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Active Power Management Using Embedded Systems Technology: A Case Study of Power Automation System of Orpheus Communications

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Abstract— This work is focused on monitoring and management of industrial or household electrical power facility through automation using Enhanced RISC microcontrollers and electronic sensors hereby reducing power expenditure and increasing energy efficiency.

Index Terms— Embedded Systems, Eucalyptus, RISC Architecture Microcontrollers, Active Power Management, Power Automation, Sensors, Data Processing.

1 Introduction

Due to the rapid increase of functionality in mobile devices, embedded technology engineers are continually tasked with finding solutions to improving power management. [1] However, embedded systems can be of extensive application in immobile large scale especially industrial power management. Manufacturing Industries, Isolated Structures, Communication Towers, Research Institutes, and Countries with Poor Power Infrastructure need efficient power management so as to get maximum use from the limited power produced. This work is carried out in a small scale scenario where certain conditions such as Failing Commercial Power, poor energy management system and dubious manipulation of commercial power bills are obtainable. These conditions also warrant the use of alternative sources of energy in the form of fossil fuel engine generators which are quite expensive for continuous operation. [2] [3] Industrial power annual expenditure in places of existing power supply challenges may range between 4 – 10% of running costs. In the instance of our case study, an average of 12% of running cost goes to power.

Embedded systems are best for this work. [4][5]Since an embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints - and it is *embedded* as part of a complete device often including hardware and mechanical parts, we can use it to control multiple processes required for this project.

A networked control of current traffic, electrical consumption computation, fuel consumption analysis, etc will all be in progress synchronously. The embedded network needs to make decisions, record and trigger multiple events while ongoing processes are not interrupted. This complicated grid therefore requires a Microcontroller network to switch relays, make computations and carry out regulation.

1.1 Control Board Circuitry

For simplicity, this work makes use of Atmel ATmega328P Microcontrollers working to control different units of the circuitry. The Atmel ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. [6]Below is a block diagram of the Microcontroller network:

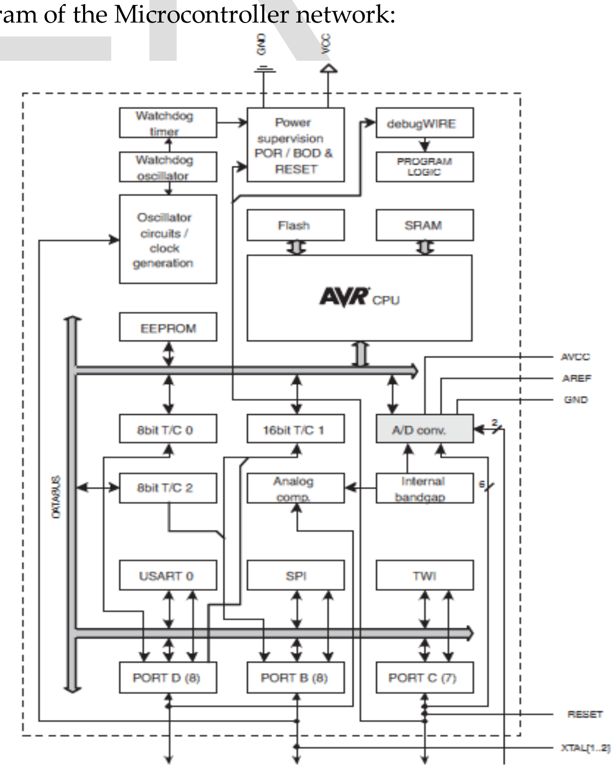

Figure 1. Block Diagram of ATmega328P [6]

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The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

1. CONTROL BOARD ARCHITECTURE

In order to acquire data, different sensors were utilized practically and hypothetically. The Sensors from their various positions may signal the control board either wirelessly or through means of data cables.

The control board consist mainly of the microcontroller and the circuit components. Data acquisition is done through the sensors. The data is processed and decisions are made automatically according to the firmware encoded in the microcontrollers or through prompts to the User via the computer software. These prompts may pop up through the mobile phone application or through the Central Monitoring System via a network.

The structure of this system is divided into four different parts:

- The Sensor Network
- The Microcontroller Unit
- The Response Network
- Central Monitoring Software (Eucalyptus[1])

1.1 Sensor Network

These comprises of group of sensors in their different locations that will be used to acquire the data needed for the microcontroller to make decisions. In the instance of this case study, the important data of note includes:

i. Fuel Volume in Storage Tank
ii. Fuel Volume in Generator Tank
iii. Temperature of Environment
iv. Sunlight Intensity to detect daylight and Night Hours
v. Motion Sensors to detect Human Activity
vi. Voltage Level Sensors to detect check availability of power in the different sources.[2]

The sensor network is as shown below:

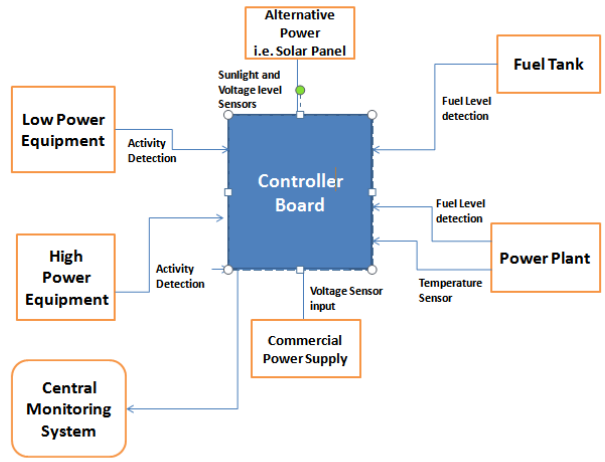

Figure 2. Block Diagram of Sensor Network

1.2 Microcontroller Unit

Depending on the facility requirements, one or more ATmega chips could carry out all the automation required. In this respect, a single chip is used. All sensors are connected via an interfacing circuitry i.e. wireless modules, voltage regulators, relays, etc as inputs to the MCU. The expected output pins are then connected to the interfacing circuitry, then to the response network.

