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Design and Experimentation of Voltage Control for PV-FED DC-DC Converter

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Abstract

A voltage regulation system is proposed for photovoltaic energy sources (PV) using Single-Ended Primary Inductance Converter (SEPIC) as a DC-DC converter to feed loads working with specific input voltage. The choose of SEPIC converter is due to the output voltage ripple of developed type converters are usually small and can be lower than 2%, also it is considered as a buck and boost converter and thereafter loads with lower or higher voltage could be powered. MATLAB Simulink is used as environment to develop control strategies to guarantee a stable voltage at the load terminals. The algorithm that is used to fulfill this role is a conventional PID controller to generate the PWM signal for the SEPIC converter. Hence, to validate the work some real-time simulations aretreated by implemented the control strategies on a low-cost control board: The Raspberry Pi Pico in order to manage the operation of system and collecting the simulation data. Also, and for verification purposes, several simulations were treated to verify the good performance of the proposed system.

Keywords: Voltage control system, Photovoltaic system, DC-DC power converters, SEPIC Converters, Raspberry Pico Board, PID controller.

I. Introduction

In recent decades, the use of renewable energy has gained importance in many applications, then an interest of researchers appeared to optimize and exploit the use of this resource. Photovoltaics in turn is among the most remarkable sources that transforms the light radiation into electricity, but what makes the recovery of energy not easy is that the photovoltaic energy production depends directly of serval parameters, namely temperature and level of irradiation. Hence an unstable voltage at its terminals. In the case where we need to supply loads with stable voltage well defined to ensure their operation. It is necessary to do what we call controlled voltage system which this is the aim of our work. The controlled voltage system must guarantee a constant voltage in the terminals of the load even if there is a change of load, change of voltage supply of the photovoltaic source.

DC-DC converters, a power electronic circuit, are used for voltage adaptation between photovoltaic source and loads. This kind of static converter are used due to low loss power, high efficiency as well its used in many industry applications.

Multiples generation of DC-DC converter has been developed over the years, on where we can find the step-up input voltage also called boost, step down input voltage the buck converter, and the buck-boost converter to get lower or higher voltage depending of the need. In this paper a special type of DC-DC converter Buck-Boost converter, type Single Ended Primary Inductance Converter (SEPIC), has been proposed to control transmitted power from photovoltaic source and loads. This type of conversion is handy when the designer uses voltages from an unregulated input power supply. However, to control the load voltage even with unregulated input voltage, the electronic switch should be controlled periodically by a PWM signal, adjusting the On and Off times to get the adequate duty cycle hence the desired output voltage.

II. Boost Converter

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors, a diode and a transistor and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter’s output (loadside filter) and input (supply-side filter). Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers, and DC generators.

A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=U*I) must be conserved, the output current is lower than the source current.

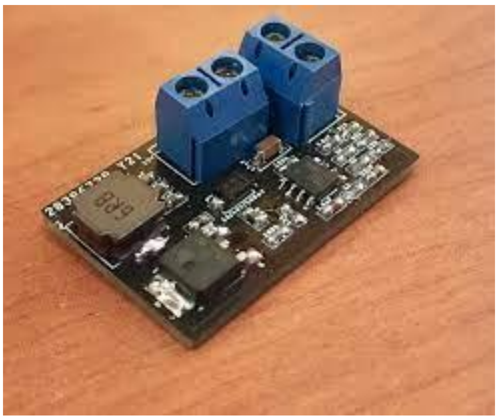
Boost Converter

III. SEPIC Converter

The Single-Ended Primary-Inductor Converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control switch (S1).

SEPIC is essentially a boost converter followed by an inverted buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same electrical polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch S1 is turned off, the output (V0) drops to 0 V, following a fairly hefty transient dump of charge. SEPIC's are useful in applications in which a battery voltage can be above and below that of the regulator's intended output.

For example, a single lithium-ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.



