Energy Management System for critical loads using Power Electronics

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Abstract: The aim of this paper is to give a brief idea about an Energy management system (EMS) for critical loads using power electronics. Here hybrid power sources (grid and photovoltaic cells) with battery storage are used to supply the stored power to the critical loads, if suppose end users increases their loads capacity at load side and this whole EMS system is used for continuous power supply to the critical loads. Photo voltaic cells are used for battery charging purpose, here batteries will be discharge the stored power at two conditions, one is when grid is shut down for little moment or for a long duration and another one is sudden increase in loads by users. Here EMS with hybrid power sources guaranties that the continuous supply of electrical power to the critical loads with or without grid with the help of stored energy from batteries.

IndexTerms - Photovoltaic cells, grid, loads, batteries, inverters, comparators, EMS.

I. Introduction

The system monitoring, controlling, and optimizing the working of the generation and/or transmission system can be done through Computer Aided tools which are operated by operators are known as Ems**.** The main purpose of using solar or photovoltaic cells to produce more power and that can be stored in batteries. The photovoltaic systems are broadly classified as standalone system and grid connected system [1]. Here batteries are mainly used to improve reliability of the standalone system [2] [4]. In this paper hybrid system (grid and solar) with battery is used to compensate the mismatch between the generation and local demand at load side.

Basically EMS includes energy storage system in the form of batteries through grid to accomplish the main three goals:

1. Make electric power available to critical loads at all times with or without main grid available.
2. Reduce peak power consumption to lower electricity costs
3. Battery can be store energy produced by DG units or during the time in which electricity from the grid is least expensive.

A grid-connected PV system with a battery backup has many advantages such as peak shaving to generate power during peak load hours, and therefore, the grid-side inverter should operate at any condition to supply uninterrupted power to the critical loads during grid fails or sudden increases in load [1][4]. When the solar radiation is less, the power quality is decreases as compared to the total harmonic distortion (THD) of the line currents, which are inversely proportional to the power into the grid. The proposed PV and grid (hybrid) system consists of three power sources (grid, PV array, and battery), two power sinks (battery, and load), and EMS for load leveling.

The EMS proposed in this paper includes energy storage in the form of batteries in order to accomplish these main goals:

i. Make electric power available to critical loads at all times with or without grid.
ii. Reduce peak power consumption to lower electricity costs
iii. Battery can be store energy through pv cells.
iv. Peak shaving is controlled quickly at the time of high power demand at load side by energy storage system.
v. Islanding or standalone mode of operation can be done, when the grid power is not available.

Many authors reseached on this EMS with different statergies, they solved many problems like smart meters problems with solution [5], controlling of droop in Inverters [7], high frequency problems in ac microgrids [8]-[9]-[10]-[11], use of cascaded dual buck converter with renewable energy applications [6]. Many authors focused on energy management system with dc loads, but in this we are focusing on EMS with solar and gird power supply for critical loads. For house hold energy management system can be built with smart meters to get detailed information about users consumption of power with bill.

II. Block Diagram for Purposed system

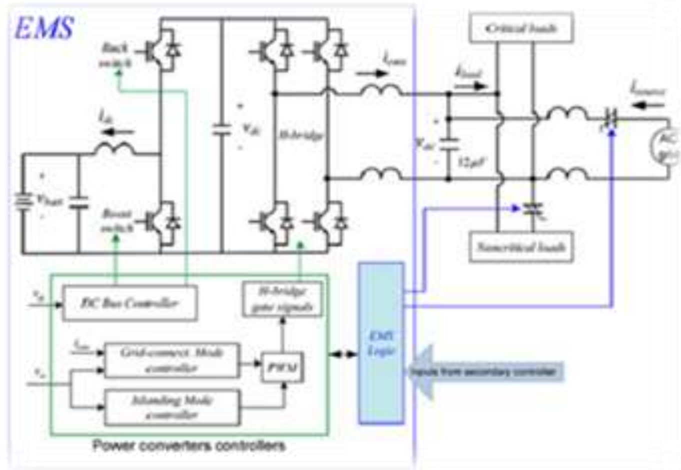

Fig.1. Architecture of EMS

Fig.1. shows the architecture of EMS with critical and non critical loads which are connected in parallel to the system.

