A Unified Power Conversion Matrix Converter Topology and High Performance PWM Strategies

R.Anitha[1] V.Mohan[2]
[1]P.G Scholar [2]Associate Professor
[1,2]Department of Electrical & Electronics Engineering
[1,2]E.G.S.Pillay Engineering College Nagapattinam

Abstract— The diversified nature of power generation and load requirement make the power conversion as mandatory. The power conversion system involves a converter topology and switching strategy. The power converter becomes helpless if the nature of input changes. For example, for ac loads with dc inputs, an inverter module is preferred and it becomes useless if the input becomes ac. Hence a unique topological structure which can make any type of output from the input given is more appreciable. That is a single topology which can perform all types of power conversions, namely rectification, inversion, dc chopping and cyclo-conversion, is today's need. This paper proposes an unique power converter topology which can perform all above mentioned power conversions. The proficiency of the power converters is more depends on the switching strategy, that is the how the pulse patterns are generated. This paper also proposes two switching strategies for cyclo-conversion. The proposed half wave symmetry variable firing angle method (HWSVFAM) and quarter wave symmetry variable firing angle method (QWSVFAM) offer enhanced fundamental component at low total harmonic distortion (THD). Complete analysis of the proposed topology and the control strategies are done in MATLAB-Simulink tool.

Key words: Multifunction Converter, Matrix Converter, Chopper, Rectifier, Inverter

I. INTRODUCTION

A single phase matrix converter can be able to directly convert AC input voltage into desired ac output voltage, which has a single stage power conversion. The matrix converter has the arrangement of bi-directional switches instead of unidirectional semiconductor switches, and controls them in an approximate time sequence for single stage conversion. There is no need for an energy storage device such as electrolytic capacitor. Matrix converters are interesting for aerospace applications, because of its high power density.

The basic concept of single phase matrix converter topology has been introduced by zuckerbeger. Then after three decades matrix converter reach for industrial applications. Now has been presented that, the topology have possible operation of all power converters. To improve the power quality, variable modulation techniques are developed.

Now a day's many power converters came in various topologies such as chopper, rectifier, converter, frequency changer. Maintenance and operation of those converters requires more maintenance and costly manpower. This matrix converter topology may reduce the need for varying converter topologies.

II. SINGLE-PHASE MATRIX CONVERTER

The matrix converter is a forced commutated converter which uses an array of controlled bidirectional switches which acts as main power elements to create a variable output voltage system with unrestricted frequency. It does not have any dc link circuit and does not need any large energy storage elements. The key element in a matrix converter is the fully controlled four-quadrant bidirectional switch, which allows high-frequency operation.

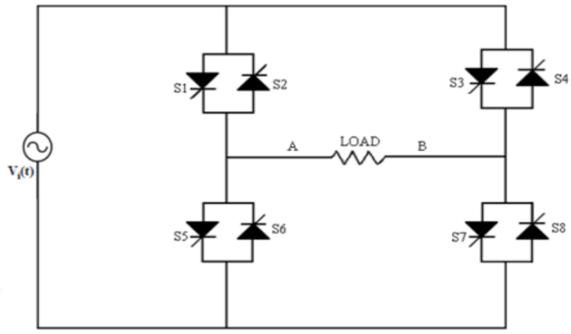
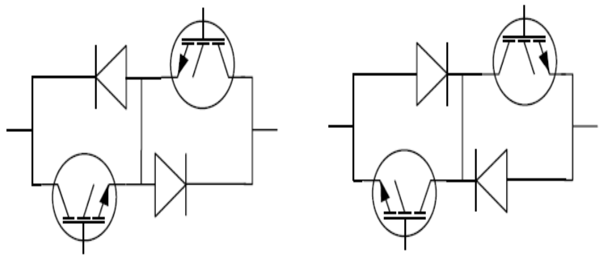


Fig. 1: single phase matrix converter topology

A. *Bidirectional Switch:*

The matrix converter requires a bidirectional switch capable of blocking voltage and conducting current in both directions. There are no such devices currently available, so discrete devices need to be used for construct suitable switch cells.



a).Common emitter Configuration b).Common collector configuration

Fig. 2: Bidirectional Switch

The common emitter bidirectional switch cell arrangement consists of two diodes and two IGBTs connected in anti-parallel as shown in Fig. 2(a). The common collector bidirectional switch cell arrangement is shown in Fig. 2(b). The conduction losses are the same as for the common emitter configuration.

