A HOLISTIC STUDY OF DIFFERENT CONTROL SCHEMES FOR PWM RECTIFIER OPERATION

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Abstract

An upgraded and very efficient rectifier type for converting AC to DC is the PWM (Pulse Width Modulation) rectifier. In contrast to conventional rectifiers, which control the output using diodes or thyristors, PWM rectifiers use controlled switching components like MOSFETs or IGBTs. PWM rectifiers are appropriate for a variety of challenging applications because they provide notable benefits in terms of efficiency, power quality, and control. However, during the design and deployment phases, their complexity and expense must be taken into account. The unit power factor PWM rectifier is developed to address the issue of harmonic pollution to the power grid caused by conventional diode rectifiers and phase-controlled rectifiers. The modelling, simulation, and analysis of a PWM rectifier based on an AC-DC converter are presented in this study. It offers an appropriate control approach for a pulse width modulation rectifier that minimizes output side ripple in the DC voltage and shapes the input current to be as sinusoidal as possible. A PWM rectifier's primary goals are to control the DC output voltage, guarantee a sinusoidal input current, and operate with a unity power factor. High-speed IGBT/MOSET switches linked in VSI topology are used to do this. These IGBTs and MOSFETs are used to control the output voltage, and passive filters make it simple to remove higher order ripples at the output. PWM method is used to reduce lower order harmonics. The control subsystem uses a network made up of a comparator, a discrete PI controller, and a discrete PWM generator to generate a gating pulse that is sent to the VSI converter based on the input and output voltages. The gating pulses to be applied to the PWM rectifier are the generator's outputs. Researchers have attempted to bring the input voltage and current into phase, decrease harmonic distortion in the input current, and create a sinusoidal input voltage by using this control method. In the closed loop system, the modulation index (m) and phi have been demonstrated to be controlled. Examined has been the impact of the modulation techniques presented on the switching frequency and line current distortion. The methodologies offered have been shown and their simulation results concluded for different loads.

Keywords—PWM, Rectifier, IGBT/MOSFET,Matlab-Simulink, modulation index etc.

I. INTRODUCTION

PWM rectifiers provide accurate regulation of the output voltage and current by actively controlling the switching of power transistors. Bidirectional power flow is supported by many PWM rectifiers, allowing for both DC to AC inversion and AC to DC rectification. PWM rectifiers reduce input current harmonic distortion by adjusting the switching frequency and pattern, which produces cleaner power. Vacuum tube diodes, chemical cells, mercury-arc valves, semiconductor diodes, silicon-controlled rectifiers, and other silicon-based semiconductor switches are some examples of the various types of rectifiers. Even synchronous electromechanical motors and switches have been employed in the past. AC-DC converters fall into two categories: circuits that use a high switching frequency for operation and circuits that use a low switching frequency (line commutated). Three different types of switches are available for AC-DC conversion: fully controlled (IGBTs / MOSFETs), semi-controlled (SCR / Thyristors), and uncontrolled (diodes). Conventional rectifiers, which are AC-DC converters that are either uncontrolled or semi-controlled, contain harmonics. Conventional rectifiers also have poor power factor, non- sinusoidal AC current, and output DC voltage ripple.

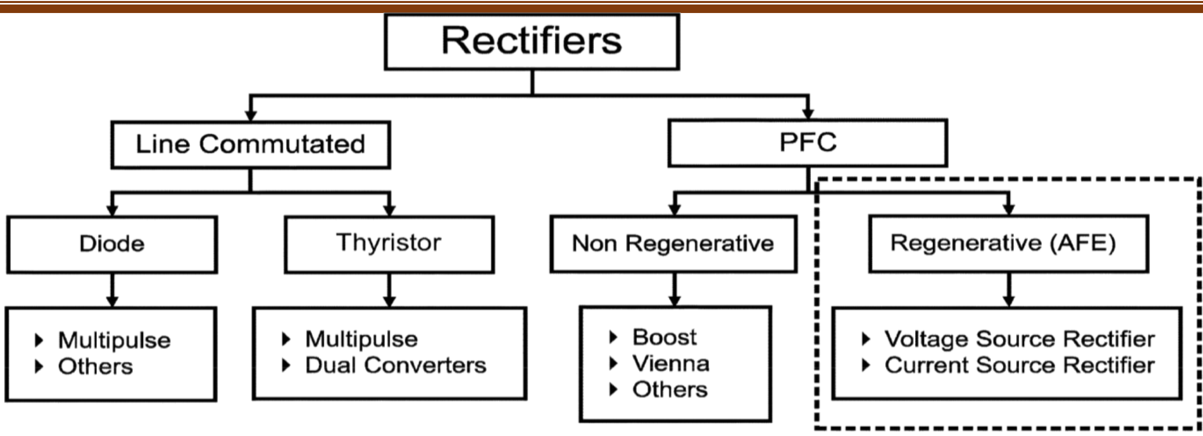


Figure-1 Classifications of Rectifier

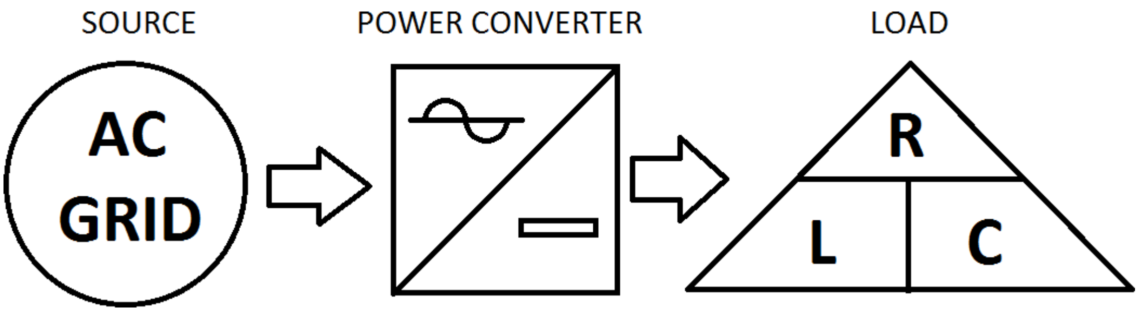


Figure 2: AC to DC conversion with combination of RLC load

Figure-1 is depicting various types of rectifiers which has multiple applications such as Electric drives, UPS systems, Battery management systems and Telecom power supplies etc. The most widely used AC-DC power converter in the past for acquiring DC power from the AC grid was the diode bridge or thyristor bridge. These bridge topologies' advantages in size, control, dependability, structural simplicity and economy are what drive their deployment.