SEPIC Converter

IV. Usage of SEPIC Converter

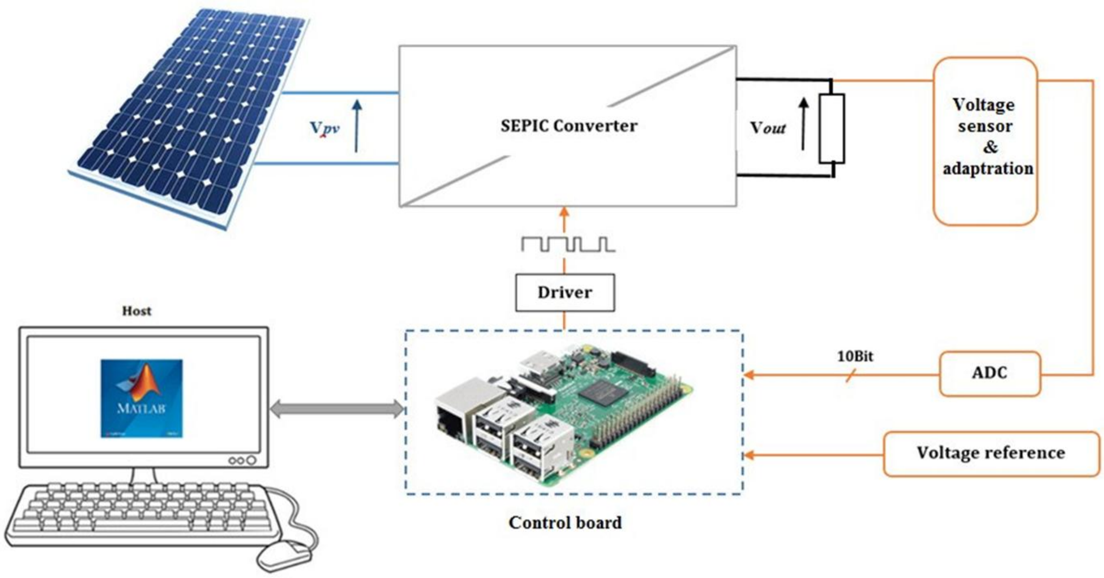
Basic converters are used to provide only steps down input voltage, case of buck converter, or steps up input voltage case of boost converter. But for many applications where we need to both step up and step down, depending on the input and desired output voltage.

The SingleEnded Primary Inductance Converter (SEPIC) presents a good solution for those kind of application, and has become popular in recent years in battery powered systems that's must step up or down depending upon the charge level of the battery. The dc-dc boost converter topology is most widely used power management and microprocessor voltage-regulator applications.

These applications require high frequency and transient response 19 over a wide load current range. They can convert high voltage into low regulated voltage and vice versa. When the switch is ON the inductor gets charged to its maximum level, because of its flexibility of ON and OFF states it can be switched to OFF state when inductor charges to its maximum capacity.

With this feature the usage of heat sinks and cooling agents can be avoided. Hence, because of its advantage we opt for this converter rather than a linear regulator.

V. Block Diagram



VI.WORKING PRINCIPLE

Whenever the supply is connected, the electricity will flow from all the elements of the board. As the sunlight falls on the solar panel, it generates some voltage. This voltage is given to the boost converter which increases the voltage. The voltage from the boost converter then flows through the voltage sensor that allows voltage which is less than 25V.If the voltage is greater than 20V, the buzzer which is connected to the sensor indicates that the voltage is high. The power supply section is required to convert AC signal to DC signal. This signal is given to the Raspberry pi Pico board and the code is dumped through a micro-USB connected to the laptop. The code is uploaded, executed and then the output voltage is shown in the LCD, which is connected to the Raspberry Pi Pico board and graph of the output voltage is shown in laptop.

