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Simulation of Uncontrolled Full Wave Rectifier Using Source Inductance

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Abstract: *As we aware the main supply from Our national gridline system is Alternating Current. However, most of the Power electronics equipment's and industrial equipment running through a direct current system. E.g Variable speed d.c drive, railway system using dc supply, battery charger and Electronics equipment's. Hereby, Rectifier are widely used in order to convert the alternating current to direct current. There are many types rectifier available in the market such as uncontrolled rectifier and controlled rectifier. This paper presents the calculation method to identify all the parameters required to design an uncontrolled full wave rectifier using source inductance. The Source inductor effect on the output current and voltage are identified. Part 2 of this paper presents the source inductor effect on 3 phase system. And the cable size of a neutral line of a converter also identified. The calculated parameter is verified using PSPICE simulation.*

Key words: *Rectifier, PSPICE, Full Wave Rectifier.*

1.0 INTRODUCTION

Power converter are playing main roles in converting electrical source in modern civilization. A power electronic system performs conversion of electrical energy. It also controls the amount of electrical energy to be given to the output. Power electronics combines power, electronics and control. Control deals with the steady state and dynamic characteristics of a closed-loop system [1]. Those power can be grouped into static and rotating power equipment's. The main purpose of power converter may apply for generation, transmission and distribution of electric energy. The ideal conversion of Power electronics is using a rectifier. The rectifier is built using few diodes. Since diode is unidirectional, the AC current is converted to DC current. The diode selection is varying according to intended output E.g for a single-phase input, 2 diode or 4 diode can be used to generate an output. The topology of the rectifier is not the new item but here so many parameters are invited to engage to the brilliant model, effects of the source inductance and spurious harmonics, nature of the driving load and power factor[2]. Chart below shows the type of rectifier.

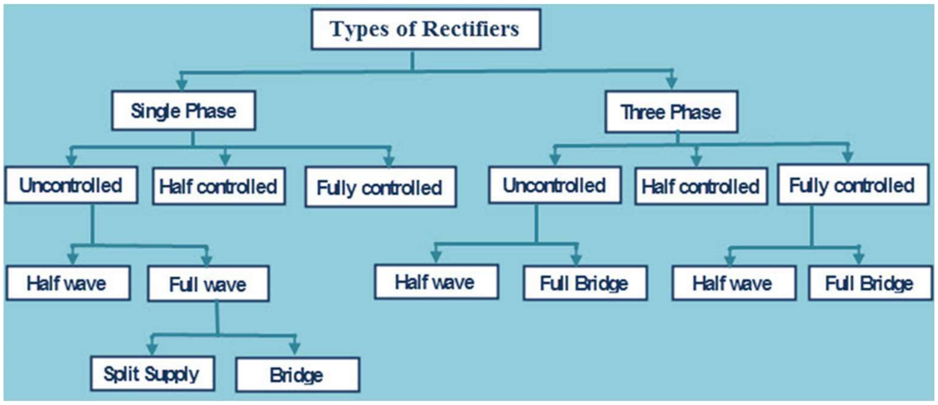


Chart 1: Types of Rectifier

The design of required output are directly depends on the selection of Inductor, capacitance and resistance. This paper will discuss thoroughly the calculation method to identify the parameter and to simulate the rectifier circuit using PSPICE.

2.0 PROBLEM 1.0 (A)

Design an uncontrolled full wave rectifier with the following specifications:

No	Parameter	Value
1	Input Supply (Vrms)	230 VAC
2	Supply type	AC
3	Frequency	50Hz
4	Output Power	1Kw
5	Source inductance (Ls)	mH
6	Output ripple voltage	8%
7	Current ripple	8% (Of DC current)

Diagram 1 shows the Uncontrolled Full wave rectifier.

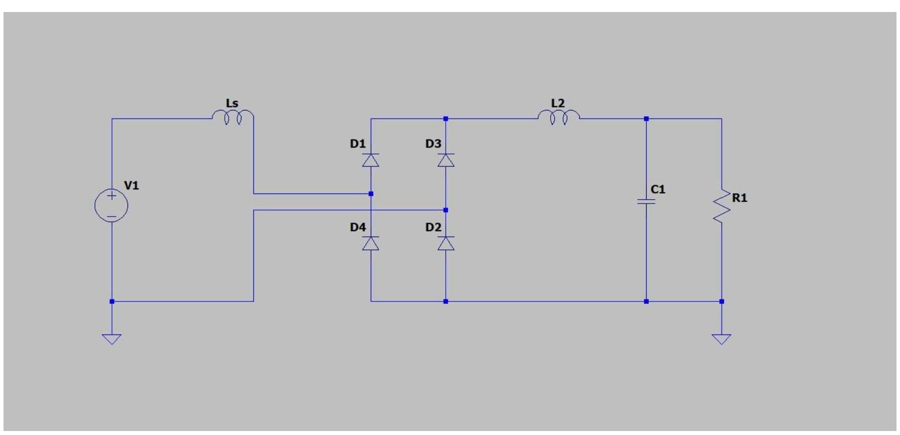


Diagram 1: Uncontrolled Full Wave Rectifier

Based on the diagram above, we need to identify certain parameter to complete the simulation

Since Vrms = 230 VAC

Vm = 230 x √2

= 325.27 V

$$V_o = \frac{2V_m}{\pi}\left(1 - \frac{\omega L_s I_o}{V_m}\right)$$ (Subtitute Vm, Lm & ω, where ω = 2∏f)

Vo = 207.07 – Io …………………… Equation 1

P = V x I (where P= 1000 watt)

1000 = Vo x Io ………………………Equation 2

By comparing Equation 1 & 2

Io = 4.95 A

Vo = 202.12 V

As we know R = Vo / Io

Hence R = 202.12 v / 4.95 A

R = 40.8 Ω

And L = R / 3ω

where L = 40.8 / (3 x 2 x ∏ x 50)

L = 0.0433 mH or 43.3 mH

Using Voltage ripple equation, we can identify the C, capacitance value :

Δ

—— = —— (The Ripple voltage is 8 %)

= ___ ____________ =

.