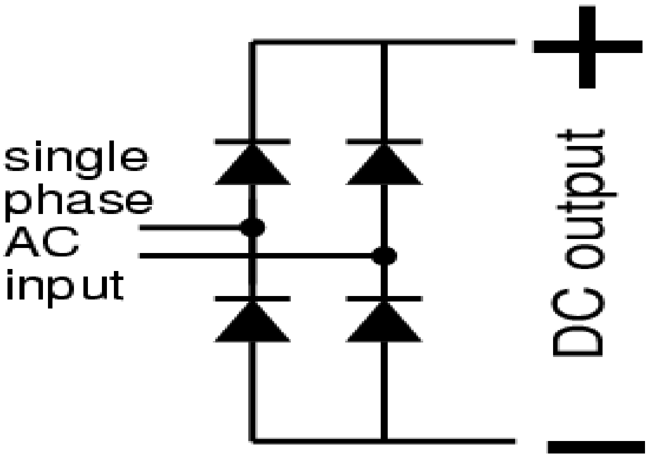
However, using these bridge circuits is highly detrimental to the AC grid because they introduce undesired current harmonics (Fig. 2) into the grid, which can have relatively large amplitudes depending on the power level of the b ridge. As a result, the grid voltage becomes distorted, which can lead to unfavourable disruptions and therefore low power quality in the nearby loads that are connected to the grid. Standards (IEEE 519, IEC 61000-3-6) [1] have been created with the goal of reducing utility pollution caused by power converters. The standards place more focus on the use of power converters, which have a lower harmonic influence on the grid, and limit the direct use of diode and thyristor bridges.

II. MODELING OF THREE PHASE BOOST RECTIFIER

Further, rectifiers can be classified as:

- Single-phase vs. three-phase
- Half-wave vs. full-wave
- Phase controlled vs. pulse width modulated

The difference between single-phase and three-phase rectifiers is in the kind of ac input that each type of rectifier receives. Diode rectifiers are the rectifiers depicted in Figures 3(a) and 3(b). The third classification has to do with the kind of semiconductor device that is used in the rectifier; diodes are used as switches in uncontrolled rectifiers, SCRs are used in phase-controlled rectifiers, and IGBTs or power MOSFETs are used in pulse-width modulated rectifiers. Pulses created using space vector or sine-triangle pulse width modulation are used to switch the rectifier.



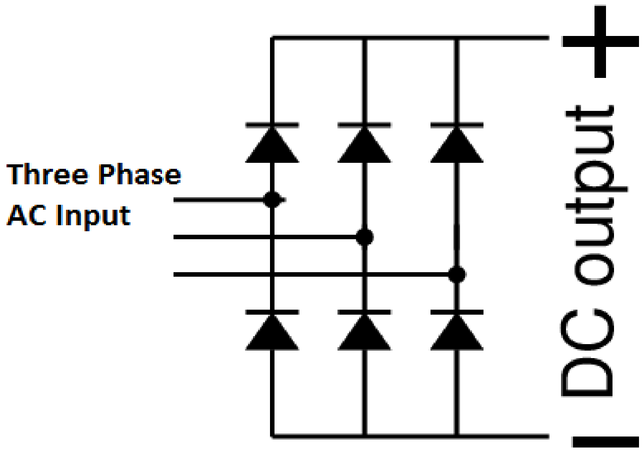


Figure 3: (a) single-phase bridge rectifier **(b) three-phase bridge rectifier**

The relationship between the input and output voltage ratios can be used to further categorize the pulse-width modulated rectifiers. Buck, boost, and buck-boost rectifiers are a few types of pulse-width modulated rectifiers. The dc output voltage of buck rectifiers is smaller than the ac input's peak value. In the same manner, the boost rectifier's output dc voltage is larger than the ac input voltage's peak value. The duty ratio of the switches controls the type of output that the buck-boost rectifier produces, which can be either higher or lower in magnitude than the ac input.

Operation of Three-Phase Boost Rectifier

The boost rectifier's extensive range of applications stems from its effective power utilization during the rectification process and output voltage boost. Six switches make up the three-phase boost rectifier, and they are switched via the sinusoidal pulse width modulation method. A converter's operation can generally be understood in terms of the input and output values as well as the switching pattern that is employed to produce the desired output. The converter's switch pattern is determined by using Kirchhoff's voltage law (KVL) and Kirchhoff's current law (KCL).

The topology of such three-phase boost rectifier is presented in Figure-4. The ON and OFF states of a single switch are assumed to have values 0 and 1 respectively; i.e.
If the device is ON then switch is on a value = 1.
If the device is OFF then switch is on a value =0.

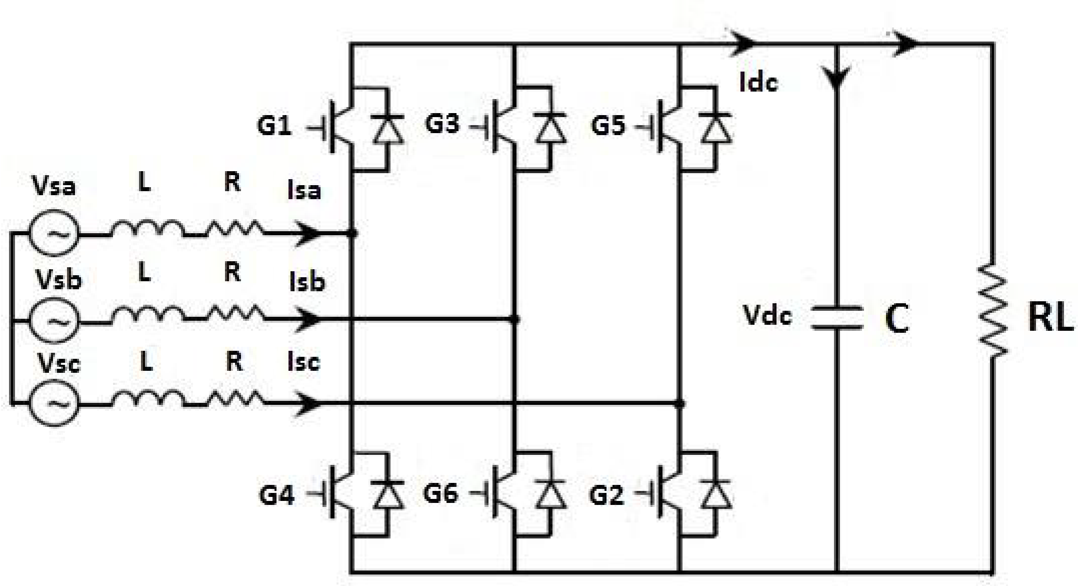


Figure 4: Topology of three-phase boost rectifier

The input dc voltage of a 3-phase rectifier depends on both the rectifier's switching pattern and input numbers. The rectifier's input ac voltages are described. Any converter's switching pattern can be described as a function known as an existence function, which is the switching pattern's mathematical representation.

