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Efficient Energy Management System with Storage

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Abstract— This paper deals with energy management strategy for AC/DC grid connected network using artificial intelligent techniques. Proposed energy management system aims at maximum utilization of energy sources considering load demand, availability of AC mains, and state of charge of battery. A Spartan 6 FPGA controller is utilized for battery scheduling process which schedules the rate of charge and discharge of battery. It also limits the battery from over charging and deep discharge and thus increasing lifespan of battery. A innovative Variable Frequency SPWM technique utilized to increase efficiency of system. It guarantees power to critical load when AC mains fail. The EMS system accomplishes peak power control by supplying battery power to local load along with AC mains when electricity cost is more. The proposed model simulated using matlab/simulink environment and result found to be better than literature modules.

Keywords—*EMS, Intelligent System, FPGA, Fuzzy Logic, H-Bridge*

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I. INTRODUCTION

Energy efficiency is a major concern for sustainable energy development activities around the world, because increasing energy consumption results in increasing CO2 emissions and long lasting impact on global warning. The energy demand has been constantly growing around the world partly because emergence of new electrical applications, such as new services and new technologies for transportation and home appliances, requiring increasing investment in energy production sector. Furthermore at specific periods of time the electricity distribution network can be under stress, because of high power demand. In order to face rising electricity demand a number of solutions for efficient energy consumption has been developed. Energy management strategy could highly influence demand for energy, such as actions to suppress ineffective energy consumption and actions to dim energy consumption at a large or medium scale [2]. Energy generation from renewable sources and new power distribution business models for active energy control has been developed. It is often mentioned that energy efficiency and renewable energy are the twin for sustainable development.

In this paper power electronics based energy management system (EMS) is proposed in order to accomplish peak power control in a single phase power system while guaranteeing continuous services to critical loads at same time. Peak power control is also known as peak shaving method which reduces charges of electricity for users with Time of Use contract and those pay for demand charges [1]. The EMS proposed in this paper includes batteries as storage device in order to accomplish three major goals: a)make power available to critical load at all time with or without main grid services available b)reduce peak power consumption to reduce electricity cost c)store energy generated from distributed generation(DG) unit or during which cost of electricity is least expensive.

II. EMS ARCHITECTURE AND FUNCTIONALITY

The proposed EMS architecture has battery bank and three legs IGBT power module which can be controlled as Voltage source or Current Source according to availability of AC mains, battery statue and user predefined conditions. The field programmable gate array (FPGA) Spartan 6 development board is use for generation of control signal for IGBT's and triacs. The triacs are used as switch for controlling flow of power between different devices. The first leg of 3-leg IGBT power module act as buck and boost converter according to availability of AC mains power and battery status. There are two voltage feedback circuit utilized to measure Vac and Vdc and two current feedback network utilized to measure Iac and Idc. The ADC MAC 3008 is utilized for interfacing between feedback network and FPGA board. The 16x2 LCD display is utilized to show mode of operation of system and time of operation. Keypad is used for giving user defined input to the system.

The battery bank is connected to buck-boost converter to control flow of current to/ from the battery. the battery bank consist of six 12V batteries connected in series to give equivalent voltage of 72V. In this system critical loads are connected directly to the AC signal generated from EMS while non critical loads are connected to the system via Triac and they can be connected or disconnected from the system according to state of battery and predefined user input. Critical loads are the loads which should be always connected to the system because they are the critical to the mission. In this system I have utilized innovative VFSPWM technique to increase efficiency of system. A series LC filter is utilized for purification of sine wave purpose. The THD obtained from given system is below 5%.

In this paper functionality of EMS demonstrated. The EMS system works on four modes of operation:-1) Idle Mode 2) Islanding Mode 3) Peak Shaving Mode 4) charging Mode

The given system can be very useful in grid connected network where there is limit on user's power consumption. This limit can be enforced by circuit breakers. The given system can ensure continuous power to given load for short duration of time without worrying about circuit breaker by keeping current rating below threshold value by using various load shading algorithm. This system can also be very useful when user has time of use (TOU) contract with power companies and pays different charge for different time in a day [8]. In this time EMS manages power flow between energy stored power and mains grid power to reduce cost of electricity. This technique is known as peak shaving or load leveling to reduce cost of electricity [2] or retail energy time shift [1]. It also ensures continuous power to critical load when mains grid supply fails. Unintentional islanding is hazardous and can cause safety problems in maintenance hence in this design special precaution for unintentional islanding is taken.

