Performance Parameters Analysis of Three phase Full Controlled Converter using PSIM Simulation

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Abstract – This paper presents the modeling and simulation of power electronic circuits and their analysis on the basis of performance parameters. It deals with the simulation analysis of three phase full converter by calculating performance parameters. For large power dc loads, three phase ac to dc converters are commonly used. Three phase half wave converter is rarely used because it introduces dc component in the supply current. Three phase full converter model is prepared on PSIM software and simulation waveforms are generated. Simulation waveforms are obtained with different firing angles.

Keywords- AC to DC converter, Firing angle, R, RL, RLE loads, PSIM software, Distortion factor.

INTRODUCTION – Power electronics concerns the application of electronic principles into situations that are rated at power levels rather than signal level. The development of new power semiconductor devices, new circuit topologies with their improved performance and their fall in prices have opened up wide field for the new applications of power electronic converters. Power electronic converters are used for the conversion of AC to DC, DC to AC, AC to AC and DC to DC power. Any power semiconductor device can act as a switch. Mostly thyristor used as a power switch in power converters. The thyristor can be triggered at any angle α in positive half cycle and the output voltage can be controlled.

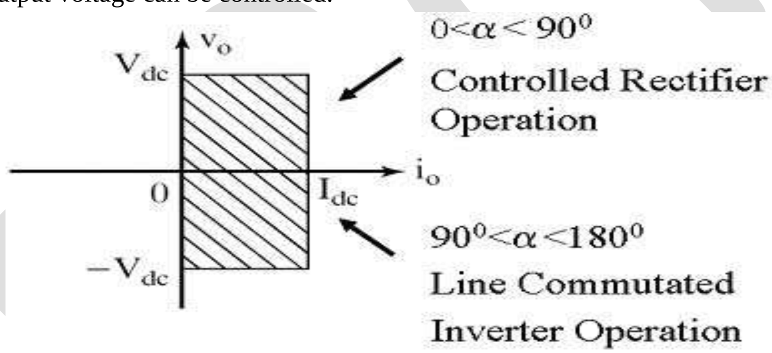

Fig-1 Rectifier quadrant operation.

PSIM FOR SIMULATION- PSIM is Simulation software specially designed for Power electronics and Motor control applications. With fast Simulation and User friendly interface, PSIM provides powerful Simulation environment for power electronics, control loop design and motor drive system studies. A circuit is represented in PSIM has four blocks: power circuit, control circuit, sensors, and switch controllers. Fig.2 shows the relationship between these blocks.

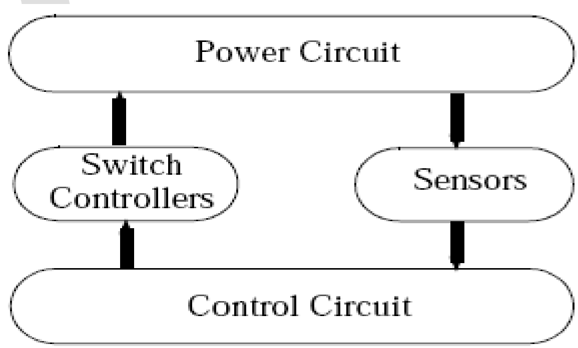

Fig.2 PSIM Simulation process

Power circuit consists of RLC branches, switches, Transformers, Motor drive modules and Renewable energy module. Control circuit has logic elements, digital control module, PI regulator etc. Sensors measure power circuit voltages and currents and pass the values to the control circuit. Control signals are generated from the control circuit and given to the power circuit through the switch controllers.

PERFORMANCE PARAMETERS- All the theoretical discussions of converters are assumed the a.c input supply is purely sinusoidal. In practical, the current at the a.c input terminal of the converters consists of a fundamental component with superimposed harmonic components. So the performance parameter evaluation is important in converter analysis. The following performance parameters are used in the analysis of three phase fully controlled converter.