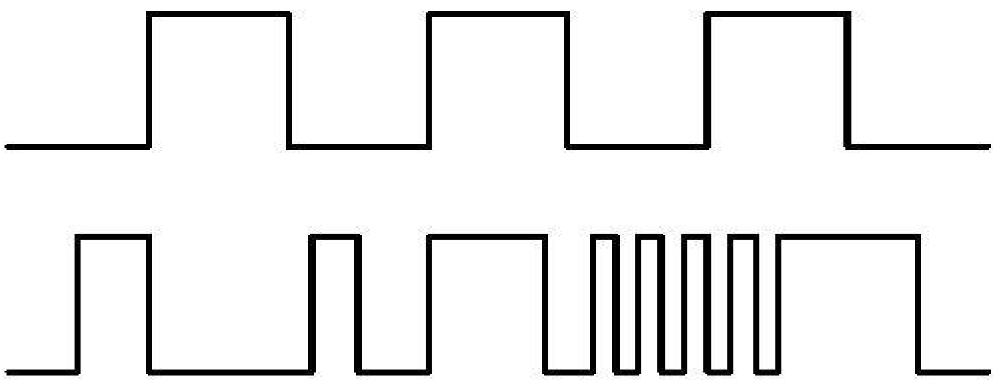


Figure 5: Modulated and un-modulated existence functions

III. SWITCHING MODES OF THREE-PHASE BOOST RECTIFIER

For 3-phase boost rectifier, the possible modes of operation that also satisfy KVL and KCL can be mathematically expressed as

$$G1 + G4 = 1 \quad (3.1)$$
$$G3 + G6 = 1 \quad (3.2)$$
$$G5 + G2 = 1 \quad (3.3)$$

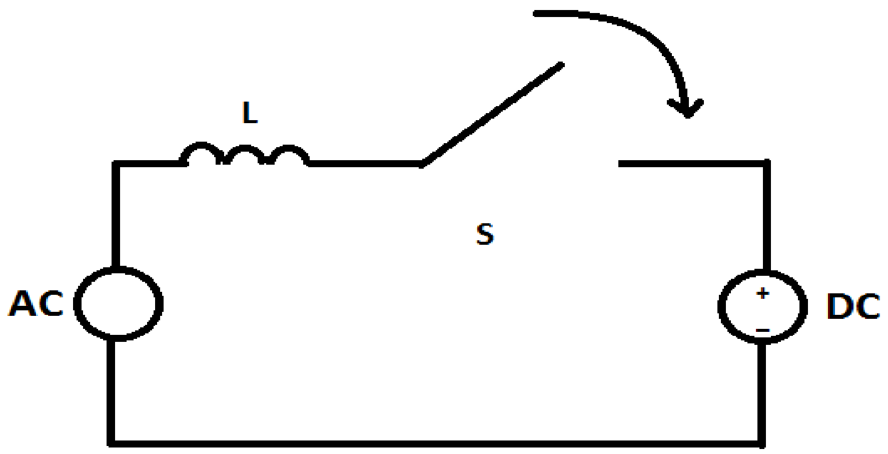


Figure 6 Simplified schematic of boost rectifier

The top and bottom devices of the same leg are unable to turn ON at the same time, as this would contradict KVL, as shown by equations (3.1) to (3.3). Assuming the boost rectifier is turned on, there are switches in the top leg and one in the bottom leg. Figure-7 provides a graphical representation of the six active stages listed in Table 2. The switches that are "ON" for each state shown are identified, and the flow channel is shown by a red line that indicates all of the active states and the switches that are "ON." The mode of operation with the bottom switch G6 and the top switch G1 turned on is shown in Figure-7(a). As a result, the ON switches control the direction of current flow. With the switches G1 and G2 turned on, Figure-7(b) depicts the second potential mode of operation.