C= 3.06 mF

2.1 SIMULATION 1.0 (A)

All the parameters identified above is inserted into the Diagram blocks for simulation using PSIPE.

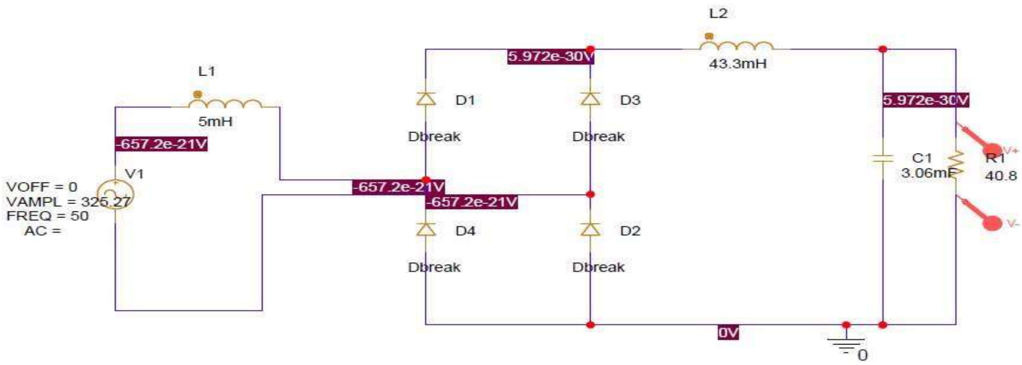
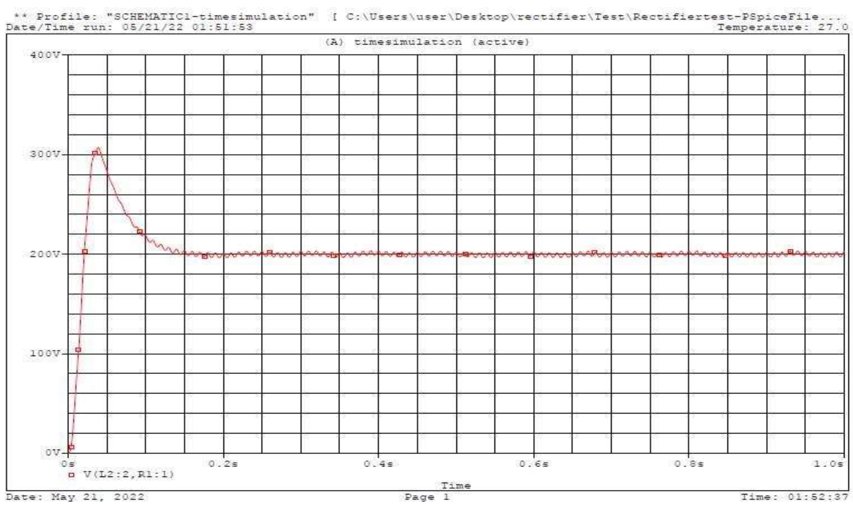
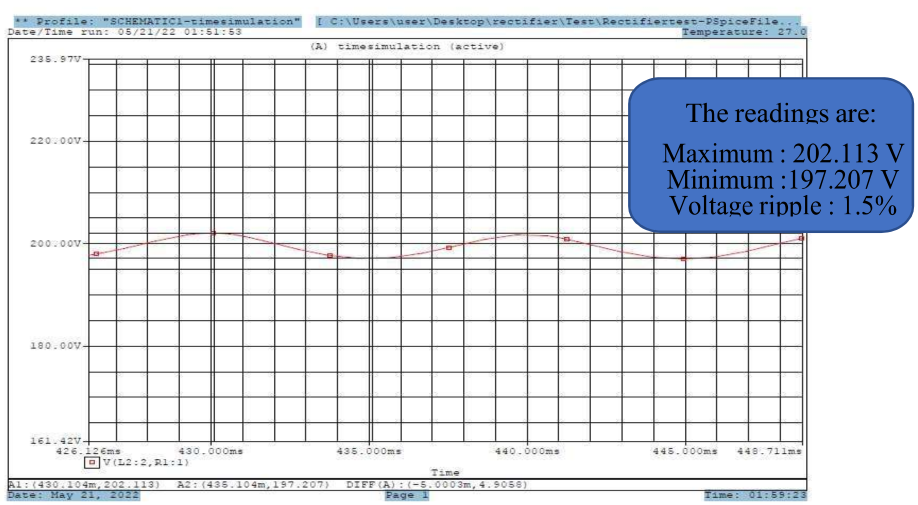


Diagram 1: Pspice Schematic for Uncontrolled Full Wave Rectifier with 5mH Inductance.

