Harmonics Analysis and Enhancement of Power Quality in Hybrid Photovoltaic and Wind power System for Linear and Nonlinear Load using 3 Levels Inverter

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***Abstract:** The emergent use of non-conventional energy resources in electrical power grid has initiated new challenge for the service load as concern to voltage balance, power quality issues and effective energy operation. Solar/ wind hybrid RES deliberated as the furthermost promising sources. Nevertheless standalone operations of distributed energy sources such as solar and wind not make sure of reliable power production principally owing to the randomness over the solar irradiance and accessibility of the wind. Hence, a combination of wind and solar energy production configuration can plan a highly reliable source of electrical energy. In This article, multi-level inverter (3 levels inverter) based grid tied hybrid solar- wind energy system based on a 3 level inverter is presented with the mitigation of power quality problems. In this work, analysis on simulation model is conceded to determine source current and voltage and percentage of total harmonic distortion. In particular, the power quality analysis is performed in grid tied hybrid solar and wind electrical power system using 3 level inverter.*

***Keywords:** Harmonics, Solar, 3 Level Inverter, Wind Energy, Power Quality.*

I. INTRODUCTION

Distributed energy sources are prospective to develop prevalent in the future owing to contrary environmental effects and intensification in power costs associated with the implementation of conventional power sources. Several remote areas over the globe cannot be substantially or prudently associated to an electrical power network. In these regions the energy demand is conservatively delivered by small-scale segregated diesel generators. The effective prices correlated with these DGs may well be excessively high owing to cut-rate fossil fuel prices together by problems in fuel supply and preservation of generators in the systems. In those conditions, RES, for example and wind system and solar contribute as a realistic substitute to additional engine driven DGs for electrical energy productions in off-grid regions [1]–[3].

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Amongst all the present DES solar photovoltaic and wind energy resources have concerned investors owing to their profusion in capability. Solar wind hybrid power resources these are more popular in the RES zone are originating large numbers of installation crosswise the world. The key benefits of these resources environmental friendly and more reliability. In the wind energy technology the grid integration of the wind power network conversion systems can be executed in two methods fixed and variable speed energy production systems. Adjustable speed energy production scheme can draw utmost energy from the power plant. Permanent magnet synchronous generator based schemes is more advantages such as a lesser amount of weight, lesser maintenance. Hybrid power system can deliver better power quality and can correspondingly lessen the cost of electrical energy. At a distance as of all the profits, the hybrid energy system has its specific encounters or difficulties like security, synchronization and quality of power nonetheless now we are discussing about PQ only [4]–[8] . In this paper power quality analysis of conventional hybrid system and hybrid system using three-level inverter are discussed.

II. MODELING OF SPV/ WIND HYBRID SYSTEM

A. Wind power System

The wind power system modeling depends on demonstration of the electrical power generator and wind turbine. The velocity of wind is specified wind turbine input and it generates output power that is called mechanical power [9], [10]. Wind turbine mechanical output is given as

$$P_w = 1/2 \quad \rho A V_v^3 \qquad (1)$$

Vw- Wind velocity (m/sec.) Pm – wind output power
β – Pitch angle of blade
A- Turbine swept area
ρ- Density of air (kg/m3)

The 500W wind turbine system is taken in account for the modeling of the crossbred power system and the parameter stipulations of the wave power system is given in Table 1.

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Table 1 Constraint Specifications of the 500 W Wind power System

Data	Rating
Wattage Power	500W
Inductance (L_q & L_d)	7.31 mH
Pair of poles (P_p)	2
cut in speed (V_c)	4 m/s
Rated wind speed (V_R)	12 m/s
Moment of inertia	0.00126811kg/m2
Impedance (R_a)	0.775Ω
Magnetizing flux (Φ_m)	0.37387 wb

The overall power generated by the wave power system is derived from equation 2. It is perceived that, the output of wave power depends on the accessibility of the velocity of wind.

$$P_w(W_v) = \begin{cases} P_w \frac{V_v^2 - V_d^2}{V_n^2 - V_d^2}; & V_d \le V_v \le V_n \\ P_{w;} & V_n \le V_v \le V_c \\ 0; & V_v \le V_d \, and \, V_v \ge V_c \end{cases} \quad (2)$$

Vw- Wind velocity (m/sec) Pw –output power (W)
Pn – system nominal power (W) VR- Rated wave speed (m/sec) Vw- wave velocity (m/sec)
Vc-cut in wave speed (m/sec) Vs-cut off wind speed (m/sec)

B. Solar Photovoltaic System

The mathematical design of the SPV system is taken in account from the elementary ISPV- VSPV characteristics of solar photovoltaic array. The SPV array output current and voltage equation are given as

$$V_{spv} = \frac{\eta KT}{q} \ln\left(\frac{I_{PH}}{I_{SPV}} + 1\right) \quad (3)$$

$$I_{spv} = I_{ph} - I_{RSC}\left(e^{\frac{q(V_{spv}+I_{spv}R_{Se})}{\eta KT}} - 1\right) - \frac{V_{spv}+I_{spv}R_{se}}{R_{sh}} \quad (4)$$

The SPV power output depends on the accessibility of solar insolation and atmospheric temperature [11], [12] and it is premeditated by applying equation 3.

