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Uninterruptable Power Supply Using Earth Battery and Solar Panel

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Abstract: The Earth today is facing a major problem of energy crisis and use of new reliable renewable energy sources is the need of the hour. Micro-organisms use soil and other organic materials in the soil to produce free ions by their metabolic activity which are left uncollected. These free ions are collected using metal electrodes with soil acting as an electrolyte or medium of transfer of ions. Each electrode produces a certain potential voltage and few tens of mill amperes of current. Thus a pair of positive and negative electrodes inserted in soil kept in an insulating container is a 'soil cell'. The voltage can be increased by connecting multiple electrodes in series and current by connecting soil cells in parallel. Series and parallel combination of soil cells becomes a 'soil battery'. The energy from the soil can be used as an uninterruptable power source to light a small cabinet along with a solar panel. The energy from Soil Battery can be used for lighting purpose when the solar panel is not functional or when its efficiency is low. The maximum power point tracking controller ensures optimum power output from both the soil battery and the solar panel, whatever be the battery voltage or the driving load. Thus a small grid comprising of soil battery, solar panel and a secondary battery can be used as an uninterruptable power supply with the optimum source in terms of power driving the load.

Keywords: Earth Battery, Maximum power point, Perturb and observe, photovoltaic, solar panel.

I. INTRODUCTION

A. The Requirement

The limited availability of conventional energy sources like firewood, fuels, natural gas has always propelled man to search for new, reliable renewable and environment friendly energy sources. Over the years, solar modules, windmills, tidal power plants were developed. But the efficiency of energy conservation and the cost incurred has always been a hurdle in utilizing these sources. Non-reliability of these sources with changes in natural environment also poses a problem of full proofness of implementing these methods. Also, many rural areas in the world today do not have access to electricity. Lighting a small bulb in such places could dramatically change the living conditions of a community.

B. What is Earth battery?

The soil is an unutilized chamber of free energy. The metabolic reactions of micro-organisms in the soil produce free ions which are left uncollected. The moist soil itself acts as an electrolyte with two different electrodes inserted in the soil completing the conduction path and thus providing a potential difference. The pair of electrodes inserted into the soil provides a certain voltage and current and is called a 'earth cell'. Multiple such cells insulated from each other can be connected in series to increase the voltage. This array of such series connected 'Earth Cells' can be connected in parallel with another array to increase the current capacity which is called the 'Earth Battery'.

C. What is Maximum Power Point Tracking?

The output power of conventional solar panels changes with irradiation, temperature and electric load characteristics. Thus maximum power is not always delivered by the solar panels and this result in loss of efficiency. MPPTs are controlled power electronic converters that ensure that a photovoltaic panel or array always deliver maximum available power. The function of MPPT is to ensure the output of solar panel approach its maximum point by continuous perturbing and observing.

D. Application Area

The soil battery, or the 'microbial fuel cell' as it is also called can provide enough voltage and current to light LED bulbs and thus can be used on a small-term basis for lighting a small cabinet(8feet by 10feet approximately). Simultaneous use of solar energy and soil battery can thus be used as an uninterruptable power source for lighting purpose with a secondary lead-acid battery providing a backup source.

E. Objectives of the paper

The paper focuses on the following aspects:

1. To provide renewable, environmental friendly and cost-efficient energy source.
2. Extract maximum electricity from solar panel and soil with concept of MPPT.
3. Provide electricity that could run any load of voltage 12V and power 9Watts.

II. LITERATURE REVIEW

A. The Earth Battery

An Earth battery is a pair of electrodes made of two dissimilar metals, such as iron and copper, which are buried in the soil. It consists of conductive plates from different locations in the electro potential series, buried in the ground so that the soil acts as the electrolyte in a voltaic cell. As such, the device acts as a rechargeable battery.

