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An advanced control technique for a Grid-Tied Hybrid Renewable energy system with Reciprocated sinusoidal PWM methodology

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Abstract. This research paper deals with the algorithm based on the extraction of maximum powerknown as Maximum Power Point Tracking (MPPT) fromGrid-tied renewable energy system. Thesporadic nature of solarinsolationand the variable wind speed create the necessity to find out the optimal power that makes certainof obtaining of maximum energy from the renewable resources. The optimization can be done by implementing the MPPT mechanism in the controller design. A new parabolic prediction method is suggested for tracking the MPP continuously and Reciprocated sine PWM technique is applied for minimizing the unwanted harmonic contents in the delivered output power. The simulation and experimental results show the efficiencyand outcome of the proposed methodologies with regard tothe control ofthe output power delivered as well as the reduction in harmonics from the system.

1. Introduction

The present energy scenario shows the hugeeradication of fossil fuels likecoal, petroleum oil andnatural gas which takes more decades to shape its original form [1], [3]. This major consumption of fossil fuels highly threatens the future generation from running out of these energy resources. Also thetremendous usage of fossil fuels leads to many environmental related problems [2]. So it has become much important to switch and utilize the renewable energy resources like wind and solar for electric power generation [5],[6].

The wind power stands out to be one of the most promising renewable energy sources of electrical power in the near decades. Most of the countries keep promoting the wind power technology in various ways [10]. In next two decades,the use of wind turbines for electric power generation will hold the highest share among all other renewable schemes [8]. A modern wind turbine starts producing the electrical power at wind speeds around 5 m/s. As wind speed increases, the power output increases linearly until it equals the rated power of the wind turbine, so that it reaches its maximum power output level [7],[10].

Solar Photovoltaic(PV) power is one of the fastest growing renewable energy technologies around the world. The sun provides the energy in the form of solar radiation [13],[14]. The intensity of this radiation received from the sun is called irradiance and also referred to as insolation. A PV cell captures the solar radiation and converts into the electrical energy [11].Due to its modular character, reliability, reduced level of noise and harmful emission, the PV cell becomes more attractive among all other renewable energy resources[12].

The integration of electrical power generated from the renewable energy sources into electricity grid is influenced by various factors such as the technology for integration, availability of resources, variation predictability,capacity of each generator and moreover the variation with time of power generated [15]. So it is very much important to integrate the renewable energy generation options with suitable control and storage methodologies [17].

2. Comparison of MPPT Techniques

The tracking of Maximum Power Point is much essential in modern photovoltaic systems [18]. A solar panel is able to transform about 35% of the solar insolation which receives on its surfaceinto electrical energy [11]. Numerous literatures show the effectiveness of various MPPT techniques used for producing maximum power. From the maximum power transfer theorem, one can better understand the concept of extraction of maximum power using MPPT techniques [16]. According to that theorem, for obtaining the maximum power output, the load impedance should match with the circuit thevenin's impedance. It can be accomplished by introducing a boost converter, which maximizes the output power by increasing the output voltage for the same current rating [17]. If the duty ratio of the converter is adjusted to an appropriate value, load impedance can be made equal to source impedance. We can discuss various MPPT techniques as highlighted in the literature part.

Perturb & Observe method, one of the well-known MPPT techniques, operates by changing the duty ratio of the converter based on the perturbation i.e. increment or decrement in voltage or current parameterof the PV array in order to find outthe power [14]. Then the estimated power is observed to increase or decrease the duty ratiocorresponding to its previous measured value. The measured voltage and current of the PV array require two sensors for power measurement.

And also, by this method, tracking the maximum power is very difficult under rapidly changingclimatic conditions. To manage the above situation, Incremental conductance method can be used for tracking the MPP [15]. By this method, MPP can be easily tracked for varying irradiance and atmospheric conditions with higher accuracy. Even though this method is faster than P&O method, it increases the complexity.

To reduce the complexity while tracking the MPP, Fuzzy logic & neural network based techniques can be proposed. Even though these techniques perform well, the cost for practical implementation is much higher [21] [22].

3. Proposed Methodology

This research work deals with a downward parabola based MPPT technique in the converter side and Reciprocated sine PWM technique in the inverter side for performance optimization ofthe given system. The optimal Maximum Power Point of solar panel is determined using the working points & the parabolic curve correspondingly based on progressive renewal process [2]. Also, this derived parabolabased systematic procedure has been suggested for fine tuning and the wrong tracking direction possibilities are decreased efficiently.