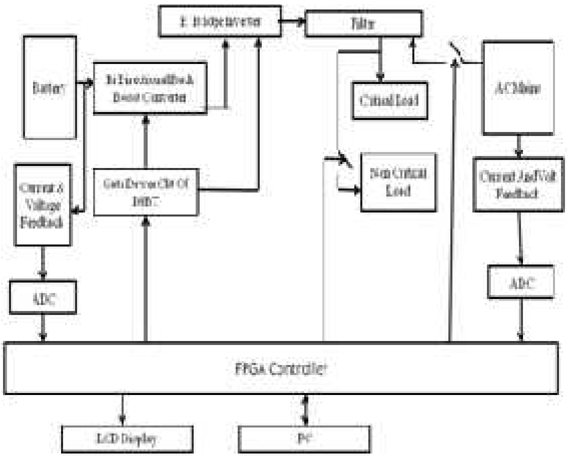

Figure 1 EMS Architecture

III. Energy Management Strategy

Intelligent energy distribution system is very important to determine how effectively power generated from EMS is distributed among various loads to optimize the performance of system. If the power generated from AC grid is sufficient then power supplied as usual as the commercial grid otherwise switching action takes place and it switches to the inversion operation. The energy stored in battery is always compared to the preset values and if it is low/above preset values then controlling action takes place to control the flow of current to/from the battery.

A. *Battery Schedulling Algorithm*

The energy management system given in paper consist of 6 84 Wh batteries connected in series as a storage device. These batteries are cheap but suffers from deep discharge as it

decreases lifetime of batteries hence an efficient EMS system is designed using fuzzy logic to optimize performance of batteries. The EMS control strategy is as shown below.

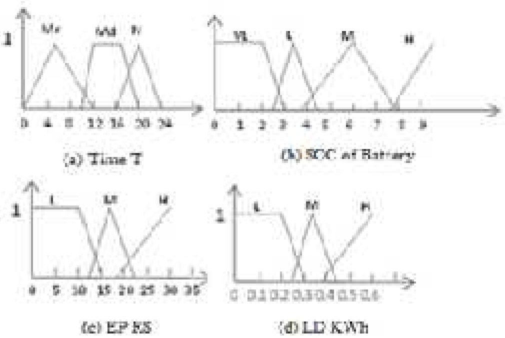

Figure 2 Membership Function for Battery Scheduling

1. *Fuzzification Process:*

The fuzzification process applied to the battery scheduling of given system based on the real time data or forecasted data as follows: Time of day (T), The Battery State of Charge (BSOC), Electricity Price (P), Load Demand (LD), Availability of AC Mains Supply. The input membership function forward its degree of membership relative to input pattern of above given functions to the given system. The time membership function takes actual time and assigns degree of membership function for the fuzzy set as shown in above Figure 2a. N stands for Night, Md Stands for Midday, and Mr stands for Morning. The battery state of charge membership function reassigns into four values as: VL (very low), L(low), M(medium), High(H) as shown in Figure 2b. The electricity price membership function is as shown in Figure 2c.It is categorized as high (H), low (L) and medium(M). The load demand membership function is as shown in Figure 2d. It is categorized as low (L), medium (M), high (H).

2. *Input Evaluation Process:*

After the membership function of each fuzzy set is determined for input next step is to evaluate each membership function and it gives its output according to input values of membership function. A typical fuzzy rule example is as shown: if (AC in H) and (T is N) and (BSOC is H) and (LD is H) and (EP is H) then (Discharge is M). the efficient fuzzy rules summerize the battery schedulling according to human experience and its main goal is to decide whether charge or discharge battry and according to which limit. Once the criteria for rules are met the output degrees of membership would be asserted according to the membership function of input.

3. *Defuzzification*

When output membership functions are calculated next step is defuzzification into output signal as mode of operation and charging /discharging rate of battery.