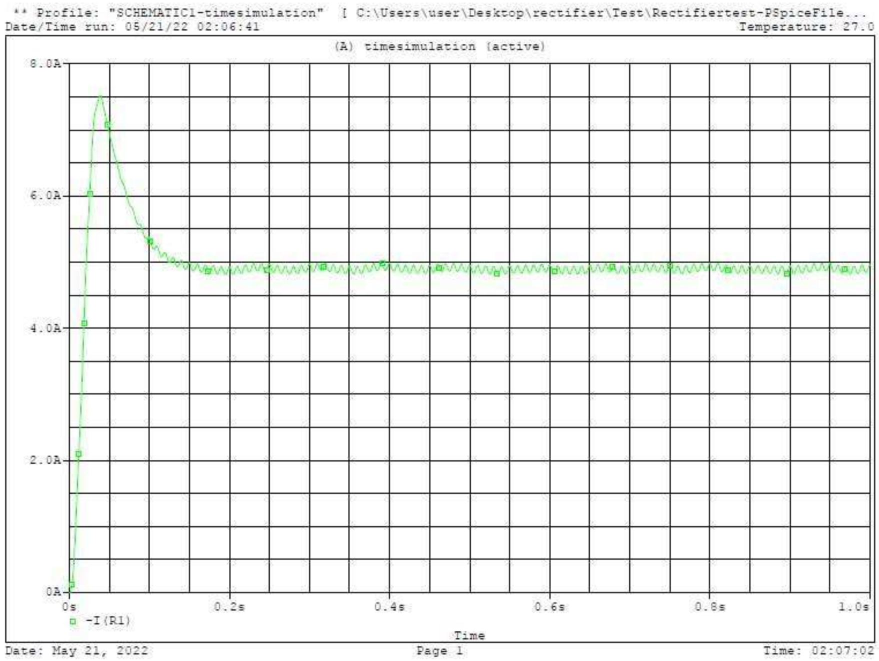
2.2 RESULT 1.0 (A)



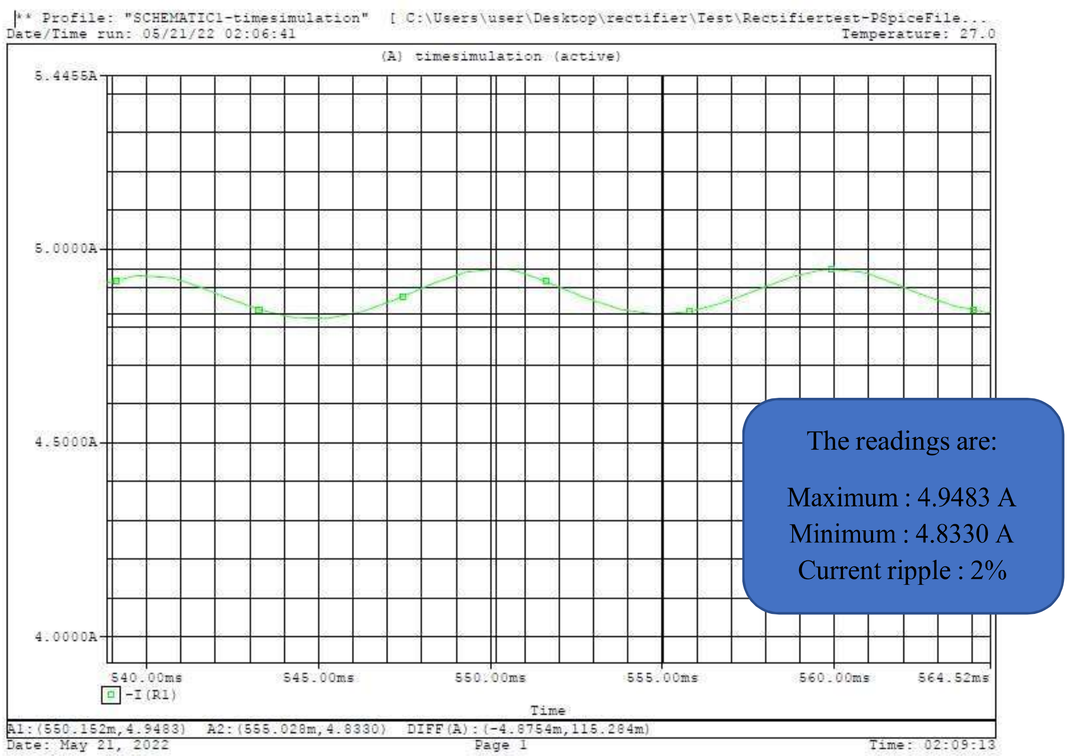
Graph 1: Output Voltage Plot



Graph 2 : Output Voltage Ripple Result



Graph 3 : Output Current Plot



Graph 4: Output Current ripple Result

From The Graph:

The Maximum reading for the Vo is 202.113 V which is similar to the calculated Vo above.
The Maximum reading for the Io is 4.9483 A which is similar to the calculated value above.
The Voltage and current ripple also within the required range.

3.0 PROBLEM 1.0 (B)

To simulate the same circuit with 10mH source inductance. The parameters are calculated and the values obtained are: Since Vrms = 230 VAC

Vm = 230 x √2

= 325.27 V

$$V_o = \frac{2V_m}{\pi}\left(1 - \frac{\omega L_s I_o}{V_m}\right)$$ (Subtitute Vm, Lm & ω, where ω = 2∏f)

Vo = 207.07 – 2Io …………………….. Equation 1

P = V x I (where P= 1000 watt)

1000 = Vo x Io ………………………Equation 2

By comparing Equation 1 & 2

Io = 5.08 A

Vo = 196.85 V

As we know R = Vo / Io

Hence R = 196.85 v / 5.08 A

R = 38.75 Ω

And L = R / 3ω

where L = 38.75 / (3 x 2 x ∏ x 50)

L = 0.0411 mH or 41.1 mH

Using Voltage ripple equation, we can identify the C, capacitance value :

Δ

—— = ——(The Ripple voltage is 8 %)

= ___ ____________ =

.

