Control Strategy of Vienna Rectifier Using Different Parameters

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Abstract - The Objective of this project is to analyze the switching characteristics, system performance and output parameters with parametric change in input. It is shown that the Vienna rectifier is able to convert a generated AC input, with variable input voltage amplitude and variable frequency to a constant DC bus voltage, whilst controlling the input current to be sinusoidal and in phase with input voltage. It is supplied with the neutralized and harmonic less input with the help of LC filter and the change in output voltage and current along with reference is feedback to the system to trigger the ideal switch. This suggests that the actual output of the Vienna rectifier (controlled as dual boost rectifier) can be delivered to the dc drive, which shows the four quadrant operation and speed control for further prospects. The values are given in rated form in dependency on the output power and on the ratio of output voltage to the amplitude of the mains voltage. Furthermore the influence of the voltage transfer ration the shape of the mains currents and on the power factor of the system is analyzed. The theoretical analysis is verified by digital simulation and a good consistency is achieved. Finally, the approach of the converter dimensioning based on graphical representation of the calculation results is described and illustrated using a specific example.

Keywords- Pulse-width Modulation Rectifier, Boost Rectifier, Controller, Vienna Rectifier.

I. INTRODUCTION

The conversion method which is AC-DC conversion has a wide diversity of application. It is used in power supply microelectronics, battery, DC motor drives. So, a rectifier is widely used for its applications. The conversion of alternating CURRENT which periodically reverses its direction into direct CURRENT which flows in one direction is known as rectification. New generation AC-DC converters reduce power consumption and increase efficiency, essential for powering the majority of electrical equipments. Now, the concept of Vienna Rectifier comes from the basic known concepts of PWM Rectifier and Boost rectifier. Our objective is to decrease voltage fluctuation, decrease current distortion and increase the dynamic performance of a rectifier.

PWM Rectifier is an Ac to Dc power converter that is implemented using forced commutated power electronic semiconductor devices. The advantage of using Pulse Width Modulation technique is the reduction of higher order harmonics. It also controls the magnitude of output voltage and improve power factor. PWM rectifiers are used in power generation applications.[1] [2] [3] [13]

A BOOST CONVERTER steps up the voltage from its supply to load.

Controller - Input current regulation in the converter is achieved by adjusting the duty cycle. Generally three basic algorithm used are P, PI and PID. Here PI controller in the Inner current loop which regulate the input current, reduce peak over shoot and steady-state error. The PI consists of two basic modes that are proportional modes and integral modes. A proportional controller (kp) reduced settling time and reduced the error but not eliminated it. An integral controller (ki) will have the effect of eliminating the steady-state error. Limiter is used to control the duty cycle within the desirable band.

The VIENNA rectifier is a three-switch rectifier (only) that features a split output DC-rail. Control is only required for three switches, which makes it a far easier implementation than the two switch-rectifiers. Control effort is still significantly higher than the single switch implementations, but the input current distortion of the VIENNA rectifier is far less than that of the single-switch implementations.

The objective was to develop an interface between a three phase AC generator operating at variable speed and a constant voltage DC-bus. The interface is required to ensure high energy efficiency by reducing reactive power consumption, as well as maintain a constant DC-bus voltage.

1.1 Two-Level Output Converters

1.1.1 H-bridge boost rectifier

A three-phase H-bridge topology is shown in Fig 1.1. It can be seen in Fig 1.1 that, by adding the diode to the DC rail, the rectifier power flow will be in one direction only. Thus the operation will then be unidirectional only.

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The control effort and complexity for the H-bridge is considerably greater than for the previous topologies discussed states that the input current can be shaped to be sinusoidal by the pulsing of only two bridge legs, effectively transforming the H-bridge rectifier into a two-switch high-frequency rectifier. (Operation of the H-bridge is the same as for the three-switch topologies)[12]

The main disadvantage of this rectifier compared to the three-switch and single switch topologies are higher transistor losses high switch electrical stresses and low reliability factors. The diode conduction losses are, however, lower compared to three switch and single-switch rectifiers. An advantage, compared to three-level rectifiers, is that the minimum boost voltage is 1.35VLL. Output capacitor ripple current stress is almost the same for the H-bridge and the three-switch variants. This topology can be controlled with a constant switching frequency. It states an approximate achievable THD for the line current of 8.2%, for the H-bridge rectifier.

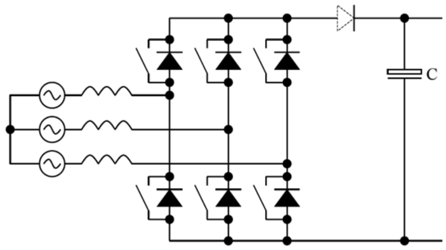


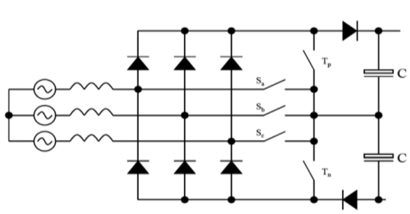
FIG 1.1: Unidirectional H-bridge Converter.

1.2 Three-Level Output Converters

1.2.1 Dual-boost three-level output converters

It shows that three-phase AC can be converted to a split DC rail with two-controlled switches. Fig 1.9 shows the implementation of the topology with AC side inductors and in Fig 1.10 the implementation with DC side inductors. The topologies shown in Figs 1.3 and 1.4 feature two high frequency control switches Tp and Tn. Switches Sa, Sb and Sc are used for the selective injection of the current into the three-phase AC supply. The state of these line switches is turned over every 60°, corresponding to when the corresponding phase voltage is within ±30° of its zero crossovers. Switching frequency of the line switches is thus twice than that of the line frequency. As can be seen from Fig 1.3 and Fig 1.4 all switches except one (Tn) require an isolated gate drive. This makes the implementation of this topology more difficult than all of the other topologies mentioned, including the H-bridge rectifier that only require isolated gate-drives for three switches. A significant disadvantage of this topology is the high output voltage required. Since one of the selector switches (Sa, Sb and Sc) will be closed at all times, the result is that the minimum voltage over each capacitor shall be the peak input line-to-line voltage. Thus the minimum boost voltage is equal to twice the rectified line-to-line voltage, or 2.45VLL. This topology can be controlled with a hysteresis type controller and with a constant switching frequency.[12]

A variation on the rectifier presented in Fig 1.5 is presented by T_max . Here a center tap switch can be used to disconnect or connect the capacitor neutral point, and allows operation for a wide range of inputs, such as variable voltage generator type inputs. Both rectifiers shown in Fig 1.3 and Fig 1.4 feature low line current distortion and very low electrical switch stresses and current stress The greatest disadvantages of both rectifiers are the high control effort (especially the topology shown in Fig 1.1 that requires additional logic and an isolated gate drive to control the centre-tap switch) and the high output voltage.



