

# Development of Solar Educational Training Kit

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**Abstract**— *The ability of utilize free resources of energy to generate electricity is one of the major tasks for environmentally research engineers. Numerous researches have been conducted to convert sunlight to direct current through Photovoltaic (PV) system. Nowadays PV research has become a popular study and has gained attention of many engineers and researchers due to free application, improving efficiency and high reliable energy source availability and is predicted to grow in years to come. With understanding of the aforementioned importance, PV systems aim to satisfy the growing demand for sustainable energy. This paper proposes a model of a real time grid assisted from low power direct current to high power alternating current as a solar educational training kit for an early education process to understand about the sustainability of energy conversion process. Integrating the switching concept, grid connection will only be switched on if the stored energy in the battery is insufficient to energize or supply the training kit. Programmable Integrated Circuit (PIC) is integrated into the educational training kit to enable it to display and indicates the battery voltage level as it also take part in switching between the battery and grid. In the nutshell, a simple and user friendly measurement training kit is intentionally designed for user's handwork purposes.*

**Index Terms**—Photovoltaic System, Educational, Training Kit, Green Development.

## I. INTRODUCTION

As the demand of the electricity is growing dramatically, resources used to supply the electricity are not sufficient to satisfy the needs. Furthermore, the finite resources such as fuels, oils, coals, gases, are reducing critically and thus, the supplies of electricity is getting limited [1]. This situation even more awful when global warming issues keep spreading badly and the world is working hard to keep green. As a result, the ability of utilize free resources of energy to generate electricity is one of the major tasks for going green and so are to replacing the existing finite resources. Energy conversion from sunlight to direct current through Photovoltaic (PV) system has become a popular study and has gained attention of many engineers and researchers such as environmental engineers. The application of this is free, unlimited, efficient and reliable energy source is predicted to grow in years to come. The implementations of PV system on the household or on the industrial have the potential to release the stress on overloaded power demand and to contribute to green energy. With understanding of the aforementioned issues, PV systems aim to satisfy the growing demand for sustainable energy and more importantly to reduce the green house effect. In this project, a real time grid assisted kit from low power direct current to high power

alternating current is modeled as a solar educational training kit for an early education exposure to understand about the sustainability of solar energy process. This system consists of temperature sensing system, voltage indicator and switching system which combined together with Programmable Integrated Circuit (PIC). The switching method integration using PIC and high power relay is to switch on to the grid connection to charge the battery when there is no sun energy availability or the battery is drained. PIC integrating enables to display and indicates the battery voltage level as it also takes part in switching between real grid and battery. Also, a temperature monitoring system is developed and installed to reduce the overheating in the solar educational kit. In the nutshell, a simple and user friendly measurement module is purposely designed to the user for handwork purposes. The module exposed the student about the principle of measuring voltage and current practically.

## II. BACKGROUND STUDY

### A. Global Issues

Global warming is the top highlighted issue for this few years and numerous methods are figured to solve the dramatic changes. One of the most effective methods in solving the issue is green technology awareness. Green technology awareness provides a platform which will reduce the green house effect on the earth. Thus, it makes the environment protected and green technology become a common yet important topic to be discussed around the world but studies on protection and technology is still not sufficient. Educational about the solar power technology provided to the student in university level is not sufficient in order to fully understand the concept of the solar power conversion. Thus, it acts as an obstacle for the student to have a further knowledge and practical application in the real practice. Besides the lack of exposition on the green technology, the student would be limited to think critically about protecting the environment. Introducing the solar educational training kit as the basic step to expose the students about green technology concern. Thus, helps the student to understand more about the concept of environment protection.

### B. Educational Purpose

Basic circuit measurement is the most important step to start as an engineering student. Practical skills such as voltage measuring in parallel while current in series act as a basic practical knowledge to the student. The scarcity of this knowledge creates limitation to the student. As an electronic engineering student, this milestone supposes to achieve by the end of the four years course but some of them still failed.

In the other words, the basic practical knowledge is not delivered through teaching to the student and one of the reason is most of the student was instill with dozens of theoretical knowledge. Hence, this educational training kit introduces a green technology based system to educate the student on the electrical, electronic and green technology. It can be used as introductory subject to the students about measuring the current and voltage on the basic circuit using multimeter. The educational training kit can also be used in the secondary school or even primary school. In the schools level, the educational training kit can be introduced during the “*Kemahiran Hidup*” subject. The syllabus exposes the student to the function of each part circuit in the solar based educational kit. And for the primary school, the student can learn about the basic name of the each component and the idea of solar power production. Throughout these lessons, the green technology idea can be exposed to the student in the early stage and the application will be more effective. Besides that, the university level students can enhance the learning process towards the characteristic of each component used in the educational training kit. While in the industrial sector, the educational training kit provides a platform to the employees to interact with the high power transformation of a PV plant. It is necessary for the employees to understand the basic operation of a PV plant. Thus, a small power consumption system can be used as a platform in introducing the basic idea of a PV plant operational before high power PV plant construction.

