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Design and Analysis of Push-pull Converter for Standalone Solar PV System with Modified Incrementalconductance MPPT Algorithm

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ABSTRACT

This paper is aimed at the analysis of Push-pull converter. Simulation is carried out by conventional Incremental Conductance algorithm and also with Modified Incremental Conductance algorithm. All the MPPT techniques, the incremental conductance (INC) algorithm is used due to the high tracking accuracy at steady state and good adaptability to the rapidlychanging all atmospheric conditions. In this paper, a modified INCMPPT algorithm is proposed, which automatically adjusts the duty cycle to track the PV array maximum power point. Compared with the conventional fixed step size method, the proposed approach can efficiently improve the MPPT accuracy. MPPT controller generated the gate pulses to the converter side. Simulation results are obtained and compared with two different MPPT Controller and also compared with non-isolated converter (Boost converter), isolated converter (Push-pull converter) using modified incremental conductance. Push-pull isolated converter is better efficiency compared with non-isolated converter are analyzed. Simulation model of an 84W solar panel is developed and results are obtained for Modified Incremental Conductance MPPT algorithm for different irradiation.

Keywords: PV system, Incremental Conductance Algorithm (INC), DC-DC converter, Modified Incremental Conductance Algorithm (Modified-INC).

1. INTRODUCTION

Photovoltaic (PV) energy is currently considered to be one of the most useful natural energy sources because it is free, abundant, pollution-free, and distributed throughout the Earth. The maximum power point tracking (MPPT) control technique, which extracts the maximum possible power from the PV array. The output power of PV arrays is always changing with weather conditions, i.e., solar irradiation (G) and temperature (T). Various methods such as the perturb-and-observe method [2], [5], and incremental conductance method [1] for the MPPT algorithm of the PV array. Steady-state oscillations always appear in both methods due to the perturbation. Thus, the power loss also increased. Although the INC method is a little more complicated compared with the P & O/hill climbing method. The INC MPP Talgorithmusually uses a fixed step size, which is determined by the accuracy and tracking speed requirement. This method is used the trade off problem is occurred between the dynamics and steady state oscillations. To solve these problems, a modified INCMPPT with variable step size is proposed in this paper. The step size is automatically tuned according to the PV array characteristics. When the step size is increased if the operating point is far from MPP. If the operating point is near to the MPP, the step size becomes small that the oscillation is well reduced and achieved to a higher efficiency [10]. In the following, the design and analysis of the modified INCMPPT is

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presented on the uniformirradiation values for PV array. Simulationis provided, and the corresponding results are achieved that the proposed method can effectively improve the dynamic performance and steady state performance simultaneously.

2. BLOCK DIAGRAM DESCRIPTION

2.1. Block diagram of standalone PV system using Modified incremental conductance MPPT Controller

The block diagram of this paper is given in the below Fig. 1. The Incremental conductance MPPT controller is being replaced by Modified INC Conductance. In the proposed Modified incremental conductance controller, the input variables are the solar voltage, current, power, duty cycle and scaling factor (N). The duty cycle (D) is used to drive the push-pull converter. The solar voltage and current are measured by using voltage and current sensors. Duty cycle generated directly from the MPPT algorithm.

The dc–dc converter is isolated type to step up the PV voltage to the level of the allowable maximum line voltage depends upon the transformation ratio.

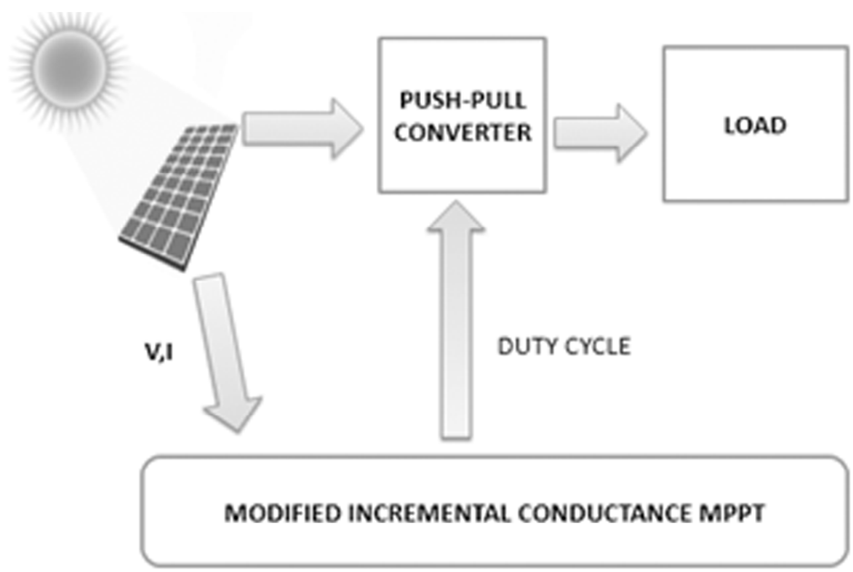

Figure 1: Detailed block diagram of standalone PV system using Modified Incremental conductance MPPT

3. OPERATION AND CONTROL

3.1. Modelling of Solar Array

Solar panel is simulated using Solar cells. Each solar cell as a parallel combination of a current source, two exponential diodes and a parallel resistor, Rp, that are connected in series with a resistance Rs. The output current I is given by

$$I = Iph - Is*(e^{\wedge}((V + I*Rs)/(N(Vt))-1)- Is2*(e^{\wedge}((V + I*Rs)/(N2*Vt))-1)-(V + I*Rs)/Rp \quad (1)$$

Where Is and Is2 are the diode saturation currents, Vt is the thermal voltage, N and N2 are the quality factors (diode emission coefficients) and Iph is the solar-generated current.

