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Design and Development of A PV / AC Grid Hybrid System in Rwanda

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Abstract: ***This project focuses on the design and development of a Solar Pv/Ac Grid Hybrid System in Rwanda supply the electricity in different houses. The solar PV /AC Grid Supply Hybrid System supply electricity to any installation by using two different source of electrical energy which are the solar PV source and national grid source control system to interchange those two supply system according to the voltage. The researcher chose a survey research design because it best served to answer the questions and the purposes of the study. The survey research is one in which a group of people or items is studied by collecting and analyzing data from only a few people or items considered to be representative of the entire group. It principle operation is that this system at the beginning, it will be using electricity from solar PV as default supply for the installation , once the PV electricity become insufficient (mean when PV battery reach at their death of discharge) there will be an automatic and intelligent switch which will cut off the electricity from solar PV and connect my installation to the AC national grid supply system and again when the electricity from PV system become sufficient(mean when the PV battery are full charged) the electricity from national grid will be cut off and again the installation will be connected to PV solar system. This project will not only provide explanation of how to design a PV/AC Grid Supply Hybrid System it will also provide deep explanation about how to design, choose, sizing of all components, calculation and formula used in order to design the solar PV System.***

Keywords: Solar, grid, battery, electricity

1. Introduction

Now days the electrical hybrid system is becoming so popular in the world because of its merit compared to other electrical supplying system. Even if it became popular recently in fact it dated back in the past for a long time.

For a PV/AC national grid supply hybrid system is a good example for an ancient hybrid system because its two supply system the solar PV and the AC national grid supply was created long time ago. For example, the AC national grid supply was there since the invention of electricity, the PV system has been used since the 18 century. The first PV was invented in 1853 by Calvin fuller, Gerald person and Daryl Chapin and in 1856 the first solar PV was available at the market. this mean that in 1856 I could have my own PV/ac national grid supply hybrid system even if it was not so advanced and not officially launched in fact I had it.

1.1 Problem statement

As we know in now days‟ electricity is significantly contributing to economic growth and social development of my country Rwanda and the world. Different types of electrical energy sources are used to supply different applications in rural and urban areas. so the different way used to generate electricity are generators, by using solar PV and electricity from national grid. But all those systems used when are used alone they have some disadvantages: Examples as generator fuel used flammable and expensive, its reliability is low, it has a low power output and cause air pollution. The AC national grid has the problem of black out and amount of money charged on electricity is high. And solar PV system has a low output power and produce electricity only during the day. So every source of electricity when it is used alone, it has some disadvantage so this is why I have chosen to design a hybrid system which will combine two source of energy in order to minimize those disadvantages. But in all hybrid system used the best in all, is the solar PV/AC grid hybrid system because resolve all those problem stated above and again combine two renewable energies. [2]

The solar PV/AC grid supply hybrid system is the best because it uses two renewable energies (solar energy and AC grid electricity) which mean that it is ensured because it doesn't cause air pollution and this system will resolve the problem of black out since it use two different supply. When one supply is off, the other will be on. And it running cost is low compared to all other system because for the most of its time it uses electricity from solar PV which get electricity from sunlight which are free and this hybrid will eliminate the manual activities used in other hybrid system due to interchanging of one electrical supply by another as it consists of an automatic switch for that task, also it helps us to identify easily the amount of voltage I have at my battery. And to identify which supply I am using by displaying it on it LCD display in additional this system keeps safe my PV battery because it changes the supply according to DOD voltage of battery.[3]

1.2 Main objective

To design and develop a PV/ ac grid hybrid system in Rwanda

1.3 Specific objectives

- To Demonstrate the advanced practical knowledge about the solar PV/AC grid hybrid system

- To design a solar PV/AC grid supply hybrid system and it designing process.
- To reduce 40% amount of money spent on electricity by introducing a PV solar system.

