Faculty of Engineering

DESIGNING SOLAR PV AUTOMATIC TRANSFER SWITCH FOR ELECTRICAL ENERGY MANAGEMENT

Nur Amni Binti Mokhtar

Bachelor of Engineering

Electrical and Electronics Engineering

with Honours

2022

DESIGNING SOLAR PV AUTOMATIC TRANSFER SWITCH FOR ELECTRICAL ENERGY MANAGEMENT

NUR AMNI BINTI MOKHTAR

A dissertation submitted in partial fulfilment
of the requirement for the degree of

Bachelor of Electrical and Electronics

Engineering with Honours

Faculty of Engineering

Universiti Malaysia Sarawak

2022

UNIVERSITI MALAYSIA SARAWAK

Grade: ____________

Please tick (√)

Final Year Project Report ☑

Masters ☐

PhD ☐

DECLARATION OF ORIGINAL WORK

This declaration is made on the 29 day of JULY 2022.

Student's Declaration:

I NUR AMNI BINTI MOKHTAR, 67079, FACULTY OF ENGINEERING (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled DESIGNING SOLAR PV AUTOMATIC TRANSFER SWITCH FOR ELECTRICAL ENERGY MANAGEMENT is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

____
Date submitted

Nur Amni Binti Mokhtar (67079)
Name of the student (Matric No.)

Supervisor's Declaration:

I AZFAR SATARI BIN ABDULLAH (SUPERVISOR'S NAME) hereby certifies that the work entitled DESIGNING SOLAR PV AUTOMATIC TRANSFER SWITCH FOR ELECTRICAL ENERGY MANAGEMENT (TITLE) was prepared by the above named student, and was submitted to the "FACULTY" as a * partial/full fulfillment for the conferment of BACHELOR OF ENGINEERING, ELECTRICAL AND ELECTRONIC ENGINEERING WITH HONOURS (PLEASE INDICATE THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: Azfar Satari Bin Abdullah
(Name of the supervisor)

Date: 29/07/2022

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*
☐ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirm with free consent and willingly declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature ____________________ (Date) 29/07/2022

Supervisor signature: ____________________ (Date)29/07/2022

Current Address:
Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak

Notes: * If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

DEDICATION

This dissertation is wholeheartedly dedicated to

My beloved parents, who instilled in me the virtues of persistence and commitment as well as supported me ceaselessly to strive for eminence and who always been my source of inspiration and strength when I'm giving up.

To my brother and sister, who always be there for me through ups and down, and continually provide their moral, spiritual and emotional support.

To my roommates, friends and course mates who always shared their opinion and encouragement upon completion this research.

Lastly, I would like to express my gratitude to my supervisor, Mr Azfar Satari bin Abdullah, for all of his guidance and consultation throughout this research.

ACKNOWLEDGMENT

The contentment which comes along with the accomplishment of this project is incomplete without mentioning a few important persons. I would like to take this opportunity to appreciate the efforts of the important persons who supported and assisted me in completing this thesis successfully.

Firstly, I would like to express my sincere appreciation to my supervisor, Mr Azfar Satari Bin Abdullah, a lecturer from the Department of Electrical & Electronic Engineering, UNIMAS, for his guidance and support throughout the accomplishment of this project. His willingness to help and provides a better approach to solve a problem related to my research is really appreciated.

Next, immerse thankfulness also goes to my parents, brother and sister for their continual support and encouragement in terms of financial and spiritual assistance all through my pursue in undergraduate study. Their belief in me has kept my spirits and motivation high during this study.

Besides, I'd want to thank all of my roommates, friends, and coursemates for their support along this journey. Without their helpful suggestion, late-night feedback sessions and moral support, I would be unable to come this far and make this project successful.

Lastly, my gratitude extends to everyone who helped and supported me directly or indirectly in completing my thesis.