### C. Cost

A part from that, the cost of the existing educational training kit is expensive and is not affordable at certain level of educational system. Due to one of this reason, development this solar educational training kit is much cheaper compare to the existing product in the market. Reducing the development cost would help to improve the educational system which is getting intention among all category people.

## III. SYSTEM APPROACH

The main purpose of this solar based education training kit is to encourage the solar technology studies among students. Apart from that, this system also can be used as a practical system to power the low power home electrical appliances by converting sunlight into electricity energy. It is also have a built-in circuit to measurement the trainer output which could provide a platform for educational purposes. As mentioned earlier in the introduction the solar educational training kit consists of solar panel, charge controller, battery as storage, temperature sensing system, battery voltage level indicator and battery charging switching system. Principally, the sunlight strikes the solar panel or also known as photovoltaic panel to convert the sunlight rays into electricity energy. This conversion happens when the sunlight strikes

the silicon plates of the solar panel, freeing the electron charges and bumping them into each other to produce the energy field [2]. The electron charges moves along one direction to provide an output as electrical power [3]. Then, the electrical power will flow to the charge controller to regulate the electricity energy generation before storing the electrical energy into battery as source [4], [5]. The charge controller function is to regulate and avoid the over-charging when the battery is fully charged. When there is a load connected to the charge controller, the charge controller allows the electrical power to flow from the photovoltaic panel into the battery and lastly allow the connected load to switch on [6]. This system uses lead acid battery which is different from car battery because it is designed is to handle the ongoing charging and discharging that occurs with the day to day variations in sunlight [7]. The battery stores the energy which will be used during the moment when the solar panel is not producing any electricity due to unavailability resource. In order to have the high current appliances connected to the developed system, an inverter can be directly connected to the load connection at the charge controller. The inverter inverts the 12 VDC direct current from the battery storage to 240 VAC alternating current. Thus, the inverted electrical energy can be used as power source to power the educational training kit and low alternating current devices or appliances (as low 3 watt).

### A. Photovoltaic System

PV system is built-up with a solar panel which converts the sunlight energy into usable electrical energy. Sunlight energy is one of the resources that generate electricity energy silently with no atmospheric emissions, green house gases that causes detrimental effects on the environment and hazardous waste. Conventionally, electricity generators require liquid or gas to transfer and combusted in order to produce the required electricity. Compared with electricity generated from fossil fuels, each PV-produced kilowatt eliminates up to 830 pounds of nitrogen oxides [8], 1,500 pounds of sulfur dioxide [8], and 217,000 pounds of carbon dioxide [8] every year according to National Renewable Energy Laboratory (NREL) research [8]. In order to produce the required voltage and current, there are two basic connections: series connection and parallel connection. Series connection requires the back contact of a cell to be connected to the top contact of another cell and vice versa. While in parallel connections, the back contact of the cell must be connected to the back contact of the other cell and the top contact of the cell must be contact to the top contact of the other cell. Fig. 1 shows when the modules are wired in series, the voltage generated will be doubled and the current is equal to current of a single cell. This condition usually referred as series string connection. Fig. 2 shows when the modules which connected in parallel. If the modules are wired in the parallel, the voltage generated will be the equivalent to the voltage of one cell while the current doubles. In order to achieve the

voltage and current required, the modules are arranged to form a PV array. The flexibility of generating different voltage and current enables the designer to create the solar power system according to the requirement of the electrical load connected to the system.