The panel specifications are tabulated in table.1

Here, there are six solar cells are connected in series shown in Fig. 2. This connection will be created one sub-system. Each subsystem connected using Simulink/MATLAB.

Table 1
Parameters for 84W solar panel

S. No	*Parameters*	*Values*
1	No. of solar cells, Ns	48
2	Boltzmann's constant, K	$1.3806*10^{-23}$
3	Irradiance, Ir0 (W/m2)	1000
4	Short circuit current, Isc(A)	4.75
5	Open circuit voltage, Voc(V)	24
6	Band gap Energy, Eg	1.12
7	Diode saturation current, Is (A)	1e-6
8	Series resistance, Rs (&!)	$5.1e^{-3}$
9	Quality factor, N	1.6
10	Quality factor, N2	2
11	Ideality factor, A	1.3
12	Temperature, T (C)	25

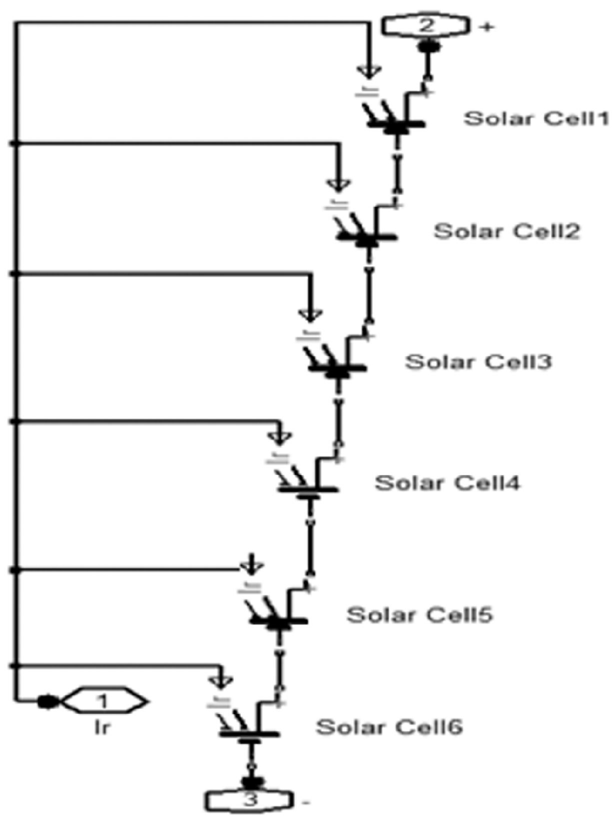

Figure 2: Group of solar cells connection in MATLAB

48 solar cells are connected and creating subsystem then this solar panel delivers voltage and current by measuring voltage and current sensors. Product of voltage and current is obtained by the solar power as shown in Fig. 3. I-V and P-V characteristics of solar array are obtained as shown in Fig. 4 and Fig. 5

3.2. DC-DC Converter

A voltage regulator is a power electronic circuit that maintains a constant output voltage irrespective of change in load current or line voltage. The dc-dc converter inputs an unregulated dc voltage input and

