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Power-Electronics-Based Energy Management System with Storage

Miss Sujata B. Girawale

Electronics and Telecommunication Dept, G.H.R.C.E.M, Ahmednagar, Maharashtra, India

Abstract: This paper demonstrates the proposed functionality of a power electronics-based energy management system (EMS). The EMS includes batteries and a digitally controlled single-phase voltage source inverter (VSI), which can be controlled as a current source or a voltage source depending on the status of the ac grid and the user's preference. The proposed EMS can give guarantees that the critical loads are powered when the ac grid fails; in which case, the VSI is controlled as a voltage source. It also expect peak power control by supplying battery power to the local loads while they are powered by the ac grid if the loads get large. The electricity cost savings will be accomplished by peak shaving are estimated. The control architecture and logic embedded in the EMS are discussed in detail.

Keywords: EMS, Peak power control, Cost saving, Peak shaving, Islanding mode.

1 INTRODUCTION

1.1 BACKGROUND

The Department of Defense (DOD) is researching methods to enhance energy security and reduce energy costs [1]. The energy security of DOD facilities rely on the commercial electricity grid. This places the operations of these facilities and the missions they support at risk.

Power electronics is a key enabling technology to interface DR to the grid and to provide the control features necessary to build a more controllable power system [6]–[8]. A digitally controlled power electronics based energy management system (EMS) can provide power flow metering and control, fault detection and correction, reliability improvements, improved electrical system security, increased generation efficiencies and other capabilities [9]–[13]. If an EMS is interfaced with the commercial electricity grid and a microgrid, then it can improve electrical energy security and reduce electrical energy cost with enhanced energy management. A block diagram of an EMS interfaced with the commercial electricity grid and a microgrid is shown in fig.1.

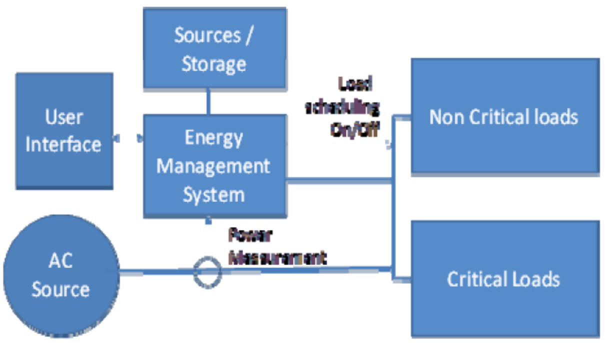

Fig .1-An EMS interfaced with the commercial electricity grid and a microgrid

Peak power control, also known as peak shaving, is a method used to reduce the electricity charges for users with time of use (TOU) contracts and those who pay for the demand charges [1]. 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.

However, if DG units, such as photovoltaic panels or diesel generators, are part of the installation the EMS can manage these resources. The EMS proposed in this paper includes energy storage in the form of batteries in order to accomplish three main goals: 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 DG units or during the time in which electricity from the grid is least expensive.

Recently researchers have used power converters to implement power management or EMS for ac and dc microgrids. Results in the literature include power quality solutions [5], stability issues [6], high frequency microgrids [7], dc microgrids [8], [9], renewable generation interface [10]–[12], optimized thirdlevel microgrid control (as described in [3]) with load and generation forecast [13]. Most publications have focused on the energy management of microgrids including several distributed resources (DR) [2], While in this paper, we focus on managing a power system that includes battery storage. Furthermore, many referenced publications deal with three-phase systems, this paper, while following along the same line of research, introduces the prospective of continuous service to critical loads with peak power shaving. It also includes a simple economic analysis to demonstrate the advantages of the peak power shaving method. EMS presented in this paper is the use of a single off-the-shelf three-leg integrated power module to accomplish all the required tasks including battery charging, peak shaving, and fault tolerance.

