

Simulation of Front End Converter Based Power Conditioning Unit

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Abstract—Commercial Automation has led to profuse research and development on highly sensitive instruments which require quality power for their operation. The development of power electronic technology makes it possible to realize many kinds of Power Conditioning Systems (PCS) to obtain high quality electric energy and enhance the control over power system. Mostly the PCS configuration is based on double conversion technique, where in raw input from source or DG set is processed through AC to DC converter and then it is inverted through DC to AC inverter. Converters are broadly classified into two types, uncontrolled and controlled rectifiers. Now-a-days IGBT based PWM converter which is also called as front end converter are most popular and used in most of the Commercial as well as Industrial applications. This front end converter not only generates the controlled DC but also controls and corrects the input power factor at unity. This circuit corrects the shape of input current of power supply to maximize the real power available from source. Due to this, the input current and its harmonics content can be improved. In this paper the simulation of PCS with IGBT based front end converter has been done using MATLAB and results are presented for various load conditions.

Keywords— Front-end Converter; PCS; PWM converter; Quality Power; P.F.

I. INTRODUCTION

Electrical load equipment requires quality power. Power conditioning system also known as a line conditioner is a device intended to improve the quality of the power. This device acts in one or more ways to deliver a voltage of the proper level which will be useful to enable load equipment to function properly. Power conditioning system also helps in power factor correction, noise suppression, transient impulse protection, etc. PCS takes power from source, process and modify it based on the requirements of the machinery to which they are connected. Various topologies are used for design and configuration of PCS or machine drives.[1]

Mostly machine drives and PCS's are configured around double conversion techniques, where in the raw AC input from the utilities or DG sets is fed to PCS. Similarly, in case of machine drive, motor is controlled through power electronics and its controller which is also known as drive. In double conversion technique raw input is processed through AC to DC converter and inverted by DC to AC inverter. In most of the configurations uncontrolled rectifiers are used as AC to DC converters. This rectifiers behaves as nonlinear load to input source which produces non sinusoidal line current. This affects the input power factor drastically. To overcome this problem, an IGBT based front end / PWM converter can be configured which not only controls the DC output but also corrects the input power factor by means of its control circuit. This circuit can also called as Automatic Power Factor Correction (APFC) circuit. [2]

The paper covers aspects for the basic circuit theory, design considerations, simulation of complete Front end converter based Power Conditioning Unit and results on MATLAB simulation software.

II. BLOCK DIAGRAM

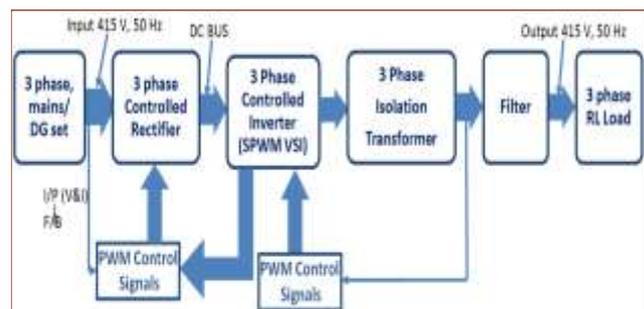


Fig 1. Block schematic of Front End Converter Based PCS

Fig. 1 shows block diagram of Front end converter based Power Conditioning Unit. Three phase input supply from utility/ mains /DG set is fed to IGBT

based converter, which controls DC output voltage at desired DC bus voltage by controlling the PWM pulses at the gates of IGBTs. In addition to this, this converter also corrects the input power factor by control strategy, where in the input current is forced to follow the input voltages. This constant controlled DC voltage generated by converter is fed to the three phase IGBT based inverter which controls the output voltage level and frequency by using SPWM control-C filter is connected at the inverter output to filter out harmonics. Step up transformer is used at the output side which increases the output voltage at the desired level and also provides proper isolation.[3] This voltage is finally given to 3 phase simulated RL load. Using this concept the simulation circuit has been made in Matlab Simulink software. Circuit simulation and their results has been explained in subsequent paragraphs.