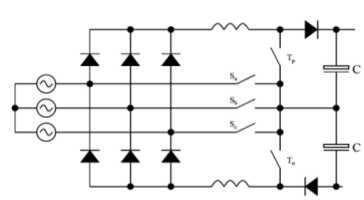


Fig1.2: Two-switch boosts converters with AC inductor, dual DC-rail. Fig 1.3: Two-switch boost converters with DC-inductors, dual DC-rail

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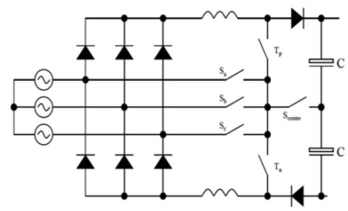
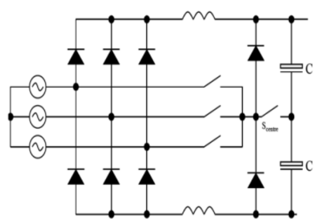


Fig 1.4: Two -switch boost converters with DC-side inductors and dual DC- rail output featuring a centre-tap switch.

1.2.2 Three-phase three-level centre-tap switch rectifier topologies

It presents two three-level rectifiers with split DC-Inductors, as shown in Fig 1.5 and Fig 1.6. The output voltage for both of these rectifiers is greater than 2.45VLL. Both rectifiers shown in Fig 1.12 and Fig 1.13 feature low line current distortion of 5-10%. The topology shown in Fig 1.12 features a single high frequency switch (S centre), with very low current stress. The star-connected switches feature very low electrical stresses. One significant disadvantage of the topology shown in Fig 1.13 is that it suffers from low frequency 360Hz ripple components superimposed on the line currents, for a line frequency of 60Hz. As can be seen from Fig 1.12 and Fig 1.13 all the switches require an isolated gate drive, for a total of four isolated gate drives.



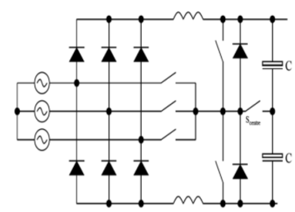
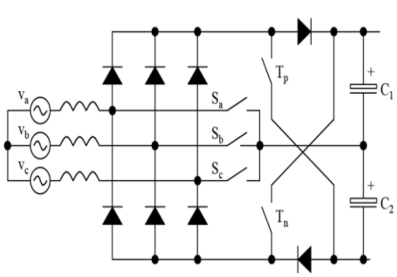


Fig 1.5: Three-level center-tap switch rectifier.

Fig1.6: Three-level inverter-leg and center-tap switch rectifier.

1.2.3 Three-level asymmetrical half-bridge topologies

It presents two split DC rail topologies that employ two PWM switches, connected asymmetrically, to shape the input current. Both of these topologies employ star-connected switches for selectively injecting current, and features low electrical stresses on the bidirectional switches. Both of these rectifiers can also be controlled with a fixed switching frequency. The input line current distortion is below 5% as can be seen from Fig 1.7 and Fig 1.8; all the switches require an isolated gate drive, for a total of five isolated gate drives. This renders the implementation of this topology more difficult than topologies mentioned in the previous sections, including the H-bridge that only require isolated gate-drives for three switches. Since this is a three-level output, the minimum boost voltage is 2.45VLL .It states the line current distortion for the 3-phase boost rectifier with DC inductors and asymmetric half bridge, shown in Fig 1.15, is below 5%.



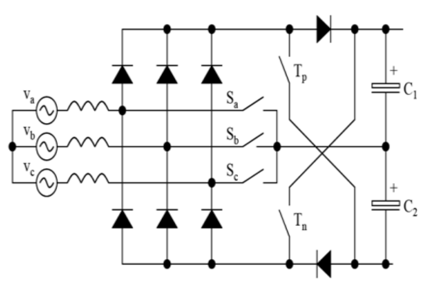


Fig: 1.7: Three-phase boost rectifier with AC inductors and an asymmetrical bridge

Fig 1.8: Three-phase boost rectifier with DC inductors and an asymmetric half bridge

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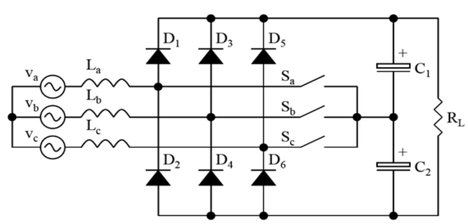
1.2.4 VIENNA rectifier

The VIENNA rectifier is a three-switch rectifier (only) that features a split output DC-rail control is only required for three switches, which makes it a far easier implementation than the two switch-rectifiers (five floating switches) and the H-bridge (three floating switches, three switches referenced to ground). Control effort is still significantly higher than the single switch implementations, but the input current distortion of the VIENNA rectifier, of approximately 8.2%, is far less than that of the single-switch implementation and is on par with the H-bridge and the two-switch and three-switch implementations. The most significant disadvantage of the VIENNA rectifier is the high boost ratio and hence, the high output voltage required (as discussed in the previous section).

The VIENNA rectifier basically functions as a two-switch boost rectifier (for the dual-boost constant switching frequency controller), with one of the switches switched at the line frequency and two switches switched at high frequency. With one switch permanently on for a 60° control block , the VIENNA rectifier can be seen as two independent boost rectifiers, one for boosting C1 and the other for boosting C2. Thus it can be seen that the minimum boost voltage over C1 and C2 will be the maximum line-to-line voltage of the input. The equivalent representation for a 60° control block (one switch "on") is shown in Fig 1.10, which points out that the VIENNA rectifier has lower switch and diode currents than all of the other dual-boost rectifiers. It states that the switch losses and diode losses for the H Bridge and the VIENNA rectifier are comparable, with both rectifiers having the same harmonic distortion. An added advantage of the VIENNA rectifier is that modules are available where all of the semiconductors of a power stage bridge leg are present.[12]



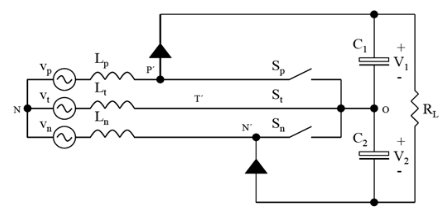


Fig 1.9: The VIENNA rectifier (three-switch three-level three-phase rectifier.

