Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF A SMART TRAFFIC LIGHT SYSTEM USING A SOLAR-POWERED STANDALONE PV SYSTEM

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Bachelor of Electrical Engineering Technology with Honours

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A project report submitted
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DEDICATION

To my beloved mother, Azuraizam Binti Omar, my late father, Ariff Bin Salleh, and my dearest sister, Alya Azrissya Binti Ariff, who have meant and continue to mean so much to me.

ABSTRACT

Nowadays, electricity generation from standalone solar energy is increasing and gaining a lot of demand, especially in developing smart technology such as intelligent traffic light systems. A standalone solar PV system can generate, store and supply power to the traffic light without depending on the grid supply. Moreover, the conventional traffic light system is inefficient. The conventional system uses a fixed timing system for each lane and depends on the grid supply to operate, which can sometimes malfunction due to power failure and cause road accidents. A smart traffic light system using a solar-powered standalone PV system has been developed to overcome this problem. This project aims to analyze the existing traffic light system by studying related articles, journals and previous works, to design and develop a smart traffic light system integrated with standalone PV solar power, and to evaluate the suitability of solar panels, charge controller, batteries and sensors in a smart traffic light system. The smart traffic light system uses infrared (IR) sensors to detect traffic density. The Arduino Nano is used as the microcontroller to control the timer of the traffic light system and change the signal appropriately based on the vehicle density. LED traffic light modules have been used to represent the traffic light signal. Thus, with the integration of a standalone PV solar system, the PV solar can provide enough electricity to power the smart traffic light system and overcome many mishaps on the road due to traffic light malfunction.

ABSTRAK

Pada masa kini, penjanaan elektrik daripada tenaga suria kendiri semakin meningkat dan mendapat banyak permintaan, terutamanya dalam pembangunan teknologi pintar seperti sistem lampu isyarat pintar. Sistem PV solar kendiri boleh menjana, menyimpan dan membekalkan kuasa kepada lampu isyarat tanpa bergantung pada bekalan grid. Selain itu, sistem lampu isyarat konvensional adalah tidak cekap. Sistem konvensional menggunakan sistem pemasaan tetap dan bergantung pada bekalan grid untuk beroperasi, yang kadangkala boleh rosak akibat kegagalan kuasa dan menyebabkan kemalangan jalan raya. Sistem lampu isyarat pintar menggunakan sistem PV kendiri berkuasa solar telah dibangunkan untuk mengatasi masalah ini. Projek ini bertujuan untuk menganalisis sistem lampu isyarat sedia ada dengan mengkaji artikel, jurnal dan karya berkaitan, untuk membentuk dan membangunkan sistem lampu isyarat pintar yang disepadukan dengan kuasa solar PV kendiri, dan menilai kesesuaian panel solar, pengawal cas, bateri dan penderia. dalam sistem lampu isyarat pintar. Penderia inframerah (IR) digunakan dalam sistem lampu isyarat pintar untuk mengesan kesibukan lalu lintas. Arduino Nano digunakan sebagai pengawal mikro untuk mengawal pemasa sistem lampu isyarat dan menukar isyarat dengan sewajarnya berdasarkan kepadatan kenderaan. Modul lampu isyarat LED telah digunakan untuk mewakili isyarat lampu trafik. Oleh itu, dengan penyepaduan sistem suria PV kendiri, solar PV boleh membekalkan tenaga elektrik yang mencukupi untuk menghidupkan sistem lampu isyarat pintar dan mengatasi banyak kemalangan di jalan raya akibat kerosakan lampu isyarat.

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V	-	Voltage
A	-	Ampere
W	-	Watt
µm	-	Micrometre
KB	-	Kilobyte
MB	-	Megabyte
Wh	-	Watt-hour
Ah	-	Ampere-hour
MHz	-	MegaHertz
MA	-	MegaAmpere

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
IR	-	Infrared
NiMH	-	Nickel-Metal Hydride
Li-ion	-	Lithium-ion
LED	-	Light-Emitting Diode
PIR	-	Passive Infrared
GSM	-	Global System for Mobile Communications
ADC	-	Aalog Digital Converter
AC	-	Alternate Current
DC	-	Direct Current
RAM	-	Random Access Memory
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
ROM	-	Read-only Memory
OTP	-	One Time Programmable
USB	-	Universal Serial Bus
IC	-	Integrated Circuit
AVR	-	Automatic Voltage Regulator
GPIO	-	General-Purpose Input/Output
UART	-	Universal Asynchronous Receiver Transmitter
SD	-	Secure Digital
PC	-	Personal Computer
SOC	-	System On Chip
PWM	-	Pulse Width Modulation
HDMI	-	High-Definition Multimedia Interface
DEV	-	Developer
IDE	-	Integrated Development Environment
RCA	-	Radio Corporation of America
PCB	-	Printed Circuit Board
MPPT	-	Maximum Power Point Tracking
ICSP	-	In-Circuit Serial Programming
DOD	-	Depth of Discharge
DOA	-	Days of Autonomy
BBTM	-	Battery Bank Temperature Multiplier
PSH	-	Peak Sun Hour
PDRM	-	Polis Di-Raja Malaysia
MIROS	-	Malaysian Institute of Road Safety Research
JKR	-	Jabatan Kerja Raya

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CHAPTER 1

INTRODUCTION

1.1 Background

Electricity is the most crucial component of a traffic signal system's operation, as the traffic control systems can function continuously in the presence of energy. Electricity failure or interruption may impair the system's operation and affect road users' safety. Moreover, conventional traffic light systems usually use underground and overhead cables to supply electric power, which can sometimes malfunction due to power outages and cause road accidents. Nowadays, standalone PV solar traffic light systems have been deployed in developed countries. By utilising solar energy, the traffic light system can reduce or eliminate its reliance on the electrical grid, enhancing its dependability and decreasing its operating expenses. Integrating solar power into the traffic light system can also reduce energy consumption and installation costs, particularly in grid-isolated or remote areas.