III. CIRCUIT SIMULATION

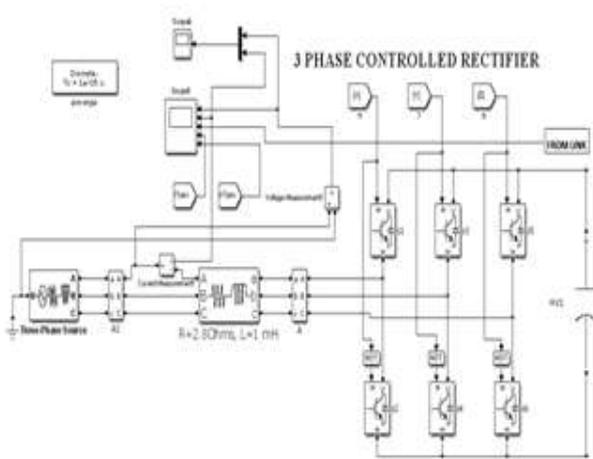


Fig 2. Simulink Model of three phase IGBT based Converter

PCS simulation is carried in steps. In first step design calculation for IGBT based Converter is carried out to select the components required to be put in simulation. Accordingly simulation circuit is built in Matlab Simulink software. Fig 2 shows the Matlab simulation block for IGBT based converter where, IGBT switches are connected in bridge form. Each IGBT has given firing trigger pulses from PWM signals. AC input is given to the rectifier through three phase power source. The source inductance and resistor's values are calculated and finalized by doing various iterations

in the simulation block. These are connected in series in between source and PCS. High value DC link capacitor is used for smoothing out DC output voltage and reducing the ripple present in it. The voltage output across the DC link is constantly monitored and controlled to desired value.

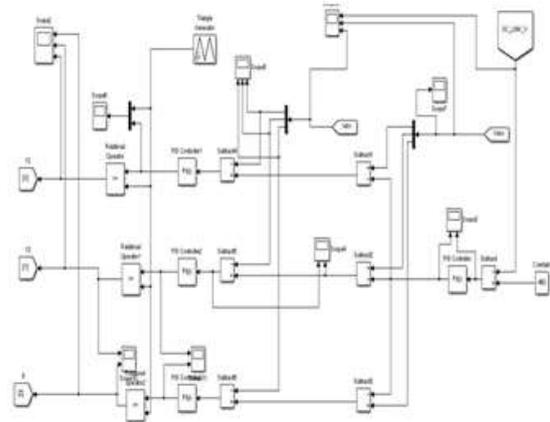


Fig 3. Control Strategy for Three Phase IGBT based converter

The control strategy is based on PWM control method. [4]Control is achieved by measuring the instantaneous phase currents and forcing them to follow a sinusoidal current reference I_{ref} . To achieve this DC voltage feedback is taken and compares with desired DC value. This output is pass through the PI controller to minimize the error. Then it is multiplied with three phase input current to obtain I_{ref} signal. Further it is compared with three phase input voltage to get modulating signal for PWM generation. Finally this signal is pass through PI controller and compared with high frequency triangular carrier wave. It will generate three basic PWM signals which are inverted to drive six IGBT legs. Control strategy is designed in such a way that, it not only generates required DC bus voltage, also controls input PF. The model uses voltage measurement block for sensing DC Link voltage. Further this DC Bus is connected to inverter.

Simulink model of three phase IGBT based inverter with L-C filter is shown in Fig 4. The regulated DC output is given to six pulse IGBT based inverter. IGBT's are triggered using SPWM control method.[5] Inverter is used to generate the required three phase voltage magnitude and controlling the frequency. Six IGBT's are connected in bridge form and triggered by the PWM control circuit. Three phase transformer is connected for stepping up the voltage to the desired

level. The voltage and current output contains harmonics and are not sinusoidal because of the non-linear load present in circuitry. Therefore, L-C filter is used to reduce harmonics and make the wave sinusoidal. Three phase load is realized by connecting resistors and inductors and by changing the values of them, the load values can be adjusted. The load is connected in STAR configuration at the output of the inverter. [6][7]