1. Distortion factor (DF) $= \frac{I_{s(fund)}}{I_{s(rms)}}$
2. Harmonic factor HF) $= \sqrt{\frac{1}{DF^2} - 1}$
3. Supply power factor (PF) $= \frac{3}{\pi}\cos\alpha$
4. Efficiency $= \frac{P_{dc}}{P_{ac}}$

THREE PHASE CONVERTER- The three phase fully controlled bridge converter has been probably the most widely used power electronic converter in the medium to high power applications. The controlled rectifier can provide controllable output dc voltage in a single unit instead of a three phase autotransformer and a diode bridge rectifier. The controlled rectifier is obtained by replacing the diodes of the uncontrolled rectifier with thyristors. Control over the output dc voltage is obtained by controlling the conduction interval of each thyristor. In phase controlled rectifiers though the output voltage can be varied continuously the load harmonic voltage increases considerably as the average value goes down. Of course the magnitude of harmonic voltage is lower in three phase converter compared to the single phase circuit. Three phase converter is shown in fig.3.

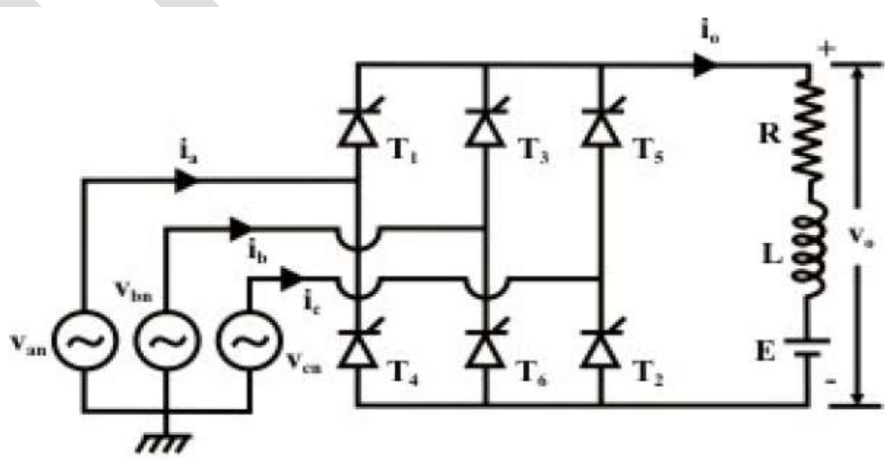

Fig.3 Three phase converter

For any current to flow in the load at least one device from the top group (T_1, T_3, T_5) and one from the bottom group (T_2, T_4, T_6) must conduct. Then from symmetry consideration it can be argued that each thyristor conducts for 120° of the input cycle. Now the thyristors are fired in the sequence $T_1 \rightarrow T_2 \rightarrow T_3 \rightarrow T_4 \rightarrow T_5 \rightarrow T_6 \rightarrow T_1$ with 60° interval between each firing. Therefore thyristors on the same phase leg are fired at an interval of 180° and hence cannot conduct simultaneously. This leaves only six possible conduction mode for the converter in the continuous conduction mode of operation. These are T_1T_2, T_2T_3, T_3T_4, T_4T_5, T_5T_6, T_6T_1. Each conduction mode is of 60° duration and appears in the sequence mentioned. Table.1 shows the firing sequence of SCRs

S.No	Firing angle	Conducting pair	Incoming SCR	Outgoing SCR	Line voltage (Load)
1	$30+\alpha$	T_6,T_1	T_1	T_5	V_{ab}
2	$90+\alpha$	T_1,T_2	T_2	T_6	V_{ac}
3	$150+\alpha$	T_2,T_3	T_3	T_1	V_{bc}
4	$210+\alpha$	T_3,T_4	T_4	T_2	V_{ba}
5	$270+\alpha$	T_4,T_5	T_5	T_3	V_{ca}
6	$330+\alpha$	T_5,T_6	T_6	T_4	V_{cb}

Table 1: Firing Sequence of SCR

Fig.4 shows the waveforms of different variables. To arrive at the waveforms it is necessary to draw the firing sequence table which shows the interval of conduction for each thyristor. If the converter firing angle is "α" each thyristor is fired "α" angle after the positive going zero crossing of the line voltage with which it's firing is associated. Once the conduction diagram is drawn all other voltage waveforms can be drawn from the line voltage waveforms. It is clear from the waveforms that output voltage and current waveforms are periodic over one sixth of the input cycle. Therefore this converter is also called the "six pulse" converter. The input current on the other hand contains only odds harmonics of the input frequency other than the triplex (3^{rd}, 9^{th} etc.) harmonics.