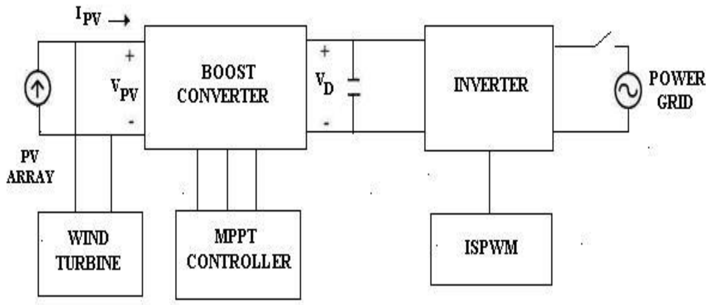

Figure 1. Functional blocks of the proposed system

Figure 1 shows the configuration of suggested hybrid system, comprising of a PV array, wind turbine, an inverter and a boost converter. A dc link which helps to establish the proper voltage level in order to connect the hybrid system with the utility network after the conversion made by an inverter.

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3.1 Converter side

The proposed MPPT procedure initially assigns three duty ratio values as D_1, D2 and D_3. After the measurement of V and I in PV array, we can obtain the three points as (D_1, P_1), (D_2, P_2) and (D_3, P_3) collectively known as a set of (P, D) measurement. With the help of these three points, we can draw the parabolic curve as shown in figure 2.

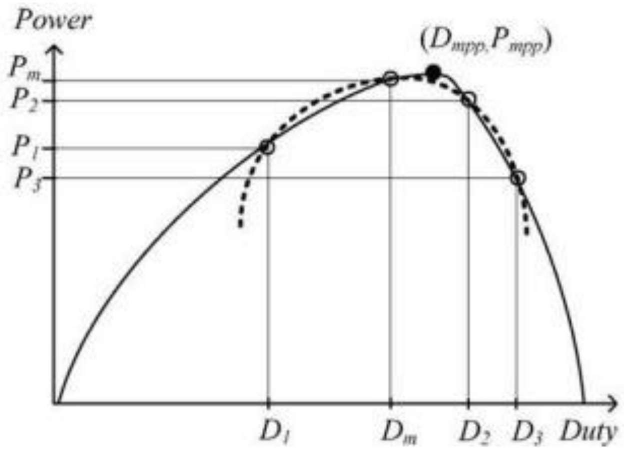

Figure 2. Parabolic curve for proposed MPPT Procedure

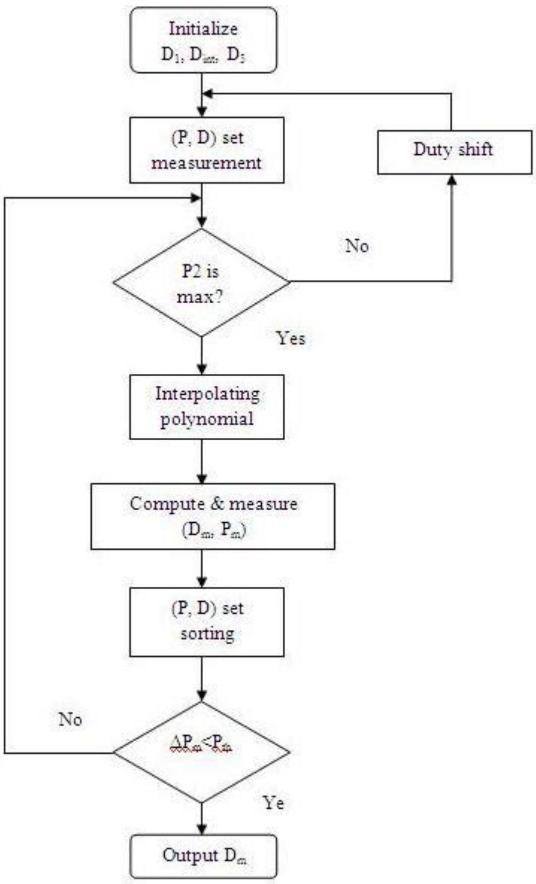

Figure3. Flowchart for proposed MPPT procedure

A parabolic function Q(x) can be represented for estimating the objective function f(x) and is given by