B. *Switching Operation of Single Phase Matrix Converter for Cycloconversion:*

The single phase matrix converter developed to accept any kind of input supply such as AC or DC.

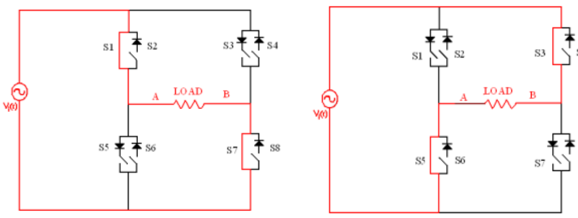


Fig. 3(a): Positive Output Cycle

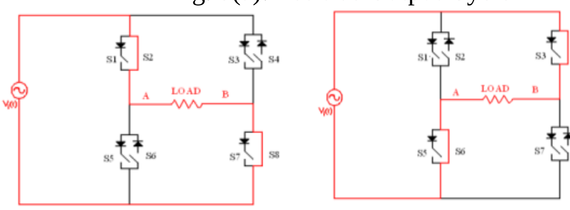


Fig. 3(b): Negative Output Cycle

Fig. 3: Cycloconverter operation

If given input voltage is AC, operation of cycloconverter for half of input frequency with positive and negative cycle as shown in fig.3(a) and fig.3(b).

C. *Existing Modulation Techniques:*

Various types of modulation techniques are available. The AC output uses Sinusoidal Pulse Width Modulation and the DC output uses Multiple Pulse Width Modulation. These modulation schemes illustrated with fig.4 (a) and fig.4 (b).

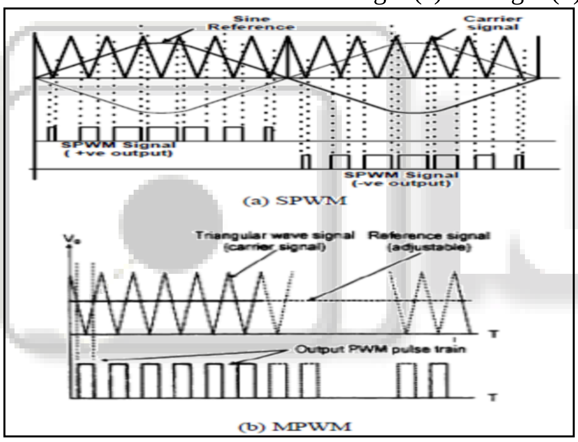


Fig. 4: Modulation techniques

III. PROPOSED TOPOLOGY

The block diagram for selection of converter and input supply is shown in fig.5. Initially some basic signal generates to synthesize the output of selected converter from generalized converter. A particular converter is selected by selection of converter block and selection of supply fully depends on converter selection. After selecting the converter and input supply trigger pulse will be generate for that converter. Then these signals send to SPMC through amplifying circuit. Details for each block are given below.

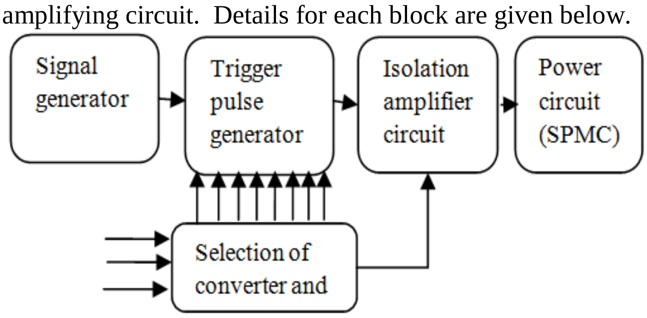


Fig. 5: Block diagram for selection of converter

A. *Basic Signal Generator:*

X1 which is a triangular wave is generated by the block of triangular wave generator, the frequency of which decides the harmonic content in the output waveform. Other signals are generated by comparing with input sine wave with various frequency or DC reference voltages depending on the converter selection as shown in the fig.6.

