

Universal Battery Module Synchronizer

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ABSTRACT: Currently off-grid solar application's specifications are limited by battery ratings thus, solar specification finalization is a backward engineering process. Based on voltage rating of the inverter or batteries, solar modules are getting selected. Generally in small, every day or household applications lead acid batteries are being used, which are of 6V, 12V and 24V; thus different voltage rated modules are required in each case.

Universal Battery Module Synchronizer (UBMS) is a device which intelligently detects the voltage rating of the load connected and communicates with the module such that the module output and the battery rating are synchronized. It will be able to behave like a DC-DC converter which will check for the module's voltage and current output and based on battery charging voltage/current requirement it will jack up or reduce the voltage and in turn reduce or increase current respectively, in order to maintain law of conservation of energy.

Thus this unit is working like a universal matching component for any system and within a system between any combination of solar modules & Batteries.

UBMS-makes your module compatible with any load

KEYWORDS: Arduino microcontroller, Battery charging, PV module, Off-Grid application, Universal Battery Module Synchronizer (UBMS)

I. INTRODUCTION

Photovoltaic technology converts sunlight directly into electricity and is emerging as a major power source due to its numerous environmental and economic benefits. A complete system includes different components that should be selected taking into consideration our individual needs, site location, climate and expectations. Solar photovoltaic energy primarily involves two fields of research i.e., technology (solar cell materials) and the balance of systems (that includes the supporting components in SPV power plants) [1]. Stand-alone or off-grid systems include common applications such as solar lanterns, solar home and street-lighting systems, solar water pumping, and stand-alone power plants for powering applications in remote areas away from access to grid electricity. Such systems are designed either with or without battery backup options.

1.1 Motivation behind the proposed system

Currently off-grid solar application's specifications are limited by battery ratings, thus solar specification finalization is a backward engineering process. Based on voltage rating of the inverter or batteries, solar modules are getting selected. Generally in small, every day or household applications lead-acid batteries are being used, which are of 6V, 12V and 24V; thus different voltage rated modules are required in each case.

1.2 Objective

The project under consideration involves the design and development of a device called Universal Battery Module Synchronizer (UBMS) which will make the installed PV module compatible with any load connected, irrespective of their individual ratings. UBMS is a device which intelligently detects the voltage rating of the load connected and communicates with the module such that the module output and the battery rating are synchronized. It will be able to behave like a DC-DC converter which will check for the module's voltage and current output and based on battery charging voltage/current

UBMS is designed such that a 60 cell, 240 W, 30 V PV module can be used to charge 12V as well as 24V batteries.

1.3 Methodology

The following methodology was followed during the project,

- Detailed study of SPV System components, Simulink and Arduino tools.
- Study and selection of suitable Arduino board for Pulse Width Modulation and its programming.
- Building up suitable simulation required
- Design of suitable hardware required..

