MAKERERE UNIVERSITY

COLLEGE OF ENGINEERING, DESIGN, ART AND TECHNOLOGY

EFFICIENCY FOR ACCESS DESIGN CHALLENGE

TEAM 001 FINAL REPORT

TITLE: STAND-ALONE SOLAR LOAD MANAGEMENT SYSTEM

TEAM MEMBERS

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A special gratitude goes to our academic Coordinator, Dr. Peter Olupot for his efforts in guiding us during the challenge.

Lastly, we are grateful to the team at Engineers Without Borders for the webinars, concept note feedback and availing us this wonderful opportunity to participate in the challenge.

EXECUTIVE SUMMARY

Team 001, Makerere University is looking forward to prototype a stand-alone solar load management system to be used in Rural Hospitals and Health Centers that have no access to the grid electricity but are powered by solar mainly. These Rural health centers particularly those in Uganda face several challenges and shortage of electricity is one of the major challenges they face in carrying out their operations. Those that are connected to the grid suffer from unreliable power due to the frequent blackouts.

However, the statistics show that solar energy can be harvested and utilized by these Health Centers in the rural areas. The only challenge left would now be the usage. We came up with this project idea, therefore, to address the challenge of inefficient usage of this solar energy in these rural health centers. This in turn will save lives and money as will be discussed in the subsequent chapters.

The main objective of this project was to create a system that can help a user manage their DC loads connected to a solar system in order to ensure effective usage of the available solar energy. Our particular focus was on DC loads as per the requirements of the challenge.

We plan to use a sales based strategy whereby our product will be sold to the end-user.

ABSTRACT

Chapter 1 gives a brief description of our product design and how it improves on solutions currently available to the target end-user

Chapter 2 gives a detailed explanation of the impact our proposed system will create in people's lives and the SDG goals that have been considered in our product design.

Chapter 3 talks about the potential of our target market and the proposed business model

Lastly, included is a list of references and appendix.

We applied for prototype funding and fortunately, we were successful. On this note, we have attached our budget and Needs Statement as an appendix.

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CHAPTER 1: PRODUCT INNOVATION

1.1 Introduction

Global energy demand is increasing rapidly in comparison to the steady growth of energy generation and transmission setups. Consequently, this widens the demand and supply gap. In traditional grids, utilities cater for this situation by increasing the total generation capacity as a function of peak demand. However, the resulted system (generation and distribution) by a large part is unutilized. Recently, two parallel approaches were developed to handle such situations: (i) using and promoting energy efficient technologies to reduce the aggregated power consumption, and (ii) developing strategies to control the aggregated power demand.

One of the existing related projects to reduce the aggregated power consumption is the intelligent load management system for smart homes and this project in particular, targets smart grids. The intelligent load management system uses devices like current transformers for sensing the current, automatic switching methods for isolation, fuses and circuit breakers for protection and it employs information and communication technology for communication between the user and utility. It also uses smart metering for measuring energy units in bi-directional as well as smart storage by use of an intelligent battery that has an embedded microcontroller for measuring the amount of charge available. This intelligent load management system is deployed in a home to schedule the electricity consumption in such a way that peaks and electricity cost is reduced to the maximum extent. These technologies address efficient generation, transmission and distribution of electricity to the end users and ensuring that the energy is always available for the end users. However, the end users do not have control of the energy available to them. These technologies are mainly designed for on-grid users. [1]

1.2 Brief Project Description

Stand-alone solar load management project is aimed at addressing the challenge of off-grid load management for DC loads only. We provide the user with the ability to control and manage the available energy by using the information provided on the user interface display from microcontroller.

The loads connected to the supply were categorized into priority loads (those that shouldn't go off at any time), intermediate loads, and the less priority loads. These are symbolized by the lights red, yellow and green respectively. The microcontrollers were programmed to cut off current supply to the different circuits according to the priority levels of the loads.

The product does have no effect on environment as it does not emit any hazardous gas under operation. This product when fully developed can be used on any existing solar system and no current will flow through the connecting wires. This is a voltage controlled device thus we can use smaller wire sizes thereby greatly reducing the total cost of the product.

The product components were readily available and cost friendly. Variation comes due to the specification of the users' load categories that alters the program written on the microcontroller as the users define the loads in terms of priority loads, less priority loads and non-priority loads. [2] The target users are off-grid Hospitals and Health Centers mainly in Rural areas of Uganda.