2. Literature Review

2.1 Definition of key concepts

- A **battery:** is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode
- **PV system:** Solar photovoltaic system or Solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity
- **Voltage:** Voltage, electric potential difference, electric pressure or electric tension is the difference in electric potential between two points. The difference in electric potential between two points in a static electric field is defined as the work needed per unit of charge to move a test charge between the two points
- **Wind turbine**: A wind turbine, or alternatively referred to as a wind energy converter, is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of vertical and horizontal axis
- **Relays:** are switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit. As relay diagrams show, when a relay contact is normally open (NO), there is an open contact when the relay is not energized.
- **SPDT** – Single Pole Double Throw. A common terminal connects to either of two others. Including two for the coil, such a relay has five terminals in total.
- **DPST** – Double Pole Single Throw. These have two pairs of terminals. Equivalent to two SPST switches or relays actuated by a single coil. Including two for the coil, such a relay has six terminals in total. The poles may be Form A or Form B (or one of each).

2.2 Theoretical perspectives

The PV/AC grid hybrid system will deliver the best solution to the society such as industries, household, living house, rural area and urban area especially to have an ensured electricity at a low running cost and at low designing cost. In fact in taking account at ensured electricity this system provide electricity using two supply when one supply is off the other is on, for low running cost this system the most of it time it use PV electricity which is free, and at the end compared to other system of supplying this the cheapest and the reliable one because it designing cost is too low it around 470000frw.

2.3 Related studies

In this chapter we will see different project and topic related to my project which provided us some idea which helped us to design my circuit adequately in taking account to the inconvenience from those other topics in order to make a good project.

And as we know my project of PV/AC GRID SUPPLY to be completed it must be composed of three systems which are the PV SYSTEM, GRID SUPPLY SYSTEM and a CONTROL SYSTEM. So this chapter of related topic will be also based on those three sub system which mean I will have to see **topic related to the PV system, related to the automated control system and topic related to hybrid system.**

2.3.1 PV system related topic

This sub chapter of PV system related topic will give us different books and journals which provided us a clear understanding on the principle working of pv system and guided us in designing and sizing my PV system.

2.3.1.1. Solar PV standardized training manual

This solar PV standardized training manual has been developed by SNV Zimbabwe in 2015 this manual provides basic technical training in the sizing, installation and maintenance of photovoltaic system. In additional it is a post training referral resource in trouble shooting and maintenance of the system. (PV solar market, 2015) the manual covers the following:

1) Introduction to renewable energy in Zimbabwe
2) Solar energy principle operation and application
3) System sizing
4) Safety precaution, basic maintenance and trouble shooting

2.3.1.2. Grid Connected Net Metering PV System

This paper presents the design of a grid connected net metering to provide the required electricity for a single residential household it was published by alternative energy tutorial in May 2018 (alternative energy co. ltd, may 2018).this is a type of PV System which is connected to the national grid.it principle working is that when you Connect my solar panels or solar array to the local power grid enables you to engage in one of the most advantageous parts of generating my own electricity: **Net Metering** or **Net Billing**. If during a sunny day more electricity is produced by my solar PV system, then you use or consume it and the excess solar power is delivered back to the utility grid with the effect of rotating my electric meter backwards. When this happens you will normally be given credits by the local power company for the amounts of electricity produced by my grid connected PV system.

It is important to note that a grid connected solar power system is not an independent power source unlike a standalone system. If the mains supply from the electrical grid be interrupted, the lights may go out, even if the sun is shining.

