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Hybrid Modulation for Reduced Switches AC-AC Multi Frequency Converter

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Abstract

This paper presents the Hybrid Modulation Technique for single phase AC-AC multi-Frequency converter to overcome the local square wave overshoot in output waveform which are responsible for harmonics content in converter and to get better smooth voltage waveform. And also, by using SPWM (Sinusoidal Pulse Width Modulation) and TPWM (Trapezoidal Pulse Width Modulation) a comparative analysis is done; it shows how converters behave with different modulation technique. The detail study of converter and modulation techniques are done here with including operation, block diagram and mathematical calculations. All the studies and experimental operation are performed by using MATLAB Simulink model simulation and the switch is used for converter is MOSFET

1. Introduction

Variable frequency-converter widely used in many applications such as speed control in motor and traction, AC drives, induction heating and Static VAr (Mondol and Halim Wang M. Kumar). Cyclo-converter is variable frequency converter, able to convert the input power at one frequency to output power at another frequency. Traditional single phase Cyclo-converter has 4 thyristor switches which produce significant harmonics and non-standard frequency components in their output voltages thus development of Cyclo-converter is kept on going to improve its performance. There are many cyclo-converter circuit available in market like traditional cycloconverter, Matrix converter (Aarthil and Porselvi Naveenchandran and Vijayaraghavan) or AC-AC converter (Agarwal et al. Ranjan and Vinit). Matrix converter is multiple conversion devise having 4 bi-directional switches for operation, but all of these converters have a greater number of switches, by this high switching and conduction losses are there. AC-AC multi-frequency converter (Agarwal and A. Kumar) is newly proposed multi-purpose converter with reduced number of switches, it has only two switches for different conversion operations. Switches are used for converter is either MOSFET or IGBT. AC-AC multi-frequency converter can be used as rectifiers, cycloconverter or as voltage variable. But converter have some limitation such as it has high THD (Falah) and this can be reduced by using modulation (Singh and Agarwal Bayındır). So, to improve the performance of converter different modulation techniques such as SPWM and TPWM are applied to converter but results are not so effective so, a hybrid modulation (Rahman and Syed Ye M. S. Uddin, Biswas, and Hosain) technique is applied to converter for better result. Previously we have number of converters (M. Uddin and Shihab) with modified circuit

but all those converters have major problem is large no of switches. Novelty of this paper is, different modulation technique is used for converter and by studies of this a hybrid modulation is applied to converter. In this paper a detail study of converter is done in section 1, diffident modulation techniques are in section 2 hybrid modulation study and waveform are in section 3, section 4 includes simulation and results, the comparative analysis is done in section 5 and finally all experimental results are concluded

2. AC-AC Multi-Frequency Converter

AC-AC Multi frequency converter (AAMFC) is used for multiple conversion using one circuit and a smaller number of switches. Multi conversion uses soft switching (i.e., MOSFET, IGBT), with less number and lower gate complexity. The circuit diagram of AC-AC multi-Frequency converter shown in Fig.1. Since the number of switches is less so the losses decreased and by this efficiency will improve. The topology proposed step up and step down Cyclo-converter. The circuit consist two soft semiconductor switches (MOSFET, IGBT), four power diodes and a center-tapped transformer. Switch can operate according to the desired application with less gate circuit complexity. Switching frequency is set equal to output frequency with half of duty cycle during the operation of Cyclo-converter. AC- AC Multi Converter only 4 modes of operation for any conversion, taking as example AC-AC multi-Frequency converter as step down cycloconverter of 25Hz the operating modes of converter shows in table 1. at any time of instant only one switch will conduct with any one diode allow to flow current through it. The center tapped transformer provides isolation between supply and load circuit. When we apply the input with constant frequency to converter, we will able to get variable frequency at output side by the help of switches applying gate pulse accordingly.

2.1. *Operating Modes of Reduced Switches AC-AC Multi Frequency Converter*

The operation of converter is discussed here, it has 4 modes of operation as shown in fig.2. table 1 shows the Operating mode with conducting duration of switches and diode

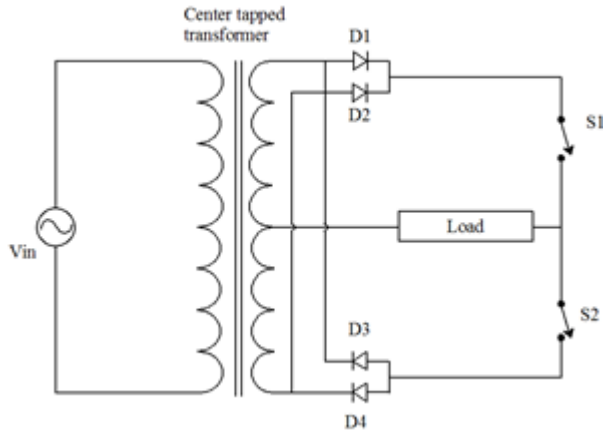

FIGURE 1. Circuit diagram of Reduced Switches AC-AC Multi Frequency Converter

2.1.1. Mode1: 0<t<t1

In this mode converter are conducts for cycle of 0 to pi, the input cycle is positive and sinusoidal, the S1 (switch) and D1 (diode) will conduct and continued to conduct to t_1. Conduction of current follows the path T/F winding 2 – D1- S1- LOAD- T/F winding2 as shown in fig.2(a)

2.1.2. Mode2: t1<t<t2

In this mode converter conduct for duration of pi to 2pi input cycle become negative S1 and D2 will conduct. In fig.2 (b) the current path is T/F winding3 – D2- S1- LOAD- T/F winding3.