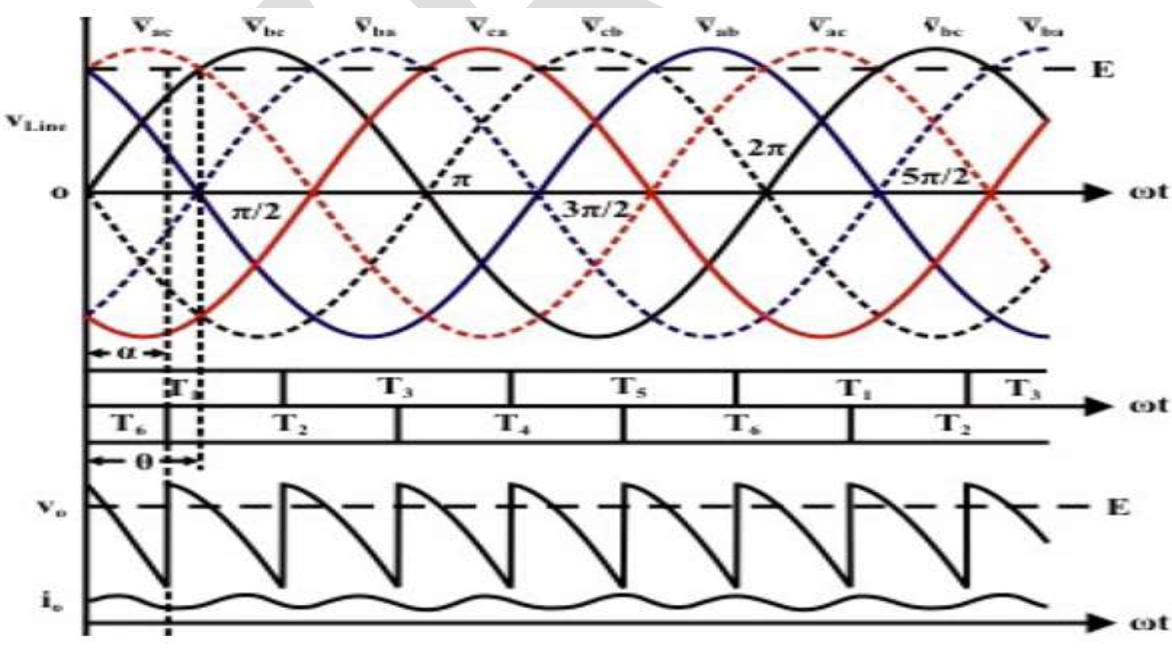

Fig.4. waveforms of three phase converter

SIMULATION- The PSIM simulation model and waveforms of three phase full controlled converter is shown if fig.5, fig.6 and Fig.7.