PPV = APVP Gn ηPVP (5)

Parameter Description	Rating
Maximum current (I_{MSPV})	7.82945 A
Maximum voltage (V_{MSPV})	24.303 V
Maximum power (P_{MSPV})	560W
Open circuit voltage (V_{OSPV})	30.6021 V
Short circuit current (I_{SSPV})	8.51029 A
Temperature (T)	25
Parallel string	3
Series connected module per string	1
Solar irradiation (G)	1000 W/m3

VSPV - SPV array output voltage
RSe - Single diode model shunt resistance
Iph - Phase current of SPV cell
ISPV - PV panel output current (A) VOSPV - SPV array open circuit voltage ISSPV - SPV array short circuit current
GN - Nominal irradiation to the SPV array

RSe - Single diode prototypical series resistance
Ƞ - Factor of Ideality
q - Charge of electron
ȠSPV - SPV panel generation efficiency (%) ASPV - SPV panel area (m2)
K - Boltzmann constant of SPV panel
T - Ambient temperature (K)
G - Applied solar insolation to the SPV array
IRSC - Reverse saturation current

III. INTEGRATION OF SPV AND WIND CROSSBRED SYSTEMS TO THE GRID

The dc output extracts from SPV system while WECS generates the ac voltage output. Different electronic power coordination's used for scheming for the semiautonomous electrical generation of these two sources. In this arrangement, the output of Solar PV array is transferred to the DC to

DC electronic power boost converter scheme and the dc linkage voltage is controlled. At the first stage rectifier is used to rectified wave power AC output voltage which is unregulated and next a DC to DC power electronic converter is needed to control voltage of DC network [13].

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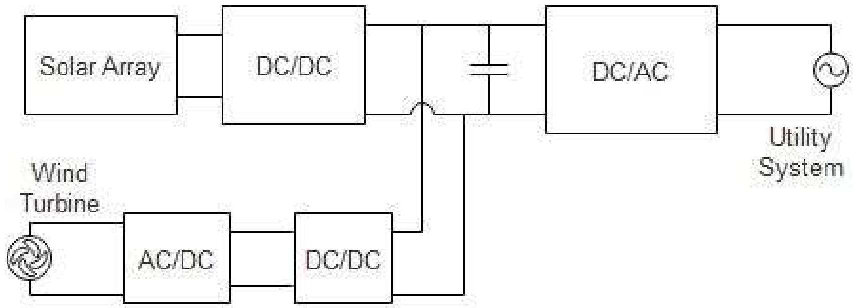

Fig.1. Distinct circuit topologies for the wind and SPV hybrid system with utility grid

IV. THREE LEVEL INVERTER SYSTEM BY SVPWM

3 stage inverters is really important because of many features including improved THD efficiency , increased power and decreased electromagnetic performance. The MLI produces voltage output at lower frequency with reduced harmonic distortion[14],[15]. A device for three- stage inverters is commonly used in large-scale AC control fields for medium and high-voltage voltage and displays the lower harmonic performance , higher power efficiency, decreased switching losses, increased electromagnetic stability and other advantages. This also faces some significant issues, however: stress regulation at neutral over modulation, generalization of 3-level strategies and high-voltage device constancy [16][17][20]. Different PWM-solutions have the principal objective to the existing THD in the framework because of the difficulties described above. If we raise the frequency of flipping, the lower series of harmonics becomes too small to evaluate a waveform with the specified frequency and the root average square value and the wave form with a sinusoidal wave resemblance. The inverter has a single device that will mix various switching states, based on the inverter rates, on which the current switching state relies. For the sake of its decreased harmonic and improved DC bus service, SV pulse width modulation approach has become the well-known PWM technique for 3 stage inverter systems. For all forms of MLI technology (diode clamping, cascading, condenser clamping), this procedure can be easily transferred to lower rates and facilities [18],[19]. For this paper the SV pulse width modulation technology was used to learn the three-level solar PV inverter systems. The graphic arrangement of three-tier inverter topology connected to grid crossbred PV / wave systems with the SV pulse width modulation method is shown in Fig. 2.

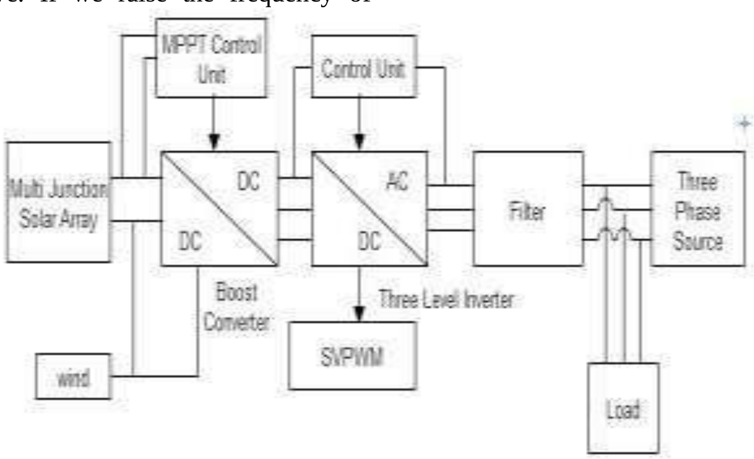

Fig.2. diagrammatic arrangement of tied to grid PV and wave HRES with three levels inverter topology by SV pulse width modulation

A three-stage PWM inverter manages the electricity network's DC capacity in astounding air conditioning efficiency .. Simulink pattern of modulation of SV pulse width as shown in Fig. 3. For a sinusoidal wave with a lower power relation, the modest technology for supplying the signal for SV pulse width modulation is a triangular high reappearance wave. The A SV pulsed width inverter produces better waveforms at no unaffected change in efficiency

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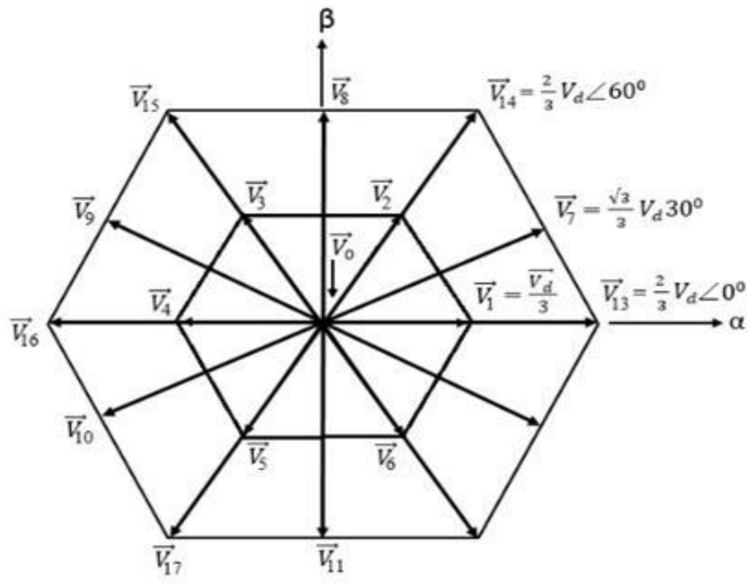