2.1.3. Mode3: t2<t<t3

In mode conduction duration is for 2pi to 3pi input cycle become positive again and S2 and D4 will conduct. The path of current is T/F winding 2 – LOAD-S2-D4-T/F winding2 as shown in fig.2(c)

2.1.4. Mode4: t3<t<t4

In this mode conduction duration for 3pi to 4pi input cycle become negative, S2 and D3 will conduct for this mode. Current path will be T/F winding3–LOAD-S2-D3- T/F winding3 as shown in fig.2(d)

3. Modulation Techniques

Modulation technique are used to improve the output waveform in converters and inverters, also it reduces the THD and losses and its gives better controllability on converter, there are various modulation technique are available such as SPWM, TPWM etc. Some of the modulation techniques are used in this paper for AC-AC multifrequency converter.

TABLE 1. Operating Modes

Mode	Duration	Conducting Devices
1	$0<t<t_1$	S1 and D1
2	$t_1<t<t_2$	S1 and D2
3	$t_2<t<t_3$	S2 and D4
4	$t_3<t<t_4$	S2 and D3

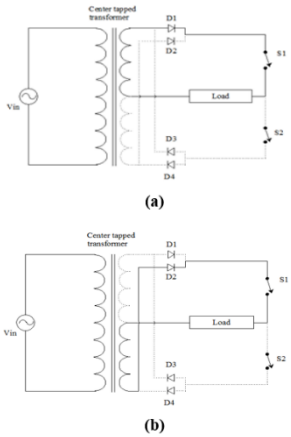

FIGURE 2. Operating modes of AC-AC multi-Converter (a) mode1 (b) mode2

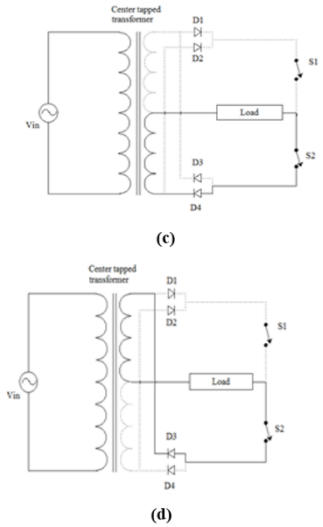

FIGURE 3. Operating modes of AC-AC multi-Converter (c) mode3 (d)mode4

The main purpose of using these techniques is to produce better output wave form, these techniques are modelled to control the switching of converters in order to get voltage waveform as near to sine wave. Using modulation technique, we have following advantages:

1. It increases the amount of fundamental comments
2. Reduce the harmonics
3. Reduce the switching losses
4. Gives the better controllability
5. It is easier to implement

3.1. Single Pulse Width Modulation

In single PWM having one pulse in per upper and lower half cycle as shown in fig.3 width of pulse is control by triangular signal, by varying $A_c$the width of gate pulse also gets changes. The gate pulse is generated by comparing rectangular reference signal amplitude $A_{ref}$to triangular carrier pulse of amplitude is A_c. the frequency f_{ref} of reference signal is same as output frequency of converter and frequency f_c of carrier wave generally high in range of kHz. The pulse of width is control by varying the ratio of A_{ref} to A_c known as modulation index

$M = A_{ref} / A_c$ .....(1)

The M lies in the range of 0 to 1.

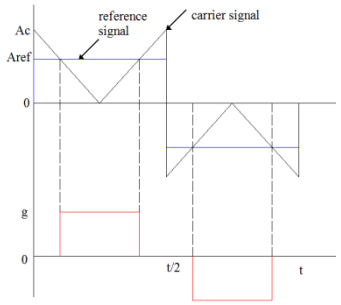

FIGURE 4. Single Pulse Width Modulation

3.2. Sinusoidal Pulse Width Modulation

In the Sinusoidal Pulse Width Modulation (SPWM), reference signal is sinusoidal wave the gate pulse shown in fig.4 the gate pulse is produced by comparing sin wave with triangular carrier wave of frequency $f_{c.}$ Reference signal has frequency $f_{ref}$is same as output frequency $f_{o.}$ SPWM is used in Industrial Application. The number of pulses in half cycle depends on $f_{c.}$ The output voltage is varied by varying the modulation index.