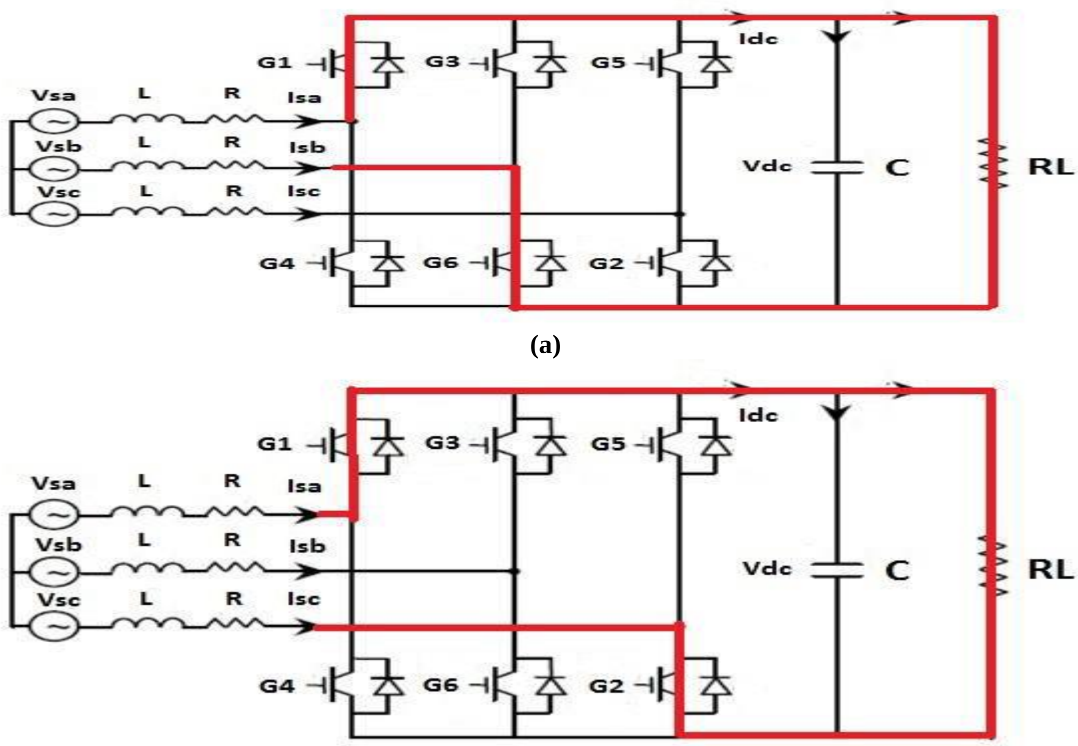


Figure 7 (a) to (b): Modes of operation of three-phase boost rectifier

IV. SIMULATION AND RESULT DISCUSSION

Hysteresis current control with resistive load

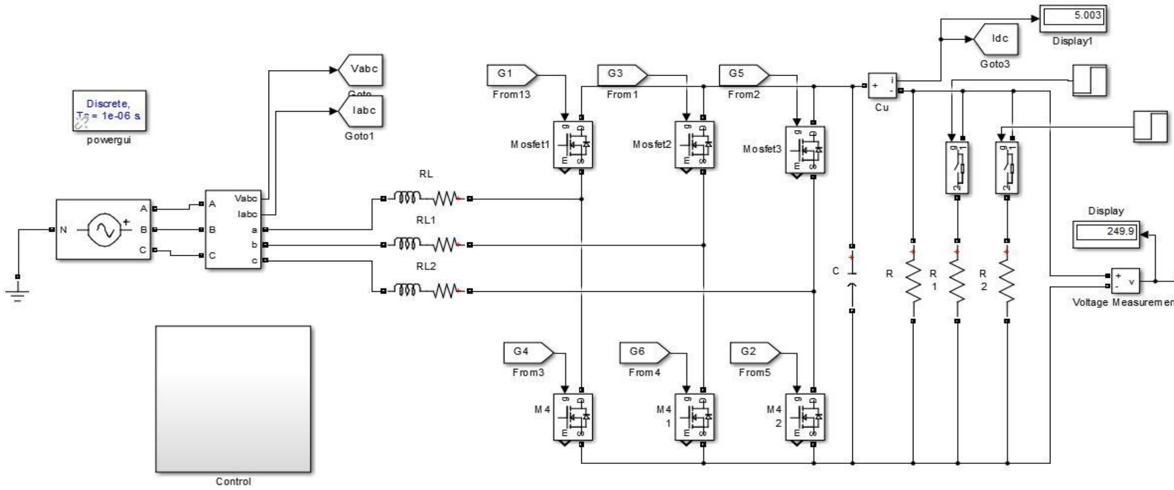


Figure 8: MATLAB/Simulink model for three phase PWM rectifier with variable resistive

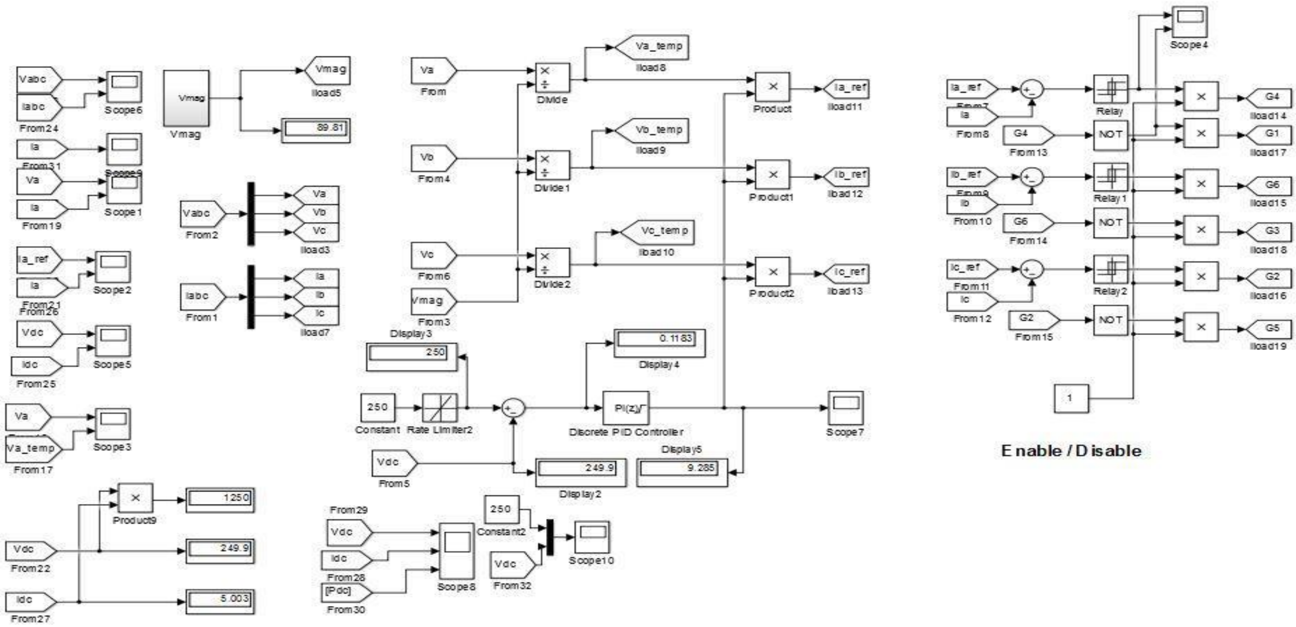


Figure-9: MATLAB/Simulink control scheme for three phase PWM rectifier with variable resistive load (subsystem)