Fig.3. rotating equivalent space vector in three phase sinusoidal systems

The ac RMS voltage output is

$$V_{ac} = V_s\sqrt{\frac{p\delta}{\pi}} \square V_s\sqrt{\sum_{m=1}^{2p}\frac{\delta_m}{\pi}} \quad (6$$

Here
δ = pulse width.
p = number of pulses

V. SIMULATION AND RESULT DISSCUSSION

To analysis the appropriateness of proposed tied to grid wave and PV HRES system, first of all a system without 3 level inverter or conventional system is considered and simulated in the MATLAB or Simulink systems. Furthermore tied to grid SPV/wave HRES system with 3 level inverter using SV pulse width modulation is premeditated. The results of simulation for total harmonics distortion and waveform of source current, source voltage, grid current, grid voltage both tied to grid SPV/ wind HRES systems without using 3- level inverter and grid connected hybrid renewable energy photovoltaic solar and wind system by means of 3 levels inverter schemes using SV pulse width modulation at different load R and machine load are specified in

Fig. 4 to Fig. 36. From the results of simulation we determine that THD is lesser in tied to grid hybrid SPV and wind arrangement using 3-level inverter corresponding to conventional arrangement at different type of load presented in Table 3 and 4.

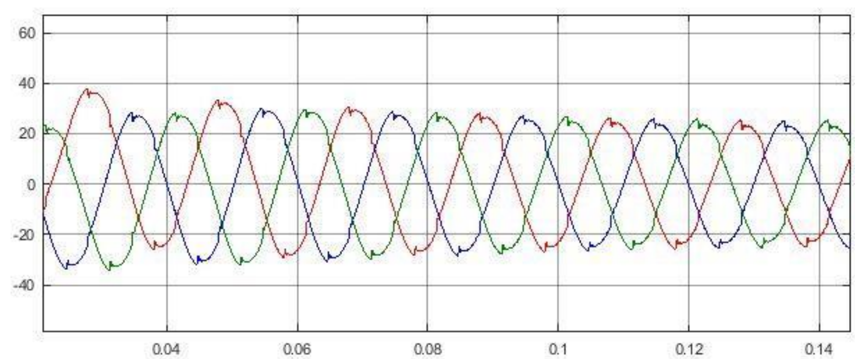

Fig. 4 Source current with conventional system

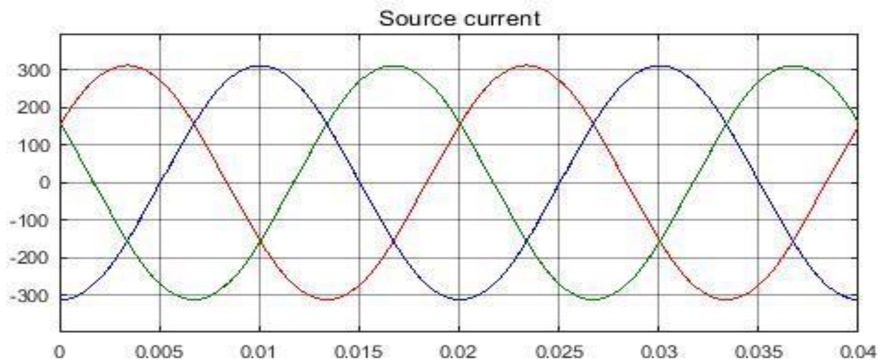

Fig. 5 source current with 3 level inverter

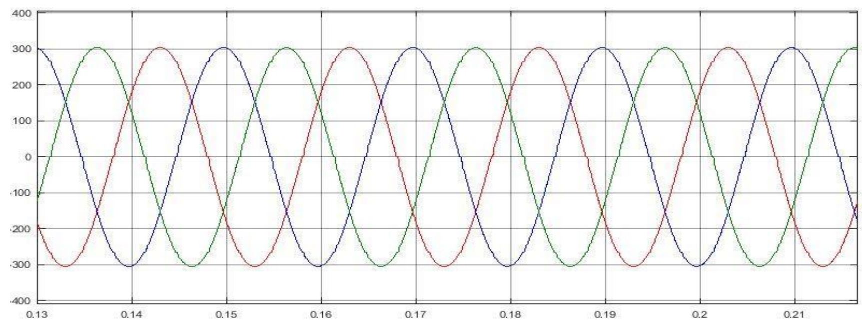

Fig. 6 Source voltage with conventional system

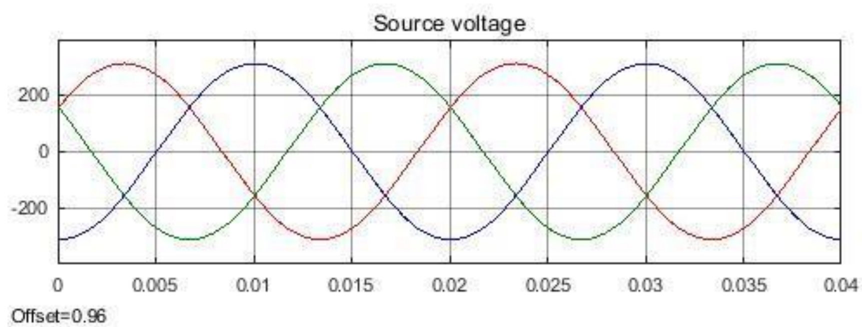

Fig. 7 source voltage with 3-level inverter

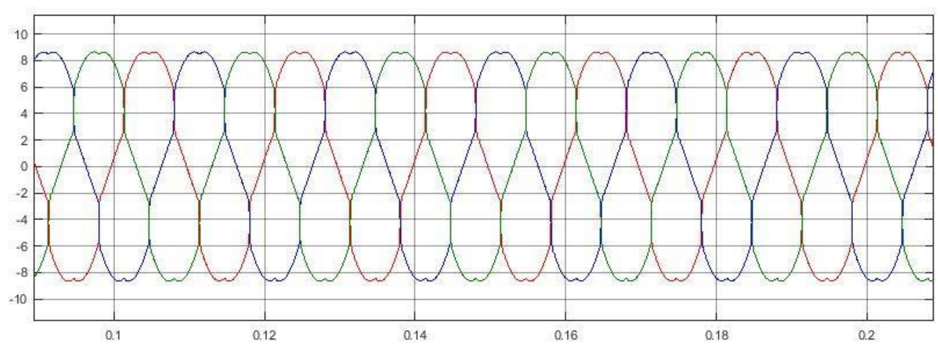

Fig. 8 grid current with conventional system

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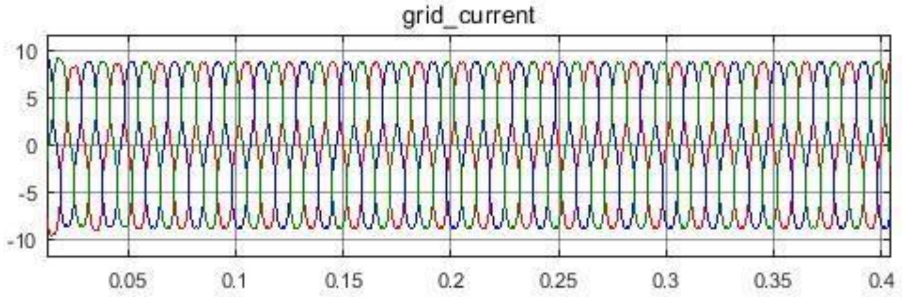