➢ **EMS Functionality**

The EMS presented in this paper includes batteries, three leg power module controlled by microcontroller kit [**ARDUINO MEGA 2560 R3]**. The Fig. 1 shows the EMS architecture with critical and non critical loads. Three legs of the power IGBT is use to control power flow of the buck and boost converter and single-phase voltage source operation (H-bridge inverter) of the respected module [10]. To produce the sinusoidal voltage for the ac loads H bridge inverter can be connected to the LC filter [output]. Critical loads are those loads to which power supply has to maintain at any condition. Here critical loads are connected in parallel to Vac with h bridge inverter for continuous service to these critical loads using a thyristor switches. Noncritical loads are also connected in parallel to Vac but these are powered when necessary by using a thyristor switch. Here buck and boost converters are used to control the dc bus voltage as user's preference [11].

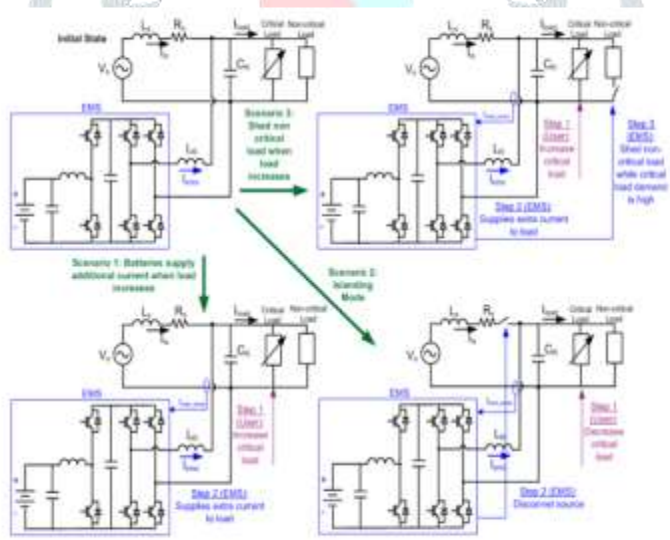

Fig.2. Scenarios of EMS system

Fig.2. shows the different scenarios of EMS system, there are three scenarios as listed below.

1. Battery supply additional current to the load when sudden increase in critical load.
2. Islanding mode occurs when EMS or source is disconnected from the system and critical load can be decreased at that time battery can discharge stored energy to the critical loads.
3. Shedding of non critical loads can be done at the high demand of critical loads and batteries can supply stored energy to critical loads to manage energy or load leveling.

III. System Flow Chart

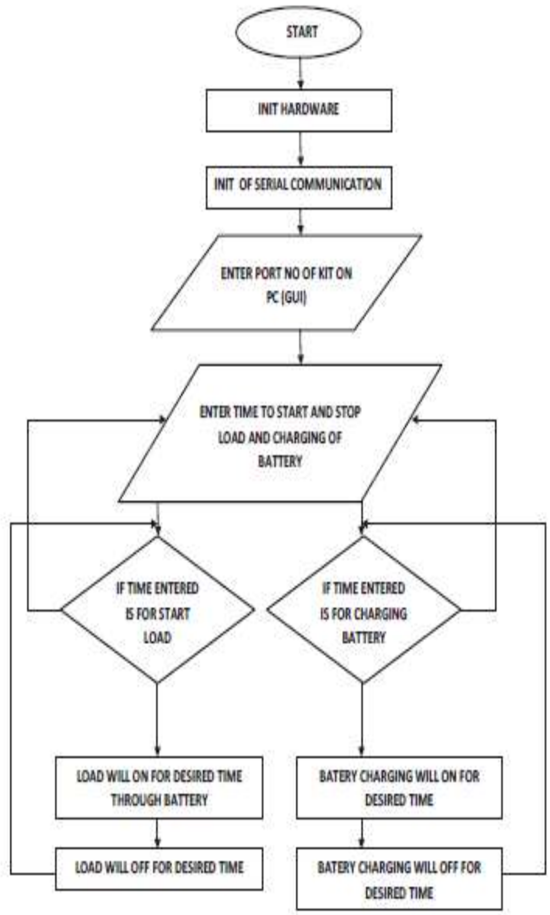

Fig 3 Flow chart of system

IV. Simulation Result of DC

Here energy management system for critical loads using power electronics can be simulated by using MATLAB R2013a for DC as well as AC systems. The DC simulation part of the EMS is shown in fig.4 and result of fig.4 is shown in fig 4(a).