$$Q(x) = Ax^2 + Bx + C \quad \text{------(1)}$$

$$Q(x) = f(x_0)\frac{(x-x_1)(x-x_2)}{\Delta x_{01}\bullet\Delta x_{02}} + f(x_1)\frac{(x-x_0)(x-x_2)}{\Delta x_{10}\bullet\Delta x_{12}} + f(x_2)\frac{(x-x_0)(x-x_1)}{\Delta x_{20}\bullet\Delta x_{21}} \quad \text{------ (2)}$$

where,

$$\Delta x_{ij} = x_i - x_j \;\; i, j = 0,1,2 \quad \text{------ (3)}$$

Also we can predict a local maximum value denoted as D_m. So, one new point can be obtained as (D_m, P_m). After measuring the new point from the parabolic curve, it is necessary to sort the(P, D) set to release the small output power among them. This procedure is examined through two successive iterations with the estimated value of maximum power. Here the purpose of iteration procedure is to determine a convergent result. In the end, if there is any discrepancy in measured power, then we can compare the ΔP_mvalue with P_{th}(the point to define the convergence) the procedure will withdraw the lowest power point. Untilobtaining the optimum duty ratio, this procedure is repeated. The DC link voltage is varied regarding to the duty ratio variation (D_{int}) on internal switch. Thus the PV array voltage (V_{PV}) is controlled via tuning and it tends to produce maximum output power at various working conditions.

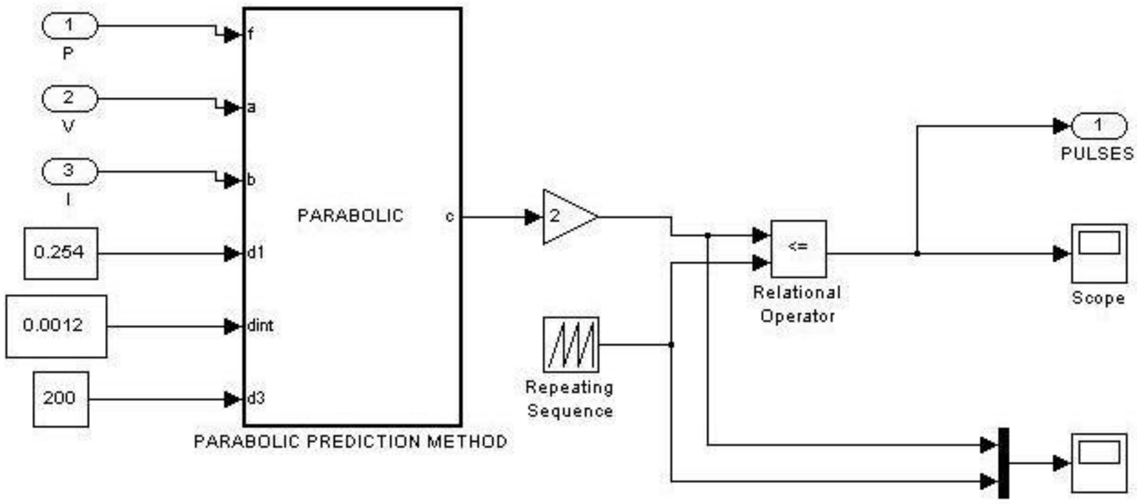

Figure 4. Simulation diagram for proposed MPPT technique

3.2. Inverter side

Here, the Reciprocated sine PWM method is used to produce gate pulses for inverter circuit. The conventional sinusoidal reference signal & the reciprocatedsine waves are utilized as two signals for this proposed technique. For a given modulation index to enhance the output voltage, the control scheme uses a reciprocated sine carrier with high frequency range. The modulating signal amplitude is continuously measured and it is matched withthe sine carrier signal. Then the measured value is greater than the sine carrier, the gate pulses are generated. The higher fundamental output voltage with better spectral quantity achieved by this proposed technique with the minimization of total harmonic distortion (THD). Also to overcome the drawbacks of over modulation (reason for lower order harmonics in output voltage), this reciprocated sine PWM technique is proposed.

