

# Novel Programmable Solar Based SIMO Converter for SMPS Applications with IOT Infrastructure

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## Keywords

SPELEC board, SMPS, programmable controller, buck converter, Arduino, P&O MPPT technique, Thingspeak, Blynk

## Abstract

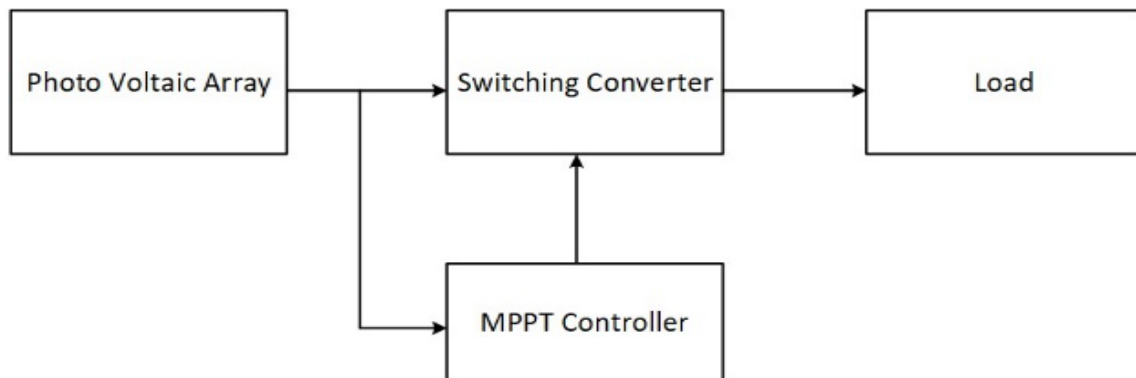
Technological advancements lead to depend more on electronic goods which consume DC power. The DC appliances need converter circuits that are unique concerning their voltage and current ratings. In this paper, IoT enabled Programmable DC-DC converter is proposed for Solar dependent on DC Loads. The economically viable reconfigurable converter is achieved using a customized IoT board SPELEC. The primary step of the design to feed the SIMO converter from 230-Watt solar panel, the second stage 25 Khz pulses are generated from the SPELEC board to trigger the converter MOSFETs and in the Third stage of design, an MPPT Petrube and Observe (P&O) algorithm is implemented to maintain SIMO converter output Voltage's constant irrespective of the solar panel voltage fluctuations based on duty change in trigger pulses to the MOSFETs. The design aimed to cater to DC loads of different voltages as 9V 12 V and 24 V act as a solar spike. IoT-enabled features are Solar Panel voltage and Load Currents along with Load isolation using Blynk Mobile operated Relay control. The Sensor data is uploaded for visualization and analysis on Thingspeak Cloud. The recorded voltage is in the range of 0 to 12v and current is 0 to 1.5A and power is from 0 to 20watts. The SPELEC Converter performance is compared with the Arduino-based converter and an improvement in ripples is recorded.

## 1. Introduction

The use of DC based loads is increasing day by day since the energy is being generated effectively from renewable energy sources particularly solar power generation which produces the DC power. To make best use of this DC power, people are preferring DC based loads like DC fans, DC bulbs, heaters, mobile chargers, electronic chargers and some electronic gadgets. However, all the chargers of electronic gadgets like laptops, headphones, mobile phones need to be charged regularly. An adapter is crucial part in any of the charger which decides the efficiency of the conversion rate, quality of the power is decided and that will obviously decide the life time of the device [1].

The DC power and DC-DC converters became more prominent these days as power generation from renewable energy resources is increasing day to day to reduce the emission of greenhouse gases. Particularly countries like India and china are concentrating more to move towards renewables as they are the only countries emitting more greenhouse gases causing environmental pollution. Among all renewable energy resources solar