Fig. 9 grid current with 3-level inverter

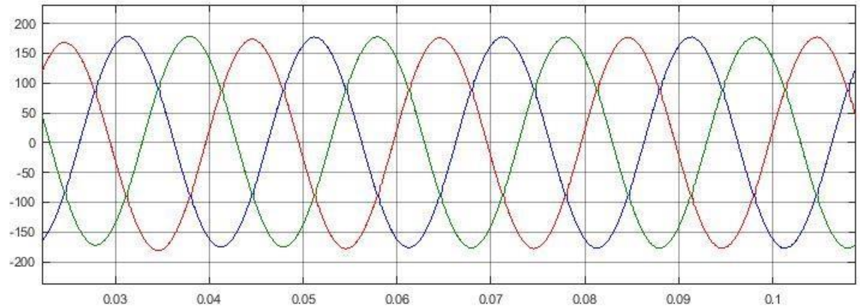

Fig. 10 grid voltage with conventional system

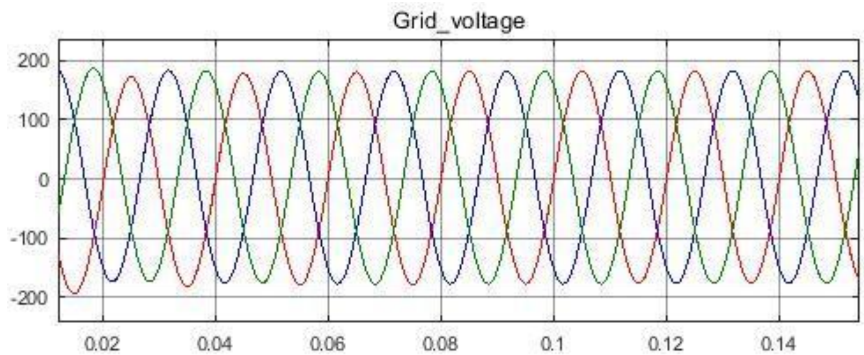

Fig. 11 grid voltage with 3-level inverter

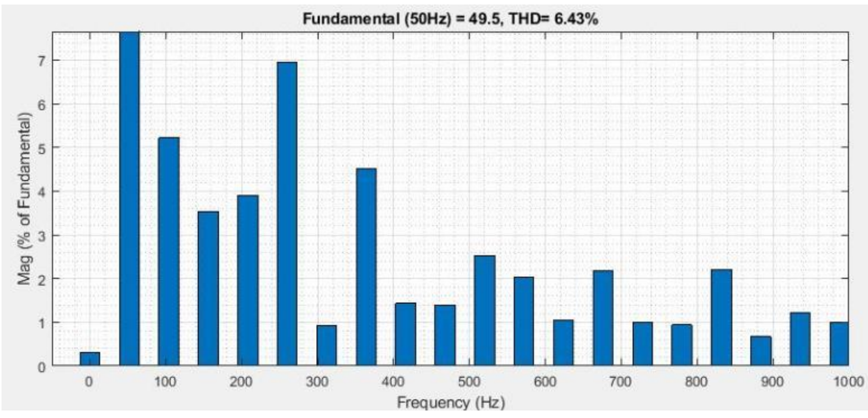

Fig. 12 THD grid current with conventional system

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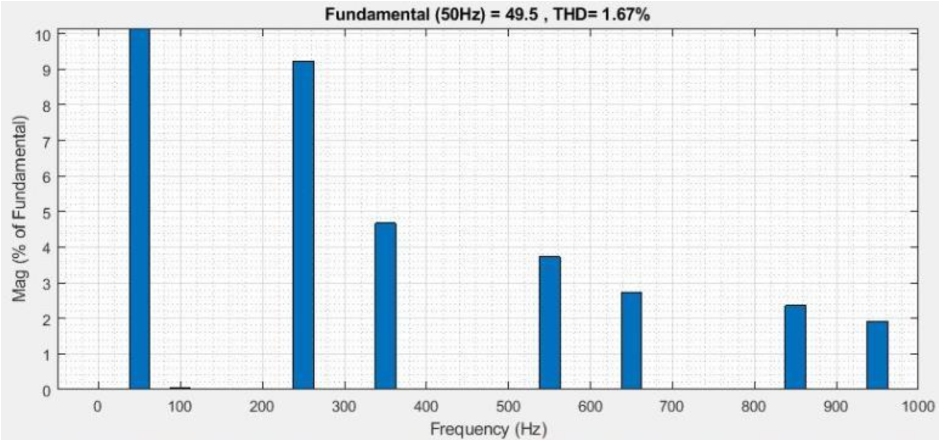