C= 3.23 mF

3.1 SIMULATION 1.0 (B)

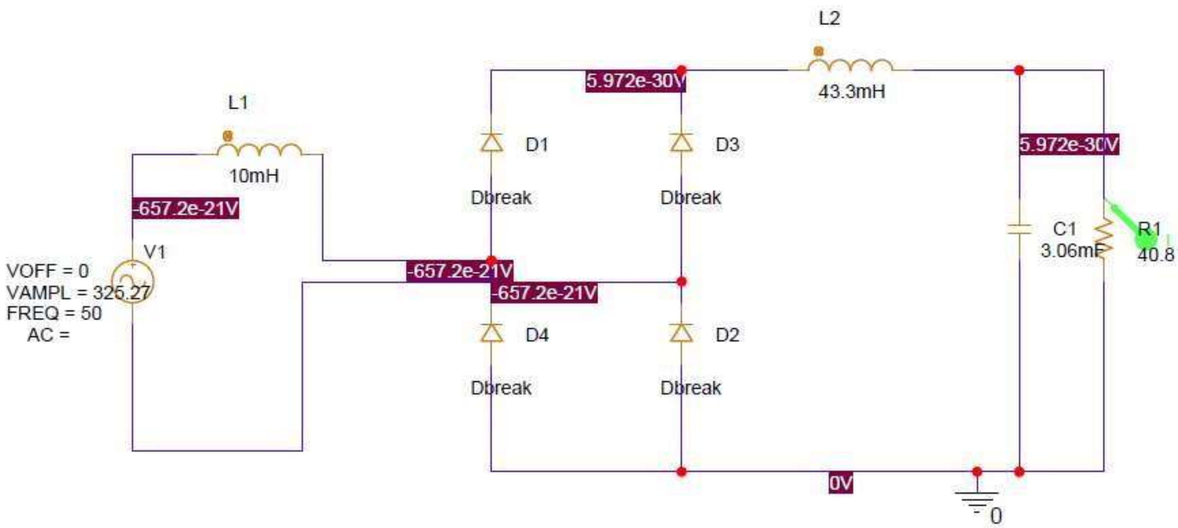
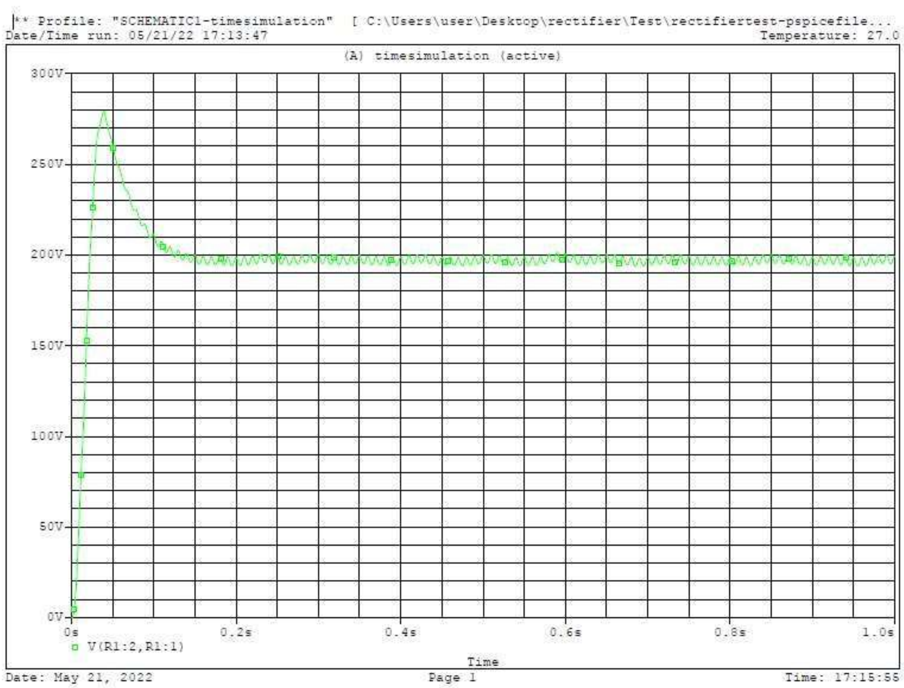
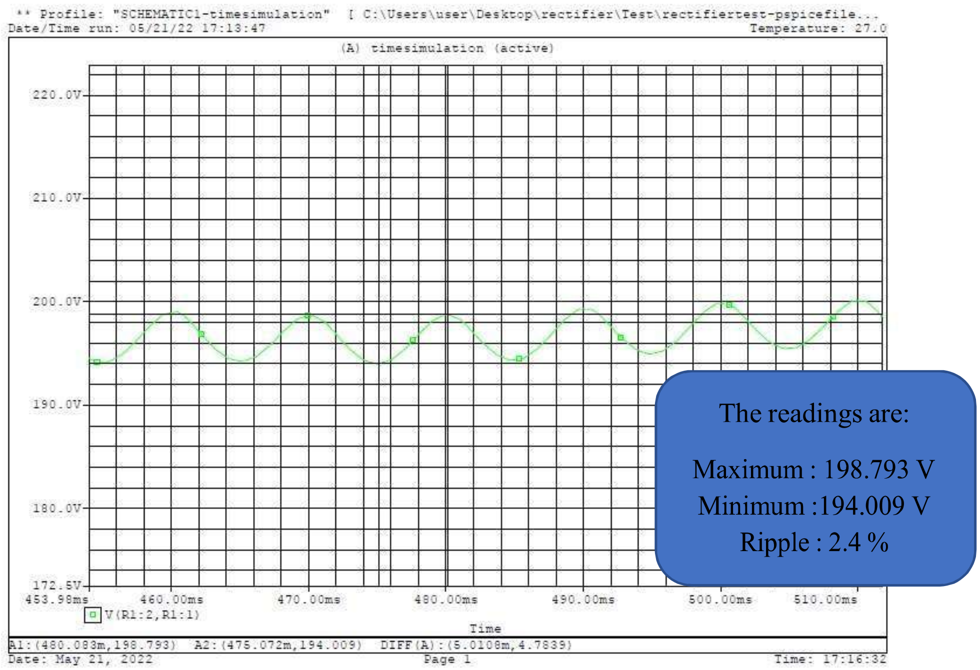


