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Design and control of renewable power system through wsn in mirogrid

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ABSTRACT
Recently the control of microgrid has been the focus of extensive research due to its flexibility to effectively utilize the micro-sources while ensuring reliability. The microgrid technology is one of the recent developments in the area of electric power systems that aid the use of non-conventional energy sources in parallel with the conventional energy sources. Monitoring and control of microgrid is essential for its efficient and effective functioning. The work presented in this paper is focused on the design, control and development of synchronization between non-conventional energy sources (photovoltaic panel) and conventional energy sources (battery) to satisfy the power demand of the grid by using WSN (wireless sensor networks) technology. The objective of this paper is to propose a prototype to study the performance analysis of power monitoring between photovoltaic panel and battery by sensing parameters like generated power, availability of power reserve etc through WSN (ZigBee). The key simulation and experimental results are included to verify the proper operation and control of microgrid.

KEYWORDS : - *photovoltaic panel, boost converter, DC-AC converter, conventional energy source ZigBee, relay, synchronization, PWM technique, microcontroller.*

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I. INTRODUCTION

Pollution concerns, increasing electricity demand and rising cost of fossil fuel has diverted mankind's attention towards renewable energy. Electricity being an essential need, its reliability and sustainability is a major focus of research. Micro grid is a new promising area of energy sector for local energy generation using renewable energy sources such as PV, wind, fuel cell, micro hydro, biomass, etc., which helps to relieve the stress on conventional generators and transmission lines. Various power circuit configurations in micro grid promise to increase the Reliability of power supply if equipped with sophisticated and suitable control strategies such as power sharing schemes for PV sources in various operating modes.

Over 60 countries around the world have set targets for renewable energy supply. The types of renewable energy include solar, wind, hydrogen, biomass, geothermal, hydropower, and biodiesel. Many of these renewable energy sources are designed to supply energy into the electric power system. Photovoltaic allow the consumers to generate electricity in a clean, reliable and quiet manner. Photovoltaic cells combine to form photovoltaic system.

Usually, a PV system is composed of one or more solar PV panels, an AC/DC power converter (also known as an inverter), and a rack system that holds the solar panels, and the mountings and connections for the other parts. A small PV system can provide energy to a single consumer, or to isolated devices like a lamp or a weather device. Large grid-connected PV systems can provide the energy needed to serve multiple customers. A single individual solar cell has a very low voltage (usually 0.5V). Hence, several cells are wired together in series giving rise to a "laminate". The laminate is then assembled into a protective weatherproof casing, thus creating a photovoltaic module or a solar panel. Modules may be then strung together to form a photovoltaic array. The electricity generated can either be stored, put into direct use (island/standalone plant), fed into a big electricity grid powered essentially by central generation plants (grid-connected/grid-tied plant), or fed into a small grid after combining with one or many domestic electricity generators (hybrid plant). Depending on the application type, the rest of the system known as balance of system or "BOS" consists of several components. The BOS is dependent on the load profile and the type of system. PV energy conversion systems can either be off-grid (stand-alone) or grid-connected. A description of both types of PV systems follows.

Off-Grid PV Energy Systems:

The off-grid PV systems are usually used in rural or remote areas, where the grid is not available or not accessible. The off-grid systems can be further divided into two sub-categories: domestic and non-domestic applications. In the former, the PV system is used to provide electricity for small communities, where connection to the power grid is not feasible. Usually small PV systems (< 5kW) are used for household applications together with an energy storage unit and a backup system. In the latter, the PV system is used to energize a single industrial or agricultural load that is not connected to the grid, such as a water pump, traffic light, or telecommunication equipment. A battery unit is used to store energy. An off-grid PV energy system consists of a solar array connected to a DC/DC converter, a battery bank and an optional DC/AC inverter as shown in Figure 1.2.

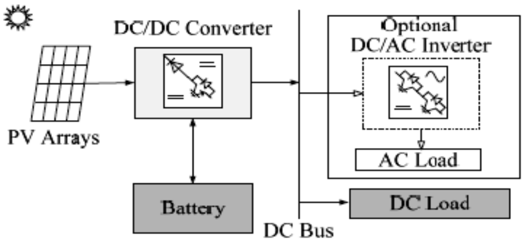

Figure 1.1 Off-grid PV energy conversion system.

