ENERGY STORAGE RESERVOIR MANAGEMENT SYSTEM FOR WSN WITH SOLAR HARVESTING

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ENERGY STORAGE RESERVOIR MANAGEMENT SYSTEM FOR WSN WITH SOLAR HARVESTING

BY

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LIST OF ABBREVIATIONS

CMU	Carnegie Mellon University
CPU	Central Processing Unit
DARPA	Defense Advanced Research Projects Agency
DAS	Data Acquisition System
DSN	Distributed Sensor Networks
DVS	Dynamic Voltage Scaling
EDV	End of Discharge Voltage
ERMS	Energy Reservoir Management System
ESD	Energy Storage Device
ESR	Equivalent Series Resistance
GSM	Global System for Mobile
IEEE	Institute of Electrical and Electronics Engineers
MIT	Massachusetts Institute of Technology
MPPT	Maximum Power Point Tracker
PC	Personal Computer
PIC	Peripheral Interface Controller
PCMs	Power Conservation Mechanisms
PWM	Pulse Width Modulation

RF	Radio Frequency
SOC	State Of Charge
SOSUS	Sound Surveillance System
WSN	Wireless Sensor Network

SISTEM PENGURUSAN SIMPANAN TAKUNGAN TENAGA UNTUK WSN BERSAMA PENUAIAN SOLAR

ABSTRAK

Kebanyakan kajian di dalam pengurusan kuasa nod WSN adalah cara untuk meminimumkan arus pada nod penderia dengan menggunakan berlainan jenis algoritma yang berkaitan dengan teknik radio penghantaran dan bagaimana untuk meminimumkan kuasa kepada unsur penderia tanpa memberi kesan pada kejituan data terkumpul. Kajian lain menggunakan algoritma menghalang kuasa kepada radio penghantaran pada masa yang terpilih bagi menjimatkan tenaga. Manakala yang lain memilih unsur penderia yang menggunakan tenaga yang rendah. Pendekatan yang diambil dalam kajian ini adalah sedikit berbeza dari kajian sebelumnya dengan pemfokusan kepada pengurusan simpanan takungan tenaga. Secara teknikalnya dengan penggabungan secara selari dua jenis penyimpan berbeza iaitu lithium ion bateri yang dapat dicas semula dan kapasitor lampau. Kapasitor lampau disambung secara siri dengan sel pengimbang, seterusnya pengawal atur arus dapat diwujudkan untuk memberi keseimbangan pada cas dan nyah cas arus dan cas voltan di antara dua siri tersebut. Beban denyut iaitu radio WSN akan dibekalkan oleh kapasitor lampau dengan keupayaan kapasitor lampau dalam pengendalian arus denyut pantas dan dengan ciri kadar cas dan nyah cas yang lebih cepat membolehkan lebih keseimbangan kepada kadar cas dan nyah cas bateri. Pendekatan di sini ialah dengan menciptakan suatu keadaan terpasang/tidak terpasang. Keadaan ini memberikan masa bagi gabungan simpanan takungan tenaga (ESD) untuk di cas dengan panel kuasa solar melalui pengecas sedia ada tanpa gangguan daripada beban. Kawalan terpasang/tidak terpasang ini juga digunakan untuk mengawal aliran kuasa dari ESD, untuk penambahbaikan kuasa, dan untuk penghantaran kuasa kepada beban penderia

dengan lebih cekap. Ini meningkatkan masa penggunaan bateri dan masa operasi nod WSN. Eksperimen dilakukan dengan empat situasi, pertama ialah kawalan dengan keadaan asal beban tanpa pengurusan tenaga dan tiga jenis reka bentuk dengan pengurusan tenaga. Keputusan eksperimen menunjukkan dengan gabung teknik tepasang/tidak terpasang dan hibrid memberikan lebih masa penggunaan kuasa. Hybrid ini dibina dengan satu bateri lithium ion dan enam 10F supercapacitor. Dua supercapacitor ini disambung secara siri dan siri ini digabungkan menjadi tiga gabungan secara selari menghasilkan 15F kapasitans. Penambahan masa operasi sebanyak 160% direkodkan. Reka bentuk yang dikemukan dalam kajian ini dapat di skalakan kepada kuasa yang lebih besar atau lebih kecil mengikut kesesuaian aplikasi.

