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# Design and implementation of EMS under critical load condition using Fuzzy & Adaptive Fuzzy Controller

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***Abstract***: The aim of work is to give a brief idea about an Energy Management System (EMS) for Critical loads using power electronics control topology. Here hybrid power sources (grid and Solar cells) with battery has 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. Battery get charged through Solar cell as well as grid too, when loads are low rated or peak power is bucked and stored in battery. 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. An energy management system (EMS) is a system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. The main purpose of using solar cells to produce more power and that can be stored in batteries to boost that power to match the input power with load power. In this synopsis proposed about Energy Management System (EMS) for Critical loads using Adaptive Fuzzy controller and fuzzy logic controller.

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**KEYWORDS:** Energy Management System (EMS) - Energy Storage - Peak Power Control-Voltage Source Inverter (VSI)

## I.INTRODUCTION

Energy savings and energy efficiency have become top priorities all around the world, stimulated by the Kyoto protocol and other pressing needs to reduce fossil fuel consumption. Additionally, energy security is a necessity for many installations such as military bases and health care facilities where reducing energy consumption must be accomplished while keeping critical electrical loads serviced at all times. In my work, Energy Management System (EMS) for critical loads using Power Electronics is presented to accomplish peak load power levelling in a single-phase power system while guaranteeing continuous service to critical loads at the same time. The power system does not need to be a micro-grid, meaning that distributed generation (DG) does not need to be part of the power system.

EMS could be used in small scale systems like microgrids. The computer technology is also referred to as SCADA/EMS or EMS/SCADA. In these respects, the terminology EMS then excludes the monitoring and control functions, but more specifically refers to the collective suite of power network applications and to the generation control and scheduling applications. Manufacturers of EMS also commonly supply a corresponding dispatcher training simulator (DTS). This related technology makes use of components of SCADA and EMS as a training tool for control centre operators for better ENERGY MANAGEMENT SYSTEM "Adaptive Control System" is used.

Adaptive Fuzzy Control is the capability of the system to modify its own operation to achieve the best possible mode of operation. Adaptive Fuzzy control systems have higher reliability and higher system performance.

Fuzzy logic controller used for efficient Energy Management System and the proper control strategy for energy storage system.

## II.SYSTEM MODEL AND ASSUMPTIONS

A microgrid controlled by an Energy Management System (EMS) for critical loads using Power Electronics can optimize the use of energy sources and energy storage systems to provide improved energy security and reduced energy cost. Basically, an EMS can used to reduce a microgrid's peak power demand on the commercial electricity grid or on distributed resources (DR).

The main purpose of this thesis to investigate the load leveling or continuous supply to the critical loads or non-critical loads using grid and battery. Battery can be store energy through photovoltaic cells as well as micro grid. When grid fails to supply power to the critical loads at that moment batteries immediately discharge power to the loads. A physics based model was developed and validated using experimental prototyping, and then the model was used to simulate load leveling.

An EMS creates the opportunity to manipulate power intelligently in a microgrid. Its functionality is demonstrated by modeling, simulation and experimental validation of the following scenarios:

1. Peak power control by tapping an energy storage system during high demand.
2. Islanding mode by necessity (loss of power) or by choice.
3. Peak power control by non-critical load shedding during transients.

By accomplishing these goals, the EMS can be very useful in commercial electricity grid connected systems where there is a limit on the user's power consumption. If the EMS keeps the load current below a set threshold at all times by load management and shedding, then the user can operate loads beyond their steady-state power limits without worrying about the circuit breaker interrupting power.

A physics based model of the EMS was developed and implemented using Simulink MATLAB R2013b software. The model was validated using a power electronics based power conversion system designed to support laboratory development and rapid experimental validation for research and thesis projects.

The power demand of critical or non-critical loads was analyzed first. For this research a single family home power demand was monitored. Second, the EMS was modeled and experimentally verified using the circuit in Figure1. Third, the validated model was used to investigate scenarios with more complex loads such as motors and diode rectifiers. Lastly, the model with the complex loads was simulated with and without the EMS.

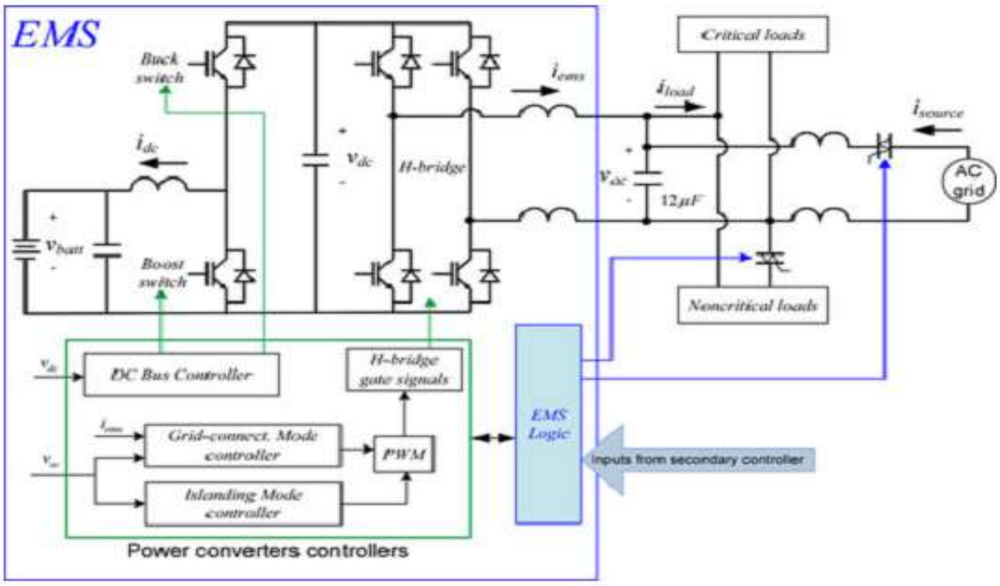


Fig.1 Architecture of EMS

Set up for AC load is shown in fig 2. With full wave bridge rectifier using diodes and here RL load can be used as critical loads to operate EMS.