1.4 Block Diagram

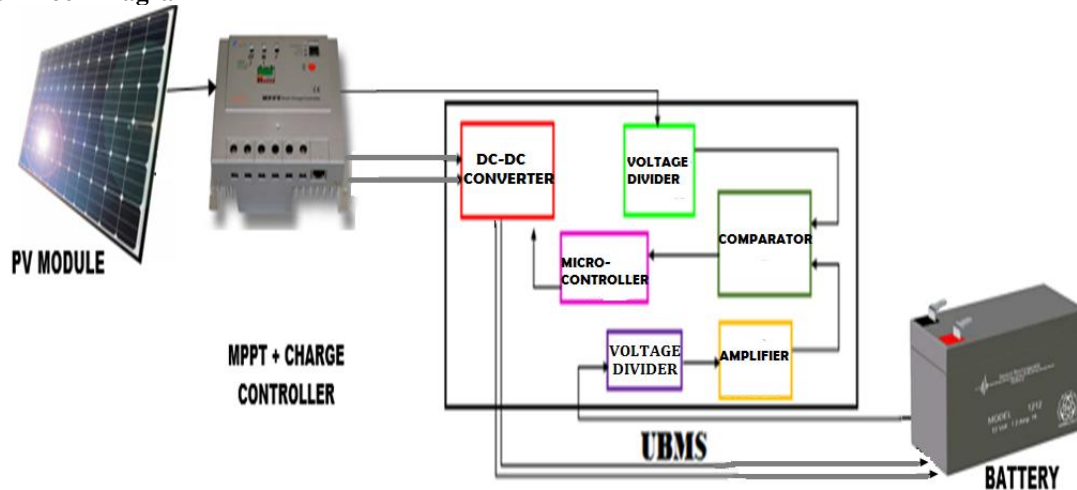


Fig.1.1 General Block diagram

The solar PV module is connected to a Maximum Power Point Tracker and a Charge Controller. The output of the MPPT is connected to a voltage divider circuit, in which the magnitude of the source /module voltage (V_s) is reduced by a desired ratio. The battery is also connected to a voltage divider such that the battery voltage (V_b) is reduced by the same ratio. This battery voltage is further amplified to obtain the reference voltage needed to charge the battery, i.e. 18V for a 12V battery and 32V for a 24V battery.

These reduced module voltage (V_{s1}) and battery voltage (V_{b1}), are then fed to a differential amplifier circuit having a gain of unity i.e., $A_v=1$. The output of the differentiator is $V_{s1} \sim V_{b1}$. This output acts as an error signal and is the input to the Pulse Width Modulator (PWM). The PWM generates pulse width modulated signals depending on the error signal and thereby regulating the duty cycle accordingly[2].

The pulses from the PWM are used to drive the MOSFET which is used as a switch in the DC-DC Buck Boost Converter. The input to the converter is the PV Module output voltage (V_s). This voltage is bucked or boosted using the Buck-Boost converter based on the switching period of the MOSFET. The converted voltage is then used to charge the battery[3].

II. SIMULATION AND RESULTS

2.1 Introduction

Simulink is a block diagram environment for multi-domain simulation and model-based design. It supports simulation, automatic code generation and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries and solvers for modelling and simulating dynamic systems[4].

We used Simulink to get our idea off the ground, reducing unnecessary costs obtained by practical trials and to find the best solutions. Simulink helped us in building and simulating the module and also analyze the results obtained. The results of the simulation of various circuits comprising our model are as follows:

2.2 Non-Inverting Amplifier

Generally for a battery to be charged, the supply voltage must be greater than the present battery voltage as this leads to the potential difference needed to charge the battery. It is found that the supply voltage must be 1.5 times that of battery voltage to charge it optimally i.e., to charge a 12V battery, 18V is needed and for a 24V battery 32V is needed. Thus the non-inverting amplifier is used to generate the reference voltage needed to charge the battery.