Fig. 13THD grid current with three level inverter

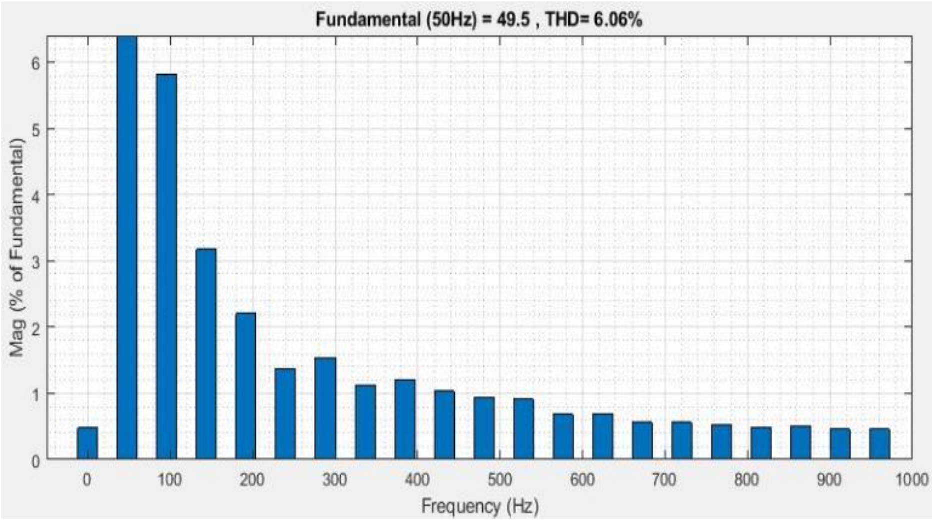

Fig. 14 THD grid voltage with conventional system

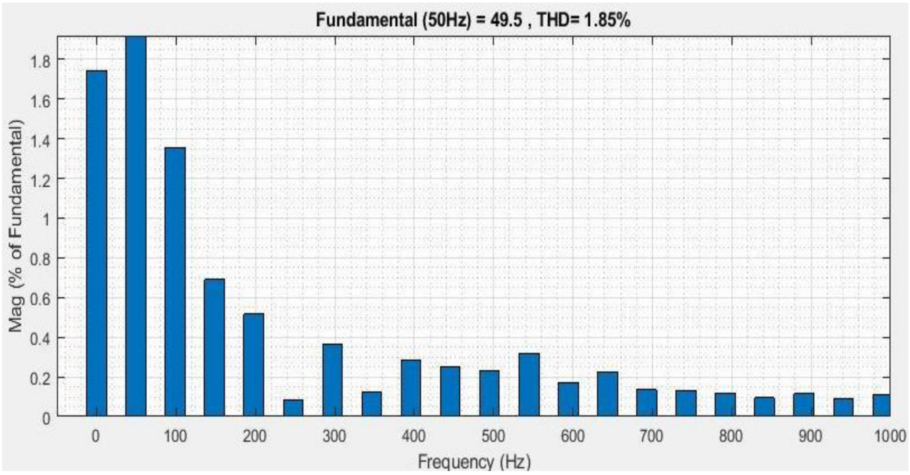

Fig. 15 THD grid voltage with three level inverter

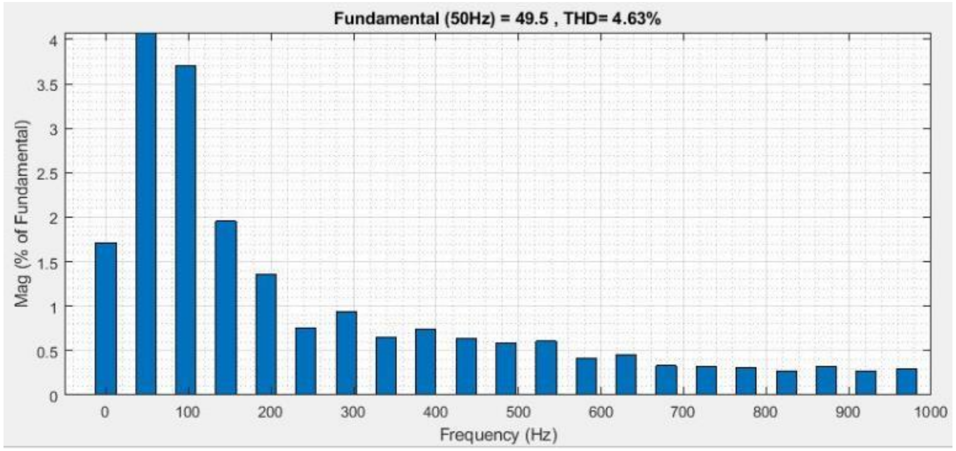

Fig. 16 THD source voltage with conventional system

