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Simulation model of 3-phase PWM rectifier by using MATLAB/Simulink

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ABSTRACT

Many industrial applications require the use of power electronic devices, which in turn help in overcoming the problems of variable load and fluctuations that occur at the end of feeding. The current study emphasizes that the use of different electric power generation systems with industrial applications needs control devices to work on improving the power quality and performance of systems in which there is an imbalance in the voltage or current due to the change of loads or feeding from the source. The present study also presents a model of a transformer widely used in industrial applications and this work includes simulating a three-phase rectifier by MATLAB. There are four cases in this work HWR (uncontrolled and controlled) and FWR (uncontrolled and uncontrolled) with different loads (R, RL & RC) including full wave type AC/DC using six electronic transformer silicon control rectifier (SCRs) once as well as unified half wave using three electronic transformer silicon control rectifier (SCRs). Simulation results include input, output voltage, and current with the waveform.

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1. INTRODUCTION

Power electronic devices (PED), it had incorporate rectifier (AC_DC), inverter (DC_AC), converter (DC_DC and AC_AC) [1]-[5]. The kind of AC_DC is one of PED that use to convert the ac voltage source to dc voltage that use to the load [6]-[8]. The rectifier utilized when the heap is DC and the source was AC [9]-[11]. There are numerous applications in industrial like battery chargers, HVDC and Elevator and so forth [12]-[14]. There are numerous kinds of rectifier with natural switch. The commonplace switch model incorporate single-stage uncontrolled, three-stage uncontrolled, three-stage controlled and single-stage controlled. These switches required gadget type nonlinear for models thyristors like (SCR, GOT & TRIAC), transistors like (IGBT) and diodes. The switch type uncontrolled like diode had no control like low power and high force. The quantity of switches in rectifier framework was one or four at utilizing single stage yet it was three or six at utilizing three stage [15]-[17]. Single stage incorporate HWR and FWR. The HWR had source and one switch at utilizing single stage or three switches at three stage. The FWR had source and four switches at utilizing single stage or six switches at three stage. Uncontrolled rectifier, there are utilizing diodes that had no control. Controlled rectifier, there are utilizing various switches like MOSFET, IGBT, TRIAC and so forth [18]-[20]. In this study, right now mimicked numerous sorts for rectifier, 3-phase rectifier uncontrolled (HWR and FWR) and 3-phase rectifier controlled (HWR) and FWR. Moreover, this survey had reproduced the diverse load(R, R_C and R_L).

2. MATHEMATICAL MODEL OF 3-PHASE RECTIFIER

Current simulations include a 3-phase rectifier with a half-mix, as well as a full-wave rectifier [21]-[24]. The work in both cases had divided into the use of two types of electronic power devices, one without control and the other with control. The mathematical model includes many terms that represent the specifications of the ingredient and it is worth noting that it has used to represent the ingredient mathematically from the crescent moon of mathematical equations. It included, root mean square values (Vrms & Irms), average values (Vavg & Iavg), input source power (Pac), output power (Pdc), efficiency (η), ripple factor (RF), form factor (FF), harmonic factor (HF), crest factor (CF), and power factor (PF) [25].

$$V_{rms} = \left\{\frac{1}{T}\int_0^T V^2(t)dt\right\}^{0.5} \tag{1}$$

$$I_{rms} = \left\{\frac{1}{T}\int_0^T I^2(t)dt\right\}^{0.5} \tag{2}$$

$$V_{avg} = \frac{1}{T}\int_0^T V(t)dt \tag{3}$$

$$I_{avg} = \frac{1}{T}\int_0^T I(t)dt \tag{4}$$

$$P_{ac} = V_{rms}.I_{rms} \tag{5}$$

$$P_{dc} = V_{avg}.I_{avg} \tag{6}$$

$$\eta = \frac{P_{ac}}{P_{dc}} = \frac{V_{rms}.I_{rms}}{V_{avg}.I_{avg}} \tag{7}$$

$$\mathrm{RF} = \frac{V_{ac}}{V_{dc}} \tag{8}$$

$$FF = \frac{V_{rms}}{V_{avg}} \tag{9}$$

$$\mathrm{HF} = \left[\left({}^{I_{s1}}/_{I_s}\right)^2 - 1\right]^{0.5} \tag{10}$$

$$\mathrm{CF} = \frac{I_{s(peak)}}{I_s} \tag{11}$$

$$\mathrm{PF} = {}^{I_{s1}}/_{I_s}\, cos\emptyset \tag{12}$$

In addition, there are three waveforms of three phase as (13), (14), (15):

$$V_1 = V_m \times \sin\omega t \tag{13}$$

$$V_2 = V_m \times \sin(\omega t - 120^0) \tag{14}$$

$$V_3 = V_m \times \sin(\omega t + 120^0) \tag{15}$$

3. SIMULATION MODEL OF 3-PHASE RECTIFIER

Simulation model of 3-phase rectifier, in this section the review had uncontrolled 3-phase rectifier for HWR, uncontrolled 3-phase rectifier for FWR, controlled 3-phase rectifier for HWR, controlled 3-phase rectifier for FWR system with different load at R, R_L & R_C. The simulation model of uncontrolled 3-phase rectifier for HWR as shown in Figures 1 to 3, the simulation model of uncontrolled 3-phase rectifier for FWR as shown in Figures 4 to 6, the simulation model of controlled 3-phase rectifier for HWR as shown in Figures 7 to 9 and the simulation model of controlled 3-phase rectifier for FWR as shown in Figure 10, Figure 11 and Figure 12.

