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Explication of PWM 1-∅ Inverter Harvesting AC from Nonconventional Energy Source

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ABSTRACT: Because of advances in solid state power devices and microprocessors pulse width modulation (PWM) is widely used in power electronics and variable speed drives to digitize the power signal so that a string of voltage pulses can be procreated by the electronic switching devices like choppers. The PWM technique has been the main choice in power inverters and DC to AC converters for decades. Forasmuch of its circuit naivety and disparate control scheme PWM technique is oftentimes used in power applications such as in motor controllers and inverters etc. The preferment of PWM rooted switching power converter upon linear power amplifier in view of lower power dissipation, easy to implement and control, no temperature variation and aging-caused drifting or degradation in linearity and Compatible with today's digital systems. Unexpectedly because of the uses of power converters and variable speed drivers neither the voltage nor the current waveform remains impeccable. They endure harmonic contamination in addition with power losses and high frequency noise. These harmonic must be removed or minimized in the system to curtail and detract harmful effect on power supply system. In this document the concept of Pulse Width Modulation (PWM) for single-phase inverters, operating principles and effect of harmonic are analyzed. The results are comprised with simulation results for a single-phase inverter.

KEYWORDS: Modulation, Pulse width modulation, Inverter, PWM converter, DC to AC converter, Fuel cell inverter.

I.INTRODUCTION

The dc to ac converter, also known as the inverter, converts dc power to ac power at desired output voltage and frequency. The DC-AC inverter is intended to take power from a DC source and converts it in to AC. As in the household inverter which receives DC power from 12V or 24V battery and then converts it in to 240V AC with a desirable frequency of 50Hz or 60Hz. Also inverters are used in industrial applications for adjustable-speed ac drives, induction heating, standby aircraft power supplies, uninterruptible power supplies (UPS) for computers, HVDC transmission lines, etc [1] [2]. The most common dc power source to the inverter is a DC batter. Recently with the advancement in fuel cell, photovoltaic array and magneto hydrodynamic technologies, these non conventional energy sources also become an important source of DC energy. The DC-AC inverters are chiefly deploying Pulse Width Modulation (PWM) technique. The PWM is an advance, useful and practical technique in which width of the Gate pulses are controlled by various mechanisms. The output of the PWM inverter is controlled by controlling the width of the pulse depending upon the load connected and provides a constant rated output voltage. Nutan flourish in semiconductor technology and power electronic devices have lead development in power electronic systems. This development helps designers to design different circuit configurations for power devices such as PWM inverters etc. A count of Pulse width modulation (PWM) dispensations are used to obtain variable voltage and frequency supply. The most elaborately used PWM scheme for voltage source inverters is sinusoidal PWM. Power electronics devices grants prominent role in power conversion techniques but also gives emanation to harmonics in the system [3]. It is eminent that harmonic defilement perverts voltage and current waveforms. More over harmonics produces additional power losses and high frequency noise that can affects proper functioning of power load and associated controllers. All these forbidding operating indication associated with power converters can be overcome with PWM converters [4].

This project focuses on step by step analysis of PWM technique implemented on a single phase inverter. The model of a single-phase inverter is discussed based on PWM technique. Simulation results are obtained using MATLAB/Simulink environment for effectiveness of the study.

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II. PWM TECHNIQUES FOR SINGLE PHASE INVERTER

The inverter is one of the power conversion devices are widely used in the world to convert DC input voltage to AC output voltage. With the advancement in solid state power technology results to the boost in use of power converters and variable speed derivers in industrial application to deliver their required energy. It is well known that the use of power derives provides a wide range of operation but also damages the power signal wave quality. This damage to the wave shape is referred as harmonic distortion [5]. Here the PWM technique unwavering itself very utilitarian. The PWM technique not only endows capacious range of operation but also ameliorates the power quality and detracts harmonic distortion in wave shape. Principally PWM signals are the camelcade of pulse with steady frequency and magnitude. These pulses with steady frequency and magnitude are than used for the switching of power devices in inverter or converters. It is more comfy to know about the type of PWM before analyzing it for single phase inverter [6].