✓ Three legs of the MOSFET 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.

l 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 MOSFET switches.

Noncritical loads are also connected in parallel to Vac but these are powered when necessary by using a MOSFET switch. The EMS presented in this paper includes batteries, three leg power module controlled by microcontroller kit [ARDUINO MEGA 2560 R3]. The Fig. 4 shows the schematic circuit diagram used to experimentally verify the EMS model with critical and non-critical loads. Three legs of the power MOSFET 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. 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.

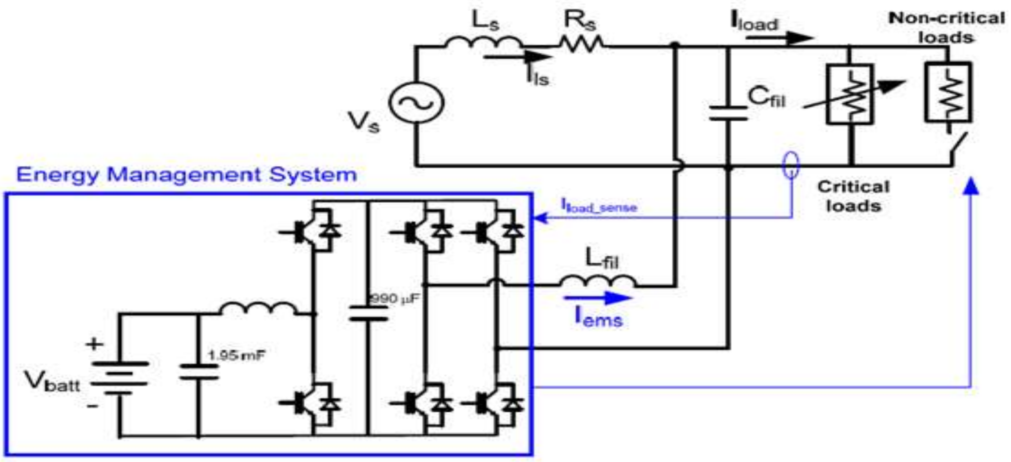


Fig. 2 Set up for AC load

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 noncritical loads in Fig 2. 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.

Table 1: Observations of system

| Parameter | Peak Shaving | Islanding Mode |
|---|---|---|
| Battery Operation | ON (Charging) | ON (Discharging) |
| EMS Current | OFF | ON |
| Load current | $I_{Source}$ | $I_{ems}$ |

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 be 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.

For better ENERGY MANAGEMENT SYSTEM "Adaptive Fuzzy Control System" is used .Adaptive Fuzzy Control is capability of the system to modify its own operation to achieve the best possible mode of operation. Adaptive Fuzzy control systems have higher reliability and higher system performance.

Fuzzy logic controller used for efficient Energy Management System and the proper control strategy for energy storage system.

- **Modes of operation of Ems in different load step changes [1]:**
- **Scenario: 1** Battery supply additional current to the load when sudden increase in load side.**(** Fig 3).

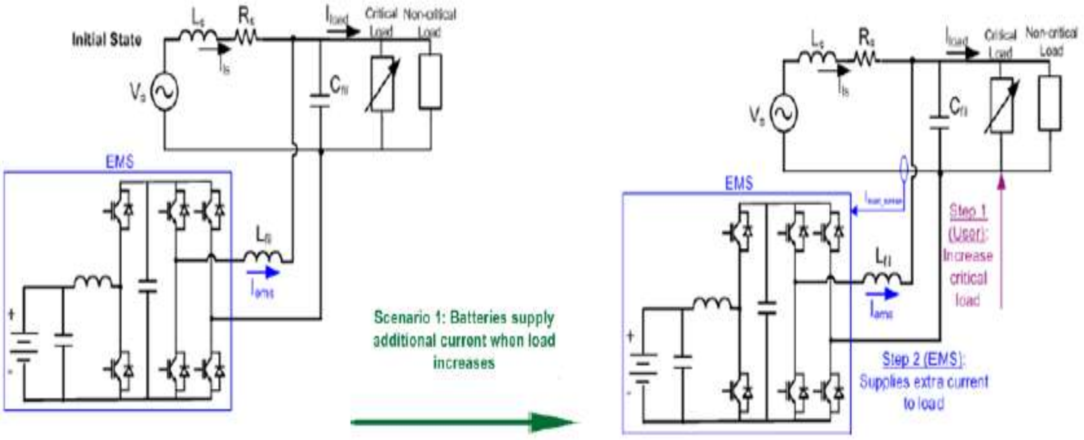


**Fig: 3.** Scenario 1, battery supply extra current

- **Scenario: 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 (Fig: 4).