Grid-Connected PV System:

Grid-connected PV systems are usually composed of three components: a PV array, a DC/DC converter and a DC/AC inverter as illustrated in Figure 1.3. Grid-connected PV systems are also categorized into two main groups: distributed grid connected applications and centralized grid-connected applications. In distributed applications the PV system is mounted on the premises of a customer who is connected to the grid. The PV system can be connected to the load side of an electricity meter, and the energy generated is used by the customer load. Any energy surplus can be delivered to the grid or vice versa. This method is called Net Metering. Another method to consider is the PV energy system as a distributed generator (DG), which is connected directly to the grid with a separate meter.

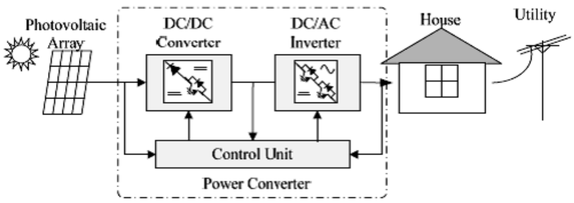

Figure 1.2 Grid-connected PV system.

In order to meet the electricity demand of the grid continuously we need to use the conventional energy source for example battery in parallel with the photovoltaic panel because of the unavailability of sunlight during night times and changes in climatic conditions. The power supply either from the photovoltaic panel is from the battery takes place by switching. This switching needs complete synchronism between photovoltaic panel and battery. An economic and reliable communication backbone along with accurate monitoring system is essential. Monitoring of the power system essentially has two main modules: communication module which is the backbone and sensor module for sensing the different parameters like voltage, current and power. Recently, WSNs have been recognized as a promising technology that can enhance various aspects of today's electric power systems, including generation, delivery and utilization, making them a vital component of next generation electric power systems, microgrids. ZigBee based WSN are proven to be more reliable in packet delivery due to mesh based multi-hop networking. In India context of application of WSNs to power systems, new ideas and implementation plans are coming up. The work presented in this paper is focused on the design, control and development of synchronization between non-conventional energy sources (photovoltaic panel) and conventional energy sources (battery) to satisfy the power demand of the grid by using WSN (wireless sensor networks) technology. The objective of this paper is to propose a prototype to study the performance analysis of power monitoring between photovoltaic panel and battery by sensing parameters like generated power, availability of power reserve etc through WSN (ZigBee). The key simulation and experimental results are included to verify the proper operation and control of microgrid.

II. LITERATURE SURVEY

2.1 Raja Vara Prasad Yerra, Alok Kumar Bharathi, P.Rajalakshmi, U.B.Desai "WSN based power monitoring in Smart Grids" IEEE transactions on power system 2011.

Smart grid technology is one of the recent developments in the area of electric power systems that aid the use of non-conventional sources of energy in parallel with the conventional sources of energy. Monitoring and control of smart grids is essential for its efficient and effective functioning. In this paper, we propose architecture for monitoring power in smart grid applications using WSN technology. A prototype power sensing module is designed and developed to calculate the power for any kind of loads. Using WSN technology, the monitored power is communicated to the sink at periodic intervals. Multi hop wireless mesh network is set up using IRIS notes to enhance the communication between the power sensing nodes and the sink. The data collected is a rich source of repository for data analysis and modeling. A number of smart actions and applications, such as power theft detection, energy efficient building design, smart automation systems and smart metering can evolve out of the proposed model. A novel power theft detection algorithm is proposed and simulated in this paper.

2.2 Rupesh G. Wandhare, Sushil Thale, Vivek Agarwal "Design of a photovoltaic power conditioning system for hierarchical control of microgrid" IEEE transaction on power system 2014.

Recently hierarchical control of micro grid has been the focus of extensive research due to its flexibility to effectively utilize the micro-sources while ensuring reliability. The work presented in this paper is focused on the design and development of a photovoltaic (PV) power conditioning system for a hierarchically controlled micro grid application. The PV interface is equipped with multiple functionalities such as droop characteristic control for both Active and reactive power sharing, centralized power sharing, adaptive power control etc. All these features make the PV interface one of the main power contributing sources. A detailed control design procedure for this micro grid PV source is given. The effectiveness of the proposed control scheme is investigated with a laboratory prototype of the micro grid with hierarchical control supported by sources like Solar PV, Wind, hydro turbine driven synchronous machine and Fuel cell based renewable energy sources. The micro grid has the capability of reconfigurable control. The Local Source Controllers (LSC) is linked with Controller Area Network (CAN) for fast data transfer and RS-485 for bulk data transfer. Battery storage is provided for prolonged energy back up and ultra-capacitor for transient and momentary power support during dynamic phase. The PV interface of this micro grid is investigated under various conditions such as large variation in its radiation level, maximum power point tracking, centralized control for active power, co-ordinate active and reactive power control with de-centralized operation, hierarchical control functionality of PV source with other micro grid sources etc. The intermittent nature of photovoltaic source causes a peculiar impact on the micro grid operation. This and other important observations are analyzed for further study and investigations into the control aspects of PV sources in a micro grid paradigm. The key simulation and experimental results are included to verify proper operation and control of the micro grid.

