Asian Journal of Information Technology 15 (3): 493-503, 2016
ISSN: 1682-3915

Genetic Algorithm Optimized Converter Topologies for Photo Voltaic System Integrated with Micro-Grid

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Abstract: This study proposes a system such that the performance improvement in load is achieved by providing micro grid connected Photo Voltaic (PV) system with Selective Harmonic Elimination Pulse Width Modulation (SHEPWM) inverter and wind mill with matrix converter. The Genetic Algorithm (GA) is used to generate the gate pulse pattern (odd and even number of switching angles) for SHEPWM inverter over the range of modulation indices. The GA optimized PI controller based space vector modulation technique for matrix converter is implemented to reduce the selective specified lower order harmonics present in the load and also improves the input power fator of matrix converter. This optimized SHEPWM inverter through PV system and optimized matrix converter through wind mill system is simulated using MATLAB Simulink and verified with the experimental results independently. Simulation results prove the validity of the proposed system for both selective harmonics and Total Harmonic Distortions (THD) are reduced on the load side and also the input power factor is improved.

Key words: Genetic algorithm, selective harmonic elimination pulse width modulation inverters, matrix converter, space vector modulation, PI controller

INTRODUCTION

The energy demand and generation is to be balanced by the renewable sources like photo voltaic, wind and biomass. The improvement of power quality has been the major issue in grid connected power electronics circuits with Distributed Generation (DG) sources. Generally, pulse width modulated voltage source inverter is used for PV system connected to grid. SHE based PWM technique offers the best solution. It is generally accepted that the performance of an inverter with any switching strategies can be related to the harmonic contents of its output voltage.

There are number of techniques used to prove that a number of solutions are available for PWM problem and also optimal solution can be obtained using different algorithms (Kato, 1999). Genetic algorithm and PSO technique are applied to optimize a Pulse Width Modulation (PWM) inverter which is superior to standard triangular PWM and random PWM techniques (Czarkowski *et al*., 2002).

From review on inverter technologies for connecting photovoltaic, some of the topologies are pointed out as the best candidates for either single PV module or multiple PV module applications (Zhang *et al*., 2003). In a dc-dc power conversion, the high step-up converter is introduced to allow the parallel operation of low-voltage PV modules. A method to obtain initial values for the SHE PWM equations according to the reference modulation index M and the initial phase angle of output fundamental voltage is proposed which are beneficial to the optimization design (Chiasson *et al*., 2004).

Recently, SHE for low-loss multi-megawatt grid connected photovoltaic inverters is investigated and identified the suitability. The elimination of specific lower order harmonics improves the performance of voltage source inverter with any number of DG sources (Wells *et al*., 2007). This SHE PWM method can provide the highest quality output at low switching frequency to control high power photo voltaic inverters to suppress the switching losses. Grid connected PV system and other renewable energy sources to utility grid are discussed. In a micro grid, same type of inverters is used to connect generating systems to grid (Agelidis *et al*., 2006).

A Matrix Converter (MC) is a device which gives single stage conversion which is used for converting directly AC energy into AC energy without any intermediate dc link. The main feature of this device is to

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convert the magnitude as well as the frequency of the output into a desired magnitude and frequency. The main advantage of matrix converter is the absence of bulky reactive elements that are subjected to ageing and reduce the system reliability. Furthermore, matrix converters provide bidirectional powerflow, nearly sinusoidal input and output waveforms and controllable input power factor. Therefore MCs is a good alternative to conventional AC-AC converter.

The input power factor of Matrix converter under light load conditions is low so it is important to improve input power factor. A new DSVM method for MC with the goal of achieving an Input power factor of unity on the main power supply side is discussed. But, this study is not discussed its harmonic nature. The direct control of MC and space vector modulated technique for MC are introduced and also discussing about only Input power factor (Sundareswaran *et al*., 2007; Blasko, 2007; Wells *et al*., 2007). The application of wind energy for matrix converter using DFIG is discussed (Eltamaly, 2008; Agelidis *et al*., 2008). The number of techniques are available to stabilize the output of matrix converter and distortions in the output and discussed (Shi and Hui, 2005; Ray *et al*., 2009; Kjaer *et al*., 2005). Some papers are in optimal allocation of renewable energy system and optimal sizing in hybrid system. But no optimized technique available for improving input power factor and reducing harmonics in load side of micro-grid tied hybrid system (Wai and Wang, 2008; Fei *et al*., 2010).

In the proposed system, harmonic elimination in load and input power factor improvement are achieved by providing GA based optimized inverter from PV system to micro grid and GA based PI controller in wind system connected to same grid. The selective harmonics and THD in the load side is reduced using optimized SHEPWM inverter. Both harmonics reduction and input power factor improvement can be achieved using optimized PI controller in matrix converter. Results proved that optimized converter topologies give better results with conventional converters for grid connected renewable energy sources.

MATERIALS AND METHODS

Grid connected PV system through optimized SHEPWM inverter: This study presents the grid connected photovoltaic system employing the proposed optimized SHEPWM inverter.

