

2017194

by Hefin Williams

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table of contents shoul follow on next page

1. Executive summary

Line spacing should be 1.5

In this report, firstly research was carried out on 4 various AC induction motor speed controllers where research was carried out into a cycloconverter, Vector controller, soft start, and a frequency/voltage inverter controller. Research is also put into Power systems where power generation, step up transformers, and step down transformers were researched in depth. Task 3 had practical and theoretical work involved where testing was carried out on a step down transformer where a short circuit and open circuit test was carried out with values and calculations with explanations/tables of findings. Task 4 has practical and theoretical work carried out on a three phase induction motor, where all workings and conclusions were noted in the report with full explanation of each. To finalise the report a conclusion was put together to finalise the findings and share the knowledge found in doing the report.

What were your findings?

2. Work plan for Life-long Learning

Line spacing should be 1.5

This assignment will be approached with a wide vision regarding single-phase transformers and three-phase induction motors. The research task will have a wealth of information concerning four different speed controllers for an induction motor with specific job application for each of the methods.

The team working aspect will be tackled with respect to others within the team where ideas and different working methods will be united. The teams will perform an open and short circuit test and a loaded test on a single-phase transformer.

To govern the equivalent circuit parameters – stator resistance, no-load/blocked rotor tests are going to be pursued on a three-phase induction motor. To determine the motors torque and stator draw over various speeds which will concentrate on the motor generating and breaking. Spelling

3. Research

3.1 induction motors, Four unique speed controllers for induction machine (motor).

3.2 Cycloconverter

Line spacing should be 1.5

An Cycloconverter is a speed controlling device for an induction motor. They provide a direct alteration for fixed-frequency alternating voltage/current to a variable voltage/current variable frequency for the use to control ac motors. The output frequency normally is limited from 33-50% of the input frequency, as there is much distortion and to limit the distortion the method is only used in low speed and high torque ac motor drives. (krishnan, 2001)

Correctly cited

This method uses thyristors similarly to a bridge rectifier. A cycloconverter does not require a DC link like other induction motor speed controllers, the cycloconverter converts AC to AC and only Changes the frequency of the output. (Lander, 1993)

Correctly cited

A simple single phase cycloconverter circuit is made up of four thyristors two of which are positive and two of which are negative. The positive and negative thyristors are for the changing of the AC half wave cycles. From which these thyristors can control the output voltage/frequency by altering the firing angle of each rectifier. (P, 2018)

In order for the motor to run smoothly a certain waveform is required. In order for an smooth waveform to occur a constant current is needed. For the cycloconverter to work. Both positive and negative bridges need to be fired up at the same time. As the motor also has an inductive load the positive half cycle will have an negative current. Where the negative half cycle will have a positive current (Shown on Figure 2), the positive and negative thyristors will be fired up as of when it is necessary, this is the rectifying mode for when either the half cycle is positive or negative. (Tolbert, 2011)

Correctly cited

3.3 Voltage/Frequency

An inverter would be used to perform this form of speed control. An V/F inverter would control the speed of the motor by lowering frequency and voltage for the motor to run slower and increase the voltage/frequency to increase the motor speed. (productronica, 2019) The voltage and frequency difference is kept linear, meaning the ratio difference will always be the same. The reason both voltage and frequency fluctuate is down to keeping maximum flux in the windings of the motor. (drive, 2023) With the maximum flux in the winding comes maximum torque. When the motor has reached its peak speed, the motor will slow down if the frequency is increased further, this is due to the max voltage being matched and the flux in the motor decreases causing greater slip and less torque. (Cope, 2021)

Correctly cited

A standard VFD can be separated into 3 main roles which are the Rectifier, Inverter and DC Bus. An rectifier converts the incoming AC three-phase voltage to DC through a bridge rectifier, which is built up of diodes, which filters the AC voltage positive half cycles through which give a dirty DC voltage. The DC bus is designed to filter the dirty DC voltage by using capacitors for a smooth cleaner more consistent voltage. (Corporation, 2023) Capacitors can be found at the start of the circuit to store energy for when the AC supply dips, they will discharge which smooths the positive half cycles out for a constant DC supply. For the inverter to have a variable AC output a insulated gate bipolar transistor (IGBT) is used to change the DC bus into a variable AC output. IGBTs are used in pairs for completion of the circuit, and to control which of the phases are supplied with power. To control the output frequency PWM is used. PWM controls the width of each pulse which throttles the voltage output as the voltage is restricted to the amount it can flow. The wider the pulse the higher the voltage/ frequency. The duration of which voltage is allowed to flow is called a duty cycle, higher the duty cycle the higher the voltage/frequency, the lower the duty cycle time the lower the voltage/ frequency. (Arbert, 2023)