Diagram 2: Pspice Schematic for Uncontrolled Full Wave Rectifier with 10mH Inductance

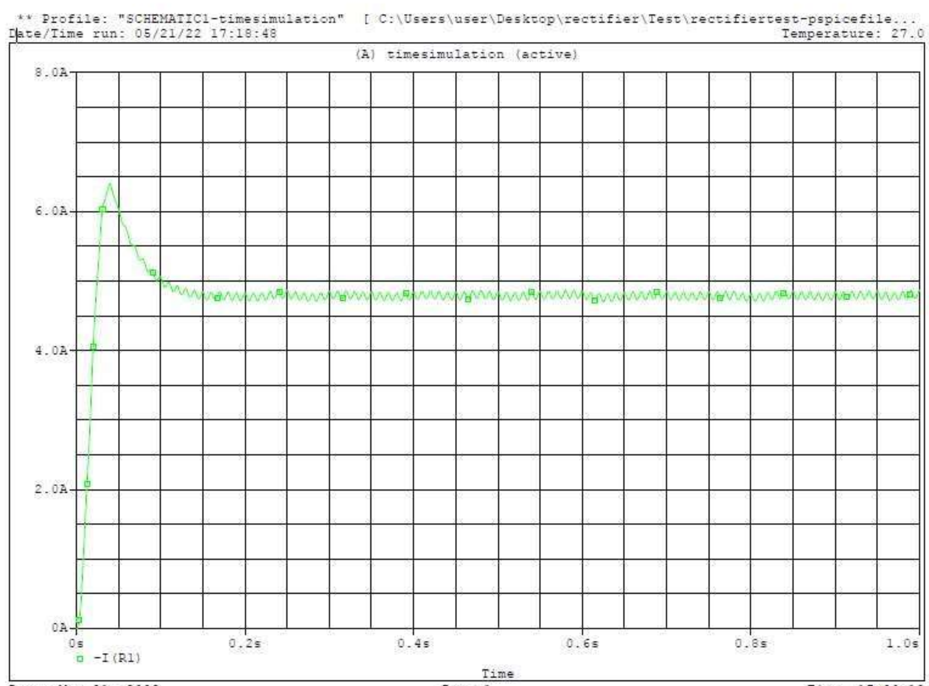
3.2 RESULT 1.0 (B)



Graph 5: Output Voltage Plot



Graph 6 : Output Voltage Ripple Result



Graph 7 : Output Current Plot

Graph 8: Output Current ripple Result

By replacing the source inductor from 5mH to 10mH , the output voltage reduced slightly lower. The Output current of 10mH source inductor also reduced. However, the reduction is very small.

4.0 PROBLEM 2.0 (C)

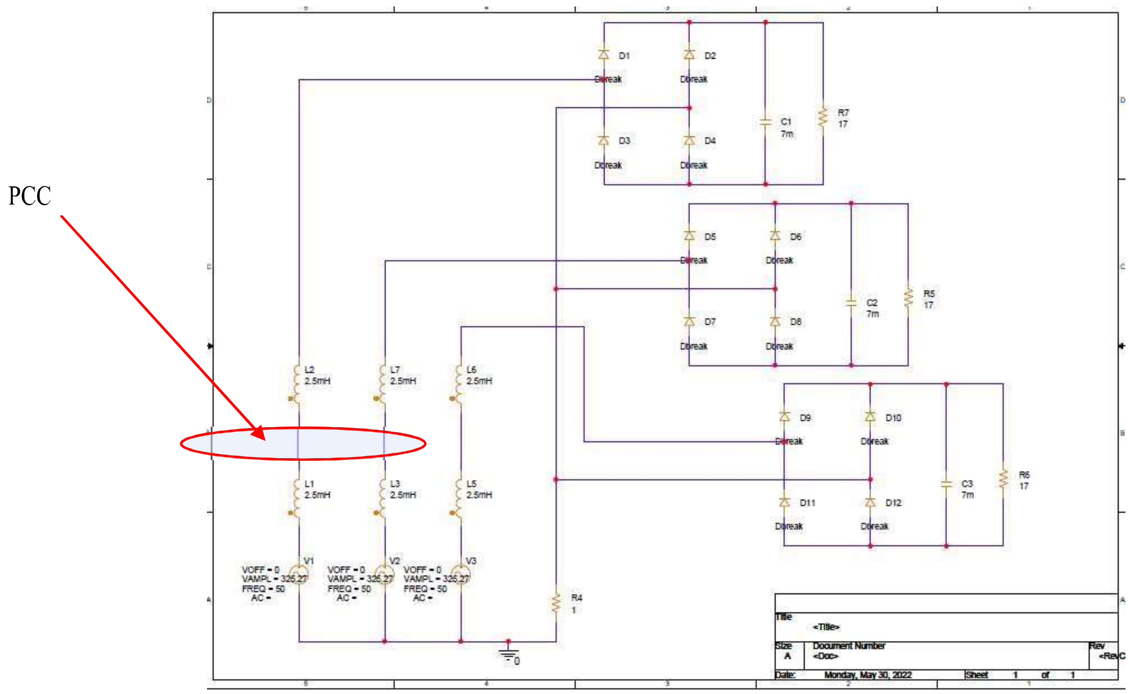
To design and simulate a 3 phase 4 wire star connection source with two equal inductances. The parameter of the design as per follows:

