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Regulated Photovoltaic Panel with Maximum Power Point Tracking for Remote Area Electrification

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Abstract— **Solar PV system has an important place in the context of rural electrification where extension of distribution grid is not economically viable due to low population and low levels of income. The proposed system enables off grid electrification by using photovoltaic panel to satisfy electrical needs of people in rural areas. This project consists of a boost converter connected to the output of a solar panel. The output of the low power-rating converter is connected to a battery. MPPT is implemented between the boost converter and the solar panel at all times then feed the converter. The report proposes a P&Q algorithm based analogue MPPT controller, which uses low complexity circuit components to realize memory elements and does not require any signal multiplier for power calculation. The algorithm performs iteration until maximum power point is reached on the panel. Modelling and controlling of the PV connected converters are presented in this report. The simulation and research validate the operation of the system under real life input and loading conditions. The simulation is tested with PV modules. The PV system converts sunlight directly into ac voltage and stepped up to 240 volts to supply local loads in the rural area. The system is cost effective, reliable and user friendly.**

Keywords— Electrification, Maximum Power Point Tracking (MPPT), Perturb & Observe, DC-DC Boost Converter, Simulink, Photovoltaic.

I. INTRODUCTION

Energy is a driving force to foster economic, social and health condition. Renewable energy will be used to achieve this objective and it would be used in a decentralized manner where conventional grid connectivity is not possible. Botswana's rural electrification currently stands at 80 percent and the Government of Botswana aims to electrify the remaining 20 percent by 2020, this was revealed by Minister of Energy in 2012. Most remote areas, which have not yet been electrified, have some common characteristics such as [1].

- Being located in areas with difficult terrain such as hills, forests, deserts and islands.
- Being part of a protected forest area could isolate the village and prevent live conductors from being drawn through it.
- Being located far from the nearest existing grid
- Very low population and low number of households
- Low power demand, probably even in the near future, as the loads are mostly lighting
- Minimal transport and communication facilities
- Low income level and low affordability
- Poor literacy levels and technical skills

Fig.1. View of Remote Area

Currently there are 70+ proposed village electrification and network extension for 2018/19 and it will take time for electricity to be evenly distributed in Botswana. The proposition to light the remaining 20 percent of rural areas does not include remote areas due to the above mentioned characteristics. This gives a clear indication that isolated remote areas are not taken into consideration because high cost will be involved and there is a need for urgent solution for an alternative source of energy to meet the needs of modern day.

There is a significant solar potential because Botswana is a semi-arid climate which is the best weather for condition for optimal solar energy. On-site generation/distributed generation (DG) based on renewable sources would be an economic option to enable faster electrification of villages as compared to extension of a central grid [2]. Advantages of distributed generation-based rural electrification include energy loss reduction, reliability of supply, and reduction of indoor pollution arising from use of conventional fuel (wood or kerosene) for lighting [3].

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The conversion of sunlight energy to electricity is relatively low and this leads to an inefficient solar system. This is caused by dynamic of irradiance and temperature. Therefore, a Maximum Power Point Tracking (MPPT) algorithm is used for efficient conversion of solar energy. The main problem solved by the MPPT algorithms is to automatically find the panel operating voltage that allows maximum power output. The popular MPPT algorithms techniques are Perturb and Observe (hill climbing method), Incremental Conductance method and Constant Voltage Method.

II. Literature Review

To gain a greater level of knowledge about the subject of solar power applications and MPPT, a major research making took place. Reading journals and websites provided a greater insight into the purpose of the project and answered many questions which arose on first glance of this project. The journals and papers which were chosen to review were obtained from the ecademia.edu website. The literature review gave a clear theoretical framework about the subject in which this project is based.

The concept of solar photovoltaics' electrification has been the cause for major discussion since its inception in the early 1800's [4]. Today the photovoltaic principle has evolved into a global leader for the provision of clean energy. To briefly describe a PV system, one can say that such a system converts light energy quanta in the form of photons into usable electricity by means of the Photoelectric Effect [4]. PV systems have evolved at a tremendous rate up until today with a continuous increase in efficiency and a systematic reduction in cost. Modern PV modules are built according to power and/or voltage specification by using a specific amount of basis-unit PV cells. These individual cells have characteristics coherent with the type of material it consists of [5].