ABSTRACT

This project describes the design and implementation of an automatic transfer switch system which can help to save energy and reduce greenhouse gases. The main concept that ultimately led to the creation of this project originated in the field of energy management. In Malaysia, the use of fossil fuels to generate energy is expanding day by day and Malaysia's power usage is also increasing annually. One of the primary causes of this problem is that the vast majority of Malaysian households rely solely on grid-connected energy sources 24 hours. As a result, energy is wasted, and customers end up paying more for their electricity. Thus, this project responds to all these challenges by providing the solution to the household that intends to reduce the energy consumption as well as the electricity bill with the installation of a solar PV system. The name of this device is Solar PV Automatic Transfer Switch for Electrical Energy Management. In this project, the utility grid acts as the primary source while PV system acts as the secondary source. The changeover phase will begin based on the predefined time in Arduino IDE. The vital components for this switching phase are the DS3231 RTC, Arduino Uno, and 1-Channel 5V relay. Besides, PZEM-004T are employed to read the parameters of the load, whereas ESP32 is utilised for data transport. Users can monitor the load's parameters via the Blynk application and LCD display. As observed, the total energy consumption for a house without energy management is 0.54kWh per day while for the household with ATS is 0.279kWh Per day. The total energy usage of ATS-equipped households is lower than a typical household. One of the key advantages of this system is that it provides a secure, sensible and readily adaptable system that gives the user with a smart household monitoring.

Keywords- *Automatic Transfer Switch; Electrical Energy Management; Blynk Application; PV system*

ABSTRAK

Projek ini menerangkan tentang reka bentuk dan pelaksanaan sistem permindahan suis secara automatic yang boleh membantu untuk menjimatkan tenaga dan mengurangkan kesan gas rumah hijau. Konsep utama yang membawa kepada penciptaan projek ini adalah berasal dari kaedah pengurusan tenaga. Di Malaysia, penggunaan bahan api fosil untuk menjana tenaga semakin berkembang dari hari ke hari dan penggunaan tenaga di Malaysia juga meningkat setiap tahun. Salah satu punca utama masalah ini ialah sebahagian besar isi rumah di Malaysia bergantung semata-mata kepada sumber tenaga yang bersambung ke grid (SEB) 24 jam. Akibatnya, tenaga terbuang dan pelanggan akhirnya membayar lebih untuk elektrik mereka. Justeru, projek ini bertindak balas kepada semua cabaran ini dengan menyediakan penyelesaian kepada isi rumah untuk mengurangkan penggunaan tenaga serta bil elektrik dengan pemasangan sistem suria. Nama peranti ini ialah Suis Pemindahan Automatik Sistem Suria untuk Pengurusan Tenaga Elektrik. Dalam projek ini, grid utiliti bertindak sebagai sumber utama manakala sistem suria bertindak sebagai sumber sekunder. Fasa pertukaran akan bermula berdasarkan masa yang telah ditetapkan dalam dalam Arduino IDE. Komponen penting untuk fasa pensuisan ini ialah DS3231 RTC, Arduino Uno dan 1-Channel 5V Relay. Selain itu, PZEM-004T digunakan untuk membaca parameter beban, manakala ESP32 digunakan untuk pengangkutan data. Pengguna boleh memantau parameter beban melalui aplikasi Blynk dan paparan LCD. Seperti yang diperhatikan, jumlah penggunaan tenaga untuk rumah tanpa ATS ialah 0.54kWj sehari manakala bagi isi rumah dengan ATS ialah 0.279kWj sehari. Jumlah penggunaan tenaga isi rumah yang dilengkapi ATS adalah lebih rendah daripada isi rumah biasa. Salah satu kelebihan utama sistem ini ialah ia menyediakan sistem yang selamat, waras dan mudah disesuaikan yang memberikan pengguna pemantauan pintar isi rumah.

Kata Kunci*- Suis Pemindahan Automatik; Pengurusan Tenaga Elektrik; applikasi Blynk, sistem suria*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