III. BASIC CIRCUIT DIAGRAM

The PV source should supply energy using power converter controlled for both active and reactive power and regulate the bus voltages whenever required. Fig.3.1 shows the block diagram representation of a power converter associated with a PV source in a microgrid. The arrangement is also supported by energy storage of battery. The instantaneous terminal voltages, DC bus voltage, load currents and injected currents by the VSC are measured and fed into the VSC control circuit. The control circuit gives appropriate gate signals to the Voltage source inverter switches as per the control strategy and thus the inverter injects the required active and reactive power by suitable switching actions of the switches. Hence the voltage regulation and frequency regulation can be improved by proper selection of the injected powers (P, Q).

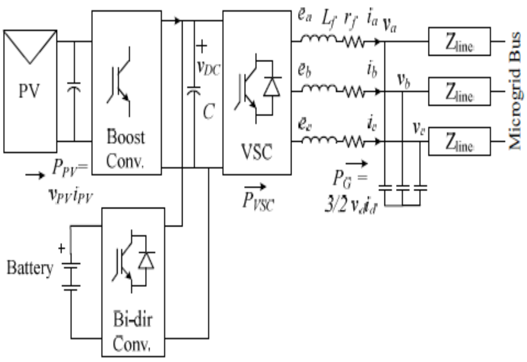

Fig 3.1: Power topology associated with PV interfaced energy storage

IV. DESIGN PROCEDURE OF BOOST CONVERTER

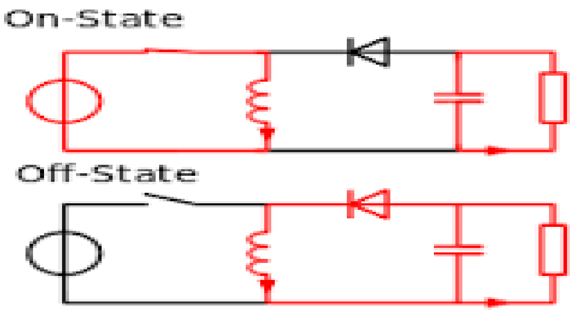

Fig 4.1: two configurations of a boost converter, depending on the state of the switch S.

The basic principle of a Boost converter consists of 2 distinct states (see figure 8):

- In the On-state, the switch S (see figure 6) is closed, resulting in an increase in the inductor current;
- In the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. These results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current as can be seen in figure 7. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

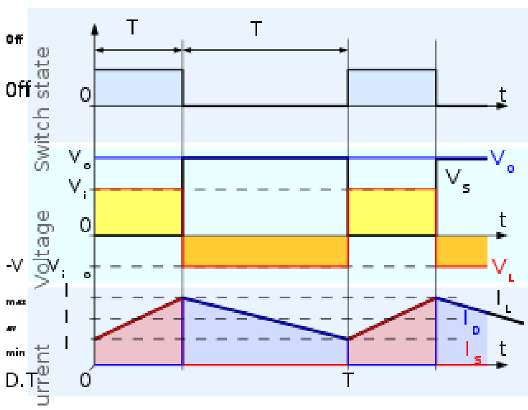

Fig. 4.2: Waveforms of current and voltage in a boost converter operating in continuous mode.

When a boost converter operates in continuous mode, the current through the inductor never falls to zero. Figure 9 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behavior) operating in steady conditions:

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{L_{On}} = \frac{1}{L}\int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_o = L\frac{dI_L}{dt}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{L_{Off}} = \int_{DT}^{T} \frac{(V_i - V_o)\, dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by: $E = \frac{1}{2}LI_L^2$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = 0$$

Substituting $\Delta I_{L_{On}}$ and $\Delta I_{L_{Off}}$ by their expressions yields:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1-D)T}{L} = 0$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

Which in turn reveals the duty cycle to be?

$$D = 1 - \frac{V_i}{V_o}$$

The above expression shows that the output voltage is always higher than the input voltage. This is why this converter is sometimes referred to as a step-up converter.

