Energy Management Systems with Storage

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Abstract:

The purpose of this paper is to explain the functionality of an Energy Management System (EMS) with storage. The EMS system consists of batteries, power converters and digitally controlled voltage source inverter (VSI) which can be regulated as either current source or a voltage source depending upon the AC grid status and customer's preference. A premier benefit of an EMS is to operate in islanding mode or provide continuous power supply to critical loads when the commercial electricity grid is lost. A secondary benefit is to reduce power consumption on the commercial electricity grid during peak power demand while islanded by performing peak power control. The modeling and simulation are done using MATLAB/Simulink.

Keywords: Energy Management System (EMS), Voltage Source Inverter (VSI), Peak power control, Islanding mode.

1. INTRODUCTION:

Efficient use of energy has become more and more important all around the world, stimulated by the Kyoto protocol and demanding immediate attention to reduce the utilization of fossil fuels. Access to the cheap energy has become essential for the functioning of modern economies. Access to cheap energy is sometimes called as energy security, is a necessity for many installations such as commercial, industrial and government facilities where reducing energy expenditure must be accomplished while serving critical loads at all times [1]. Peak power control, also known as peak shaving, is a method used to reduce the electrical charges for customers with a time of use (TOU) contracts and those who pay for the demand charges.

The three main objectives of this energy management systems:

1) Make electric power available to critical loads at all times with or without main grid service available.
2) Reduce peak power consumption to lower electricity costs, and
3) Store energy produced by Distributed Generation units [2].

2. CONSTRUCTION AND FUNCTIONALITY OF EMS:

Critical loads are those loads which must be powered at all the time because they are connected in series. Noncritical loads are connected in parallel to Vac however, they can be shed when necessary using thyristor switch as shown in the Fig. 1. The AC grid can also be disconnected from supplying the loads if needed to island the operation of EMS. Typically islanding mode occurs when an AC grid fails to supply power. In this mode of operation, the power to critical loads is assured by drawing energy from the battery pack.

The functionality of EMS has been simulated using MATLAB/Simulink . The following outlines are discussed:

1) Peak power control by tapping the energy storage system during high power demand,
2) Islanding mode of operation when the main AC grid fails or no longer available [3,4],
3) Battery charging mode.

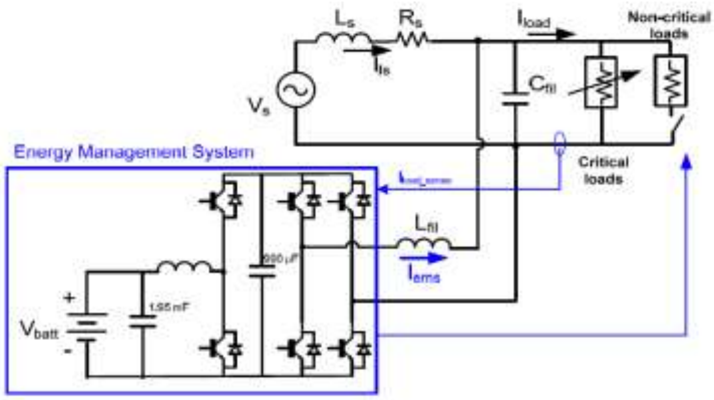

Fig. 1. EMS Construction

3 SIMULATION MODEL:

The simulation circuit of power electronics based energy management system with storage as shown in the Fig. 2. EMS presented in this paper consists of batteries and three leg power module. One leg of the three-phase IGBT module is controlled to achieve buck and boost power flow and H-bridge inverter from the other two legs of the module. The H- bridge inverter, thus, formed is connected to an output LC filter to produce a sinusoidal voltage for AC loads. There are two voltage sensors and two current sensors to monitor V_{dc}, V_{ac}, $i_{ems,}$ and i_{load} respectively. A battery back is connected to the first leg of buck and boost switch to achieve bi-directional flow of power to/from the battery.