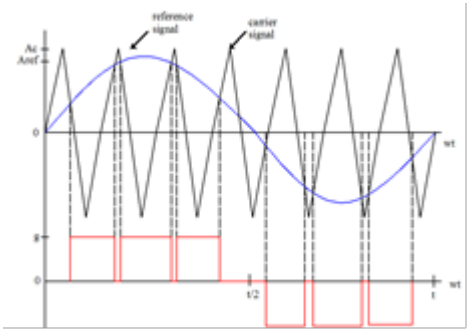

FIGURE 5. Sinusoidal Pulse Width Modulation

3.3. Trapezoidal Modulation

The gate signal is generated by comparing a triangular carrier wave with trapezoidal signal. This technique come under advanced modulation technique. The trapezoidal wave is obtained by limiting triangular wave magnitude to $\pm A_{ref.}$ The frequency of f trapezoidal is the $f_r$same as the output frequency and triangular carrier wave frequency is in the range of kilo Hz.

$A_{ref} = A_{ref}(max)$ .....(2)

Where,

$A_{ref}(max)$ = triangular wave amplitude

= triangular factor

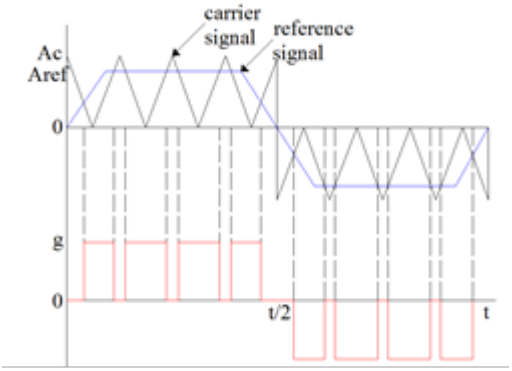

FIGURE 6. Trapezoidal Pulse Width Modulation

4. Hybrid Modulation

In the hybrid modulation technique gate pulse is generated by 3 stages as shown in block diagram of hybrid modulation fig.6. 1^{st} stage sinusoidal signal of frequency (f_{ref}) is compared with positive triangular pulse (V_{c1}) and negative triangular pulse (V_{c1-}) then generated waveform is subtracted by positive pulse from negative pulse this will give quasi square wave form now this quasi square waveform is subtracted from sinusoidal waveform this will give the reference wave form (V_{ref}) as shown in fig.7 now these reference signal is compares with triangular wave this will give the generating gate pulse (V_g) and it will give to switches S1 and S2. Frequency of carrier is 10 kHz is chosen for this converter. Voltage output performs sinusoidal pulse width modulation (SPWM) by using a sine wave and compare with positive and negative carriers' wave (V_{c1}) and (V_{c1-}) by this we are obtaining signals of the switching. The amplitude of carrier (V_{c1}) and (V_{c1-}) is 1 unit, (V_{c1-}), and the phase difference is 180.

The modulation waveform shown in fig7, SPWM (Sinusoidal Pulse Width Modulation) is done by using sine wave of vm amplitude and positive (V_{c1}) and negative (V_{c1-}) carrier wave with the amplitude is $V_{c1.}$ Hybrid modulation will reduce the overmodulation that will help to minimize local square in output wave form and quality will improve.

S1= $V_m \sin\omega t$

V_{c1}= triangular pulse of amplitude 1 shifted by 1 at upward having frequency of 10 kHz

V_{c1-}= triangular pulse of amplitude of 1 and shifted downward by 1 having frequency of 10 kHz

K= 2

Vc_2= triangular pulse of amplitude 1.8 with frequency of 10 kHz

V_m=4

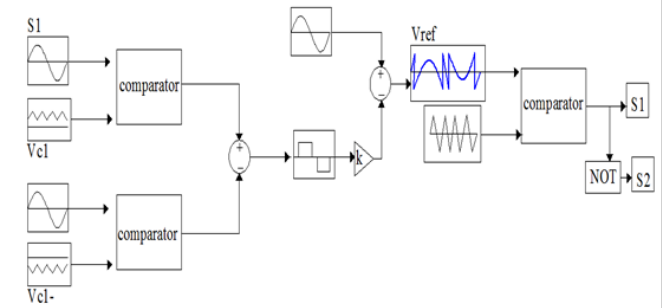

FIGURE 7. Block diagram of Hybrid Modulation

5. Simulation and Results

The simulations are performed on MATLAB software and all the results are shown below. To perform the operation, we chose MOSFET as switch, to complete all the 4 mode of operation 4 DIODES are used in circuit with three winding linear transformers. Load is taken as resistive load with the value is 10 ohms. Generating pulse is provided according to