Optimized SHEPWM inverter: The unipolar-three level SHEPWM waveform is used to find the appropriate N+1 switching angles so that N number of non triplen odd harmonics such as 5th, 7th, 11th...nth harmonics are eliminated from waveform where n = 3N+1 for N = 2, 4, 6 ... (even) and n = 3 N+2 for N = 1, 3, 5 ... (odd). Assume the waveform is quarter wave symmetry. In this study, optimized switching angles are produced to eliminate the lower order harmonics such as 5, 7, 11 and 13th harmonics. By including both the even and odd number of N, there are multiples of solutions available to reduce selective harmonic content. So far, SHE PWM methods are available for certain odd values of N (Agelidis *et al*., 2006). The output voltage equation of the inverter is:

$$V_o = \sum_{n=1}^{\infty} a_o + \left(a_n \cos n\omega t + b_n \sin n\omega t\right) \quad (1)$$

Where:

a_n = The almost zero for all n

B_n = For odd and even values of n

The range of switching angles is to be between 0 and 90°C. The pulse width modulation pattern with odd values and even values of switching angles are considered. Assume $b_n = V_n$. For odd values of N, Eq. 1 becomes:

$$V(\omega t) = \sum_{n=1,5,7,\ldots} vn \sin n\omega t$$
$$Vn = \frac{4v_{dc}}{n\Pi\left[\sum_{k=1}^{N+1}(-1)^k \cos(n\alpha_k)\right]} \quad (2)$$

The objective function for optimization is:

$$V(\alpha) = \left(|v_1| - 1\right) + |v_5| + |v_7| + |v_{11}| + \ldots |v_{(3N+2)}|$$
$$|v_1|, |v_5|, |v_7|, |v_{11}|, |v_{13}| \ldots |v_{(3N+2)}| < \epsilon \quad (3)$$

For even values of N, Eq. 1 becomes:

$$V(\omega t) = \sum_{N=1,5,7} \ldots vn \sin n\omega t$$
$$Vn = \frac{4v_{dc}}{n\Pi}\left[\sum_{k=1}^{N+1}(-1)^k \cos(n\alpha_k)\right] \quad (4)$$

The objective function for performing optimization process is:

$$V(a) = \left(|v_1| - 1\right) + |v_5| + |v_7| + |v_{11}| + \ldots |v_{(3N+1)}|$$
$$|v_1|, |v_5|, |v_7|, |v_{11}|, |v_{13}| \ldots |v_{3N+1}| < \epsilon \quad (5)$$

The magnitude of the harmonic component for odd and even values of N is given by the Eq. 2 and 4. In that, N (odd/even) is the number of odd harmonics to be

Table 1: Harmonic content in percentage for SHEPWM inverter fed grid through PV system

Harmonics in load voltage	Harmonic content in percentage for optimized SHEPWM inverter fed grid through PV system: Even value of switching angles	Odd value of switching angles
5th	1.28	4.17
7th	8.99	1.37
11th	2.17	5.36
13th	0.17	-

eliminated corresponding switching angles are N+1(even/odd). Till (3N+2)/(3N+1) harmonics have to be eliminated completely from the waveform through calculating the N+1 switching angles for quarter cycle of period. M is the modulation index and it is given by V_1/V_{dc}. V_1 is the fundamental magnitude at a particular modulation index. The values of the modulation index can be varied from 0-1. In the above Eq. 5 V_5, V_7, $V_{11}...V_{(3N+2)}/V_{(3N+1)}$ are the normalized magnitude with respect to fundamental of harmonics to be eliminated (Wells *et al*., 2007).

Then, the arrangement for the switching angles should be given as, α_1, $\alpha_2...\alpha_{N+1}$. The solution, i.e., switching angles must satisfy:

$$\alpha_1 < \alpha_2 < ...\alpha_{N+1} < 90°C$$

The selected individuals should have minimum harmonic distortion and the switching angle should lie between 0 and 90 with desired level of accuracy. For example, N = 4 (even value) number of odd harmonics to be eliminated, N+1 = 5 switching angles are chosen per quarter cycle in the case to eliminate 5, 7, 11 and 13th (till 3N+1=13) harmonics. The switching angles calculated for quarter wave then the rest of angles (for one cycle) can be calculated.

The Genetic algorithm is a search mechanism based on the principle of natural selection and population genetics. The objective function is a measure of performance evaluation. It is describing a measure of effectiveness of eliminating selected order of harmonics. It may be odd or even values of switching angles. Genetic algorithm is performed in MATLAB code (M-file) for the above objective Eq. 3 and 5. Optimized odd (N = 4) and even (N = 3) switching angles are found for different MI.

Grid connected PV system through GA based SHEPWM inverter: A mathematical model of a PV cell is developed using MATLAB Simulink environment and given as the input voltage of 100 V to SHEPWM inverter. The optimized SHEPWM inverter fed to grid through the above modelled PV system is shown in Fig. 1. The projected scheme has been simulated in MATLAB Simulink. The SHEPWM inverter circuit includes a voltage

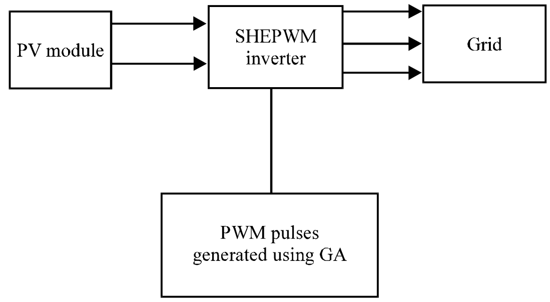

Fig. 1: Block diagram- grid connected PV system through optimized SHEPWM inverter

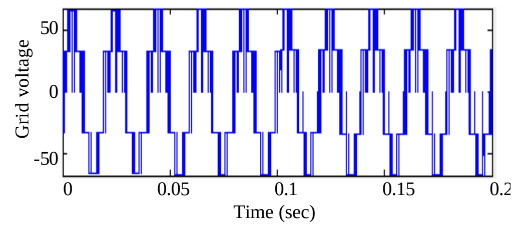

Fig. 2: Output voltage of grid connected PV using optimized SHEPWM inverter

of 100 V and frequency of 50Hz.The output of inverter is connected to 230 V grid through a step up transformer. The objective function in Genetic Algorithm is written in such a way that it reduces 5, 7, 11 and 13th harmonics present in grid based on switching angles (odd/even). The pulse width modulated pulses are generated based on optimized switching angles and given to the three phase inverter (Table 1). The output voltage is shown in Fig. 2.

