SOLAR POWER SUPPLY AND MANAGEMENT FOR REMOTE EMBEDDED LINUX SYSTEM

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

AH	Amper Hour
AJAX	Asynchronous JavaScript and XML
ARM	Advanced RISC Machine
AT	Attention Telephone / Attention Terminal
CPU	Central Processing Unit
DAC	Digital to Analog Converter
DIO	Data Input Output
FSF	Free Software Foundation
FTP	File Transfer Protocol
GSM	Global System for Mobile
HTML	Hyper Text Markup Language
LAMP	Linux Apache MySql PHP
LAN	Local Area Network
LCD	Liquid-Crystal Display
LED	light-emitting diode
OS	Operating System
OSI	Open Systems Interconnection
PC	Personal Computer
PCI	Peripheral Component Interconnect
PHP	Personal Home Page
RAM	Random Access Memory
RoHS	Restriction of Hazardous Substances
SBC	Single Board Computer
SD	Secure Digital
SMS	Short Message Service
SoC	System On Chip
SQL	Structured Query Language
TCP	Transmission Control Protocol
TS	Technologic Systems
USB	Universal Serial Bus
3G	Third Generation of Mobile Telecommunications Technology

Solar Bekalan Kuasa Dan Pengurusan Bagi Sistem Linux Remote Embedded

ABSTRAK

Kebelakangan ini, sistem terbenam yang menggunakan tenaga solar sebagai sumber kuasa di kawasan tertentu yang mempunyai bekalan elektrik. Kajian ini bertujuan untuk merekabentuk dan membangunkan Sistem Pengurusan Kuasa Suria yang Stabil (SSPMS) dengan menggunakan TS-7800 *SBC* dan solar bekalan kuasa dan pengurusan bagi sistem linux remote embedded (SPsmRELS). Papan litar utama yang digunakan adalah TS-7800 SBC, dan persisian lain ialah TS-9700 A/D, 3G USB modem, panel solar, bateri, pengatur voltan dan sensor. Bahagian kawalan keseluruhan sistem telah ditetapkan di dalam TS-7800. Panel solar disambungkan kepada bateri melalui litar pengatur voltan bagi menyalurkan voltan yang diperlukan. TS-7800 disambungkn ke bateri melalui pengatur voltan yang mampu menurunkan voltan kepada 5V dari bateri yang mempunyai 12V (cas penuh). Makluman akan dihantar kepada admin sekiranya bateri tidak dapat caj atau cuaca mendung pada waktu tertentu. Pembangunan ERPMS adalah berasaskan bahasa C. Sistem operasi Debian/Linux 6.0.0 (Squeeze) digunakan untuk menyokong 3G USB Modem yang digunakan untuk berkomunikasi antara ERPMS dan admin melalui SMS. Bateri dan data panel solar disimpan ke dalam pangkalan data TS -7800 SBC untuk memudahkan admin memantau data dengan pelayar web. Keputusan eksperimen menunjukkan bahawa ERPMS yang dapat menyokong sehingga maksimum tujuh (7) jam pada perubahan penuh. Satu ciri yang menarik untuk ERPMS adalah, admin boleh mendapatkan akses kepada pangkalan data melalui mana-mana pelayar web dan admin juga boleh mematikan ERPMS dengan menghantar SMS mengandungi (init 0).