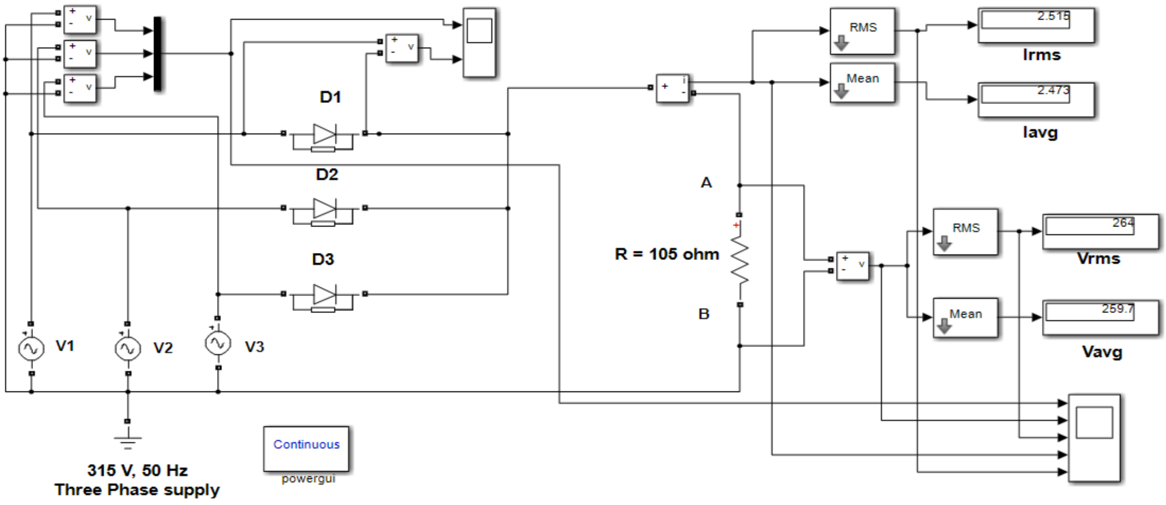


Figure 1. The simulation model of uncontrolled for HWR at load (R)

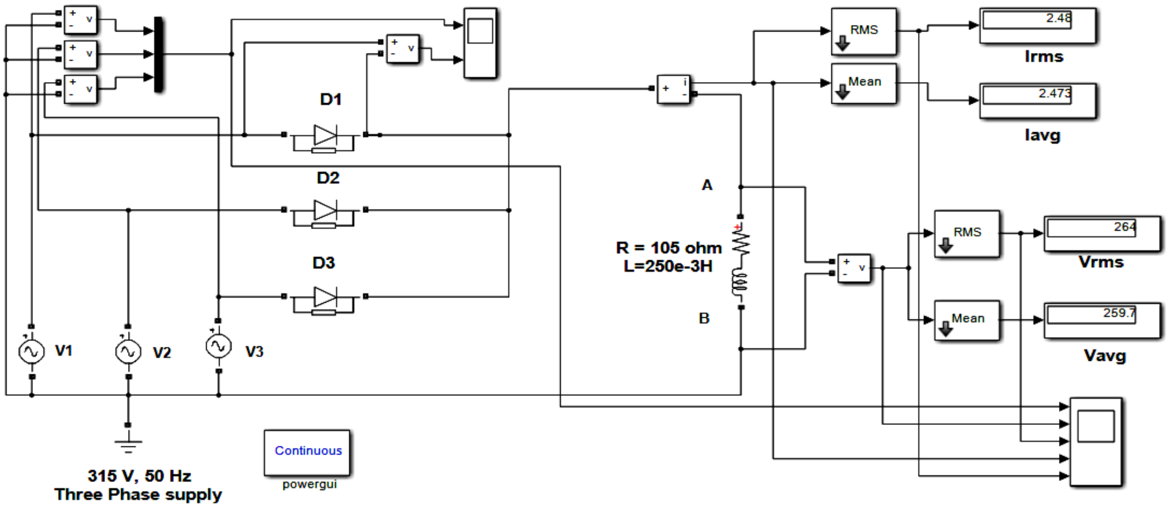


Figure 2. The simulation model of uncontrolled for HWR at load (R-L)

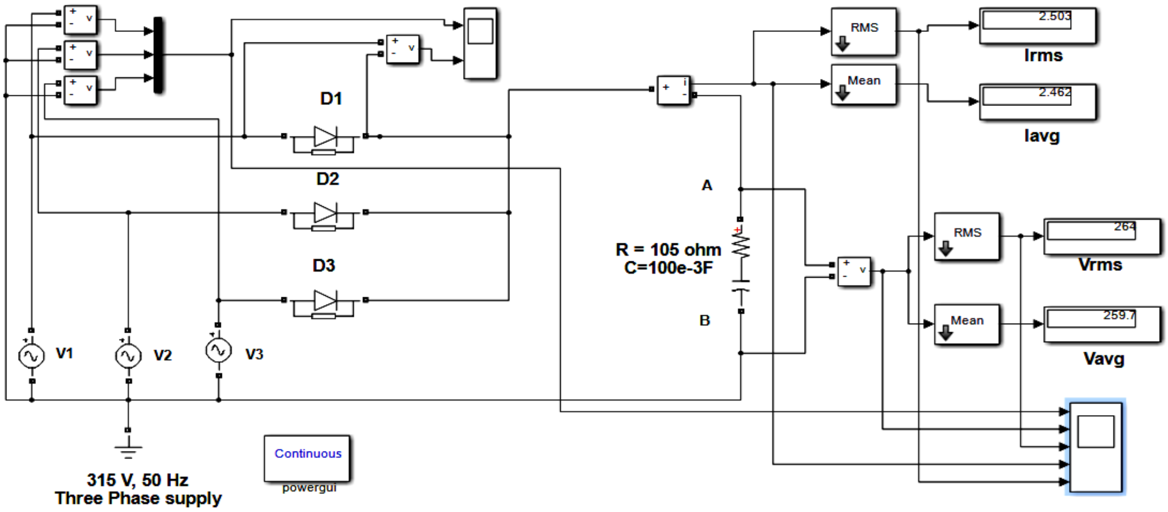


Figure 3. The simulation model of uncontrolled for HWR at load (R-C)