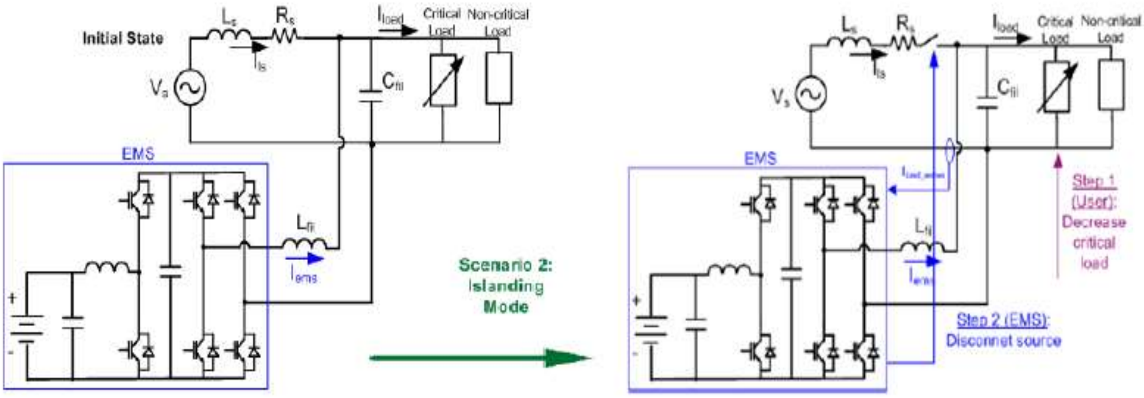


**Fig: 4.** Scenario 2, Island mode EMS disconnected

- **Scenario: 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 (Fig: 5).

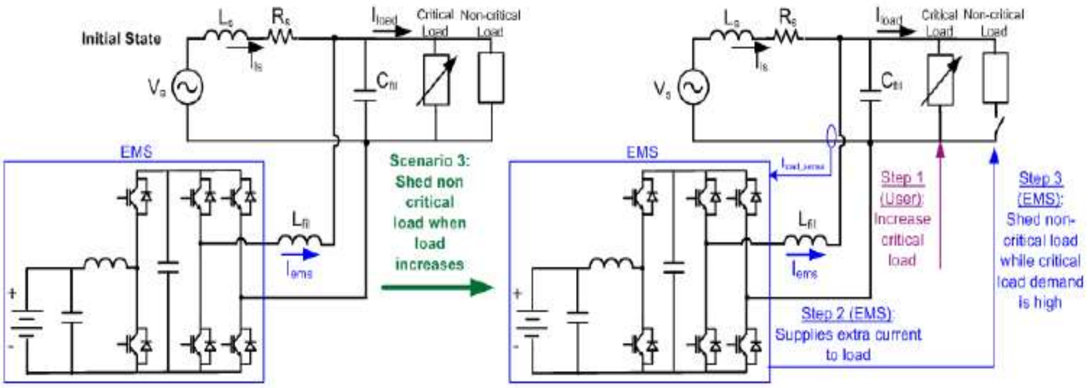


**Fig: 5.** Scenario 3, Shedding Non critical loads

The PVmicro grid system is designed to operate in two modes; Grid-Interactive and Islanded mode. In grid-interactive mode the battery system operates in parallel with the PV system. The PV system operates normally as a typical grid-tied solar PV system.

During peak sun hours of the day the battery system is less active, but when the PV system is not utilizing the majority of the inverter capacity (i.e. at night) it is able to actively participate in fast response frequency regulation.

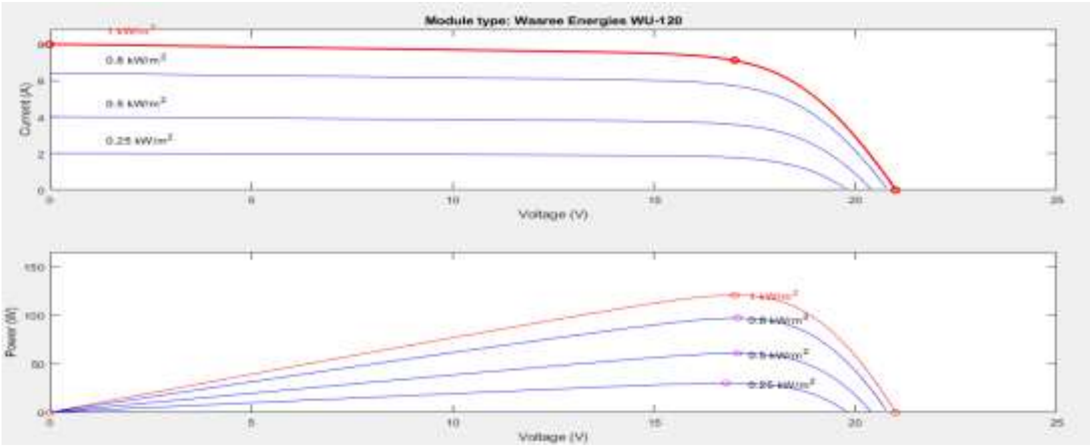


**Fig: 6** load characteristic of PV Cell

Maximum power point tracking (MPPT) is an algorithm implemented in photovoltaic (PV) inverters to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and load. Engineers developing solar inverters implement MPPT algorithms to maximize the power generated by PV systems

Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there.