V. BLOCK DIAGRAM AND WORKING

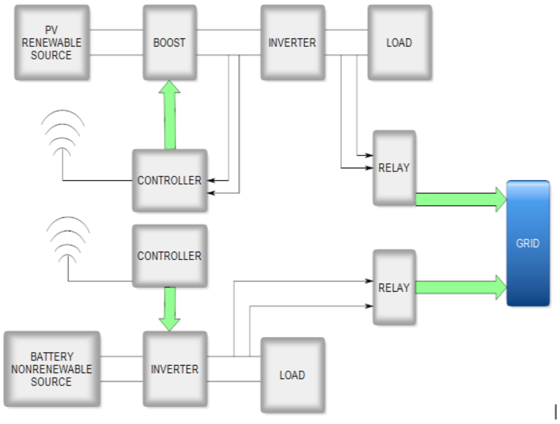

Fig 5.1: block diagram of the prototype

The fig 5.1 shows the schematic diagram representation of control of microgrid. It mainly comprises of photovoltaic panel as non conventional energy source, DC-DC boost converter, inverter, 8-bit 80C51 5V microcontroller, ZigBee, DPDT relay, load. The arrangement also consists of battery which acts as a conventional energy source.

When sunlight falls on the photovoltaic panel, these uses light energy from the sun to generate electricity through photovoltaic effect so we get DC voltage. The voltage which is available from the solar array is variable and less. In order to obtain constant voltage DC-DC converter is used. The voltage generated by the array is less it can be increased by interfacing it with boost converter which considerably steps up the output voltage which could meet the demand of power. The output of the converter is fed to inverter1 which generates AC voltage. The Pic 8-bit microcontroller is used for firing pulse generation. It has inbuilt PWM and A/D converters. The microcontroller is programmed to generate the firing pulses with fixed duty cycle using PWM technique. The arrangement also consists of Arduino board it consists of 14 digital input/output pins. The IGBT pulse pin is connected to pin -11, output of the boost converter is connected to pin AO (analog input) of the Arduino board. The pin 13 of board acts as a toggle switch pin. The arrangement also consists of DPDT relay acts as a decision making device that detects abnormal or fault conditions and initiate protection actions. It is connected to inverter1, inverter2 and load. On the other side the battery used as conventional energy source which connected to the inverter2.

If the voltage within the reference values, the toggle switch pin will become high and it is sensed by the ZigBee1 and bulb will glow from the output of solar panel, if the voltage below the reference values, the toggle switch pin will become low and it is sensed by the ZigBee2 and bulb will glow from the battery. There should be proper synchronization for the control and operation of microgrid. It is verified both by simulation and experimentally with a laboratory prototype of input 12V and output 230V shown in below fig 5.2 and CRO output of frequency 32 kHz is shown in fig 5.3.