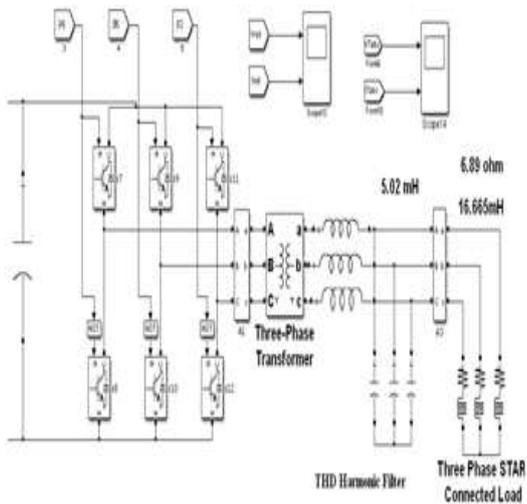


Fig 4. Simulink Model of three phase IGBT based inverter

Fig.5 shows the control strategy based on SPWM technique for IGBT based inverter. The 3 three phase signals shifted by 120 deg used as a reference signal for PWM signal generation. This generated PWM signals are used to switched ON and OFF IGBT bridges effectively for getting required AC output voltage. Using a pulse width modulation switching scheme the switches of the inverter are switched ON and OFF several times per half cycle. The duty cycle can be controlled by varying the On/Off time per switching period. The average output voltage can be

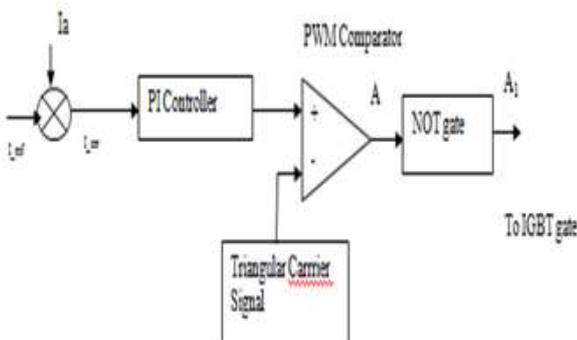


Fig.5 PWM Generation circuit

maintained at the desired set point by controlling the duty cycle. To achieve this, the PWM control circuit has been designed as shown in Fig. 6 wherein the output of three phase signal (load current) is fed back to comparator which gets compared with the reference signal.

The output of this comparator is compared with triangular carrier signal to generate three prime phase shifted by 120° PWM signals. By using three NOT gates total 6 PWM signals are generated to drive the 6 IGBT's. The frequency of the carrier signal determines the switching frequency. On the designed circuit optimum switching frequency of 2 kHz is selected out of several iterations.

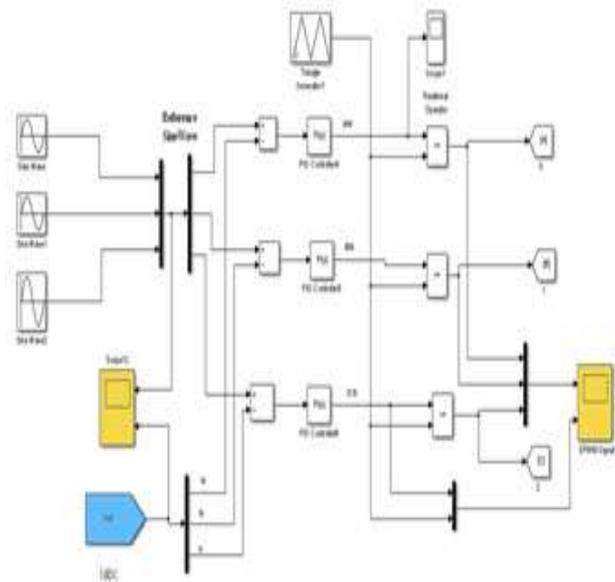


Fig.6 Control Circuit of IGBT based Inverter

Control strategy is realized for controlling the three phase inverter for maintaining the constant voltage output as shown in Fig 6. PID control technique used in which PID control block has set values of kp and ki which can be changed to get the desired output values. The PWM signals are obtained by superimposing triangular waves on sinusoidal waves to generate the pulses needed to trigger the IGBT's of Inverter.

Triangular wave generator is connected to generate triangular wave of desired magnitude and switching frequency.

A) Complete Simulation Diagram of PCS

After building the individual power modules such as converter and inverter, they are interconnected to

build complete simulation circuit of Power conditioning system. The circuit is as shown in Fig. 7.