Fig 1.10: Equivalent model for the VIENNA rectifier for a 60 degree control block (one switch closed)

So the concept can be drawn that from the topologies discussed the VIENNA rectifier offers the best compromise in terms of performance, component count and controllability. It offers the same or better performance (harmonic distortion) as most multi-switch topologies, whilst utilizing fewer switches. With the dual-boost constant switching frequency controller, the VIENNA rectifier is easy to control and it's just as easy to set-up an equivalent control model for the VIENNA rectifier. If the control is implemented digitally, the effort for implementation of the dual-boost controller shall be the same as for unified constant-frequency integration controller, whilst offering lower switching losses.

II: METHODOLOGY

2.1 Terms Related To Simulink

SCOPE- The simulink scope block displays the signal with respect to simulation time. The scope's input signals are characterized as continuous or discrete. It supports any data type that simulink supports including real, complex fixed point or enumerated data types. It can display multiple channels within one signal depending on dimensions i.e. scalar, vector or matrix. The display features of scope, includes simulation control, multiple signals where multiple signals can be plotted on same y-axis using multiple input plots. It allows us to modify the scope parameter values before and after simulation. Using auto scaling margins can be drawn at the top and bottom of the axes during or at the end of simulation.

2.1.1 Three Phase Input Signal

A three-phase voltage source is used to generate sinusoidal voltage signal of 230V and moreover displaced from each other by 120 degree. The AC Voltage Source block represents an ideal voltage source that maintains sinusoidal voltage across its output terminals, independent of the current flowing through the source.

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2.2.2 Inductor

Vienna Rectifier employs line Inductance of 125mH.Its tendency is to resist the changes in current by creating and destroying the magnetic field. As a result, the output voltage is always much higher than the input voltage i.e. boosting the input voltage.

2.2.3 Lc Filter

The Vienna Rectifier uses LC filter (Inductive Capacitive filter) to remove the ripples and distorted AC components in order to get ripple free, distortion less DC component to reach the load .Here, only the alternating current is allowed to pass through the capacitor, which blocks the DC. The inductor only allows the direct current to pass.

2.2.4 Igbt

An IGBT or Insulated Gate Bipolar Transistor is a semiconductor device controllable by gate signal. Here, it is employed as a switch i.e. in ON state allows power flow through it and in OFF state does not allows power flow. It works by applying voltage to a semiconductor component, thus in turn changing its property to block or create an electrical path. Therefore, it controls the switching of diode in the rectifier circuit.

2.2.5 Pi Controller

PI Controller is employed in Vienna Rectifier as it eliminates forced oscillations and steady state error, resulting in the operation of an ON-OFF Controller.

2.2.6 Operator

By using the desired value of operator, we can generate the desired ramp signal and can also generate triggering pulse for operating the switch.

2.2: Design Procedure

The Fig below clearly describes the design of the VIENNA RECTIFIER circuit. The circuit depicts three phase input signal with the phase displacement of 120 degree with each other respectively.An input voltage of 230V is applied to each of the input sources which in turn generate a sinusoidal input voltage.Then, the three phase input signal is connected to the LC filter, in which the ripples of the AC component is reduced and makes it less distorted. Here, as per the electrical property, the capacitor allows the alternating current to flow through it and blocks the direct current, and the inductor allows the direct current to pass through it. Then, it is connected to the three line inductances of 125mH each, due to its tendency to resist changes in current by creating and destroying a magnetic field. When the switch is closed, the current flows through the inductor with an increased slope, which is responsible for creating a back emf opposite to the applied voltage. When the switch is opened, the charging current will be reduced as the impedence is higher. The magnetic field which was created will be destroyed in order to maintain the current towards the load. Thus, the polarity will be reversed at the discharging time. As, a result two sources will be in series creating a higher voltage (Vac1 + eLu1) EQ…..(12), to charge the capacitor through diode. Thus, making the output voltage always higher than the input voltage i.e. boosting the input voltage. The rectifier circuit employs 6 diodes with an IGBT switch. The switch is controlled by the firing of the diodes with a proper sequence to generate the desired output. This generated output passes through diode 7 (series connected to the load), capacitor. The capacitor gets charged and we get the capacitive output voltage and current, which gets further, discharged through the resistive load, R. Therefore, we get the desired DC output voltage. So it is a boost type rectifier. Initially we are using the 3-phase ac supply voltage through Y-connected resistor, in which the voltage and the current both will be in phase. Therefore, VIENNA RECTIFIER converts this generated 3-phase AC input (with variable voltage and frequency) to constant DC output (with a pulsating dc and constant frequency).Then the output voltage and the reference voltage, 400V, is taken and passed through the adder circuit. This generates a small error signal which is passed through PI (discrete) controller and then the output of the controller is merged repeating sequence (say Ramp signal). The ‘>=’ (operator) is being used which generates a triggering pulse signal to trigger the IGBT switch.

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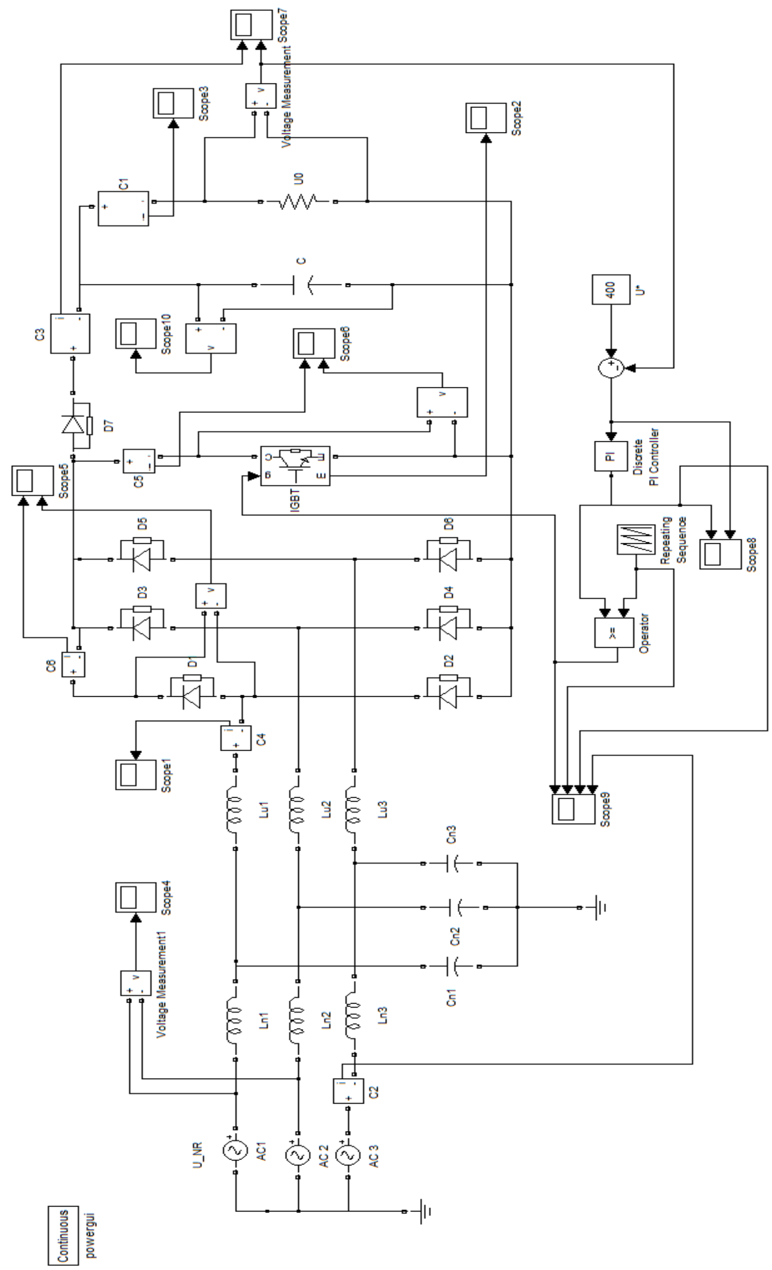