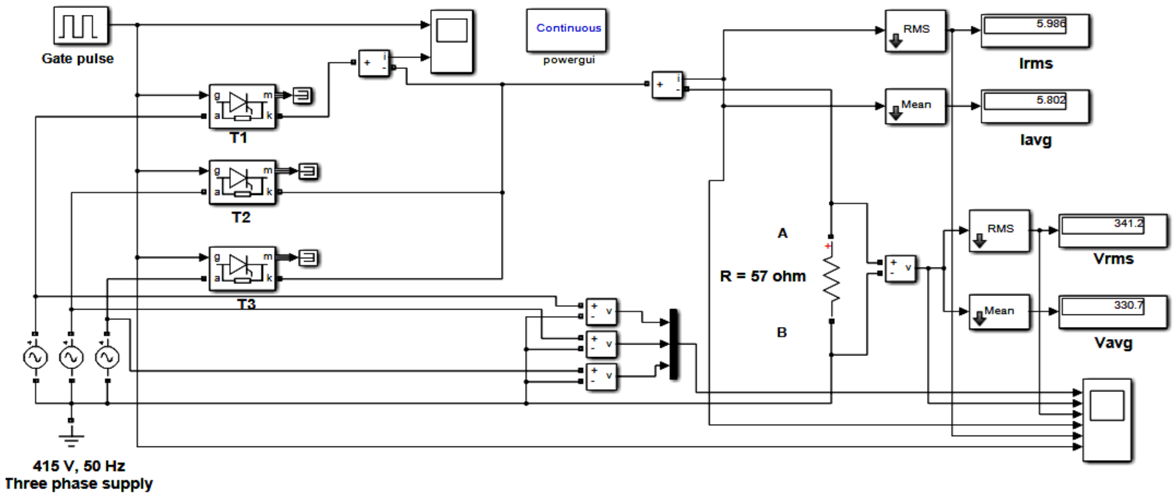


Figure 4. The simulation model of controlled for HWR at load (R)

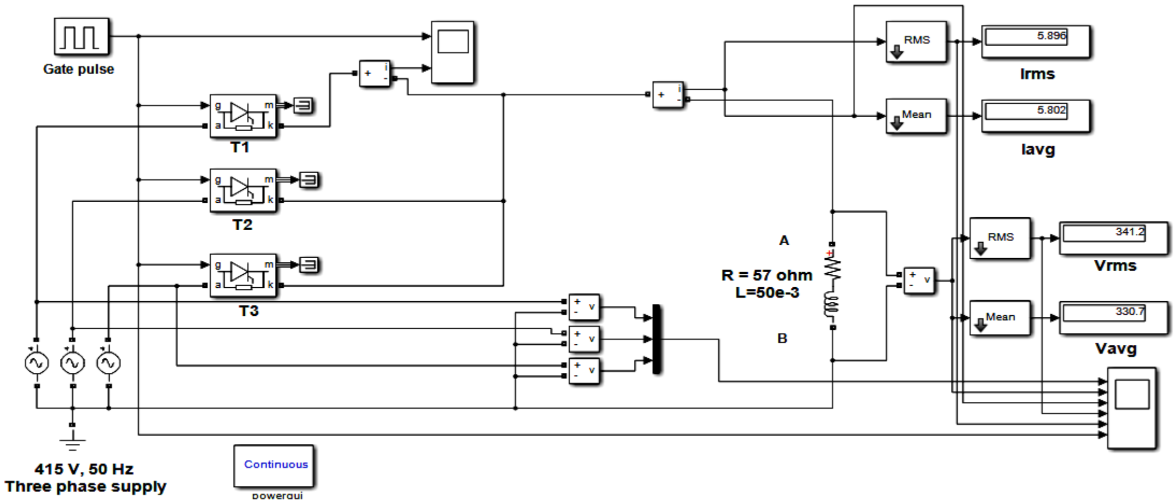


Figure 5. The simulation model of controlled for HWR at load (R-L)

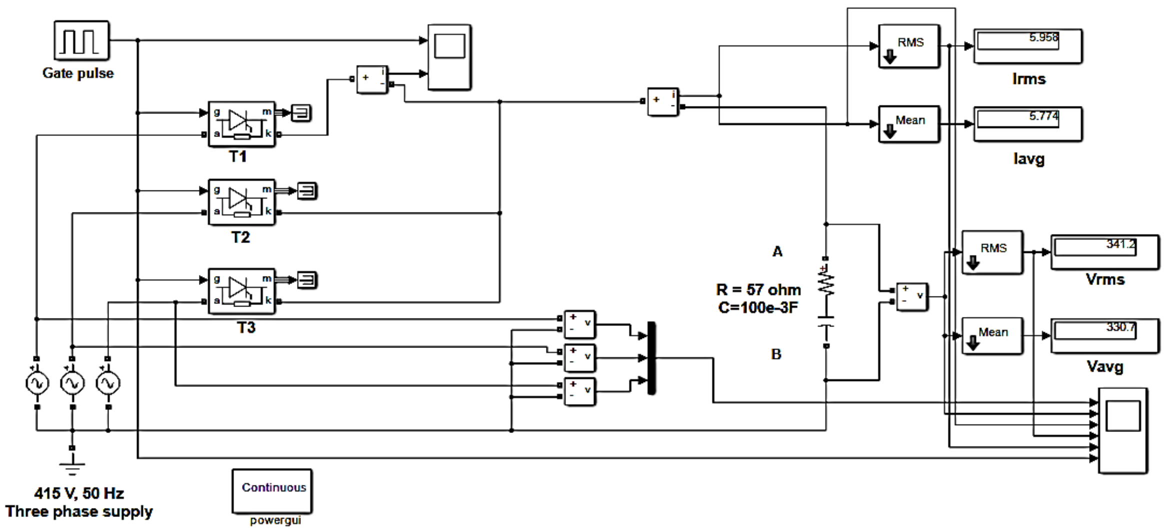


Figure 6. The simulation model of controlled for HWR at load (R-C)