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ABSTRACT

Most of the study in managing power on wireless sensor network node (WSN) is mainly on how to minimize current of the sensor node by using different types of algorithm applied to the radio transmission technique and on how to minimize power consumed by the sensing elements without affecting the accuracy of the data collected. Other research applied algorithm on radio transmission technique are by turning off the radio whenever possible to obtain energy savings. In other hand the sensoring element chosen must be very low energy consumed. The approach taken in this thesis is slightly different compared to other studies. The approach is to focus on the energy storage reservoir. Technically a parallel combination between two different types of energy storage chosen are the rechargeable lithium ion battery and supercapacitor. Supercapacitor are connected in series by using a simple cell balancer, a current regulator is created to give a balance charge and discharge current and charge voltage between the two series. Pulse load which is WSN radio will be supplied by supercapacitor since the capability of supercapacitor in handling pulse current faster due to the ability of faster charged and discharge characteristic giving a more balanced charge and discharge of the battery. The approach here is to create an on/off charging environment, giving the combination of energy storage device (ESD) time to being charged from solar panel through available charger without disturbance from the load. The on/off control from the timer is also used to control the power flow from the ESD, for power enhancement, and to deliver the power to the load efficiently. This improves the

battery usage time and WSN nodes operation times. Experiments taken under four different approaches, the first one is control using the initial condition of the load without energy management and three designs with energy managements. The experimental results show that with the combination of on/off technique and the hybrid (battery and supercapacitor) can achieve much longer runtime for the WSN node. The hybrid are built with one lithium ion battery and six 10F supercapacitor. The supercapacitor is connected two in series in three parallel combination giving total of 15F capacitance. An improvement of 160 % of the operating time for the WSN node is observed. The design presented in this research can be scaled to larger or smaller power capacities for a variety of other applications.

CHAPTER 1

INTRODUCTION

1.1 Overview

The increase use of wireless sensor devices nowadays requires an efficient power solution to extend device operation and enhance battery life. The need for power solution is critical as the wireless sensor application has penetrated in many important areas in this modern era. This application is used in the military as a security monitoring device (Du and Chen, 2008). Wireless sensor network is also utilized for industrial monitoring (Agajo and Theophilus, 2010). Another example is the application of wireless sensor in environmental monitoring (Ye et al., 2009). The application continues in the health monitoring system (Jafari et al., 2005; Aygun and Gungor, 2011). Other application of wireless sensor network is in intelligent traffic system (Sharma et al., 2011). These are a few example of applications of wireless sensor networks be developed in recent years.

Basically, each of the wireless sensor network composed of a gateway node and several nodes distributed or positioned in the environment of interest. It will able to sense the significant area, do the decision making based on the collected data, and also communicate the data to a central location via ad-hoc network (Wang et al., 2010). Each wireless sensor nodes contains four sub-systems mainly: computing sub-system, a communication sub-system, a power sub-system and a sensing sub-system (Healy et al., 2007a).

The computing sub-system normally is a microcontroller unit mainly in charge of sensor management, data processing, and data transfer in the work state. The

microcontroller can be from Atmel family or PIC family (Wang et al., 2010; Albesa et al., 2007). In order to make the sensor node communicate with each other and with a base station, a communication sub-system is required. The power sub-system consists of a battery that provides the power to the sensor node. The sensing sub-system is linked to the outside world as the sensor transducer translates physical phenomena to electrical signals (Healy et al., 2007).

Each wireless sensor network needs to be powered up using battery or other power source available. For building application, to power a wireless sensor node it will not arise problem, but for application needs in remote area, power will be a great issue that has to be solved beside communication between nodes. A power management system must be taken into consideration. Power has been one of the major limitations in wireless sensor node's application. Most of the wireless sensor nodes depend on power source lifetime. The application is usually embedded in energy constrained environments (Srisathapornphat & Shen, 2002).

WSN application needs power management because of the sensor node’s unique dependence on battery lifetime (Akyildiz et al., 2002). The unique characteristics as a result of WSNs that comprise lots of immobile devices rather than mobile devices. This is due to the low-cost design, weight constraint, limited size, ad-hoc technique of deployment, and the power constraint environment. In addition, the batteries are also a complex device because of many factors in such operation, which are battery dimensions, the diffusion rate of the active material in the electrolyte, and type of electrode material used (Raghunathan et al., 2002). Thus

the selection of batteries to be used is also one of the important considerations in WSN application.

Generally worldwide, the energy sources for wireless sensor network is used in monitoring complex phenomena and in data communication. Thus, more effective energy management approaches have been developed in recent years at the sensor nodes, then at the cluster and network levels in order to lengthen the network runtime as much as they can. Recently it was found out that because of certain sensor used in such application, the energy has been drained more for acquiring the data than the energy used for communication of that data (Raghunathan et al., 2006; Alippi et al., 2009).