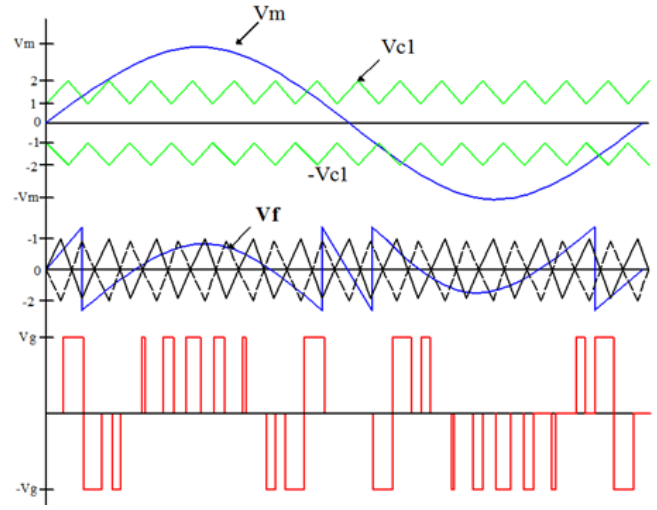

FIGURE 8. Waveform of Hybrid Modulation

table 1 using pulse generator having pulse width of 50 %. For the simulation, Simulink model is formed by using MATLB software following parameters are used shown below in table 2. Fig.8 show the output waveform of AC-AC multi-Frequency converter as step down frequency of 12.5Hz the input data given as V_{in}= 230 volts,50 Hz. Now the converter works as step-up frequency of 200Hz shown in fig.9 the input parameters same as given in previous case.

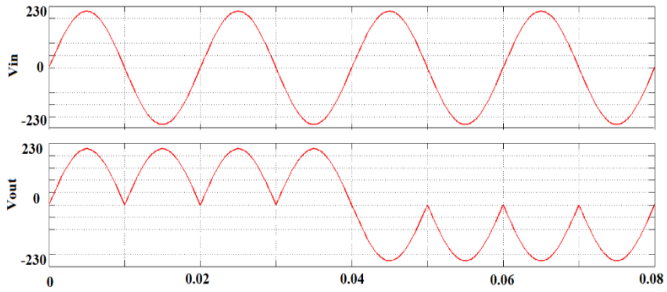

FIGURE 9. waveform of AAMFC with output frequency 12.5Hz

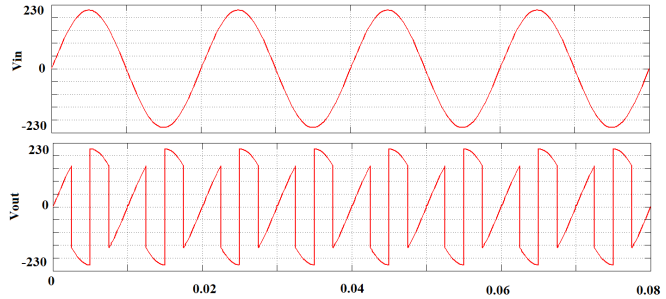

FIGURE 10. waveform of AAMFC with output frequency 200H z

Now the Sinusoidal Pulse Width Modulation is introduced in converter, and we can reduce the harmonic component of converter. In SPWM module index (M) is taken as 0.8 and carrier frequency is 10k Hz is provided. Fig.10-fig 13 shown the THD of converter for different frequencies, by using SPWM we able to reduce Higher order harmonics components but still there is lower order harmonics as can be seen in fig.

To eliminate harmonics an advanced modulation technique i.e. Trapezoidal Pulse width modulation is performed in converter the gate pule is generated by comparing trapezoidal signal of magnitude ± 0.7 (A_{ref}) to triangular carrier with magnitude of 1unit. Frequency of carrier is 10 kHz. With TPWM we can able achieve low THD is 53.64%, 54.73%, 60.36% and 60.64% for frequencies 12.5Hz, 25Hz, 100Hz and 200Hz respectively as shown in fig,14-fig.17 THD of converter with TPWM, but still the results are not satisfying and, in this technique, we are getting higher order harmonics as shown in figures.

So, to minimize THD we go with Hybrid modulation, we can reduced low order harmonics such as $3^{rd,}$ 5^{th} and 7 harmonics and also almost negligible higher order harmonics this is achieved by making two stage modulation as discussed in hybrid modulation technique above, we able to achieve reduce THD 20-30 % of previous Modulation technique. Fig18-21 shows the THD of frequencies 100Hz, 200Hz, 12.5Hz and 25Hz.

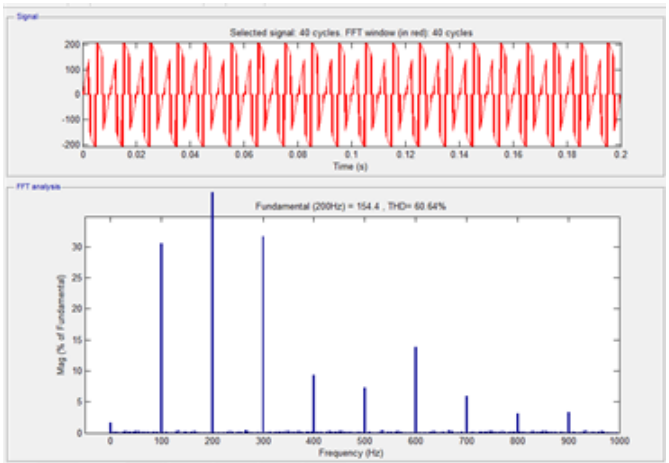

FIGURE 11. THD of AAMFC with SPWM at output frequency 200 Hz

6. Comparative Analysis

Multi converter has fewer switches, has reduce conduction and switching losses, overall losses also