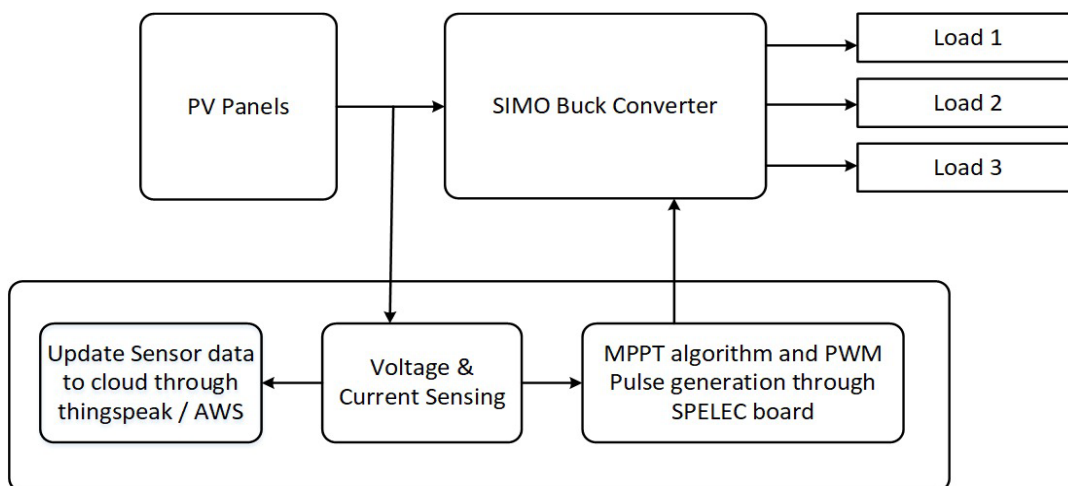
power due to its abundance nature and availability at free of cost, more research is going on PV system for off grid and on grid. Tracking maximum available power from PV panels is the major problem faced in the solar PV system [2]. There were 24 maximum power point tracking techniques were proposed in the literature and many converters were also proposed [3]. This paper aims at designing a novel converter which uses an embedded controller to generate the gate pulses to switch on the semiconductor device in the power electronic converter and also can implement the MPPT technique.



**Fig. 1** Block diagram of PV system comprising of switching converter

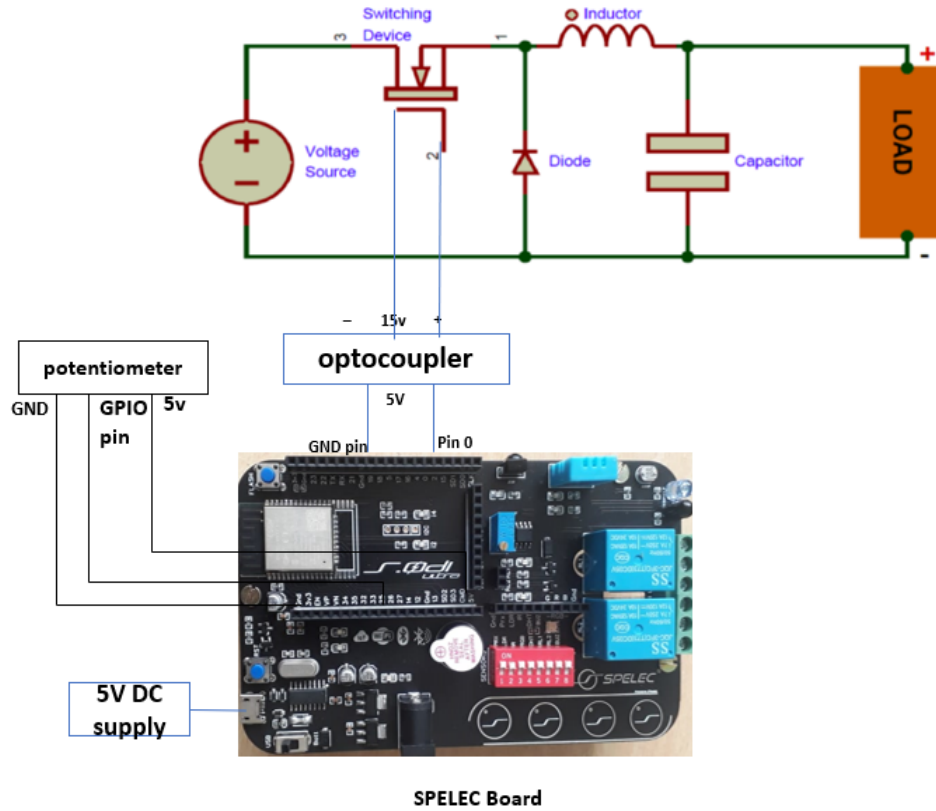
In literature many converter topologies are proposed and implemented in terms of programmable control due to the challenges in power supplies to the switching converters [1]. The embedded controllers offer more flexibility to tune the generation of trigger pulse for attaining the desired converter output. Renewable sources are gaining attention led to the increase in converter demand. The stochastic nature of the source challenges the power converter to maintain the power constant to the load. The introduction of more tunable frequency generator offers added advantage to solar SMPS also improves the load versatility.

