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Solar Tree

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Abstract

A solar tree is an artistic and functional installation that takes inspiration from the natural form of a tree, utilizing solar panels arranged as leaves to capture sunlight and convert it into electrical energy. These eco-friendly structures are often found in space-constrained urban settings, where they not only generate power but also provide shade and serve as visual symbols of green energy. Solar trees are composed of several key parts: the solar panels which gather and convert solar energy, the branches that hold the panels, the trunk which supports the structure and contains the wiring, and the base that keeps the tree anchored and stable. Beyond their usefulness, solar trees also contribute to public education about the advantages and potential of renewable energy. Our project aims to harness solar energy efficiently through an innovative design inspired by natural trees. Our system incorporates a combined 50 watts of solar panel power mounted on a tree-like structure, allowing for optimal sunlight exposure. To enhance energy conversion, we employ a Maximum Power Point Tracking (MPPT) solar charge controller, utilizing the Perturb and Observe algorithm. The MPPT controller dynamically adjusts the panel's operating voltage and current to maximize power output, ensuring efficient utilization of available sunlight. This solar tree serves as a sustainable and aesthetically pleasing solution for clean energy generation in urban and outdoor environments.

Keywords: Solar tree, MPPT charge controller, Perturb and observe algorithm, Synchronous buck converter

INTRODUCTION

Our project is a cutting-edge method for efficiently and compactly utilizing solar energy. This project features a unique structure that emulates the form of a tree, with photovoltaic panels serving as leaves to capture sunlight. The design is not only space-saving but also integrates seamlessly into urban landscapes, providing both functional energy production and aesthetic value. At the heart of this system is a 50-watt output power capability, which, while modest, is sufficient for various applications such as lighting, charging small devices, or contributing to a household's energy needs. The solar energy captured by the panels is managed by a state-of-the-art MPPT (Maximum Power Point Tracking) solar charge controller. This controller employs a synchronous buck converter, a highly efficient type of DC-DC converter that steps down voltage while maintaining a constant output power level. [1]

With the use of MPPT technology, which adjusts to variations in sunlight intensity and angle, the solar panels are guaranteed to run at their peak power point for the duration of the day. This maximizes energy harvest and increases overall system efficiency. The energy is then stored in a battery, providing a reliable power source that can be used day or night. This project not only showcases the potential of renewable energy in urban settings but also serves as an educational platform to promote awareness of sustainable energy solutions. It's a testament to how technology

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can be harmoniously integrated with nature, offering a glimpse into the future of green energy infrastructure. [2]

In essence, a solar panel is an assembly of solar cells that combine to generate electricity from sunlight. The materials used to make these cells have the ability to produce electricity when exposed to sunlight because they display the photovoltaic effect. In order to optimize the amount of sunlight it captures, the panel is often coated with a reflective material. Electrons in the solar cells are liberated from their atoms by the sun's rays, which then passes through the material to generate energy. Utilizing this electron movement, a current is created that can be utilized to charge batteries or operate electrical appliances. PV Panels: These elements harness sunlight and convert it into electrical power. Branches: These provide the necessary support for the PV panels. Trunk: This central column is the mainstay of the tree, enclosing the electrical wiring. Base: This segment ensures the solar tree's firmness and stability. Fig 6 and 7 [3]

MPPT Charge Controller

The MPPT, or Maximum Power Point Tracking charge controller, is a sophisticated device used in solar panel systems to optimize the conversion of solar energy into electrical energy. It's like a smart manager for your solar panels and batteries. The MPPT controller makes sure the solar panels run at their maximum power point, or the energy-producing capacity. In order to efficiently charge the battery, it then transforms this energy into the proper voltage. Consider it as a dynamic matchmaker connecting the batteries and the solar panels. It constantly adjusts the energy transfer to ensure the battery charges at maximum efficiency, even as conditions change throughout the day. As a result, you maximize the power of your solar panels and improve the life of your batteries by charging them more quickly and thoroughly. To put it simply, the MPPT charge controller is an essential part of any solar power system that makes sure your investment in solar energy is working as hard as it can. It is a cutting-edge tool that improves solar power systems' efficiency. It's a specialized DC-DC converter that fine-tunes the electrical output from solar panels to ensure batteries charge optimally. Here's a breakdown of its technical workings

Voltage and Current Adjustment: The controller dynamically alters the voltage and current from the solar panels to suit the battery's charging requirements, maximizing the charge rate based on the sunlight available. [4]

Maximum Power Point Tracking: The device persistently monitors and tweaks the voltage to pinpoint the solar panels' maximum power point (MPP), which is the condition under which the panels generate the most power. This point changes with the intensity of sunlight and ambient temperature.