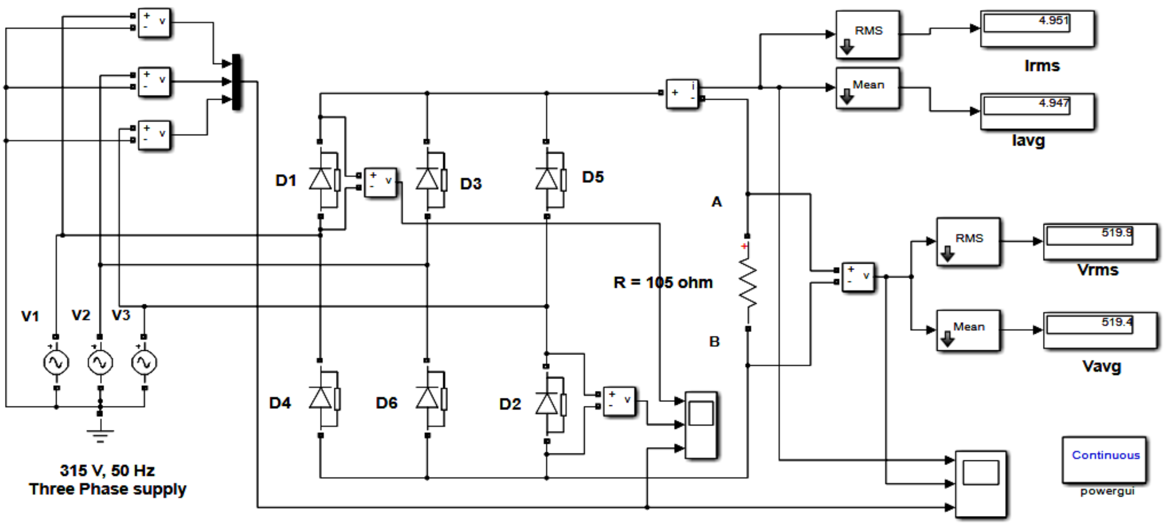


Figure 7. The simulation model of uncontrolled for FWR at load (R)

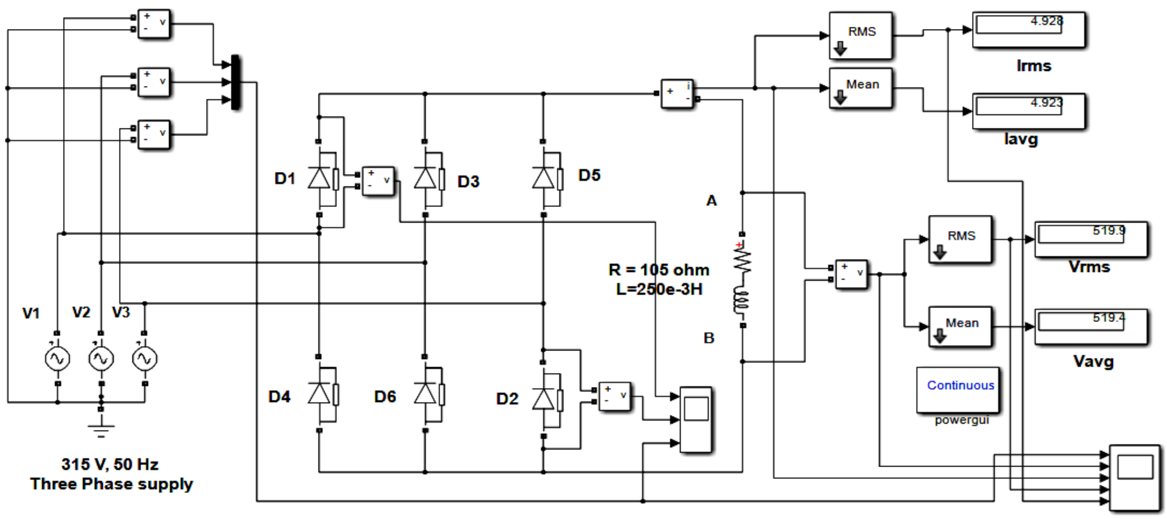


Figure 8. The simulation model of uncontrolled for FWR at load (R-L)