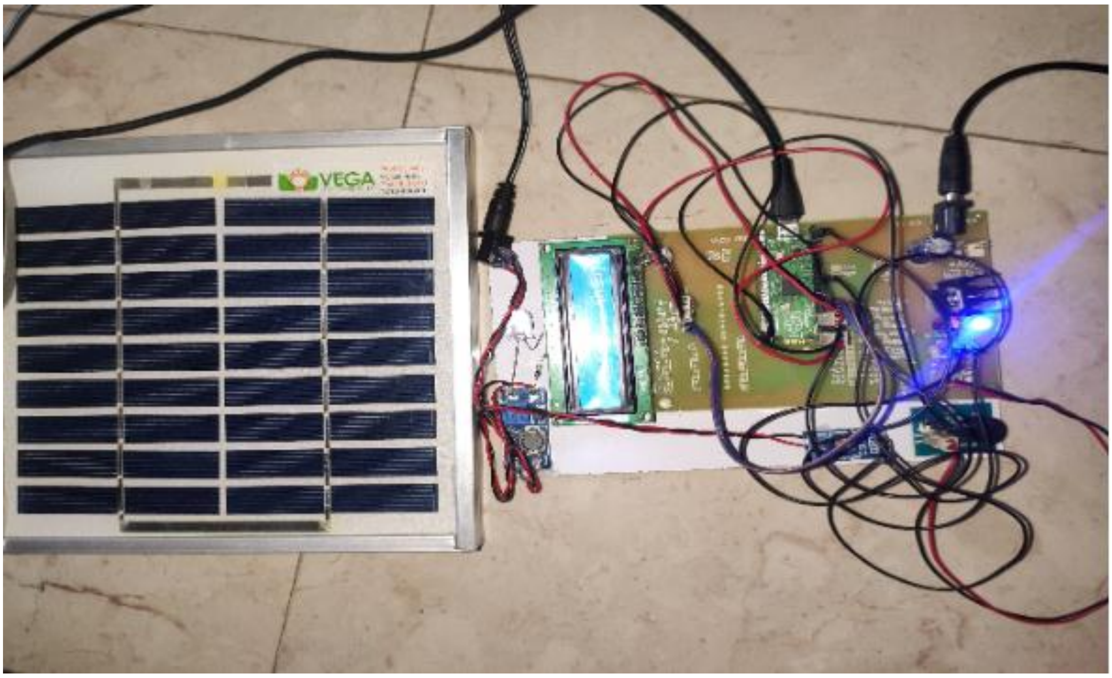
VII. SOFTWARE USED

Software: C programming Language

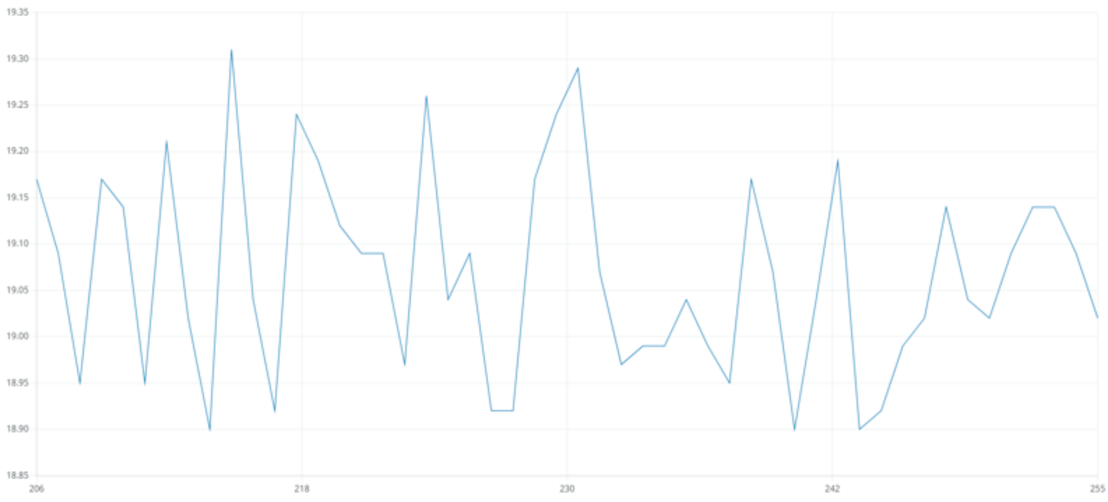
We here consider C programming language as it is the low-level programming among all the high-level programming languages. Here, We want complete control of the hardware right down to the individual bit of a register, then we know that the C is the ultimate choice.