Enhanced Conversion Efficiency: By transforming the higher voltage from the solar panels to the voltage level suitable for battery charging, MPPT controllers achieve up to 30% more efficiency compared to traditional PWM controllers.

Synchronous Buck Converter: The synchronous buck converter within MPPT controllers is superior to conventional converters as it employs transistors instead of diodes, which minimizes energy loss during the conversion process. [56]

Need for MPPT Charge Controller

Any solar power system that wants to get the most power out of the PV module must have an MPPT solar charge controller. This device compels the PV module to run at a voltage that is near to the maximum power point in order to draw the maximum amount of power that is available. The system's output is highly efficient, but the MPPT solar charge controller makes the system simpler overall. Every solar panel (PV) generates its maximum power at a voltage of roughly 17V (usually 16.5V). MPP, or Maximum PowerPoint, is the name given to this stage. Thus, the MPPT solar charge controller's job is to keep the PV voltage at this MPP in order to maximize the amount of electricity that can be extracted from that solar panel (PV). Compared to PWM controllers, MPPT controllers can increase system efficiency by up to 30% by ensuring that the solar panels are operating at their peak power. It works well with a variety of solar panel voltages and is especially useful in setups where the battery voltage is considerably lower than the panel voltage. Figure 1[711]

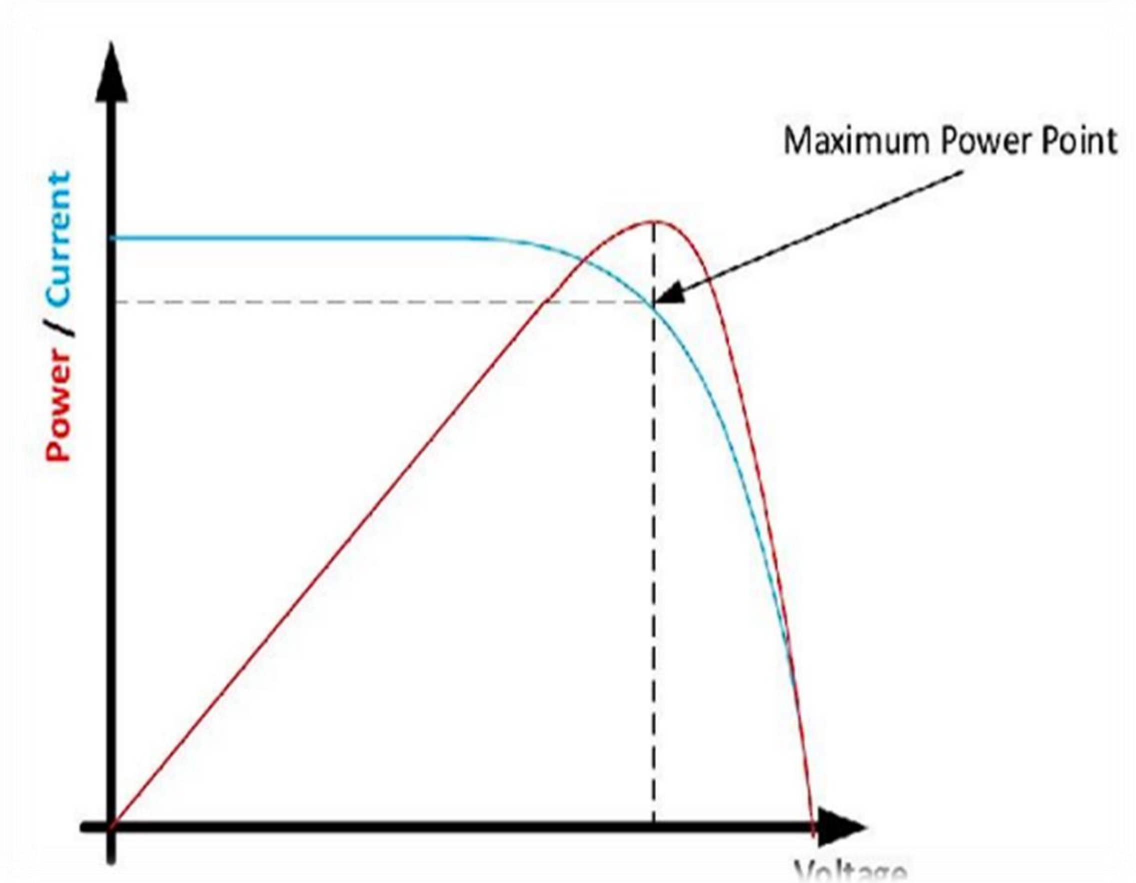

Fig. 1: I-V characteristics of solar panel

Perturb and Observe Algorithm

The Perturb and Observe (P&O) algorithm is a method used in photovoltaic (PV) systems to find the Maximum Power Point (MPP), which is the condition under which a PV cell produces maximum power. The P&O algorithm is essentially a feedback control loop that continuously adjusts the voltage to ensure that the PV system operates at the MPP despite changes in environmental conditions like sunlight and temperature. The algorithm is favored for its simplicity and effectiveness, although it can sometimes oscillate around the MPP, which can lead to less-than-optimal power production. To mitigate this, some variations of the P&O algorithm include adaptive step sizes or other enhancements to improve stability and response time

Perturbation

The algorithm slightly adjusts the voltage supplied to the PV cells. Observation: Following that, the power output change brought on by this voltage change is measured. Analysis: Based on the perturbation, the program ascertains if the power has grown or reduced. Adjustment: The algorithm continues to disturb the voltage in the same direction if the power increases. If the power decreases, it changes direction. Iteration: This process is repeated until the power output stabilizes, indicating that the MPP has been reached. Fig 2 [12]