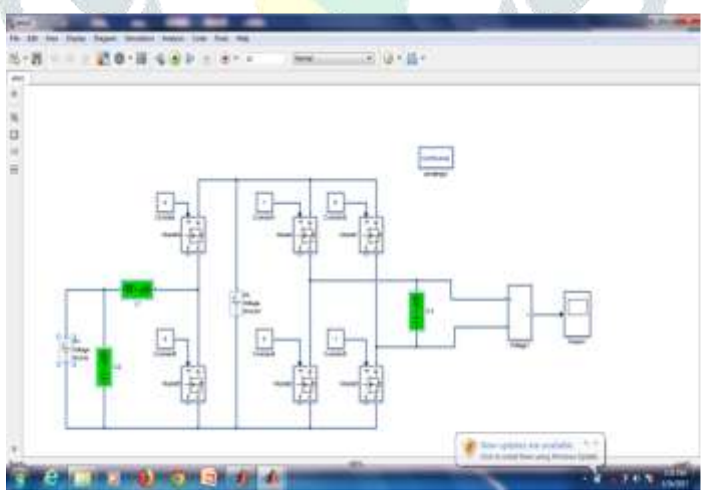

Fig.4. DC simulation part of EMS

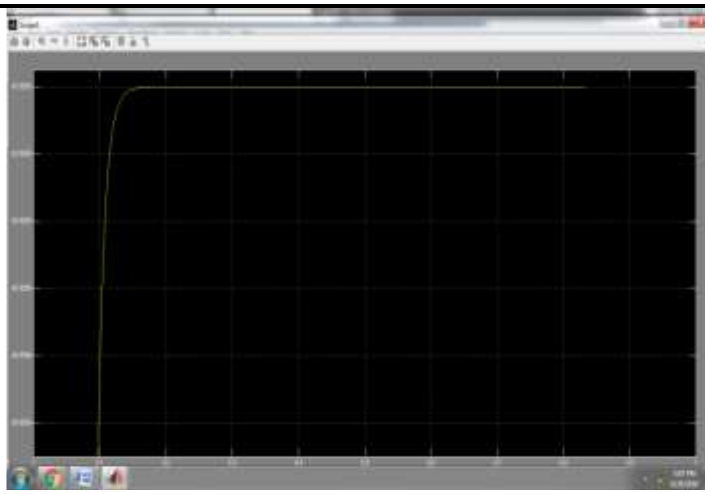

Fig 4 (a) Output result window of fig (4)

Here fig (4) can be done by using fig (1) Power MOSFET's are used in place of Power IGBT's to work under lower voltages with higher communication speed and greater efficiency. The result of simulation part of fig 4 is shown in fig 4(a), at starting it has errors as run time increases then we get pure DC wave form. The X-axis represents the run time period of the above simulation system (0.1 to 1.0 sec) and Y-axis represents the voltage range of the respected system (0 to 100 volts).

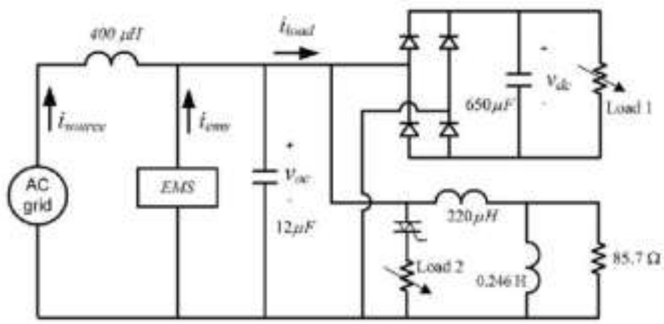

Fig. 5 AC load set up

Set up for AC load is shown in fig 5. With full wave bridge rectifier using diodes and here RL load can be used as critical loads to operate EMS. The aim of this set up to show the modes of operation of Ems in different load step changes.

A. Peak power control

Here source current is indirectly related to RMS current in the load, which is controlled to achieve Peak power control or peak shaving in the system. A minimum current is set for the load to activate the load, suppose load current get upper hand or exceed this minimum current the EMS can able to supply through battery, this will help to keep the peak current below the grid current.