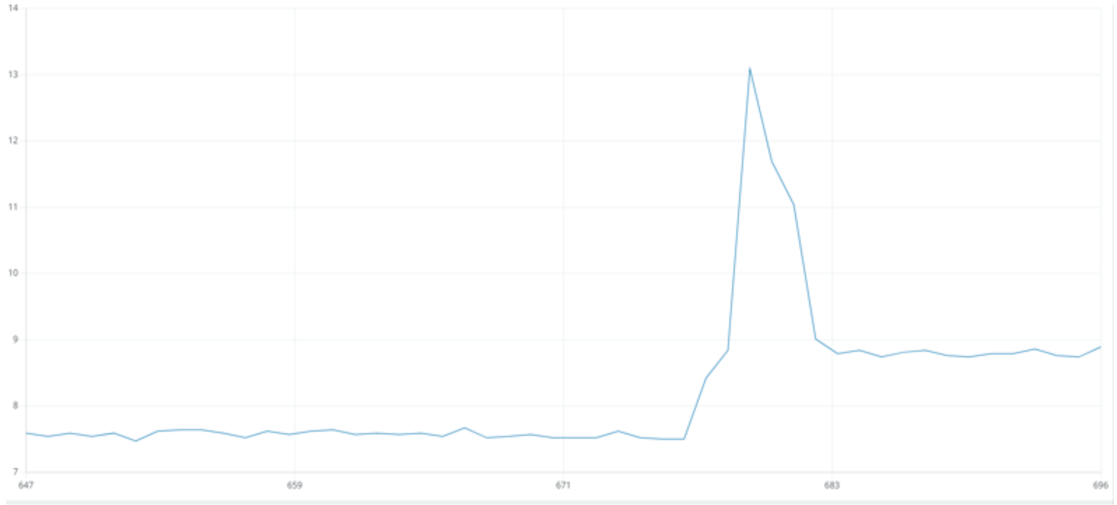
VIII. HARDWARE RESULTS

Control board using Boost converter



Working of the control board

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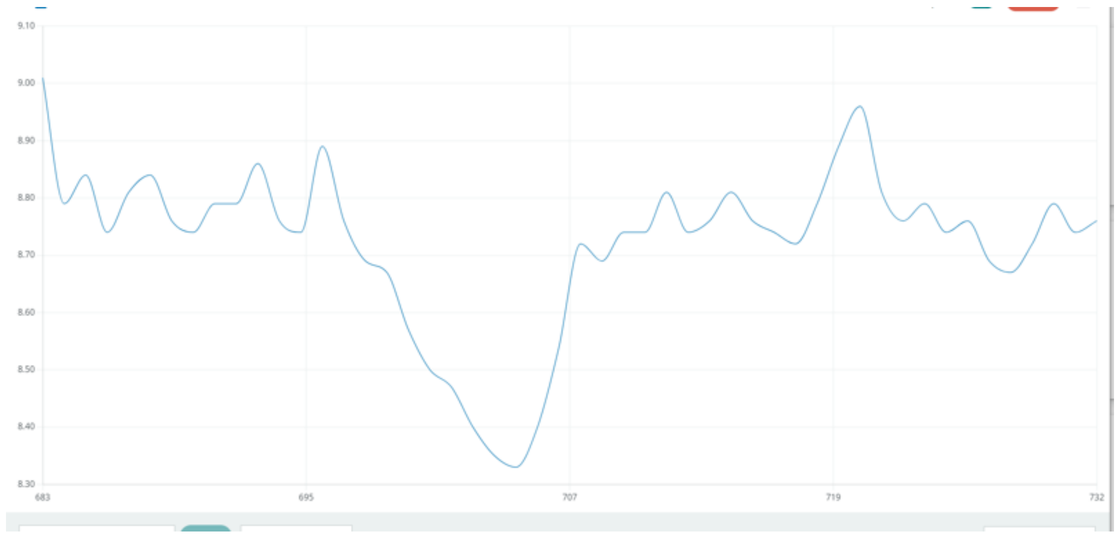