No	Parameter	Value
1	Ls	2.5mH
2	Capacitance	7mF
3	Resistor	17 Ohm

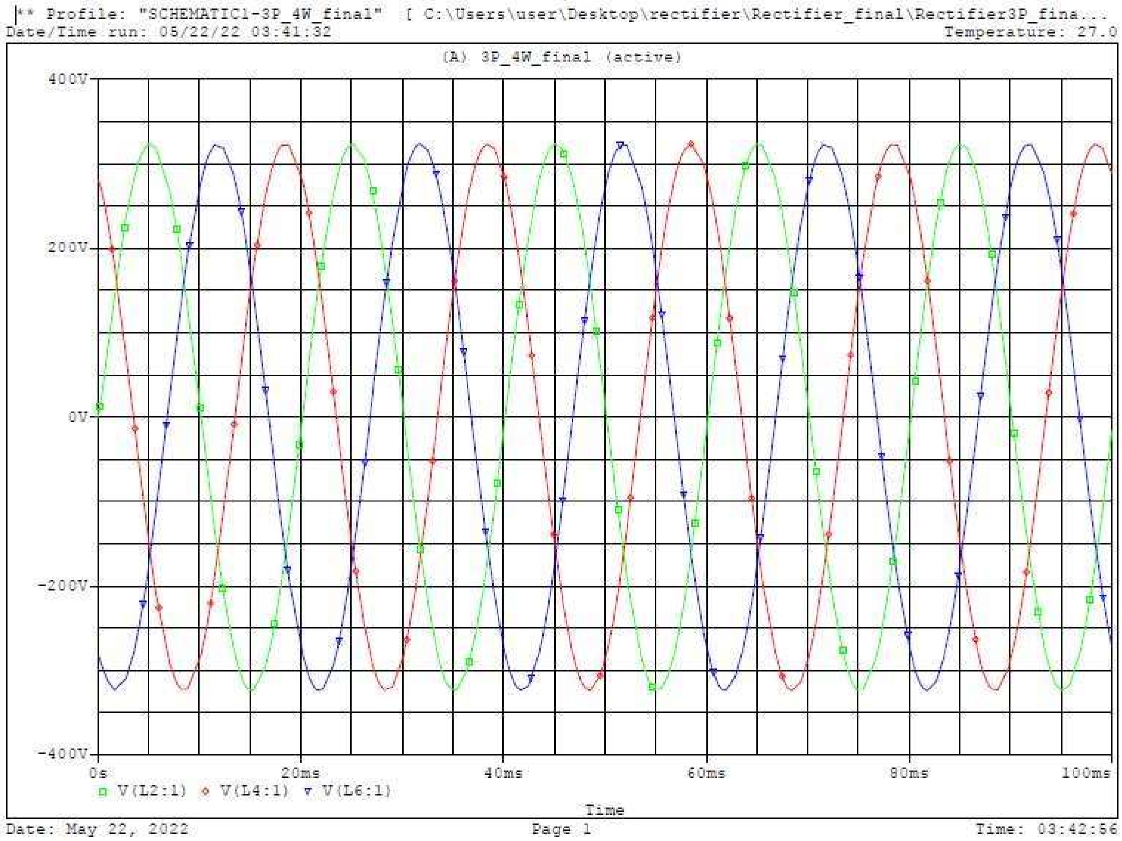
Using PSipe to simulate the diagram to measure and analyze the following reading:

1. Vpcc
2. Line Current
3. Neutral Current
4. Suggestion on the neutral wire

SIMULATION 2.0 (C)