A. MICROGRID

The microgrid concept can be applied to any subsystem currently attached to the distribution grid. The size of the microgrid can vary. Multiple coordinating microgrid may be necessary to support a single building or one microgrid

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may be sufficient to support a single family home. In either case, each microgrid coupled with an EMS should be sized based off the critical loads it supports and the DR available to support those critical loads. For the purposes of this research, a single family home was chosen to represent the loads of a potential microgrid. To apply the conclusions drawn from this approach to a larger building or multiple buildings, the power capability of the microgrid's DR would have to be increased or the building would have to be broken down into multiple microgrid capable of coordinating together or operating independently to support all the critical loads

1.2 Energy Management Systems

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. These monitor and control functions are known as SCADA; the optimization packages are often referred to as "advanced applications". 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 center operators. It is also possible to acquire an independent DTS from a non-EMS source such as EPRI Energy management systems are also often commonly used by individual commercial entities to monitor, measure, and control their electrical building loads. Energy management systems can be used to centrally control devices like HVAC units and lighting systems across multiple locations, such as retail, grocery and restaurant sites. Energy management systems can also provide metering, sub metering, and monitoring functions that allow facility and building managers to gather data and insight that allows them to make more informed decisions about energy activities across their sites.

1.3 Energy Storage

Energy storage is the capture of energy produced at one time for use at a later time. A device that stores energy is sometimes called an accumulator. Energy comes in multiple forms including radiation, chemical, gravitational potential, electrical potential, electricity, elevated temperature, latent heat and kinetic. Energy storage involves converting energy from forms that are difficult to store to more conveniently or economically storable forms. Bulk energy storage is dominated by pumped hydro, which accounts for 99% of global energy storage. Some technologies provide short-term energy storage, while others can endure for much longer.

A wind-up clock stores potential energy (in this case mechanical, in the spring tension), a rechargeable battery stores readily convertible chemical energy to operate a mobile phone, and a hydroelectric dam stores energy in a reservoir as gravitational potential energy. Fossil fuels such as coal and gasoline store ancient energy derived from sunlight by organisms that later died, became buried and over time were then converted into these fuels. Food (which is made by the same process as fossil fuels) is a form of energy stored in chemical form. Ice storage tanks store ice (thermal energy in the form of latent heat) frozen by otherwise wasted energy at night to meet peak daytime demand for cooling. The energy isn't stored directly, but the effect on daytime consumption is equivalent.

The energy present at the initial formation of the universe is stored in stars such as the Sun, and is used by humans directly (e.g. through solar heating), or indirectly (e.g. by growing crops or conversion into electricity in solar cells). As a purposeful activity, energy storage has existed since pre-history, though it was often not explicitly recognized as such. An example of mechanical energy storage is the use of logs or boulders as defensive measures in ancient forts—the logs or boulders were collected at the top of a hill or wall, and the energy thus stored was used to attack invaders who came within range.

In the twentieth century grid electrical power was largely generated by burning fossil fuel. When less power was required, less fuel was burned. Concerns with air pollution and global warming have spurned the growth of intermittent renewable energy such as solar and wind power. Wind power is uncontrolled and may be generating at a time when no additional power is needed. Interest in storing this power grows as the industry grows. Off grid electrical use was a niche market in the twentieth century, but in the twenty first century it has expanded. Portable devices are in use all over the world. Solar panels are now a common sight in the rural settings worldwide. Access to electricity is now a question of economics, not location. Powering transportation without burning fuel, however, remains in development.