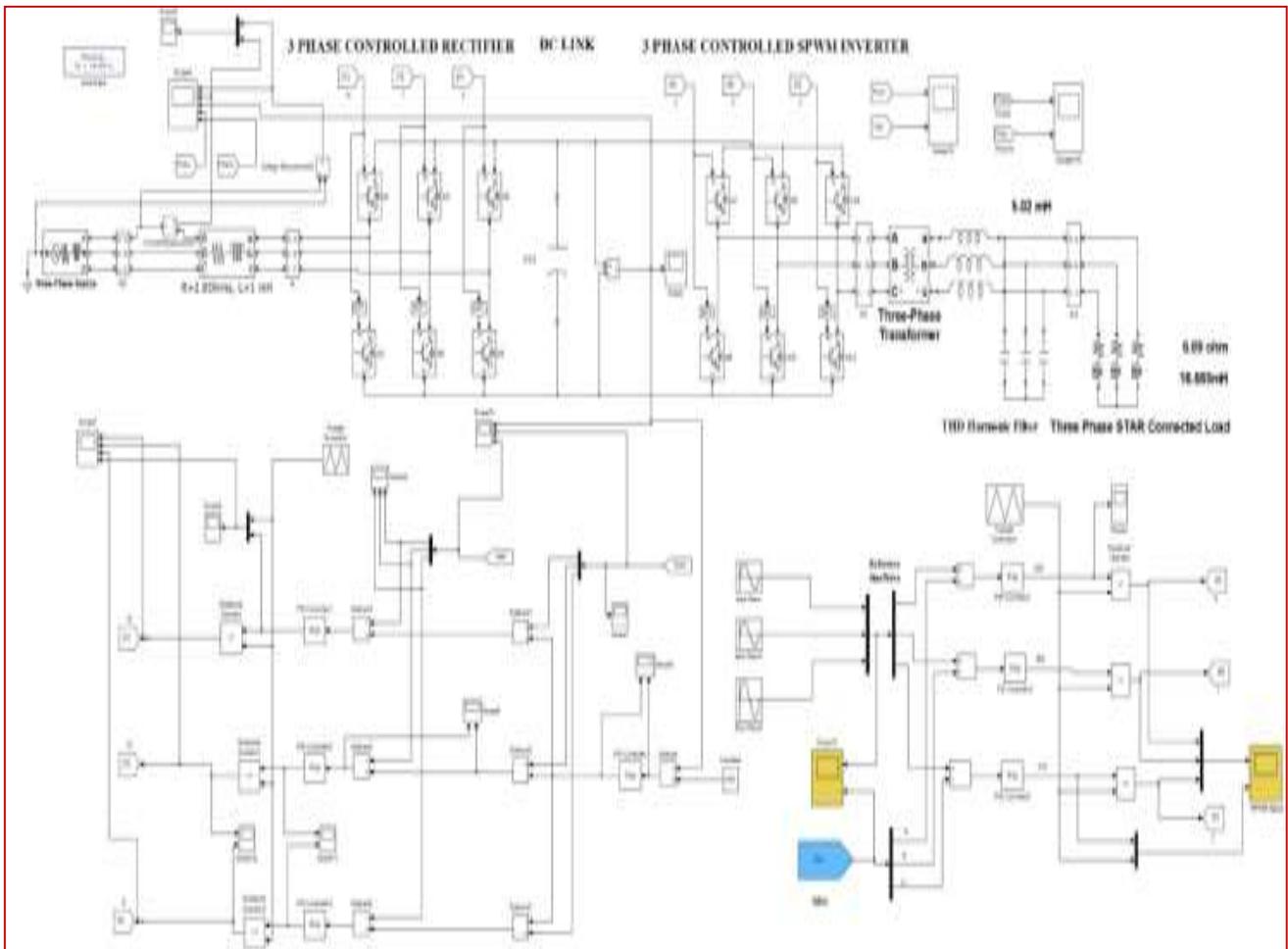


Fig.7 Complete Simulation Circuit of PCS

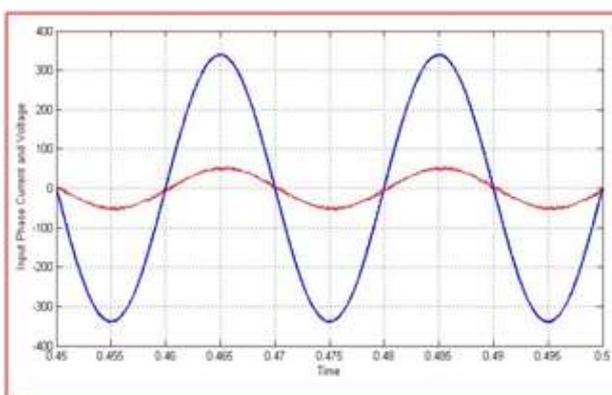


Fig.8 Wave form for Automatic Input Power Factor Correction

The simulation results at each stage has been discussed in succeeding paragraphs. After building the Simulink blocks, the results are studied by carrying out several iteration in the circuit. Fig 8 shows the waveform of power factor correction input side. As seen in simulation output waveforms for current and voltage which are in phase, no lead or lag was observed i.e. power factor is made unity. By changing the input resistance and inductance values, magnitude of input current and voltage can be controlled.

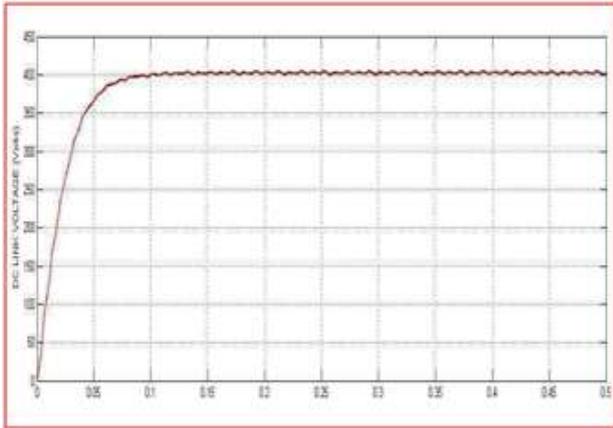


Fig 9 DC Link Voltage from converter output