1. Single pulse width modulation: This technique employs only one pulse per half cycle for controlling inversion of DC to AC. The power output of the inverter in controlled by controlling the pulse width. The gate signal are procreate by liken a rectangular reference signal with triangular wave. The frequency of the triangular wave composes the fundamental frequency of output voltage [7].
2. Multiple pulse width modulation: The harmonic content can be reduced by using several pulses in each half cycle of output voltage. This technique employs umpteen pulses per cycle for controlling modification of DC in to AC. The generation of gate signal for switching of power switches by encountering of reference signal with a triangular signal. The frequency of triangular signal composes the number of pulses per cycle. This type of modulation is also known as uniform pulse width modulation (UPWM) [7].
3. Sinusoidal pulse width modulation (SPWM): This method instead of deploying uniform pulse width modulation technique as in UPWM, the multifold width of pulse is used. Span of the pulses is decided by comparing a triangular wave with a reference sinusoidal wave of specified amplitude. By this method the width of the gate pulse is proportion to the amplitude of the sine wave. The number of pulses per half cycle depends on triangular wave frequency [8].
4.

III. INVERTER DYNAMICS

The very basic designing and working principle of inverter is shown in fig. 1. The main device is the power switches. These power switches converter fixed DC in to square wave AC. As given in fig. 3. Here fuel call is used as renewable energy resources of 40V and 1.5 KW DC power [9] [10]. This DC voltage is converted in to 40V square wave AC by using a full bridge fully controlled power MOSFET converter. In the full bridge system of working 4 power switches are used namely 1, 2, 3 and 4. The operative function of these switches is commended by suitably synchronized gate pulses from pulse generator [11]. For sobriety a resistive load is used. When MOSFET 1 and 2 is triggered with suitably synchronized pulse than positive half pulse is procreated in output and similarly the negative half pulse by gating MOSFET 3 and 4. Collectively by pertinent and synchronized operation of MOSFETs a decided value square wave AC voltage can be obtained in output [12], as shown in fig. 3. Basically inverters are echeloned in two fallacies as shown in fig. 2. Furthermore falling on the basis of AC output waveform inverters can be classified in to three more classes namely square wave, modified sine wave and pure sine wave [13]. The square wave is the unpretentious and uncostly type but unfortunately it is having low power quality with harmonic distortion of nearly about 45%. This distortion in the square wave inverters can be reduced using PWM technique as analyzed forward up to 20% or below.

IV. SINGLE PULSE MODULATED INVERTER

The operative functioning of a 1-Ø single inverter has been discussed above. The mathematical investigation of 1- Ø full bridge inverter for single pulse modulation technique is brawl as under. The harvest of a 1- Ø full bridge inverter is shown in fig. 3. From the fig. 4 it can be revealed that the pulse width is symmetrical over the $\pi/2$ and $3\pi/2$ in positive and negative half cycles serially for exhaustive operating cycles. This allude that the out turn of the inverter is incumbent on the width of the pulse and hence is the controlling essence of the whole operation [13]. As shown in the fig. 4 pulses are symmetrical over the whole operation for positive and negative gyre resultant for the output can be earned using Fourier series expansion as:

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$$V_0 = \sum_{k=1,3,5...}^{\infty} \frac{4V_s}{k\pi} \text{Sin}\left(\frac{k\pi}{2}\right).\text{Sin}(kd).\text{Sin}(k\omega t) \quad \text{........ (1)}$$

In the same way a general solution for k^{th} order harmonic component can be procured as

$$V_k = \frac{4V_s}{k\pi} Sin(kd) \quad \text{........ (2)}$$

The fundamental harmonic component than can be obtained by putting $2d = \pi$ and k=1.
There for

$$V_0 = \frac{4V_s}{\pi} \quad \text{........ (3)}$$

In equal way the value of V_{rms} can be given as

$$V_s.\sqrt{2d/_\pi} \quad \text{........ (4)}$$

From the above equations it is located that for supreme value of fundamental current value of harmonics of order 3, 5, 7…. are quite low and hence can be unconsidered worthily. This rewards in the improvement of the power quality. But for inferior value of fundamental current value of harmonic current of order 3, 5, 7…. are homologous. This out comes in the degradation in the power quality.