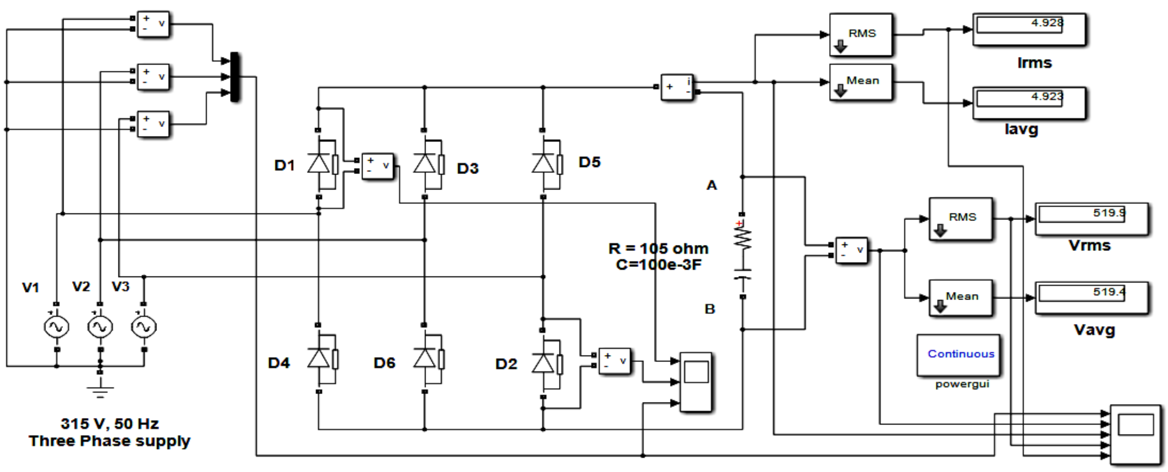


Figure 9. The simulation model of uncontrolled for FWR at load (R-C)

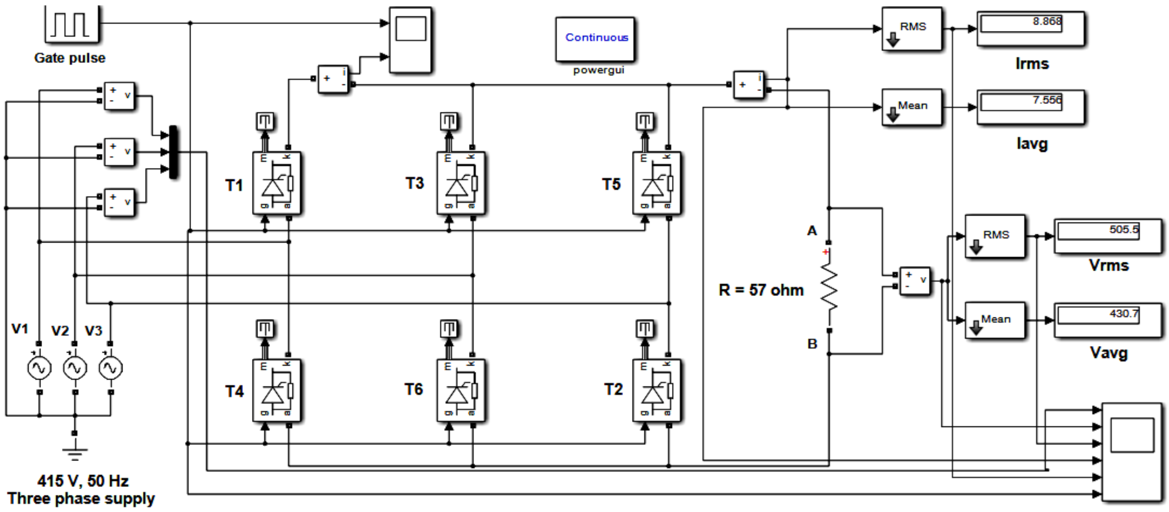


Figure 10. The simulation model of controlled for FWR at load (R)

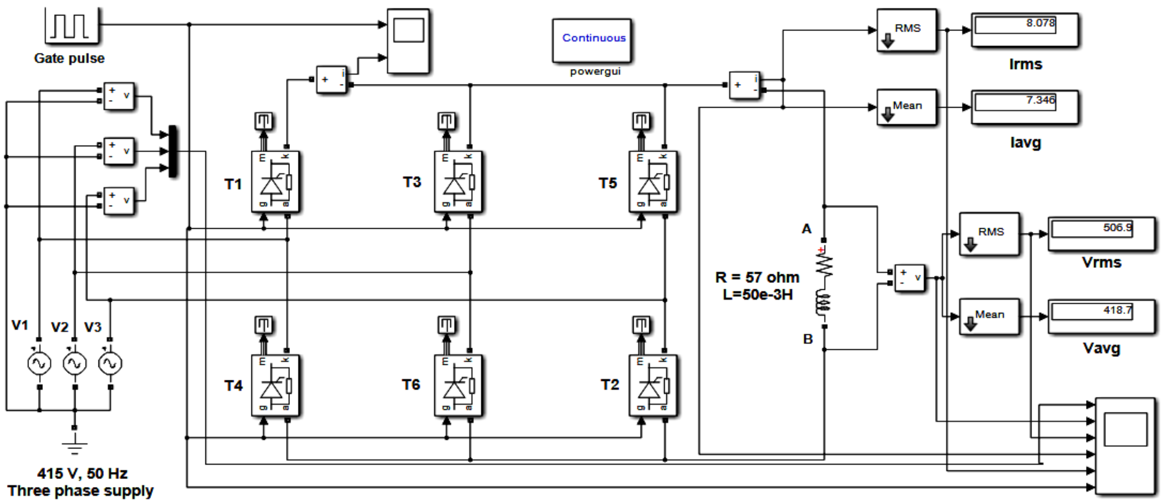


Figure 11. The simulation model of controlled for FWR at load (R-L)