1.3 Main Project Components

Since we are looking at a stand-alone solar system, our initial components for the design were a solar panel, a charge controller and a battery. Other project components are discussed below;

1.3.1. Ampere Hour meter

This is a measuring device that measures DC charge stored in the battery in Ampere Hour Meters. The dc charge measured acts as input to the main microcontroller for controlling the final circuit microcontrollers. The ampere hour meter measured the battery capacity, and then relayed the information to the main microcontroller

1.3.2 Main microcontroller (Arduino)

This was programmed as a master controller that sends switching commands to the final circuit microcontrollers. The main microcontroller was programmed in such a way that should the battery capacity go below a certain specified limit; it limits the current flowing to the different loads. The main microcontroller sends switching commands to the socket microcontroller depending on the load categorization when the charge in the battery has reduced to 60%. It sends switching commands to the light microcontrollers when the charge in the battery reduces to 40%.

The main microcontroller and the ampere hour meter were embedded in one device i.e. a black box casing.

1.3.3 Final circuit microcontrollers (Arduino boards)

These are two Arduino microcontrollers i.e. socket microcontrollers and light microcontrollers programmed using C++ language to receive switching command from main microcontroller. Power supply to the sockets is switched off when the battery charge reduces to 60% for socket microcontroller. For the case of light microcontroller, when the battery charge reduces to 40%; the main microcontroller reduces the current flowing to the bulb thus dimming the lights.

These additional microcontrollers are connected to the different circuits immediately after the Distribution Board and they are in communication with the main microcontroller though communication cables.

1.3.4 Selector switch

This is used for manual override of the system in case the end user needs to connect a load that has been switched off depending on the battery charge and its categorization i.e. (priority, intermediate and non-priority). The selector switch also serves as a safety mechanism during maintenance as the end user can operate manually for their convenience. This switch is attached to the black box embedding the main microcontroller and ampere hour meter. In case the end user wants to use a load that has been cut off by the automated system, then he/she can press the manual button and the system will switch to manual selection.

1.3.5 Dimmer lights and Motion Sensors

This is another mechanism incorporated to reduce the current flowing to the bulbs so that the remaining charge can last longer. This is because lights are our priority loads and we do not want them to be completely off. On this note, we program the microcontrollers to limit the current through them to the different lighting loads hence dimming them. We also incorporated motion sensors in the design so that the lights are off in case there is no one occupying the room.

From $Q = It$. where Q = total DC charge, I = current and t = time taken to discharge the charge.

Dimmers reduce the amount of current flowing through the bulb when total charge has reached to 40%. Motion Sensors are programmed to detect movement of people, therefore, they only light on when there are people using the room or corridor.

1.3.6 User interface

This is incorporated for the user to monitor the amount of the energy available for planning purposes.

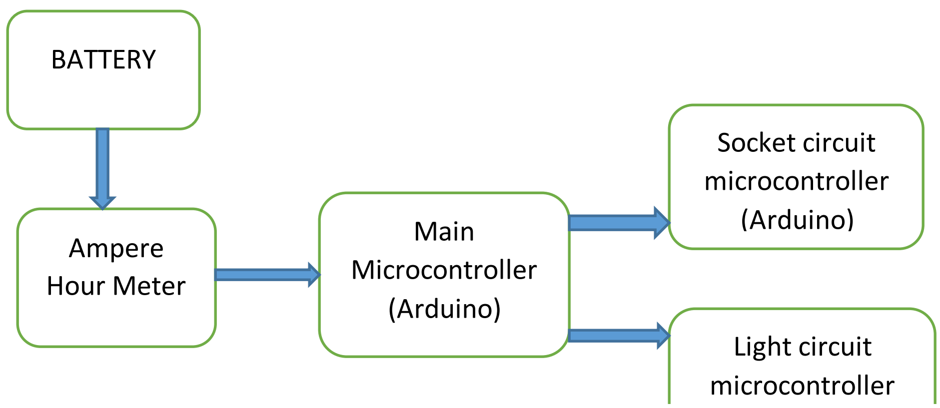


Figure 1: Block diagram of the components

Figure 2: Block diagram of the main components

The switching was done using a MOSFET. MOSFETS have a fast switching speed and are voltage controlled devices, therefore, will not consume current during cut off mode. The microcontroller was then programed to regulate the current entering the gate terminal of the transistor thus switching off or on the circuit.