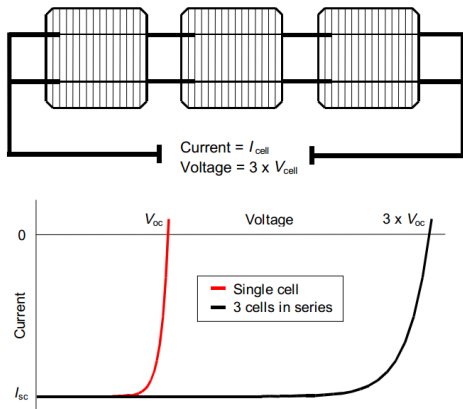


Fig. 1: Series Connection of the Array

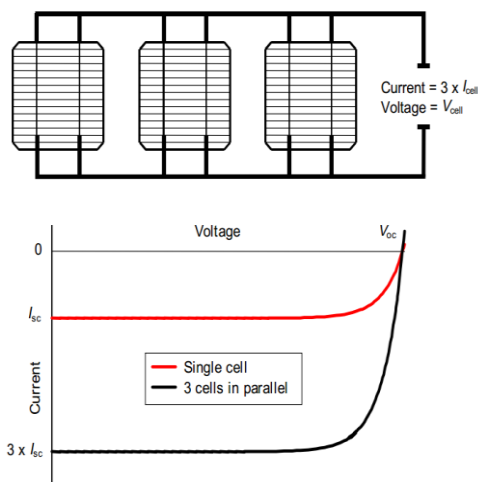


Fig. 2: Parallel Connection of the Array

### B. Energy Storage

To make the system more effective when there is no sunlight availability; storage technologies have been introduced to use the stored energy from battery. Although ultra-capacitor technology aims to replace the battery technology in the coming years but for instant, research on the use of ultra-capacitor as the storage system for photovoltaic system is yet waiting to be clarified and thus, battery technology remains the first choice as the storage system for photovoltaic system [10]. Different system requires different types of storage technologies, for a standalone photovoltaic systems, lead acid battery is the first choice storage method. For a photovoltaic system, a deep discharge battery is required for photovoltaic application [1].

### C. Charge Controller

A charge controller regulates the output of the solar panel that is required to store the regulated energy source into battery storage. A normal solar panel produce fluctuating

output voltage which is approximately from 15 Volts to 20 Volts and this voltage need to be regulated to avoid damaging the battery storage. Basically, the function of a charge controller is to prevent overcharging condition the battery bank storage.

#### i) Overcharging Condition

Overcharging condition usually happen when the array of solar panel is operating under well weather condition (typically noon hours). The output or the energy produced by the array often higher than the battery and load demand. Without using charge controller, the current is directly proportional to the irradiance will charge the battery without considering the needs of the battery. Problem such as grid corrosion, gassing, battery heating, and electrolyte loss will happen if the unregulated charges are supply to the battery when the battery is fully charged. Those problems leads the battery to premature failure. The charge controller isolates the array of the solar panel from directly supply energy to the battery. Instead, it provides an alternative method to fully charge the battery without overcharging. The charge controller limits and interrupts the current supply from the array of solar panel to prevent overcharging condition when the battery is fully charged. There are few methods in preventing the overcharging condition. One of the methods is setting set point of the battery. Voltage regulation set point (VR) is the limitation of the battery voltage that the charge controller uses to accomplished the task of charge regulation. Array reconnect voltage set point (ARV) is used by the charge controller to reconnect the source from the solar plate array to the battery when the charges of the battery drop until AVR set point and thus, charging backs the battery. ARV set point is the references point of the battery charges that requires the array to start charging backs the battery.

#### ii) Over Discharging Condition

When the demand of the loads goes high and the supply rate form the array is not sufficient to charge back the battery, the charges in the battery will continuously drop or discharged until the charges in the battery is completely empty. When this condition occurs, it will weaken the bond between grids and the active materials because the reaction occurs close to the grids. Thus, the battery life time will eventually drop. The charge controller controls the limitation for the battery to continuously supplying the load. It will automatically interrupt and disconnect the battery from the load once the voltage or charge of the battery reached certain low sate. Pre-set or adjustable low voltage load disconnect set point (LVD) is the set point used by the charge controller to control over discharging condition. It can be accomplished by creating an open circuit connection between the load and the battery. A normal charge controller device provide an indicator signal or feedback to alert the user when it disconnect the circuit and it will automatically reconnect the circuit when the battery is recharge back until a certain level. Load reconnect voltage set point (LRV) refers to the point where the battery supply is reconnected to supply back the

load Fig. 4 shows the graph of VR set point, ARV set point, LVD set point and LRV set point.

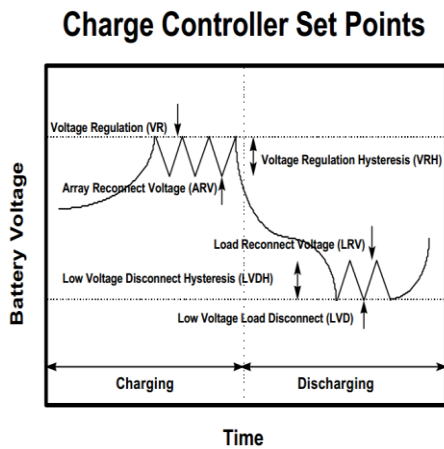


Fig. 4: Relationship of VR, AVR, LVD, and LRV

Fig. 5 below shows the basic connection in the charge controller that builds up with the array from solar panel, battery and load.