TABLE 2. Parameters and Values

Parameters	Values
AC Power Supply (V_{in})	230 volts
AC Input Frequency (f_{in})	50Hz
Load Resistance (R)	10Ω
Modulation (m)	0.9

TABLE 3. Comparative Table

Frequency (Hz)	Without Modulation	SPWM	TPWM	Hybrid Modulation
12.5	70.62%	63.10%	53.64%	69.99%
25	62.60%	60.42%	54.73%	62.00%
100	62.60%	54.95%	60.36%	43.39%
200	62.75%	52.56%	60.64%	43.55%

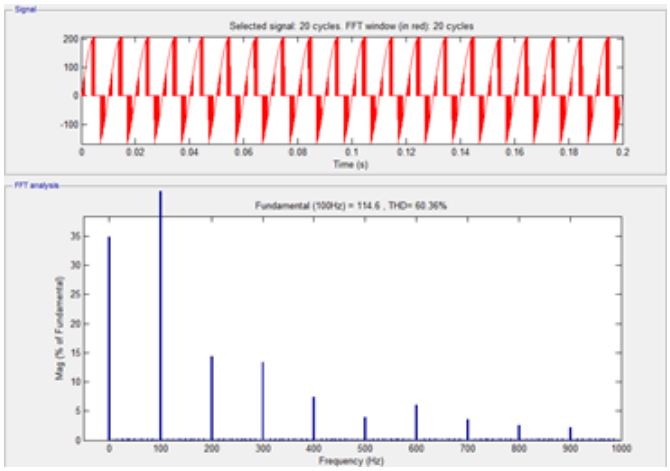

FIGURE 12. THD of AAMFC with SPWM at output frequency 100 Hz

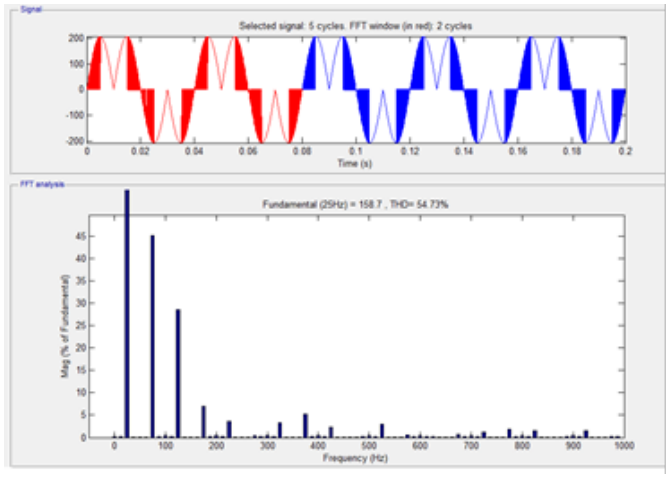

FIGURE 13. THD of AAMFC with SPWM at output frequency 25Hz

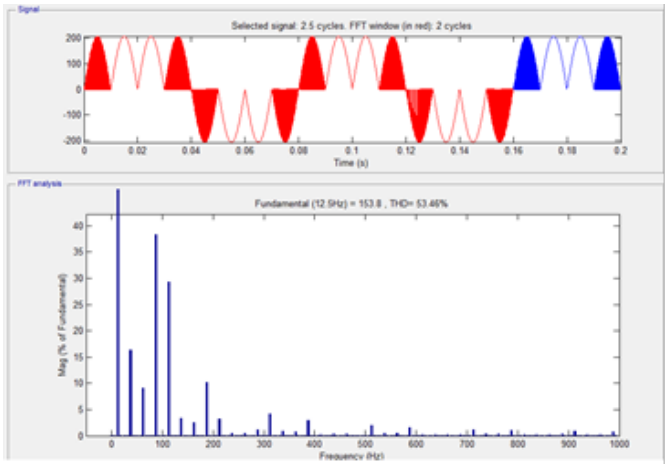

FIGURE 14. THD of AAMFC with SPWM at output frequency 12.5 Hz

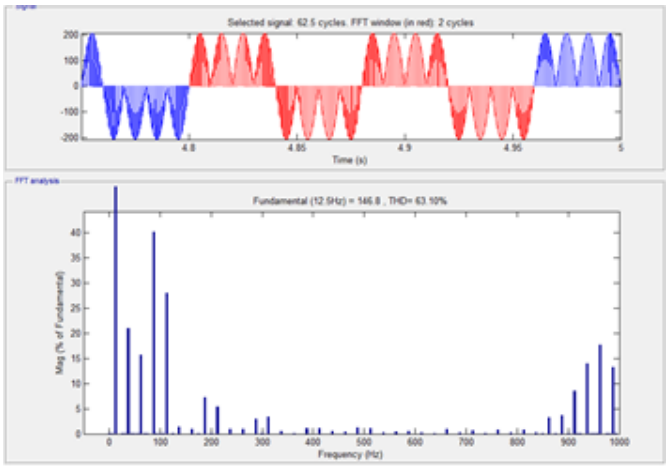