2.3: Comparative Study

Now, we are going to analyze the switching characteristics, system performances and output parameters with parametric change in output which are seen with the help of respective scopes. Also, we are going to study the nature of different parameters which are line input ,supplied voltage, distortion less input current, capacitive voltage, output current and nature of triggering pulse for different changes in the value of Uo (load resistance), C (capacitance) and L (line inductance).

All the below study is experimented on MATLAB software. In this paper, the different topologies are depicted graphically.

SCOPE REFERENCES- In the following study, we have introduced scope 7 for indicating output voltage, according to the model. Scope 3: Output Current; Scope 1: Input Voltage Scope 9: Triggering Pulse , Repeating Sequence as a ramp signal, Output of PI Controller , Input Current (Distortion less) ; Scope 10: Capacitive Voltage

CASE 1: AC Input Voltage - 230V; Line inductances (Lu1, Lu2, and Lu3) - 125m; Load Resistance - 10000 ohm; Capacitance - 500*10ˆ6 F.

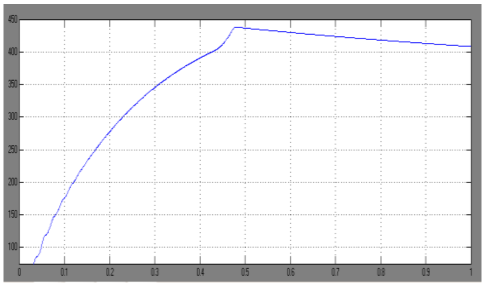


Fig:-2.1

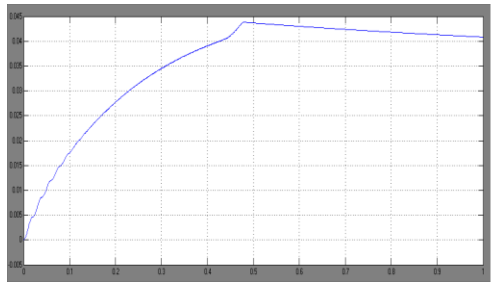


Fig:-2.2

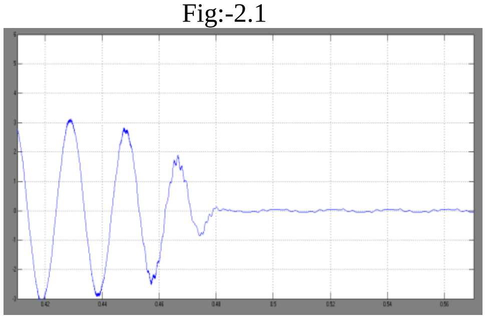


Fig 2.3

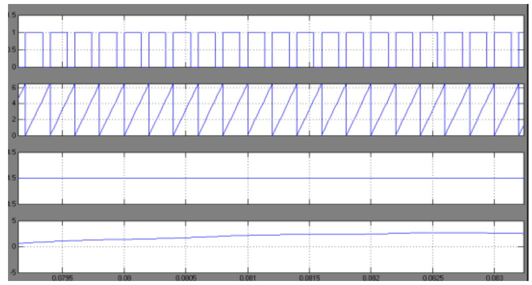


Fig 2.4

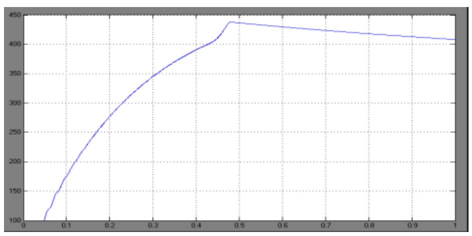


Fig 2.1: Observed under Scope 7 (Output Voltage) In this Fig we study the nature of output voltage as above 400V (approx)

Fig2.2:We observe this particular output under scope 3. In this Fig the output current is above 0.04 A (approx).

Fig 2.3: We observe this waveform under scope 1. In this Fig applied input voltage of 230V is shown. The waveform is sinusoidal in nature and distorted.

Fig 2.4: We observe this waveform under scope 9. In this Fig the waveforms specify triggering pulse, repeating sequence as ramp signal, output of PI controller and input current respectively. The nature of triggering pulse, ramp signal and output of PI controller remains almost constant throughout. The change we will be able to see in input current. Here, input current is approximately 1A.

Fig2.5: Observed under Scope 10 In this Fig is shown the capacitive voltage which is same as that of the output voltage i.e. above 400V.

CASE 2: AC input voltage - 230V ; Line Inductances (Lu1, Lu2, and Lu3) - 125mH.; Load Resistance - 15000 ohm ; Capacitance - 800*10ˆ6 F.