In some energy management in WSN, the use of the ambient power source also comes into application for charging and supporting the main power supply. Those sources are solar power and wind power that have been employed for years. Furthermore, a lot of research attempted in applying any type of energy sources to provide power for autonomous sensors. These energy sources are thermal, magnetic, radiant, mechanical, and biochemical energy sources (Penella & Gasulla, 2007; Thomas et al., 2006). However, the commonly wide usage of wireless sensor nodes up to now utilize solar energy and wind energy, because of the sufficient power delivered by these sources. The characterization of these two types of power sources has been described in great length in the literature (Corbus, et al., 1999; Islam 2005; Gevorgian et al., 1998; Santos & Antunes, 2003; Enslin et al., 1997; Koutroulis et al, 2001; Wu et al., 2003; Lee et al., 2003; Noguchi et al., 2002).

Another energy management in wireless sensor network applications is using other energy storage beside batteries, which is supercapacitor. Supercapacitor have gained broad attention nowadays due to their power density, low equivalent series resistance (ESR), and low leakage current than electrolytics. Other works also used solely supercapacitor as an energy storage device in their sensor networks by installing larger capacitance of supercapacitor to support the energy requirement of the nodes and longer life operation (Maxwell, 2007; Eu et al., 2011; Saggini et al., 2010).

1.2 Problem Statements

An energy storage system in power system for any application can be defined as any other state of a system, with which it is possible to store generated energy, to conserve it and use it in times of need. According to this definition, energy storage in power systems can be employed in the arrangements of charge, store, and discharge. (Danila et al., 2011; Ter-Gazarian, 2011). There are a few methods to enhance power usage for wireless sensor nodes (Pantazis & Vergados, 2007). Conventional wireless sensor node uses solely batteries as their main power source making the WSN node very dependent on battery lifetime (Akyildiz et al., 2002). In order to meet the requirement of continuous function of the nodes, the battery usage is in bulk quantity or it has to be replaced frequently. Power management can be applied at any unit consist in the wireless sensor nodes. Srisathapornphat & Shen (2002) shows that by using the method of turning off the radio transceiver interface module when there is no communication activity saves the wireless sensor node energy usage. This mechanism is applied at the data communication unit. However, most of the energy or power management in wireless sensor requires complicated solution and there are

still opportunities for the research concerning energy management. Referring to the research that used Dynamic Power Management (DPM) with Scheduled Switching Mode (DPM-SSM) protocol (Sausen et al., 2007) to extend WSN lifetime, the technique that been used here is always switching the node to a sleep state after a data packet transmission. The result shows that in average, 108 hours running time without DPM-SSM and 148 hours of operating time with DPM-SSM gives 37% increament of operating time (Salvadori et al. 2009). The approached technique in this research is to switch off the entire circuit using periodically on/off condition to the energy reservoir and charging as well as discharging mechanism for battery and supercapacitor. Therefore, the aim of this project is to create energy management based on energy storage with solar panel. Two types of energy storage that is involved are lithium ion batteries and supercapacitor. The voltage results from an application using batteries solely are compared with results from the application of two types of energy storage combined with suggested energy management technique and solar.

1.3 Research Objectives

The objectives of this project are:

a) To study the on/off techniques and choose the appropriate energy storage device.

b) To create on/off condition for the energy reservoir system.

c) To build the prototype based on the proposed design.

d) To test and analyse experimental results.

1.4 Research Contribution

This research work contributes a technique to prolong wireless sensor node run time with the use of lithium ion batteries and supercapacitor in support with solar panel. This research provides knowledge about the energy storage device and the interconnection between this device which are lithium batteries and super capacitor. At the same time, the on/off condition for charging and discharging technique is also described in great length. This research also shows component selection to implement energy storage management.

1.5 Scope of Research

This thesis can be categorized into two major parts. The first part is about the design of energy management system that involves an energy calculation process, calculating available energy resources capacity and time operating of the system based on the power supply. The next step is selecting the energy storage devices that are lithium ion battery and supercapacitor as the energy reservoir. Then, charging and discharging method is designed to support the power flow of the system and described with details as an appropriate method for the system. Second part is on data analysis. Data in the form of voltage and current that are obtained from electronic sensor are used for data analysis.

1.6 Outline of Thesis

This thesis discusses about designing an energy management of wireless sensor nodes using renewable energy source, which is solar with batteries and super capacitor. Pulse width modulation (PWM) was applied as the techniques to charge