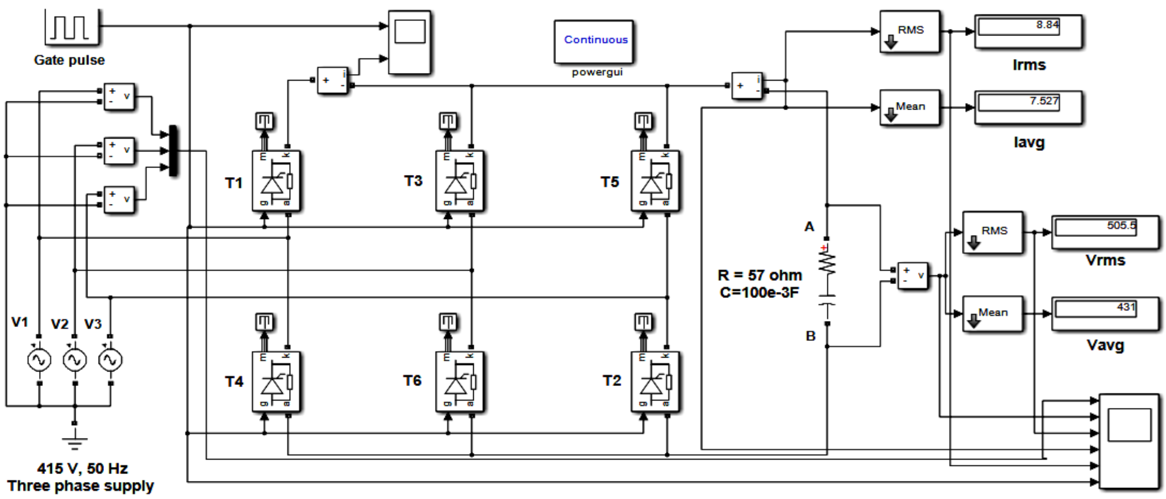
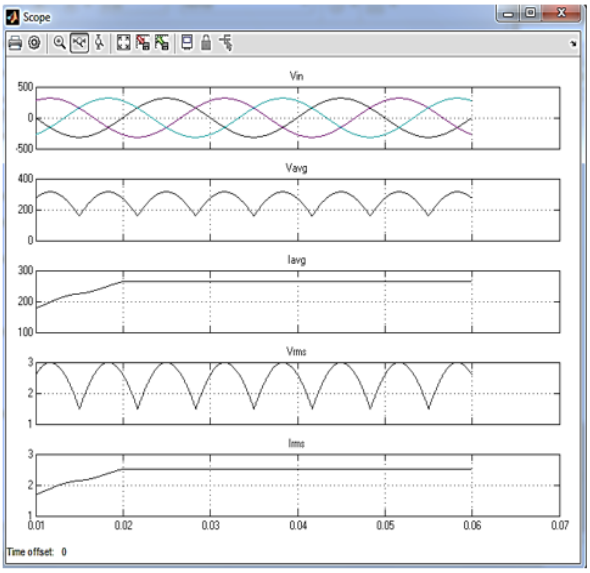


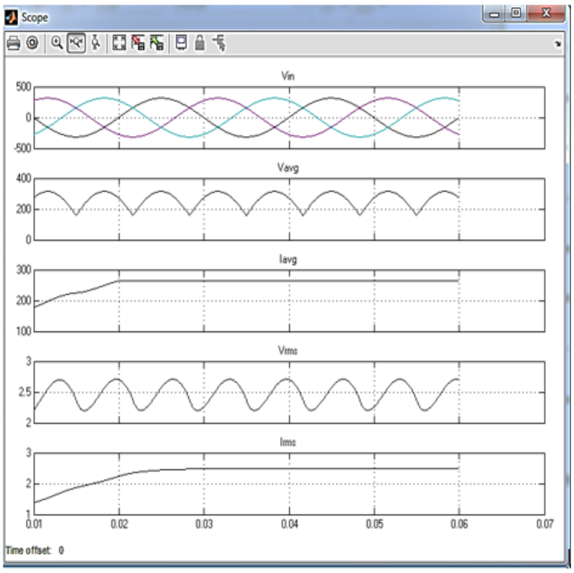
Figure 12. The simulation model of uncontrolled for FWR at load (R-C)

4. SIMULATION RESULTS FOR 3-PHASE RECTIFIER

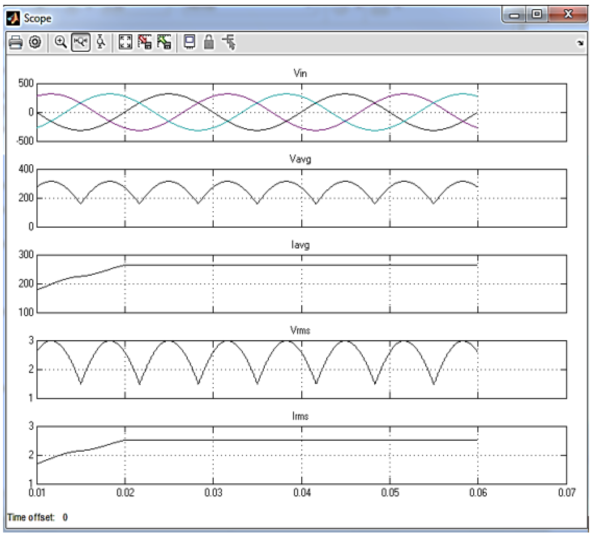
Simulation results, in this section the review had uncontrolled 3-phase rectifier for HWR, uncontrolled 3-phase rectifier for FWR, controlled 3-phase rectifier for HWR, controlled 3-phase rectifier for FWR system with different load at R, R_L & R_C. The simulation model of uncontrolled 3-phase rectifier for HWR as show in Figure 13, the simulation model of uncontrolled 3-phase rectifier for FWR as show in Figure 14, the simulation model of controlled 3-phase rectifier for HWR as show in Figure 15 and the simulation model of controlled 3-phase rectifier for FWR as show in Figure 16. The Tables 1 and 2 include the characteristic of the parameter system, the Tables 3 to 7 include the simulation results for uncontrolled 3-phase rectifier for HWR, controlled 3-phase rectifier for HWR, uncontrolled 3-phase rectifier for FWR, and controlled 3-phase rectifier for FWR.