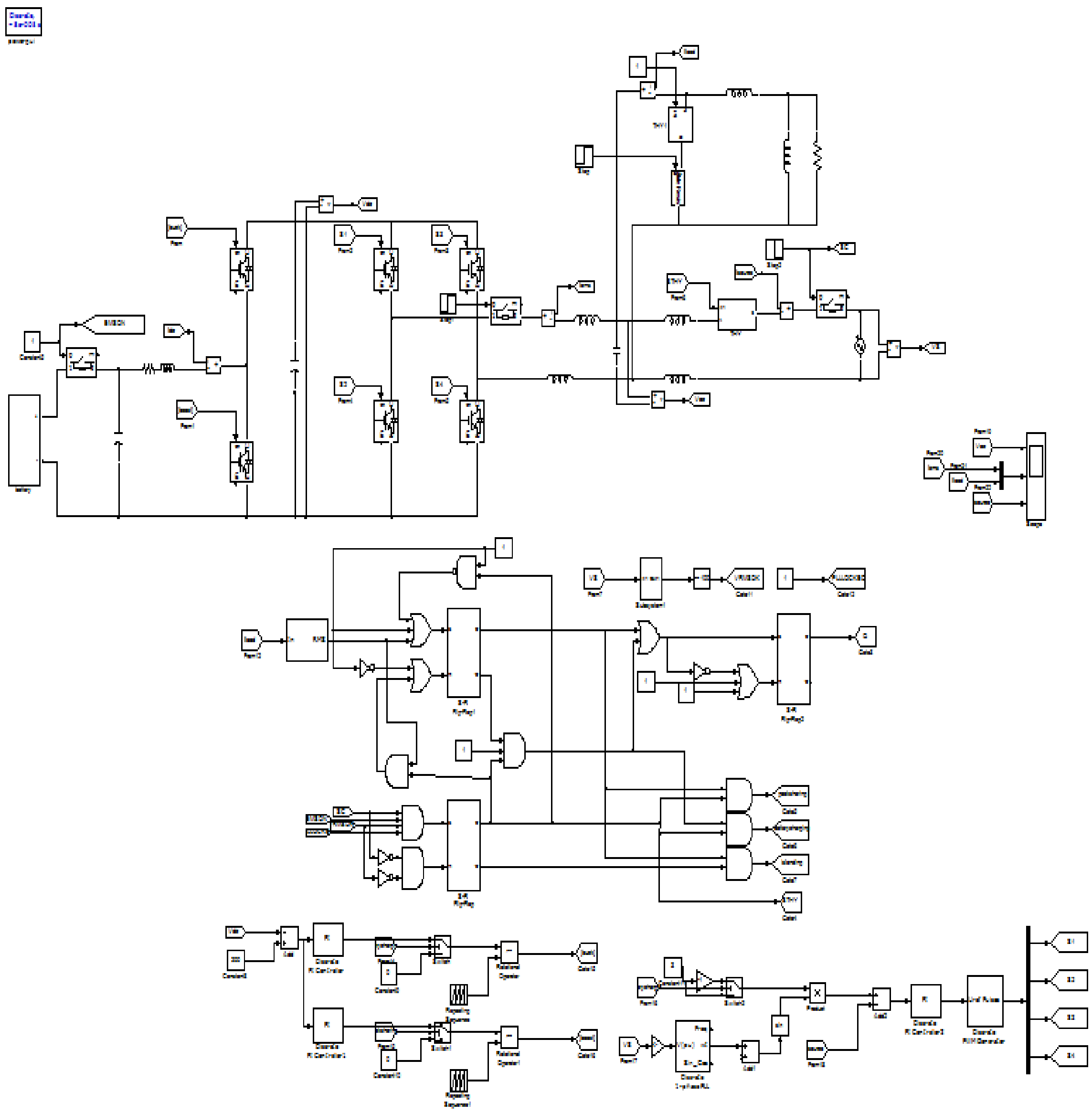

Fig. 2. Simulation Diagram

4 EMS CONTROL SYSTEM:

There are two different levels of control for the Energy Management System. The primary control system includes the power converter module controllers, which generate the gate drive signals. The secondary control system is a higher level controller, which can include customer input and makes decisions based on factors such as battery state of charge and lifetime, cost of electricity, time of day, load priority etc. There are four secondary controller inputs distinct logical commands; Run, charge, Source Connect (SC) and Current Threshold (CT).