B. Soil conductivity:

Soil conductivity is an important parameter for the working of earth battery. Soil conductivity determines the output power of the cell. The conduction of electricity in soil takes place through the moisture-filled pores that occur between individual soils particles. Therefore, the electrical conductivity of soil is determined by the following soil properties

1. Porosity: The greater soil porosity, the more easily electricity is conducted. Soil with high clay content has higher porosity than sandier soil. Compaction normally increases soil electrical conductivity.
2. Water content: Dry soil is much lower in conductivity than moist soil. [2]
3. Salinity level: Increasing concentration of electrolytes (salts) in soil water will dramatically increase soil electrical conductivity. The salinity level in most soils is very low. [2]
4. Cation exchange capacity (CEC): Mineral soil containing high levels of organic matter (humus) and/or 2:1 clay minerals such as montmorillonite, illite, or vermiculite have a much higher ability to retain positively charged ions (such as Ca, Mg, K, Na, NH₄, or H) than soil lacking these constituents. The presence of these ions in the moisture-filled soil pores will enhance soil electrical conductivity in the same way that salinity does.
5. Temperature: As temperature decreases toward the freezing point of water, soil electrical conductivity decreases slightly. Below freezing, soil pores become increasingly insulated from each other and overall soil EC declines rapidly. [2]

C. Metal electrodes:

An electrode is an electrical conductor used to make contact with a non-metallic part of a circuit (e.g. a semiconductor, an electrolyte or a vacuum). An electrode in an electrochemical cell is referred to as either an anode or a cathode. The anode is now defined as the electrode at which electrons leave the cell and oxidation occurs, and the cathode as the electrode at which electrons enter the cell and reduction occurs. Each electrode may become either the anode or the cathode depending on the direction of current through the cell. The electrodes act as way to tap the energy from the ground. These electrodes have different potential in the soil since different metals have different strengths to oxidize or get reduced. The potential difference thus produced depends on the difference of the potential of electrodes used as cathode and anode. The table shows different electrodes with their potential. To get maximum potential difference from the cell the electrodes with maximum separation must be used.

Table 2.1 Potential difference of Metal

Metal	Potential (V)
Magnesium(Pure)	-1.75
Magnesium(Alloy)	-1.60
Zinc	-1.10
Aluminum(Alloy)	-1.05
Aluminum(Pure)	-0.8
Steel(Clean)	-0.50 to -0.80
Steel(Rusted)	-0.20 to -0.50
Cast Iron	-0.50
Lead	-0.50
Steel(Concrete)	-0.20
Copper	-0.20
Brass	-0.20
Bronze	-0.20
Steel(Mill Scale)	-0.20
Cast Iron(High Silicon)	-0.20
Carbon	+0.30
Graphite	+0.30
Coke	+0.30

D. Maximum power point (MPP)

The installation of photovoltaic (PV) generationsystems is rapidly growing in response to concernsrelated to energy security and environmental issues suchas global warming. PV generation system is consideredas a clean andenvironmentally-friendly source of energy. It is necessary to utilize the solar panels maximally as they typically form the most expensive component of a photovoltaic remote area power supply. MPPTs are controlled power electronic converters that ensure that a photovoltaic panel or array always deliver maximum available power. A photovoltaic array under uniform irradiance exhibits current-voltage characteristics with a unique point called the maximum power point where array produce maximum output power. The I-V characteristics of a PV array and hence its MPP changes as a consequence of the variation of the irradiance level and of the panels' temperature (which is in turn function of the irradiance level, of the ambient temperature, of the efficiency of the heat exchange mechanism and of the operating point of the panels), it is necessary to track continuously the MPP in order to maximize the power output from PV system, for a given set of operating conditions. [3] As the power supplied by solar arrays depends upon the insolation, temperature and array voltage, it's necessary to draw the maximum power of the solar array. If the solar energy system provides power to a load, the system often operates away from maximum power points of the solar array.