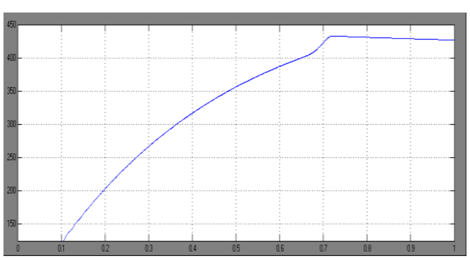


Fig 2.6:

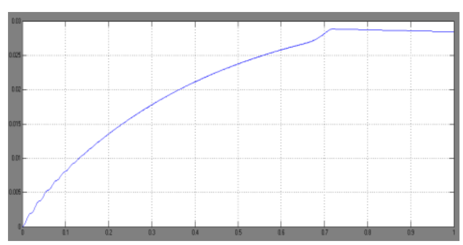


Fig 2.7:

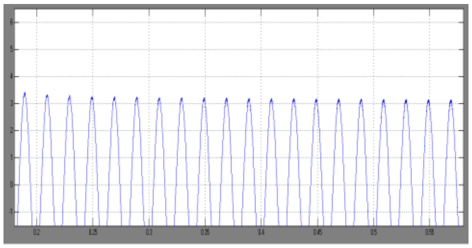


Fig 2.8

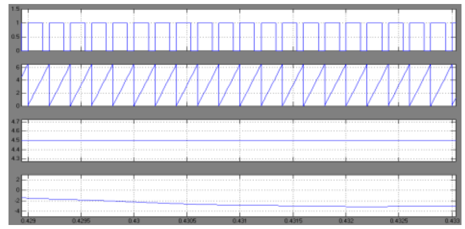


Fig 2.9

Fig 2.6: We This Fig shows that the output voltage remains almost same i.e. above 400V (approx). (No significant change in the output voltage).Another change is observed in the time axis which has increased to 0.1sec from the 1st case which was 0.05 sec.

Fig 2.7: In this Fig we observe that the output current is above 0.025A (approx). Thus, we can say that the output current has decreased slightly from the case 1.

Fig 2.8:. In this Fig applied input voltage of 230V is shown. The waveform is sinusoidal in nature and distort

Fig 2.9: In this Fig the waveforms specify triggering pulse, repeating sequence as ramp signal, output of PI controller and input current respectively. The nature of triggering pulse, ramp signal and output of PI controller remains almost constant througho. The change we will be able to see in input current. Here, input current is approximately from -1.5A to -2.5A.

Here Capacitive Voltage is same as Case 1.(Fig:2.5)

CASE 3: AC input voltage - 230V; Line inductances (Lu1, Lu2, and Lu3) -125mH. ; Load Resistance - 800 ohm; Capacitance - 300*10ˆ6 F.

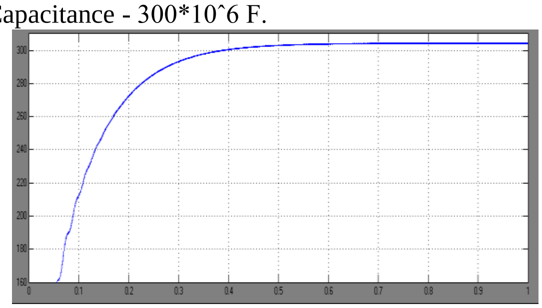


Fig 2.10: Observed under Scope 7

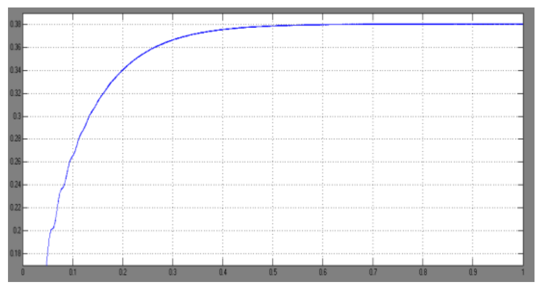


Fig 2.11: Observed under Scope 3

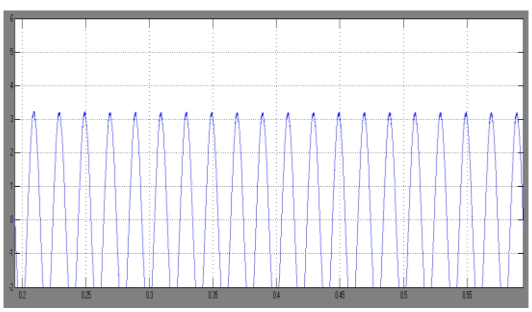


Fig 2.12:

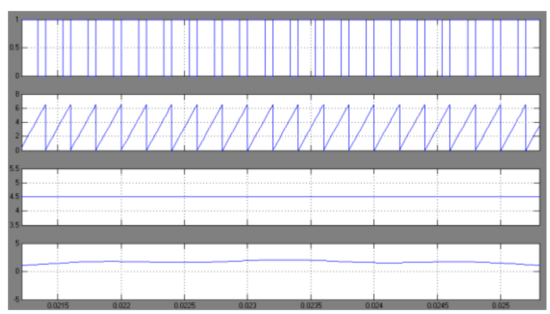


Fig 2.13:

Fig 2.10: In this Fig we can see that there is a massive decrease in the output voltage in comparison to the previous two cases i.e. above 300V (approx).Thus, in this case the load independent nature is no more existing, it has become load dependent.

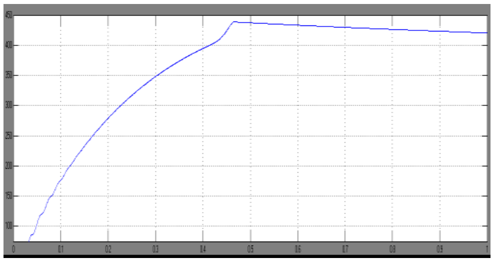
Fig 2.11:. In this Fig we observe that the output current is around 0.38 A. Thus, we can say that the output current has from the case 1.increased massively from the previous two cases.

Fig 2.12:. In this Fig applied input voltage of 230V is shown. The waveform is sinusoidal in nature and distorted.

Fig 2.13: In this Fig the waveforms specify triggering pulse, repeating sequence as ramp signal, output of PI controller and input current respectively. The nature of triggering pulse, ramp signal and output of PI controller remains almost constant throughout. The change we will be able to see in input current. Here, input current is approximately from 1.5A to 2.0.A

Here, Capacitive Voltage is same as Output Voltage (decreased massively).

CASE 4: This case is directly compared with CASE 1. Here we have taken the load resistance is taken as 15000 ohm the capacitance is of 500*10ˆ6 F, keeping the rest of the parameters same as CASE 1.