Solar energy is a type of energy obtained directly from the sun and converted to electrical energy, the most environmentally friendly form of energy that does not contribute to climate change or energy crises. The two most significant advantages of solar energy are that it has no fuel costs and produces no greenhouse gases throughout the solar energy generation process [1]. Furthermore, a standalone PV solar model integrates all components necessary for electricity generation and supply, including the solar photovoltaic panel, battery, charge controller, and load [2]. A battery is added to store the excess energy generated by the solar panel, which can be utilized at night or on overcast days. A charge controller is connected to the battery to protect it against overcharging and regulates the system's general performance.

This project focuses on developing a standalone PV solar system to power the smart traffic light system. The infrared (IR) sensors are used in the smart traffic light system to detect the traffic density and transmit the data to the Arduino Nano. This microcontroller will vary the timer of the traffic light system based on the vehicle density and change the signal appropriately. Therefore, with the integration of a standalone PV solar system, the generator can provide enough electricity to power the traffic light system and overcome many mishaps on the road due to traffic light malfunction.

1.2 Problem Statement

When an area experiences power outages, it affects the conventional traffic light system to malfunction since it uses underground and overhead cables to supply the electric power. This matter causes the smoothness of the traffic to be disrupted and causes road accidents. Moreover, the number of vehicles on the road has proportionally increased to the global population growth, resulting in road congestion, especially in urban cities. This road congestion happens due to the configuration of conventional traffic light systems that use a fixed timer program to give signals to road users. As a result, the drivers need to wait longer for the signals to turn green even though there are no vehicles at other intersections. The long traffic light timer not only stresses the drivers but also results in significant fuel waste and increases the carbon dioxide emissions from the queued vehicles. Thus, using a standalone PV solar system to power the smart traffic light system can solve the problems mentioned above.

1.3 Project Objective

The main objective of this project is to propose a systematic and effective methodology to power a smart traffic light system by using electricity produced by the PV solar panel integrated with a backup battery. Specifically, the objectives are as follows:

i. To analyze the existing traffic light system by studying related articles, journals and previous works.
ii. To design and develop a smart traffic light system integrated with standalone PV solar power.
iii. To evaluate the suitability of the solar panel, charge controller, battery and sensor in a smart traffic light system.

1.4 Scope of Project

The scope of the project is defined as follows:

a) This project is targeted to be used at road intersections.
b) The infrared (IR) sensor is used to detect the traffic density and control the program of the traffic light system.
c) The type of solar panel used in this project is polycrystalline solar panels.
d) The battery used to store the excess energy generated by the solar panel is the rechargeable Lithium-ion (Li-ion) battery.
e) The system in this project uses Arduino Nano as the main microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarises the theories and system design for a standalone PV solar generator and smart traffic light system. Moreover, this chapter also explains the overview of the conventional traffic light system and the statistic of accidents occurring at traffic light intersections. The existing projects from related articles, journals and works also have been discussed and compared so that the outcome of this project will be better.

2.2 Overview of Existing Project System

This section will review some previous project designs and implementations that have been conducted in connection with this project system. Several outstanding researchers have spent years finding the best way to optimize smart traffic signal systems and standalone PV solar systems.

2.2.1 Adaptive Traffic Lights through Traffic Density Calculation on Road Pattern

This project was developed to control the traffic light signal timing based on the traffic density calculation on the road pattern. The traffic density was calculated by processing the image on various road patterns. Then, a server collected data and managed traffic signal operations at a crossroads. The camera, mini pc (Raspberry Pi) and Wi-Fi router adapter were used. The battery Lithium Polymer (LiPo) 12.6V was utilized as a power supply, and its voltage was regulated to 5V before being linked to the Raspberry Pi through a UBEC voltage regulator. A Wi-Fi adapter was used to connect the Raspberry Pi to the server through Wi-Fi, allowing the server to operate each traffic light via the Raspberry Pi. Then, the Raspberry Pi will send the server the current traffic density for monitoring purposes. However, the image processing method was unsuitable for this system because several noises interpreted as objects remain in the image frame even though several filtrations had been done [3].

2.2.2 Density Based Traffic Signal System Using Arduino UNO

The density-based traffic light system was designed to control traffic based on density at the road intersection with the four-ways lane. The infrared (IR) sensor was used in this project to measure the traffic density by counting the number of vehicles passing through the IR sensors. Then, the IR sensor detected the vehicle density and transmits the data to the microcontroller to process and control the delay time of the traffic signal. This project used Arduino UNO ATMega 328P as its microcontroller.

Furthermore, the system integrated three light-emitting diode (LEDs) colours: red, yellow, and green, which were applied following traffic conditions. The road with the most vehicles was given a green signal, while the remaining routes received a red signal. Additionally, they developed the technology in this project with a 1000 millisecond delay. The microprocessor monitored traffic based on the sensors’ output and adjusted the signals; hence, traffic was regulated by the delay [4].

2.2.3 Smart Traffic Light Control System

The smart traffic light control system was designed and implemented as an automated traffic light system with traffic-based timing to increase the traffic flow efficiency on urban roads. This system worked by adjusting the duration of present traffic lights to durations that varied according to the density of vehicles on the roads. Besides, this smart