Solar Power Supply And Management For Remote Embedded Linux System

ABSTRACT

Nowadays, solar system is used a power source to support embedded system application in remote area. This research aimed is to design and develop a Stable Solar Power Management System (SSPMS) for TS-7800 Single Board Computer (SBC) and called Solar Power Supply And Management For Remote Embedded Linux System (SPsmRELS). The main board is TS-7800 SBC, and the other peripherals are TS-9700 ADC, 3G USB modem, solar panel, battery, voltage regulator and sensors. TS-7800 SBC is controlling part for the whole system. The solar panel connected to the battery through the voltage regulator circuit to provide the battery with required voltage. The TS-7800 connected with the battery through a voltage regulator circuit which manages to serve 5V to TS-7800 SBC where the battery output voltage up to 12V (full charge). A notification is sent to the user once the battery is low. The SPsmRELS development base is C language. Debian/Linux 6.0.0 (Squeeze) operating system is used to support 3G USB Modem which is used to communicate between SPsmRELS and admin through SMS. The battery and solar panel data are stored into a database into TS-7800 SBC to let the admin able to monitor the data by web-browser. The experimental results show that the SPsmRELS able to support maximum seven (7) hours at full change. An interesting feature for SPsmRELS is, admin may get access to the database through any web-browser and can shutdown the SPsmRELS by sending SMS contains (init 0).

CHAPTER 1

INTRODUCTION

1.1 Overview

Energy is an indispensable necessity to manage and enhance the standard of life. One of the most established manifestations of energy is solar energy. In remote areas where electricity is not available, the solar energy use a free sunlight and converting it into usable power by using a solar panel. It's energy source free, clean and infinitely renewable. There are many uses for solar power such: water heating systems, battery chargers, satellite power system, and others (Hossain et al., 2008).

A Remote Power Management offers the ability to immediate power cycle, restart the system, provide method for system monitoring via web browser. Embedded systems frequently reside in machines that are required to run continuously for long time without failures, and in some cases, recovery by themselves if an error happens. According to the software, it is usually developed and tested more carefully than personal computers. Embedded systems are known for their rugged and small size, portability, low power consumption, as well as low cost.

All embedded systems contain hardware and software. The hardware is represented by single board computer (SBC). The SBC is used with a component-level design; it's complicated and cannot be manufactured locally by an organization or team of engineers. But, as processors have become faster and memory denser, SBC capabilities have increased and costs decreased. The increasing affordability of these computers has motivated the design of new forms by several SBC manufacturers. The software are like C, C++ language and PHP and MYSQL database.

By increasing the use of Internet technology, make more possible to monitor and to control the systems remotely. In this research, studies chose the TS-7800 SBC, solar panel, TS-9700 A/D, modem and battery as hardware. In software use C language, MYSQL database, PHP and AJAX. In this project will study how the SBC board (TS-7800) is powered by charging the battery from the solar energy, using solar cells and monitored the system via the Web.

The research studies are develop the system to monitoring of charging the battery and manifest the solar panel especially in remote areas, it can be used a small solar as portable. The importance of this research is to make the SBC work as efficiently as possible.

1.2 Problem Statement

The main target in this research is to use TS-7800 SBC in remote area, where the power needed to be supplied to SBC for maximum 7 to 8 hours. Recently, there are several companies marketing their power management system with different regulated options. The current power management products are expensive, short term service, no notification option and they are not rechargeable by solar light, and also complex.

1.3 Objectives

The objectives of this research are as follows:

1. To design and develop a remote solar power management system for TS-7800 SBC.
2. To design the battery and solar panel status monitoring system.
3. To save data into database created inside TS-7800 SBC.
4- To send and recieve notification between the system and the user through SMS.

1.4 Scope of Project

In this project, the solar panel is used to power up the TS-7800 SBC, especially when the system placed in a remote area. The solar panel offer the power during day time, or during absence of sun. The battery is used as a storage unit to provide the TS-7800 SBC with power. Because the voltage of the solar panel, battery and SBC are unequal, it needs to use voltage regulator circuits to offer suitable power to every device. 3G USB modem used as communication method with the user if any error accrue. The battery can support the TS-7800 SBC with power for 7 hour and need to 5 hour to reach to full charge in case good sunlight, in this system can control on shutdown or restart through SMS sending from the user to SBC and can send SMS from TS-7800 SBC to the user at any error.