FIGURE 15. THD of AAMFC with TPWM at output frequency 12.5 Hz

got reduced, and by this efficiency is increased and hence performance of converter is improved in Multi converter. The multi converter has less gate complexity, simpler in design, and compact in size. The performance of converter is improved by using PWM techniques. SPWM is not more

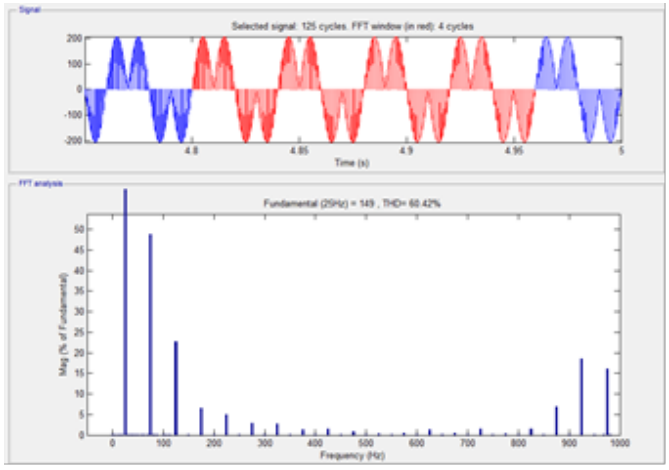

FIGURE 16. THD of AAMFC with TPWM at output frequency 25 Hz

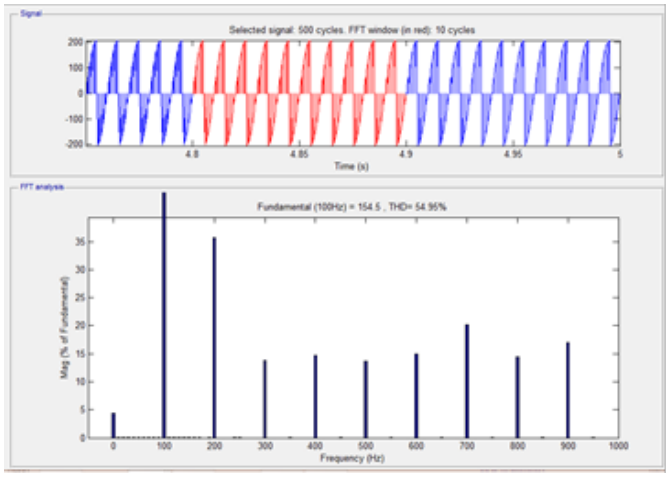

FIGURE 17. THD of AAMFC with TPWM at output frequency 100 Hz

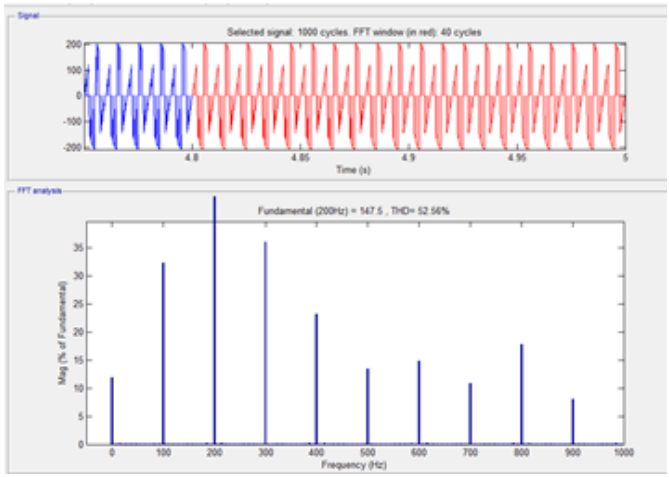

FIGURE 18. THD of AAMFC with TPWM at output frequency 200 Hz

effective to converter whereas TPWM is more effective in lower order frequency output shown below;