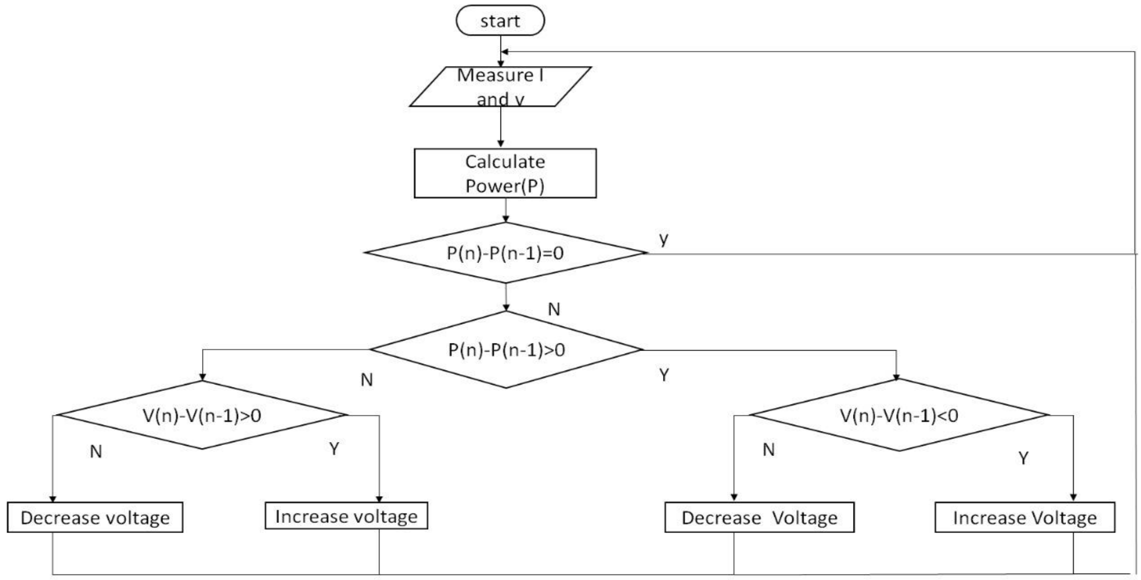

Fig. 2: Flow chart of perturb and observe algorithm

Synchronous Buck Converter

A diode that is linked inversely to the inductor of a synchronous buck converter is used to wheel the current through it. However, a loss occurs here due to the diode's 0.7V forward voltage drop. A buck converter's overall efficiency is reduced by this loss. It is possible to lower the forward voltage drop to 0.1V by substituting a MOSFET for this diode. which raises the converter's overall efficiency. Stepping down a voltage from a higher voltage to a lower voltage is accomplished via the synchronous buck converter. In today's market, synchronous buck converters are highly sought-after and offer highly efficient solutions for a variety of uses. The power stage formulas for a synchronous buck running in continuous conduction mode are provided in this application note. A synchronous buck converter can supply a large current with minimal power loss and generates a regulated voltage that is lower than its input voltage. The synchronous buck converter is made up of input and output capacitors, an output inductor, and two power MOSFETs, as seen in Figure 3. The circuit's input voltage is directly coupled to Q1, the high-side MOSFET. IUPPER is given to the load through Q1 when Q1 is turned on. Q2 is off and the inductor's current increases (charging L) throughout this period. Q2 comes on when Q1 shuts off, and Q2 then supplies ILOWER to the load. The inductor current drops during this period (discharging L). [13-16]