1.5 Dessertation Organization

The dissertation is divided into five chapters. Chapter two contains the literature review of the related work. Chapter three explain the methodology that explain the methods, rules and ideas that used in this project, this section describes the hardware and software composition of the system architecture. Chapter four describes the results of this project. Chapter five presents conclusion of the research. Recommendation for future work also presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The remote power management used to offer power to the places where electricity is not available also allows the user to control the power of many remote devices remotely and locally such as: solar panel, embedded devices, battery, etc. With the rapid growth of telecommunications systems, it becomes possible to design remote power management system by using mobile or modem. Single Board Computer (SBC) offers the reliability and low power.

2.2 Power Management System

Any electronic device needs power supply to operate. The generation and control of regulated voltages which are required to operate an electronic system called power management (PM). The elements of power management system typically linear regulators, capacitor, voltages references, etc.

The power management system (PMS) should be provide a stable electric power to the system and warranty the system running with high reliability, stability and safety (Xu et al., 2009). There are many power resources and one of them is solar power which is clean and available. The solar power can offer power at a limited time of day, so it needs the storage device to save the power (shiau et al., 2007). Solar power management system is divided into three section: the first section is the solar panel,

second section is battery management and the last section is a power conversion, used to convert the power drawn from the solar panel to the using systems.

A solar power system requires panels for generation, batteries for storage, and voltage regulator to keep the batteries within a safe operating range. Solar energy is also called photovoltaic energy (PV). The PV module consists from a PV cells (Preethishri, et al., 2011) connected in series or in parallel. These cells convert sunlight to energy by the photovoltaic effect. Photovoltaic (PV) cells are collected together to create a solar module.

There are many types of solar panel such as: Monocrystalline silicon (mono-silicon or single silicon), Polycrystalline silicon (multicrystalline, multi-silicon, ribbon) and thinfilm. The solar cell types and characteristics showing in Table 2.1 below (Pierrosolar, 2013).

Table 2.1: Solar Cell Technologies structure, pros and cons.

Solar Cell Technology	Structure	Pros	Cons
Monocrystalline	Formed from single crystal of silicon	- most efficient - They are not hazardous to the environment.	Mono-crystalline solar panels are more expensive than polycrystalline due to the complexity of the process required to make them.
Polycrystalline	Formed from multiple crystal of silicon	-Polycrystalline panels are more affordable than mono-crystalline panels due to being easier to make and using multiple silicon cells.	Polycrystalline solar cells are less efficient than polycrystalline solar cells.
Thinfilm	Formed from amorphous silicon	- less expensive. - flexible and can be bent without breaking.	- far less efficient than mono-crystalline and polycrystalline. - Their performance degrades faster over time.

The battery management section refers to controls and monitors the battery and delivery of the solar power drawn from the solar cell panels. The amount of energy stored in a battery is commonly measured in ampere hours (AH) (Roger and Jerry, 2000). There are many types of batteries: Nickel Cadmium (NiCd), Nickel-Metal Hydride (NiMH), Lead Acid, Lithium Ion (Li-ion) and Lithium Ion Polymer (Li-ion polymer). Table 2.2 below show the properties of each types (Batteryuniversity, 2014).

Table 2.2: Characteristics and Applications of Batteries.

Battery	Special characteristics	Applications
Nickel Cadmium (NiCd)	- long life - high discharge rate - economical price	- biomedical equipment - professional video cameras power tools
Nickel-Metal Hydride (NiMH)	- higher energy density compared to the NiCd	- mobile phones - laptop computers
Lead Acid	- Inexpensive and simple to manufacture - Low maintenance requireme-nts	- hospital equipment - wheelchairs - emergency lighting - UPS systems.
Lithium Ion (Li-ion)	- fast growing battery system - used where high-energy density	- notebook computers - cellular phones.
Ion Polymer (Li-ion polymer)	- Flexible form factor - Light weight	- mobile phones

Voltage regulators circuits used to offer suitable voltage for battery or SBC. The voltage regulators are classified into two types: switching voltage regulators and linear voltage regulators, the switching voltage regulators more efficient than linear, but the linear voltage regulators are cheaper and produce less noise than switching regulators (Choi et al., 2007).