This SHEPWM inverter is dedicated for 5, 7, 11 and 13th harmonics present in the system. The 5 and 11th harmonics create negative sequences and can cause overheating or the tripping of over-current protection devices. Even value of switching angles is selected for eliminating 5, 11 and 13th harmonics completely. The 7th harmonics causes destructive heating and leads to de-rating of transformer and capacitor bank and also improper operation of voltage balance relay may occur. Selection of odd value of switching angles reduces 7th harmonic completely. According to the applications, either odd or even angle are selected to eliminate selective harmonics (Kulkarni and John, 2013). The above results prove that SHEPWM inverter is best to reduce selective harmonics in the load of grid connected PV system so that THD also reduced.

RESULTS AND DISCUSSION

Experimental results: The validity of the SHEPWM inverter is verified using the prototype. The parameters concerned and the switching angles are the same as that

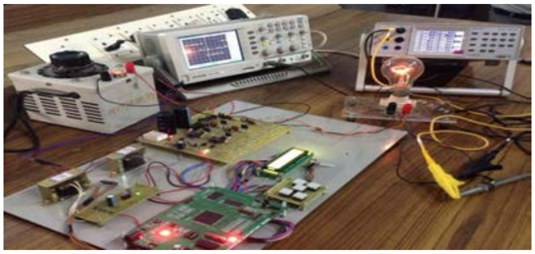

Fig. 3: Experimental setup of SHEPWM inverter

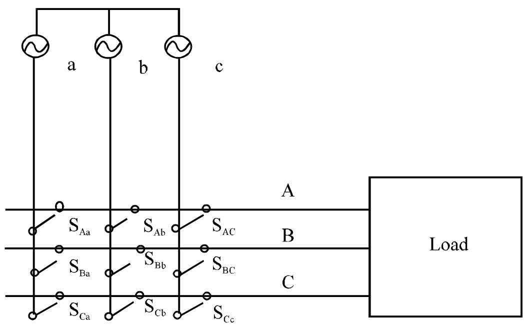

Fig. 4: Matrix converter

employed in the simulation. ADSP-BF533 is used to select the odd or even number of switching angles so that it reduces the selective harmonics in the output. The optimized switching angles are calculated using GA. ADSP-BF533 is programmed in such a way that it produces the pulse according to the given odd or even value of switching angles through keypad. These pulses are given to the inverter IRF840 through MOSFET driver IR2110. By selecting the required pattern using the keypad, corresponding pulses are generated using the DSP thereby producing the suitable triggering pulses that regulate the ON and OFF time of the inverter. According to the application, pattern can be selected so that it reduces the selective harmonics. The above setup is verified with RL load. This technique eliminates the selective harmonic content in the output of the optimized SHEPWM inverter. The experimental setup of SHEPWM inverter is shown in Fig. 3.

Table 2 shows that the harmonic content of the SHEPWM inverter and it is less. Optimized SHEPWM inverter designed in this section is used for the proposed system to connect PV system to micro-grid.

Grid connected wind energy system through GA based matrix converter

Optimized matrix converter: The switching function of the switches, $S_{kj}(t)$ in the above matrix converter is defined as "1" when it is ON and defined as "0" when it is OFF (Fig. 4).

Table 2: SHEPWM inverter harmonic content (experimental value)

Harmonic content	Harmonic content of SHEPWM inverter
V5	6.292
V7	19.871
V11	4.664
V13	5.080

$$S_{kj}(t) = \begin{cases} 1 \\ 0 \end{cases} \text{for} k \in \{a, b, c\} \text{ and } j \in \{A, B, C\} \quad (6)$$

The constraint of the switches is expressed by the following Eq. 7:

$$S_{aj} + S_{bj} + S_{cj} = 1 \text{for} j \in \{A, B, C\} \quad (7)$$

With the above constraints, in the matrix converter there are 27 different switching combinations for connecting output phase to input phases if the above mentioned combinations can be analyzed in three groups as shown in Table 3 from 512 possible combinations. The space vector modulation technique is a mathematical model which is using 27 switching combinations out of 512 switching combinations. The duty cycles of the switches are modulated for various voltage transfer ratio and finally, it is increased from 0.5-0.866 by using this modulation technique. And, this method active switching combinations with 3 zero switching combinations to complete one full cycle (Azmi *et al*., 2013). For each switching combinations, the input and output line voltages can be expressed in terms of space vectors as:

$$V_i = \frac{2}{3\left(v_{ab} + v_{bc} e^{\frac{j2\pi}{?}} + v_{ca} e^{\frac{j4\pi}{?}}\right)} = v_i e^{j\alpha i} \quad (8)$$

$$V_i = \frac{2}{3\left(v_{ab} + v_{bc} e^{\frac{j2\pi}{?}} + v_{ca} e^{\frac{j4\pi}{?}}\right)} = v_o e^{j\alpha o} \quad (9)$$

Group 1: Each output phase is directly connected to the three input phases in turns with six switching combinations. In this case, the phase angle of output voltage vector and input voltage vector depend on each other. Similar condition is valid for current vectors too. For the SVM technique, these switching states are not used in the matrix converter because the phase angle of both the vectors cannot be controlled independently.