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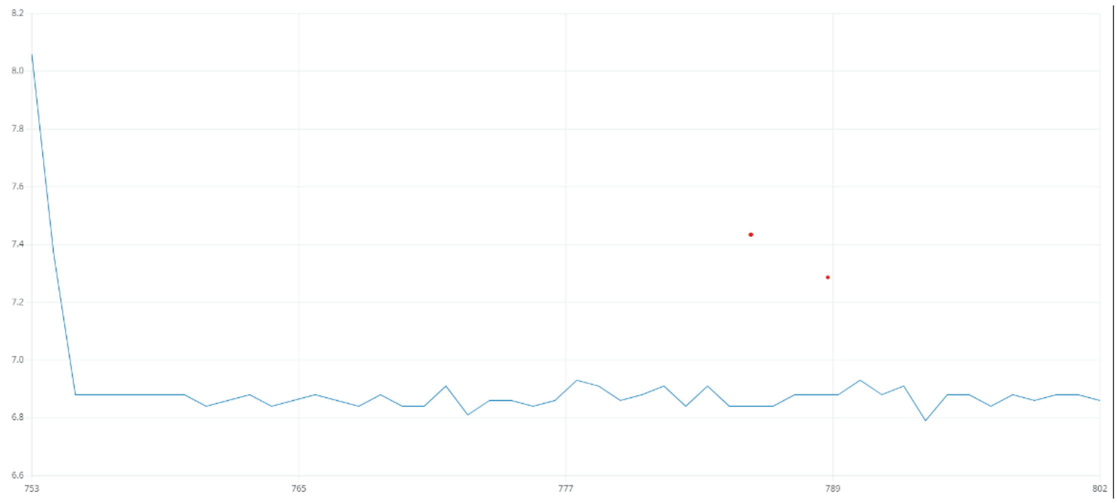
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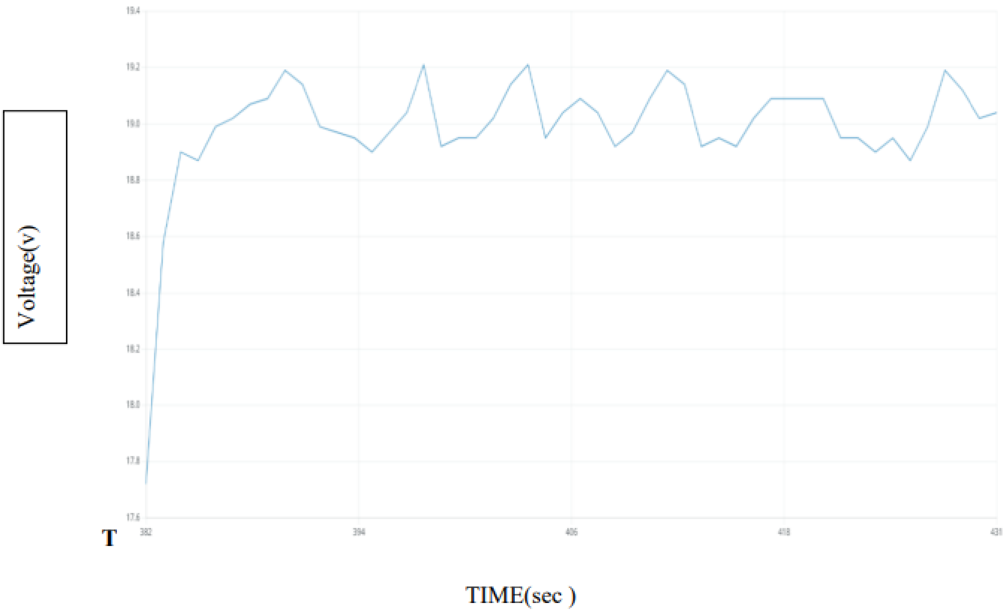