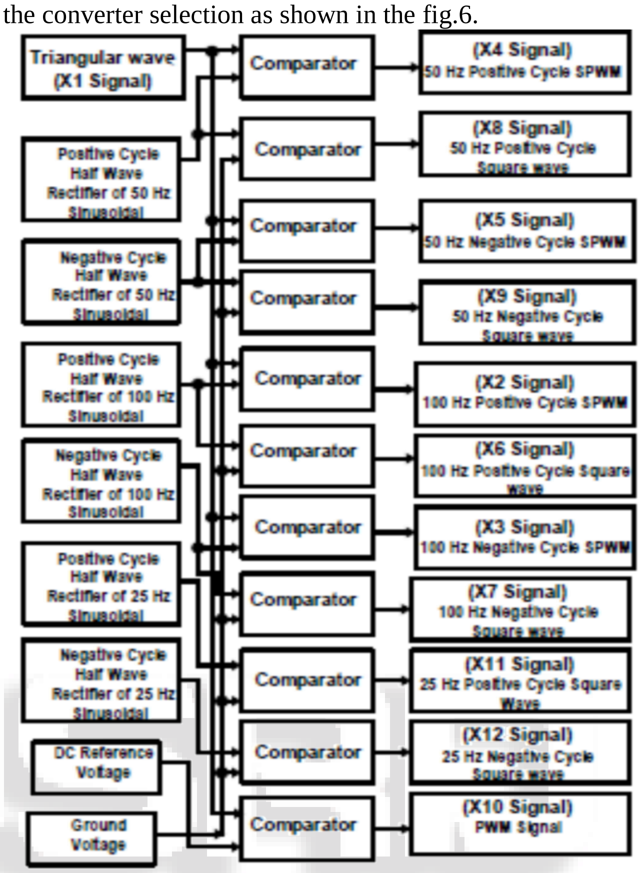


Fig. 6: Basic signal generator block

B. *Selection of Converter and Input Supply:*

The selection of converter depends on combinational 3×8 decoder circuit. There are eight output channel with respect to given input, which is shown in table 1. Selection of converter depends on output channels i.e
(Y0, Y1, Y2……Y7).

A	B	C	Selected output
0	0	0	Y0
0	0	1	Y1
0	1	0	Y2
0	1	1	Y3- Cycloconverter
1	0	0	Y4- Cycloinverter
1	0	1	Y5- Chopper
1	1	0	Y6- Rectifier
1	1	1	Y7- Inverter

Table 1: Truth table for decoder

The generalized converter has two types of supply sources; they are DC supply and Single phase AC supply. The selection of input supply for converter selection done with the help of particular switch, which is connected in series with the source

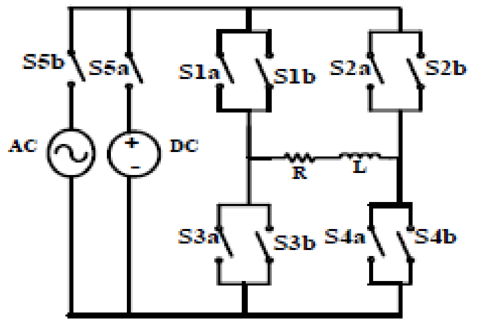


Fig. 7: Generalized single phase matrix converter

C. Trigger Pulse Generator:

After the converter selection, trigger pulse produced for a particular converter through trigger pulse generator block. trigger pulse to IGBT's for selected converter generated by logical operation as shown in the table 2.

Logical operation	Conducting switches	Selected converter
Y5.X10	S1a,S4a	Chopper (first quadrant)
Y7.X6 Y7.X7	S1a,S4a S2b,S3b	Inverter
Y6.X4 Y6.X5	S1a,S4a S2a,S3a	Rectifier
Y3.X11.X4 Y3.X11.X5 Y3.X12.X4 Y3.X12.X5	S1a,S4a S2a,S3a S2b,S3b S1b,S4b	Cyclo Converter

Table 2: Logical operation for trigger pulse generation

D. Pulse Amplifier:

The trigger pulse from the logical operation may can't able to trigger the device into conduction state because of low power signal. These pulses fed to pulse amplifier block to amplify the signal into high power level. Then these pulses isolated by opto-coupler 4N35 and fed to the respective device to conduct.

E. Power Circuit:

Depending on the selection of the converter logical operation particular converter operation will be execute from a generalized single phase matrix converter power circuit.

IV. PROPOSED SWITCHING STRATEGIES

CFAM may not be considered as an optimal solution for many applications, compared to Constant Firing Angle Method Symmetry Firing Angle Method may have better performance. Therefore there is two new control strategies are developed, they are *half wave symmetry variable firing angle method* (HWSVFAM) and *quarter wave symmetry variable firing angle method* (QWSVFAM) are proposed to elevate the performance of matrix converters.

A. Half Wave Symmetry Variable Firing Angle Method (HWSVFAM):

The HWSVFAM has different firing angles for each input half cycles, while the firing angles of the first and K_f^{th} (third for this case) pulses are the same and hence it possesses half wave symmetry. The load receives a full input half cycle at the middle segment of the output half cycle $((K_f+1)/2)^{th}$ and progressively reduced conduction for the other segments. The harmonic content of the output voltage reduced due to this variable phase controlled operation. Here β_1 is the delay angle, and $\beta_2=2\pi+\beta_1$. The basic operation of HWSVFAM is shown in Fig.8.