## 2. Methodology and Implementation of Proposed Embedded Controller



**Fig. 2** Basic block diagram of the proposed controller

The above figure shows the block diagram of the proposed work. where PV panels were connected to three different loads through the DC-DC converter. since the loads that were chosen are below 12v rating so buck converter is used. the proposed Embedded board will generate gate pulses to trigger MOSFET in the converter. the voltage and current sensors will continuously monitor the panel voltage and current and any deviation occurred, the duty will be adjusted automatically in the proposed Embedded board.



**Fig. 3** Embedded board interface to the converter

The above figure shows the actual circuit diagram describing the generation of gate pulses from an Embedded controller board. The board has inbuilt PWM LED pins. The gate pulses of required duty cycle can be generated from these pins using Arduino/python ide. The output from the embedded board will be connected to the buck converter through an optocoupler. Here the optocoupler serves two purposes one is to isolate the driver board and power converter and the second one is to amplify the gate pulse voltage from 5v to 15v as the embedded board can generate only a pulse of 5v whereas the voltage needed to trigger the switch in power converter is 15v.

**Table 1** Comparison of SPELEC board with trending boards in market

Features	Arduino	Node-MCU	SPELEC
Processor cores	AVR RISC (8-bit)	ESP8266(LX106) (32-Bit)	Xtensa LX6 (32-bit)
CPU Frequency	16MHz	80MHz	240MHz
Speed (1 million operations)	7.11sec	3.82sec	0.39sec
Wi-Fi	No	No	Yes
Bluetooth	No	No	Yes (v4.2)
BLE	No	No	Yes
Flash Memory	32KB	4MB	16MB
EEPROM	1KB	4 to 4096 Bytes	4KB
SRAM	2KB	128KB	520KB
GPIO	14(10- bit)	17(10-Bit)	32(12-Bit)
Busses	SPI, I2C, UART	SPI, I2C, UART, I2S	High-Speed SPI, I2C, 2-I2S, 3- UART, SDIO, CAN
PWM frequency	500Hz (8 bit)	1KHz (8 bit)	70KHz (8 bit)

### 3. SIMO Converter Simulation

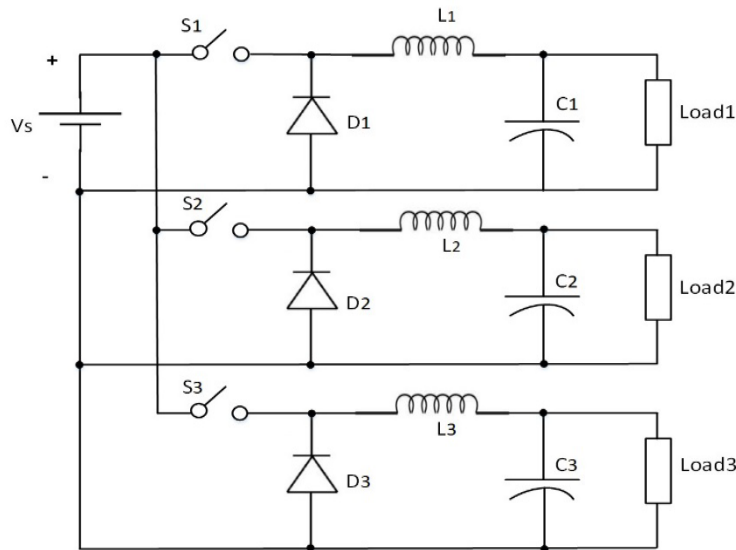


Fig. 4 Single input multiple output buck converter circuit diagram

The proposed system includes a DC buck converter to lower the voltage from a higher level provided by the power source to a lower level required by the load connected to the SPELEC board. This is important because it helps ensure that the board and any connected devices receive the correct voltage, which can prevent damage and increase energy efficiency. The converter also allows the voltage to be adjusted, which is useful when different voltages are needed for different projects or components. Three buck converters are connected parallelly and the loads are connected across capacitors to use it as multi output converter. The same panel voltage of 12v is applied to all three parallel branches of the converter. Simulation is performed in NI-Multisim to check the performance analysis and the output waveforms were captured for 30%, 50%, 75% duty for 3.6v, 6v, 9v respectively and shown below.