The microcontroller logic is written in "C" such that data is read from the sensors, computations and decisions are then made.

If the diesel volume in the storage tank is below a specified level, the conditional statement in the logic fires a call to the Text Messaging/Email API within the Monitoring Software to send a notification to the Manager or person to notify.

1.3 The Response Network

The Response Network is built to alter the operation of the equipment that they are to control. Below is a block diagram:

[1] Eucalyptus: Software coded by Ayoade Adetunji. Product of Lanibranded Ideas and Technological Concepts Limited
[2] Visit https://en.wikipedia.org/wiki/List_of_sensors for list of available sensors

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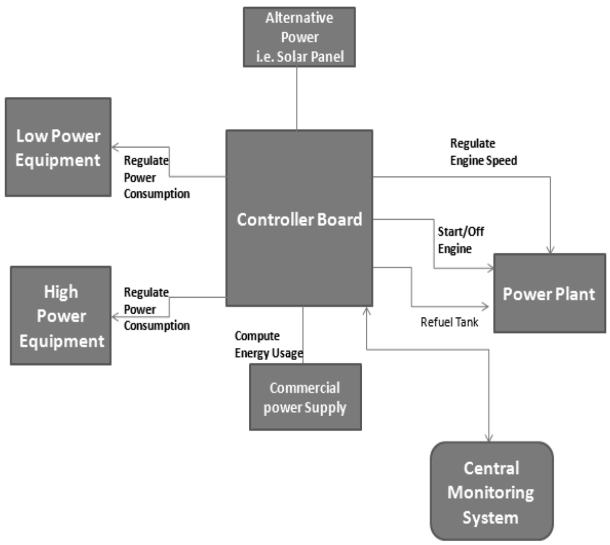

Figure 3. Block Diagram of Response Network

As can be seen in the diagram above, the Distribution board of the facility is wired such as to separate all heavy electrical loads from light ones. The response network on receiving instruction from the MCU, re-route supply for low power equipments to an alternative power (solar panel). This may be as simple as Relays, rectification or voltage divider circuits and it can be as complicated as an engine speed control system to regulate fuel consumption of the Power Plants. The Eucalyptus* (CMS) itself is the software part of the Response Network as will be seen in the next part.

1.4 Central Monitoring System

Eucalyptus coded in java runs on a dedicated computer system. Aside monitoring the operations of the MCU, it also relates the data input from the MCU to the user/users via a GUI which may be through a web browser or client application. Hence it also will execute inputs from Users. The CMS is built such that it can be accessible through a network. Hence, commands can be executed via the internet once the user logs into the account. User could also alter or shut down activities of the MCU.

2. RESULT

This work was carried out within June to July 2015 in Orpheus Communications (A Radio Station). As at this period, the CMS had not being in full operation. However, there was approximately 35% reduction in power consumption costs.

Occurrences such as Fuel Theft and Bad Maintenance were totally eliminated, while unexpected Engine Failure was minimized. Better managerial decisions could be made as daily power consumption cost could be computed along with several projections. The Automation led to a lot of possibilities. Below is a graph showing a decline in expenditure of the Department from July to August:

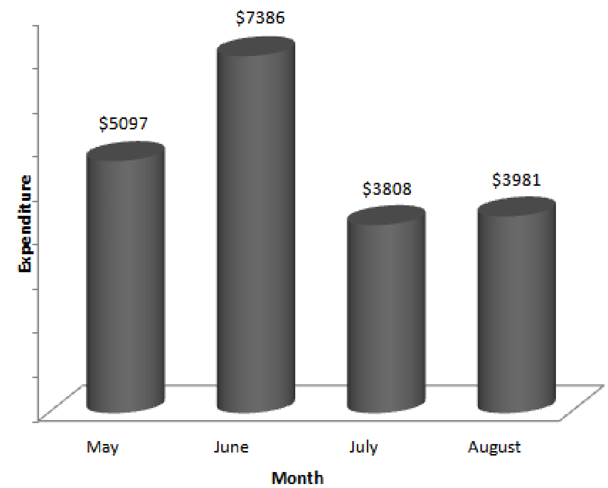

Figure 4. Monthly power cost of the Engineering Dept.

3. CONCLUSION

[7] Every day we are paying more for energy than we should due to poor insulation, inefficient lights, appliances, and heating and cooling equipment - money we could save by investing in energy efficiency.

This power automation system though significantly focuses on power management; yet, other benefits in aspect of security (as mentioned in theft deterrence of fuel) and safety come into play. In terms of safety, in the absence of activity within the building, in order to conserve power; the microcontroller will switch off devices (as indicated in the preferences of devices that can be switched off in absence of human supervision) that were left on, i.e. electric heaters. This could potentially stall a fire hazard.

With the results achieved in Orpheus Communications as a starting point, if this research is implemented on industrial level, we could be managing energy efficiently and saving more money for other researches.

4. ACKNOWLEDGMENT

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