(a)

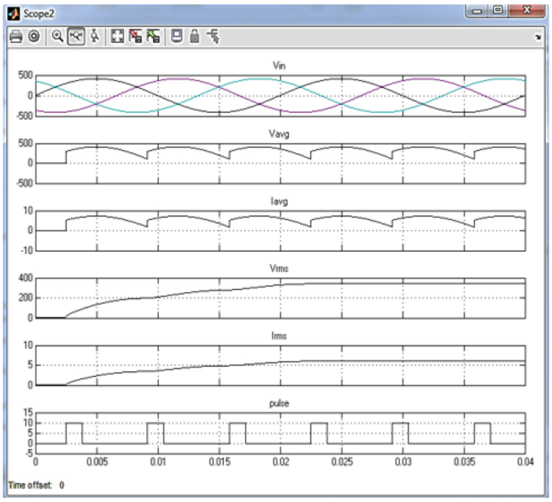


(b)

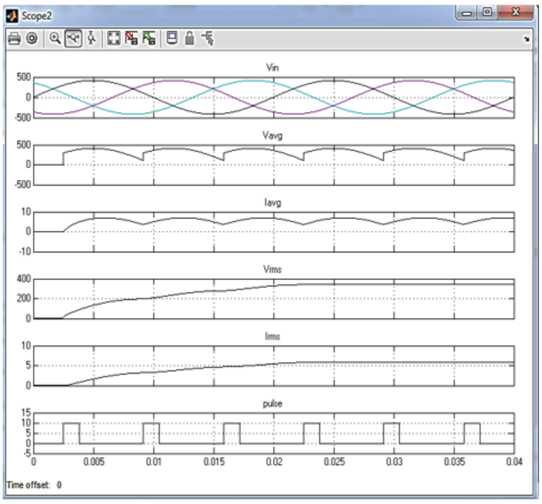


(c)

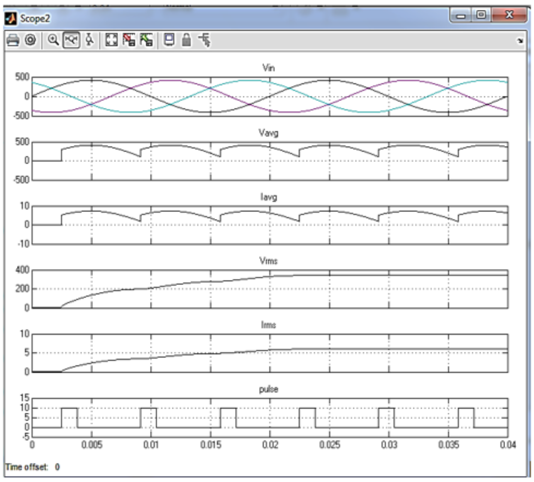
Figure 13. The simulation model of uncontrolled for HWR; (a) Uncontrolled HWR at load (R), (b) Uncontrolled HWR at load (R-L), (c) Uncontrolled HWR at load (R-C)



(a)

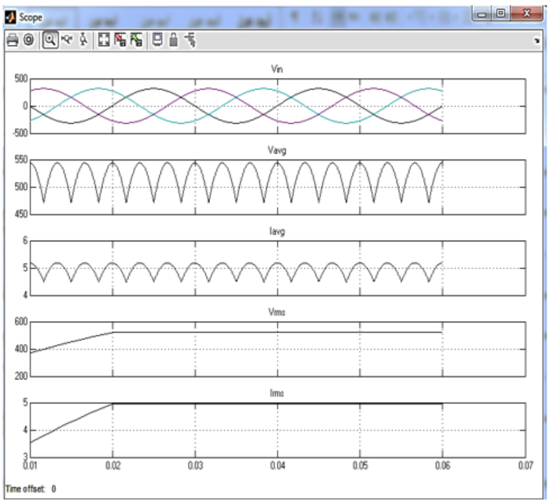


(b)

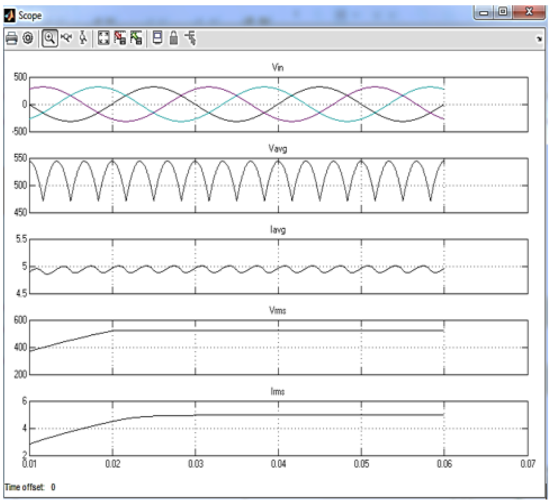


(c)

Figure 14. The simulation model of controlled for HWR; (a) Controlled HWR at load (R), (b) Controlled HWR at load (R-L), (c) Controlled HWR at load (R-C)

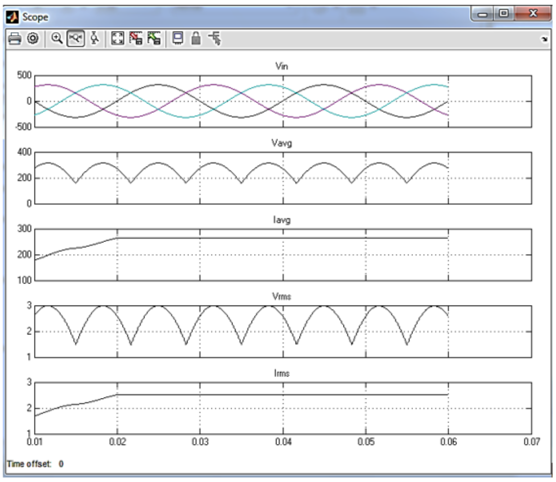


(a)