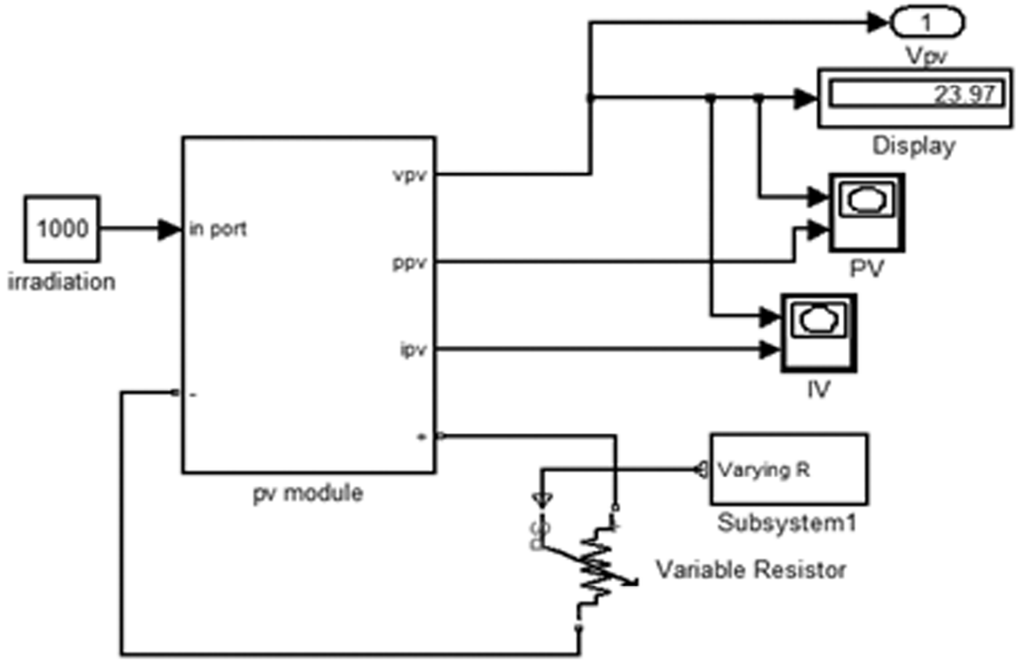

Figure 3: Overall PV Module using Simulink

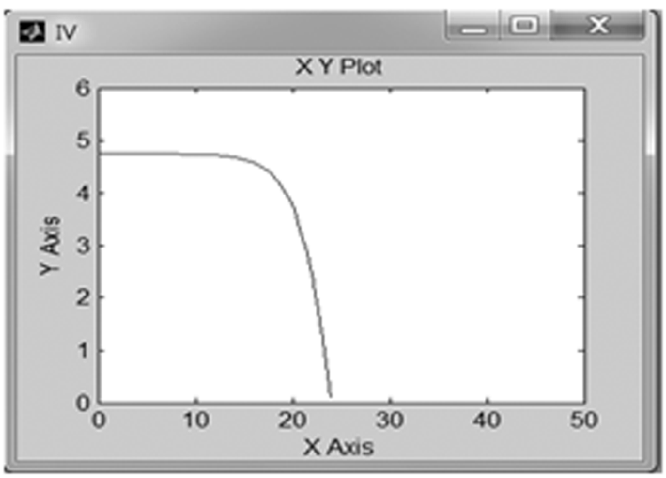

Figure 4: I-V characteristics of solar array

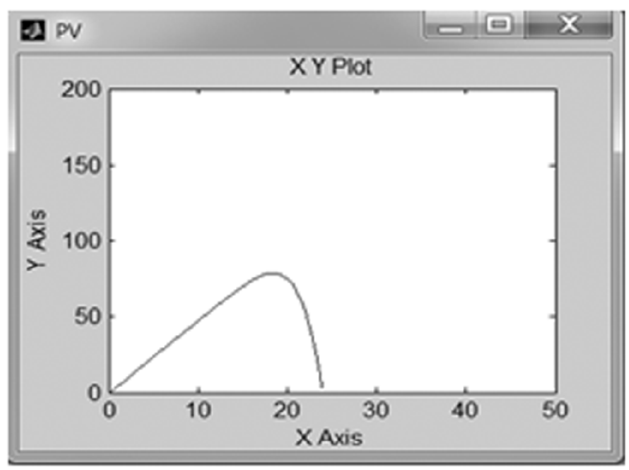

Figure 5: P-V characteristics of Solar array

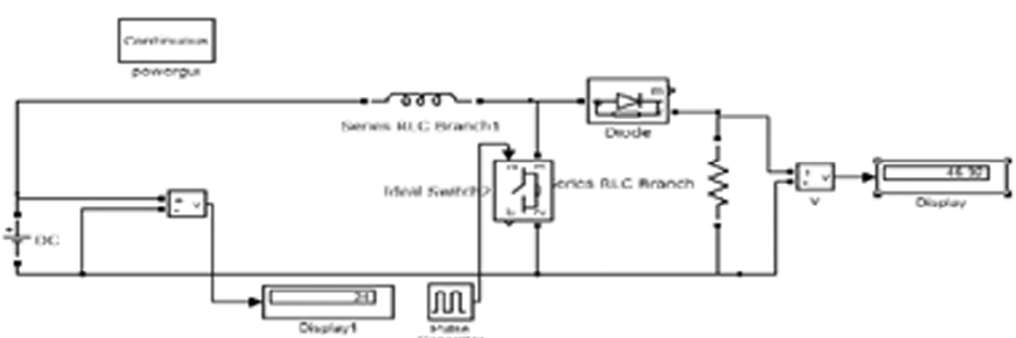

Figure 6: Simulink diagram of boost converter

outputs a constant or regulated voltage. Converter operate as the main part of the MPPT. A dc/dc converter acts as an interface between the load, when proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. There are two different types of converter commonly used. Isolated and Non-isolated converter. In this paper, implement the two types of converter. One is non-isolated converter i.e., Boost converter and another one is isolated converter i.e., Push-pull converter. Simulink model for boost converter shown in Fig. 6. A push pull converter is used to maintain and also to step up the voltage. A push pull converterconsists of a dc input voltage source Vin, Inductor L, controlled switch S, diode D, filter capacitor C, and the load resistance R, Transformer T.