Group 2: There are 18 switching combinations in this group in which the active voltage vector is created at variable amplitude and frequency. Amplitude of the output voltages depend on the chosen input line voltages. In this case, the phase angles of the output voltage space vector and the input voltage space vector are independent of each other. Similar condition is applicable for current vectors too.

Group 3: It having three switching combinations consists of zero vectors. In this case, all th e output phases are connected to the same input phase. For balanced three-phase input voltages, the neutral voltage is equal to zero mathematical the relationship of the input voltages can be expressed as:

$$V_a + V_b + V_c = 0$$

The output phase voltage of the matrix converter is a product of the switching function and the input phase voltages given by Eq. 10:

$$\begin{bmatrix} V_A \\ V_B \\ V_c \end{bmatrix} = \begin{bmatrix} S_{aA} & S_{bA} & S_{cA} \\ S_{aE} & S_{bE} & S_{cB} \\ S_{ac} & S_{bc} & S_{cC} \end{bmatrix} \times \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (10)$$

The input line and output line currents can be written as:

$$i_i = 2/3\left(i_a + i_b e^{j2\Pi/3} + i_c e^{j4\Pi/3}\right) = I_i e^{j\infty i} \quad (11)$$

$$i_o = 2/3\left(i_A + i_B e^{j2\Pi/3} + i_C e^{j4\Pi/3}\right) = I_o e^{jBo} \quad (12)$$

Grid connected wind energy system through matrix converter with optimized PI controller: The general circuit of the matrix converter contains wind energy system with phase voltage of 100 V. The matrix converter consist of nine bi-directional switches in which each switch is comprises of two IGBTs connected in anti-parallel. The output of matrix converter is connected to grid at point of common couplin.

The grid is composed of programmable voltage source of 100V phase-phase voltage with source inductance. Input power factor varies for different load conditions. It is poor for light load condition and is nearly unity under normal or heavy output loads. So, the above set up is analyzed with light load and normal load condition.THD and lower order harmonics of load are also high under any load condition in matrix converter fed grid. Space vector modulation control technique is used for matrix converter.

In the above general circuit, Genetic Algorithm (GA) based optimized PI controller is introduced in gate pulse generation side to improve input power factor and reduce harmonic distortion. Compensation angle of modulating signals given to SVM decides its output and input performance. Figure 5 and 6 shows the matrix converter fed grid with optimized PI controller.

Table 3: Genetic algorithm program parameters

Parameters	Values
Initial population size	50
Maximum number of generation	50
Probability of cross over	0.5
Mutation probability	0.035
Performance measure	Compensating angle

The objective function is a measure of performance evaluation. It is describing a measure of effectiveness of improving power factor and reducing harmonics. Genetic algorithm is performed in MATLAB code for the objective Eq. 13. The compensation angle for modulation signals is decided by:

$$\delta comp = \left(k_p + \frac{k_i}{s}\right)\Delta e \quad (13)$$

Where:

Δe = The error signal
K_p = The proportional gain
K_i = The integral gain

The value of compensated angle δcomp is maintained between the values 0 and δ max.The Δe is the difference between actual phase angle between input voltage and current of matrix converter and reference phase angle. The suitable values of Kp and Ki are obtained using GA. The obtained compensated angle is fed as angle difference between the modulation signals of SVM generation technique. The input power factor and Harmonics are analyzed under different load conditions. For satisfactory results Genetic algorithm program parameters are as follows in Table 3.

The K_p and K_i values found for better result are 0.12 and 1, respectively. In this proposed work, the compensating period required to maintain a high power factor is same as the PWM sampling period (Tpf = Ts). As the output changes within the range of light load conditions, the PI still functions well in terms of the steady-state and dynamic performance achievement of the input side. Furthermore, this proposed method is independent on the input filter and power supply parameters which are quite sensitive during practical operations.

Under light load condition: The matrix converter fed grid with optimized PI controller is verified with light load. The load side output voltage and output current for this case are shown in Fig. 4 and 6, respectively. Comparing the FFT analysis waveforms of matrix converter with PI controller to the FFT analysis waveform of matrix converter without PI controller, the output with PI

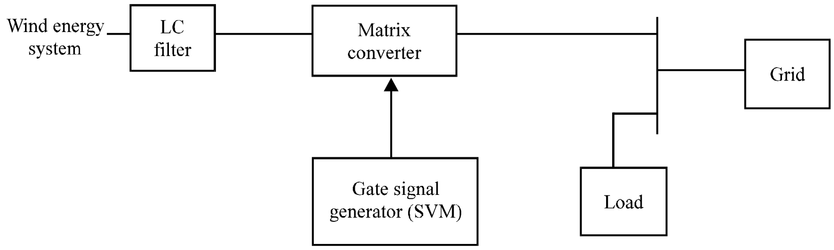

Fig. 5: Matrix converter fed grid without PI controller

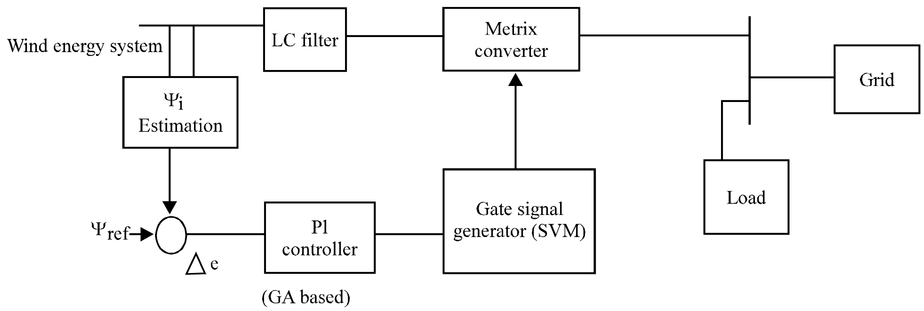

Fig. 6: Matrix converter fed Grid from wind energy system with optimized PI controller