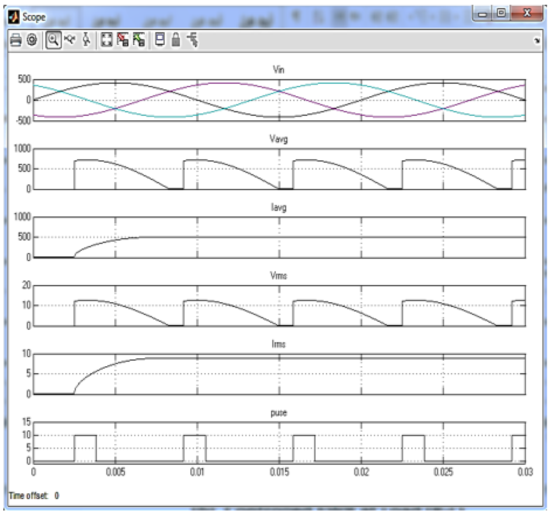
(b)

Figure 15. The simulation model of uncontrolled for FWR; (a) Uncontrolled FWR at load (R), (b) Uncontrolled FWR at load (R-L), (c) Uncontrolled FWR at load (R-C)

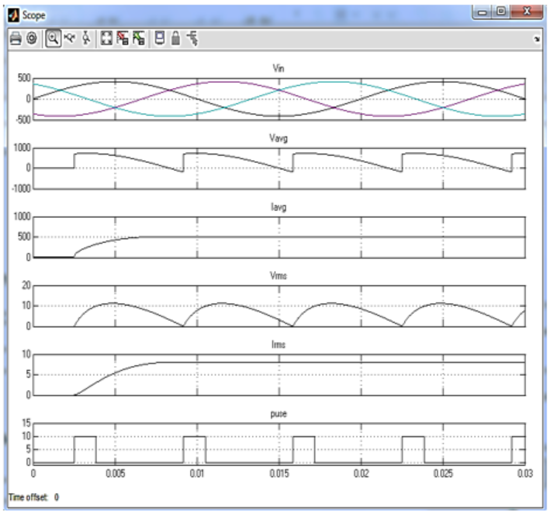


(c)

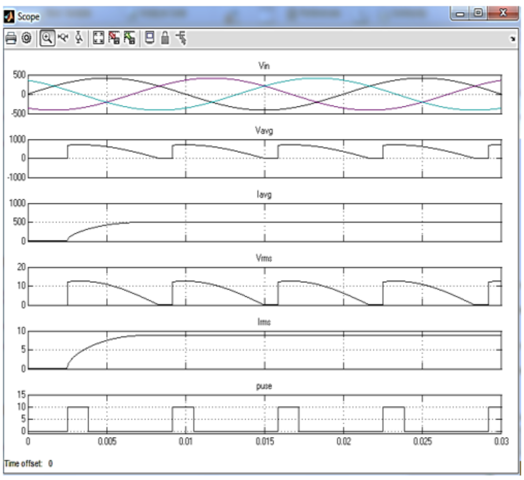
Figure 15. The simulation model of uncontrolled for FWR; (a) Uncontrolled FWR at load (R), (b) Uncontrolled FWR at load (R-L), (c) Uncontrolled FWR at load (R-C) *(continue)*



(a)



(b)



(c)

Figure 16. The simulation model of controlled for FWR; (a) Controlled FWR at load (R), (b) Controlled FWR at load (R-L), (c) Controlled FWR at load (R-C)

Table 1. Characteristic of the parameter for 3-phase rectifier for uncontrolled system

Parameters	Values
Supply Voltage (V)	315
Supply Frequency (Hz)	50
R (Ω)	105
L (mH)	250
C (μF)	100

Table 2. Characteristic of the parameter for 3-phase rectifier for controlled system

Parameters	Values
Supply Voltage (V)	415
Supply Frequency (Hz)	50
R (Ω)	57
L (mH)	50
C (μF)	100

Table 3. Simulation results of uncontrolled 3-phase rectifier for HWR system

Load types	Vavg (V)	Iavg (A)	Vrms (V)	Irms (A)
R	259.7	2.473	264	2.55
R-L	259.7	2.473	264	2.48
R-C	259.7	2.462	264	2.503

Table 4. Simulation results of THPR of controlled 3-phase rectifier for HWR system

Load types	Vavg (V)	Iavg (A)	Vrms (V)	Irms (A)
R	330.7	5.802	341.2	5.989
R-L	330.7	5.802	341.2	5.898
R-C	330.7	5.794	341.2	5.958

Table 5. Simulation results of uncontrolled 3-phase rectifier for FWR system

Load types	Vavg (V)	Iavg (A)	Vrms (V)	Irms (A)
R	519.4	4.947	519.9	4.951
R-L	519.4	4.923	519.9	4.928
R-C	519.4	4.923	519.9	4.928

Table 6. Simulation results of THPR of controlled 3-phase rectifier for FWR system

Load types	Vavg (V)	Iavg (A)	Vrms (V)	Irms (A)
R	430.7	7.55	505.5	8.868
R-L	418.7	7.346	506.9	8.868
R-C	431	7.527	505.5	8.84

Table 7. Characteristic values for 3-phase rectifier and FWR

Characteristic type	Characteristic values for HWR	Characteristic values for FWR
P_{dc} (watt)	945	3021.49
P_{ac} (watt)	673.2	2574
η%	70.8	85.18
FF	1.016	1.0009
RF	0.1827	0.04

5. CONCLUSION

The current study had carried out and included the three-phase rectifier using simulation of the three-phase rectifier by relying on circles to represent the rectifier in order to verify the different views of the researchers. In addition, to put a study in the hands of the readers, represented by how the three-phase rectifier works in different modes, which had detailed above.

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