Advantages of Push-pull converter such as low input current stress, high voltage conversion ratio and low conduction loss of switches [3], [4], [6]-[9]. Then this converter is high efficiency and the low voltage ripples. When the switch S1 is in the on state, current flows through D1. When S2 is active current flows through D2. At the time only one switch is active state. The secondary is arranged in a center tapped configuration. Output Voltage cycle is given inthe following equation

$$V_{out} = 2 * Vin * D * (Ns/Np) \quad (2)$$

Where, D – Duty cycle

Ns – No of turns in the secondary winding

Np – No of turns in the primary winding

This output voltage is depend on the transformation ratio. Transformation secondary output will be high frequency AC. The required DC output obtained after rectification using diodes by use of rectifier & filter circuit. Normal dc supply is applied to the push-pull converter and also corresponding output voltage are obtained as shown in Fig. 7.

The selected parameters of converter are tabulated in Table 2.

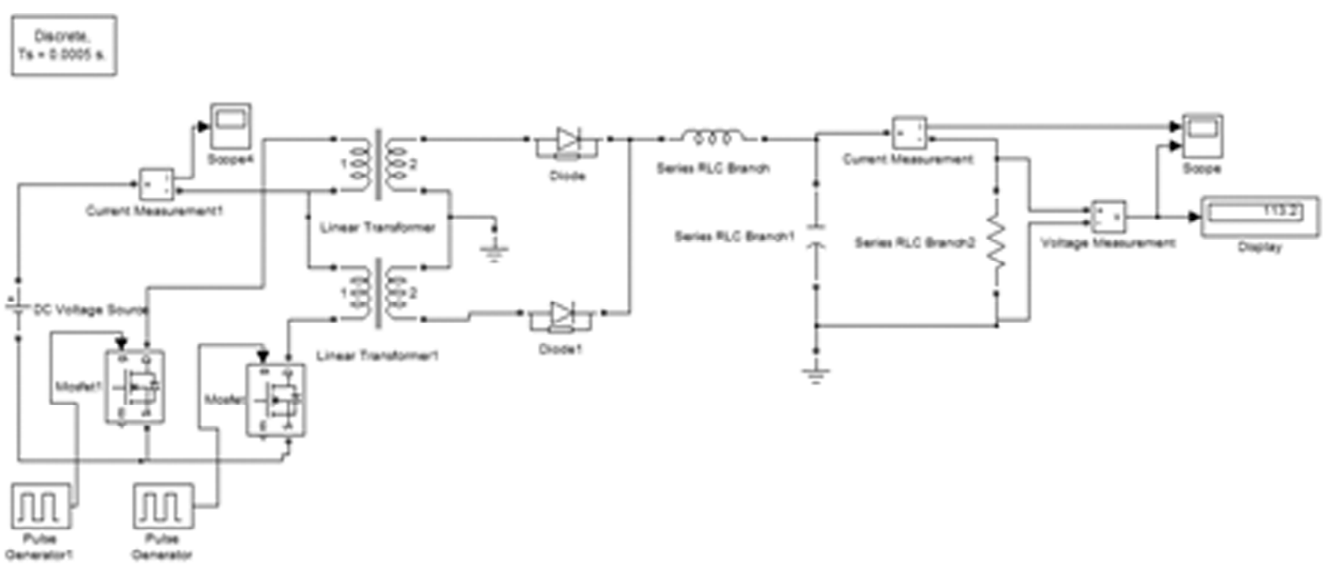

Figure 7: Simulink diagram of Push-pull Converter

Table 2
Selected parameters of converter

S. No	*Parameter*	*Value*
1	Resistor (R)	100
2	Input inductor (L)	2.585e-3
3	Output capacitor (C)	220e-6
4	Switching frequency of switches	20 kHz
5	Transformer ratio Np: Ns	1:5

3.3. Maximum Power Point Tracking (MPPT)

This paper proposes the method to track power maximum power point by using incremental conductance method as well as using modified incremental conductance method

3.3.1. Mppt Using Incremental Conductance Algorithm (Conventional Algorithm)

Incremental conductance (IC) algorithm is based on that the derivative of PV power by the voltage is equal to zero. Accordingly, at the maximum power point,

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I + V\frac{dI}{dV} = 0 \tag{3}$$

$$-\frac{I}{V} = \frac{dI}{dV} \tag{4}$$

Here, MPPT is used in the converter side. MATLAB coding used for INC algorithm is shown in the Fig. 8.