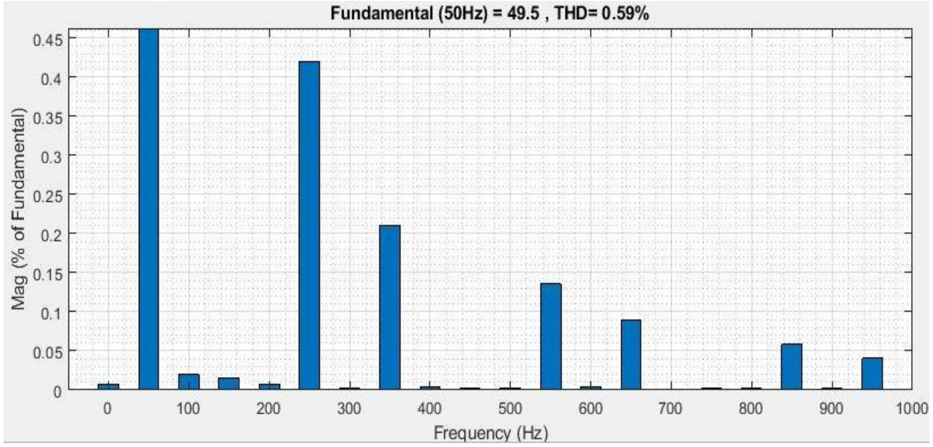

Fig. 17 THD source voltage with 3- level inverter system

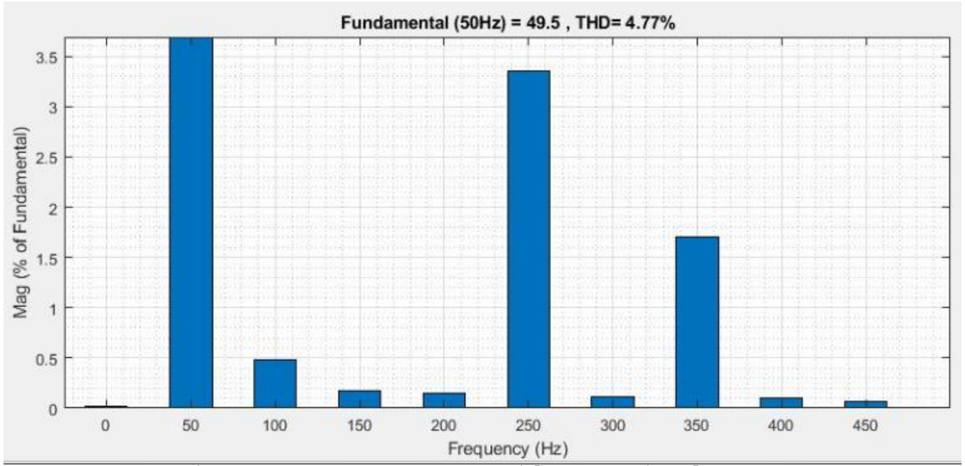

Fig. 18 THD source current with conventional system

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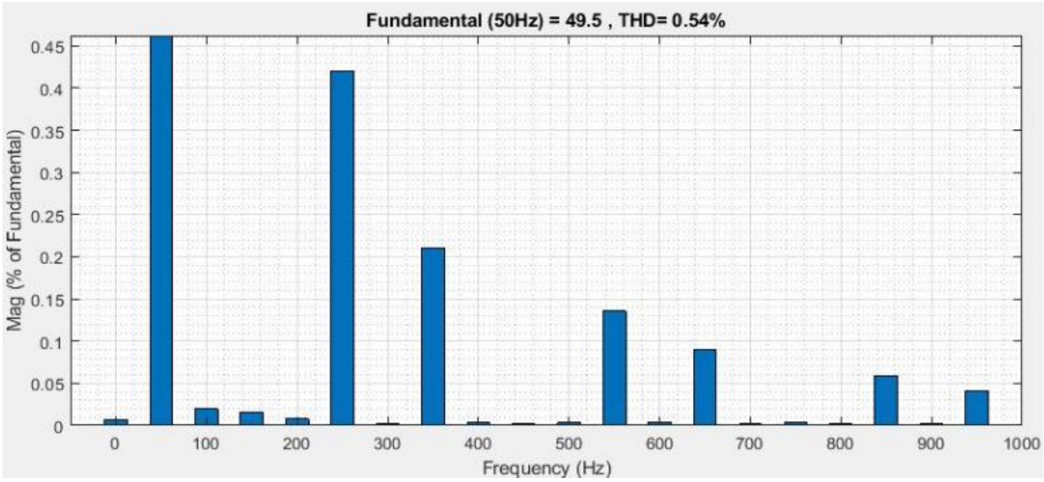