Photovoltaic solar system gives an alternative way in which people can enjoy electricity they cannot get from the national grid due to the distance available and prices involved in it. Studies shows that solar electricity is important in bringing about development in the disregarded areas particularly the rural areas. It plays a more substantial role in supporting the use of electric light for evening studies, electrical appliances usage such as TVs, radios, and cellular phone charging, and most of all it supports income generating activities.

Photovoltaics (PV) system converts sunlight directly to produce DC output by means of PV cells. One of the best solar manufacturers in 2019 were ranked based on the efficiency of the solar panel as stated below [6];

- SunPower (22.2 %)
- LG (21.1 %)
- Solartech Universal (20.2 %)
- Silfab (20.0 %)

Solaria (19.4 %)

Studies shows that the majority of the solar panel range from 15% to 25% efficiency rating. The conversion of sunlight to electricity is low and researchers shows that a Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel and boost converter is also used to stabilize the DC output.

To allow the PV system to produce the maximum possible power, many maximum power tracking techniques and algorithms have been developed. MPPT method ensures that maximum voltage and maximum current is reached as much as possible to make maximum utilization of PV modules and minimize the power with reference to environmental conditions [7]. The different types of MPPT algorithm include Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control [8].

In this paper, Perturb and Observe algorithm is implemented. The algorithm is carried out by observing the array output power and determining the next action either to increase or decrease the array operating voltage. Iterations are carried out on the array until maximum power point is located. A DC-DC boost converter is introduced in the system. This converter is also useful for PV maximum power tracking purposes where the objective is to draw maximum possible power from the solar panels at all times and all conditions irrespective of the load. An inverter is another component of importance in any independent solar panel and battery power back-up system that requires AC power. Inverters are electronic devices that serve the purpose of changing direct current to alternating current to run electrical appliances. This system is thus feasible and will benefit people in rural in terms of convenience and cost.

III. Proposed System

This project is about electrification of remote areas to improve the socio-economic positons of rural people. The conversion of sunlight energy to electricity is relatively low and this lead to an inefficient solar system. This is caused by dynamic of irradiance and temperature. This main problem solved by the MPPT algorithms is to automatically find the panel operating voltage that allows maximum power output. Therefore, a proposed idea is to build a system using Maximum Power Point Tracking algorithm namely, Perturb and Observe method for efficient conversion of solar energy. The following Fig.2 shows a proposed MPPT system block diagram which consists of the solar panel, microcontroller, DC-DC converter and DC output. The Fig.3 shows block diagram of the proposed distribution of DC supply.

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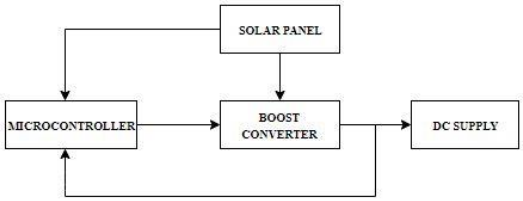

Fig.2. MPPT System Block Diagram

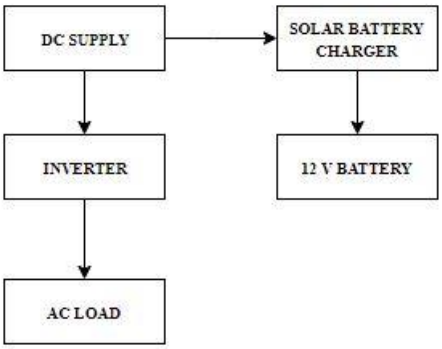

Fig.3. Distribution of DC Block Diagram

The solar panel produces a DC output, which is connected to the boost converter to charge the storage battery at a constant voltage and to power the inverter. The solar and the battery provide power supply to the inverter to be stepped up from D.C source to AC source. The solar also charges the battery during the day for night use. DC-DC boost converter is used to boost voltage.