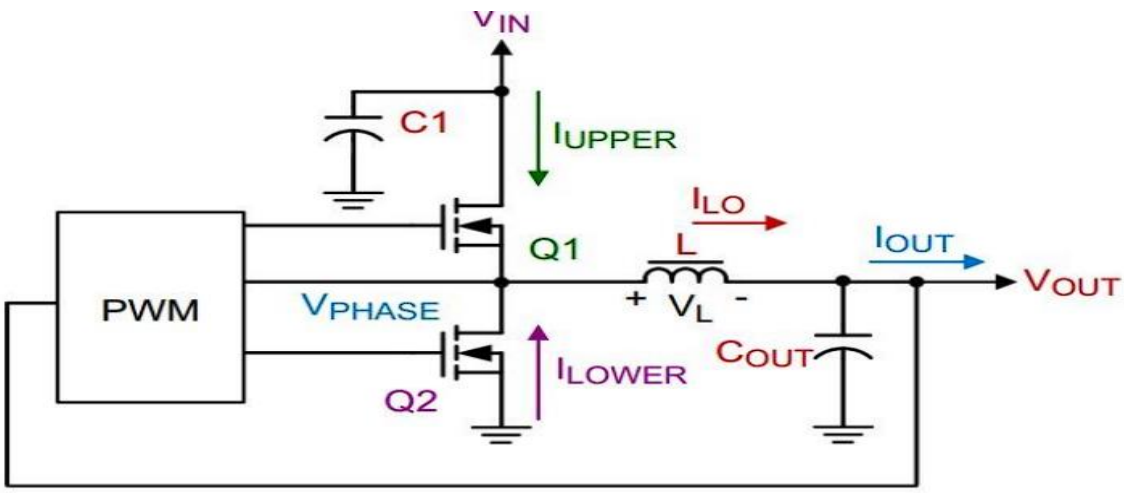

Fig. 3: Synchronous buck converter

Simulation

Simulation of Synchronous Buck Converter

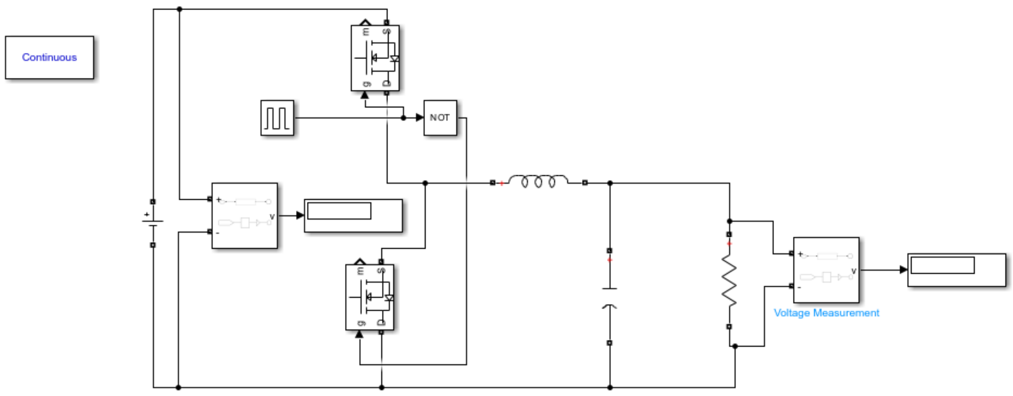

Fig. 4: Simulation of synchronous buck converter with dc source

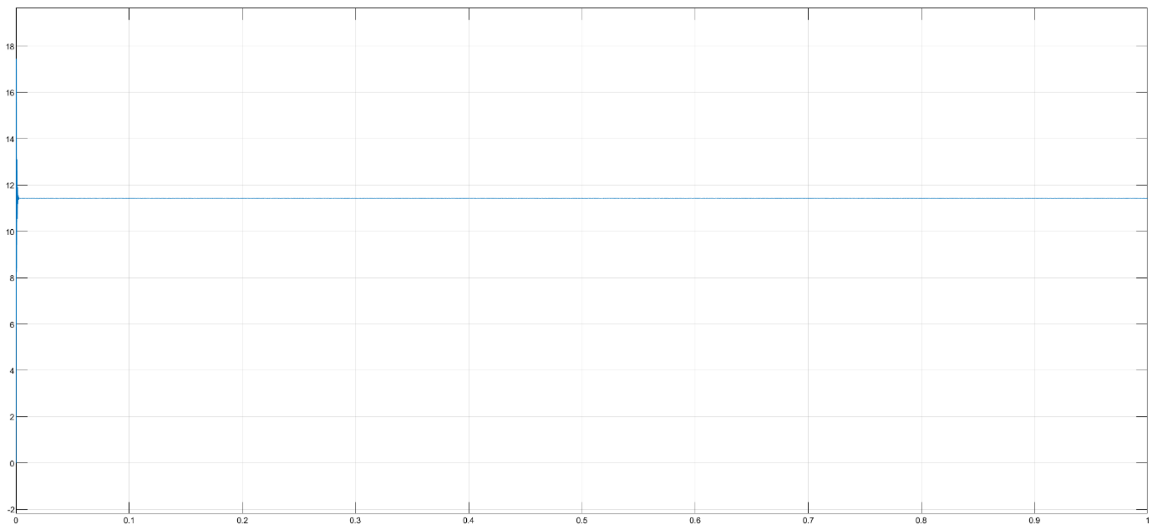

Fig. 5: Simulation result of synchronous buck converter

In this we have done the simulation of a synchronous buck converter using an inductor, capacitor, mosfet and a dc supply of 24 and our requirement was to get an output of 12v which we get from considering the value of inductor and capacitor. Fig 4, 5 [17]