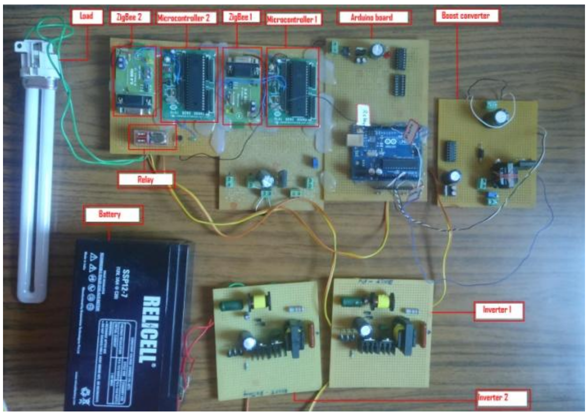

Fig 5.2: laboratory prototype

VI. SIMULATION CIRCUIT DIAGRAM AND RESULTS

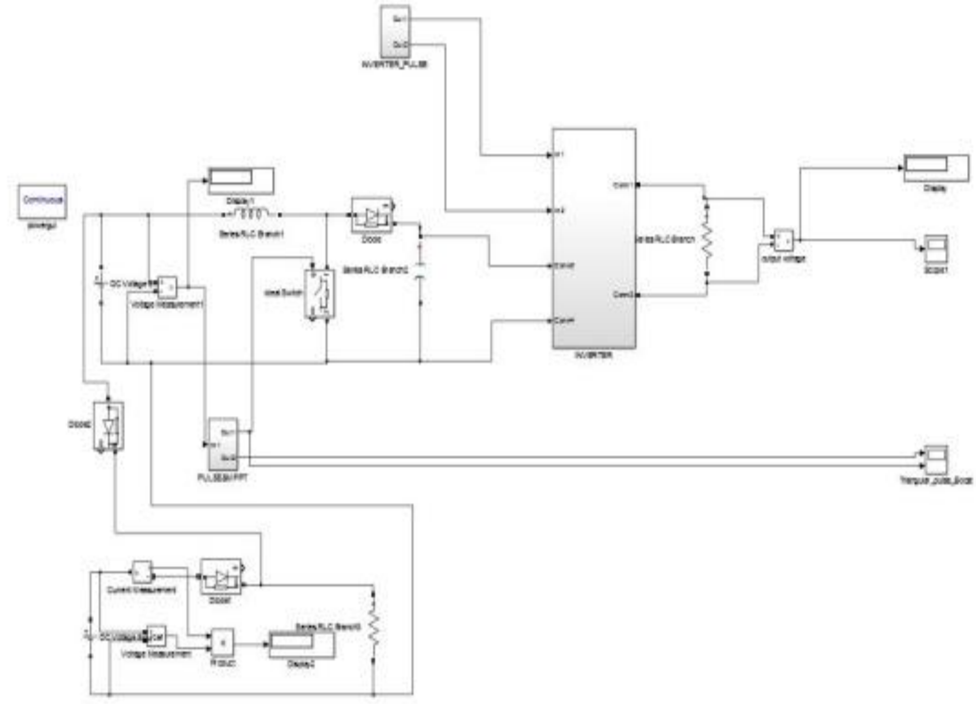

Fig 6.1: simulation circuit diagram

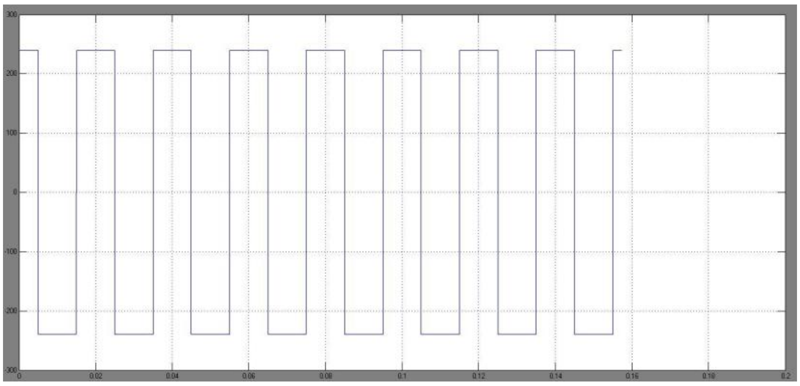

Fig 6.2: Pulse MPPT

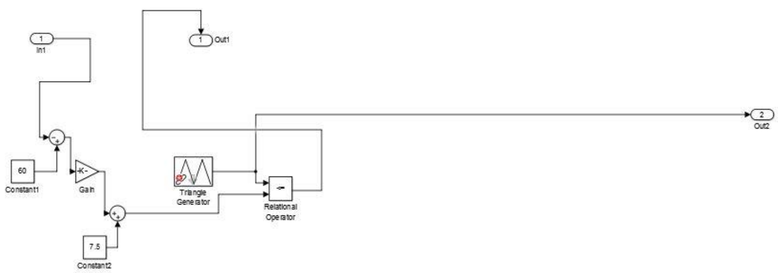

Fig 6.3: Output voltage of 230v

VII. CONCLUSION

A complete system for the remote monitoring and control of PV plants has been presented and its capabilities have been investigated and tested. The use of the WSN extends the effectiveness of the system independently of where the plants are placed, even far from the electrical distribution network and from the traditional and wired telecommunication systems. Due to the low cost and diffusion of the WSN devices, the transmission system is fairly cheap and it is expected to become cheaper and cheaper. At the same time, we are involved in extending the phenomena that can be remotely monitored and controlled, especially if related to the power generation based on renewable sources. In this paper, architecture for power monitoring system using the WSN technology is proposed. A prototype for power sharing between conventional and non conventional sources is developed. It is clear from the experimentations that the WSN may be successfully employed to microgrid for monitoring and controlling purpose.

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