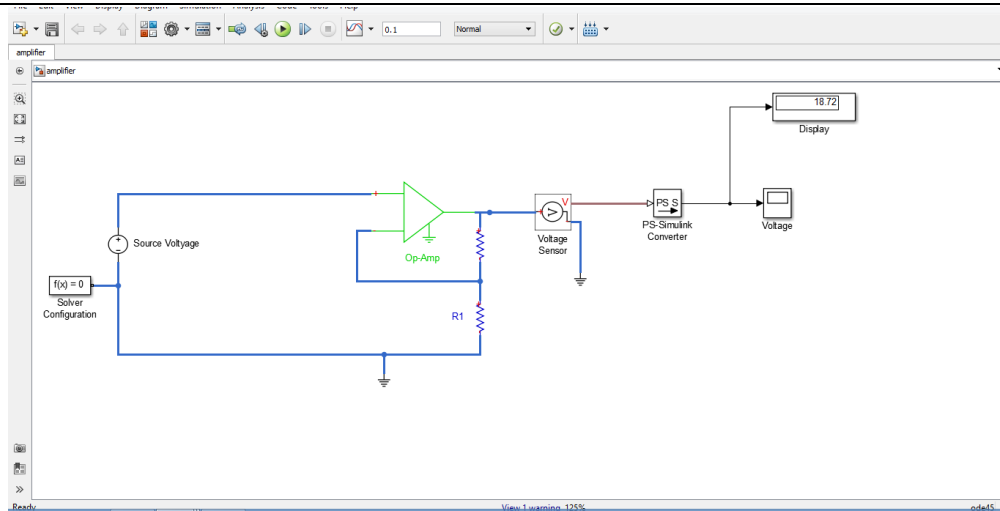


Fig. 2.1 Simulation of Non-Inverting Amplifier

Where,

Source Voltage = 12V

$R2 = 497\Omega$

$R1 = 1k\Omega$

Obtained voltage = 18.72V

Therefore, gain = $18.72/12 = 1.56$

2.3 Difference Amplifier as Comparator

A difference amplifier circuit compares two voltage signals and determines which one is greater and the result of this comparison is indicated by the output voltage. By connecting one voltage signal onto one input terminal and another voltage signal onto the other input terminal the resultant output voltage will be proportional to the “Difference” between the two input voltage signals of V_1 and V_2 .

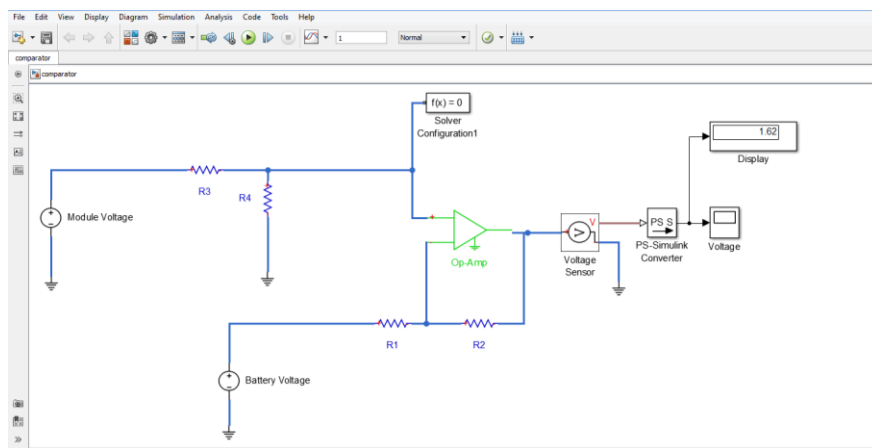


Fig. 2.2 Simulation of Difference Amplifier as Comparator

Where,

Module Voltage = 4.86V

Battery Voltage = 3.24V

$R1 = R2 = R3 = R4 = 1k\Omega$

Obtained Voltage = 1.62V

Therefore, Difference Voltage = $4.86 - 3.24 = 1.62V$

2.4 DC-DC Buck-Boost Converter

2.4.1 Boost Mode

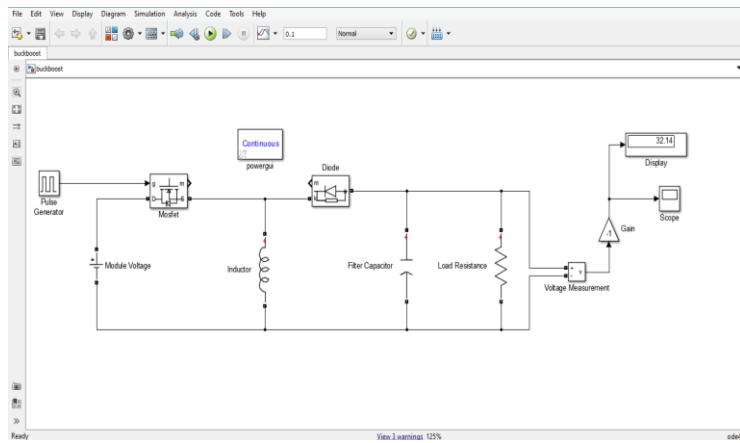


Fig. 2.3 Simulation of DC-DC Converter in Boost mode and the output voltage waveform