CHAPTER 2: SOCIAL IMPACT

2.1 Introduction

Electricity is considered a luxury in some parts of Africa. When it comes to its supply in public health facilities however, it can mean life or death. Many health workers in Uganda testify of the negative impact of working in the dark, because of the threat it poses on their work. In many parts of sub-Saharan Africa, fewer than one-third of health facilities have reliable access to electricity [3].

Without sufficient energy, midwives are forced to deliver babies without any overhead lights, doctors treat patients through the darkness while relying instead on the glow of a cell phone or candle to illuminate the room, thus making deliveries and treatment more difficult and dangerous for mothers and children. Also, if the cold chain is inoperable when supplies arrive, vaccines, blood and other medicines may go to waste. [3]

Figure 3: A health worker without an overhead light relying on the glow of a cell-phone

2.2 Consequences of inefficient energy usage

When Uganda's privatized electricity supplier shuts off power to hospitals, the results are catastrophic. In 2012, 150 babies on oxygen concentrators at a hospital in Jinja district died after utility company UMEME Uganda Limited turned off the electricity with no prior notice. In 2015, Kiboga District Hospital was without power for over a month. UMEME disconnected the supply because the government of Uganda had not paid the bill of over 100 million Uganda Shillings (US$26,600). Kiboga District hospital, for example, serves over 100,000 people. When it went without power for a month, doctors said they were unable to provide even basic first aid such as sutures because they could not sterilize tools. Vaccines and blood went bad because of the lack of refrigeration. Laboratories could not perform diagnostic services without power. The maternity wing was in complete darkness, and Cesarean sections could not be performed. Mothers died on their way to the capital Kampala or private clinics to access emergency obstetric care, which could not be performed due to lack of electricity. This problem persists as the country continues to suffer inadequate power supply resulting in a 12-hour load shedding schedule over several months now; the hospital experiences at least three days a week of power cuts [3].

Lack of sufficient lighting increases the risk of infection and birthing complications. Every day, approximately 830 women die from preventable causes related to pregnancy and childbirth, according to the World Health Organization, and a good number of these deaths is due to issues relating to inadequate, and unreliable supply of electricity. Even when power is available, unreliable electricity can still lead to tragedy. In 2017, three oxygen dependent newborns died when the power failed at a Sierra Leone hospital. Sadly, this is not an isolated phenomenon. Across the world, blackouts can result in severe medical consequences [4].

2.3 Proposed Solution.

The statistics above show the severity of the problem of inadequate supply of electricity. The promotion of solar usage, and a load management device to accompany it is one of the feasible solutions, to eradicate this growing number of deaths, and other related conditions that are brought about by lack of reliable power. This gave us a motivation that the solution we are coming up with is user friendly because it’s to be used mainly in health centers, located in rural areas that are not connected to the grid. With access to the reliable energy, health care workers can now take advantage of critical technology like ventilators to supply oxygen for small and premature newborns, refrigerators to preserve vital vaccines, microscopes to make diagnostics, or laptops to keep digital records. With controlled usage of the available energy, care for mothers and babies in the health centers and clinics is safer. Fewer infections occur, blood transfusions happen more rapidly, and deliveries are more successful. Proper and reliable usage of power also allows doctors to use electric diagnostic and medical equipment to be treat life-threatening diseases.

2.4 Justification of our Proposed solution

Achieving progress on providing quality health care which is UN Sustainable Development Goal 3 directly relates to increasing sustainable and reliable energy access i.e. Sustainable Development Goal 7. With the stand-alone solar management system, rural facilities can have an effective way of managing the little power that they harvest from the sun.

Since 2013, with support from the U.K. Department for International Development and at the request of the UN’s Sustainable Energy for All initiative, the United Nations Foundation and its partners have worked to explore and document the impact of electrification on rural health facilities and help bring sustainable clean energy to communities in need [4].

As of February 2018, this initiative known as powering healthcare has completed the installation of solar power to 62 off-grid, rural health clinics in Uganda and Ghana with 242 kilowatts of power. Combined, these 62 installations are expected to serve and improve the accessibility of health care for 650,000 people [4].