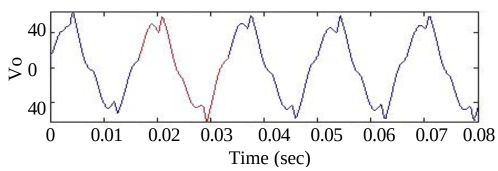

Fig. 7: Output voltage of MC fed grid with PI controller under light load condition

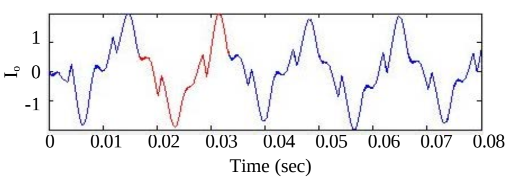

Fig. 8: Output current of MC fed grid with PI controller under light load condition

controller is better in increased input power factor of 0.921. And also, the overall output voltage THD value is reduced from 20.01-16.23%. The current THD is reduced to 38.6%. The lower order harmonics are also reduced and discussed in next study.

Under normal load condition: The general circuit is verified with normal load condition. There is no problem of low power factor on input side. But, harmonics are reduced more. The voltage THD value is reduced from

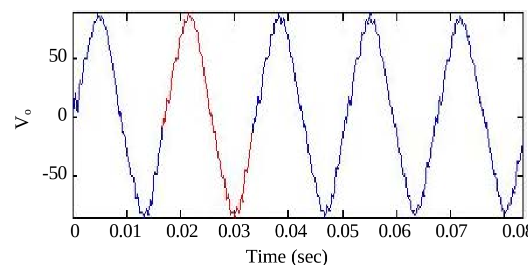

Fig. 9: Output voltage of MC fed grid with PI controller under normal load condition

13.03-7.82% with the help of optimized PI controller. The current THD is reduced from 15.56-7.53%. The input power factor is nearly one. The voltage transfer gain is also better compared to circuit without PI controller. The load side output voltage and output current for this case are shown in Fig. 7 and 8, respectively.

Figure 9 shows the comparison of input power factor matrix converter under light load condition with optimized PI controller. The value of input power factor without PI controller is 0.608 and with PI controller is 0.921. The power factor is improved by 50%.

Figure 10 and 11 shows the lower order harmonics for converter without PI controller and with PI controller. Figure 12 shows the comparison of both. The comparison of overall THD values for converter without and with PI controller is shown in Fig. 13.

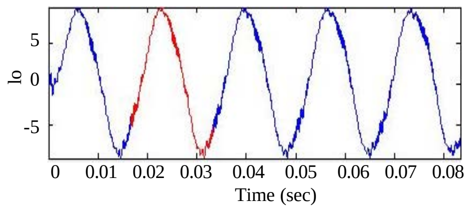

Fig. 10: Output current of MC fed grid with PI controller under normal load condition

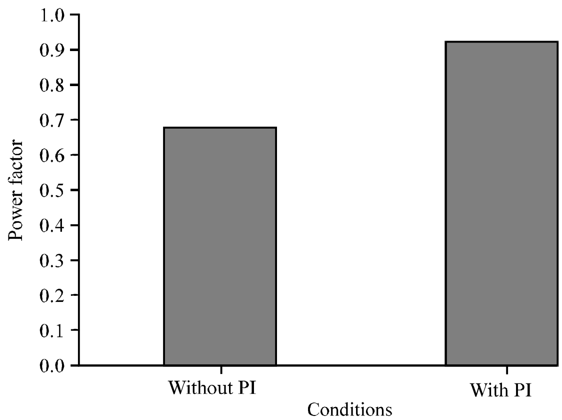

Fig. 11: Input power factor under light load condition

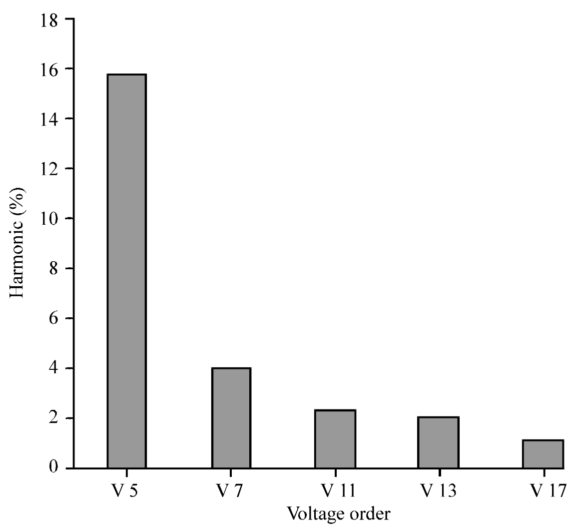

Fig. 12: Lower order harmonics without PI controller under light load condition

The input power factor is nearly one in MC fed Grid with and without PI controller. Figure 14 and 15 show the lower order harmonics of matrix converter under normal load condition without and with PI controller. The comparison of both is shown in Fig. 16 and 17 shows the overall THD in both the case.