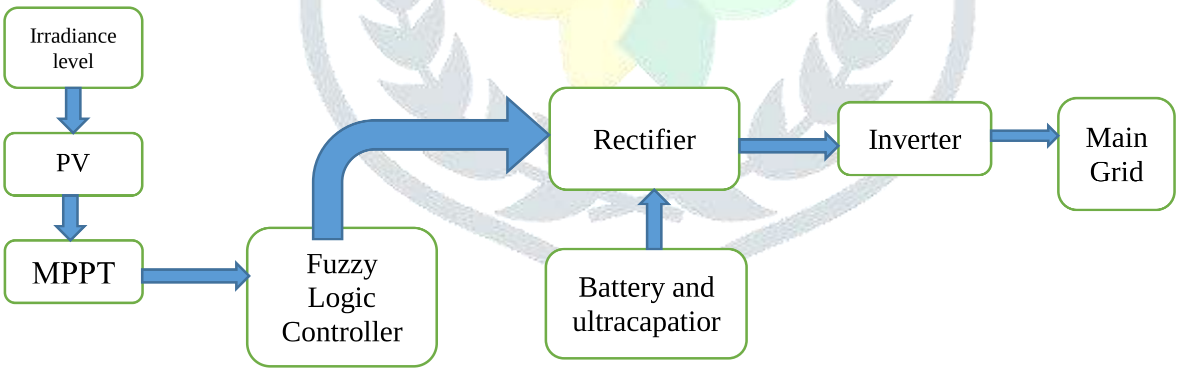


**Fig: 7 EMS system with FUZZY LOGIC Controller**

In this paper, the voltage raising type-pulse controller is considered. Two types of fuzzy controllers used for the control of boost converter are investigated; the simulation results confirm the above mentioned advantages. In order to prove the dynamic characteristics of the PID fuzzy controller being fast and robust, simulation studies using PSIM program are carried out and compared to the results of the conventional loop gain design method for which MATLAB program is used

An exact mathematical formulation of the problem is not possible.These difficulties are due to the time-varying nature of the given logic process. FLC logic is widely used in machine control. Fuzzy logic refers to the true or false. The fuzzy controller consists of three stages namely the input stage, processing stage, and output stage.

The input variables are mapped by the sets of membership functions known as fuzzy sets. A control system may have a truth table value equal to either 0 or 1. The controller accepts the input given by the system which is then given and maps them into their membership functions and truth values.

The basic drawback of fuzzy logic is it is completely dependent on human intelligence and expertise. These are not widely used due to the acquisition of inaccurate data. The efficiency of the system is not high because they majorly work on inaccurate inputs.

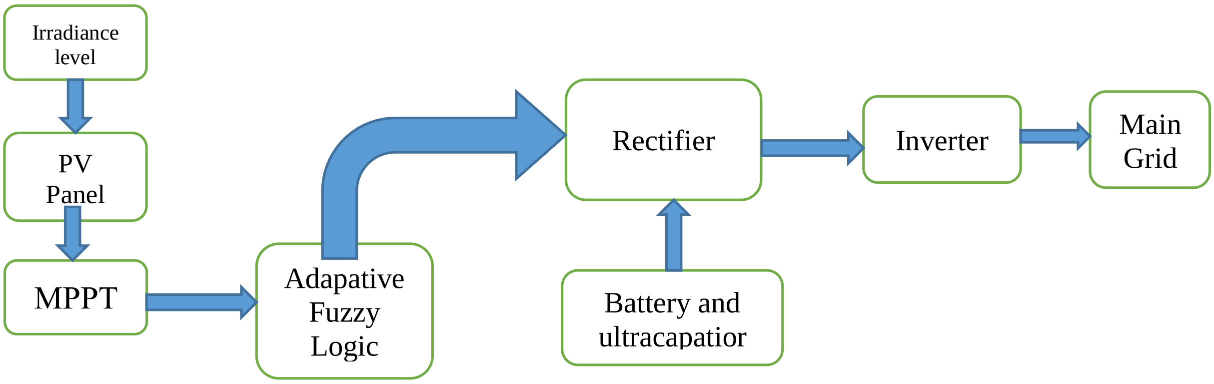


**Fig: 8 EMS system with ADAPTIVEFUZZY LOGIC Controller**

An adaptive neuro-fuzzy inference system or adaptive network-based fuzzy inference system (ANFIS) is a kind of artificial neural network that is based on Takagi–Sugeno fuzzy inference system. For using the ANFIS in a more efficient and optimal way, one can use the best parameters obtained by genetic algorithm

The ANFIS has some advantages, including the ability to capture the nonlinear structure of a process, adaptation capability, and rapid learning capacity. The ANFIS has been applied to many areas including economics, passenger demand forecasting, energy, and the environment. Automatic adaptation capability. Rapid learning Capacity High flexibility allows many variants.

- **Output waveforms of three modes of operation of Ems in different load step changes :**

  - ***Peak Shaving With the AC Grid Connected***

    A threshold is set for the load current, such that when the load RMS current exceeds this threshold, the EMS supplies some of the load current. This keeps the peak current drawn from the ac grid below a set limit.

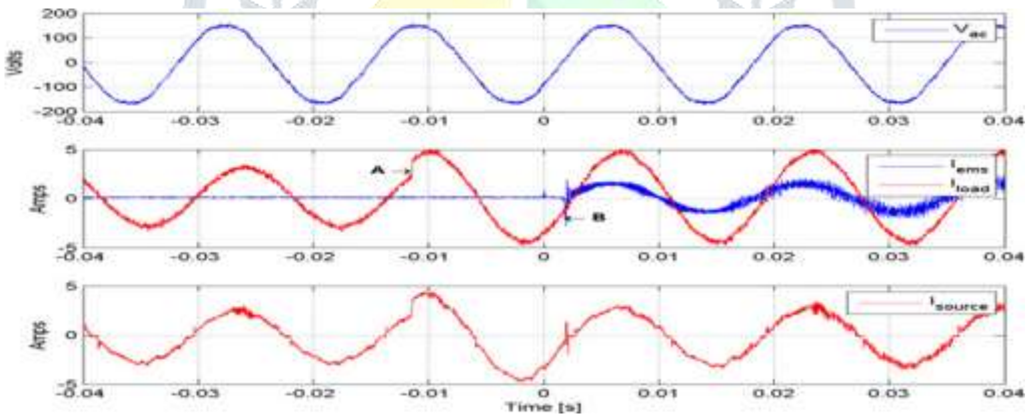


**Fig: 9** Peak shaving with the EMS providing some of the load current from the battery pack when the load increases.

  - ***Battery Charging With the AC Grid Connected***

    The EMS turns ON to charge the battery at $t = 0$ s in Fig. 11as demonstrated by the EMS current *I*ems being 180° out of phase with respect to the ac voltage. As can be noted from Table I, only linear loads are used for this experiment, because the diode rectifier load is disabled. The battery charging mode of operation is allowed because the load is light, so the EMS does not need to provide an additional current for peak shaving