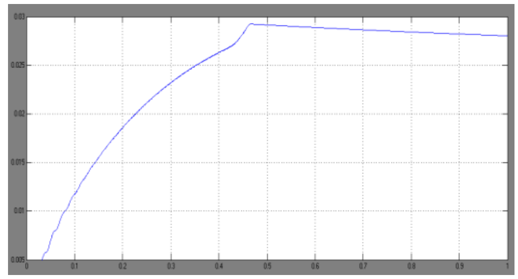
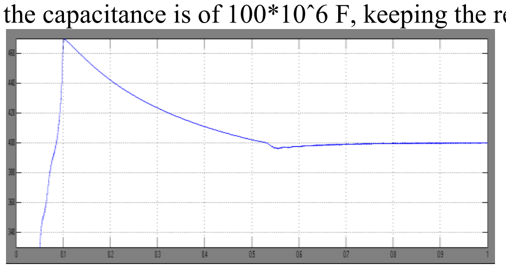


FIG 2.14: We observe this particular waveform under scope 7. In this Fig it is seen that on increasing the resistance and on keeping the capacitance constant, there does not occur any change in the output voltage, i.e. it remains above 400V (approx).

FIG 2.15: We observe this particular waveform under scope 3. In this Fig it is seen that on increasing the resistance and on keeping the capacitance constant, the output current is above 0.025A (approx), which is similar to that of CASE 2.

CASE 5: This case is directly compared with CASE 2. Here we have taken the load resistance is taken as 15000 ohm the capacitance is of 100*10ˆ6 F, keeping the rest of the parameters same as CASE 2.



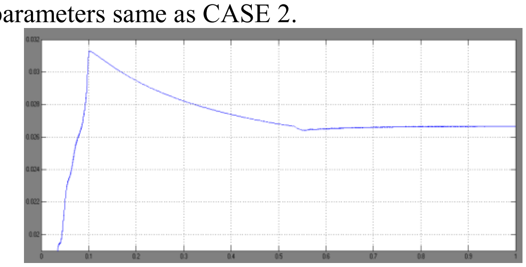
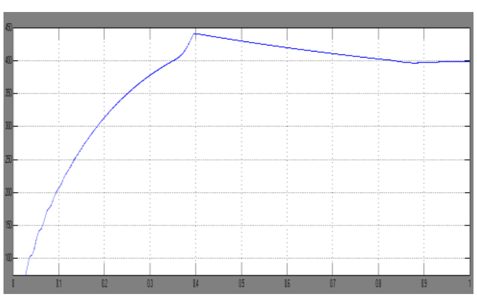


Fig 2.16: We observe this particular waveform under scope 7. In this Fig it is seen that on keeping the resistance same and on decreasing the capacitance, the output voltage decreases to around 400V. The nature also changes highly.

Fig 2.17: We observe this particular waveform under scope 3. In this Fig it is seen that on keeping the resistance same and on decreasing the capacitance, the output current decreases to above around 0.26A. The nature also changes highly.

CASE 6: This case is directly compared with CASE 1and CASE2. Here we have decreased the load resistance to 8000 ohm and also decreased the capacitance to 400*10ˆ6 F, keeping the rest of the parameters same as CASE 2.



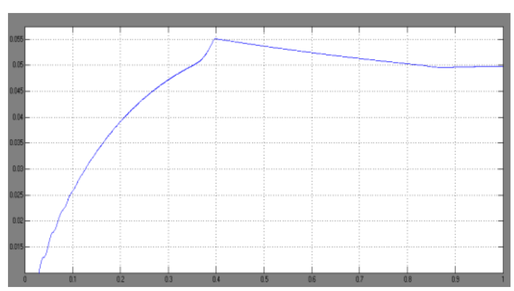
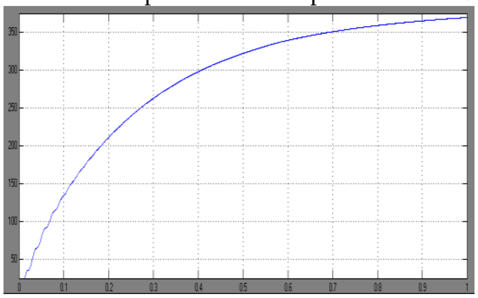


FIG 2.18: We observe this particular waveform under scope 7. In this Fig it is seen that the output voltage remains same as of CASE 1 and CASE 2 i.e. around 440V.

FIG 19: We observe this particular waveform under scope 3. In this Fig it is seen that the output current has increased up to 0.054A (approx) as compared with CASE 1 and CASE 2.

CASE 7: Here we are making the comparative study with respect to inductance. We have increased the inductance to200mH and compared to all the previous cases.



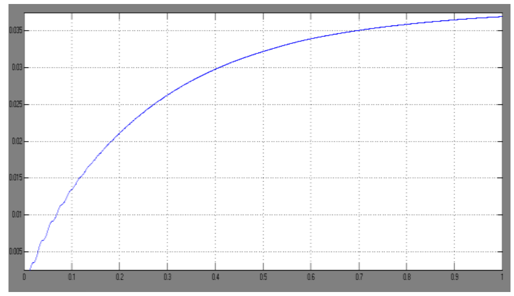
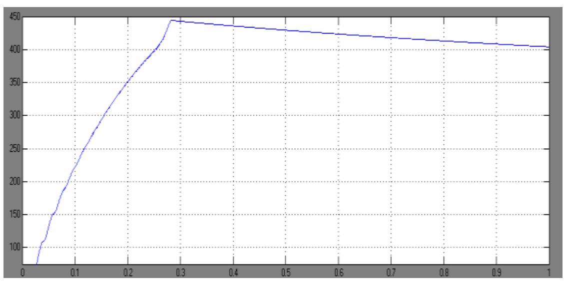


Fig 2.20: We observe this particular waveform under scope 7. In this Fig we have increased the line inductances to 200mH. By doing so we observed that the output voltage has decreased to around 350V.

Fig 2.21: We observe this under scope 3. By increasing the line inductances to 200mH we can observe that the output current decreases to around 0.035A.

CASE 8: Here we are making the comparative study with respect to inductance. We have decreased the inductance to 75mH and compared to all the previous cases.



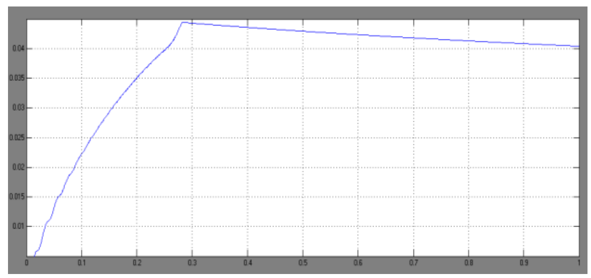
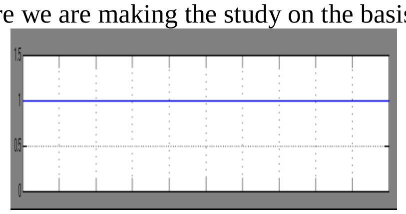


FIG 2.22: We observe this under scope 7. In this Fig we have decreased the line inductances to 75mH. By doing so we observed that the output voltage has increased to around 440V.