V. MULTI PULSE MODULATED INVERTER

In this system of working instead of ply single pulse for modulation of power signal a train of multiple pulses are used for the positive as well as negative half cycles [14]. The frequency and amplitude of the pulses used are constant and symmetrical for the whole operation as shown in fig. 5. The output of this modulation is shown in fig. 6. The output voltage signal can be derived by using Fourier series expansion as [15].

$$V_0 = \sum_{k=1,3,5...}^{\infty} \frac{8V_s}{k\pi} \text{Sin}(k\gamma).\text{Sin}(kd/2).\text{Sin}(k\omega t) \quad \text{........ (5)}$$

For ingenuity the above equation is derived for 2 pulses only as given in fig. 7.
In the same way the amplitude of the k^{th} order harmonic is given as:

$$V_k = \frac{8V_s}{k\pi}\text{Sin}(k\gamma).\text{Sin}(kd/2) \quad \text{........ (6)}$$

The alteration in harmonics with variation in frequency of modulation is shown in fig. 9

VI. RESULTS

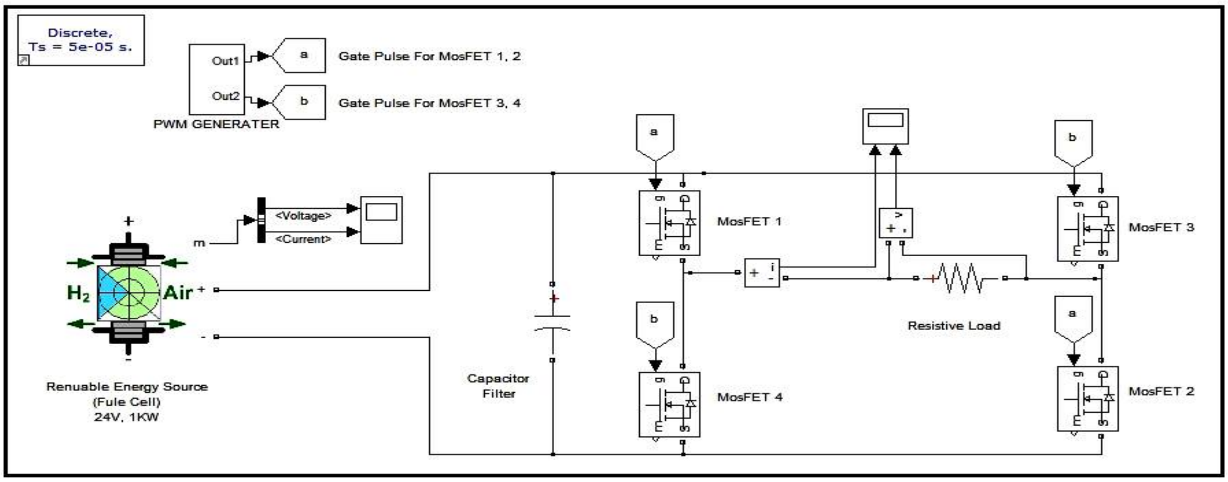

Fig. 1 presents Simulink Model of Single Phase Inverter with 4 MOSFET switches and a 40V, 1Kw DC fuel cell as renewable energy source.