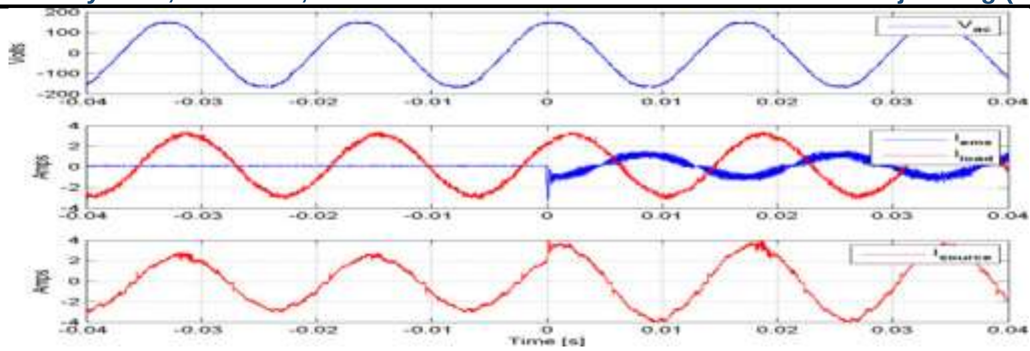


**Fig. 10**. EMS turning ON at t = 0 to charge the battery pack.

➢ ***Islanding Mode of Operation***

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, noncritical 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. Noncritical load shedding is easily accomplished by the EMS by opening the thyristor switch connected to the noncritical loads (shown in Fig. 1).When the ac grid is available again, then the EMS restores the loads to the ac grid, therefore, terminating the islanding mode of operation.

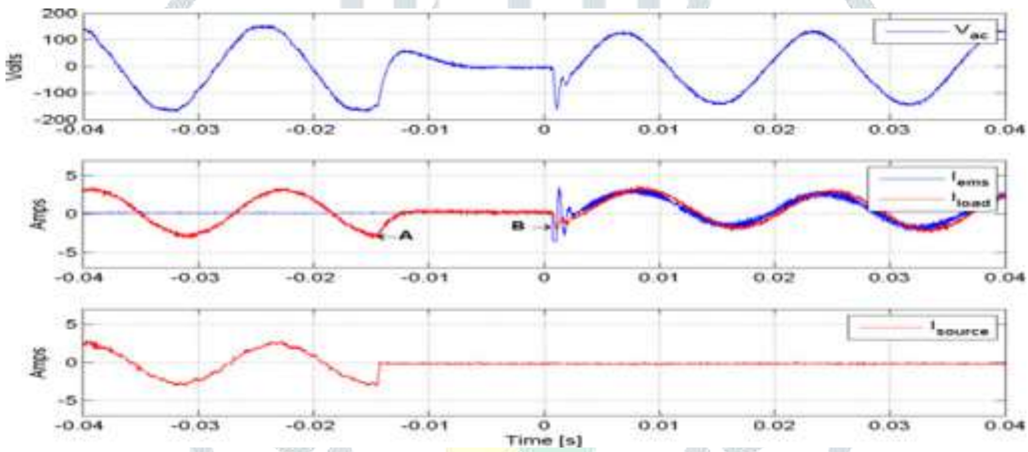


**Fig. 11**. Experimental waveforms showing ac grid failure and the EMS taking the loads into islanding mode.

## IV. RESULTS

- **Experimental results**

### 1. Fuzzy Logic Controller Output Waveforms

Based on a battery cycle life model and experimental results, it has been shown that the battery life extension of about 55% due to the battery/UC HESS with controlling the SOC (Source Connect) of ultracapacitor while smoothing the battery power profile can be achieved. It is clear that these acquirements increase the life spans of the battery, and ensures the feasibility of the hybrid system considering the defined input voltage range of the converter.