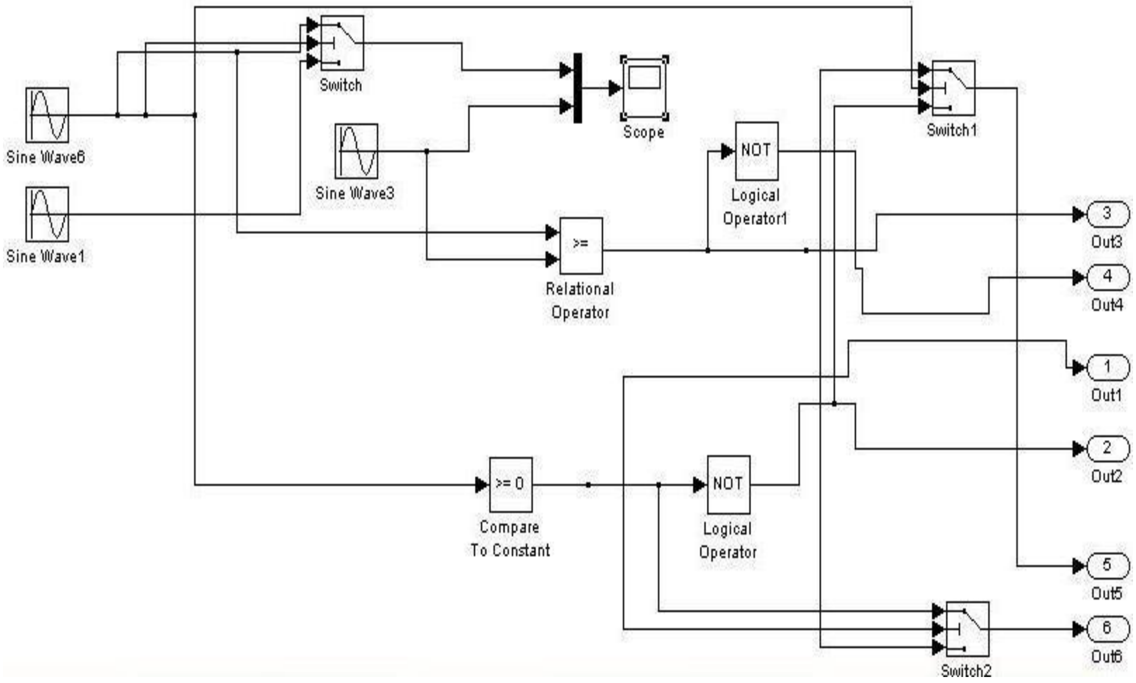

Figure 5. Simulation diagram for proposed PWM technique

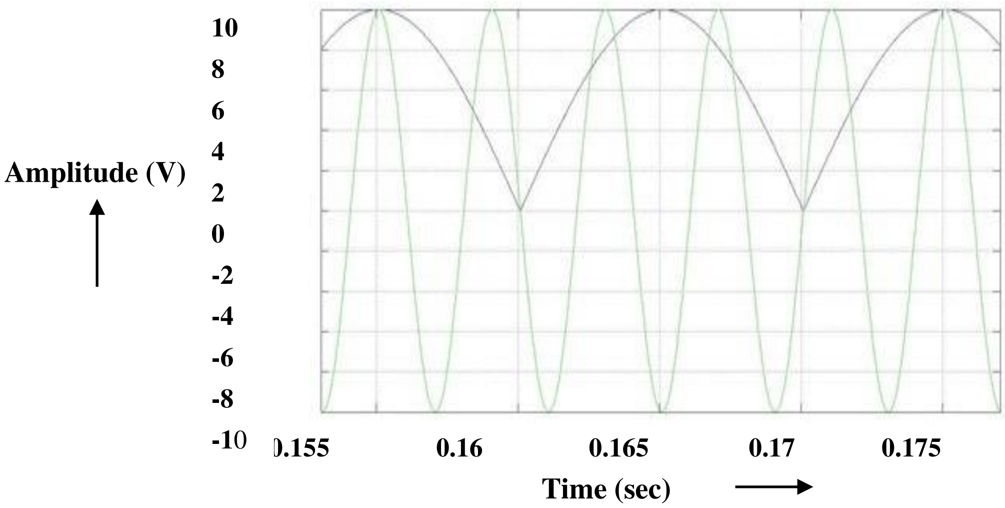

Figure 6. Carrier and reference signals

4. Simulation Results

The proposed methodology is implemented for a hybrid grid-tied renewable energy system which comprising of a wind and a solar energy source that connected to the grid network. The simulation

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result shows the effectiveness of proposed techniques for both MPPT tracking and Pulse width modulating. The simulation result also shows the inverter output which is almost a sine wave with 230V magnitude and nominal 50Hz frequency with low THD.