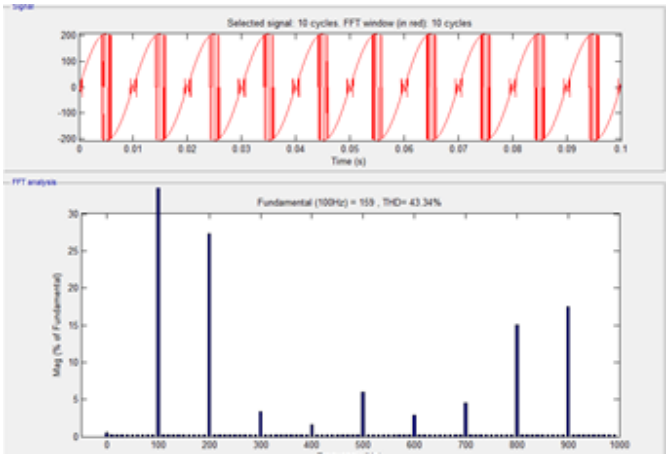

FIGURE 19. THD of AAMFC with Hybrid Modulation at output frequency 100 Hz

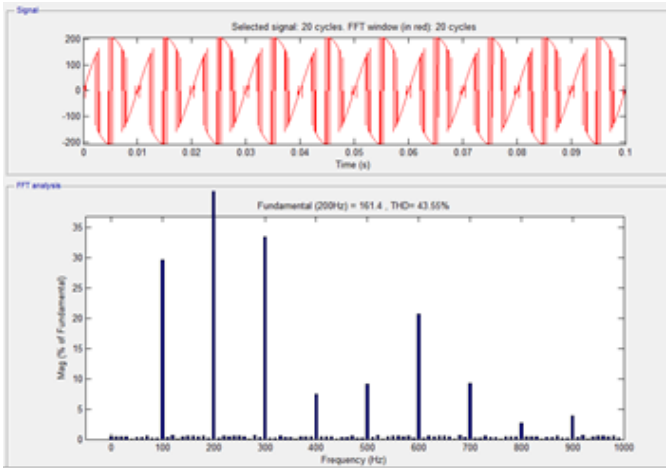

FIGURE 20. THD of AAMFC with Hybrid Modulation at output frequency 200 Hz

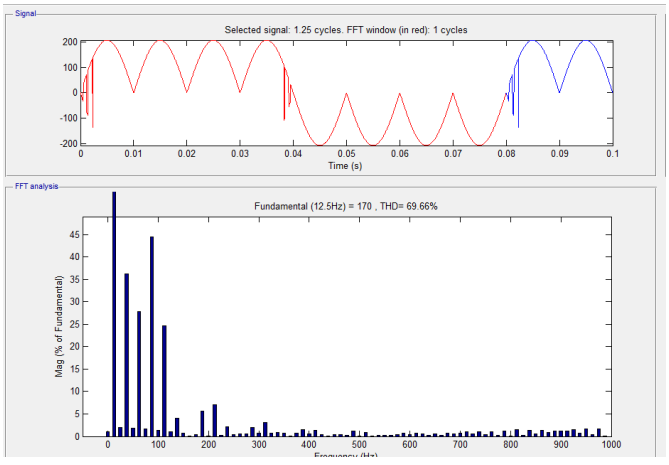

FIGURE 21. THD of AAMFC with Hybrid Modulation at output frequency 12.5 Hz

THD can be eliminated by using modulation technique as discussed and performed above, SPWM and TPWM, but we didn't achieve better result

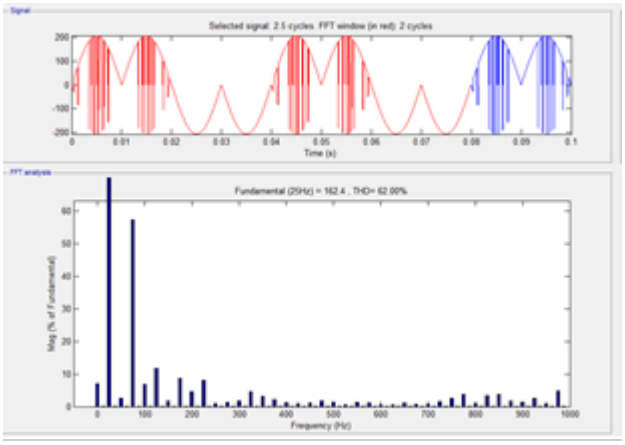

FIGURE 22. THD of AAMFC with Hybrid Modulation at output frequency 25Hz

using this technique we are getting higher amount of lower order harmonics such as 2^{nd}, 3^{rd} , 5^{th} and 7^{th} which are dominating in converter and reducing it performance and efficiency also they large amount of higher order THD component which cannot be neglected as shown in the chart 1, the THD analysis of AC-AC multi-Frequency converter and the by table we can see that hybrid modulation is hybrid modulation is more effective, it almost eliminated all higher amount harmonics in converter with decreased lower harmonics component as can see in fig18-fig. 21. Also, by seeing the chart, THD is reduced. We can able to achieve THD up to 60%. As shown in table 2 without any modulation THD of converter is range of 60-70% whereas in hybrid this value is reduced to 40-60 %.