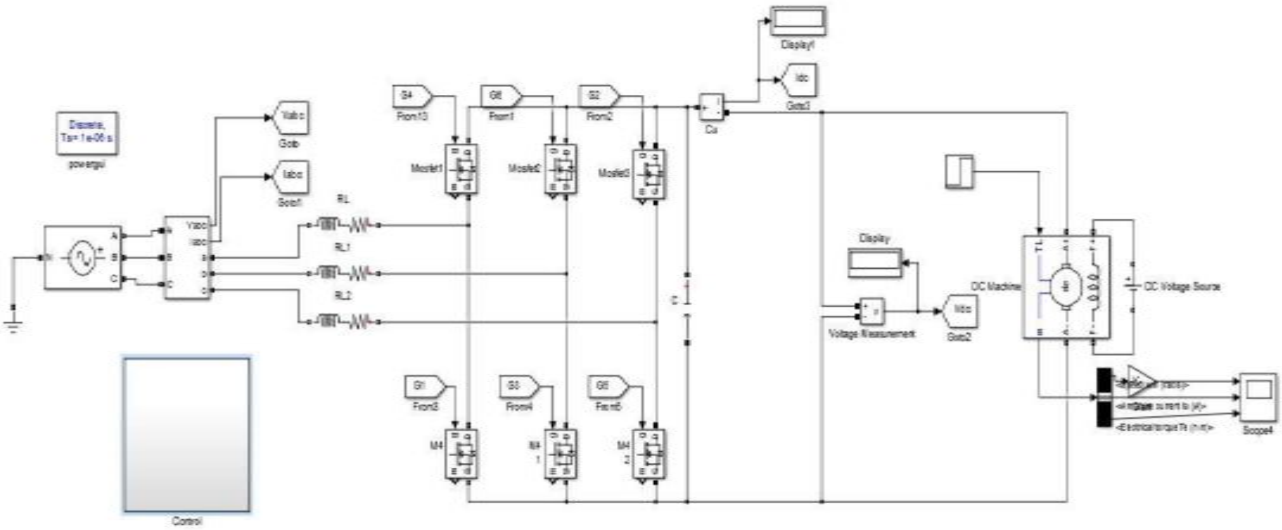


Figure 10: MATLAB/Simulink model of Hysteresis current control with DC motor load

Simulation Results

Results of three phase PWM rectifier are divided in to four parts

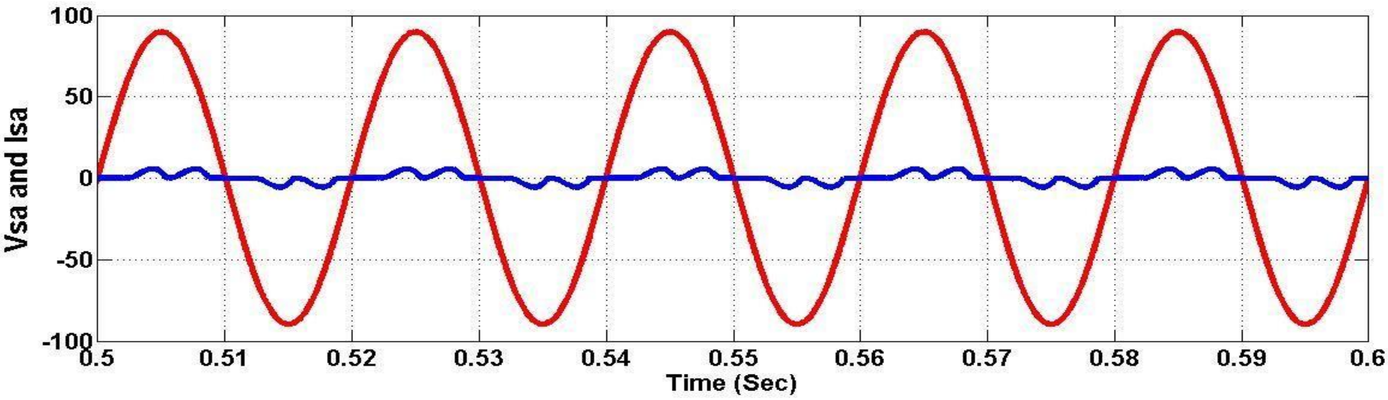


Figure 11: Waveform of source voltage (V_{sa}) and source current (I_{sa})