Where,

Module Voltage = 27V

Duty Cycle = 55%

Obtained voltage = 32.14V

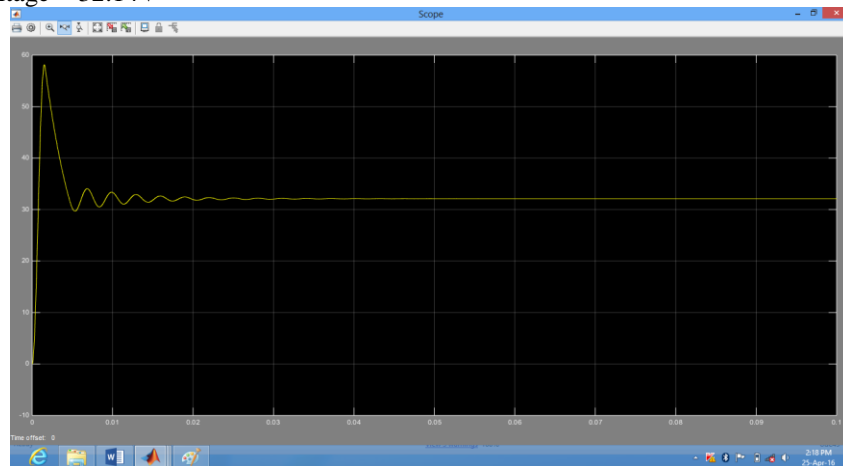


Fig. 2.4 Output voltage waveform of Boost Converter

2.4.2 Buck mode

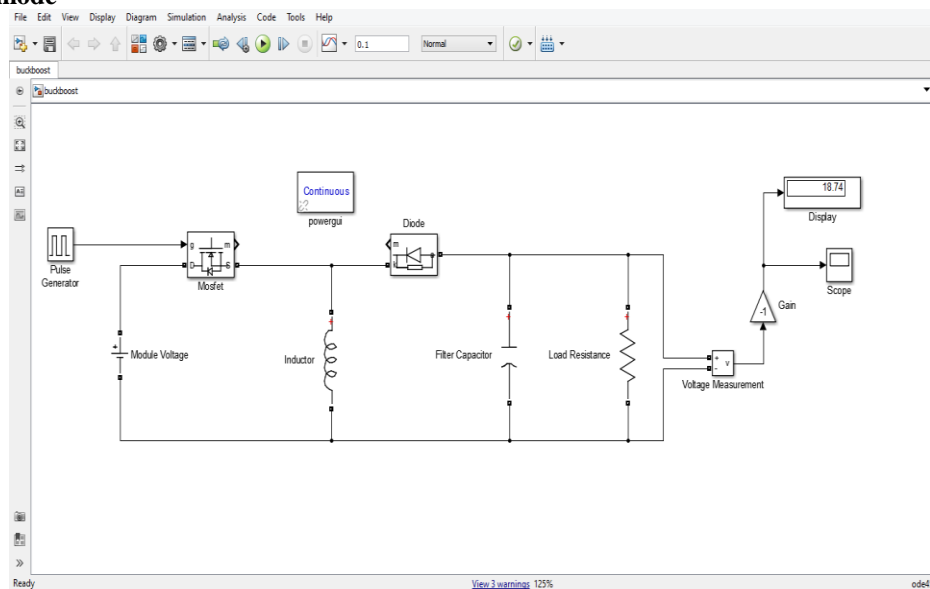


Fig. 2.5 Simulation of DC-DC Converter in Buck mode

Where,

Module Voltage = 27V

Duty Cycle = 42%

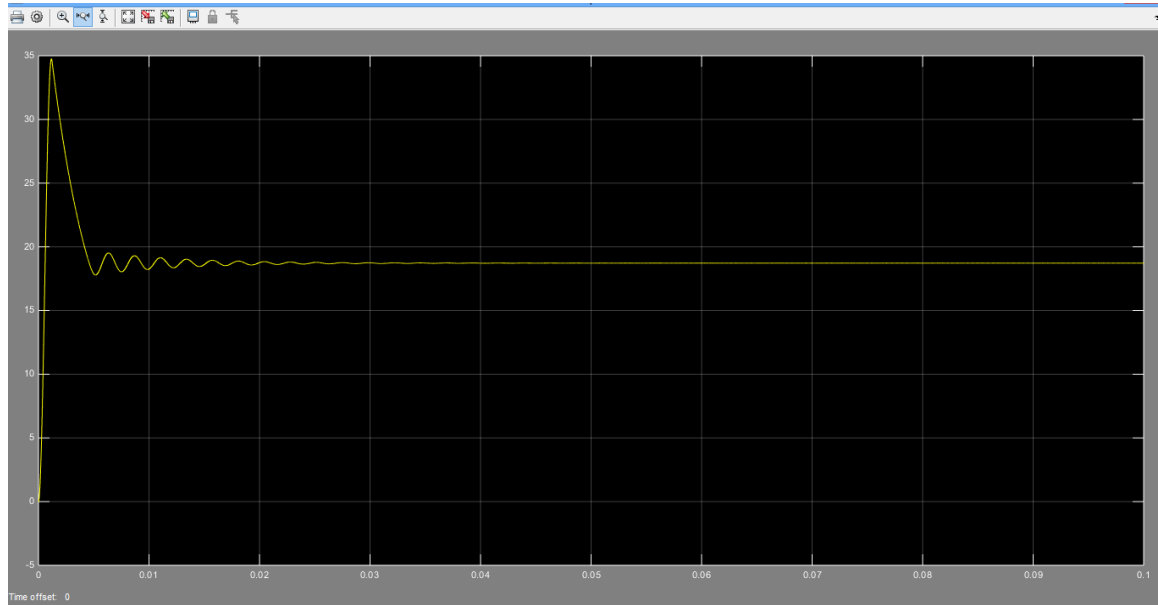


Fig. 2.6 Output voltage waveform of Buck Converter

2.5 Complete Simulation

On combining all the circuits, the complete simulation of UBMS is given as follows,