A square pulse signal from the microcontroller is act as an oscillator to drive the boost converter by switching a transistor in an ON and OFF mode continuously at an operating frequency of 10 kHz. A PIC16F876A is used to work a PMW controller of the system, which takes analogue input as voltage and current from the photovoltaic module and changes its module according to the input.

A 2N222 NPN Transistor is driven by a square pulse of 10 kHz from the microcontroller for switching the transistor ON and OF continuously. It gives an output voltage magnitude that greater than the input voltage magnitude. The duty cycle is customized through feedback path B which receives the input from the battery. The duty cycle of the generated pulse from the microcontroller is customized such that the off-grid home solar powered battery system extracts maximum power from the photovoltaic panel to the battery or to the load. The Fig.4 shows the proposed MPPT circuit diagram. The Fig.5 shows the DC supply distribution circuit diagram.

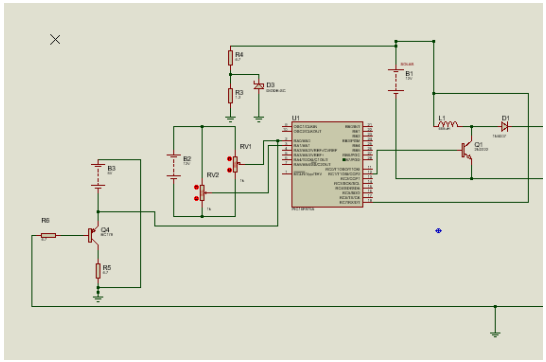

Fig.4. MPPT System Circuit Diagram

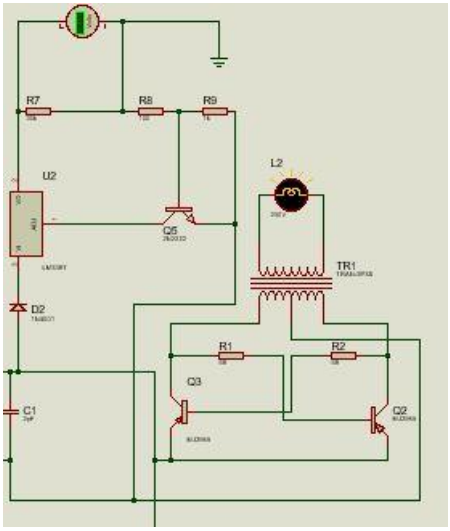

Fig.5. Distribution of DC Circuit Diagram

IV. RESULTS

In developing this system, the Perturb and Observe algorithm is developed through MATLAB code and mikroC code. The MikroC code is loaded on the microcontroller chip and the results are displayed by the oscilloscope connected. This maximum power tracking technique uses iteration process or perturbation to meet the objective of extracting maximum power from the PV panel. Respecting the results achieved it is possible to conclude that, the PV simulation ensures that the theoretical digits, namely the voltage factor assumed, is a very approximate value of what can be expected in real implementation of the solar panel. There are several different topologies of converter circuits and MPPT algorithms. Algorithms can always be improved by the cost of complexity, computer power and cost. Topologies can be combined to extract the best from each other carrying their

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particular drawbacks and advantages. MPPT algorithms can work on several different information sources such as light and temperature, voltage and current and also from pilot cells. There is always the cost factor and reliability when trying to produce the most efficient system.

V. Conclusion

The proposed system includes MPPT solar system, which is designed to adjust solar voltage to utilize the maximum power output of the solar array to achieve maximum efficiency. An MPPT solar system allows the maximum power to be harvested and it provide substantially more power when the temperature is below 30 degrees Celsius and when the irradiance is very low. This project provides power or electricity using solar panel as it is efficient and an economic option that enables faster electrification of villages to people at remote areas. Solar was chosen to be the best alternative for rural electrification because is cheap and more efficient than biogas. This system remains the perfect option for villager because it is cheap and does not require much attention.

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