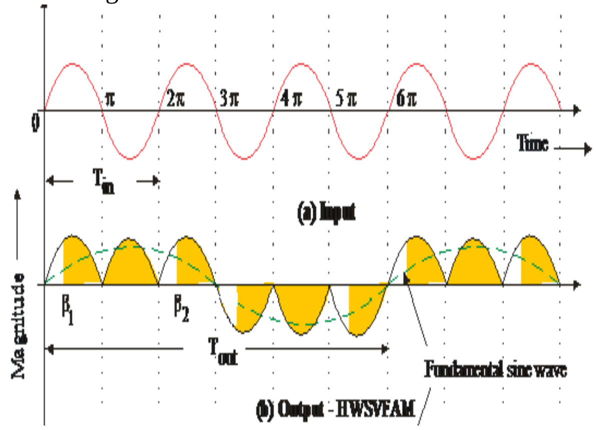


Fig. 8: Half wave symmetry variable firing angle schme

B. Quarter Wave Symmetry Variable Firing Angle Method (QWSVFAM):

The quarter wave symmetry method has the use of both natural and forced commutation for achieving quarter wave symmetry in the output. In QWVFAM the first quarter of output half cycle while the third quarter is an exact mirror image of the first quarter. The harmonic content may reduced efficiently by this technique. Here γ_1 is the delay angle, where $\gamma_2=3\pi-\gamma_1$. The basic operation of QWSVFAM is shown in Fig.9.

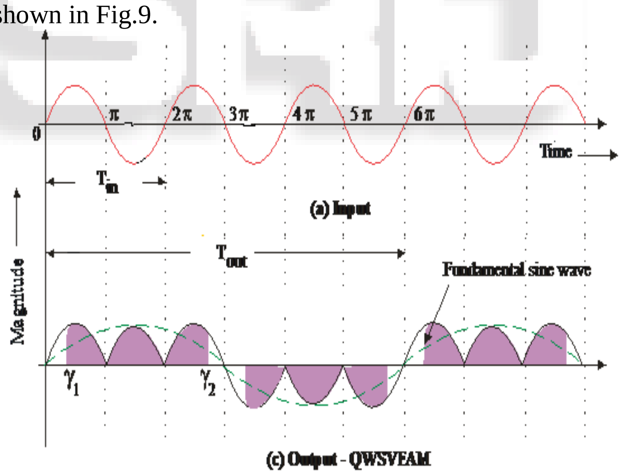


Fig. 9: Quarter wave symmetry variable firing angle method

V. SIMULATION RESULTS

The single-phase to single-phase cycloconverter with different control strategies is simulated using computer software Matlab. The circuit specifications are input voltage=230V/50Hz, K_f=3 and the load resistance=10.

The proposed strategies are compared with the existing control techniques for a common conduction angle of 420° (per output half cycle). The switches in CFAM method in each half cycle are fired at 40° [∵ (180°-40°) x3=420°].

A. Constant Firing Angle Method (CFAM):

The existing CFAM is shown in Fig.10, with harmonic spectrum.

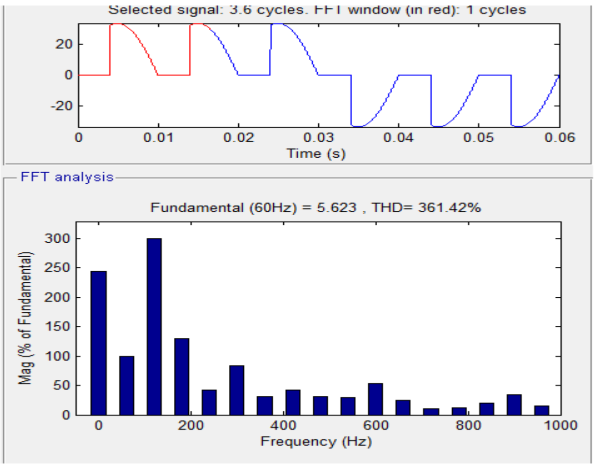


Fig. 10: Constant Firing Angle Method

B. Half Wave Symmetry Variable Firing Angle Method (HWSVFAM):

In HWSVFAM, a conduction angle of 420° is obtained when β_1=60° and β_2=240°. Fig.11 shows the waveforms and the spectra of the output voltage and input current respectively.