Fig.19 THD source current with 3- level inverter system

Machine Load

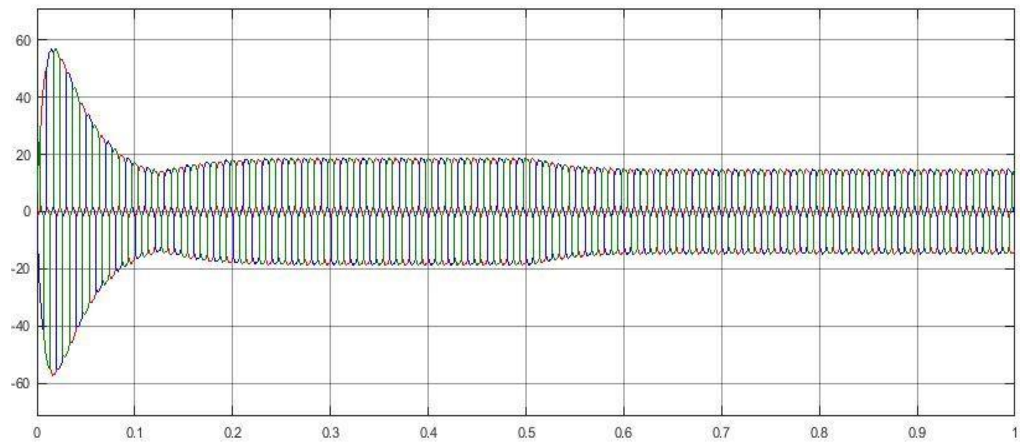

Fig. 20 Source current with conventional system using machine load

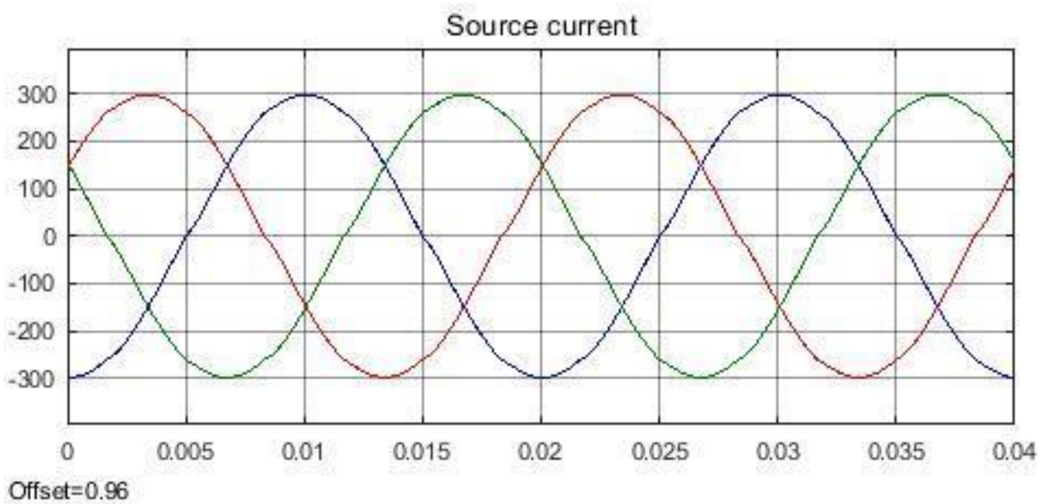

Fig. 21 source current with three level inverter system using machine load

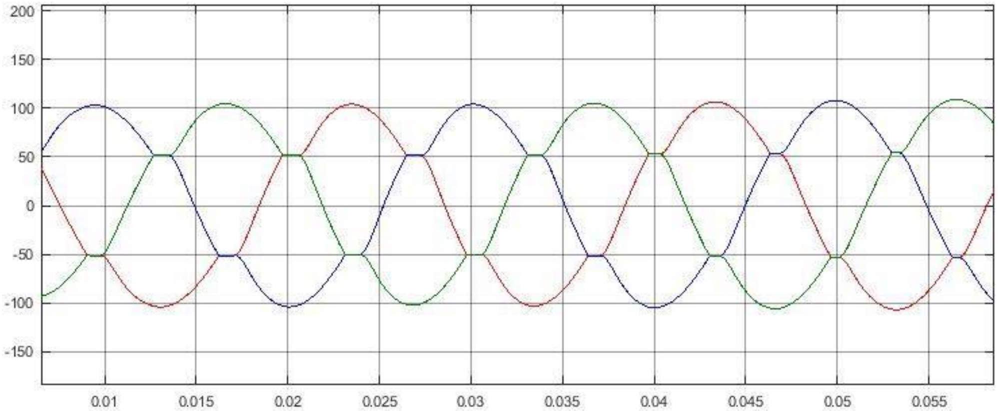

Fig. 22 Source voltage with conventional system using machine load

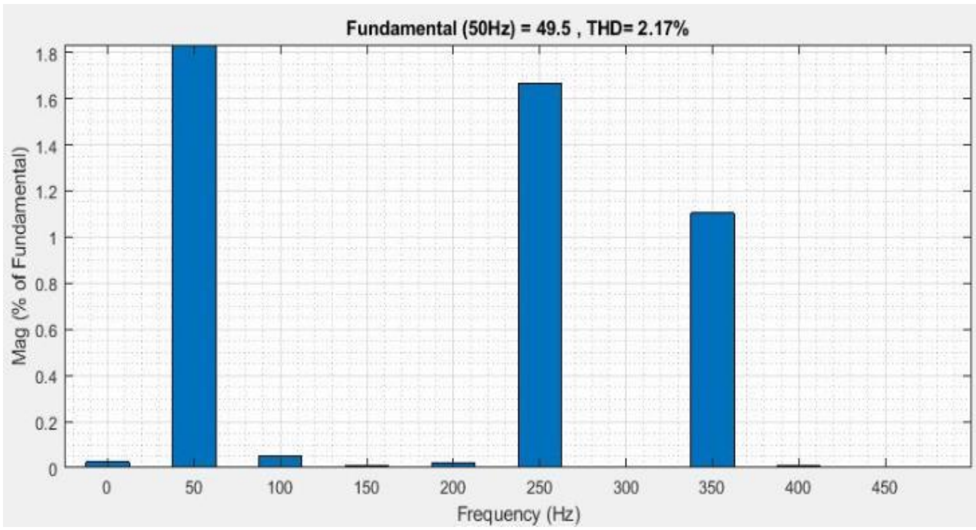

Fig. 28 THD source current in conventional system using machine load

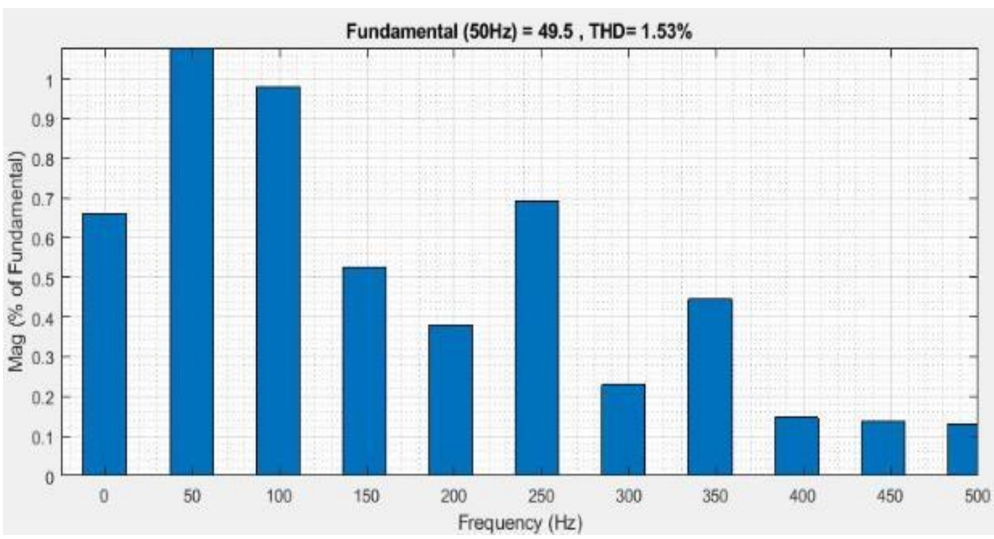

Fig.29 THD source current with three level inverter using machine load

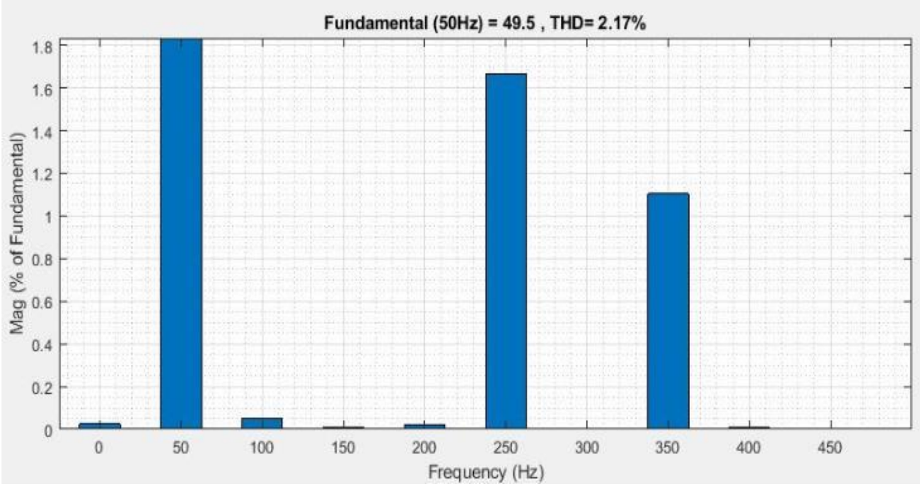

Fig. 30 THD source voltage with conventional systems using machine load

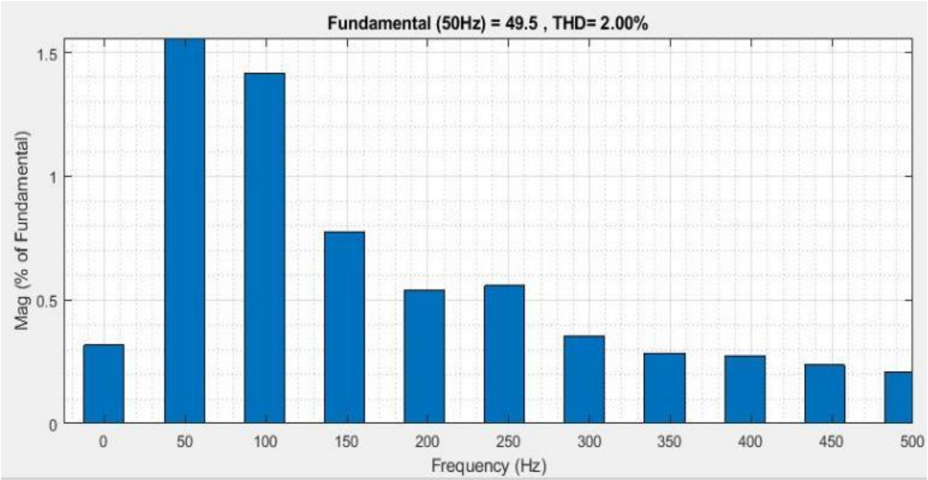

Fig. 31 THD source voltage with three level inverter systems using machine load

Table 3. Comparative analysis of grid tied hybrid SPV/ wave system without three levels inverter & with three levels inverter schemes at R load

Type	Grid tied conventional crossbred SPV/wind system (THD)	Grid tied crossbred SPV/wind system
Source current	4.51%	0.51%
Source voltage	4.47%	0.51%
Grid Current	6.67%	2.87%
Grid voltage	6.26%	2.87%

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Table 4. Comparative analysis of grid tied hybrid SPV/ wave system without three levels inverter & with three levels inverter schemes at machine load

Type	Grid tied conventional crossbred SPV/wind system (THD)	Grid tied Crossbred SPV/wind system with 3 level inverter (THD)
Source current	2.17 %	1.53 %
Source voltage	2.17 %	2.00 %
Grid current	5.36%	3.14 %
Grid voltage	5.37 %	2.48 %

VI. CONCLUSION

This paper demonstrates the PQ improvement by utilizing an SV Pulse Width Modulation Scheme for grid hybrid SPV / Wave systems through a three-tier inverter. The harmonic integration into the prearranged device is able to be diminished and a 3-level inverter network will match source, grid power and voltage wavelength. The hybrid SPV / wind configuration with a three-stage inverter eliminates the overall harmonic distortion in contrast with traditional systems. The aim of the article is to direct the investigator to improve the efficiency of the control of the grid timing with MLI for lower THD in systems (5, 9 and 7 levels etc.).

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