Grid Connected PV System

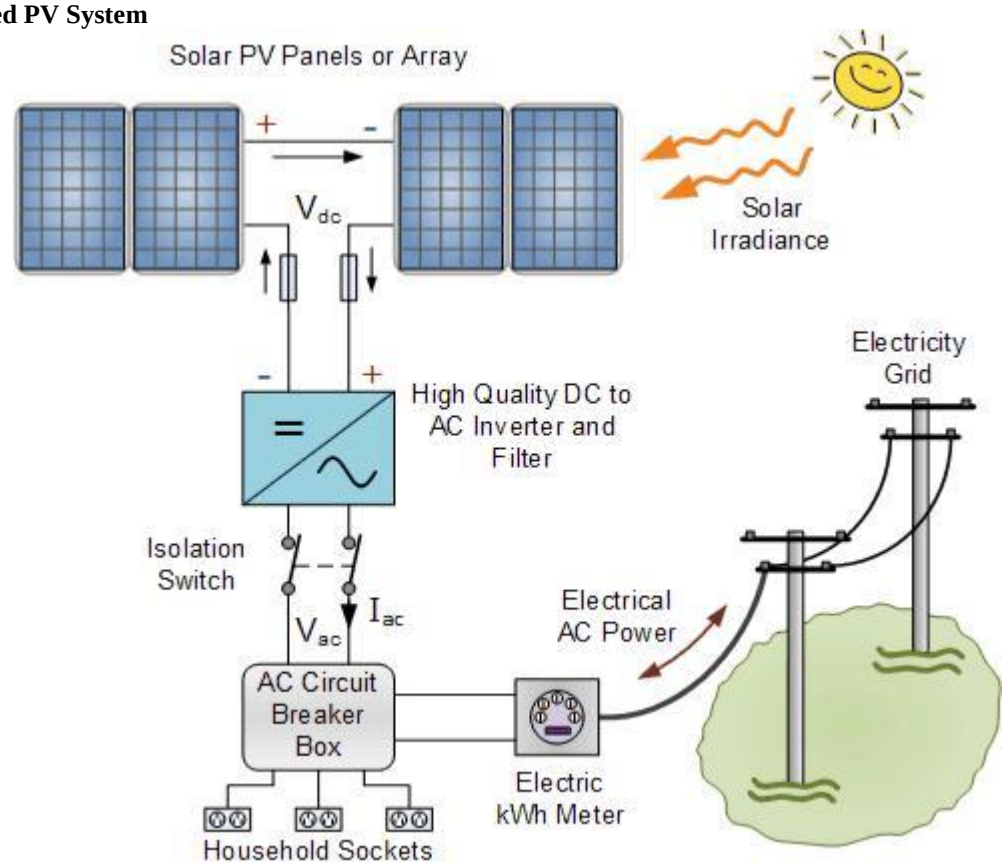

Figure 1: Grid connected system with batteries

2.3.2. Arduino Based Control System Related Topic

This sub chapter will be consisting of different books and document that I have related on and which provided us some information and idea during the design of my Arduino based control system as. my control system uses the principle of change over to control the two supply then most of those books are based on the different type of change over system. Let's start.

2.3.2.1. An Automatic Electrical Based Change Over Switch

The automatic change over with generator control mechanism is a system designed to select between two available sources of power giving preference to one out of the two sources.

In this case, the selection is between power sources from EUCEL (main source) and a generator The automatic changeovers switch work on the operation of the power unit which was well organized and coordinated for an efficient performance. The operational process is outlined below

1) The control circuit is active when there is AC mains supply.
2) The main s is made the references point.
3) When the main source goes off and the generator is on, it changes directly to the auxiliary source.
4) Power supply is interchanged the moment the AC mains are restored. Immediately after this, the generator is switched off by the user. In this circuit I have buzzer use as an indicator so it rings 5 second when the main source goes OFF and it tell the user to go to switch ON the generator and then it again to ring when the main s it restored this it again to tell the user to go to switch OFF the generator and it stop ringing simultaneous during stopping generator. (Butumwa, 13/July/2016).

2.3.2.2. Automatic changeover switch using triple five (555)

According to the development of electric traction. Modern methods of railway operation. Had been implemented an automatic changeover switch by using triple five 555 as you shown the meaning of implementation below; Here this article presents the principle, design and operation of automatic changeover circuit where in a DC load like a series of LEDs are driven either by a battery or an AC-DC power supply.

Automatic Changeover Switch using triple 555 timer Circuit

This circuit is based on the principle of bistable mode operation of 555 Timer. In this mode, the Timer output is either high or low depending upon the status of trigger and reset pin. The Timer output is connected to a transistor which acts as a switch, being on or off depending upon the Timer output. Two LEDs in series are used as a load. In case of transistor being switched off, LEDs are driven by the AC-DC power supply whereas in case of transistor being switched on, LEDs are driven by the battery. (hub, 2015).