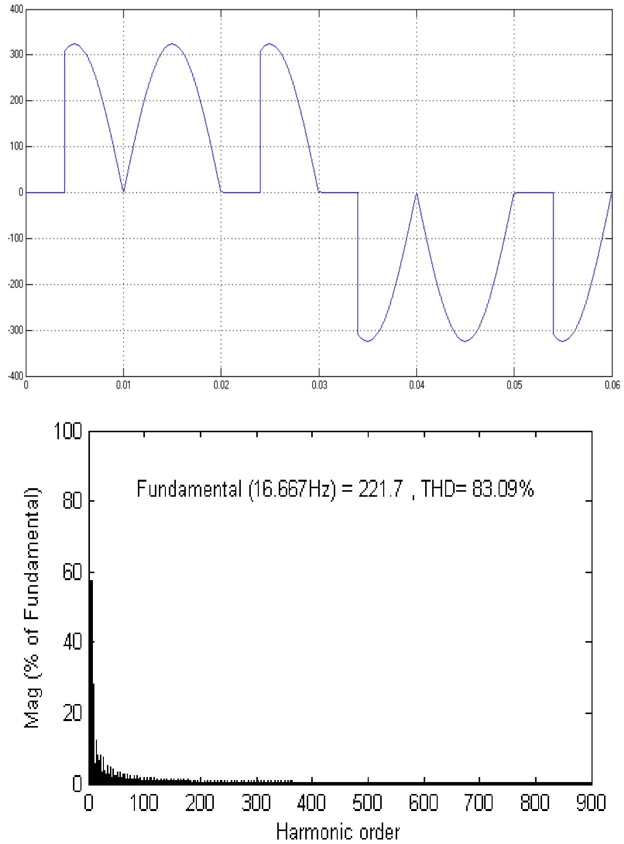


Fig. 11: Half Wave Symmetry Variable Firing Angle Method

C. Quarter Wave Symmetry Variable Firing Angle Method (QWSVFAM):

In QWSVFAM the conduction angle of 420° results when γ_1=60° and γ_2=480° Fig.12 shows the output voltage and input current waveforms.

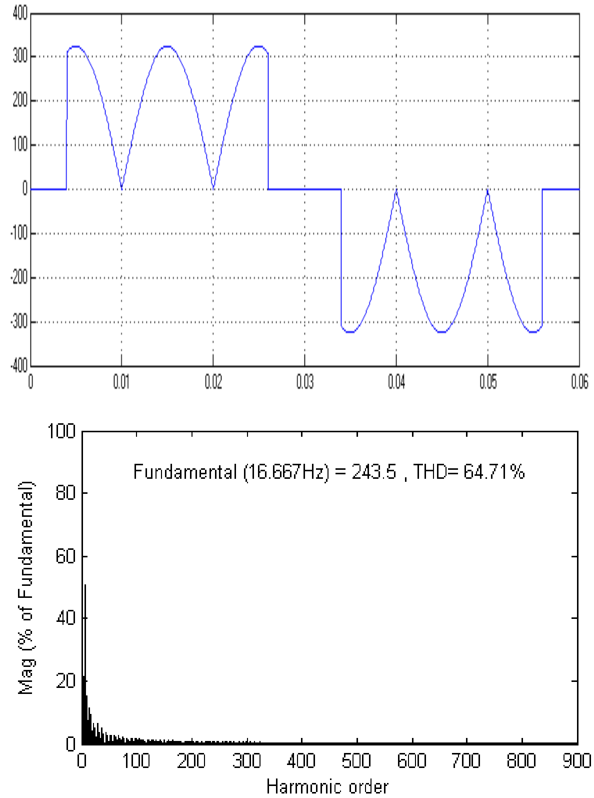


Fig. 12: Quarter Wave Symmetry Variable Firing Angle Method

D. Comparison of Fundamental Voltage with Firing Angle between Proposed Methods and CFAM:

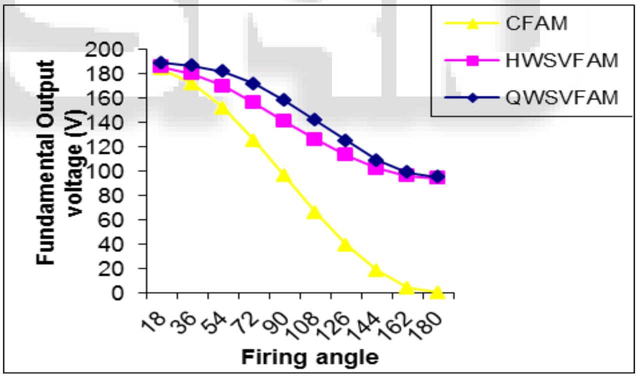


Fig. 13: Comparison of Fundamental Voltage with Firing Angle between Proposed Methods and CFAM