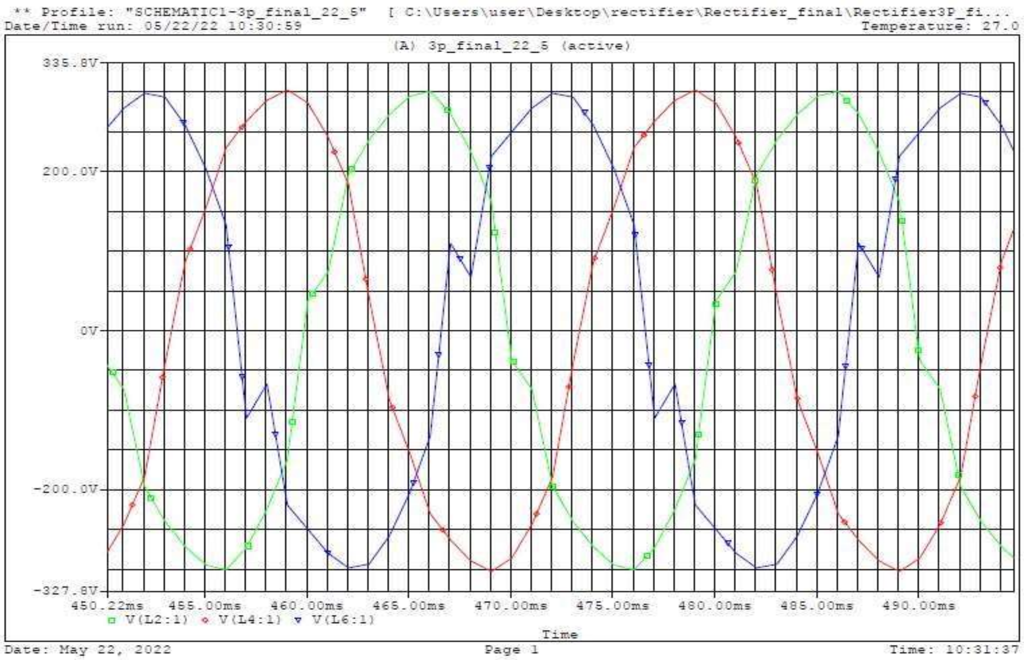


3.2 RESULT 2.0 (C)

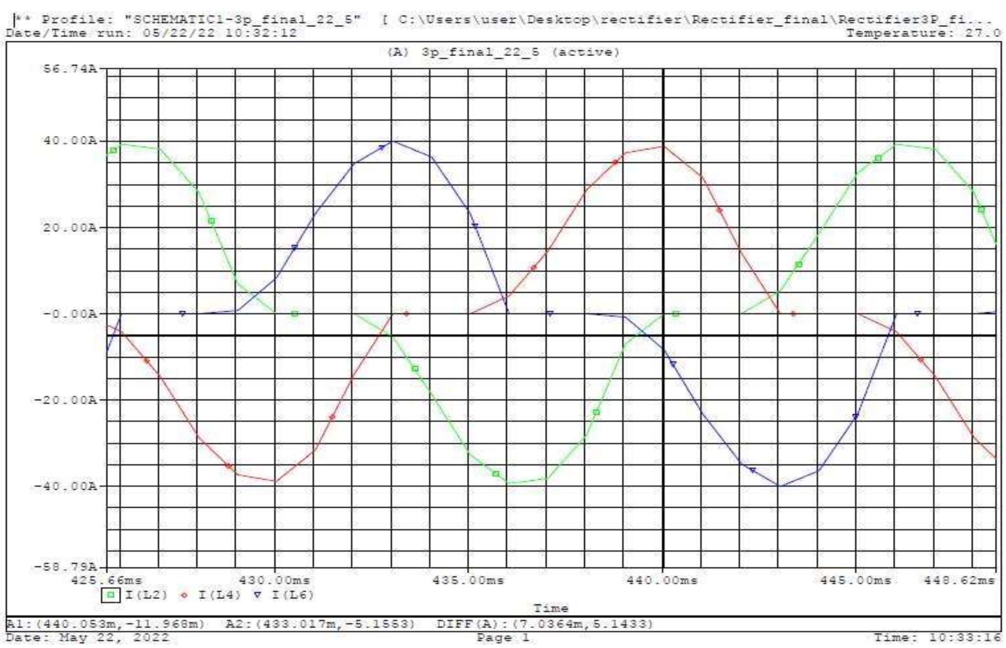


Graph 9: Three Phase input voltage

1. The reading of input Voltage shows 325.27 V
2. The phase of the voltage is correct

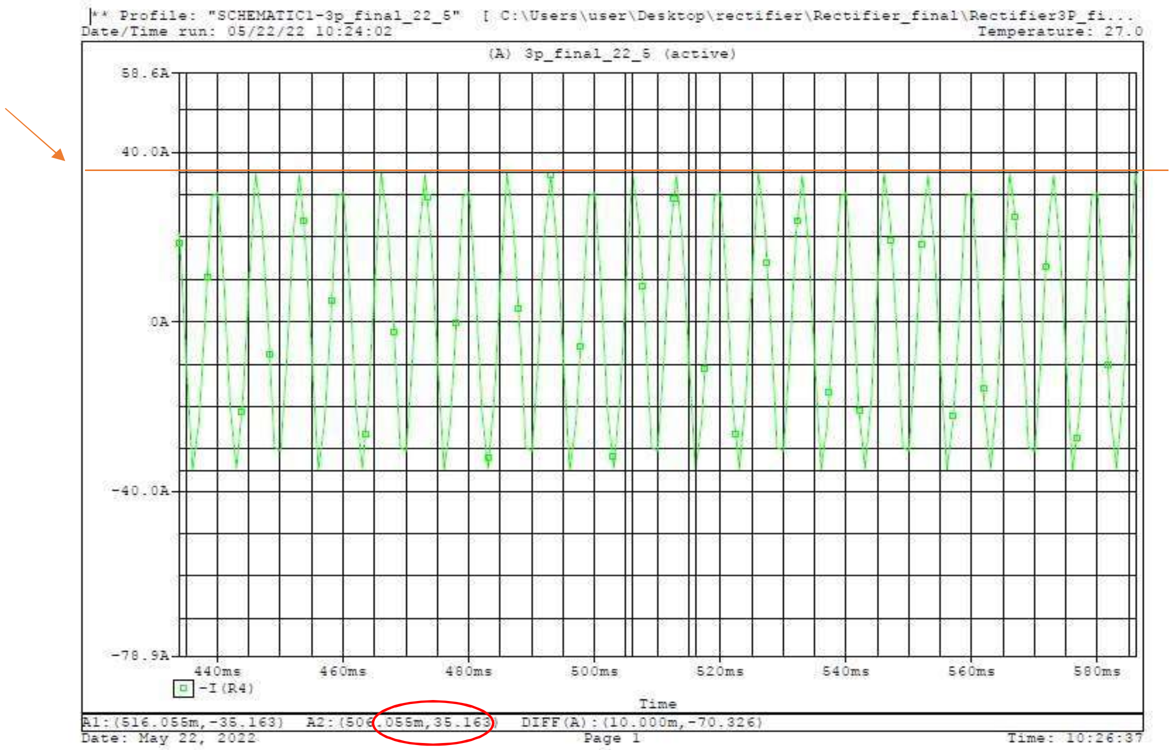


Graph 10: Three phase Voltage at PCC 1. The voltage are slightly distorted due to inductor