Simulation of Push-pull converter using incremental conductance as shown in the Fig. 9.

```
function D = MPPT(V,v,I,i,d)
d = 0.5;
dv=V-v;
di=I-i;
if (dv == 0)
if (di == 0)
D=d
else
if (di > 0)
D = d+0.2;
else
D = d-0.2;
end
end
else
if (di/dv == (I/V))
D = d;
else
if (di/dv > I/V)
D = d+0.2;
else
D = d-0.2;
end
end
end
```

Figure 8: Embedded MATLAB File using MPPT (INC) control algorithm

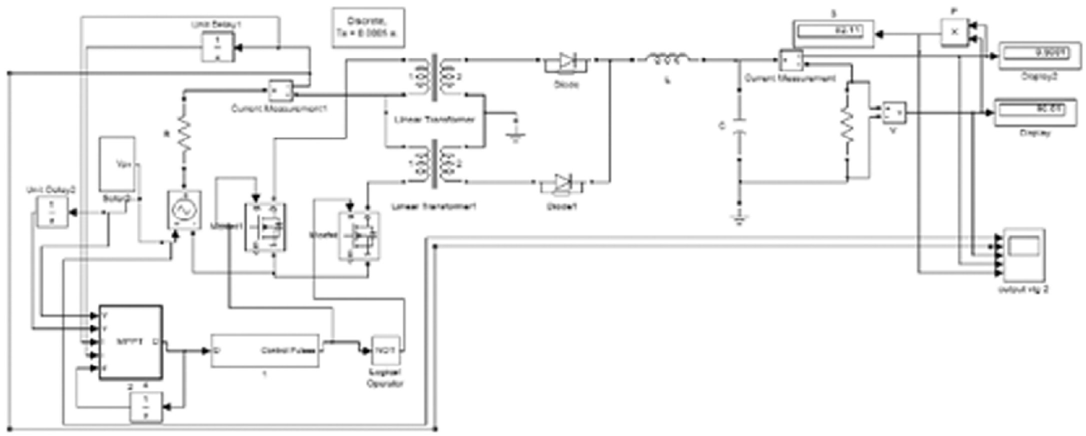

Figure 9: Simulink diagram of converter circuit using incremental conductance MPPT controller

3.3.2. Mppt Using Modified Incremental Conductance (Proposed Algorithm)

The incremental conductance MPPT should make a satisfactory trade off problem between dynamics and oscillations.

Equation for the step size is,

$$\text{Step} = N*\text{abs}|dp/dv| \tag{5}$$

The variable step size rule must satisfying the following condition.

$$N*\text{abs}|dp/dv|<dD \tag{6}$$

Where, |dp/dv| fixed step = Dmax is the at fixed step sizeoperation of Dmax.

The scaling factor can therefore beobtained as,

$$N<\text{Dmax}/|dp/dv \tag{7}$$

Where, dD = change of duty cycle, dp = change of power, dv = change of voltage, N = scaling factor.

Modified Incremental conductance MPPT flowchart shown in the Fig. 10.

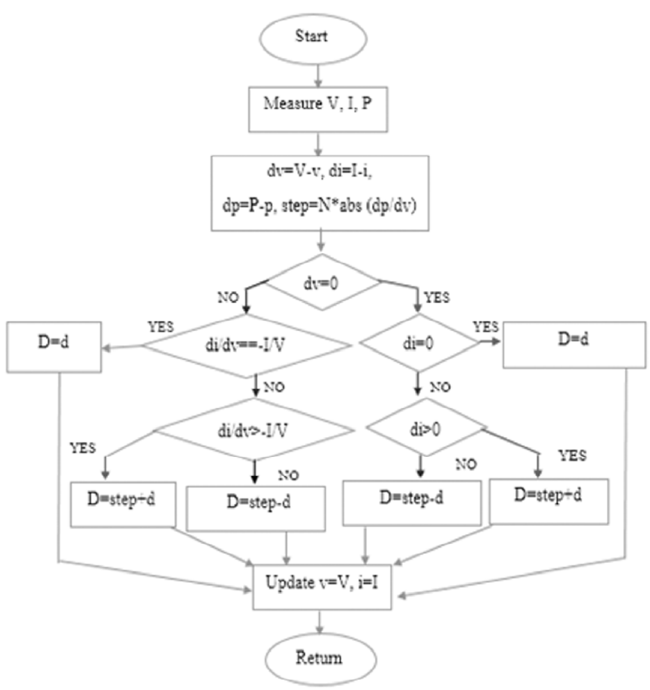

Figure 10: Flowchart of modified incremental conductance MPPT algorithm

Step size values are very small compared than duty cycle values so accurately tracking the maximum power points for each different irradiations values. Modified Incremental conductance MPPT MATLAB coding shown in the Fig. 11.

One of the non-isolated converter (boost) is used. In this paper compared with two different types of converters are simulated. Here, simulation of boost converter and push-pull converter using modified incremental conductance MPPT controller are simulated as shown in the Fig.12 and Fig. 13.