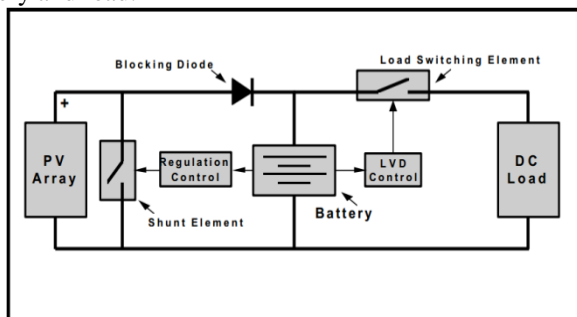


Fig. 5: Basic Connection of Charge Controller

#### D. Inverter

Inverter is used to convert the 12 Volt DC to 240 Volt AC. In other words, it converts the battery supply to the real power grid supply in order to power up the normal electrical application. It is necessary create an AC supply for a PV system since the PV system is an off-grid application. Inversion is the process where DC power from the PV array is converted to AC power. The supply generated can use to power up the low power application such as low power fan, lights, battery charger and other low power electrical equipment. As in our real life, although most of equipment using DC power to operate, but our electrical power infrastructure are based on AC power. The circuit generates positive and negative cycle by using the IC 4047. The output of the circuit will then be connected to a high power transformer to step up the voltage from 12 volt AC to 240 AC.

#### IV. DISCUSSION

This solar base educational kit will not only provide as a simple circuit trainer to the user but as well as an introduction on green technology education. By converting the unlimited, free, green source such as sunlight energy into electrical energy, it helps to power up the simple circuit trainer and thus reduces the usage of electricity supplied from

government. The student can use the concept of solar panel to apply in a household where it can be used to reduce the electric bill. The student will be able to understand the basic concept of the simple circuit measurement and the solar power education. Furthermore, the DC to AC conversion can be used to power up the other low power educational trainer. A combinational study of solar knowledge and circuit subject can be done by using this concept. The solar base educational kit is not only built together with the solar panel, but it also builds together with the connection to the real power grid. This indicates that even the solar panel did not receive any sunlight or the energy in the battery is insufficient, it still can be operated by switching it to the real power grid. The real power grid will only be switched on when the battery reached a certain threshold low level. As the grid is turned on, it will charge the battery again and supplying to the educational kit as well as the power supply on the kit. Therefore, it makes the educational kit is available at days, night even raining days. By having the battery indicator, the PIC will detect the voltage level available in the battery, if the battery drains until a certain level; it will charge back the battery using solar power or real grid connection. Besides, the system also integrated with a temperature sensor. The temperature sensor will take as a role to measure the temperature generated by the transistor and regulator inside the system. If the temperature inside the system reached a certain level, the PIC will trigger on the cooling circuit and cool down the system.

#### V. CONCLUSION

The solar educational training kit enables the user to understand the characteristic of solar cell modules and thus, applying in the real life in going green concept. The basic solar power storage system and requirement enables user to understand the concept of storing charge and reuse it without wastage of energy. Power conversion form low power DC to high power AC can be used to save energy from the real grid connection. Besides of reducing the cost of the electric bill, the idea provide a platform on reducing green house effect and it can be act as source to replace the finite resource to generate electricity. By using the solar panel, the education about solar generation can be inserted in the syllabus of science subject. The solar educational kit act as an intermediate and an alternative method in introducing green technology to the user in a more practical method. This small step enables the user to provide basic services to the earth in terms of going green.

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**Engr. Ranjit Singh Sarban Singh** was born on 30 April 1982. He received his Diploma of Technology Computer (Electronics Engineering) from Politeknik Seberang Perai, Malaysia in 2003. He then graduated with a Bachelor Degree in Electronics Engineering (Computer Engineering) from KUTKM Malaysia in 2006 and received his Master of Science Engineering from Multimedia University, Melaka Malaysia. His keen interest is in image processing motion estimation, solar system application and electronics applications. Besides that, the author is involved in the development of motion estimation algorithm application, actively involved in smart consumer electronics applications and design and development solar systems.

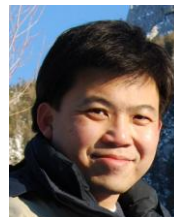


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**Engr. Siva Kumar Subramaniam** was born on 16 July 1981. He received his Diploma of Electronics Engineering from Politeknik Ungku Omar, Malaysia in 2002. He then graduated with a Bachelor Degree in Electronics Engineering (Industrial Electronics) from KUTKM Malaysia in 2006 and his Master studies in Electronics Engineering in the same institution in 2009 which is now known as Universiti Teknikal Malaysia, Melaka. Since his keen interest in industries matters and strong support from the university, the author is involved in the development of the industrial based application such as monitoring systems, automation for industries and control base applications. Engr. Siva Kumar has a few collaboration with industries in accomplishing a number of research projects and consultancy works in Malaysia for the past few years. Apart from, research works with industries, Engr. Siva Kumar also supervises secondary school students for their final year projects.



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