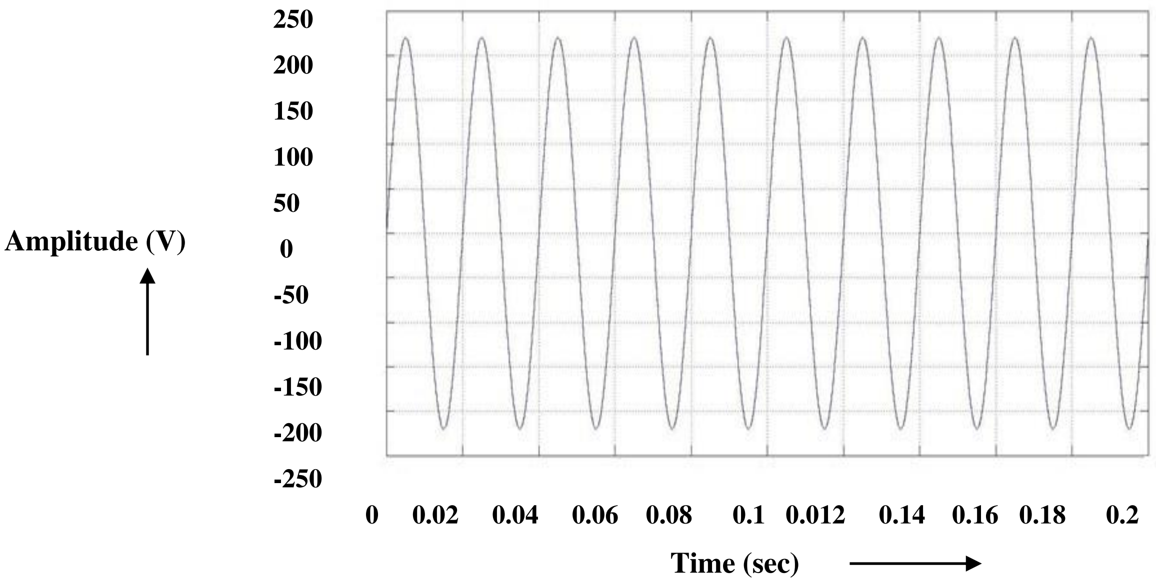

Figure 7. Inverter Output

4.1Design Specifications

Windmill Module	
Speed of Generator	200 RPM
Pitch angle	1 degree
Speed of wind	12 metre/sec
Solar Module	
Irradiance	5 W/m^2
I_{SC}	70 Amp
V_{OC}	40 Volt
Temperature	15 degCelsius
Boost Converter	
L_1	5 mH
C_1	1000µF
F_s	20 KHz
Parasitic Capacitor (C_{PV})	75 nF

Table 1. Simulation Design parameters for various components

5. Experimental Results

This hardware kit as shown in fig. 8 mainly comprising of a module of hybrid PV/Wind, a controller module, a converter &an inverter module. The voltage generatedby the PV/Wind module is provided to the boost converter. The Reciprocated Sine PWM technique has been implemented and pre-loaded to PIC16F877A controller. The generated PWM pulses from the controller will be given to the

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inverter circuit and it controls its ac output with low THD. The experimental results have been observed by a Digital storage Oscilloscope.