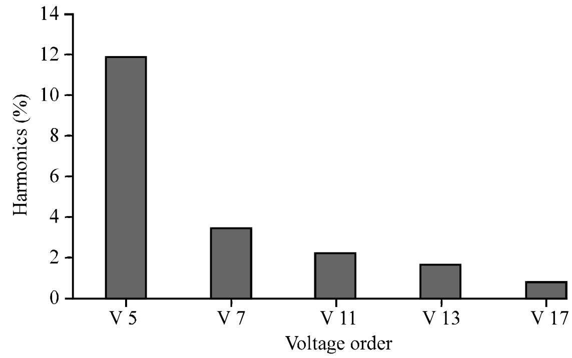

Fig. 13: Lower order harmonics with PI controller under light load condition

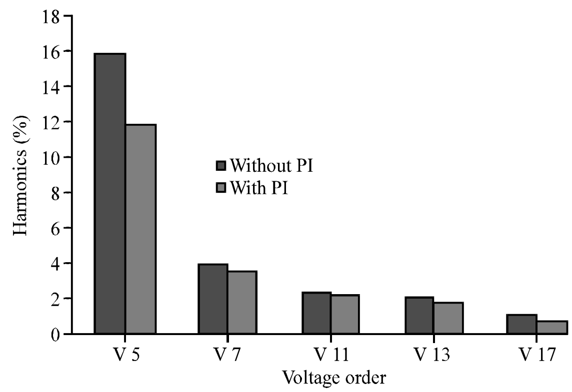

Fig. 14: Comparison of lower order harmonics under light load condition

Table 4: Comparison of THD, IPF and lower order harmonics under light load condition

Matrix converter	Input power factor	V_5	V_7	V_{11}	V_{13}	V_{17}
Without PI controller	0.608	15.75	3.98	2.31	2.05	1.10
With PI controller	0.921	11.81	3.54	2.21	1.72	0.79

Table 5: Comparison of voltage and current thd under light load condition

Matrix converter	Overall voltage THD%	Overall current THD%
Without PI controller	20.01	40.16
With PI controller	16.23	38.99

From the above results the performances of MC fed grid under light (1.5A) and normal load (10A)condition in terms of input power factor, THD and lower order harmonics are improved by optimized PI controller design. The proposed work has been used in MC fed grid under any load condition. Table 4 and 5 shows the comparison of THD, input power factor and lower order harmonics of matrix converter without and with PI controller under light load condition (Fig. 18 and 19).

Table 6 and 7 show the comparison of THD, IPF and lower order harmonics of matrix converter without and

Table 6: Comparison of THD and lower order harmonics under normal load condition

Matrix converter	Overall voltage THD	V_5	V_7	V_{11}	V_{13}	V_{17}
Without PI controller	13.03	0.35	0.84	1.17	0.91	0.84
With PI controller	7.82	0.02	0.83	1.10	0.89	0.55

Table 7: Comparison of voltage and current THD under normal load condition

Matrix converter	Overall voltage THD (%)	Overall current THD%
Without PI controller	13.03	15.56
With PI controller	7.82	7.53

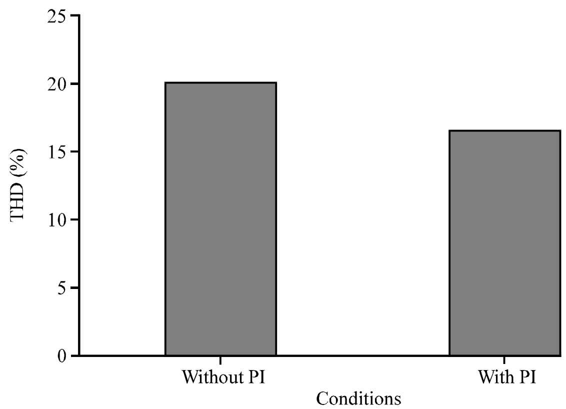

Fig. 15: Comparison of overall Voltage THD values under light load condition

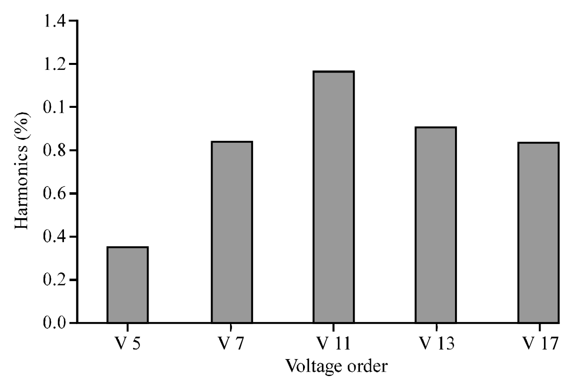

Fig. 16: Lower order harmonics without PI controller under normal load condition

with PI controller under normal load condition. From the above tables, it is observed that the values of overall voltage and current THD and lower order harmonics are less for matrix converter from Wind energy system connected to grid with optimized PI controller than without PI controller under any load condition. The input power factor for matrix converter fed grid is improved for light load value by introducing optimized PI controller.

The above results prove that optimized matrix converter gives best result at any load condition for grid connected wind energy conversion system.