4. SIMULATION RESULTS

The simulated waveform of boost converter using modified incremental conductance as shown in the Fig. 14.

```
function D = MPPT(V,v,I,i,P,p,d)
d = 0.5;N=0.001;
dv=V-v;
di=I-i;
dp=P-p;
dp=V*I-v*i;
step=N*abs(dp/dv);
if (dv == 0)
if (di == 0)
D=d     ;
else
if (di > 0)
D = d+step;
else
D = d-step;
end
end
else
if (di /dv == -I/V)
D = d;
else
if (di /dv > -I/V)
D = d+step;
else
D = d-step;
end
end
end
```

Figure 11: Embedded MATLAB File using MPPT (Modified-INC) control algorithm

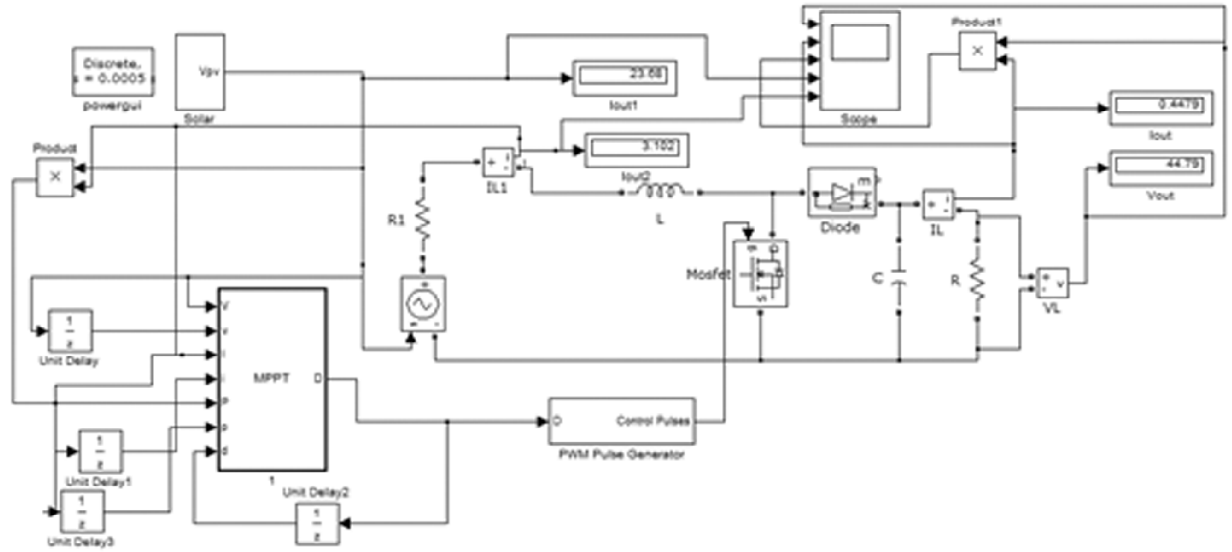

Figure 12: Simulink diagram of boost converter circuit using Modified Incremental conductance MPPT controller

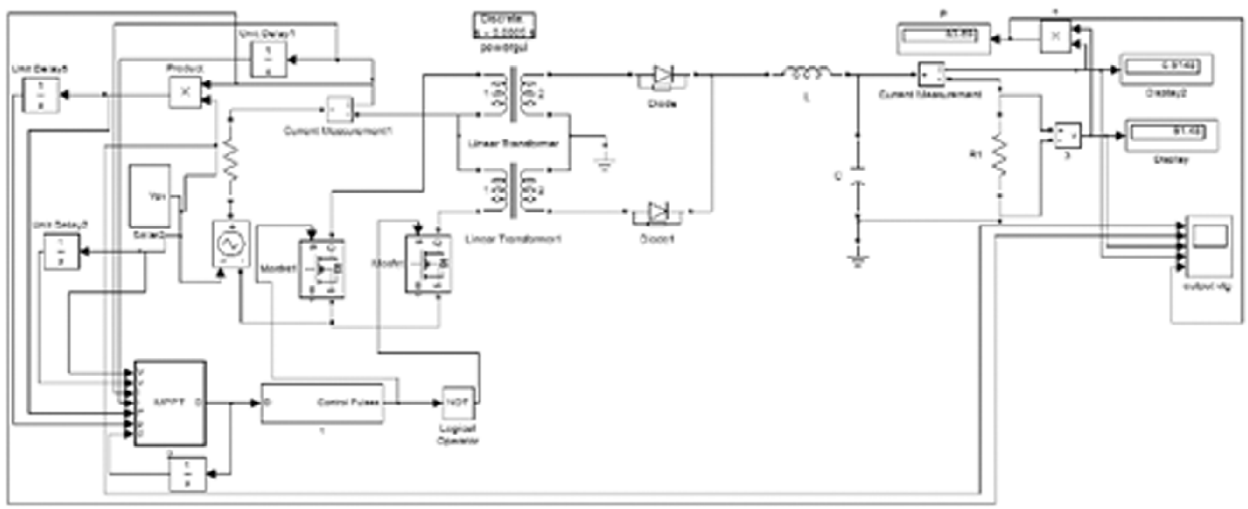

Figure 13: Simulink diagram of Push-pull converter circuit using Modified Incremental conductance MPPT controller