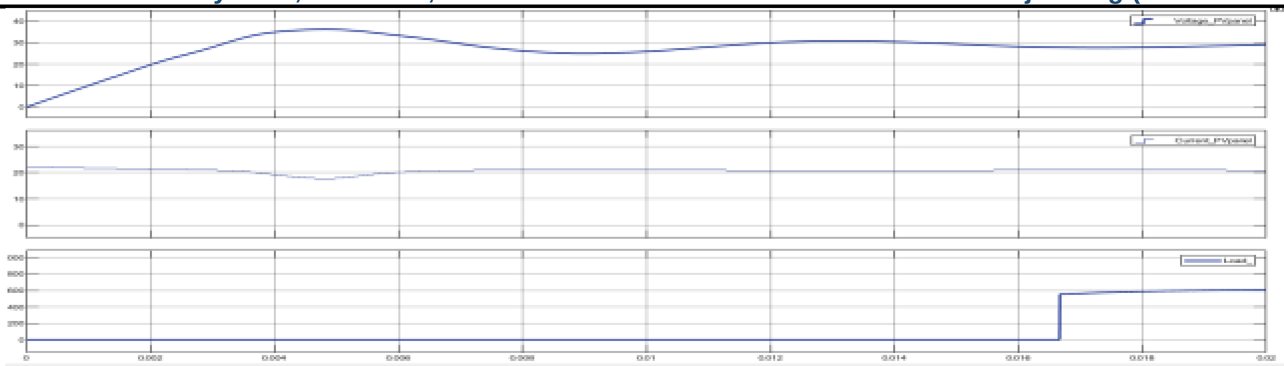

Fig: 12 PV Pannel Output

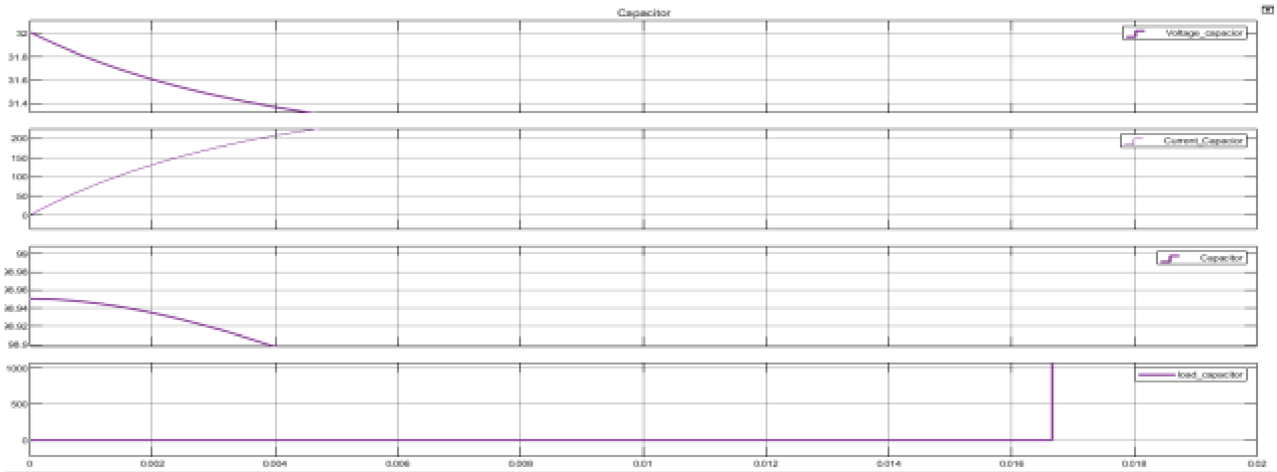


Fig: 13 Ultracapacitor Output

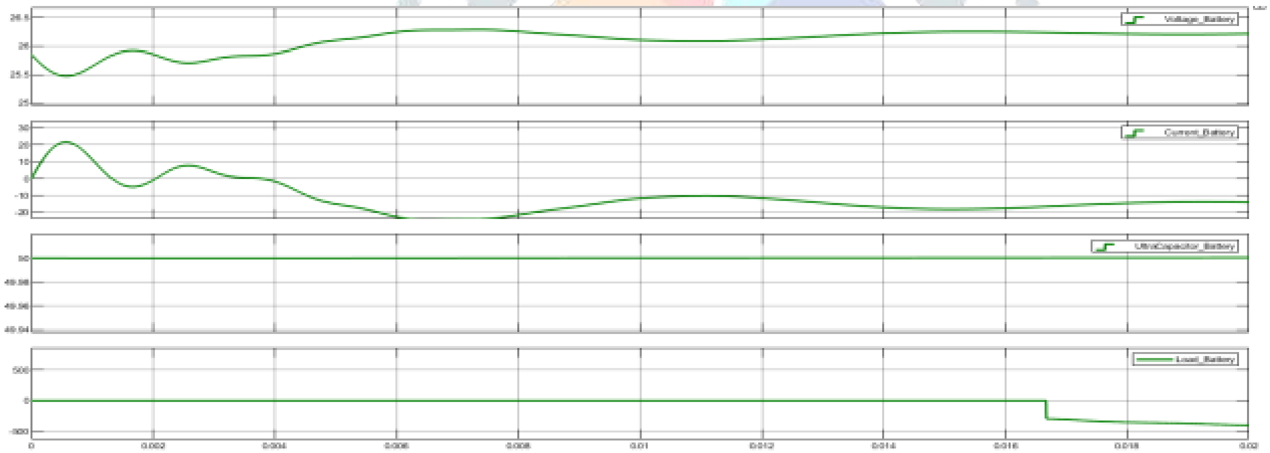


Fig: 14 Battery Output

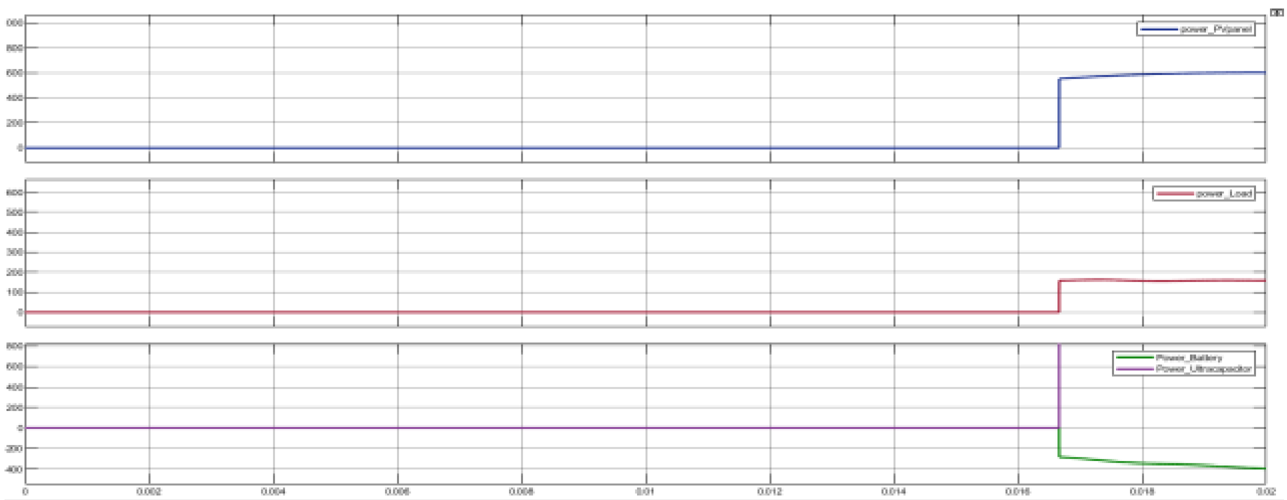


Fig: 15 Power Output

### 2. Adaptive Fuzzy Logic Controller Output Waveforms

An EMS has been designed for controlling the SOC of UC while extra smoothing the battery power profile. By applying this EMS, it is aimed to ensure the practicability of the hybrid system and to decrease the battery power peaks thus extending the battery cycle life. For better ENERGY MANAGEMENT SYSTEM "Adaptive Fuzzy Control System" is used .Adaptive Fuzzy Control is capability of the system to modify its own operation to achieve the best possible mode of operation.