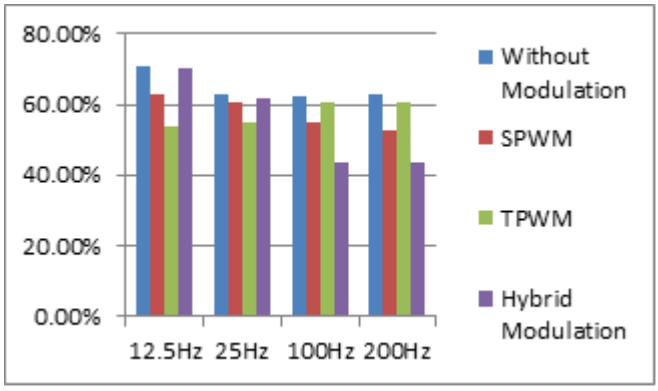

Chart 1: AAMFC with different modulation technique

7. Conclusion

A high-performance reduced witches AC-AC Multi Frequency Converter with simple and compact characteristic is shown in this paper. The single-phase AC-AC multi-Frequency converter with reduce no of switches has able step up/down the ac input voltage depending on the switching time. Thus, because of less switches it has lower switching losses, lower electromagnetic interference noises, and higher power efficiency can be achieved. Reduced Switches AC-AC Multi Frequency Converter has the following advantages 1.it has few switches 2. The cost of the circuit is less. 3. Low THD. 4. Compact in size. By the above parameter discussed we can conclude that the AC-AC multi-Frequency converter is more compact, better efficacy less complexity, and simple in design. Total harmonic distortion (THD) of converter has reduced for different output frequencies by using Hybrid Modulation, converter performance has been improved and we are getting lower THD as compared to other Modulation techniques and it is quit more effective for those frequencies which are more than base frequencies, overall, the Hybrid Modulation is easy to implement and effective.

References

Aarthil, G. and T. Porselvi. “Modeling and Simulation of Matrix Converter Using Space Vector PWM Technique”. *International Journal of Science and Research (IJSR)* 6.3 (2017): 1754–1758. 10.21275/art20171927.

Agarwal, Vineeta and Anupam Kumar. “Rhythm Singh and Robin T.J “Modifed PWM Schemes for Cyclo-inverters”. *InternationalPower Engineering Conference (IPEC)* (2015): 655–660.

Agarwal, Vineeta, et al. *Modified PWM Scheme for Cycloinverter*. IEEE, May 2007. 655–660.

Bayındır, N S. “DSP-Based PLL-Controlled 50-100 KHz 20 KW High-Frequency Induction Heating System for Surface Hardening and Welding Applications”. *IEE Proceedings - Electric Power Applications* 150 (2003): 365–365. 10.1049/ip-epa:20030096.

Falah, Ammar. “Total Harmonic Distortion of Single-Phase Mid-Point Cycloconverter Comparison between MOSFET, IGBT and GTO Power Devices”. *International Journal of Computer Applications* 181.35 (2019): 10–15. 10.5120/ijca2019918300.

Kumar, Mayank. "A Novel Soft Switched Cycloinverter". *IEEE Transactions on Industrial Electronics* 62.1 (2015): 153–162. 10.1109/tie.2014.2331035.

Mondol, Md and Halim. "A Compact and Cost Efficient Multiconverter for Multipurpose Applications". *IEEE Access* 8 (2020): 86810–86823. 10.1109/access.2020.2992986.

Naveenchandran, P and Vijayaraghavan. "Modulation Techniques in Switching Devices". *International Journal of Pure and Applied Mathematics* 116.13 (2017): 137–142.

Rahman and Syed. "Optimized FPGA Implementation of PWAM-Based Control of Three-Phase Nine-Level Quasi Impedance Source Inverter". *IEEE Access* 7 (2019): 137279–137290. 10.1109/access.2019.2942210.

Ranjan and Vinit. "Commutation Problem of Single Phase Matrix Converter with PWM Phase Shift Dead Time Technique". *IEEE International Conference on Power Energy, Environment & Intelligent Control (PEEIC)* (2018). 10.1109/peeic.2018.8665420.

Singh, Navdeep and Vineeta Agarwal. "Delta-Modulated AC–AC Converter for PM WECS". *IEEE Transactions on Industrial Informatics* 11.6 (2015): 1422–1434. 10.1109/tii.2015.2489161.

Uddin, Md. Shihab, Shuvra Prokash Biswas, and Md. Kamal Hosain. "A Single Phase to Single Phase Step-Down Cycloconverter for Variable Speed Drive Applications". *2020 IEEE Region 10 Symposium (TENSYMP)* (2020): 1148–1151.

Uddin, Md and Shihab. "A New Generalized Step-down Single-Stage AC/AC Power Converter". " *Sustainability* 12.21 (2020): 9181–9181. 10.3390/su12219181.

Wang, Chien-Ming. "A Single-Stage Series-Resonant Transformer-Isolated AC-AC Converter". *13th IEEE Conference on Industrial Electronics and Applications (ICIEA)* (2018). 10.1109/iciea.2018.8397864.

Ye, Manyuan. "Research on Modified Hybrid Frequency Modulation Technology of Type-III Asymmetric CHB Multilevel Inverters". *Electronics* 9 (2020): 263–263. 10 . 3390 / electronics9020263.

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