This therefore creates a strong desire and motivation to advance on the system technology by adding a stand-alone solar load management system to be used by these health center units, and clinics spread across the country

Figure 4: How a health center with a Solar system and an advancement with the stand-alone load management system would look like in the night

2.5 Product Feasibility

To increase the feasibility of the load management system, we intend on training individuals in the ministries of health, health care workers, and community members on how the systems work. Using a comprehensive approach to solarizing health clinics and adding a component of load management to it, these solutions can supply sustained power for years to come. A training held like this rules out the difficult aspect of the design features, and technicality of the project, the targeted users will have learnt the aspects of how the load management system works.

Figure 5: A sensitization session taking place after the installation of Solar units by the UN foundation

CHAPTER 3: PRODUCT SCALABILITY

3.1 Introduction

The stand-alone load management system targeted the rural off-grid hospitals and clinics of Uganda which use stand-alone solar energy.

Currently, rural hospitals and clinics have no standard way of managing the available energy apart from good management practices like maintaining equipment properly and insulating any areas that are heated or cooled [5]. These good management practices are important but monitoring available energy and control of the users' power usage is extremely important and a much better alternative. Very few rural hospitals use energy-efficient appliances and devices since they are more expensive than standard efficient models. However, with also the use of energy-efficient appliances, the energy demands change in the near term and this also necessitates the need for a load management system.

3.2 Affordability

Since most rural hospitals and clinics are privately owned, they can pay for the load management system because the purchasing power of private institutions is far greater than that of public institutions in Uganda specifically. The figure below shows the public and private hospitals in rural areas of Masaka, Mpigi, and Iganga.

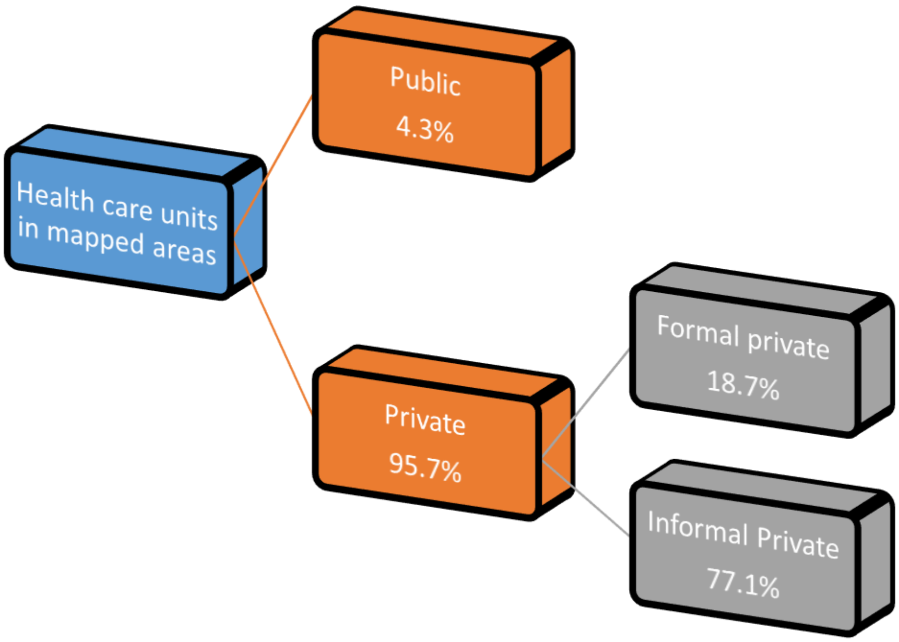
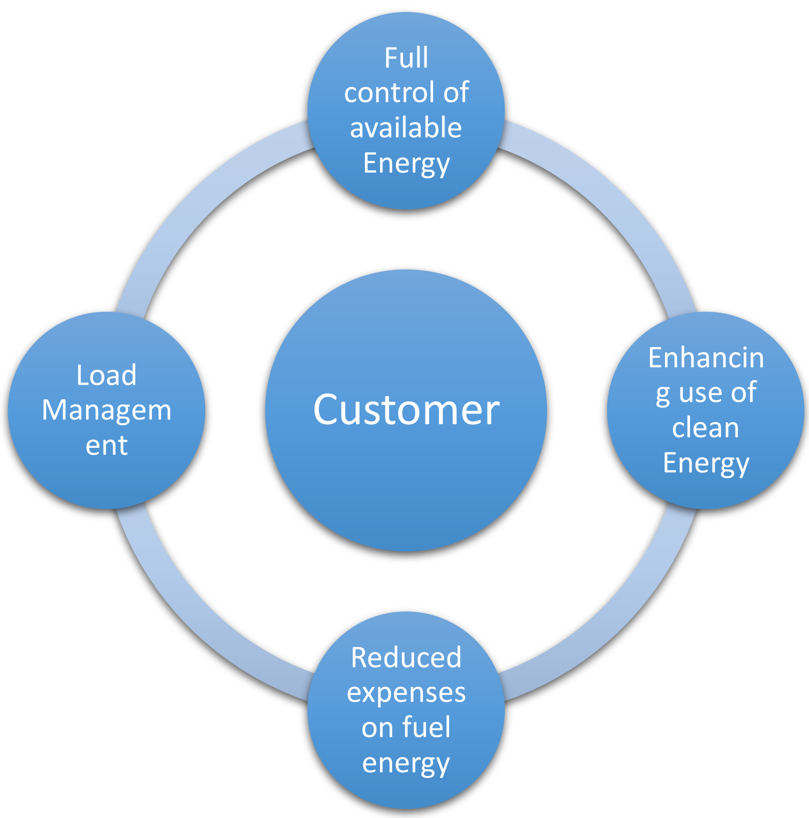