IV. Intelligent System

Intelligent energy distribution system determines how effectively the power generated from renewable sources is distributed. The system decides when to use the energy stored in the battery, that is whenever the power generated from the commercial electricity grid is very low then the switching action takes place, switches to the solar grid. If the energy generated from the solar panel is sufficient then power supplied as usual as the commercial grid otherwise controlling action takes place to decide which load to be connected to the system according to battery state. The energy stored in the battery is always compared with the preset levels and if it is low then it communicates with control room to take necessary steps. If the energy level is below the first preset level then the power that goes to the least priority devices are automatically shut off and the high priority devices are run and if the energy is below that then the next priority devices are shut off and allows to run only the highest priority devices giving a signal to take the necessary actions.

The power monitoring device has two power sockets to measure the power consumption of devices that can transmit the status of the battery and receives the control signals to control the power through the devices. Fig.1 shows the basic block diagram for intelligent and efficient distribution system consisting of FPGA controller; thyristor control unit. User interface, power sensing unit and AC power supply exist in the system. The EMS system consisting of a CT sensor which gives current values of battery and AC mains supply which can be handed by the FPGA controller. The power management methods are of two types, efficiency oriented and user oriented. In the efficiency method the generated power and the battery charging conditions are transmitted to the smart power management system and it is compared with the power consumption data stored in the FPGA controller unit. But the problem with this technique is that it finds only the optimal time to use the charging battery for decreasing power consumption and electric charges. In this paper we proposed a user oriented method to run the devices by setting the priorities and run the device having highest priority for a long time compared to the devices having least priority, which increases the efficiency in the point of user. The block diagram in Figure 1. having three sockets is nothing but three loads. The intelligent system efficiently distributes the power generated from the solar panel to these prioritized loads depending upon the status of the battery. Energy Management System Algorithm is as follow:

Step1: All devices are Initialize.

Step2: Initially Inverter sections is in OFF state condition.

Step3: Devices are run with AC mains supply

Step4: In FPGA one pin is programmed to monitor the AC power, when it is goes off, the load is connected to the inverter.

Step5: Now the battery energy is connected to the meter

Step6: In FPGA the stored energy is always compared with presetting levels

Step7: If the stored energy is greater than the power consumption then the least priority device is automatically turn off while high priority device remains turn on..

Step8: Whenever the AC grid power is present then the thyristor connects load to the AC mains supply.

Step9: Results are displayed on LCD

V. SIMULATION RESULTS

The EMS shown in Figure (1) was built in laboratory to show EMS functionality. The battery pack voltage is 72V it is boosted to create output DC voltage of 200V. which is then inverted to give output voltage of 120V AC. In inverter filter shown in Fig (1) consist of output capacitor of 6μf and inductor of 1.5H distributed on both side of capacitor. The EMS functionality can be demonstrated in two ways i.e When AC grid supply is connected and when AC grid supply is absent.

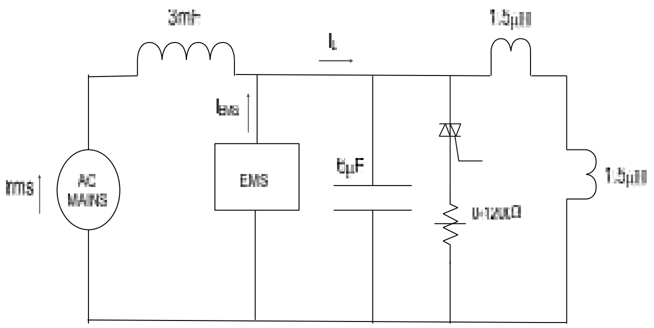

Fig 3 Functional Diagram for EMS System

A. *Peak shaving and Battery Charging With AC Mains Connected:*

Residential and commercial time of use (TOU) electricity rates include different rates at different time of the day (such as on-peak and off-peak) and also demand charges. Demand charges are based on the customer's peak demand on a given month, usually averaged over a 15-minute period [1]. TOU rates are devised by the power companies to encourage customer to shift their loads away from the peak demand time and in general reduce their peak power consumption. The ideal customer would draw constant power at all hours of the day. Reducing the peak power consumption results in significant cost savings. Peak shaving is a known technique [1] used to achieve this objective by use of stored energy. Electrical energy is stored during the times when electricity cost is lowest (typically at night) and used during the times when electricity cost is highest, in order to reduce the overall electricity charges. While it may not be cost effective to acquire a battery pack with the sole purpose of peak shaving, if storage is part of an existing system then EMS installed to increase the reliability of system.