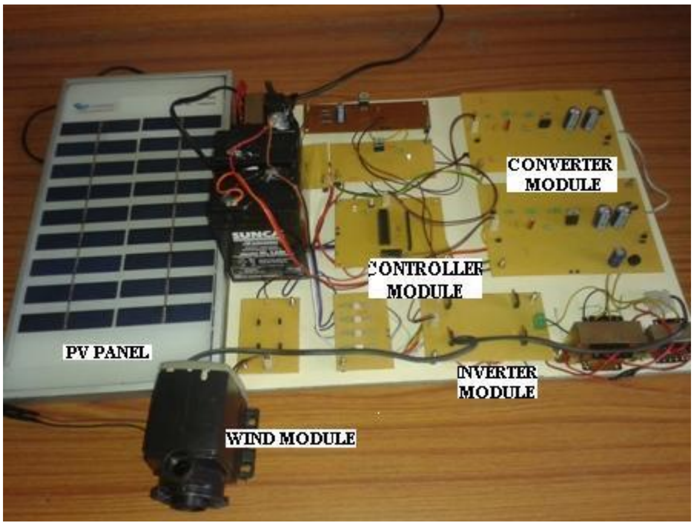

Figure 8.Hardware kit

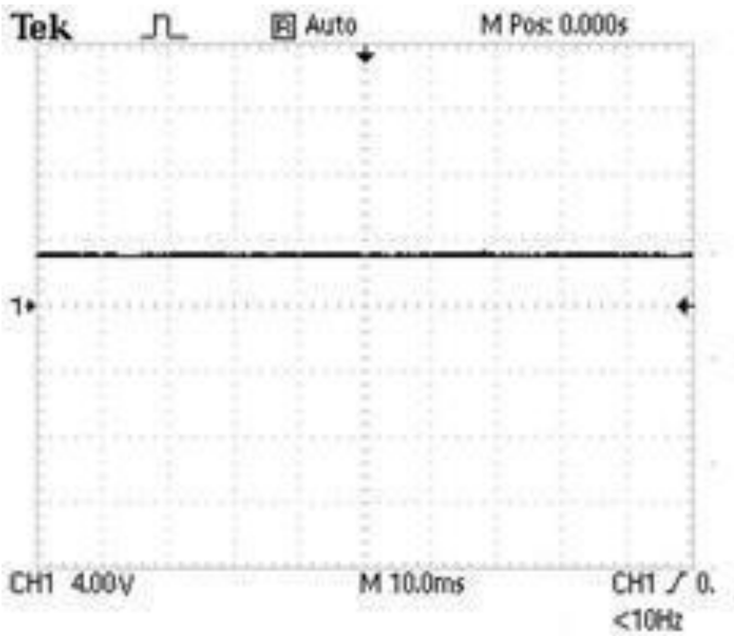

Figure 9. Input voltage

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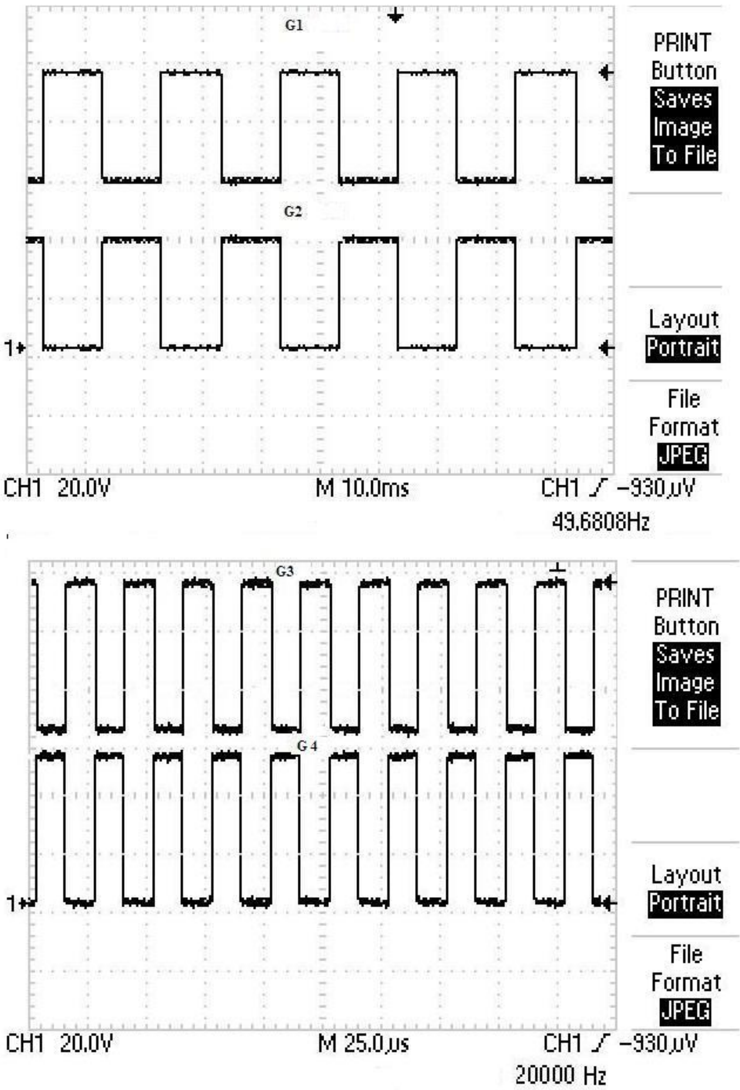