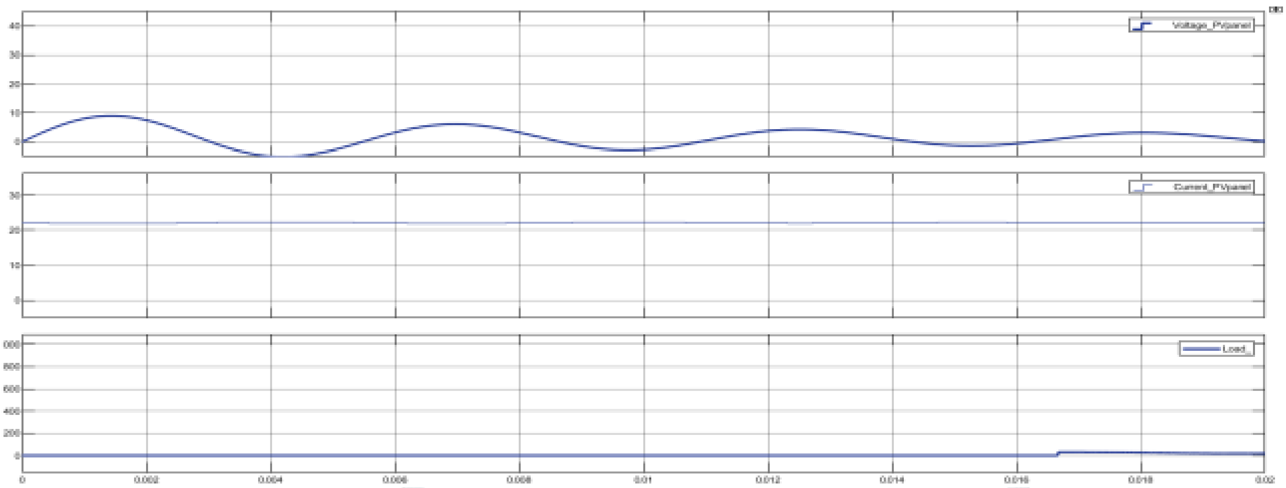

**Fig: 16** PV Pannel Output

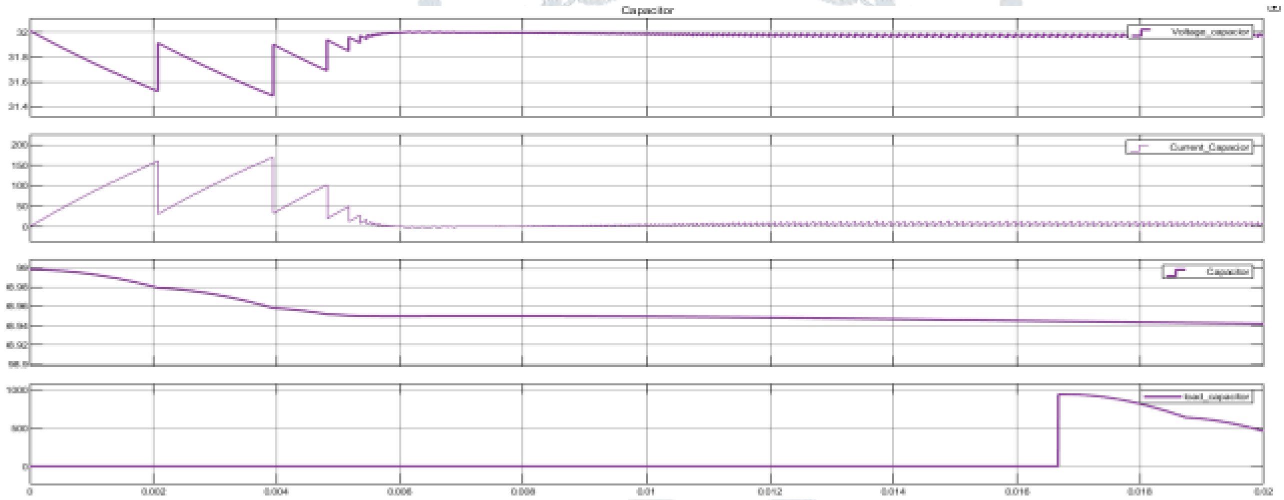


**Fig: 17** Ultracapacitor Output

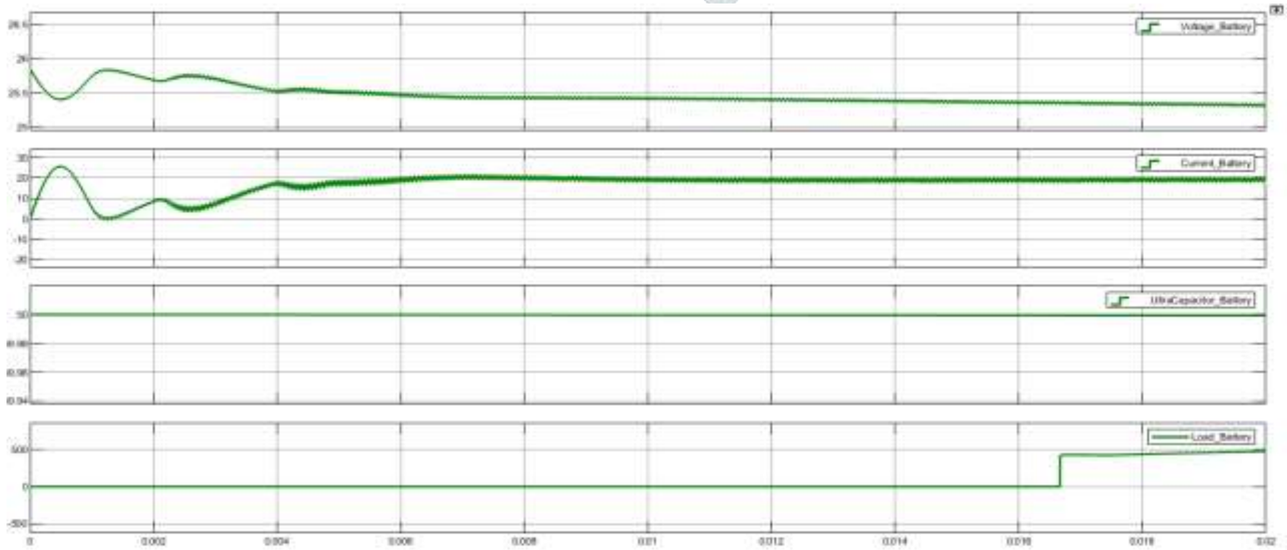

**Fig: 18** Battery Output

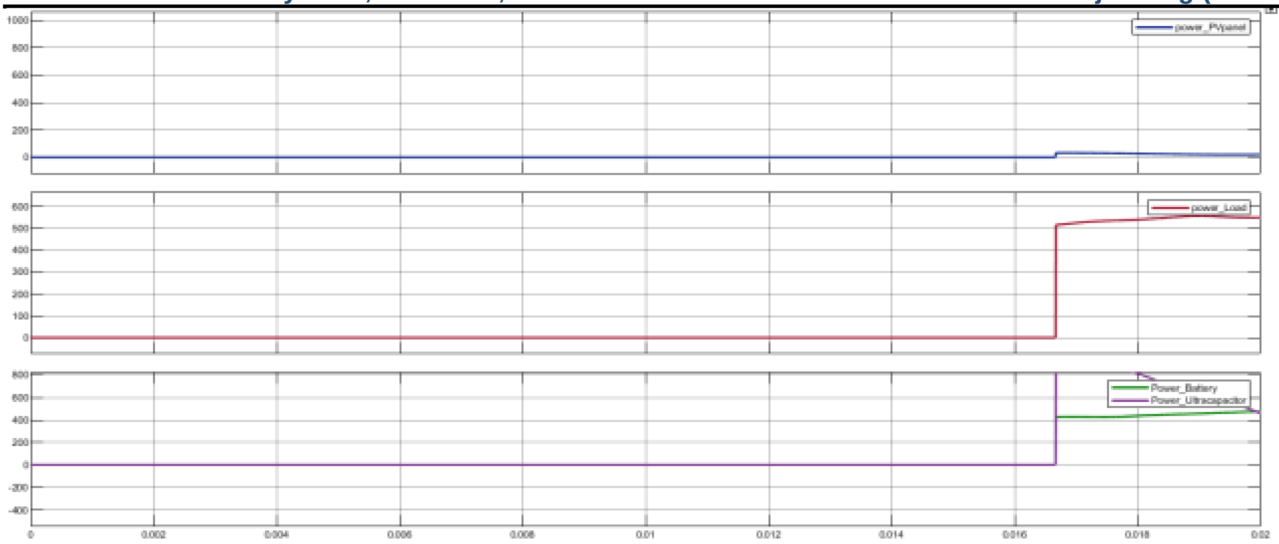


**Fig: 19** Power Output

## VI. CONCLUSION

This paper a fuzzy logic and adaptive fuzzy logic based energy management strategy (EMS) for a battery/ultracapacitor hybrid energy storage system (HESS) has been presented in this work. The HESS is composed of a bidirectional non-isolated multi-input dc-dc converter which can achieve power flow between each input source and output port. An EMS has been designed for controlling the SOC of UC while smoothing the battery power profile. By applying this EMS, it is aimed to ensure the practicability of the hybrid system and to decrease the battery power peaks thus extending the battery cycle life.

After analysing the proposed system, first of all, its performance has been tested via a simulation study based on UDDS. Finally, based on a battery cycle life model and experimental results, it has been shown that the battery life extension of about 55% due to the battery/UC HESS can be achieved. It is clear that these acquirements increase the life spans of the battery, and ensures the feasibility of the hybrid system considering the defined input voltage range of the converter.

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