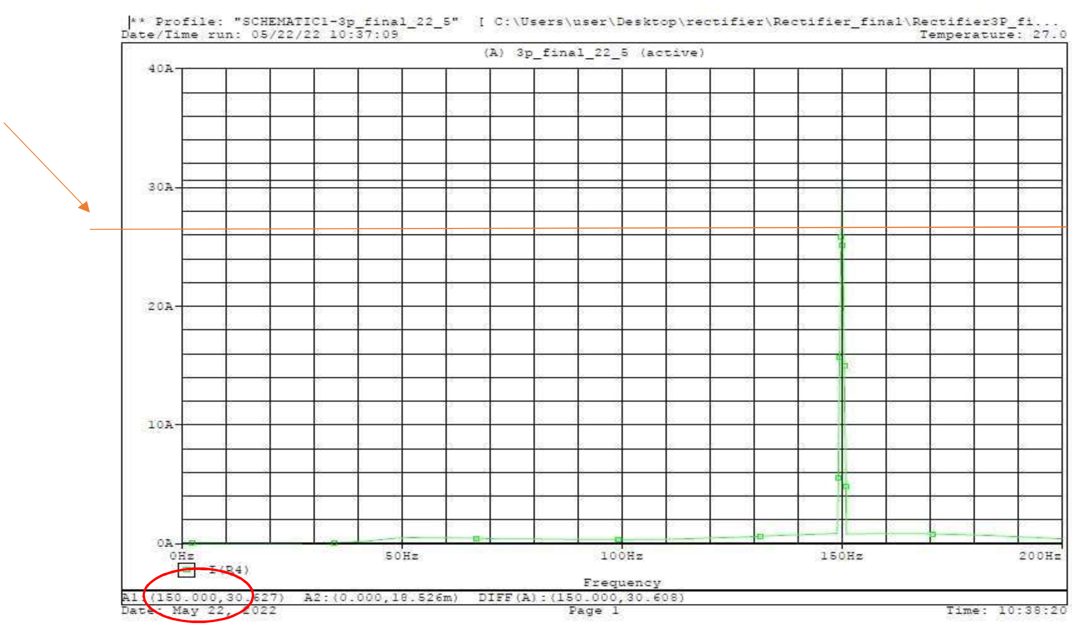
Graph 11: Three Phase Current at PCC

1. The current at PCC are distorted due to the inductor effect.



Graph 12 : The Current of Neutral Line

1. The reading of current at neutral line is 35.163 A



Graph 13 : Fourier Transform (3rd Harmonic)

1. The reading of 3rd Harmonic is 30.627

3.3 SUITABLE CABLE SIZE FOR THE NEUTRAL LINE

The maximum current carrying conductor in Neutral is 36A Based on IEC 60364-5-52 requirement, the load factor must be 0.86

Hence, the Total current shall be :

$$= 36A/0.86 \approx 42\ A$$

Current Carrying Capacity (Amps) of Cables (Copper Conductors)

Single core 70°c thermoplastic insulated cables (e.g. PVC Singles), non-armoured with or without sheath. All values assume an ambient temperature of 30°c and a conductor operating temperature of 70°c.

Conductor CSA	Reference Method A (enclosed in conduit in thermally insulating wall etc)		Reference Method B (enclosed in conduit on a wall or in trunking etc)		Reference Method C (clipped direct)		Reference method F (in free air or on a perforated cable tray horizontal or vertical)				
							Touching			Spaced by one diameter 2 cables, 1ph ac or dc flat 3 cables, 3ph ac flat	
	2 cables, 1ph ac or dc	3 or 4 cables, 3ph ac	2 cables 1ph ac or dc	3 or 4 cables, 3ph ac	2 cables, 1ph ac or dc	3 or 4 cables, 3ph ac	2 cables, 1ph ac or dc flat	3 cables 3ph ac flat	3 cables, 3ph ac trefoil	Horizontal	Vertical
$1mm^2$	11	10.5	13.5	12	15.5	14					
$1.5mm^2$	14.5	13.5	17.5	15.5	20	18					
$2.5mm^2$	20	18	24	21	27	25					
$4mm^2$	26	24	32	28	37	33					
$6mm^2$	34	31	41	36	47	43					
$10mm^2$	46	42	57	50	65	59					
$16mm^2$	61	56	76	68	87	79					
$25mm^2$	80	73	101	89	114	104	131	114	110	146	130
$35mm^2$	99	89	125	110	141	129	162	143	137	181	162

Table 1: Manufacturer Recommendation on cable size

The maximum current flow based on recommended factor is 42 A. Hence, cable is more than 42A current carrying conductor are needed for the neutral line. Hence, 10sqmm are selected as the recommended neutral cable. The 10sqmm 4 cable will withstand a total 50A as current carrying conductor.

CONCLUSION

Based on problem 1(A) & 1 (B) the source inductor are leakage inductor. By increasing the inductor value, the output voltage drops.

Based on problem 2 (C), the input is distorted due to the introduce of source inductor. The source inductor causes the Output a huge 3rd Harmonic.

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