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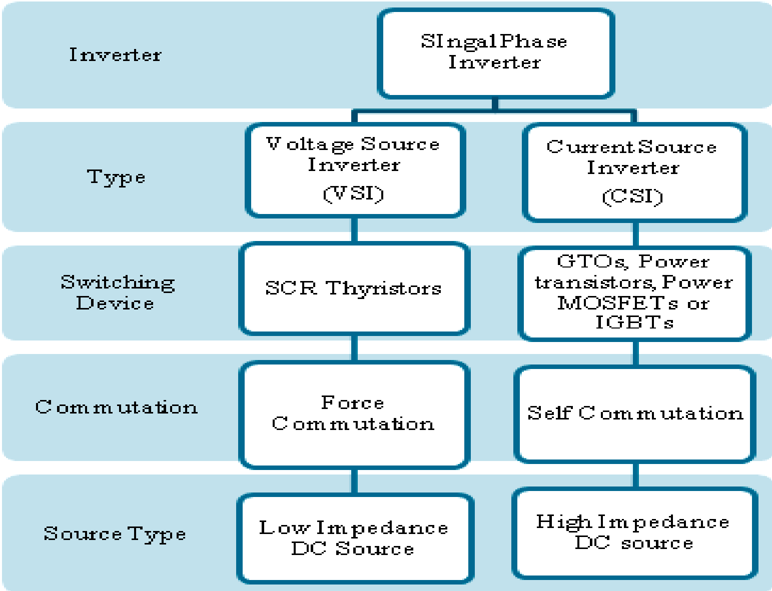

Fig. 2 Classification of Single Phase Inverters on the bases of source, switching devices, commutation techniques etc.

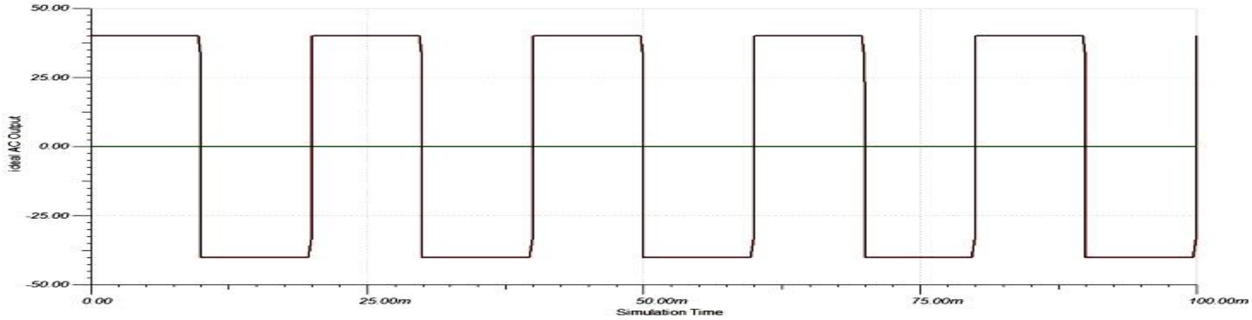

Fig. 3 Shows the output of 1- Ø full bridge inverter with symmetrical pulses over positive as well as negative half cycles. The frequency and amplitude of the AC output is symmetrical and constant through the operation on inverter.

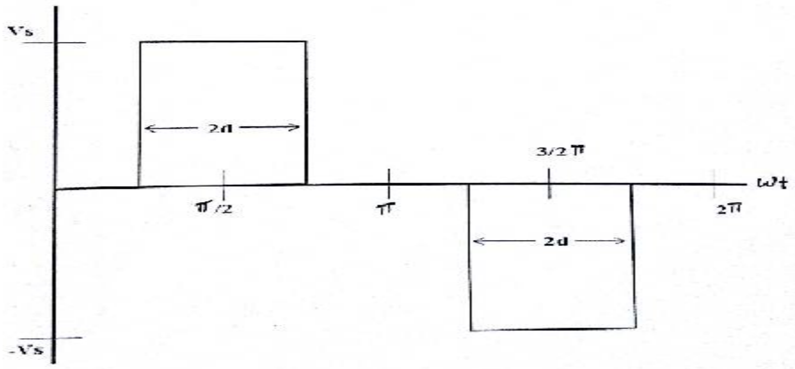

Fig. 4 shows the single pulse modulation with one pulse for positive and negative half cycles respectively. The pulses are symmetrical over the whole operation of modulation.