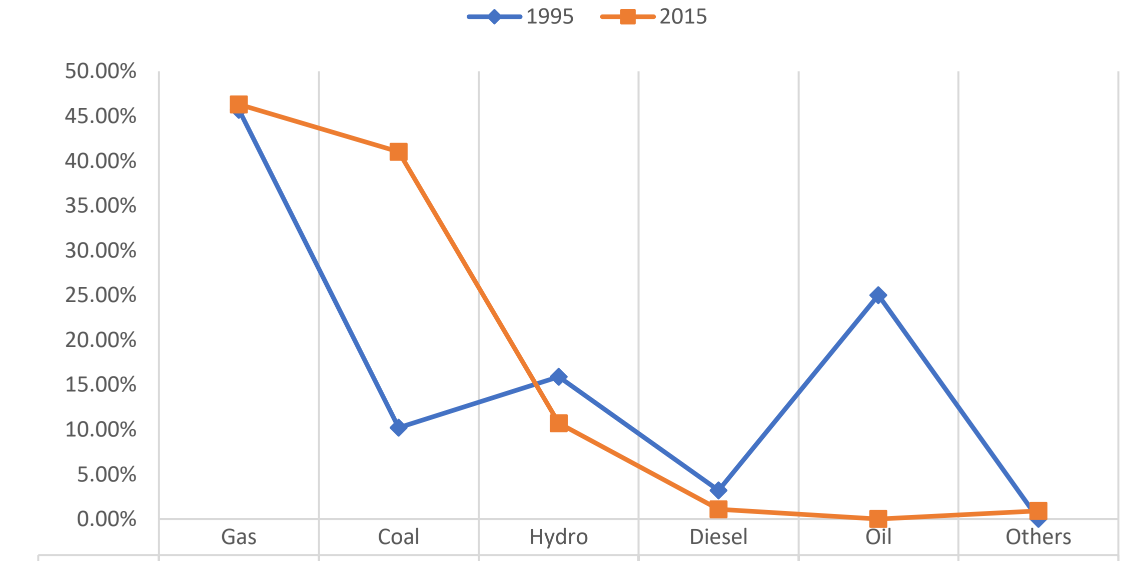
RE	-	Renewable Energy
USD	-	United States Dollar
CO_2	-	Carbon Dioxide
N_2O	-	Nitrus Oxide
CH4	-	Methane
PV	-	Photovoltaic
ATS	-	Automatic Transfer Switch
SEB	-	Sarawak Energy Berhad
LCD	-	Liquid Crystal Display
RES	-	Renewable Energy Sources
Wi-Fi	-	Wireless
IoT	-	Internet of Things
SPD	-	Surge Protection Devices
FYP	-	Final Year Project
GCPV	-	Grid-Connected Photovoltaic
OGPV	-	Off-Grid Connected Photovoltaic
DC	-	Direct Current
AC	-	Alternating Current
RMS	-	Root-Means-Square
CPU	-	Control Processing Unit
PF	-	Power Factor
TNB	-	Tenaga Nasional Berhad
SESB	-	Sabah Electricity Sdn Bhd
MTS	-	Manual Tranfer Switch
SCT	-	Soft-Closed Transition
GSM	-	Global System Mobile
UPS	-	Uninterruptible Power Supply
SPP	-	Solar Power Plant
SEC	-	State Electric Company
PWM	-	Pulse Modulation Index
LED	-	Light Emitting Diode
PCB	-	Printed Circuit Board
IDE	-	Integrated Development Environment
OLED	-	Organic Light Emitting Diode
pm	-	Post Meridian
am	-	Ante Meridian
I/O	-	Input-Output
Li-Po	-	Lithium Polymer
RTC	-	Real-Time Clocking
MOV	-	Metal Oxide Varistor
DMM	-	Digital Multimeters

CHAPTER 1

INTRODUCTION

1.1 Background of Project

Renewable energy (RE) sources are clean and sustainable energies with a high potential for sustainable energy, addressing the increased concerns for the gradual depletion of fossil fuels and global warming caused by greenhouse gas emissions. There are several types of renewable energy in Malaysia, including solar, hydro, and biomass. In the past few years, renewable energy development has intensified and received good attention. Defiance of all these sources, the most promising cleaned renewable energy source is solar energy. Solar energy development offers enormous potential for environmentally friendly electricity generation. Documented back in 2015, most of the national electricity was yielded from fossil fuel-based energy. **Figure 1.1** shows Peninsular Malaysia's electricity-generating mix from 1995 to 2015 [1].



	Gas	Coal	Hydro	Diesel	Oil	Others
1995	45.70%	10.20%	15.90%	3.20%	25.00%	0.00%
2015	46.30%	41.00%	10.70%	1.10%	0.00%	0.90%

Figure 1.1: Peninsular Malaysia's electricity-generating mix from 1995 to 2015.

In 2050, renewable energy might generate more than 80% of electricity. Solar thermal power plants are the most cost-effective renewable energy source among the available options. By 2050, solar thermal power plants will provide around 10% of global electricity [2].