2.3 Remote Power Management System

Any device need source of power to run, this power can supplies it by different way such as electric power, solar power, wind power (Burger, 2014). This power can measure easy when its near by using multimeter, but, if the system or device placed in a remote area the monitors becomes difficult, so, by use of the communicating methods

like mobile, modem..etc, can monitor and control any device remotely.

2.4 Power Management for Embedded System

With fast evolution of communicating technology, in addition to expanding interests of energy-saving and environment protection, power management of devices on embedded systems has become more important (Yue et al., 2005). Embedded system used many types of single board computer (SBC) products. The SBC offer scalable performance and low power solutions. There are many types of SBC such as: BeagleBone Black (beagleboard, 2013), Cosmic Board (Phytec, 2014), ODROID-U3 (Hradkernel, 2013), Raspberry Pi (Raspberrypi, 2014) and TS-Series (Technologic Systems, 2013). Table 2.3 show the power supply for these different boards.

Table 2.3: Voltage and Current for variable types of Single Board Computer.

Single Board Computer	Voltage	Current
BeagleBone Black	5 V	0.4 A
Cosmic Board	5 V	1 A
ODROID-U3	5 V	0.4 A
Raspberry Pi	5 V	0.3-0.7 A
TS-Series	5 V	1 A

2.5 Existing Product

When using solar energy, power consumption become important for devices which are battery-powered (Jiangwei et al., 2006). Power management has been studied by many researchers. For example Scott et al. (2011) explained the solar car system. This system enables sensing of the battery voltage and current, the motor controller voltages and currents, and the vehicle's speed and location, in this project using TS-7250 SBC.

Zhang et al. (2010) study an automated power model construction technique. This study uses built-in battery voltage sensors and information of battery discharge behavior to monitor power utilization. A software implementation of the power estimation tool has been publicly released on the Google Android Application Market. This system used six components: CPU and LCD as well as GPS, Wi-Fi, audio, and cellular interfaces.

One of the application that used the battery is a heart defibrillator. During preparation stages the battery draws about 10 Ampere, the battery must still work because sometimes it needs several shocks to get the patient's heart going again. This device is powered by nickel-cadmium or lead-acid batteries (Batteryuniversity, 2014).

All solar panel products uses DC power of 12 V or 24 V DC. Also the solar cell uses the same basic construction (Solarstik, 2014). The method for Inverted Metamorphic (IMM) solar cells developed by Vanguard Space Technologies (Vst-inc, 2014), demonstrated high efficiency and thin cell technology. Scientists from Stanford University are now able to create flexible and thin solar cells that made from standard materials, also, its like a sticker can applied to any surface (Gizmag, 2014). Solar power used in racing cars get their power from the solar panels placed on the surface of

the car (about, 2014).

Roger and Jerry (2000) explained an Outdoor Lighting System, this system used to offer nominal lighting on the road to allow people to see a walkway in the night. In this system, suppose lamp will draw 0.75 A when they are operating, it can be used in a single 12 V battery with a minimum capacity of 48 Ah. The PV model used in this system approximately 50 watts at maximum power, so the charging will be 15 to 16 volts. Because the road remains lighting all night, the calculation performed in a winter night is 15 hours and summer night will be 9 hours.

Corciova et al., (2012) studied the mini solar vehicle MSV. This system monitoring the following: battery level whilst charging via solar panel or electricity grid, solar panel temperature, mileage and speed. The system is based on a Chip KIT MAX32, the board is based on the Arduino platform with the same commands. All the data is also saved on a SD card, but no database used in this system.

Nasrudin et al., (2011) discussed the Light Dependent Resistor (LDR) configuration for line tracking robot application. The aim of this project is to construct a robot that has capability to follow the white line placed on a horizontal smooth surface lighted by LED and the low cost light dependant resistor as the sensor. The robot is formed by three important components which are two LDRs, microcontroller PIC16F887 and two stepper motor.