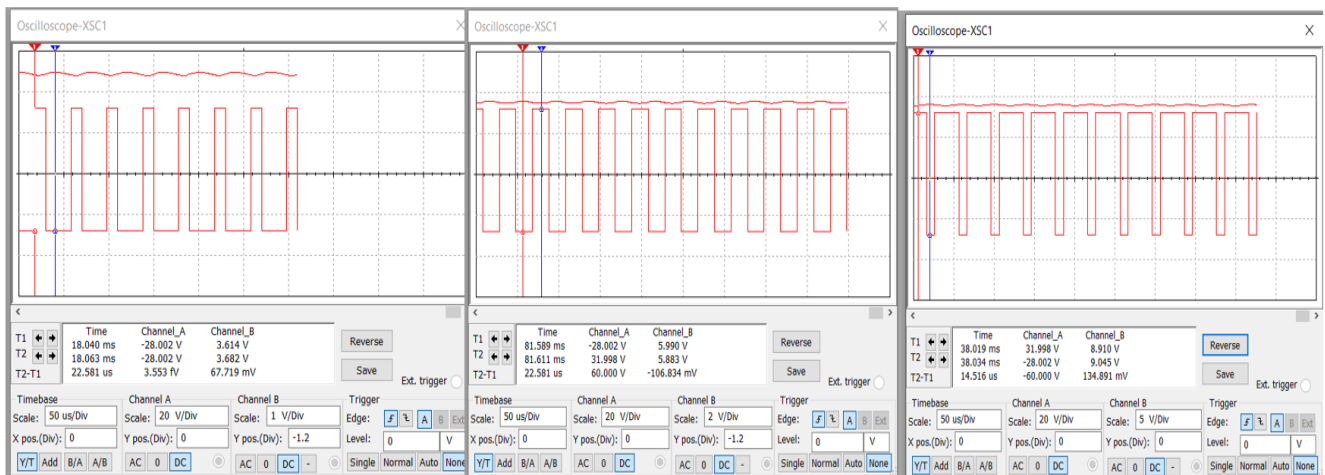


Fig. 5 Gate pulse and output voltage waveforms in multisim

### 4. Experimental Setup

The experimental setup includes Converter (SMPS), DC Regulated Power Supply, a variable load(rheostat), DSO to observe the output and the proposed embedded controller board (SPELEC). Figure 5 shows the experimental setup. The proposed SPELEC board which is used as an Embedded Controller has many advanced key features when compared to other trending boards available in market like Arduino, Node-MCU. The SPELEC board distinguishes itself as a superior choice among trainer boards like Arduino and Node-MCU, primarily due to its specialized features and tailored design that cater to a wide range of educational and development needs in electronics and electrical engineering. Unlike its counterparts, the SPELEC board is engineered with an emphasis

on providing an integrated learning experience that encompasses both fundamental and advanced aspects of electronics, making it an ideal tool for both beginners and advanced users. A comparison table is given in table no.1. from the table, it is clear that the proposed board is superior among other boards in terms of CPU frequency, Flash memory, SRAM, No. of GPIO pins, busses, no. of PWM pins and PWM frequency. The board has many features of FPGA board and is very economical.