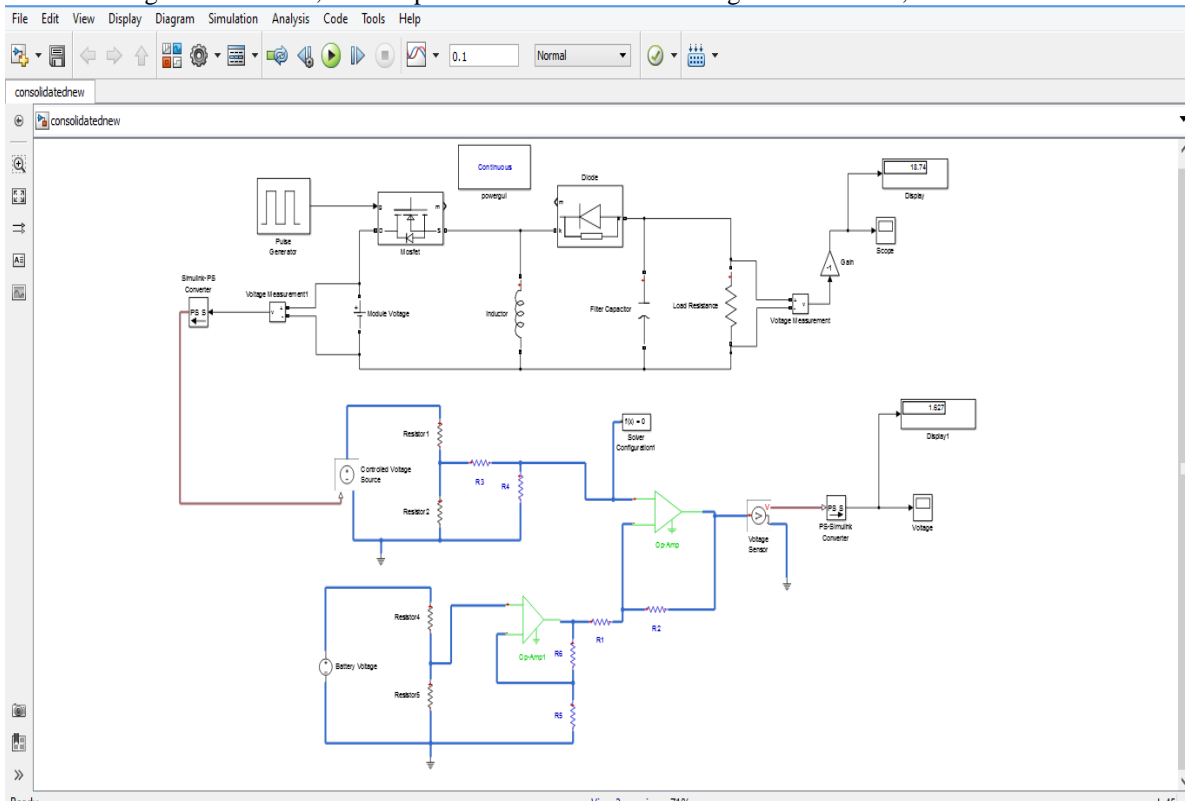


Fig. 2.7 Complete Simulation of UBMS

III. PRACTICAL IMPLEMENTATION AND RESULTS

The detailed circuit diagram of UBMS is given in the figure below.

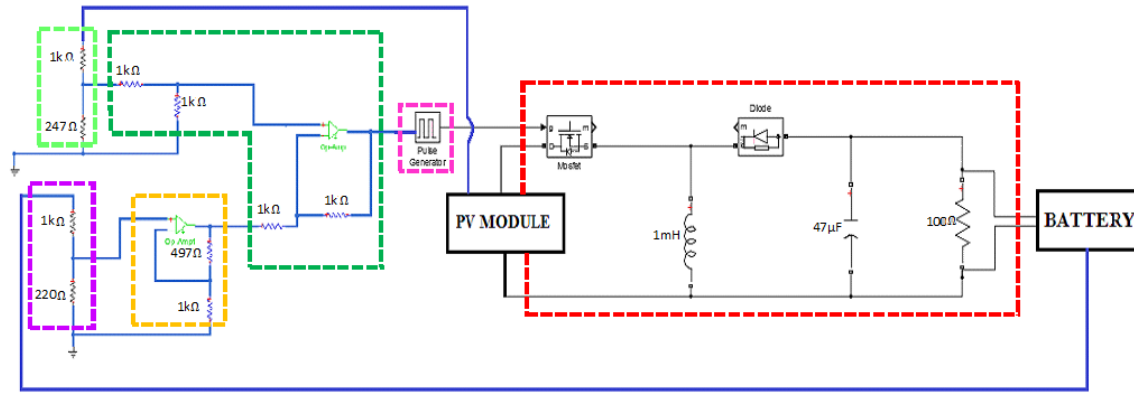


Fig.3.1 Detailed Circuit Diagram

An Arduino Uno micro-controller was used as the pulse generator[5]. Pins 3, 5, 6, 9, 10, and 11 of the Uno provide 8-bit PWM output with the *analogWrite()* function. The Uno has six analog inputs, labeled A0 through A5, each of which provides 10 bits of resolution (1,024 different values). By default, they measure from ground to 5 volts, although it is possible to change the upper end of their range using the AREF pin and the *analogReference()* function.[6]

The results obtained from the experimental setup is tabulated as follows

Table I. Results obtained from the experimental setup of UBMS

Sl.No.	Module Voltage (V_s)	Battery Voltage (V_b)	UBMS output voltage (V_o)
1	27V	12V	18.14V
2	27V	24V	31.56V
3	18V	6V	10.03V
4	18V	12V	18V
5	18V	24V	31.23V

Based on the above results it was observed that the output voltage of the UBMS was equal to almost 1.5 times the battery voltage. This obtained voltage was found to be sufficient to charge the battery efficiently.

IV. CONCLUSION AND FUTURE SCOPE

Universal Battery Module Synchronizer (UBMS) is a device which intelligently detects the voltage rating of the load connected and communicates with the module such that the module output and the battery rating are synchronized. UBMS has got two prolonged applications and commercial benefits. They are:

- The end user need not worry about system design, any combination will work if it is connected to this unit.
- Irrespective of the size of the system (1kVA, 2kVA, 5kVA etc. as it varies from customer to customer), UBMS will be the common unit into the system.

Thus, this unit is working like a universal matching component for any system and within a system between any combination of solar modules and batteries.

The UBMS can be connected to the module directly or can be incorporated along with the MPPT and charge controller unit for commercial use. If it is used for domestic purposes, the MPPT can be overlooked and only the charge controller can be used on the load side. In the case of an array of modules, a UBMS must be connected to every individual module of the array.

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