Yamin et al., (2013) study the Embedded Solar Tracking Instrumentation System. This system using Atmega32 microcontroller. The system consists of Light Dependent Resistor (LDR) sensor, DC motor and Xbee wireless system. Atmega32 microcontroller is the main component for controlling the system. Atmega32 microcontroller has 40 pins and every pin has their own functions. Some of the features used in this project are programmable I/O line, 8-channel 10-bit analog to digital

converter (ADC) at PORTA and universal synchronous asynchronous receiver transmitter at PORTD (Pin 14 and Pin 15).

2.6 Single Board Computer (SBC)

Single board computer occupied a great place these days, because of owned properties like low power, small size and cost. Single board computer (SBC) usually run a Linux distribution of an SD card and can interface with a desktop computer through the Ethernet, HDMI video, USB ports, audio out (Technologic Systems, 2013). Software platforms that are usually used on these devices is Linux (Industrial Single Board Computer Based on OMAP5 Processor). There are many type of SBC designed according to the required applications, one of them is Technologic Systems (TS). Table 2.4 compares the features of Technologic Systems ARM- based SBC's (Technologic Systems, 2013).

Table 2.4: ARM-based SBC product feature.

Product	TS-7800	TS-7300	TS-7260	TS-7250	TS-7200
CPU	500 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9
RAM(std.)	128 MB	32 (64-128 opt) MB	32 (64-128 opt) MB	32(64 opt.) MB	32 (64opt.) MB
Flash	512 MB	2 MB	32MB	32 (128 opt.) MB	8 (16 opt.) MB
Ethernet (Mbps)	Gigabit 10/100/1000	Dual 10/100	10/100	10/100	10/100
Flash Socket	SD Card	SD Card	SD Card	Compact Flash	Compact Flash
Default Kernel	2.6	2.6	2.4	2.4	2.4
Debian Linux	Yes	Yes	Opt. SD	Opt. USB	Opt. CF
COM Ports	3	10	3	2	2
LCD	Opt.	Yes	Yes	Yes	Yes
USB	2	2	2	2	2
Price	$229	$189	$149	$129	$119
Power Supply	5VDC	5VDC	20VDC	5VDC	5VDC

2.7 Embedded Linux

Embedded Linux is using of the Linux kernel in embedded devices. There are more applications for embedded devices like cars, ATMs, airplanes, and airport terminals. Embedded Linux differ from desktop Linux in many points such as embedded Linux running in embedded system product single board computer (SBC), improvement board and Linux kernel used real time (EmbeddedCraft, 2012).

Debian GNU/Linux refer to a unique software distribution that contains of combination of the GNU tools, the Linux kernel, and other important free software. There are many distributions of Debian GNU/Linux operating system support for

hardware devices and systems or software package configuration. Table 2.5 explain different version of Debian Linux distributions (Debian, 2013).

Table 2.5: Different version of Debian GNU/Linux.

Debian Linux version	Code name	Initially released	Released
4.0	Etch	April 8th, 2007	May 22nd, 2010
5.0	Lenny	February 14th, 2009	March 10th, 2012
6.0	Squeeze	February 6th, 2011	February 15th, 2014
7.0	Wheezy	May 4th, 2013	February 8th, 2014

2.8 Summary

There are many reasons for using solar power (clean, available and renewable resource) there are many types of solar cell. The Polycrystalline solar cell chosen for this research because it's more affordable and not expensive. The solar power available with the availability of sunlight, it needs to save the power in case of absence the sunlight. For this reason use the battery, the Lead Acid battery used because it is inexpensive, simple to manufacture and low maintenance requirement. The TS-7800 SBC used in this project because it's provide many features as high performance**,** it contains many interfaces like PC/104, and It's low power and available.