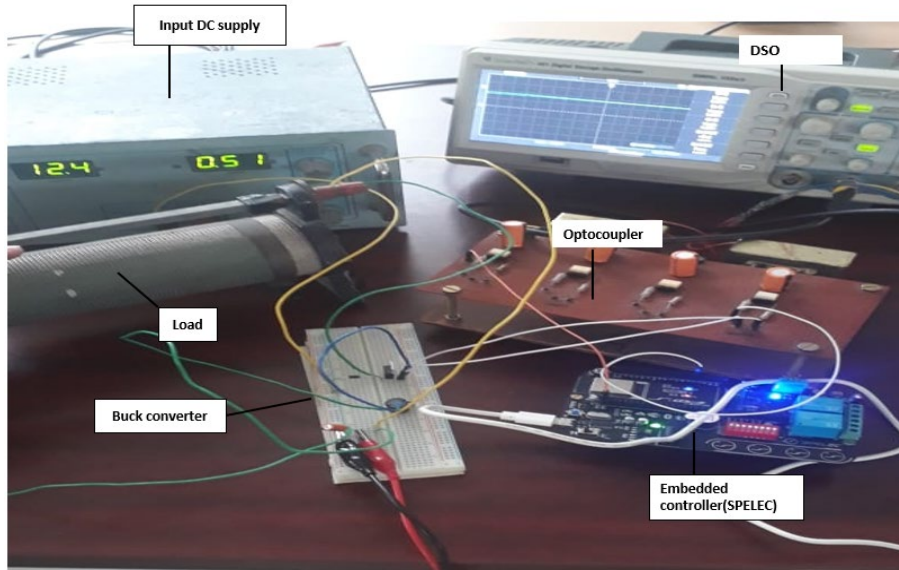


Fig. 5 Experimental setup for hardware

### 5. P&O Algorithm Implementation from SPELEC Board

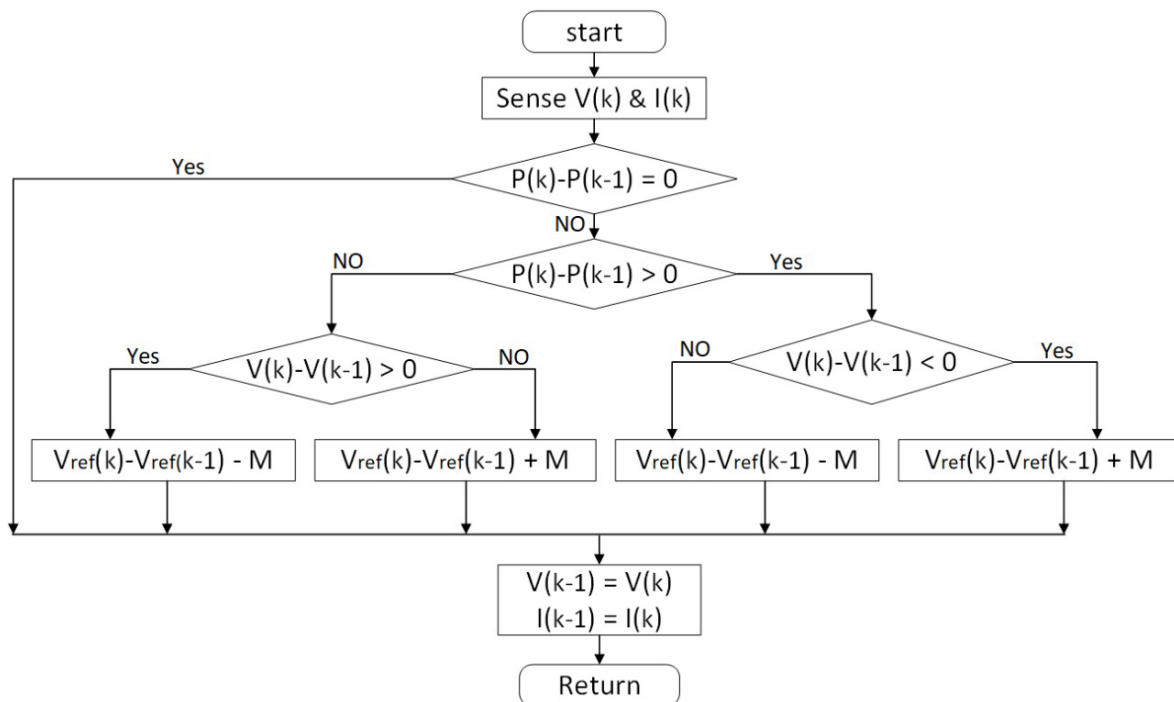
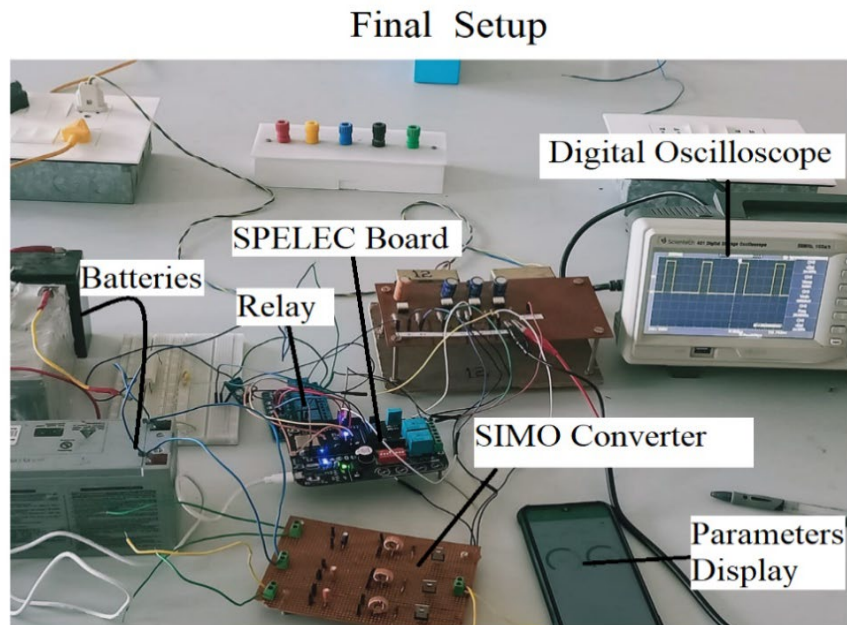