3. Materials and Methods

3.1 Study Design

The researcher chose a survey research design because it best served to answer the questions and the purposes of the

study. The survey research is one in which a group of people or items is studied by collecting and analyzing data from only a few people or items considered to be representative of the entire group

3.2 Data collection methods

Data collection method is an important phase of the research, because mistaken data collection leads to worthless result. Good result requires good choice of methods and techniques to use for making research and data collection. This project of PV/AC GRID HYBRID SYSTEM is achieved due to knowledge combination from the class, colleagues, different books and internet. Below are methods I will use.

3.2.1. Documentation

In my project I used documents found in the school library books, class notes, some of websites on the internet, as well as rapports done by the other researchers have been consulted. My research was carried on general electronic to find more information about using microcontroller, LCD, relays and also on general electricity in order to find information about the designing of the PV system.

3.2.1.1 Primary data

Then we have gotten primary data of my project PV/AC GRID HYBRID SYSTEM from the different places I visited and from the people who work there and other extra information I got it from my supervisor who help us for analyzing those data and for better understanding for those data.as my system is composed of three systems then I got those primary data from different places. which means the PV SYSTEM primary data I get it from the electrical workshop (EEE) of RP IPRC KARONGI where I found different component to be used on my pv system then I had a good guiding and explanation about it sizing from the workshop assistant I meet at the EEE workshop, and then for my second system which are the control system I have to go to Kigali and visit the FARUNUX company where I have gotten all the component to be used to build up my control system which are Arduino , LCD , RELAY , voltage regulator and were he explain us about the suitable component for my system and finally I consulted my supervisor who helped us so much in the coordination of all information I get and give us the key data needed for my project.

3.2.1.2 Secondary data

Secondary data are data which have already been collected and analyzed by someone else. So to get those secondary data I have checked different books which talk about the working and designing of my PV/AC HYBRID system and other book which their subject are related to my subject and finally I have used internet website in search addition note I have missed in the books of the notes My supervisor had helped us to size and designing a PV system and my control system.

3.3 Data analysis

Data analysis, I used tables and block diagrams data analysis has been analyzed and interpreted in reference to the recognized objectives. It consists of editing the information from the books, web site and coding the responses. When data were being processed.

3.4 Data needed

The purpose of this study is to design PV/AC hybrid system by regarding on the value condition, improvement and innovation of the PV hybrid system.

Information on this project will take place on a PV hybrid system such as:

- Power consumption and PV system sizing
- The design of a control system based on Arduino

3.5 Materials used to analyses data

To analyses data, I have gotten for my project I have used some electrical and electronic laboratory equipment's, like multimeter to help us measuring the voltage and current that will be consumed by the installation or on which my project will be implemented on, and it was used again to check out the continuity of my relay, Arduino and also I used it to identify different terminal of my battery. And then as my project consist an Arduino then I used different PC software for checking my Arduino state like Arduino IDE for checking whether my Arduino code are correct and use PROTEUS software for helping me in simulation for my Arduino, fritzing for drawing circuit.

4. Results

Introduction

This chapter I start will clearly describes and discuss about all material, apparatus and component that will be used to make my PV/AC grid supply hybrid system and provide information and all details about their principle operation, types and their classification. As I have seen above in the first chapter of my project I have seen that my PV/AC GRID HYBRID SYSTEM will be consisting of three main part in order to be complete; those three main part are two supply system and one control system which will be used to interchanging them during the operation of my installation according to the information researcher have. The two supply system to be used the first one will be the solar PV system which will take the electricity from the sun by using many component such as PV panel, charger controller, batteries and inverter and the second supply system will be the national grid supply system which will take electricity from national grid will be dealing with some of it few component because other main component are situated at the grid station then the control system which will be used to control the two supply it will be a block circuit composed with many electronic component such as an Arduino uno, relays led, LCD to display amount of voltage I will be having from the PV system. So let start with the description of each component of each system by starting on the PV system.