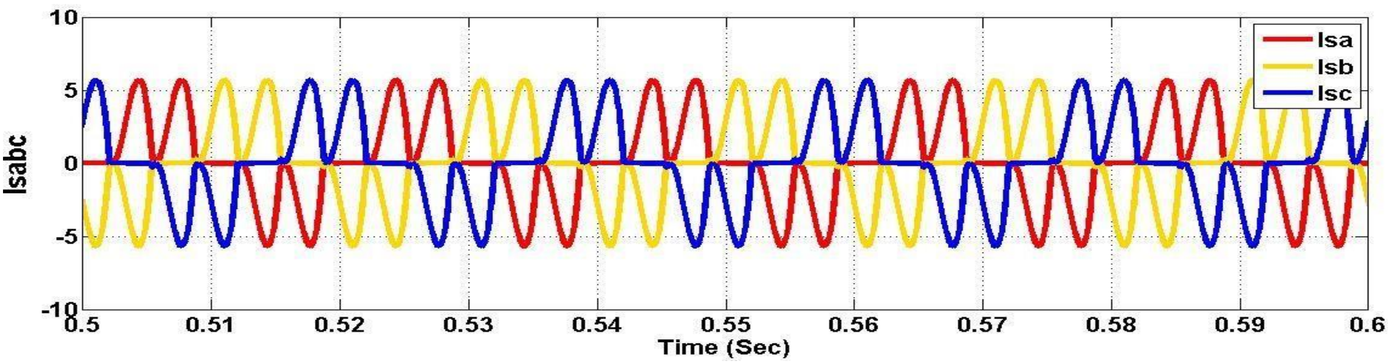


Figure 12: Waveform of source currents (I_{sabc}) – without control

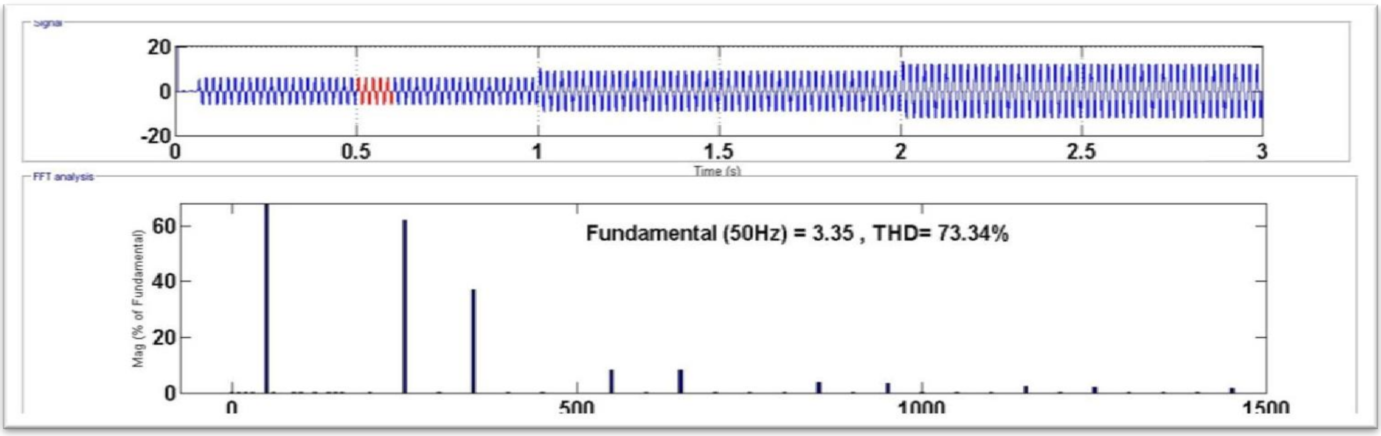


Figure 13: FFT analysis of source current and current THD = 73.34%

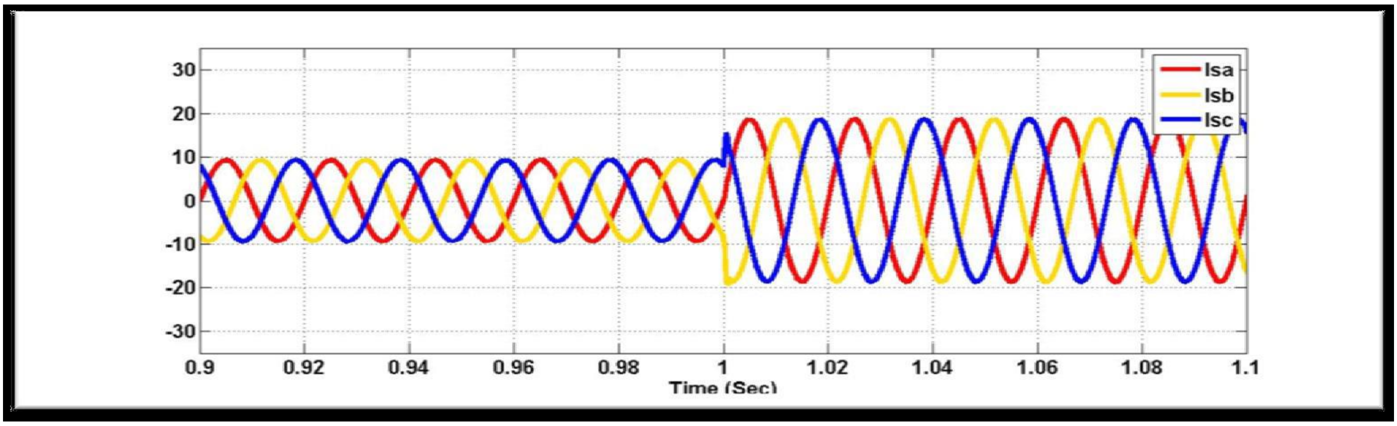


Figure 14 Source current (I_{sabc}) with PWM rectifier-Hysteresis current control for load switching 5A to 10A

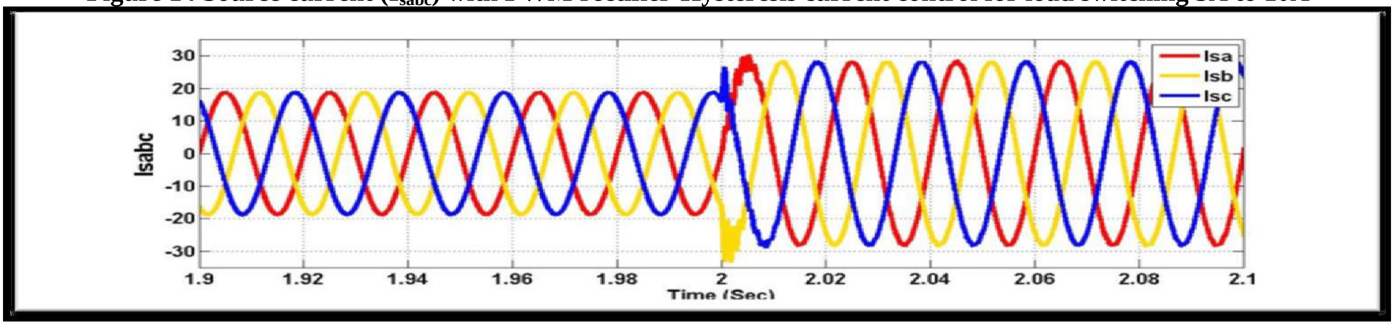


Figure 15 Source current (Isabc)) with PWM rectifier-Hysteresis current control for load switching 10A to 15A

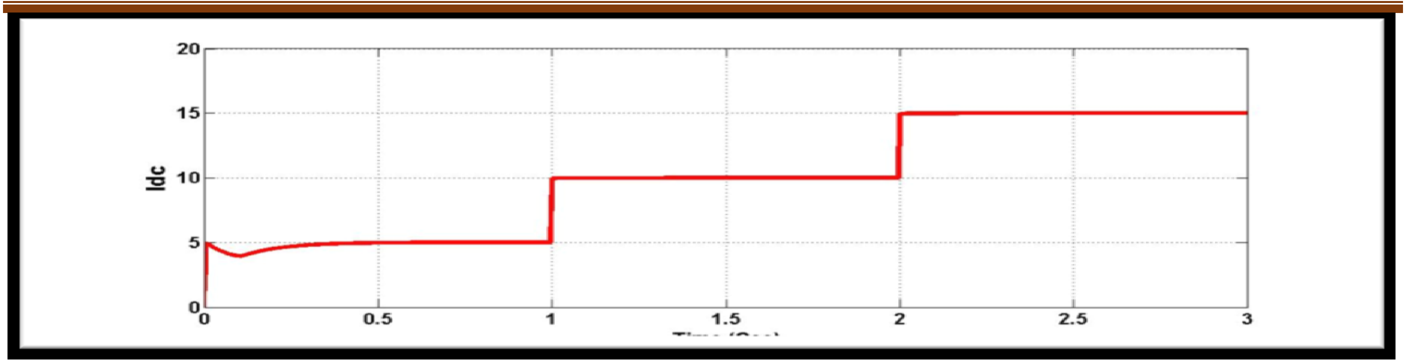


Figure 16 Waveform of output DC current (Idc) for different loading condition. (With PWM rectifier – Hysteresis current control)