Fig. 6 Flow chart of P&O algorithm

The advantages of P&O algorithm over other MPPT techniques are mainly its ease of implementation and higher conversion efficiency. It doesn't involve solving any complex mathematical equations like fuzzy and neural

network algorithms. Its cost of implementation is also less so this P&O algorithm was chosen to implement MPPT technique.

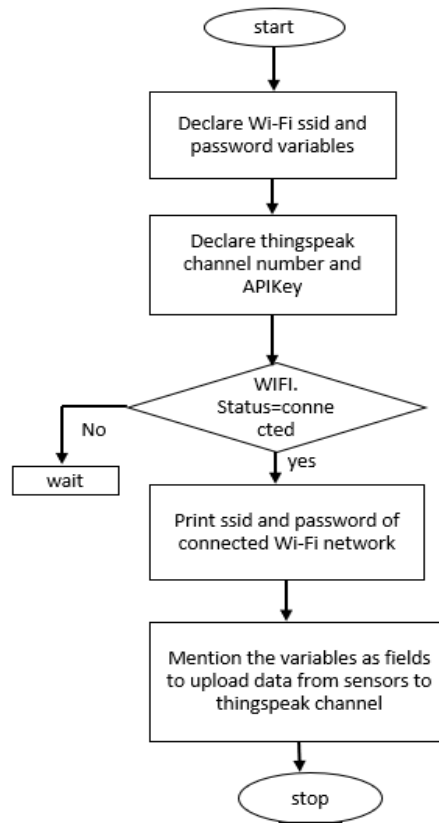
The main aim of a MPPT technique is to maintain the converter output voltage constant irrespective of the change in panel voltage and load current. In P&O algorithm it calculates the power by multiplying panel voltage and load current. The duty cycle will be incremented or decremented corresponding to the changes in panel voltage of that instant and previous instant. At last, it updates the history for next iteration. Figure 6 shows the implementation of P&O MPPT technique where the panel voltage and load currents are sensed through voltage and current sensors. Current sensor for SPELEC board needs to be calibrated since the input voltage it takes is only 3.3v, so a voltage divider circuit needs to be employed in between. Whereas the voltage sensor can be connected in parallel to the PV panel directly.