E. Comparison of THD with Firing Angle between Proposed Methods and CFAM:

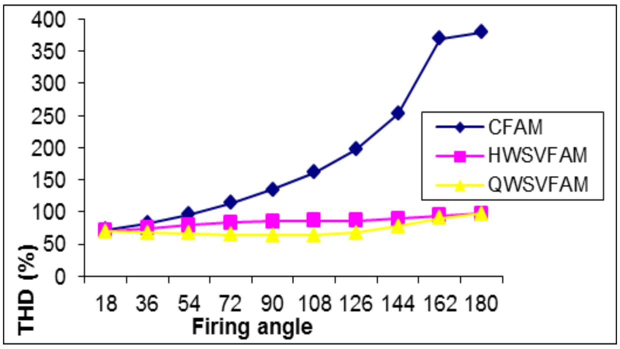


Fig. 14: Comparison of THD with Firing Angle between Proposed Methods and CFAM

F. Comparison of Output Voltage Spectra with Different Cycloconverter Control Strategies:

Strategy	V_1	V_3	V_5	V_7	THD
CFAM	168.30	72.11	103.15	57.36	85.25
HWSVFAM	166.52	59.04	95.21	50.80	79.98
QWSVFAM	178.62	46.22	53.82	79.28	65.17

VI. CONCLUSION

Matrix Converter reported to have attracted characteristics such as, Inherent good four quadrant operation, Absence of bulk capacitor, Provide dc link s bi-directional power flow, nearly sinusoidal input and output current waveforms and a controllable input power factor and Increased power quality. CFAM is a conventional method which may perform poor. HWSVFAM, QWSVFAM is offering higher fundamental and lower THD for the entire range of firing angles. The experimental results are simulated for proposed firing angle schemes.

REFERENCES

[1] Ajay Kumar Gola and Vineeta Agarwal," Implementation of an Efficient Algorithm for a Single Phase Matrix Converter" Journal of Power Electronics, Vol. 9, No. 2, March (2009)
[2] Daniels and D. Slattery, "New power converter technique employing power transistors," Proc. Inst. Elect. Eng., vol. 125, no. 2, pp. 146–150, Feb. (1978).
[3] E. Stacey, "An unrestricted frequency changer employing force commutated thyristors," in Proc. IEEE PESC'76, (1976), pp. 165–173.
[4] G. Kastner and J. Rodriguez, "A forced commutated cycloconverter with control of the source and load currents," in Proc. EPE'85, (1985), pp. 1141–1146.
[5] J. Rodriguez, "A new control technique for AC–AC converters," in Proc. IFAC Control in Power Electronics and Electrical Drives Conf., Lausanne, Switzerland, (1983), pp. 203–208.
[6] L. Gyugi and B. Pelly, Static Power Frequency Changers: Theory, Performance and Applications. New York: Wiley, (1976).
[7] L. Huber and D. Borojevic, "Space vector modulator for forced commutated Cycloconverters," in Conf. Rec. IEEE-IAS Annu. Meeting, (1989), pp. 871–876.
[8] M. Braun and K. Hasse, "A direct frequency changer with control of input reactive power," in Proc. IFAC Control in Power Electronics and Electrical Drives Conf., Lausanne, Switzerland, (1983), pp.187–194.
[9] M. Venturini and A. Alesina, "The generalized transformer: A new bidirectional sinusoidal waveform frequency converter with continuously adjustable input power factor," in Proc. IEEE PESC'80, (1980), pp. 242–252.
[10] M. Venturini, "A new sine wave in sine wave out, conversion technique which eliminates reactive elements," in Proc. POWERCON 7, (1980), pp. E3_1–E3_15.
[11] P. D. Ziogas, S. I. Khan, and M. H. Rashid, "Analysis and design of forced commutated cycloconverter structures with improved transfer characteristics," IEEE Trans. Ind. Electron., vol. IE-33, pp. 271–280, Aug. (1986).
[12] V. Jones and B. Bose, "A frequency step-up cycloconverter using power transistors in inverse-series mode," Int. J. Electron., vol. 41, no. 6, pp. 573–587, (1976).