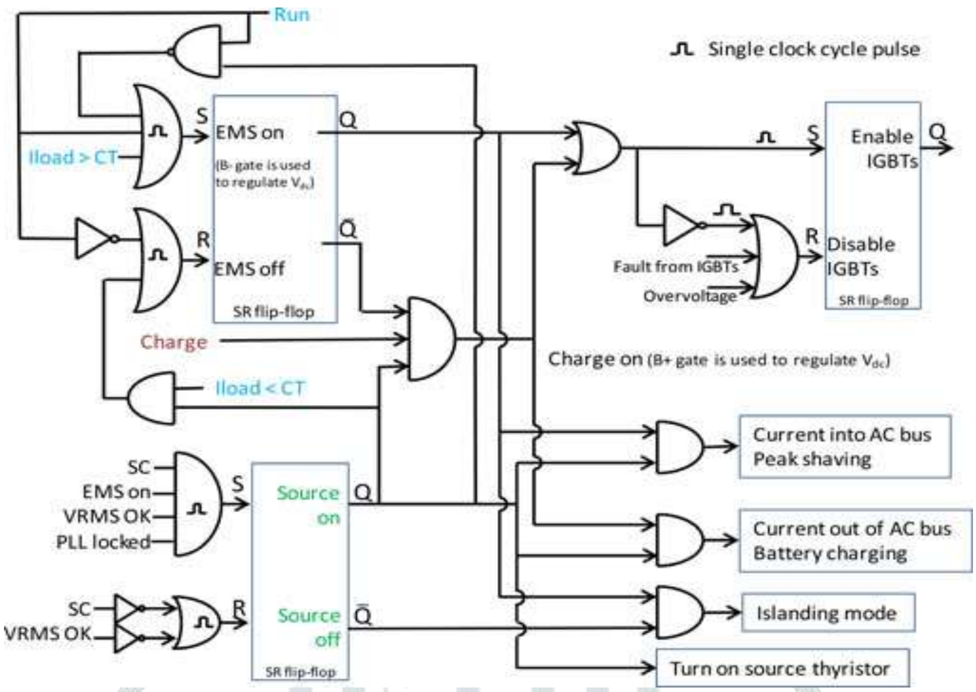

Fig. 3. EMS logic diagram

Fig. 3 shows the controller logic diagram of EMS. If Run is high, the EMS will operate in islanding mode. If Run is low, EMS does nothing. If charge is high, battery will be charged through EMS. If SC is high, EMS will connect Vac to the AC source if the AC source RMS voltage is above 100 Vrms. If the load current exceeds the peak power control (CT), then EMS will continue to inject current otherwise, EMS will turn off after connecting to AC source. If Vrms OK is high, the AC grid RMS voltage is above a set threshold. If the signal is low, the EMS switches from grid connect to islanding mode of operation. There are three different modes of EMS control namely:

1) EMS control in islanding mode [5]
2) EMS control in current injection mode [5]
3) DC bus control algorithm [5]

5 SIMULATION RESULTS:

5.1 Peak shaving and battery charging with the AC grid connected:

Commercial and industrial customers save on their electricity bills by reducing peak power consumption. Energy is stored when electricity cost is low and uses during the pace when the electricity costs are high. Peak power control is also similar to load levelling, but maybe for the purpose of reducing the peak power consumption.