Fig 6.5.1 : The voltage after step up

The voltage after step up

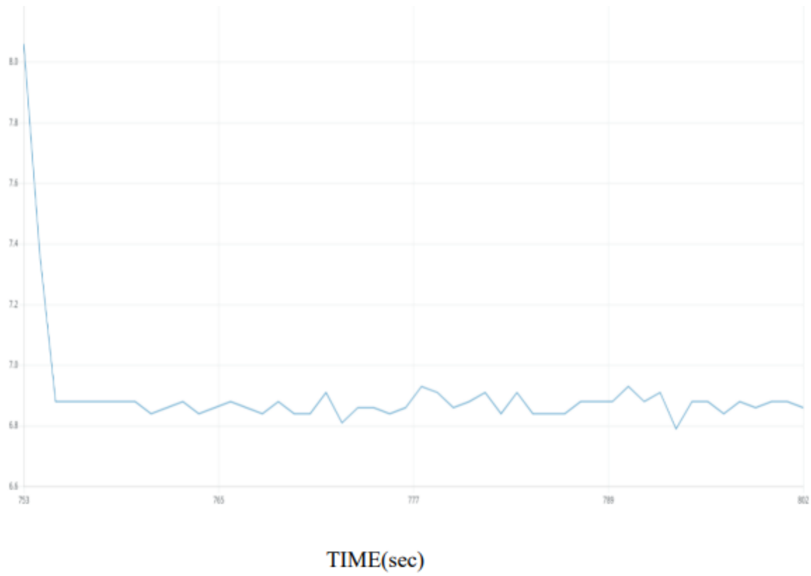
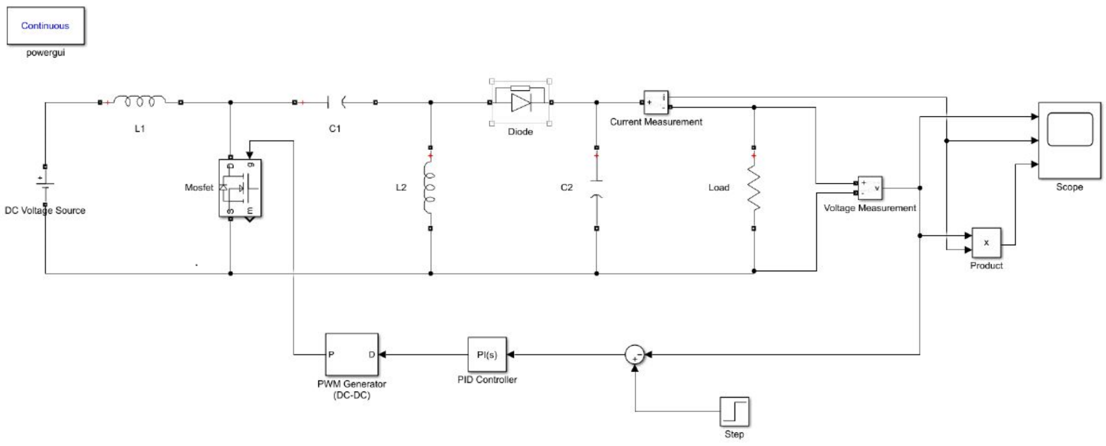


