition time)

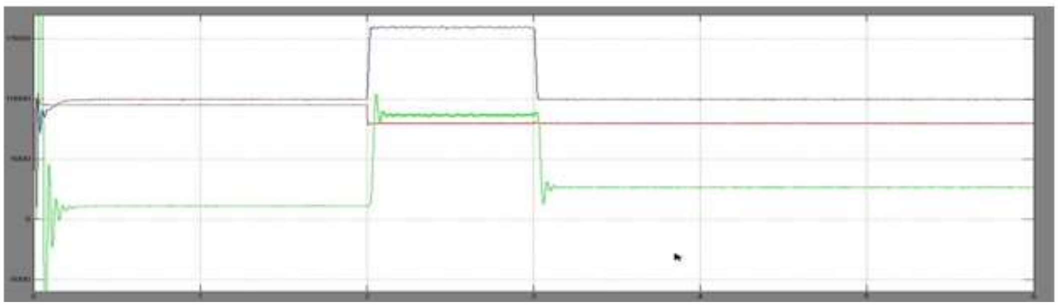

Figure.11. Power Flow of PV-Battery System

CONCLUSION

This paper proposes a control and power management system for PV Battery system with both DC and AC buses in islanded mode. Therefore DC and AC buses are under full control by the CAPMS in islanded mode. The presented CAPMS is able to manage the power flows in converters of all units flexibly and effectively. Furthermore CAPMS ensures a reliable power supply to the system when PV power fluctuations dueto the unstable irradiance or whenever PV array shut downs due to the faults. The CAPMS optimizes the reference values for each unit and sends the PWM (pulse width modulation) signals to the inverter and converter to control the power flow in the hybrid system and voltages of DC and AC buses. Proposed CAPMS employs one of the most popular methods, the incremental conductance, MPPT (maximum power point tracking) under various conditions. This also allows additional loads to access the systems withoutextra converters reducing operational and control costs.

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