Fig 2.23: We observe this under scope 3.By decreasing the line inductances to 75mH we can observe that the output current increases to around 0.045A.

CASE 9: Here we are making the study on the basis of the operator.



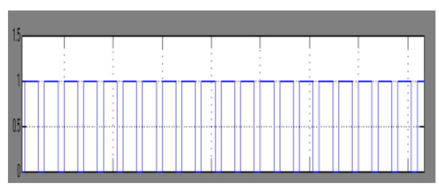


FIG 2.24: This particular waveform is observed under scope 9. In this Fig with operator 1, no triggering pulse is present.

FIG 2.25: This waveform is observed under scope 9. In this Fig with operator -1, proper sequential pulses are present.

(Fig 2.1 – 2.25 – All are under MATLAB Simulation.)

III. RESULTS & DISCUSSIONS

We can come to a discussion that the Vienna Rectifier offers the same or less input current harmonic distortion. The Vienna rectifier with its 3 level output, allows any DC to DC converter to be used at the rectifier output and with constant switching frequency control, no additional circuitry is required to balance the two output capacitors. The Vienna rectifier has only 3 switches, which are significantly fewer than other active rectifiers with the same performance (in terms of harmonic distortion).The Vienna rectifier requires less control effort (in terms of number of isolated gate drives required) than other active rectifier topologies in comparable performance (in terms of harmonic distortion).With constant switching frequency dual-boost control sufficient sensing effort is provided to implement dual-boost control or unified one cycle control if needed. Implementation of the Vienna rectifier is eased

by the availability of single bridge leg modules. Dual boost constant frequency control is not dependent on a fixed line frequency, making it ideal for variable frequency type inputs.
We observe the following changes from the above experimentation as represented in graphical formats:-
On increasing the values of resistance and capacitance the output voltage remains the same whereas the output current has decreased slightly (from Case 2(scope 7 and scope 3 respectively)). Again, on decreasing the values of resistance and capacitance the output voltage decreases abruptly and the output current has increased abruptly (from Case 3(scope 7 and scope 3 respectively)). Further we observed that on increasing the resistance and keeping the capacitance same the output voltage remains same but output current decreases (Case 4(scope 7 and scope 3 respectively)).Increasing the resistance and decreasing the capacitance the output voltage and the output current decreases and the nature of the waveforms changes (Case 5(scope 7 and scope 3 respectively)).Decreasing the resistance and increasing the capacitance makes the output voltage same but increases the output current. On increasing the inductance, both the output voltage and current decreases and on decreasing the inductance both the output voltage and current increases (Case 9 respectively (scope 7 and scope 3 respectively)).Finally, we have observed that only when the operator is -1, then there is a generation of triggering pulse (Case 9(scope 9)).From the mathematical expression we can conclude, the speed of the drive through VIENNA rectifier can be controlled by triggering pulse, as we are increasing the firing angle, speed should be decreased
We can also mathematically express and prove as follows:-
Three Phase Signal
Applied input to the rectifier:
Vac1 = Vm Sin wt. (1)
(Here Vm = max amplitude = 230V.)
Vac2 = Vm Sin (wt-1200). (2)
Vac3 = Vm Sin (wt+1200). (3)
[18]
Line current flowing through the inductors at a time instant, is

ILu1 = $\frac{\sqrt{3}}{2}\delta pM^{-1}\cos(\phi_N)$ [Since, they are star connected] (4)

(Where, ϕ N = Angular interval of the axis)
Now,

δ_p = $\frac{T_{on}}{T}$ (Duty Cycle). (5)

(Where, Ton = IGBT on Time
Toff = IGBT off Time.)

M = $\frac{U_0}{V_{ac1\max}}$ [For 1st Phase]. (6)

(Where, M = Voltage transformation ratio between Dc output and peak value of main Input Voltage.)

Similarly,

ILu2 = $\frac{\sqrt{3}}{2}\delta pM^{-1}\cos(\phi_N - \frac{2\pi}{3})$ (7)

ILu3 = $\frac{\sqrt{3}}{2}\delta pM^{-1}\cos(\phi_N + \frac{2\pi}{3})$ (8)

Mode 1 Operation
When the switch, IGBT is on, then the current is flowing through line inductors, filter inductors, Bridge Rectifier and IGBT. Then,
In this time duration, the inductors start storing energy.
Then, the voltage across the line inductors are,

$$e_{Lu1} = L_{u1}\frac{dI_{Lu1}}{dT_{on}} \tag{9}$$

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$$e_{Lu2} = L_{u2}\frac{dI_{Lu2}}{dT_{on}} \tag{10}$$

$$e_{Lu3} = L_{u3}\frac{dI_{Lu3}}{dT_{on}} \tag{11}$$

In this duration due to the presence of inductor, current is gradually increased with di/dt slope.
For this reason the respective Figs (associated with output current).
Fig:-4.2, Fig:-4.7, Fig:-4.12, Fig:-4.17, etc. which will show the slope of gradually increment of 0 to 0.5.
In the same way, due to the presence of the capacitor across the load circuit, voltage across the capacitor will discharge across load resistance with dv/dt.
Mode 2 Operation
When IGBT is remaining in off position, then the total voltage (means source voltage is added to voltage across line Inductor). i.e.
Vac1 + eLu1..............(12). is being delivered across the load, due to this reason the voltage is boosted from 230V to above 400V and i.e. reflected in the fig:-4.1,4.6,4.11 etc.
So, the rectified average output voltage, which is appearing across the load circuit, is:

$$\frac{6}{2\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha}(V_{ac1}-V_{ac2})dwt \tag{13}$$

$$U_{0avg} = {3\sqrt{3}V_m}/{\pi}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha}\sin(wt)dwt \tag{14}$$

Current expression for the same, is

I0avg = $$\frac{U_{0avg}}{R} = {3\sqrt{3}V_m}/{\pi R}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha}\sin(wt)dwt \tag{15}$$

Now for the DC drives, expression for the speed is

$$N = \frac{V - I_a R_a}{K\phi} \tag{16}$$

Hence, the input voltage can be written as,

$$V = K\phi N + I_a R_a \tag{17}$$

So, substituting the average output voltage of the rectifier at the place of dc drive's input voltage we get,

$${3\sqrt{3}V_m}/{\pi}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha}\sin(wt)dwt = K\phi N + I_a R_a$$

$$N = \left(\frac{3\sqrt{3}V_m}{\pi}\cos\alpha - I_a R_a\right)\frac{1}{K\phi}$$

Now for DC shunt drives;

ϕ = Constant.