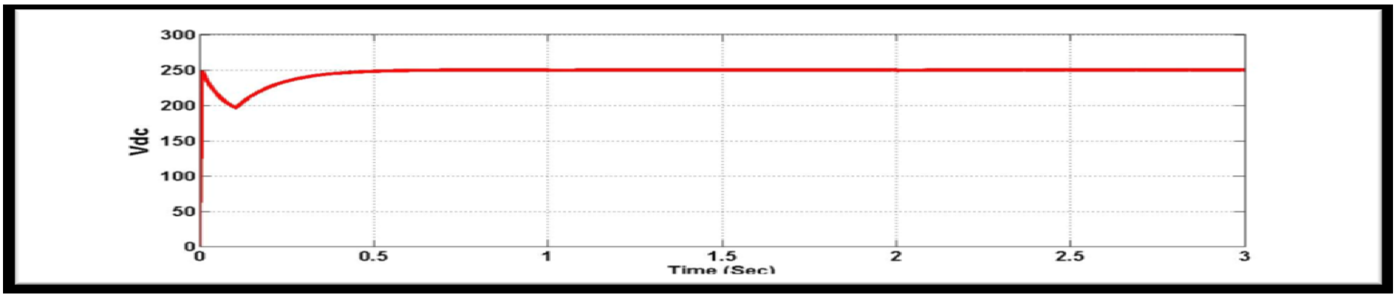


Figure 17 Waveform of output DC voltage (Vdc) for different loading condition. (With PWM rectifier – Hysteresis current control)

As the system is operated as closed loop control, so the output voltage is stable-250V dc at every loading condition. V_{dcref} = 250V dc (<155V dc as Vs = 110V)

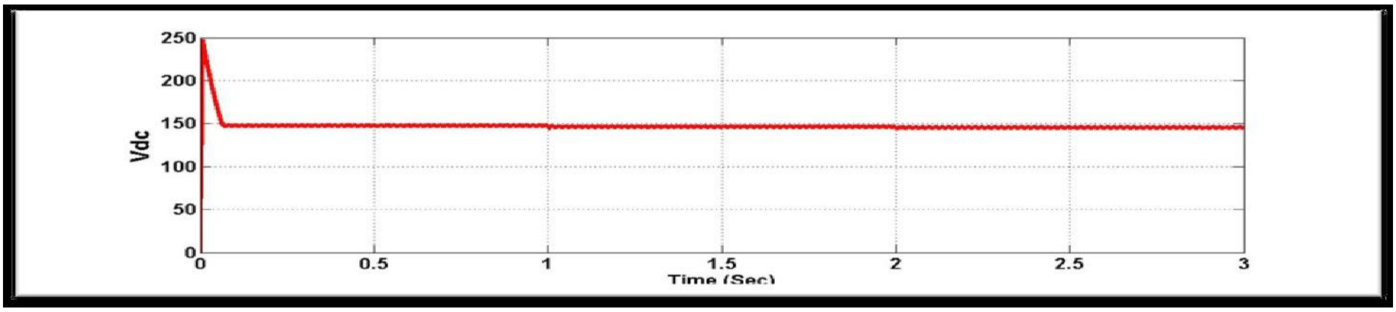


Figure 18 Waveform of output DC voltage (Vdc) for different loading condition.
(Without PWM rectifier – Hysteresis current control)

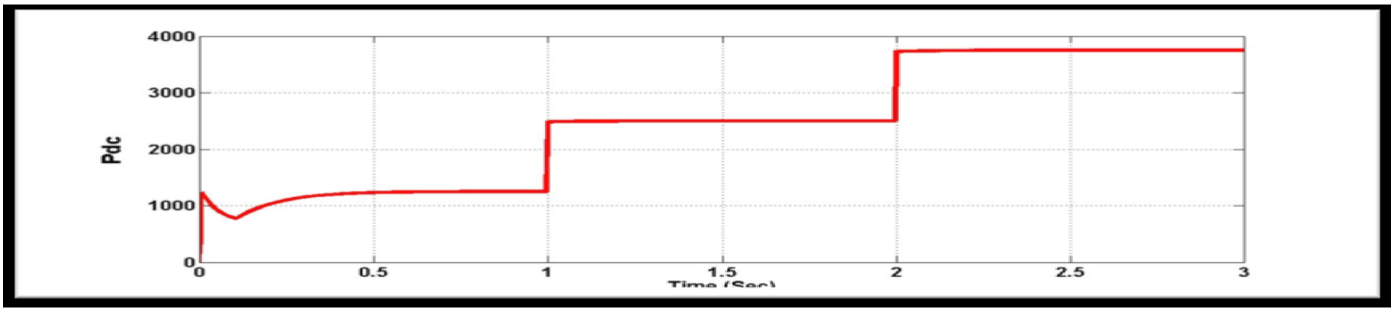


Figure 19 Waveform of output DC power (Pdc) for different loading condition.
(With PWM rectifier – Hysteresis current control)

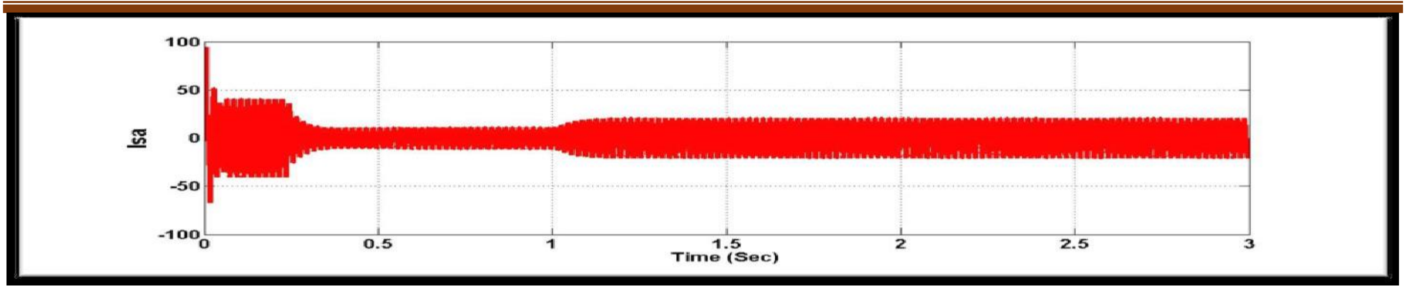


Figure 20 Waveform of source current with DC motor load
(With PWM rectifier – Hysteresis current control)

Phase-A current is shown in figure- 20, inrush current is observed at starting. Torque is set 50 N.m. from 0 to 1 Sec. Then it is changed to 10 N.m. at 1 Sec.