Fig.2.1 shows the solar array I-V characteristics and the load curve, together with constant power curves ($P = VI = \text{constant}$). It is observed that the delivered output power, which is represented by the operating point 1, is significantly smaller than the maximum output power, which is represented by point 2. In order to ensure a maximum power transfer, DC/DC converters are used to adjust the voltage at the load to the value of $V_r = \sqrt{(P_m.R)}$, r – equivalent resistance of the load. [1]

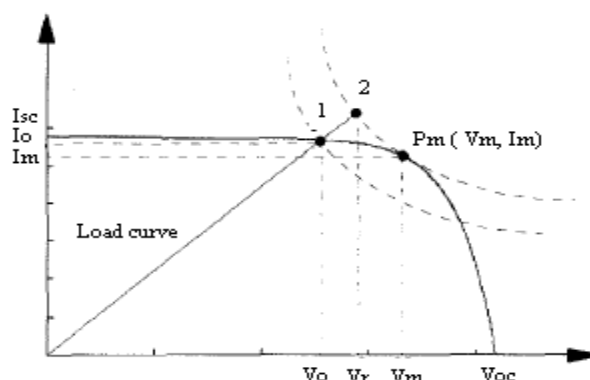


Fig 2.1 I-V characteristics of a PV module [1]

E. MPPT algorithm

Perturb and Observe (P&O) method

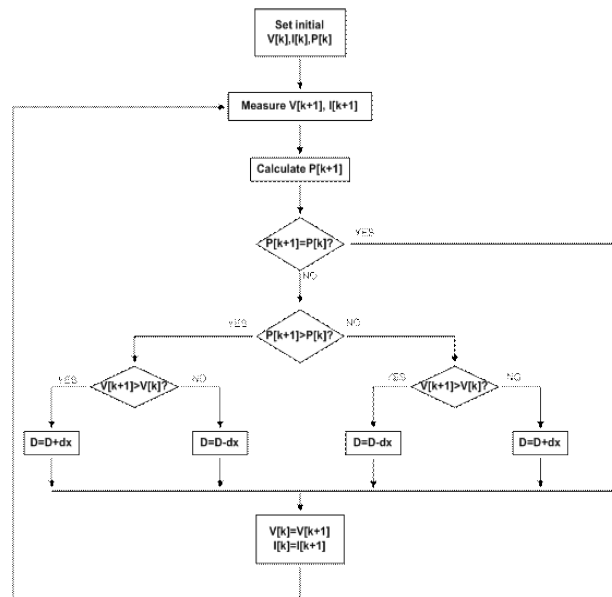


Fig 2.2 P&O algorithm

It can be seen that incrementing (decrementing) the voltage increases (decreases) the power when operating on the left of the MPP and decreases (increases) the power when on the right of the MPP as shown in Fig.2.2. Therefore, if there is an increase in power, the subsequent perturbation should be kept the same to reach the MPP and if there is a decrease in power, the perturbation should be reversed. This algorithm is summarized in Table 2.2. The algorithm also works when instantaneous (instead of average) PV array voltage and current are used, as long as sampling occurs only once in each switching cycle. The process is repeated periodically until the MPP is reached. The system then oscillates about the MPP. The oscillation can be minimized by reducing the perturbation step size. However, a smaller perturbation size slows down the MPPT. Hill climbing and P&O methods can fail under rapidly changing atmospheric conditions as illustrated in Fig.2.2. Starting from an operating point A, if atmospheric conditions stay approximately constant, a perturbation ΔV in the PV voltage V will bring the operating point to B and the perturbation will be reversed due to a decrease in power. However, if the irradiance increases and shifts the power curve from P_1 to P_2 within one sampling period, the operating point will move from A to C. This represents an increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the MPP and will keep diverging if the irradiance steadily increases. To ensure that the MPP is tracked even under sudden changes in irradiance uses a three-point weight comparison P&O method that compares the actual power point to two preceding ones before a decision is made about the perturbation sign. Two sensors are usually required to measure the PV array voltage and current from which power is computed, but depending on the power converter topology, only a voltage sensor might be needed. The PV array current from the PV array voltage is estimated, eliminating the need for a current sensor. A load output current (LOC-MPPT) method type of P&O method is used which uses the load current as the control variable. [4].

Table 2.2 Summary of Hill climbing and P&O method

Perturbation	Change in Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

[4]

A DC-to-DC converter is an electronic circuit which converts a source of direct current from one voltage level to another. Electronic switch-mode DC to DC converters operate by storing the input energy temporarily and then releasing that energy to the output at a different voltage and current. Just like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there's no energy manufactured inside the converter. In fact some energy is used by the converter circuitry and components while doing their job. It is this principle that makes a DC-DC Converter essential for MPPT. The converter presents an electrical load to the solar panel that varies as the

output voltage of the converter varies [4]. This load variation in turn causes a change in the operating point of the panel. Thus by controlling the operation of the DC-DC converter, the power output of the panel can be improved.