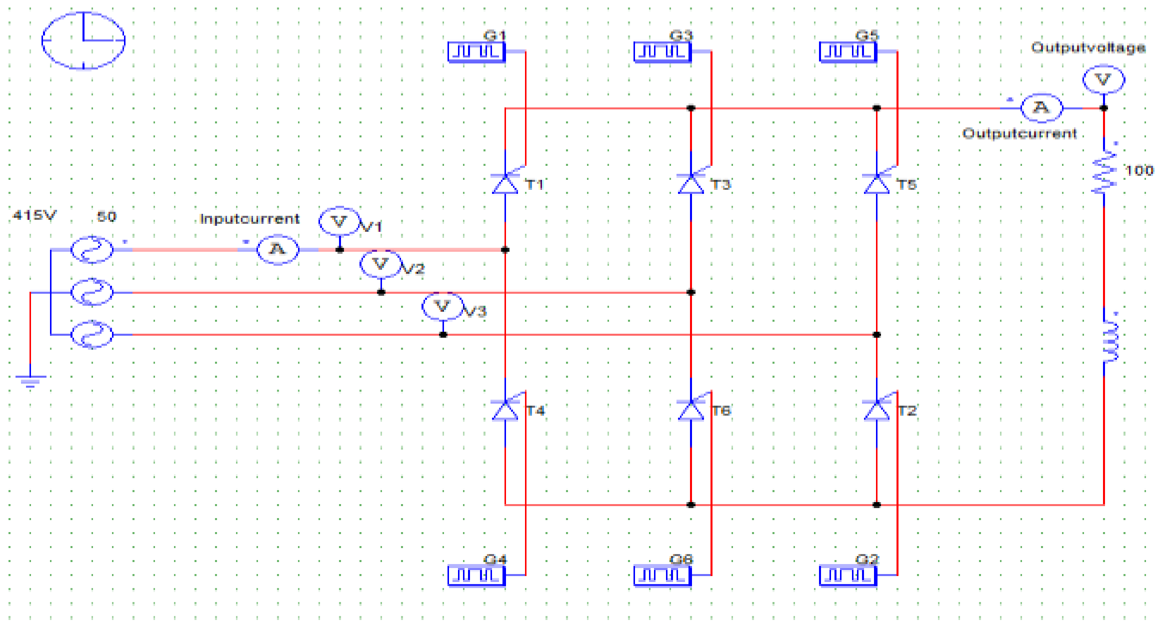

Fig.5 Simulation model of three phase full converter

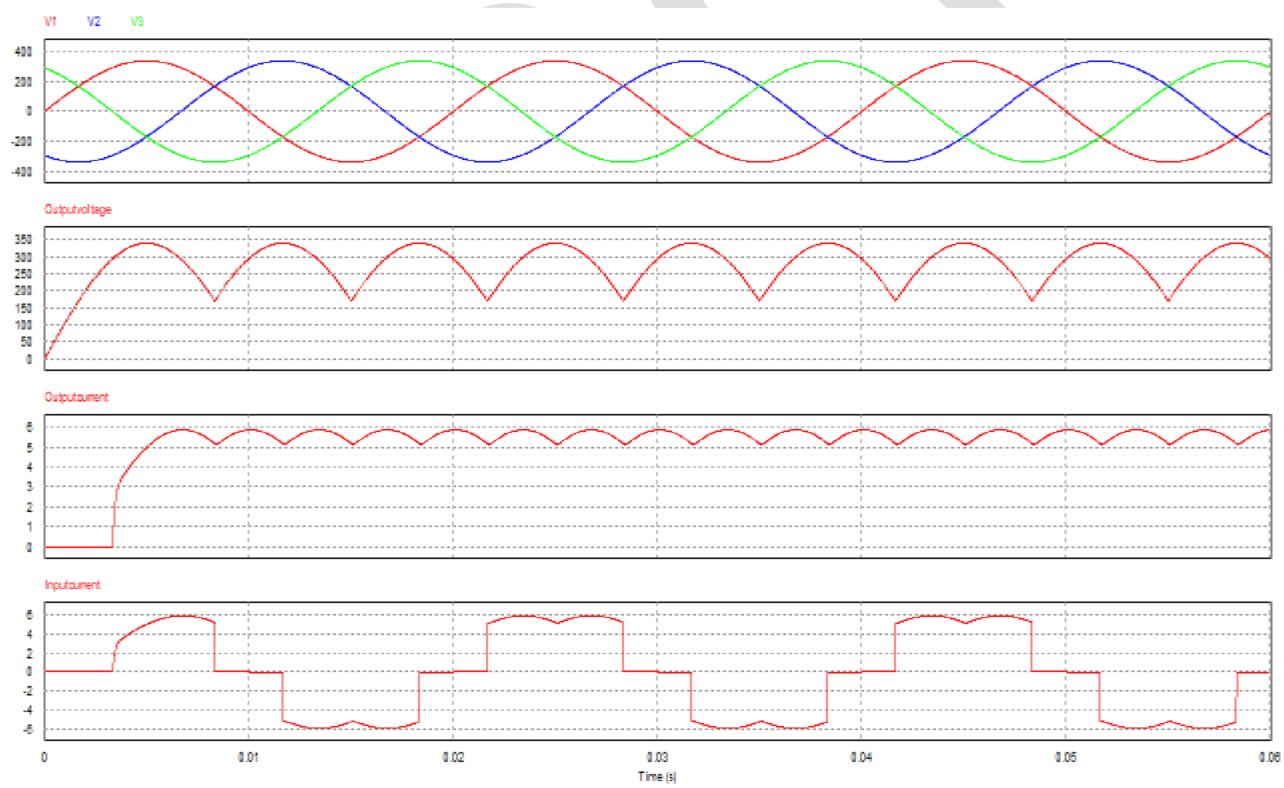

Fig.6 Simulation results: Input current, output voltage, output current, input current.