Figure 6: showing percentages of public and private Hospitals rural areas of Masaka, Mpigi, and Iganga

3.3 Customer Value Proposition



The customer will be able to minimize the possibility of blackout when the available energy is managed appropriately thus reducing inconveniences, economic losses hence longer energy supply to provide refrigeration for the drugs, laboratory equipment and lightning in the hospitals.

The customer will also be able to get an enhancement of the solar energy since the solar energy will now be more attractive since its able to support the customer's power system longer.

These Health Centers can decide to use another energy source to back up the already existing solar system as an alternative to our idea. Since this is an off-grid setting, some of the back-up alternatives could be wind power or a standby diesel generator. However, our idea provides a cheaper solution to these two alternatives. A backup diesel generator is always coupled with high maintenance and operating costs due to the high fuel costs. In the case of wind power, it is unreliable and initial startup costs are extremely high. The availability of wind power is also location-specific. All these factors make having an alternative energy source a more expensive solution compared to our proposed load management system.

Another alternative Health Centers could use is assigning a specific person to do the manual switching of the loads. This person would have to identify the priority and non-priority loads and constantly monitor the battery capacity. The person would then have to switch off the non-priority loads incase the battery capacity goes below a certain threshold value. However, this can be a very tedious process and the designated person is likely to commit very many errors with time. Therefore, the best solution would have to be our proposed automated load management system as it is less prone to errors.

3.4 Revenue Model

We plan to use a sales based strategy where the product is sold to the customer. We will then get to know the user's high priority loads, intermediate and less priority loads and setup the product as necessary to control the loads. Offer product warranty as confidence in solar products is strongly driven by warranty. This is particularly so in the Northern and Eastern parts of the region [6].

We also look forward to partner with local solar companies/ distributers like solar energy for Africa, Solar Uganda, Solar Connect International, etc. for them to incorporate the solar load management product in their new solar installations.

The product will be also advertised using various methods through TV stations, Radio stations, Newspapers, Facebook platforms, websites, and visiting some customers to explain the product.

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[6] Market Asssessment of Modern Grid Lightning Systems in Uganda, 2014.

APPENDIX

NEEDS STATEMENT

We need the funding such that we can be able to build a prototype. Building this prototype will require us to make extensive research about our idea concept and this, will in turn, help us to garner more knowledge on our idea and in particular on load management systems. Given the fact all the team members are pursuing a BSc. in Electrical Engineering, designing a prototype will give us an opportunity to enhance our skills in circuit assembling and designing. Most of the funds will go into buying hardware components such as Arduino boards as illustrated in our budget and some will be used to buy a license for Proteus Software as the free version is limited.

Our project is solely based on designing a load management system for a rural off-grid hospital with a solar system set up. Inefficient use of this energy can lead to severe consequences. Kiboga District hospital, for example, serves over 100,000 people. When it went without power for a month, doctors said they were unable to provide even basic first aid such as sutures because they could not sterilize tools. The maternity wing was in complete darkness, and Cesarean sections could not be performed. Mothers died on their way to the capital Kampala or private clinics to access emergency obstetric care, which could not be performed due to lack of electricity.