Design for Synchronous Buck Converter

- Voltage input, V_{in}=24V
- Voltage output, V_{out}=12V
- Frequency,f =50khz

$$L = V_{out}*(1-V_{out}/V_{in})/f*I_o$$

$$= \frac{12*(1-12/24)}{50000*0.3} = 40*10^{-6}H$$

$$C = \frac{V_{out}/V_{in}*(1-V_{out}/V_{in})*I_o}{f*V_o}$$

$$= \frac{12/24*(1-12/24)*0.3}{50000*0.3} = 220*10^{-6}\ F$$

Simulation of Solar Tree

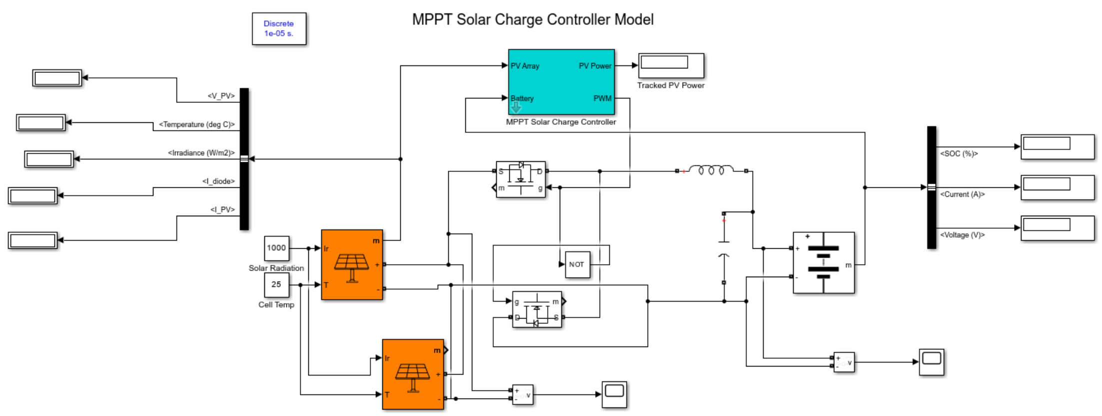

Fig.6: Simulation of solar tree

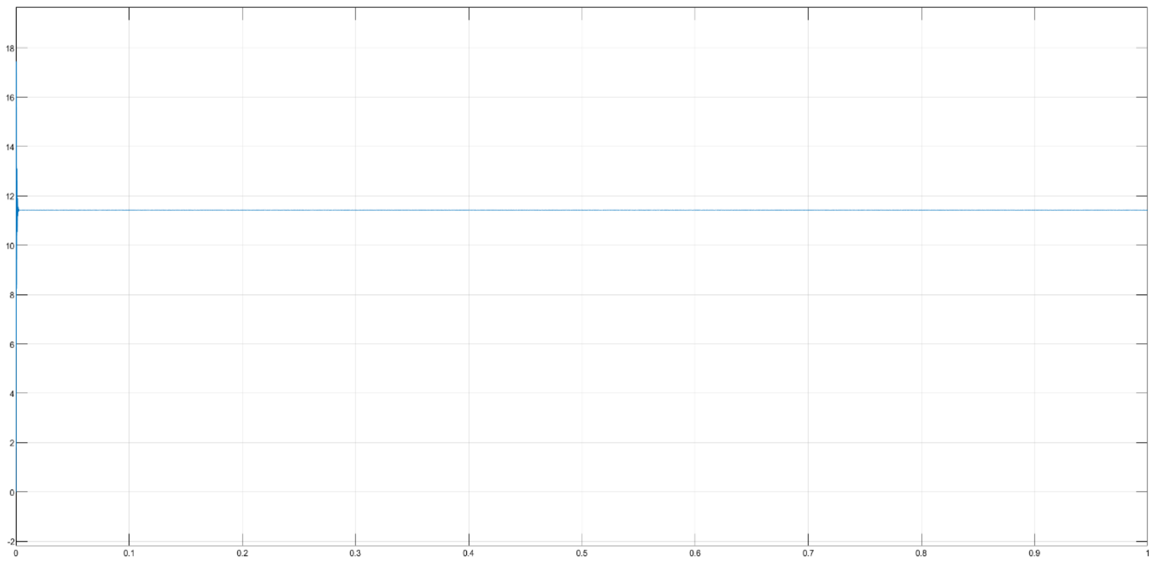

Fig.7: Simulation result of output voltage

CONCLUSIONS

A solar tree is an artistic and functional installation that captures solar energy using a design inspired by a natural tree. Its branches are adorned with solar panels, which serve as leaves, creating a compact and efficient structure that can fit into urban spaces where ground area is scarce. Not only does it offer a visually pleasing alternative to traditional solar arrays, but its unique configuration also allows for optimal sunlight absorption. This innovative concept not only conserves space but also enhances the aesthetic of its surroundings, all while contributing to the generation of clean, renewable energy.

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