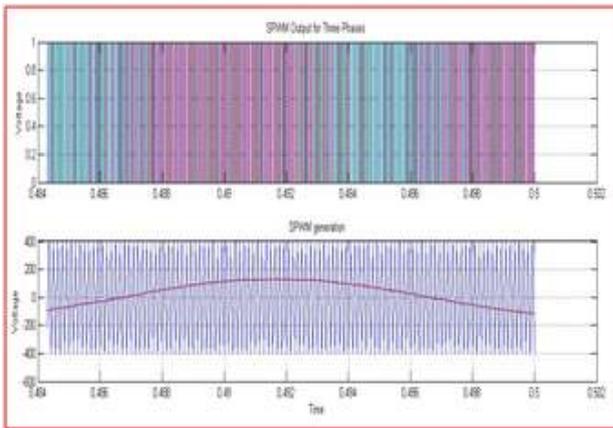


Fig 10 PWM Output Waveform for Three Phase Controlled Rectifier

Output of controlled DC link voltage is shown in Fig.9 Front end controlled rectifier converts AC voltage to DC voltage, this has transient period for stabilization of DC voltage to constant DC voltage. Ripples are present in the output that can be smoothed out by tuning the values of filter.

Fig. 10 shows the generation of PWM signals for triggering the power devices of controlled rectifier.

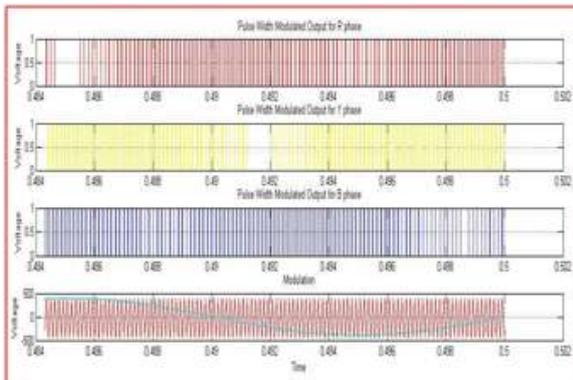


Fig 11 SPWM Output Waveform for Three Phase Controlled Inverter

By varying pulse width of PWM signals the output voltage can be changed with respect to the voltage required for load. The switching frequency of triangular wave is set to 2 kHz and magnitude of 450 volts.