According to the United Nations Environment Programme and Sustainable Development Goal 7, sustainable energy presents an opportunity to transform lives and economies while safeguarding the planet. With this project implemented, therefore, there will be improved standards of living because of the efficient use of solar energy. This project will, therefore, address goal number seven as the efficient use of solar energy makes it sustainable and reliable.

PROJECT BUDGET

Item number	Item Description	Link to item/quote where appropriate	Quantitiy	Unit Cost	Cost
1	Arduino Board	https://store.arduino.cc/arduino-m	1	$ 40.00	$ 40.00
2	Atmega chips	https://www.amazon.com/SparkF	3	$ 55.00	$ 165.00
3	Black box casing		1	$ 30.00	$ 30.00
4	Jumper wires	https://www.amazon.com/dp/B07	1 set	$ 70.00	$ 70.00
5	soldering gun	https://heatfounder.en.made-in-ch	1	$ 150.00	$ 150.00
6	soldering wire	https://www.alibaba.com/product-	1 roll	$ 12.00	$ 12.00
7	Proteus Software	https://www.labcenter.com/pricing/comm/		$ 248.00	$ 248.00
8	Communication cable	https://www.aliexpress.com/item/	1 roll	$ 10.00	$ 10.00
9	Digital Multimeter	https://www.jumia.ug/airstar-digita	1	$ 12.00	$ 12.00
10	prototyping Boards	https://www.jumia.ug/generic-10p	3	$ 3.00	$ 9.00
11	Ampere Hour Meter	https://www.indiamart.com/prodde	1	$ 115.00	$ 115.00
12	LCD Display	https://www.alibaba.com/product-detail/LCD1602-LCD-1602-I			$ 12.00
13					
14					
15					
				Total	$ 873.00

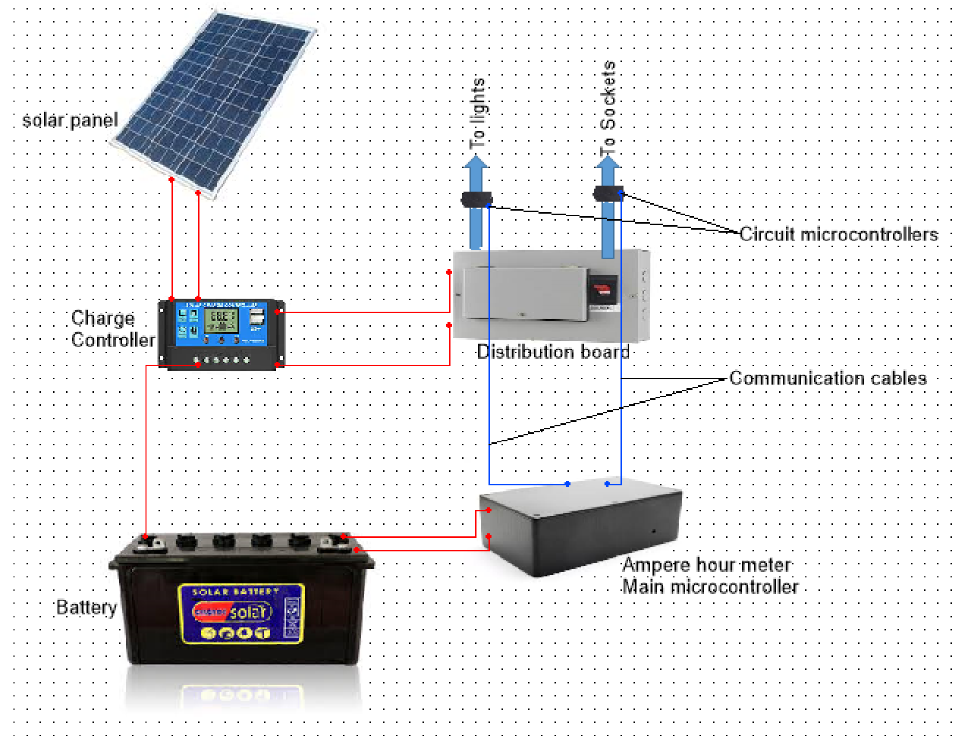

Figure 7 showing a general Layout of the Proposed System