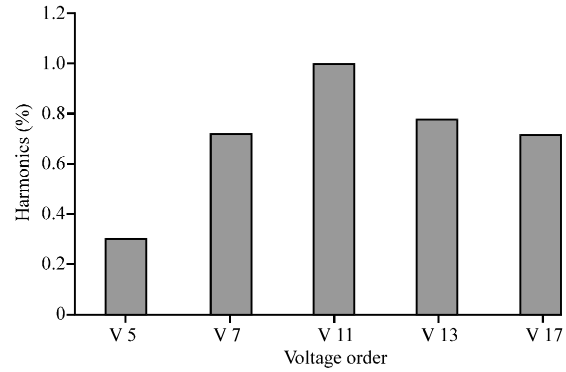

Fig. 17: Lower order harmonics with PI controller under normal laod condition

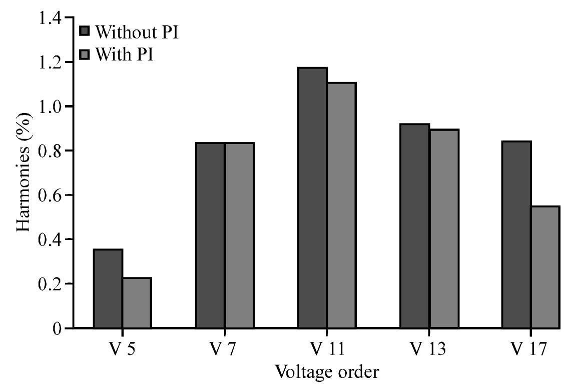

Fig. 18: Comparison of lower order harmonics under normal load condition

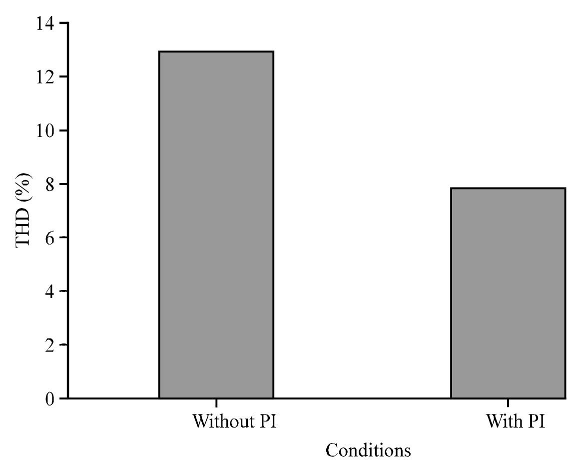

Fig. 19: Comparison of overall voltage THD value under normal load condition

Table 8: THD and selective harmonics in matrix converter output

Matrix converter	Overall voltage THD (%)	V 5	V 7	V 11	V 13	Input power factor
With optimised PI controller	3.7	3.1	0.6	0.1%	0.3%	0.91

Table 9: THD and selective harmonics in load side of hybrid system

Harmonic order	Output load voltage harmonics	Output load current harmonics
5	0.09	0.10
7	0.06	0.07
11	0.03	0.04
13	0.03	0.03
17	0.02	0.03
THD	0.56	0.63

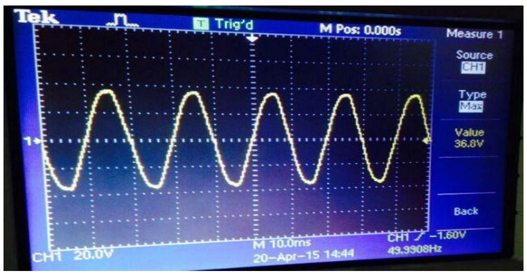

Fig. 20: Output waveform (experimental)

Experimental results: The validity of the Matrix converter is verified using prototype. This prototype consists of AC supply source which is given to the matrix converter. In matrix converter operation, AC supply is given to the zero crossing detector and the reference signal is given to the PIC Microcontroller 16F877A. In PIC, the carrier signal and the reference signals are compared and the PWM signals are produced and these signals send to the driver circuit where the gate pulse created to switching the respective MOSFET switches. The output is verified for RL load. The input voltage is set as 50V. The above simulation set up is implemented and the output voltage is tabulated. Figure 20 shows the output waveform for the experimental setup.

Table 8 results prove that matrix converter fed system provides reduced harmonic distortion and improved input power factor. The optimized matrix converter is selected for wind energy system connected to grid. The optimized matrix converter designed in this section is selected for the proposed system to connect wind energy system to Micro-grid.

Proposed system: The performance of the grid connected Renewable energy sources (solar or wind system) is validated using above mentioned optimized converters individually in the previous sections. In the proposed scheme, performance improvement is achieved by providing GA based optimized SHEPWM inverter (odd values of switching angles) from PV system to micro grid and the optimized matrix converter from Wind energy system to same grid. Genetic algorithm is used to find the optimal solution of switching angles for SHEPWM inverter and to optimize the PI controller by proper design of compensation angle. The proposed system is to reduce selective harmonics and THD in the load side using optimized SHEPWM inverter (odd number of switching angle) and optimized matrix converter which is coupled to the same grid. This system of different converters topology in a grid offers the best results. The overall circuit of proposed scheme is shown in Fig. 21.

Micro-Grid modelling is done using MATLAB Simulink with a voltage of 230V. Modelling of optimized SHEPWM inverter and optimized Matrix converter are taken from previous section with same specifications. The micro grid connected photovoltaic generation systems and wind energy conversion system through optimized converters is simulated and the results are obtained. The ouput voltage is measured on the load side of the micro grid. The specifications of proposed system are as follows:

SHEPWM inverter:

- Input voltage; 100V (from PV cells)
- Inverter output voltage; 100 V
- Frequency; 50 HZ
- No. of switching angles; 5
- Harmonics to be eliminated; till 13th harmonics

Matrix converter:

- Input voltage; 100 V (from wind mill)
- Converter output voltage; 100 V
- Load
- Real power; 1000 W
- Reactive power; 100K VAR

Micro-grid:

- Number of renewable energy sources connected; 2 (wind and solar system)
- Grid voltage; 230 V, 50 Hz, Three phase

Figure 22 and 23 shows the FFT analysis of load connected to grid.