Compared to 2009, Malaysia's overall main energy supply was grown by 20.92 per cent in 2015, reaching 90,187 kilotonnes of oil equivalent (ktoe). Overall energy consumption rises 26.84 per cent from 40,845 to 51,807 ktoe in the same period [3].

Most of Malaysia's electricity is produced from fossil fuels. Over 94.5 per cent of all electrical power is generated by fossil fuels, including oil, natural gas, and coal. Figure 1.1 shows the latest Peninsular Malaysia's electricity-generating mix from 1995 to 2015. It shows that fossil fuels contributed the most energy generation in Malaysia, especially in Peninsular Malaysia. Referring to the percentages above, oil, hydro, and diesel show decreasing rates from 1995 to 2015, while coals increase from 10.2% to 41.0%.

Although fossil fuel is one of the most energy usages in Malaysia, the challenges had risen when the petrol prices indicated a descending trend in 2014 and 2015. The fossil fuel prices decreased drastically from 96.26 USD per barrel (2014) to 52.43 USD per barrel (2015). However, in 2020, fossil fuel prices will rise 57.67%, which is 110 USD per barrel [4]. Besides, the inconsistent cost of petroleum had several consequences on the distribution of income among Malaysia's different ethnicities. The increases in the fossil fuel price leads to escalating the manufacturing budget and, at the same time, can shock the economic progress negatively.

Other than the fluctuation of fossil fuel prices, fossil fuel usage in the electricity sector also leads to air pollution and a shortage of natural resources in the future. It will lead to precariousness like harm to the environment and sustainability of energy choice. In this case,electric power consumption has a long-run relationship between average temperature and average rainfall. Malaysia is located in Southeast Asia in the Equational area, which has ahot and humid environment. In 2013, Malaysia recorded the average rainfall at 250 centimetres while the average temperature was 27 °C [5]. The global temperature will rise again in the next century. By that, a direct relationship exists between climate change and the consumption of energy.

Furthermore, using fossil fuels for power generates greenhouse gases, such as CO2, N2O, fluorinated gases, and CH4, contaminating the environment. [6]. The discharge of greenhouse gasses as a consequence of human endeavour has incited climate change worldwide.

As a result, solar radiation is plentiful. Solar power technology is one of the most cost-effective, capable of supplying 10% of world electricity, and is expected to meet 80% of global electricity needs by 2050 [7]. The average daily irradiationreceived by South-Asia Malaysia is between 4.21kWh/m^2 and 5.56kWh/m^2. By 2020, Malaysia aims to set up accumulated capacity radiant energy to 190MWp. **Table 1.1** shows renewable energy accumulated set-up capacity (MW) [8].

Table 1.1: Renewable Energy (RE) set-up capacity (MW)

Year	Cumulative RE installed capacity in MW					
Energy sources	Solar	Solid waste	Biomass	Biogas	Mini-hydro	Total
2011	9	20	110	20	60	219
2015	65	200	330	100	290	985
2020	190	360	800	240	490	2080
2025	455	380	1190	350	490	2865
2030	1370	390	1340	410	490	4000
2050	18,700	430	1340	410	490	21,370

Nowadays, most households adopt solar panels to produce electricity. Solar power panels capture solar energy and convert it to electricity using the photovoltaic (PV) effects. The use of solar panels depends on the size and quality of panels. A standalone system is typically used for household solar PV systems because it is suitable to install in rural and urban areas. Apart from that, the standalone system is unaffected by power outages because it has a battery backup and can keep the household appliances running. Nevertheless, when all ofthe power is used up, an alternative power source is needed. The other solar PV systems are grid-connected PV and hybrid PV systems.

Thus, a Solar Photovoltaic (PV) Automatic Transfer Switch for Electrical Energy Management is designed. This device automatically transfers the switch from primary sources to secondary sources based on the pre-determined time and connects back primary supply. The primary source is the main grid, the power supply from SEB, while the secondary source is the Solar Photovoltaic (PV) system.**Figure 1.2** shows the general block diagram of Solar Photovoltaic (PV) Automatic Transfer Switch:

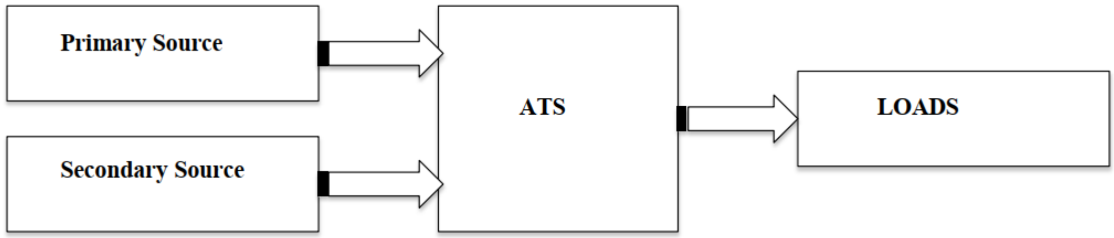


Figure 1.2 : Block Diagram of ATS for Energy Management using PV system

There are eight (8) basic components used to design this device: DC to AC inverter, 1-channel Relay with an optocoupler, LCD screen, PZEM-004T, power supply (battery), load terminal block,Arduino, ESP32 and real time clocking module. The relay driver module transfers electrical load from one supply to another supply. The measuring voltage, current, pf, frequency, power and energy will be loaded into ESP32 then all of the will be sent to the Blynk Application and LCD display for the monitoring operations.

To sum up, this ATS device is developed and designed for electrical power supply and energy management systems. This device is designed to transfer a switch that activates the secondary sources (Solar PV system) based on the pre-determined time from the primary sources (utility grid). At the same time, ATS is designed to avoid manual switches on the secondary power supply. All of the data that collected by PZEM-004T will be send to the ESP32 Wi-Fi module for monitoring purpose. Lastly, the delay feature is installed in this device to prevent both power supplies from fluctuations.

1.2 Problem Statement

Based on the current situation, energy usage in Malaysia mainly depends on fossil fuels. A significant amount of carbon dioxide is emitted into the atmosphere when fossil fuels are burnt. Climate change is a result of carbon dioxide emissions trapping heat in the atmosphere. Fossil fuels also contribute to greenhouse gas (GHG) emissions and environmental impact in other ways. In terms of GHG, the 12th Malaysia Plan intends to reduce the GHG emission intensity of Gross Domestic Product by 45% in 2030, which is in line with the Paris agreement. Besides, it also stated that the utilization of existing and new technologies, including co-generation, solar thermal, and fuel cell, will be encouraged even further. Additionally, efforts will be made to establish mechanisms that will facilitate climate action, such as carbon prices, as well. Besides the other step in order to reduce the CO2 is by managing the energy usage. In this term, good energy management will result in a reduction of the amount of CO2 and GHG emissions.

Other than that, most transfer switches nowadays use a Manual Transfer Switch (MTS). MTS required an operator to physically flip a switch to transfer loads from primary to secondary sources. This MTS lacks of security, and it is not well suited for a vast facility that requires consistent power. Besides, the most significant drawback of MTS is the amount of time required to reconnect to the electrical power supply. As a result, downtime for the company or house will be significantly longer. Compared to an Automatic Transfer Switch, ATS will automatically kick on the secondary supply based on the set time of the secondary sources to trigger.

In addition, the existing transfer switch doesn’t have a monitoring system for energy usage because it is less equipped with a Wi-Fi feature. As a result, the Wi-Fi capabilities on the ATS make this easy for the user to keep track of everything because it emerged as the most significant revolution in becoming an advanced industry in energy management schemes such as the Internet of Things (IoT). IoT can be associated with the advancement of the Fourth Industrial Revolution (IR4.0), which is a notion that refers to links between the physical and the digital world. Besides, the transfer switch without Wi-Fi feature will make the user hard to monitor the transfer load because all the data is only being displayed on LCD of ATS. In contrast, ATS equipped with Wi-Fi will display the data and can be operated vaguely using a smartphone.

Apart from that, the ATS is vulnerable to surges because of the existence of electrical appliances such as fans, lightning, machines, etc. Basically, surges often exist at the ATS's service entrance location. In order to preserve the backup power system, it is essential to protect the ATS input. By that, providing the safety protection system on the ATS is crucial because it can help to reduce the risk of electrical system damage from upstream occurrences like lightning and switching surges caused by regular and abnormal distribution system activities. Additionally, an ATS utility side is often included in electronic circuitry. These circuits must be safeguarded for the ATS to function properly.