Figure 4 shows current and voltage waveform for EMS system when output load is varied from 1200Ω to 85Ω.

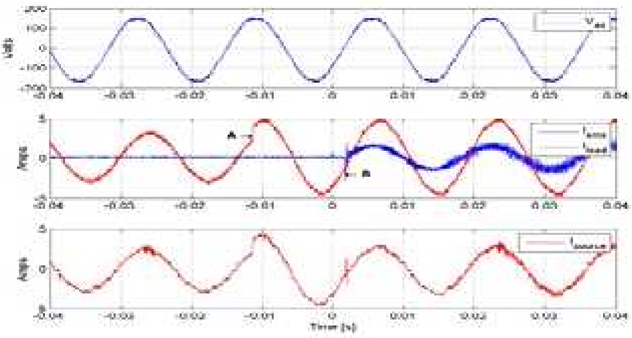

Fig 4: EMS Current and Voltage Waveform
When AC Grid Supply Present

B. *EMS Powering Control Grid When AC Mains Falls:*

In order to provide power to critical loads when the AC grid fails, the EMS detects grid failure and acts as a voltage source for the critical loads. In this mode of operation non critical loads can be shed depending on the state of charge of the batteries and other factors determined by the user or by the secondary control system. Non critical load shedding is easily accomplished by the EMS by opening the thyristor switch connected to the non-critical loads.

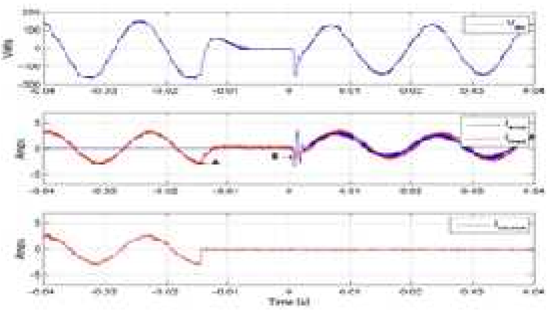

Fig 5 EMS Current and Voltage Waveform
In Islanding Mode

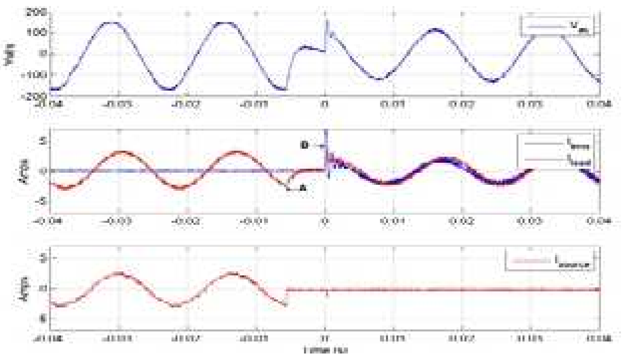

Fig 6 EMS Vol. and Current Waveform When AC Grid Supply Restored

VI. APPLICATIONS

The EMS given in paper can provide continuous power to critical load when AC grid supply is absent. Also the EMS can reduce cost of electricity by implementing peak shaving method. It involves storing electrical energy when cost of electricity is lower and then utilizing the stored energy when the cost of energy is higher. The given system can easily been modified to include green energy sources like wind, solar, fuel cell to reduce CO2 emission as well as reduced cost of electricity. The given system can be use to reduce peak hour demand of electricity. An intelligent battery scheduling algorithm is use which result in increasing lifespan of batteries.

VII. CONCLUSION

In this paper we proposed a system to distribute the power generated from renewable sources efficiently In this paper functionality of power electronics based energy management system is demonstrated. Experimental results show how EMS system supports critical loads when AC grid supply is absent as well as restored when AC grid supply resume. Peak shaving method is use to reduce cost of electricity and power consumption during peak hour of day. The given system can be use as a standalone DC grid supply in remote areas where electricity is not available. By using intelligent control algorithm the battery span of life can be increased.

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