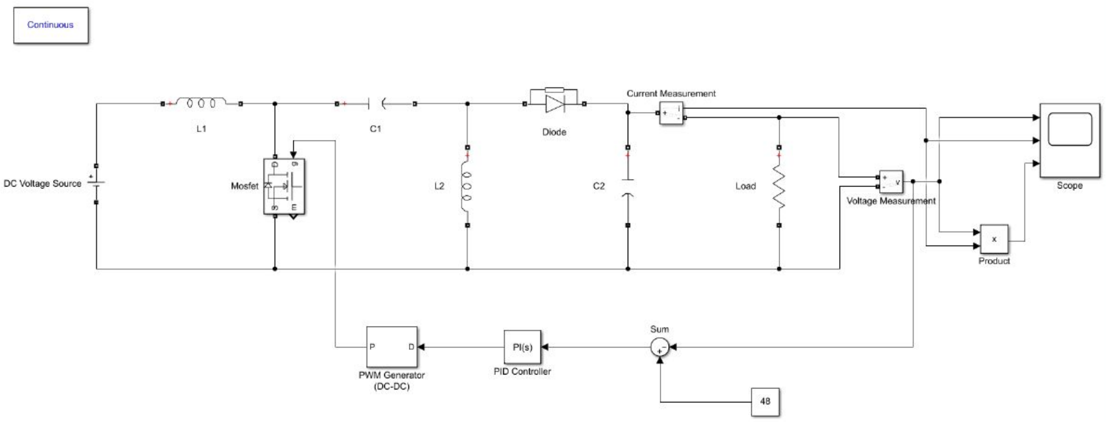
Fig 6.5.2 : The

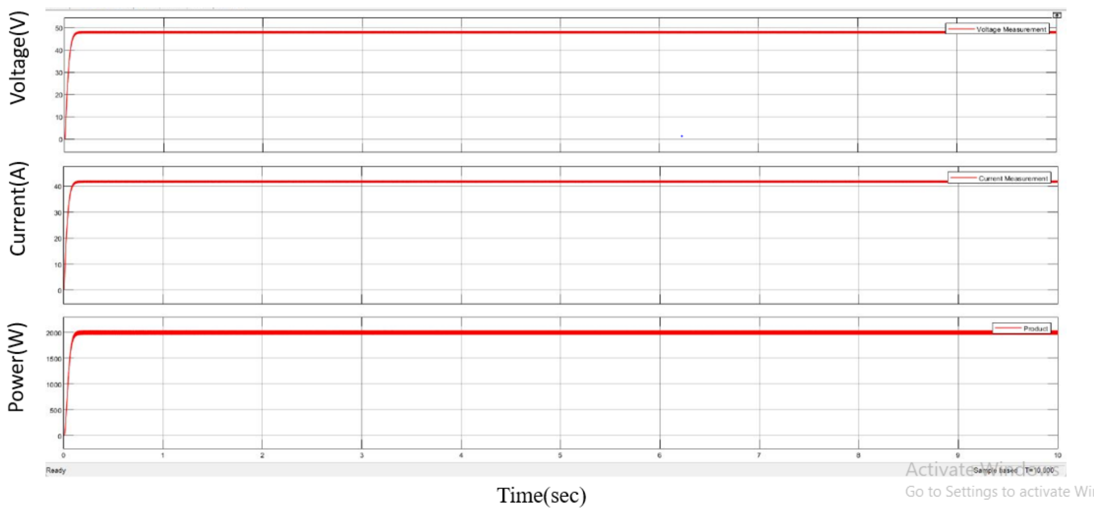
The voltage after step down

IX. SIMULATION RESULTS

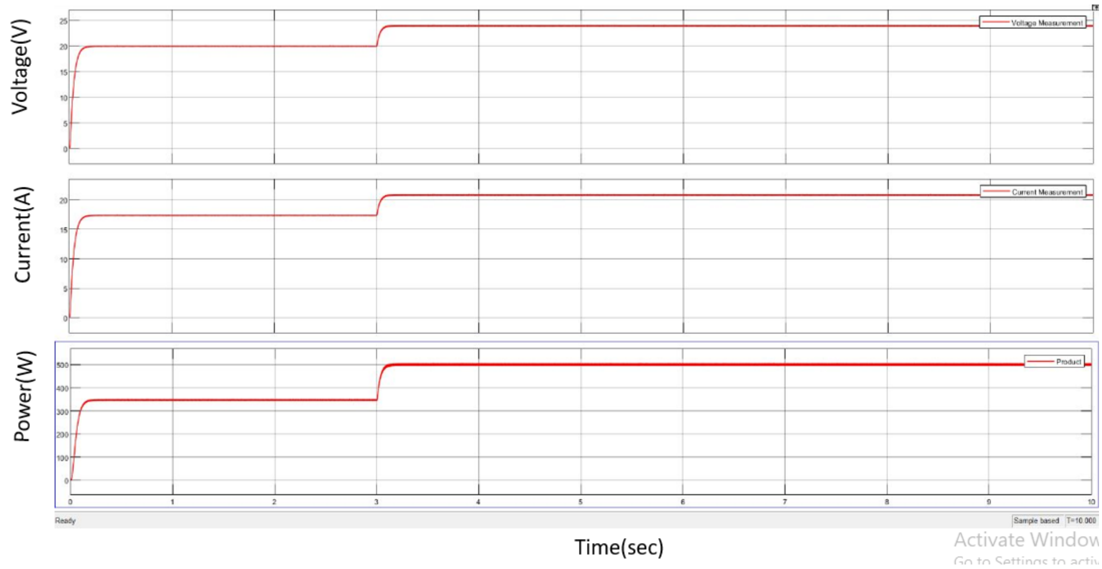


Simulink Diagrams





The simulation results when the voltage is considered to be constant.



The simulation results when the voltage is set to be a step voltage.

Conclusions:

Voltage control system for photovoltaic sources, which could be extended to other no-regular sources, using a DC-DC converter as an intermediate block between source and loads in order to guarantee the transfer of the power. To validate the proposed system, simulations were treated under MATLAB Simulink environment and implemented low-cost control board to improve the good behaviour of this system in real-time implementation.

Besides, when SEPIC structure with coupled inductors is used, the reproduction of the curves of the photovoltaic panel is done in a reliable way and also the PV stresses are limited.

Many applications where we need to do both step up and step down, depending on the input and desired output voltage. The Single-Ended Primary Inductance Converter (SEPIC) presents a good solution for those kind of application, battery powered systems that’s must step up or down depending upon the charge level of the battery • For the control part, control strategies are proposed to control the transferred power to loads.

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