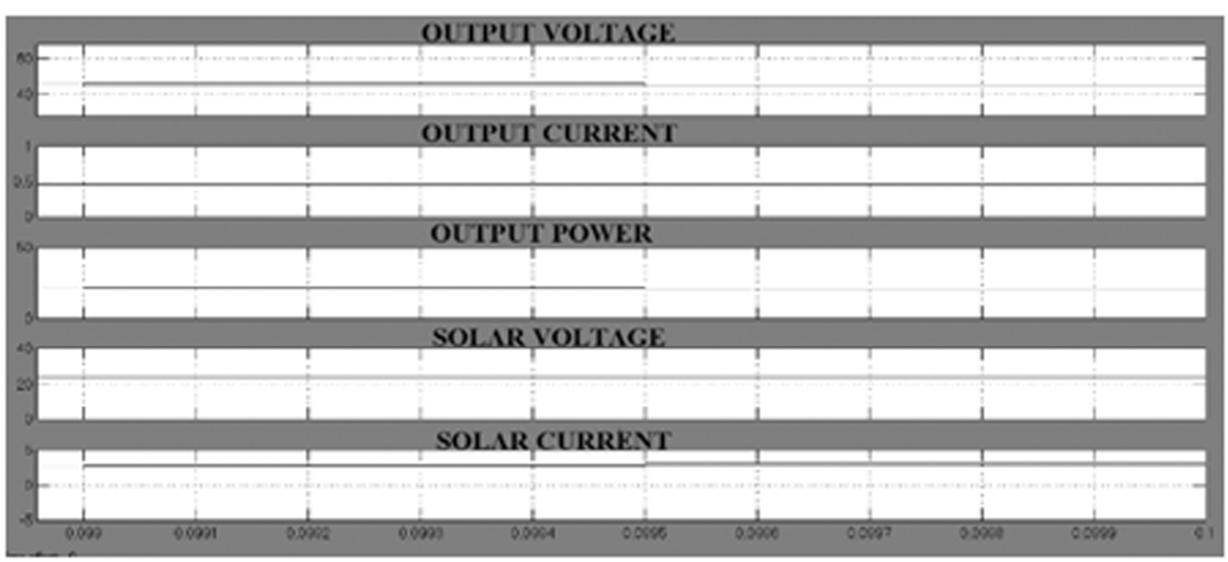

Figure 14: Simulated output waveform of Boost converter for standalone solar system using MPPT-Modified INC algorithm

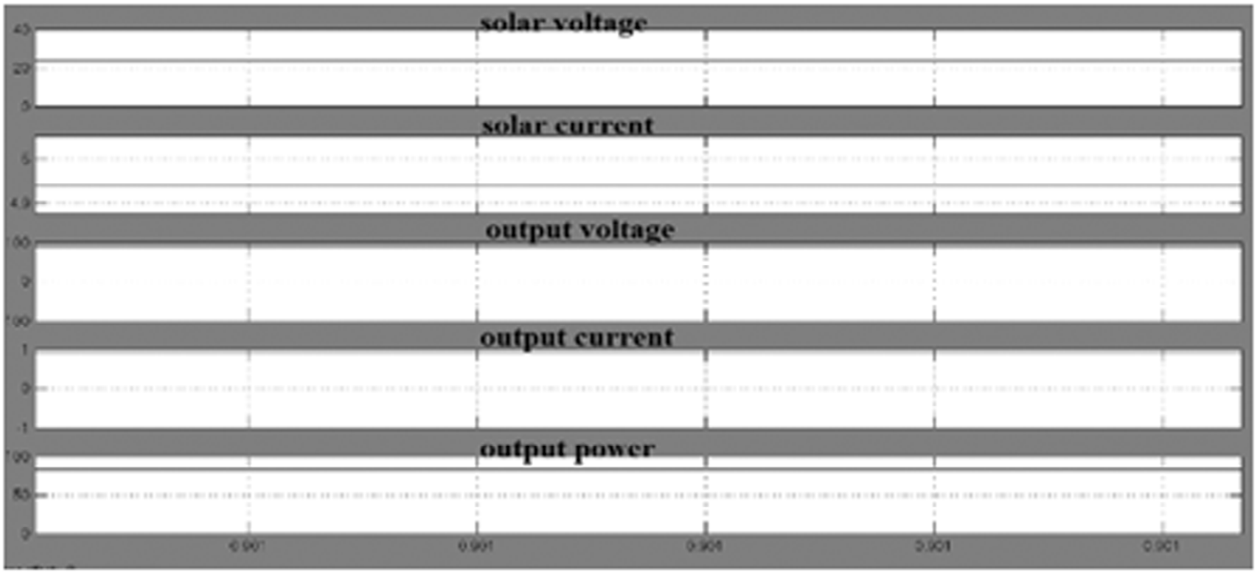

Figure 15: Simulated output waveform of push-pull converter for standalone solar system using MPPT-INC algorithm