B. Islanding mode of operation

This Island mode can be takes place when grid fails to supply power to the critical loads, at that moment EMS suddenly get noticed that GRID fails to supply so it acts as voltage source and immediately batteries starts discharging the stored power. Here non critical loads are supposed to be get shed on or removed from system depending on the battery charged percentage or status. Non critical loads are removed very easily from the system by opening the MOSFET switch, which are connected in parallel to the non critical loads [**Fig (1)]**. When AC grid reactivated then EMS will automatically restore the critical loads to the grid supply and automatically battering discharging mode will get shut on and starts storing energy from solar cells.

Here battery power can be used in two conditions, one at sudden increase in loads by users and second one is when ac grid fails to supply power to the loads.

Parameter	Peak shaving	Islanding mode
Battery operation	ON (Charging)	ON (discharging)
EMS current	OFF	ON
Load current	Isource	Iems

Table 1: Observations of system

Here table 1 shows the observations of the system. There are four blocks in row and three blocks in column with parameters, battery operation, EMS current and LOAD current and parameters, peak shaving and Islanding mode respectively. When grid at on condition and peak shaving is done by EMS then battery can be charged by solar system and grid is fails at that time battery start discharging the stored energy to the loads. Here EMS current doesn't flow to the loads at the time of peak shaving and load current may operated by source current [Isource] at peak shaving condition. During Island mode EMS current can be supplied to the critical loads at that time load current will be Iems.

V. Simulation result of AC

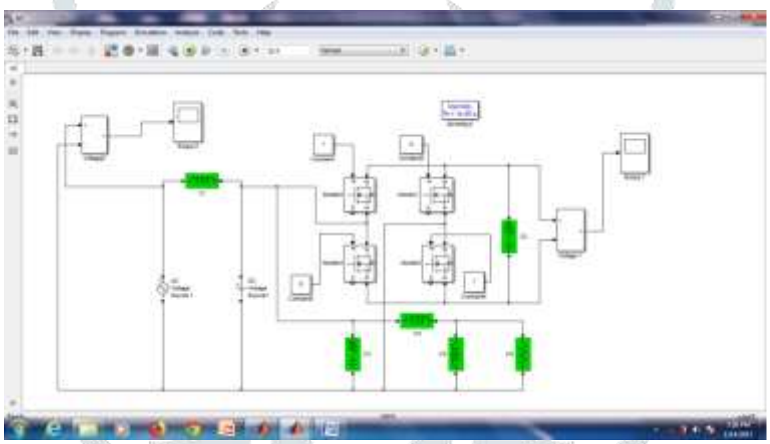

Fig.6. AC simulation part of EMS

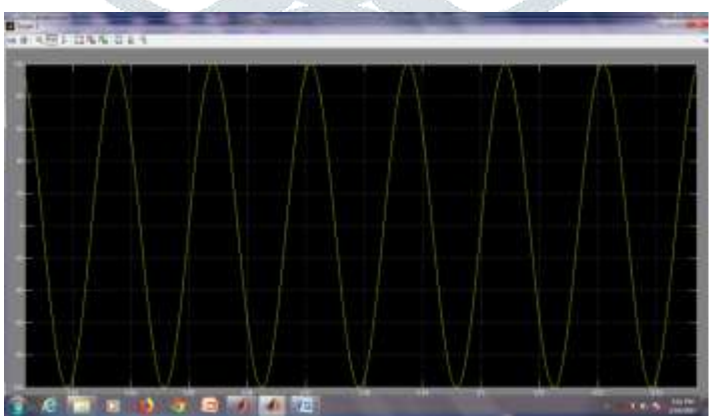

Fig.6 (a) Input voltage result window of fig (6)

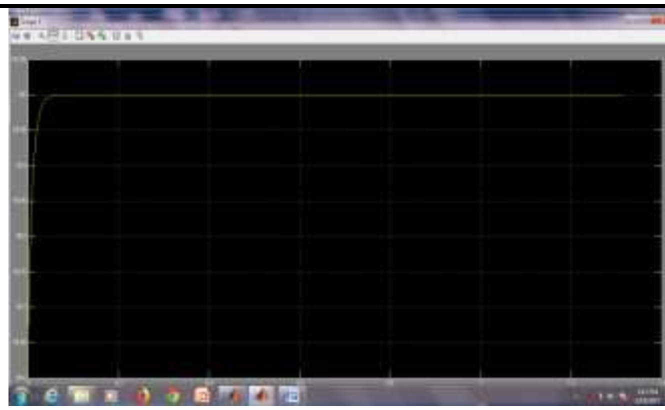

Fig 6 (b) Output result window fig (6)