Peak power control is attained by controlling the RMS current in the load, which is related to the source current. A threshold value is set for the load current, such that when the RMS current overshoot this threshold value, the EMS supplies some of the load current. This keeps the peak current drawn from AC grid below a set limit. The threshold value can be changed by altering the EMS reference current by the secondary controller. The EMS can be computerized to provide reactive power as well as current harmonics as required by the customer.

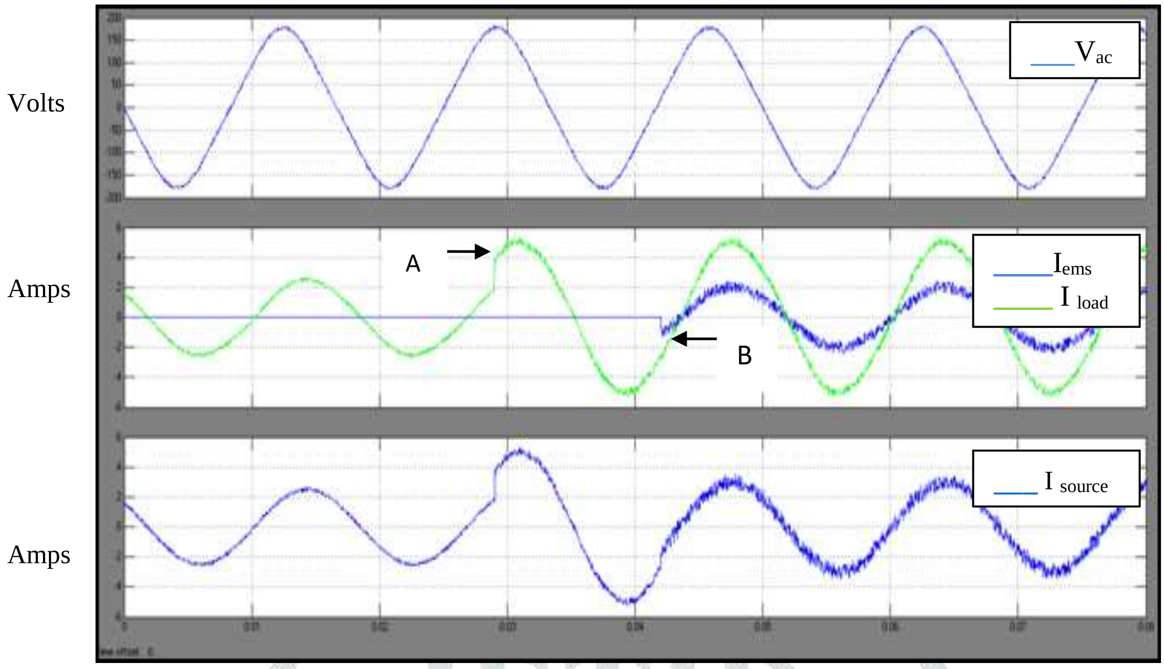

Fig. 4. Peak shaving with the EMS providing some of the load current from the battery pack when the load increases. Load 2 steps from 600 to 80 Ω (A), and then, the EMS turns ON (B). All the loads are linear.

The EMS turns ON to charge the battery Fig. 5 as explained by the EMS current being 180 degrees out of phase with respect to AC voltage. When the electricity cost is low and loads are light, the secondary controller turns ON the battery charger mode.