**Fig. 7** Hardware setup for P&O implementation with SPELEC board

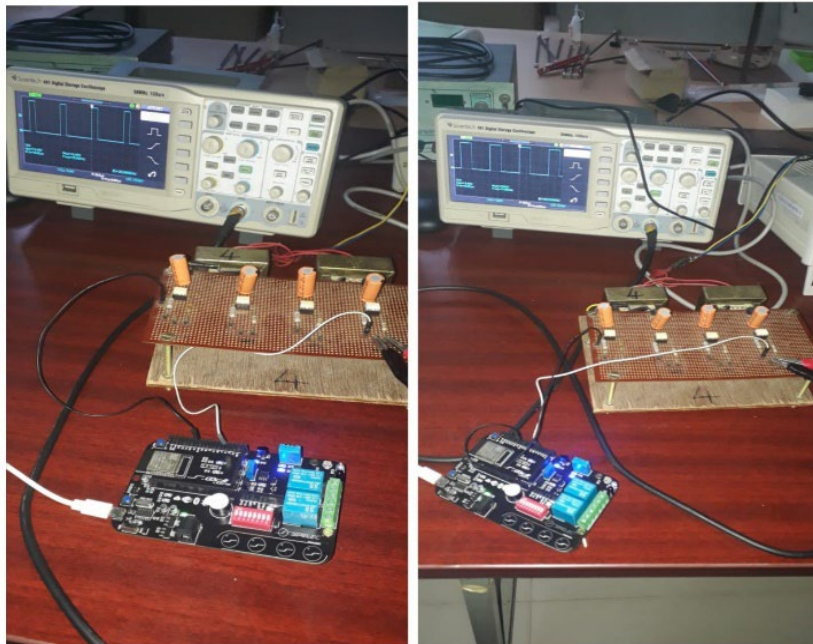
## 6. Uploading Sensor Data to Cloud Through Thingspeak

Remote monitoring promises the efficient utilization of the system equipment, ensures the equipment safety and security and also it makes planning and estimation easier. IoT is the best way to achieve this. Reading the sensor data and uploading it to cloud makes remote monitoring possible. The change in panel voltage and load currents can be tracked remotely if they can be uploaded to cloud. Data can be uploaded to cloud through thingspeak by creating a channel in it. A channel in the thingspeak refers to a particular space where our own data can be saved in the cloud. Each field in a channel refers to one sensor data that we are going to upload to cloud. Through the channel we can send the data in forms of fields and can upload videos and can upload the same data to github also provided mentioned the github link.



**Fig. 8** Flowchart to upload the sensor data to thing speak cloud

## 7. Results and Discussions



**Fig. 9** Gate pulse of variable duty generated from SPELEC board

A pulse with 25 KHz frequency, 17v amplitude and duty cycle varying from 0 to 100% is generated as shown in the figure 9. Variable duty is obtained programmatically, potentiometer is not used here.

The generated gate pulse is applied to buck converter and results were recorded at different duty ratios like 70%, 50% and 30% and the corresponding output voltages were observed. In figure 10 the first plot shows gate pulse of certain duty and the second plot shows the corresponding output voltage of the converter. The same was performed using Arduino board also which generated a gate pulse of just 945Hz frequency due to which the ripple in the output voltage was very high and eventually the mean output voltage also got very less and the same were tabulated in the table no.2.

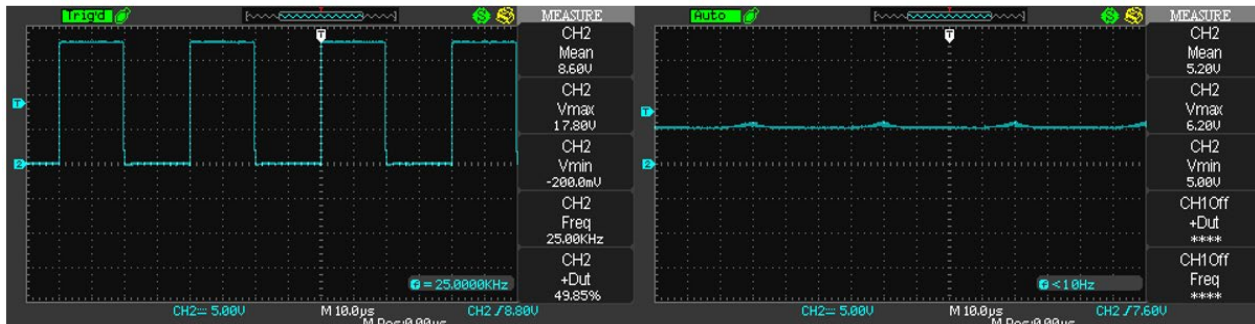


Fig. 10 Gate pulse of 50% duty and corresponding output voltage

The input voltage to the converter, duty ratio, corresponding mean output voltage obtained using SPELEC and Arduino boards both expected and actual, % deviation is tabulated in the below table.