The boost converter is also known as the step-up converter. As the name implies it's typically application of converting a low input-voltage to a high out-put voltage, essentially functioning like a reversed buck converter . [5]

III. IMPLEMENTATION

3.1 Proposed Block diagram

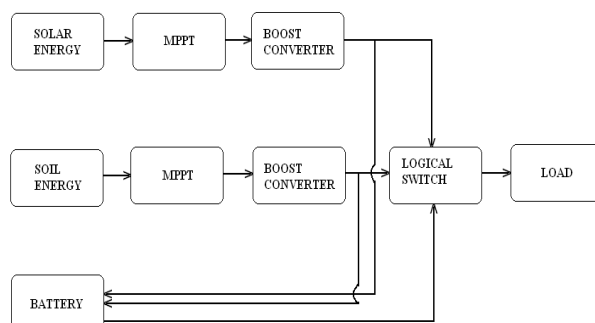


Fig 3.1 Proposed block diagram

There will be three sources to drive the load:

1. Energy from solar panel.
2. Energy from soil.
3. Secondary source as battery.

Maximum power is extracted from solar panel and soil battery by the principle of Maximum Power Point Tracking (MPPT). The output voltage is maintained constant with the help of Boost Converter. The output of the Boost converter is given to the logic switch. Logic switch consist of single pole triple throw arrangement. Out of the three sources which ever has highest power will drive the load .

From boost converters the power is constantly supplied to the secondary battery to charge it. Load is a 9W-LED lamp.

IV. Results

Based on available information, we practically tested the combination of electrodes, results obtained are tabulated as below:(see table 3.1)

The following experiment was conducted on moist soil. The type of soil was medium black sol. As seen from the table, though the voltage obtained from carbon-zinc electrode pair is more, the total power is less as compared to copper-zinc. Hence we selected copper-zinc pair for our final implementation.

Second important factor in our project was the type of soil to be used. The mineral content in the soil varies depending on geographical conditions. So we conducted research on different types of soil such as Red soil, Black soil, Sea shore soil, Hill soil.(see table 3.2) The results obtained are:

Table 3.1 Electrode pair comparison

Electrode pairs	Voltage (V)	Current(mA)	Power (mW)
Copper - Steel	0.46	0.35	0.161
Aluminium – Cast Iron	0.6	0.1	0.06
Copper – Aluminium	0.5	0.4	0.2
Steel – Zinc	0.9	0.6	0.54
Copper – Zinc	0.9	1.07	0.963
Carbon – Zinc	1.4	0.54	0.756

Table 3.2 Soil properties

Type of soil	Voltage(V)	Current(mA)
Dry Black Soil	0.75	0.01
Moist black Soil	0.8	3.3
Red Soil	0.78	2.88
Red Soil With Salt	0.785	8.6
Soil Under Tulsi Plant	0.787	12.5
Moist Black Soil With Salt	0.8	30

From the experiments conducted we came to conclusion that maximum power generated is by using moist black soil with salt added. So our soil cell consists of two metal electrodes copper (positive) and zinc (negative). The electrolyte is the moist black soil with salt added to it. This is kept in an insulating container of plastic. This cell is capable of giving 0.8volts and current of 30 mA. We tried testing LED of mill watts as load to the soil battery. We connected four pair of copper – zinc electrode n series. Each cell was kept in an insulating container (plastic box). The output we got was 3.42volts and 30 mA of current. The LED glowed with its full intensity and for

around one hour neither of three parameters (voltage, current and intensity) decreased. This proved that the power generated by soil battery is a reliable source and our experiment was successful.

FUTURE SCOPE

Based on the exhaustive study done on soil and metal electrodes a soil battery was implemented. We propose to implement a solar panel along with battery to provide uninterrupted power supply for a 9W-LED lamp. Also a boost converter will be implemented using the MPPT concept to deliver the power to the load with maximum efficiency.

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