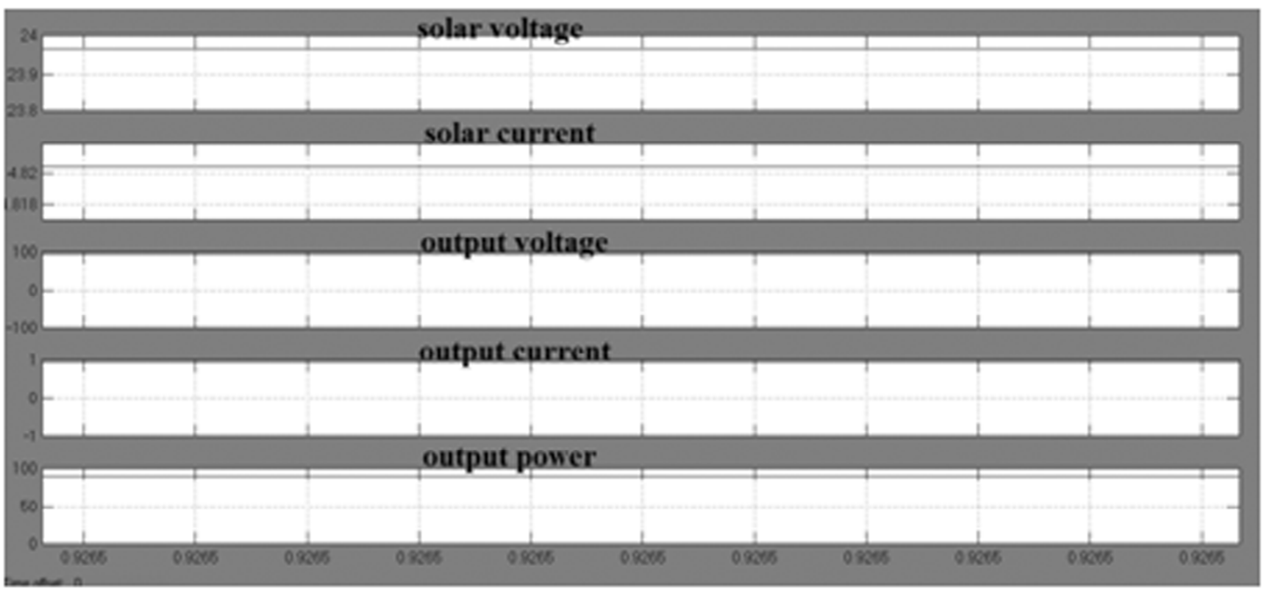

Figure 16: Simulated output waveform of push-pull converter for standalone solar system using MPPT-Modified INC algorithm

The simulated waveforms with two different controllers are compared as shown in Fig. 15 and Fig. 16. The waveforms include Solar PV voltage, PV current, converter voltage, converter current and Output Power.

5. CONCLUDING REMARKS

A standalone PV system with using modified incremental algorithm is proposed. The MPPT controller as an incremental conductance method and Proposed MPPT also achieved. This proposed MPPT controller is to track the maximum power point and obtain high efficiency and it has an advantage of smooth and rapid transition to the maximum power point. Proposed incremental conductance has the some advantages such as the Systems can be easily upgraded and it can be used to improve existing traditional

Controller systems. Results have been tabulated in Table.3.

The converter output voltage ripples are reduced compared the using of conventional MPPT controller. Results have been tabulated in table 4.

Table 3
Performance Comparison of two different MPPT controllers.

G(w/m²)	*MPPT-INC*			*MPPT-Modified INC*		
	Voltage(V)	*Current(A)*	*Power(W)*	*Voltage(V)*	*Current(A)*	*Power(W)*
1000	90.61	0.906	82.1	91.48	0.92	83.6
800	88.91	0.89	79	89.97	0.89	80.9
400	83.69	0.84	69.9	84.11	0.84	70.7

Table 4
Performance parameters Comparison of two different MPPT

Parameters	*Mppt-inc*	*Mppt-modified Inc*
Output voltage ripple (%)	0.4415	0.2405
Efficiency (%)	97.04	98.92

Table 5
Comparison between two converters

G(w/M²)	*Non-isolated Converter Using Mppt-modified Inc*			*Isolated Converter Using Mppt-modified Inc*		
	Voltage (V)	*Current(A)*	*Power(W)*	*Voltage(V)*	*Current(A)*	*Power(W)*
1000	44.7	0.45	20.16	91.4	0.92	83.6
800	43.8	0.44	19.29	89.9	0.89	80.9
400	40.5	0.41	16.64	84.1	0.84	70.7

In this paper push pull isolated converter MPPT with direct control method are employed i.e., PI controller is eliminated. The proposed control system is capable of tracking available PV panel output power under the varying weather conditions. Thus, improves the efficiency of the PV system and reduces power loss and system cost. In this paper, finally compared output performance of isolated and non-isolated converter using modified incremental conductance MPPT. The better accuracy achieved by isolated converter than non-isolated converter and also compared between two different MPPT controllers. Proposed MPPT controller is used main advantages using this algorithm, the oscillation is well reduced and achieved to a higher efficiency. Then the non-isolated and isolated converters are simulated and compared the output performance for both converters. Results have been tabulated in Table. 5 for better understanding with both the converters.

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