Table 2 Converter output voltage using SPELEC board

S. No	Input voltage (v)	Duty ratio %	output voltage (v) (SPELEC board)	Output voltage (v) (Arduino board)	Output voltage (v) theoretical	% deviation For SPELEC board	% deviation for Arduino board
1	12	70.5	8.2	6.3	8.46	0.03	0.255
2	12	49.85	5.2	4.3	5.9	0.11	0.277
3	12	31.55	2.4	1.6	3.7	0.35	0.56

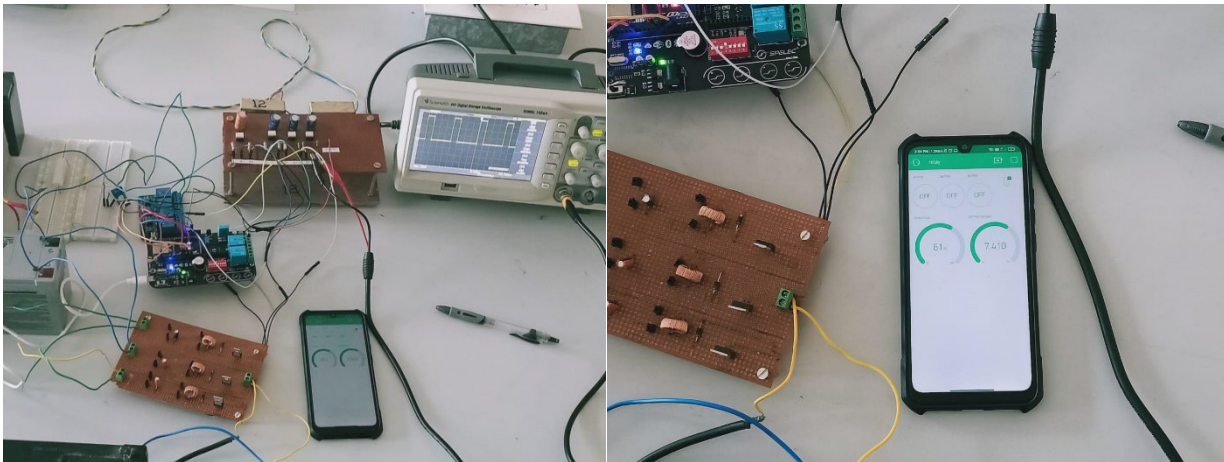
The sensor data recorded is uploaded to cloud through thing speak by creating a channel and in the channel two fields were created named as voltage and current to upload the voltage and current sensor data respectively. Data is updated to corresponding fields to cloud at the rate of 15sec. The supply voltage is varied from 0 to 12v and the load current is changed from 0 to 1.5A.



Fig. 11 Uploading current and voltage sensor data to cloud through thing speak

Another mobile based IoT application called 'Blynk' is used to upload the sensor data to cloud just like the way in Thingspeak. A relay is used additionally which allows to switch on/off the loads remotely from mobile by

programming. It displays the load current and voltages of corresponding output ports 1,2,3. It also helps to monitor the system behavior remotely from mobile. The setup diagram is shown in the following figure.



**Fig. 12** Control and monitoring the load voltage and current using Blynk app

## 8. Conclusion

In this paper a novel programmable converter for solar based SMPS applications is proposed and demonstrated its performance in generation of high frequency duty cycle and compared with Arduino board. The mean output voltage of the DC-DC converter is improved and percentage deviation or ripple in the output voltage is also reduced. The SPELEC board is cost effective compared to FPGA controllers. The P&O algorithm was implemented using SPELEC board and Arduino boards as well. The sensor data which is panel voltage and load current are also uploaded to cloud through thing speak and Blynk applications which can be used to monitor and control the source and load parameters remotely that enables the remote monitoring of the system.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm their contributions to the paper, "Novel Programmable Solar Based SIMO Converter for SMPS Applications with IOT Infrastructure," as follows: Kalyan Dusralapudi and Narasimha Raju.K were responsible for the **study conception and design**. **Data collection** was carried out by Sumanjali Chundu. **Analysis and interpretation of results** were performed by Kalyan Dusralapudi, Sumanjali Chundu, and Kattupalli Sudhakar. The **draft manuscript** was primarily prepared by Sumanjali Chundu with contributions from Kattupalli Sudhakar. All authors reviewed the results and approved the final version of the manuscript.*

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