ENERGY MANAGEMENT SYSTEM BASED ON POWER ELECTRONICS

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Abstract:
This paper demonstrates the 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 EMS 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 accomplishes 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 accomplished by peak shaving are estimated. The EMS functionality is demonstrated by experimental measurements on a laboratory prototype. The control architecture and logic embedded in the EMS are discussed in detail.

Keywords: Microcontroller (LPC2148), optocoupler, energy meter, battery.

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 this paper a power electronics based energy management systems (EMS) is presented to accomplish peak power control in a single phase power system while guaranteeing continuous service to critical loads at the same time. 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 microgrid, 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: a) make electric power available to critical loads at all times with or without main grid service available b) reduce peak power consumption to lower electricity costs and c) 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 energy management systems (EMS) for AC and DC microgrids. Results in literature include power quality solutions [7], stability issues [8], high frequency microgrids [9], DC microgrids [10][11],
renewable generation interface [12][13][14], optimized third level microgrid control (as described in [3]) with load and generation forecast [15][16]. Most publications have focused on the energy management of microgrids including several distributed resources (DR)[2][17][18][19][20], while in this paper we focus on managing a power system that includes battery storage. Furthermore, many referenced publications deal with three phase systems, while this paper focuses on a single phase inverter based EMS. Carnieletto et al. in 2011 [21] and, more recently, Wai et al. [22] and de la Fuente et al. [23] have presented single phase inverters for grid interface in both grid connected and stand-alone mode of operation. This paper, while following along the same line of research, introduces the prospective of continuous service to critical loads with peak power shaving.

II. The Hardware System

Micro controller:

This section forms the control unit of the whole project. This section basically consists of a Microcontroller with its associated circuitry like Crystal with capacitors, Reset circuitry, Pull up resistors (if needed) and so on. The Microcontroller forms the heart of the project because it controls the devices being interfaced and communicates with the devices according to the program being written.

Arm7tdmi:

ARM is the abbreviation of Advanced RISC Machines, it is the name of a class of processors, and is the name of a kind technology too. The RISC instruction set, and related decode mechanism are much simpler than those of Complex Instruction Set Computer (CISC) designs.

Liquid-crystal display:

Lcd is a flat panel display, electronic visual display that uses the light modulation properties of liquid crystals. Liquid crystals do not emit light directly. Lcds are available to display arbitrary images or fixed images which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

III. Design of Proposed Hardware System

In this project we will maintain energy consumption of different Renewable energy sources of household and also control the appliances. Generally, renewable energy sources are using effectively for household purpose the units of load consumption are transmitted. So that consumer can maintain data base. Hence, consumer can know the indoor environment
consumption units and also he can control the home appliances. The EMS 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 accomplishes 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 accomplished by peak shaving are estimated. The EMS functionality is demonstrated by experimental measurements on a laboratory prototype. The control architecture and logic embedded in the EMS are discussed in detail.

Opto Couplers:

There are many situations where signals and data need to be transferred from one system to another within a piece of electronics equipment, or from one piece of equipment to another, without making a direct electrical connection. Often this is because the source and destination are (or may be at times) at very different voltage levels, like a microcontroller which is operating from 5V DC but being used to control a triac which is switching 230V AC. In such situations the link between the two must be an isolated one, to protect the microprocessor from over voltage damage. Relays can of course provide this kind of isolation, but even small relays tend to be fairly bulky compared with ICs and many of today's other miniature circuit components. Because they are electro-mechanical, relays are also not as reliable and only capable of relatively low speed operation. Where small size, higher speed and greater reliability are important, a much better alternative is to use an Optocoupler. These use a beam of light to transmit the signals or data across an electrical barrier, and achieve excellent isolation.

Energy Meter:

An electricity meter or energy meter is a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour. Periodic readings of electric meters establish billing cycles and energy used during a cycle. In settings when energy savings during certain periods are desired, meters may measure demand, the maximum use of power in some interval. In some areas the electric rates are higher during certain times of day, reflecting the higher cost of power resources during peak demand time periods. Also, in some areas meters have relays to turn off nonessential equipment.

EMS Control in Islanding Mode:

Islanding or stand-alone mode occurs when the AC grid is deenergized or the EMS is disconnected from the AC grid. The control algorithm for this mode of operation. The amplitude of the AC voltage, \( v_{ac} \), is set to 110 Vrms. The electrical angle, \( \phi \), is defined by...
integrating the angular frequency which is set to 60 Hz. Unipolar pulse width modulation (PWM) is used to drive the H-bridge IGBTs. This open loop control algorithm does not compensate for RMS output voltage deviations or provide any active damping but these capabilities are easily implemented as required.

IV. Conclusion

In this paper the functionality of a power electronics based EMS is demonstrated with a laboratory prototype. The control system designed to perform the experimental implementation of typical scenarios is presented in detail. Experimental data is shown to demonstrate how the EMS 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. Experimental measurements with linear and non-linear loads demonstrate how the EMS, controlled in current mode, provides some of the power to the loads to accomplish peak shaving, thus reducing the cost of electricity. A simple economic analysis is provided in support of this statement.

V. Results

VI. References

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