Figure 10. Gate pulse output

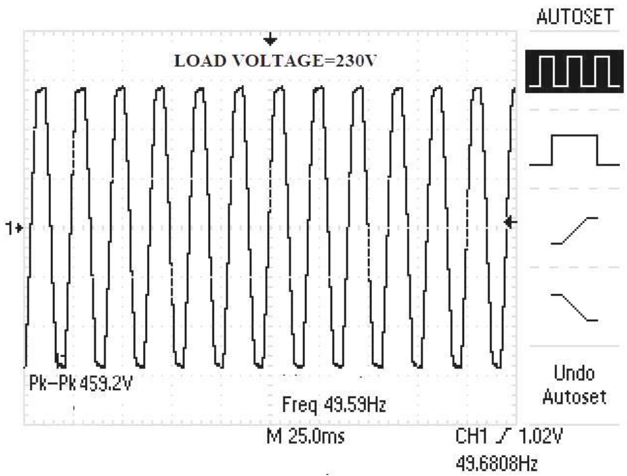

Figure 11. Inverter output

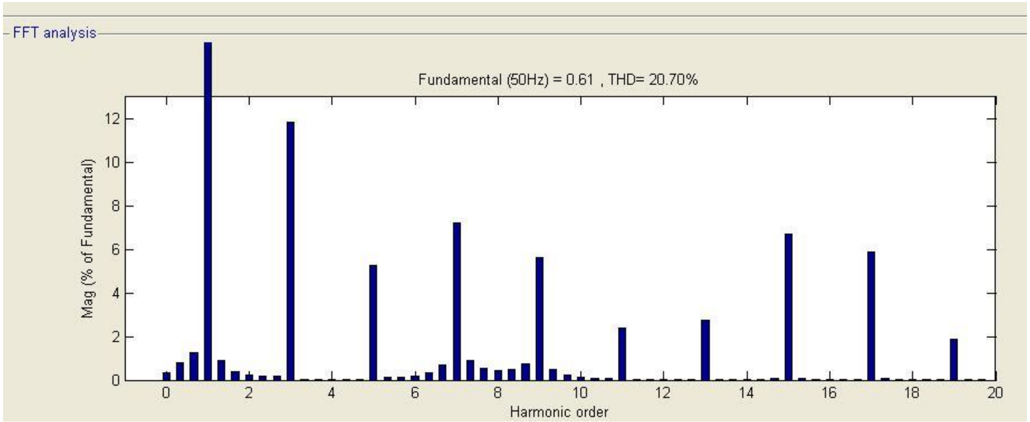

Figure 12. Harmonic spectrum without RSPWM

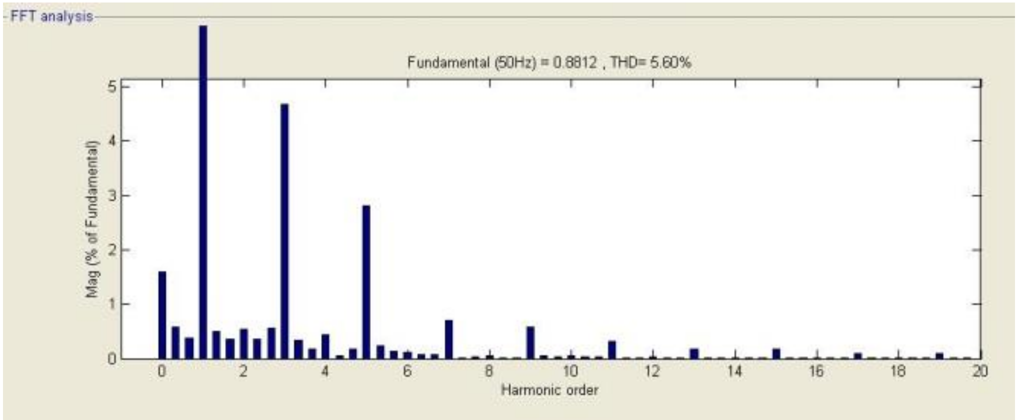

Figure 13.Harmonic spectrum with RSPWM

S.No	Description	Inverter output (V)	THD
1	Without RSPWM technique	215	20.70%
2	With RSPWM technique	230	5.60%

Table 2. Comparative analysis

6. Conclusion

This paper proposes the design and implementation of grid-tied hybrid power generation system. The maximum power from PV/wind combinationcan be extracted by using a well-defined and well-designed MPPT algorithm. The simulation and experimental studies show that power and voltage are at controllable state even under variation of environmental conditions. This proposed methodologyresults in high efficiency, better transient and stability are attained even at presence of disturbances**.**

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