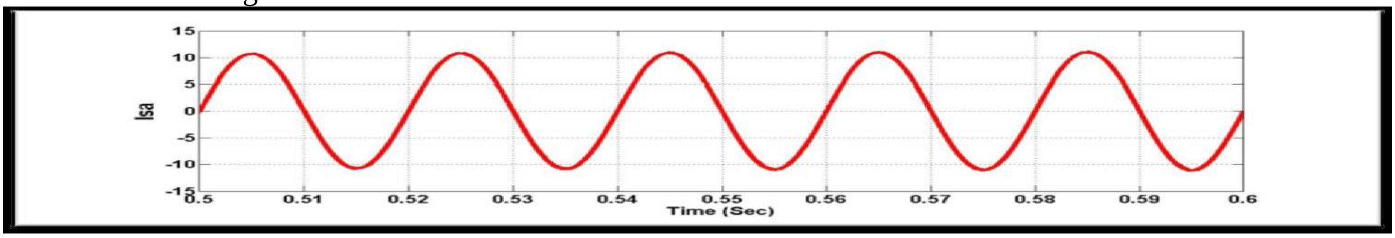


Figure 21 Waveform of source current (Isa) with DC motor load
(With PWM rectifier – Hysteresis current control)

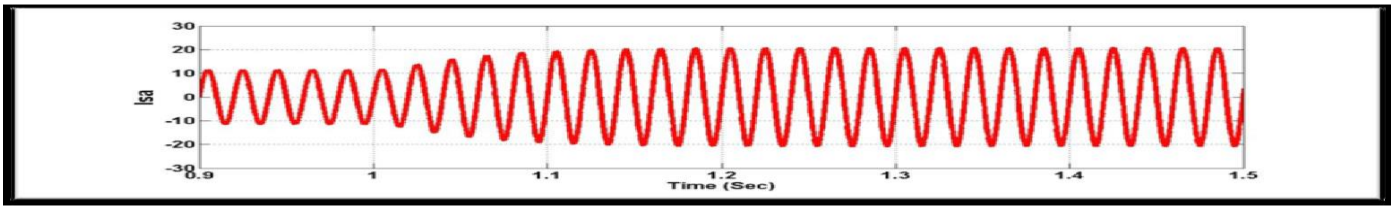


Figure 22 Waveform of source current (Isa) with DC motor load
(With PWM rectifier – Hysteresis current control)

As discussed above, load current is raising after 1 sec that effect is observing.

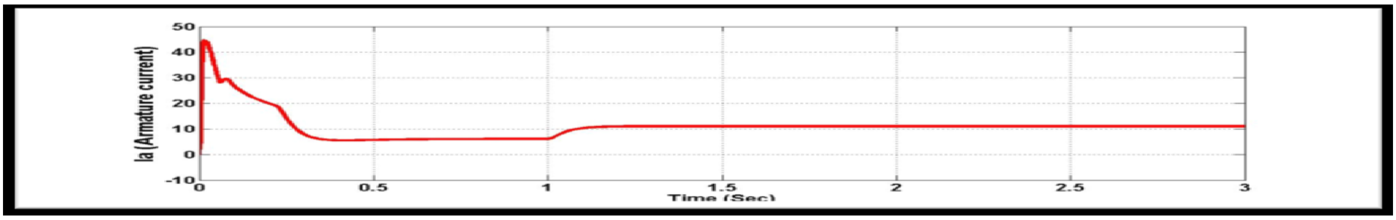


Figure 23 Waveform of armature current (Ia) of DC motor load (With PWM rectifier – Hysteresis current control)

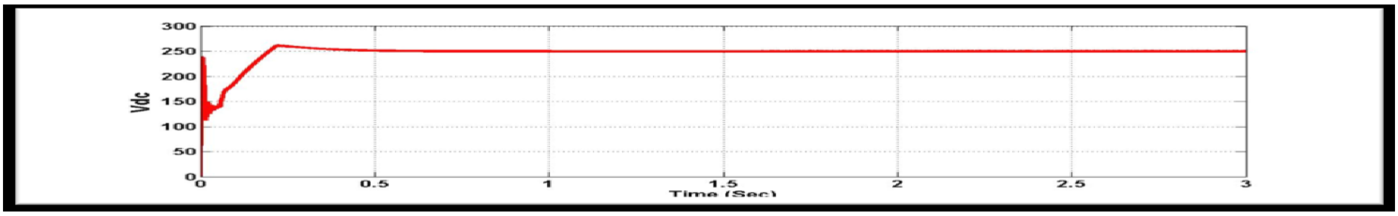


Figure 24 Waveform of output voltage (Vdc) with DC motor load
(With PWM rectifier – Hysteresis current control)

V. CONCLUSION

The modelling, simulation, and analysis of a PWM rectifier based on an AC-DC converter are presented in this study. It offers an appropriate control approach for a pulse width modulation rectifier that minimizes output side ripple in the DC voltage and shapes the input current to be as sinusoidal as possible. A PWM rectifier's primary goals are to control the DC output voltage, guarantee a sinusoidal input current, and operate with a unity power factor. High-speed IGBT/MOSET switches linked in VSI topology are used to do this. Power quality concerns are explored in this dissertation study, and a three-phase PWM rectifier model with hysteresis current control and theory based on dq is suggested to reduce current harmonics. The suggested three phase PWM rectifier model produces sinusoidal and in-phase voltage and current waveforms for a range of loads and loading circumstances. FFT analysis is used to reduce total harmonic distortions.

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