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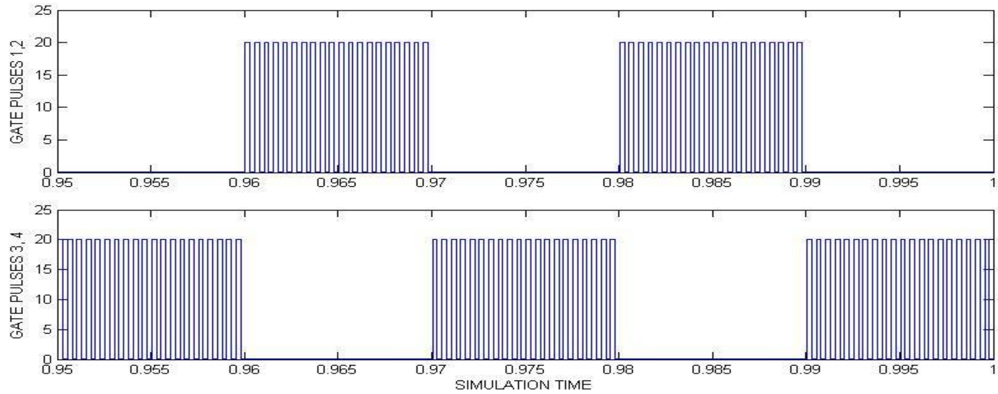

Fig. 5 shows multiple gate pulse for the switching of MOSFET pairs 1, 2 and 3, 4 respectively. It can be clearly seen from the fig that the pulses are equally spaced and identical in frequency and amplitude. The pair 1, 2 provides positive half pulses and pair 3, 4 results in negative half pulses of AC output.

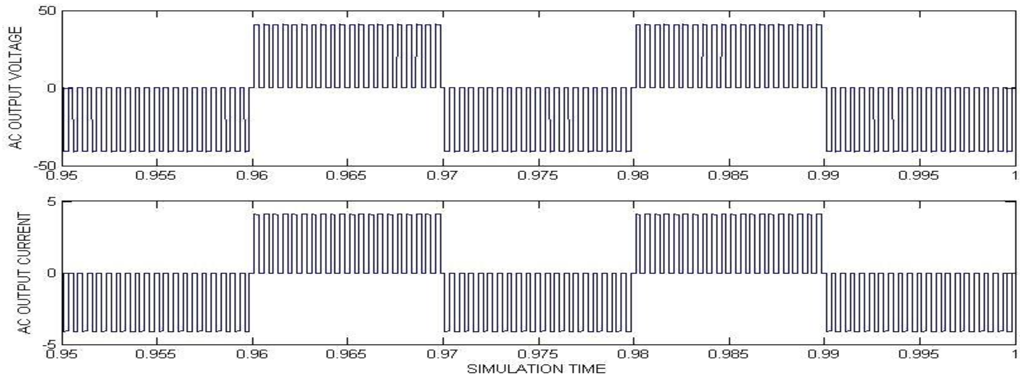

Fig. 6 represents AC output voltage and current of the full wave bridge inverter. The output is clearly having multiple pulses of modulation. This implies that the output is modulated with MPWM technique.

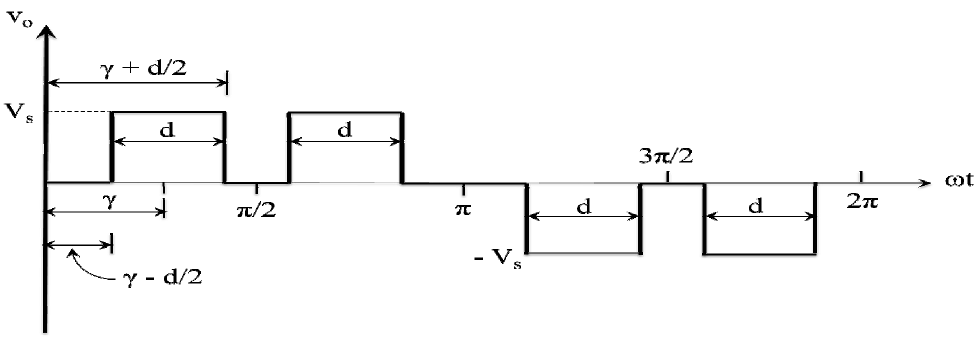

Fig. 7 presents multiple pulse technique for modulation. For simplicity only two pulses per half cycle are considered for analysis. The two pulses are having equal width ‘d’ over the positive and negative half cycle. Frequency and amplitude of the pulses are kept constant all over the operation.