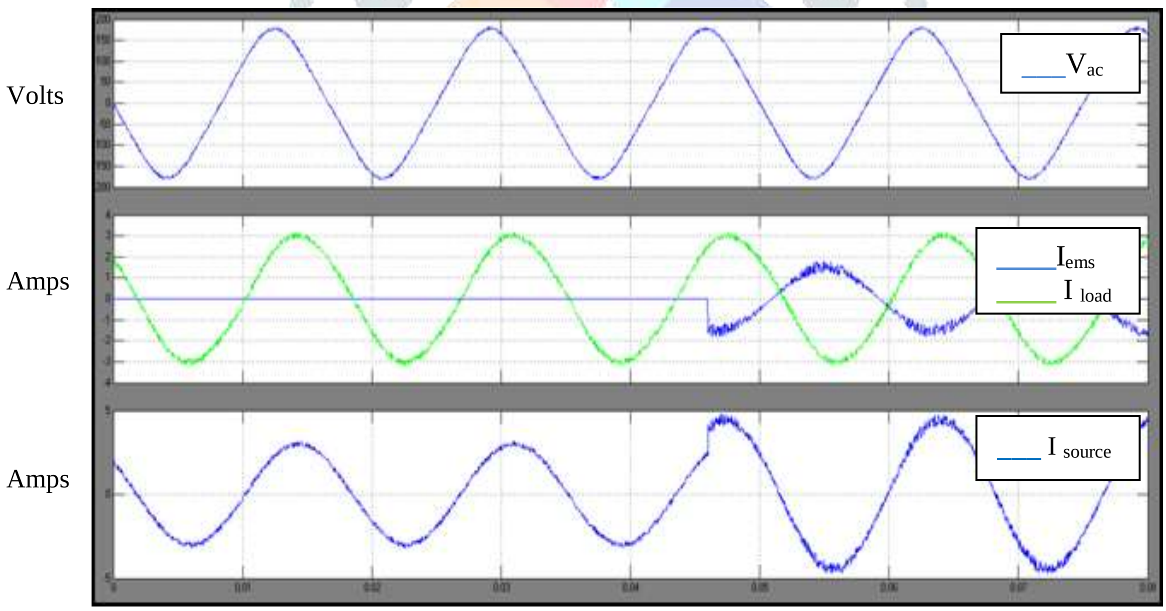

Fig. 5. EMS turning ON at t=0 to charge the battery pack

5.2 **EMS powering critical loads when AC grid fails- Islanding mode:**

When the ac grid fails, in order to supply energy to critical loads. EMS detects the failure of an AC grid and acts as a voltage source for critical loads. Noncritical loads can be shed depending upon the state of battery charge and shedding can be achieved by the EMS by opening the thyristor switch connected to the noncritical loads. When the AC grid is accessible, then EMS renews the loads to the AC grid, consequently halting the operation of islanding mode.