The fig (6) shown above is the simulation part of the ac loads set up. Power MOSFET's are used instead of diodes to form full wave bridge rectifier, to convert input AC voltage into DC voltage. By turning on constants 1 and constant 4 we can able to convert Ac voltage in to DC voltage. The input voltage window is shown in fig. 6(a) with sinusoidal waveform and it can be measured in scope 2 and the output voltage window is shown in fig. 6(b) with DC waveform and it can be measured through scope 1. The X-axis represents the run time period of the above simulation system (0.1 to 1.0 sec) and Y-axis represents the voltage range of the respected system (0 to 100 volts).

VI. Proposed Hardware Block Diagram

The fig (7) shows the proposed hardware block diagram for EMS with opto coupler with drier circuit TPL250 kit, solar panel, battery, load and input ac/dc source.

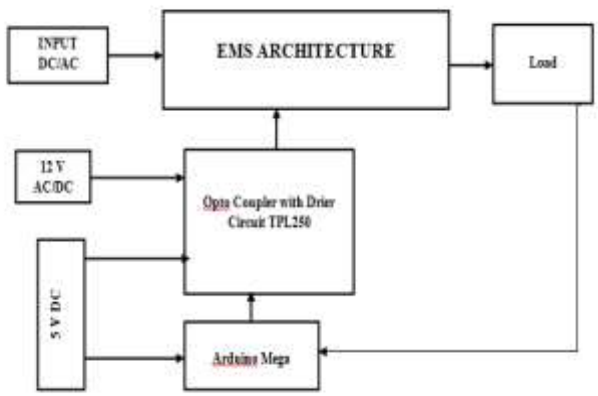

Fig: 7. Proposed Hardware Block Diagram

The input source consist mainly 4 parts, a transformer, a rectifier, a filter, and a regulator put together. The output of the dc power supply is used to provide a constant dc voltage across the load. Let us briefly explain the function of each of the elements of the dc power supply.

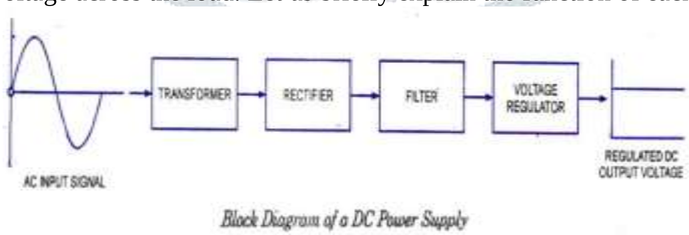

Fig: 8. Block diagram of DC power supply

Transformer: These are mainly used here to supply ac power to the system. It is also used for step up and step down of the voltage across the input. With step-up and step-down the out may vary.
Rectifier: As already knows rectifiers are mainly used for converting sinusoidal ac voltage into pulsating dc voltage, either positive or negative as users required.
Filter: The rectifier voltage is always pulsating dc hence it contain unwanted ac components it, this filter is used to remove the unwanted ac components from the rectifier output voltage and given to the dc loads.
Selection of driver circuit: MOSFET TLP 250**,** Capacitor 2200μf**,** the current rating of the TLP250 opto coupler is 1.5A, voltage is 10V and maximum operating frequency is 25 kHz.

VII. Applications

An EMS can be implant with photovoltaic cells in buildings or military places to achieve continuous services to the critical loads using battery. The main aim this paper is not only to supply continuous power supply to the loads also to reduce tariff of electricity. The application are which may provide utility bill tracking, real-time metering, building HVAC and lighting control systems, building simulation and modeling, carbon and sustainability reporting, IT equipment management, demand response, and/or energy audits. Managing energy can require a system of systems approach.

VIII. Conclusion

By using this technique of energy management system critical load are powered even if AC grid fails. The control system with photovoltaic cells designed to perform the experimental set up of schemes are furnished in this paper. The EMS supports critical loads when the ac grid becomes unavailable or sudden increase in load and EMS can be connected to the grid for automatic connect or disconnect from the system. The main advantage of EMS is to accomplish peak power control in load side. Experimental set up shows, how the EMS can be controlled for AC loads when grid fails or sudden increase in the load by end users with the help of power stored in the battery by photovoltaic cells.

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