2 PROPOSED SYSTEM OVERVIEW

2.1 PROPOSED ARCHITECTURE AND CONTROL ALGORITHM

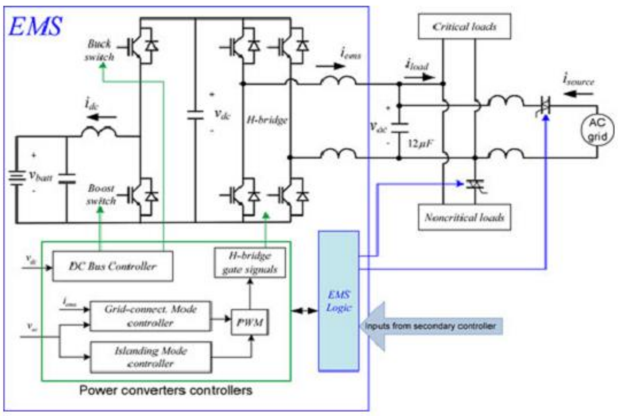

Fig -1 EMS architecture

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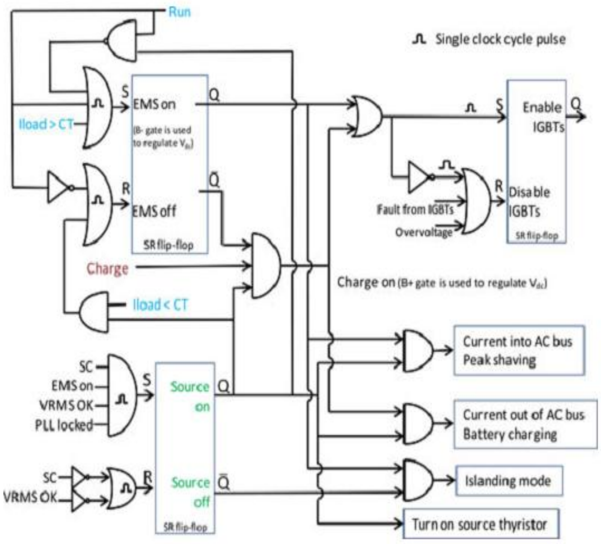

Fig. 2 EMS logic flowchart Run, Charge, SC and CT are inputs from the operator or secondary controller.

The EMS control algorithm was developed with the following goals, listed here in order of priority:

1 Power must be available to the critical loads at all times. As an example, if the main power supply (commercial electricity grid) is down, then battery power will be used to support critical load operation.
2 Reduce the peak power demand of the microgrid on the main power source by using battery power and by non-critical load shedding.
3 Maximize the state of charge of the battery.
4 Make power available to non-critical loads.

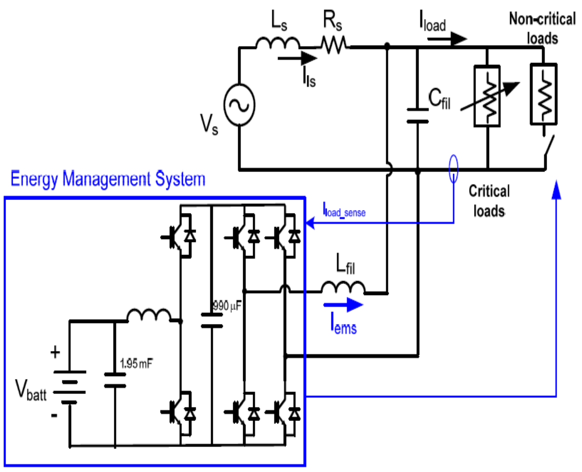

Fig 3- proposed EMS structure

3. SOFTWARE OVERVIEW

3.1 MATLAB/ SIMLUNK:

Simulink is a platform for multidomain simulation and model-based design of dynamic systems. It provides an interactive graphical environment and a customizable set of block libraries that let you accurately design, simulate, implement, and test control, signal processing, communications, and other time-varying systems. Add-on products extend the Simulink environment with tools for specific modeling and design tasks and for code generation, algorithm implementation, test, and verification.

Simulink is integrated with MATLAB, providing immediate access to an extensive range of tools for algorithm development, data visualization, data analysis and access, and numerical computation. Creating and Working with Models. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis.With Simulink, you can quickly create, model, and maintain a detailed block diagram of your system using a comprehensive set of predefined blocks. Simulink provides tools for hierarchical modeling, data management, and subsystem customization, making it easy to create concise, accurate representations, regardless of your system's complexity.

Key features

- Extensive and expandable libraries of predefined blocks
- Interactive graphical editor for assembling and managing intuitive block diagrams.
- Ability to manage complex designs by segmenting models into hierarchies of design components.
- Model Explorer to navigate, create, configure, and search all signals, parameters, and properties of your model
- Ability to interface with other simulation programs and incorporate hand-written code, including MATLAB algorithms.
- Option to run fixed- or variable-step simulations of timevarying systems interactively or through batch simulation.
- Functions for interactively defining inputs and viewing outputs to evaluate model behavior.
- Graphical debugger to examine simulation results and diagnose unexpected behavior in your design.
- Full access to MATLAB for analyzing and visualizing data, developing graphical user interfaces, and creating model data and parameters
- Model analysis and diagnostics tools to ensure model consistency and identify modeling errors.

4. CONCLUSION

Thus, we have studied power electronics based EMS which can give us controlling and management of power with storage facility. The control system designed to perform the experimental implementation of typical scenarios is presented in detail. EMS can supports critical loads when the ac grid becomes unavailable and how the connection to the ac grid is restored by the EMS when the ac grid becomes available again. Additionally, the EMS can accomplish other advantageous tasks such as peak shaving. Also EMS can controlled in current mode which provides some of the power to the loads to accomplish peak shaving, thus reducing the cost of electricity.

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