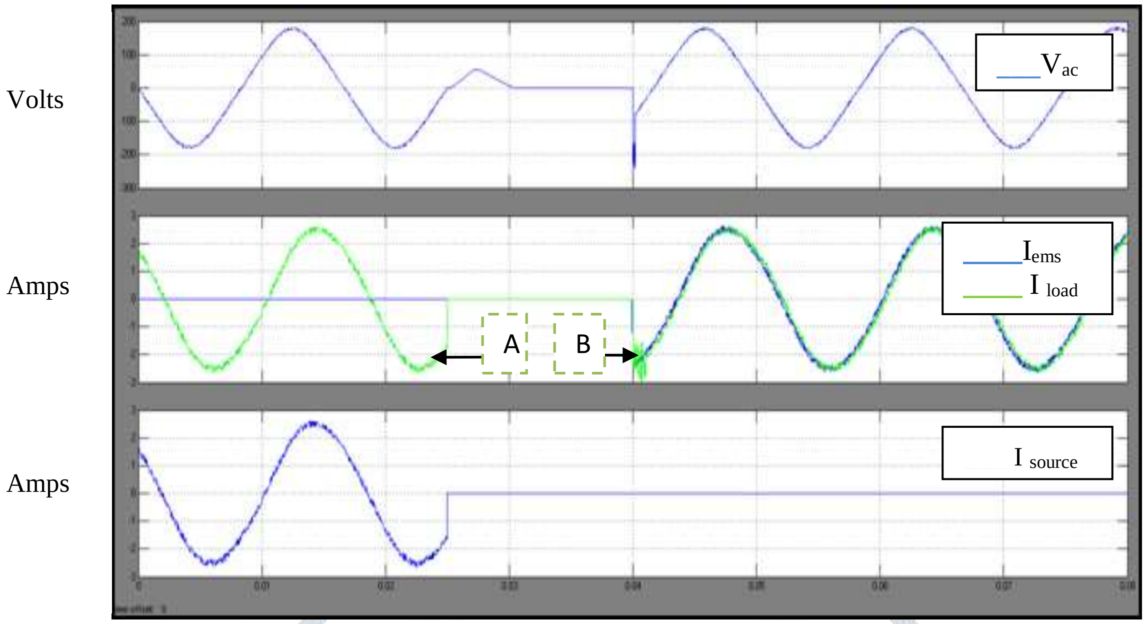

Fig. 6. Experimental waveforms showing AC grid failure (A) and the EMS taking the loads into islanding mode (B).α=20π.

The RMS voltage of the AC bus is checked to detect when islanding mode is required. There is a delay in the detection of the loss of the source due to low pass filter in the detection algorithm, the low pass filter with a corner frequency can be adjusted in order to change the speed of transition from grid connect to islanding mode.

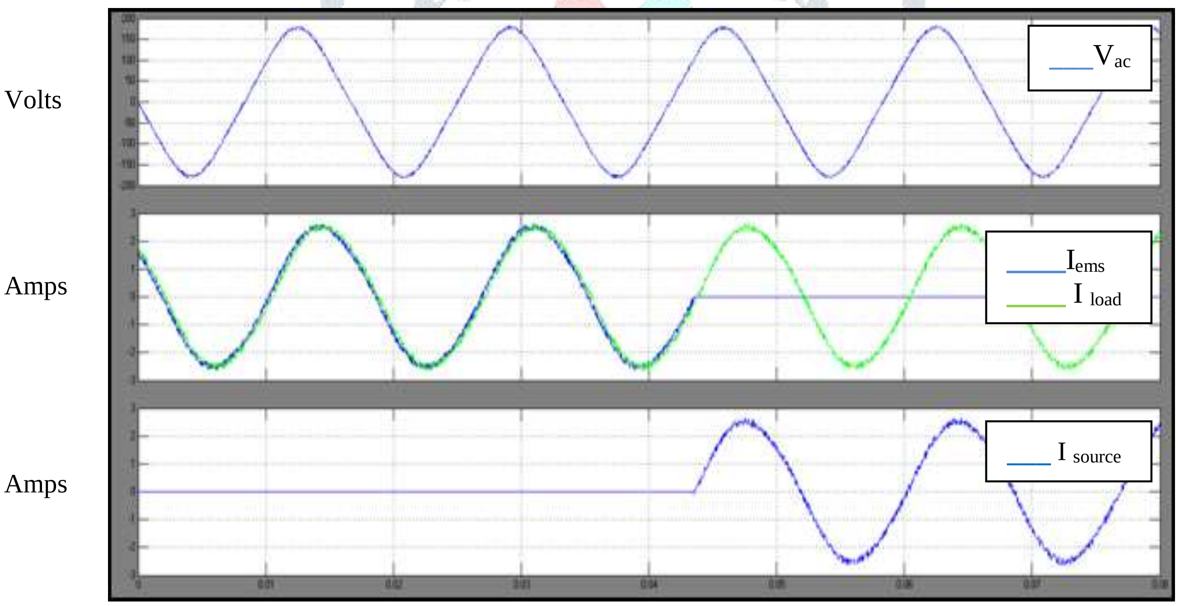

Fig. 7. Experimental waveforms showing the AC grid being restored at t=0.

6 CONCLUSION:

In this paper, the EMS functionality is demonstrated with a simulation. Simulation results are shown to demonstrate how EMS supports critical loads when AC is grid is unavailable and how the connection is restored when AC grid is available. Additionally EMS can achieve peak power control and electrical energy is stored during the times when electricity cost is low and used during the times when the electricity cost is high, in order to reduce the electricity charges.

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