Fig 11 shows the generation of PWM output for inverter control. From the results it is studied that, the measured output voltage is 560 Volts peak to peak i.e. 400 Volts RMS which is very near to desired voltage of 415 Volt. PWM template is produced for inverter three leg twin IGBT's triggering circuit. This is generated by comparing carrier triangular wave with reference sinusoidal wave.[8]

Crossover points give PWM template with high and low signals. Output of SPWM generation is given to the gates of IGBTs present in three phase inverter circuit.

The Fig 12 shows the three phase output voltage and load

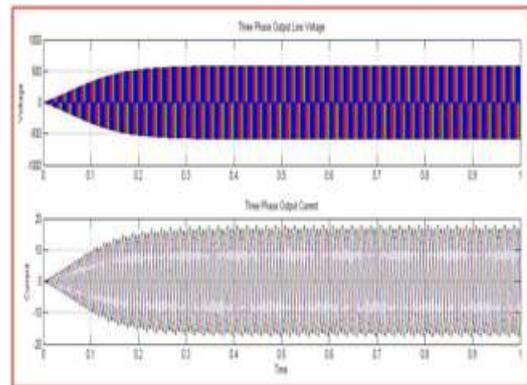


Fig 12 Output Three Phase Voltage and Current Waveform without Filter

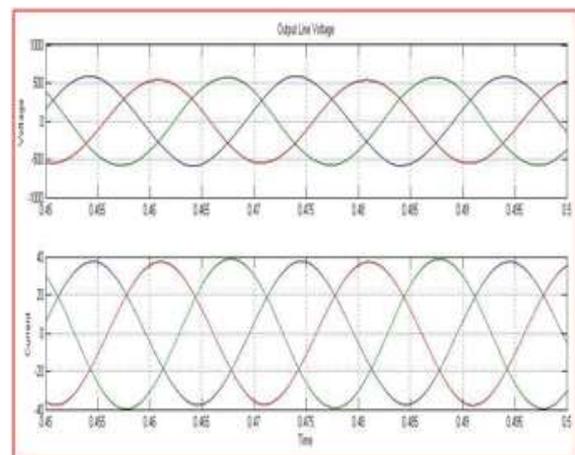


Fig 13 Output Three Phase Voltage and Current Waveform of IGBT Inverter with filter

VI SIMULATION INFERENCE

TABLE I LOAD ITERATIONS

The iterations in the load values were carried out and the inference is as shown in the Table I.

Sr. No.	Power (kVA)	Impedance (Z Ω)	P.F.	Current (A)	Observed Power (kVA)	Calculated Power (kVA)
1	20	8.618	0.8	27.8	19.97	20
2	17	10.152	0.8	23.6	16.89	17
3	15	11.48	0.8	20.86	14.86	15
4	13	13.25	0.8	18.08	12.69	13
5	10	17.22	0.8	13.91	9.81	10
6	7	24.624	0.8	9.73	6.83	7
7	5	34.47	0.8	6.95	4.22	5
8	3	57.45	0.8	4.15	2.91	3
9	1	172.345	0.8	1.39	0.92	1

VI. CONCLUSION

Design and simulation of 20KVA, 3 Phase, 50 Hz APFC based Power Conditioning System has been successfully completed in MATLAB 2013 simulation software. The simulation was based on double conversion technique wherein it uses IGBT based front end Converter followed by IGBT based six pulse inverter. The complete circuit was built around MATLAB Simulink modules available.

The exhaustive analysis was carried out by changing electrical parameters like modulation index, switching frequency etc. Various load iterations up to its rated capacity were carried out to study the characteristics and circuit behavior. The analysis includes the harmonic assessment of input/output current and voltage waveforms. Special emphasis was given to the generation of a DC component in the inverter output voltage in the case that the power delivered to load in all conditions remains nearly constant.

ACKNOWLEDGMENT

The authors wish to thanks Shri. V. V. Parlikar Director, Research and Development Establishment (Engrs.), Alandi Road, Dighi, Pune-411015 for constant encouragement and valuable guidance to publish this paper in National conference on “Electrifying Experience In Electrical Transportation in India” Feb 2018. Thanks to the entire design team for their valuable suggestions and support.

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