Kϕ = Constant. $I_a R_a$ = Constant. So, we can write; $N \propto \left(\frac{3\sqrt{3}V_m}{\pi}\cos\alpha - k\right)$ (18)

Therefore, $N \propto \cos\alpha$

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Hence, we can say that, we can control the speed of a dc drives, by controlling the triggering angle α ,of a VIENNA Rectifier

IV. CONCLUSION

For using LC filter in our rectifier circuit, input should have less harmonic content for every cycle. Due to the presence of a single switch, the switching loss will be reduced. Normally, in case of 3-phase bridge circuit where 6 switches were applicable, S1 and S4 both were in the same length. If, the commutation of S1 and the firing of S4 was not same then there is a question for short circuit phenomenon. That can be overcome by using VIENNA rectifier. In our circuit, series inductor and parallel capacitor are used for load part, due to which we can use this system for under damped and over damped strategy.We can change the width of the voltage waveform (by pulse-width modulation) which will be applied to the drive, with variable speed.We can use this circuit for the braking purpose of DC drive.The circuit will be less complicated due to the usage of single switch and proportionally cost will be reduced.From the mathematical expression we can conclude, the speed of the drive through VIENNA rectifier can be controlled by triggering pulse, as we are increasing the firing angle, speed should be decreased. Normally, a four quadrant operation of a DC drive can be achieved by a dual converter in earlier days, which can be replaced by our diagram by changing the modulating index (firing angle). Also, there is a scope in
increasing the number of IGBT switches to get a enhanced frequency output.Harmonic distortion can also be reduced to get a smoother output.

V. REFERENCES

[1] B. Singh, B.N. Singh, A. Chandra, K Al-Haddad, A. Pandey and D.P. Kothari, "A Review of Three-Phase Improved Power Quality AC-DC Converters", IEEE Transactions on Industrial Electronics, Vol. 51, No. 3, pp.641-660, June 2004.

[2] J.W. Kolar and H. Ertl, "Status of the Techniques of Three-Phase Rectifier Systems With Low Effects on the Mains", 21st INTELEC, Copenhagen, Denmark, pp.14.1June 1999.

[3] E.H. Ismail and R Erickson, "Single-Switch 3ϕPWM Low Harmonic Rectifiers",IEEE Transactions on Electronics, Vol. 11, No. 2, pp.338-346, March 1996.

[4] M. Tou, K. Al-Haddad, G. Olivier and V.R. Rajagopalan, "Analysis and Design of Single-Controlled Switch Three-Phase Rectifier with Unity Power Factor and Sinusoidal Input Current", IEEE Transactions on Electronics, Vol. 2, No. 4, pp.856-862, July 1997.

[5] J.C. Salmon, "Circuit topologies for pwm boost rectifiers operated from 1-phase and 3-phase ac supplies and using either single or split dc rail voltage outputs", Applied Power Electronics Conference and Exposition (APEC), Conference Proceedings, Vol. 1, pp. 473-479, 1995.

[6] Bose, B.K.: Recent Advances in Power Electronics. IEEE l'kansactions OnPE, Vo1.7, No.1, pp. 2-16 (1992).

[7] Zhang, H.: Reversible Rectifiers. PhD Thesis, University of Surrey,Guildford, England, (1992).

[8] Kolar, J.W., Ertl, H., and Zach, F.C.: Approzimate Determination of the Current RMS Value of the DC Link Capacitor of Single-phase and Three-phase PWM Converter Systems. Proceedings of the 3rd International (1st European) Power Quality Conference, Paris, Nov. 13-15

[9] Dixon Jr., L.H.: Filter Inductor and Flyback lhnsformer Design for Switching Power Supplies. Unitrode Switching Regulated Power Supply Design Seminar Manual, SEM-700, pp. M6-1-M6-6 (1990).

[10] Ismail, E., and Erickson, R.W.: A Single lhnristor Three-Phase Resonant Switch for High-Quality Rectification. Conference Record of the 23rd Power Electronics Specialists Conference, Madrid, June 29-July

[11] Jacobus Hendrik Visser “Active converter based on the VIENNA rectifier topology interfacing a three-phase generator to a DC-bus” Supervisor: prof. M.N. Gitau Department: Electrical, Electronic and Computer Engineering Degree: M.Eng. (Electrical)

[12] Active Converter Based On The Vienna Rectifier Topology Interfacing a Three-Phase Generator To A Dc-Bus By Jacobus Hendrik Visser Submitted in partial fulfillment of the requirements for the degree Master of Engineering (Electrical) in the Faculty of Engineering, the Built Environment and Information Technology UNIVERSITY OF PRETORIA March 2007

[13] Redl, R., and Balogh, L.: RMS, DC, Peak, and High-Frequency Power-Factor Correctors with Capacitive Energy Storage. Proceedings of the 7th Applied Power Electronics Conference, Boston, MA, Feb. 23-27

[14] Koczara, W.: Unity Power Factor Three-phase Rectifier. Proceedings of 6th International (2nd European) Power Quality Conference, Oct.14

[15] Prasad, A.R., Ziogas, D., and Manias, 5.: An Active Power Factor Correction Technique for Three-phase Diode Rectifiers. IEEE l'kansactions on PE, Vo1.6, No.1, pp. 83-92 (1991).

[16] Malesani, L., Rossetto, L., Spiazzi, G., Tenti, P., Toigo, I., and Dal Lago, F.: Single-Switch Three-phase AC-DC Converter with High Power Factor and Wide Regulation Capability. Proceedings of the 14th IEEE INTELEC, Washington, D.C., Oct. 4-8, pp. 279-285 (1992).

[17] Space Vector-Based Analytical Analysis Of The Input Current Distortion Of A Three-Phase Discontinuous-Mode Boost Rectifier Syste Johannw . Kolar, Hanse Rtl, Franzc . Zach

[18] Joeannw . Kolar, Hans Ertl, Franzc . Zach Technical University Vienna, Power Electronics Section, Gusshausstrasse 27, A-1040 Vienna, Austria Phone: (Int)43-1-58801-3886 Far: (Int)43-1-5052666