4.1. PV system

4.1.1 Types of PV System

Types PV systems are broadly classified into three distinct types:

1) **Stand-alone systems:** where the energy is generated and consumed in the same place and which does not interact with the main grid. Normally, the electricity consuming/utilizing device is part of the system, i.e. solar home systems, solar street lighting system, solar lanterns and solar power plants.
2) **Grid-connected systems:** where the solar PV system is connected to the grid. The grid-connected system can either be a grid-tied system, which can only feed power into the grid and such system cannot deliver power locally during blackouts and emergencies because these systems have to be completely disconnected from the grid and have to be shut down as per national and international electrical safety standards. Some grid-connected PV systems with energy storage can also provide power locally in an islanding mode.
3) **Solar PV hybrid system**: In a hybrid system, another source(s) of energy, such as wind, biomass or diesel can be hybridized with the solar PV system to provide the required demand. In such type of system, main objective is to bring more reliability into the overall system at an affordable way by adding one or more energy source(s).

4.1.2. Major component of PV system

Solar PV system includes different components that should be selected according to my system type, site location and applications. The major components for solar PV system are **PV module**, **solar charge controller**, **inverter**, **battery bank**, **auxiliary energy sources and loads** (appliances).

4.1.3 Principle operation of a PV standalone system

The PV system is a system that converts sunlight into electricity by using many components. Lets begin step by step the process how electricity is produced by PV. The PV system consist of a p module which is used to take sun light and convert it into electricity by using it cell and then send the produced electric current to the charger controller which will stabilize that current and then send it to the battery bank where it will be stored in order to be used later the electricity from the battery will be send to the charger controller where it will be stabilize again and then will be sent to the inverter in order to convert that low DC voltage from the charger controller into high AC voltage which is adequate for a given application or load. Let's start the description of each component of PV system.

4.1.4 Description of PV system component

4.1.4.1 PV module

Electricity is generated directly from sunlight using photovoltaic cells. Photovoltaic means an electric voltage caused by sunlight. Cells are made of a form of silicon. Silicon is a hard material from sand that is either dark blue or red in appearance. Solar cells are solid-state devices that absorb light and convert light energy directly into electricity. They do this completely inside their solid structure and have no moving parts. Electricity is generated when sunlight hits the solar cells and produces an electric current. This electricity can be used right away, fed to the electric power grid or stored in batteries for later use. (K. S. Sudhakar, May).

Some term to know about a PV arrays

- **SOLAR CELL** - The basic photovoltaic device which generates electricity when exposed to sunlight. A combination of cells gives a module
- **MODULE** - The smallest complete, environmentally protected assembly of solar cells and other components (including electrical connectors) designed to generate dc power when under concentrated terrestrial sunlight. Combination of many modules give arrays
- **PANEL** - A collection of one or more modules fastened together, factory preassembled and wired, forming a field installable unit.
- **ARRAY** - A mechanically integrated assembly of panels together with support structure (including foundations) and other components, as required, to form a free-standing field installed unit that produces dc power.

The photoelectric or PV effect is the process through which a solar cell is able to convert sunlight, which is made up of photons, into electricity. Photons contain varying amounts of energy corresponding to the different wavelengths of light. (Kumar, 2006).

5. Conclusion

For concluding the PV/AC GRID HYBRID SYSTEM has operated as I expected. I was able to implement all the functions specified in my proposal. The biggest challenge I had to overcome in this project was that this project for being complete i had to design two different type of system and then combine them in order that they can work as one system. The first system to design was the electronic system which is my control system and the second system was to design an electrical system which is PV SYSTEM supply.

And after a successful working of my project, i think that this project will be suitable to be used and marketable because this project has an advanced control system which exchange it supply automatically, also because this system is economic due to the use of the sun rise as one source of electricity , and also it is inexpensive due to the cost of the design of it control system and it low power consumption which doesn't exceed 12VDC and finally this system is so reliable for different application because of it high output power.

6. List of Abbreviations

AC	Alternative Current
DC	Direct Current
F	Frequency
IST	Institut Superieur de Technologies
I	Current
LCD	liquid crystal display
LED	light emitting diode
NO	normally open
NS	synchronous speed
NFL	full load speed
P	number of poles
R	Resistor

RMS	root means square value of an alternating current or voltage
S	slip
V	Volt
W	Watt

7. Acknowledgment

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8. Authors' Contributions

JR conceptualize the idea and both others contributed equally thereafter.

9. Authors' Affiliation

Both authors are affiliated to Distance production House University/ IST Burkina Faso.

10. Conflict of interest

We declare not conflict of interest

11. Funding

None

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