Table 9 shows the THD and lower harmonics in load side of grid connected renewable energy sources fed

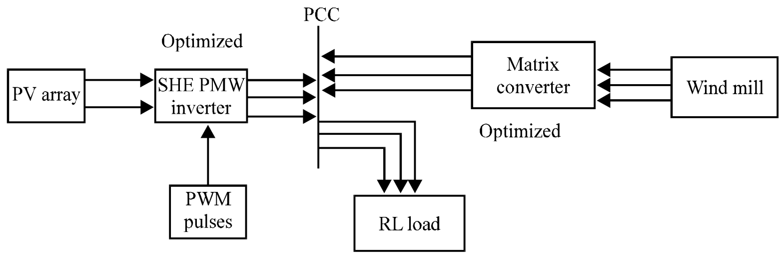

Fig. 21: Overall circuit for proposed system

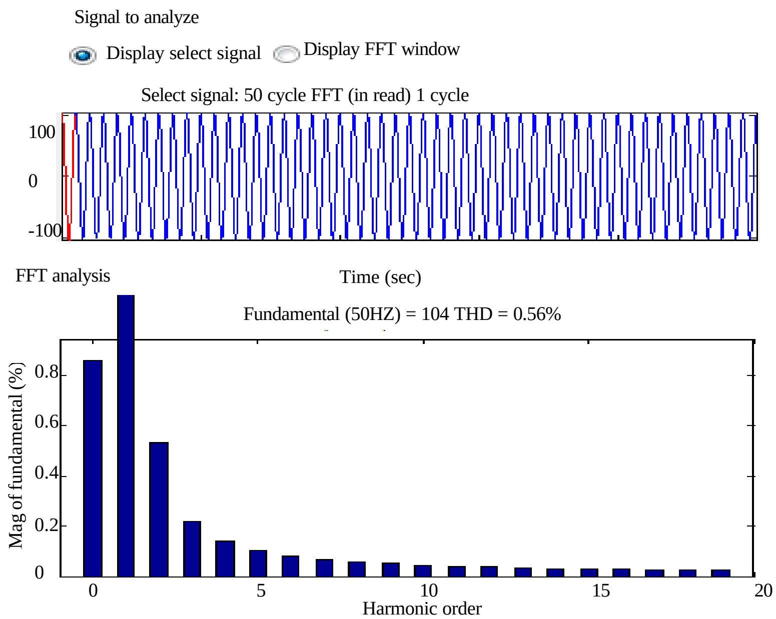

Fig. 22: FFT analysis of load voltage

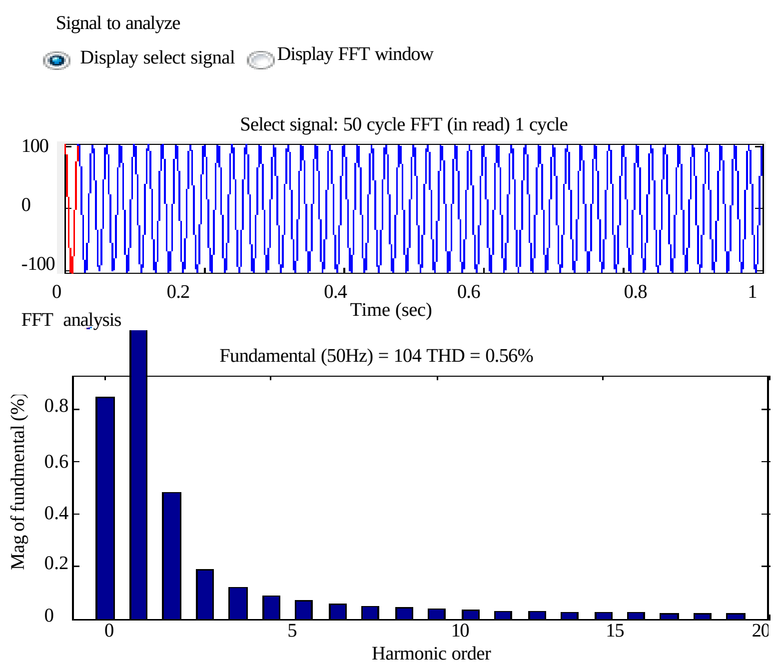

Fig. 23: FFT analysis of load current

through optimized SHEPWM inverter and optimised Matrix converter. The input power factor of matrix converter is 0.871. From the above results, it is proved that grid connected PV system through SHEPWM inverter and wind mill fed through optimised matrix converter provide reduced THD and selective harmonics and improved power factor.

CONCLUSION

A novel approach to reduce the lower order harmonics, total harmonic distortion in load and to improve input power factor of the system connected to grid is proposed in this research study. The grid connected photovoltaic generation system coupled to SHEPWM inverter tends to be a better solution compared to that of conventional inverter coupled to the grid in the reduction of lower order harmonics. Matrix converter fed grid from wind system is capable of operating at high power factor under any load condition with reduced harmonic distortion using optimized PI controller. In the proposed method, the micro grid connected photovoltaic generation system and wind energy system coupled through SHEPWM inverter and matrix converter offers much less THD and lower order harmonics in comparison with usage of conventional converter connected with the grid. The simulated results of proposed system proved that total harmonic Distortion as well as lower order harmonics (5, 7, 11, 13th) are reduced in the load connected to micro grid and also input power factor is improved. Selective harmonics in proposed method satisfies the harmonic distortions of grid code requirement. According to the assortment of harmonics to be eliminated either odd or even, switching angles are selected. This is useful when some optional harmonics are held undisturbed and other harmonics has to be removed from the output.

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