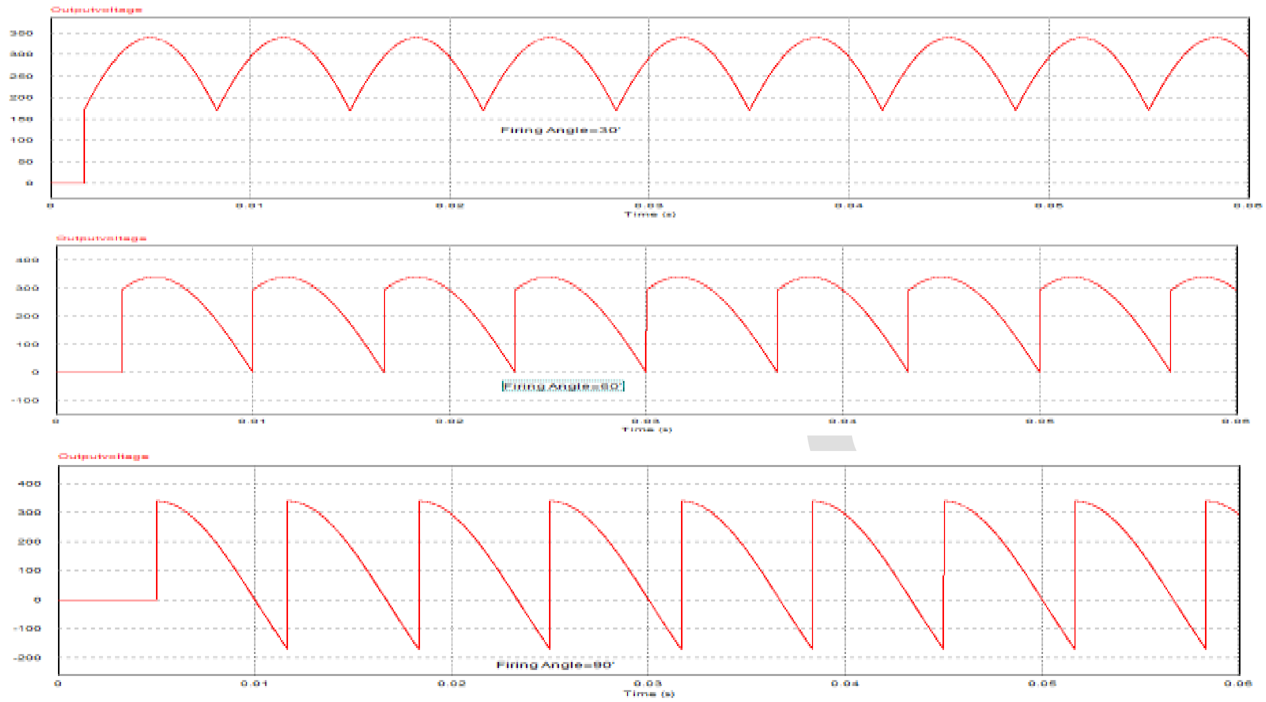

Fig.7 Simulation results: Output voltage waveforms at α=30̊, 60̊, 90˚

RESULTS- The performance parameters of three phase fully controlled converter are obtained by using the simulation waveforms. The following table shows the results obtained.

Firing Angle	DF	HF	PF	Efficiency
0̊	94.8%	30.5%	0.952	73.28%
30̊	94.9%	30.7%	0.821	68.17%
60̊	95.4%	30.7%	0.438	59.37%
90̊	95.4%	30.7%	0	31.08%
120̊	95.4%	30.7%	-0.447	12.68%

Table 2: Performance Parameters of Three phase full converter

CONCLUSION- As power electronic systems are getting more complex today, the simulation used for analysis is requiring more features. The performance parameters of three phase full converter were calculated by using PSIM simulation. Different types of waveforms were obtained by designing the firing circuits. The performance parameters are tabulated for various firing angles. The waveforms are obtained from the simulation are compared with the actual waveforms of three phase full converter. These results are useful where controlled dc power required.

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