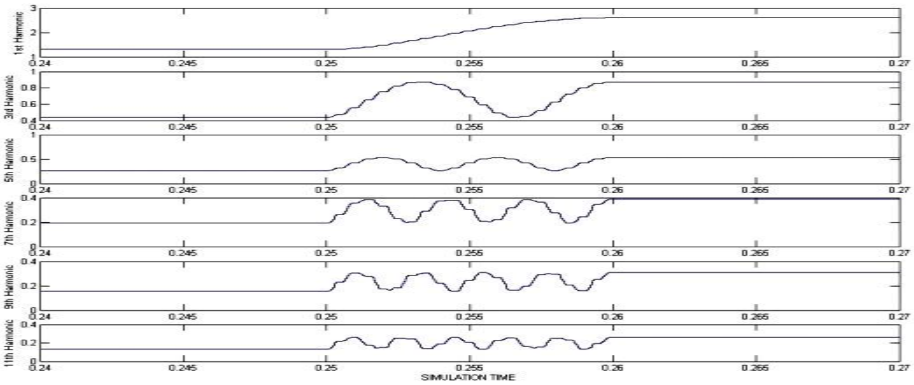

Fig. 8 shows the harmonic distortion in Current for Multi pulse modulation. Fig presents the variation in the 1, 3….and 11th harmonics in the AC output current of the inverter. Distinctly amplitude of the harmonics is decreasing with higher order of harmonics.

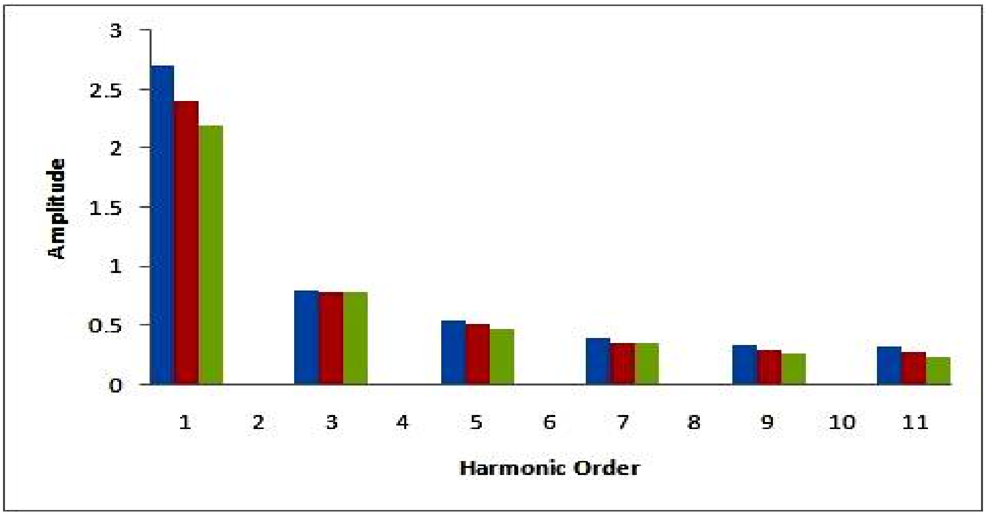

Fig. 9 gives change in harmonic with change in frequency of modulation. The variation in the amplitude of various harmonics represented is for 1K, 1.5K and 2K Hz frequencies respectively.

VII. CONCLUSION

From the aloft said work it is glaring that PWM technique is very helpful for improving the power quality. Further there are more goodness factors of PWM as PWM improves the power factor of the supply system as high as .95, helps in reducing the size of DC link capacitor and inductor, reduces the harmonic content in output AC, improves the transient operation of the system and also overall cost of the system can be reduced with the use of PWM. The PWM technique also sustains a deficiency. As all the switching operation of the system is substantiate in the existence of load current hence the power switches restrained to the higher value of $^{di}/_{dt}$ and $^{dv}/_{dt}$ ratings. This emphasis the designer to exercises with higher rating of power switches. Owing to the high values of advantage of PWM technique this drawback is affordable.

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