3.4 Vector Control

Line spacing should be 1.5

Vector control used Frequency drives to control the speed of the motor, these specific drives are known as VDSs. This method allows maximum torque at all speeds. Speeds of which where the motor will almost be as stand still, although this will cause the motor to work extremely hard and potentially **Spelling** rheat without an additional cooling fan. (Barman, 2016) Vector control over a motor od precise and has opened many more applications for AC motors as they can be used for precise machinery (CNC) and for high speed applications. As the vector control can apply high spikes of voltage at one time which will cause the motor to respond instantly which makes precision applications much simpler with AC motors. The high Voltage impulse create a instant response within the stator. Controlling a AC motor using Vector control is a likewise application of a DC motor. (Fernandez, 2021) As DC motors use a tacho generator to identify the speed of the motor for feedback, the AC motor Vector controlled does not require feedback and monitors its speed by comparing the VFD where the current will be manoeuvred to put any errors right. (Transdrive, 2023)

Correctly cited

3.5 Soft start

Soft Starts is a motor controller that uses phase angle control. It's used to softly decrease the high current surge when a motor is starting up, gradually controlling the speed of ramp up of the motor until it reaches its required speed. The soft start allows the motor to ramp down to a hold. The control over the motor acceleration and deacceleration gives a much smoother and safer outcome for control over a motor when compared with methods like Direct On Line (DOL) and STAR/DELTA starters where they start up on immense start up currents. (Figure 3) shows the circuit diagram of a soft starter unit, where the thyristor's firing circuit is shown, they control the gradual increase of voltage to the motor. (Jones, 2022)

3.6 Power Systems

A power system is usually made up of many sub stations which include primary transmission, power generation, secondary transmission, substations, primary distribution, and secondary distribution. Normally a electrical system will have its electricity generator where a voltage will be generated before being distributed the frequency must be matched and noise must be filtered out, after which the voltage will be stepped up for long distance distribution or will be stepped down depending on the voltage for the consumer which in the UK is either 400V line voltage and 240V phase Voltage. (NPC, 2023)

A power plant will generate the most electrical energy whether they burn renewable energy, waste fuel, nuclear energy, or a gas. Energy is generated usually by generating heat where water will be boiled to create a gas (steam) which will be at very high pressures, this high-pressure steam is then used to turn a turbine and then distil to turn back to a liquid where it will also turn a turbine. The turbine is connected to a generator where it will produce electricity.

The voltage generated will then be stepped up before connecting to the grid which is a very high voltage. A higher voltage the lower the current and will transfer more electricity with a smaller cable which reduces the cost of the infrastructure, when the voltage is at the consumers end there will be a step-down transformer where the voltage will simply just be stepped down to a safe and usable voltage. (E4U, 2021)

4. Transformer Investigation

Line spacing should be 1.5

4.1 Introduction

Open and short circuit practical test carried out on a single-phase transformer. Before the practical was carried out a risk assessment was fulfilled (See appendix 'G22a Risk assessment table.'). When the practical was carried out suitable PPE were worn, and wiring regulations were followed. Before and after the practical was carried out the power was isolated and locked giving no risk/potential of an electric shock. Only a competent personnel had access to the key that would unlock the isolator. The transformer used in this practical was A 230V, 50Hz single-phase transformer with a 1:2 turns ratio. As the transformer gradually heats up when it is energised, testing was pursued after a short while for a fair test to take place as temperature changes the electrical resistance in copper. The tester used to gather the results of the practical was an Chauvin Arnoux power & quality analyser. After the values were gathered, calculations were carried out to determine the approximate equivalent circuit parameters to be annotated and drawn. All tests were carried out in groups where everyone worked together whether it was setting the experiment up, changing the values/wiring, and calling/writing the values down.

4.2 Open circuit test

A open circuit test was carried out on the transformer, the parameters measured was input voltage, input current, input power, and the frequency. (See appendix 'Results from open-circuit test')

To calculate the core losses ' R_c ' within the primary coil of the transformer. Power loss equation must be used, the power loss equation can be rearranged to find ' R_c '. (See appendix 'Equation 1')

From calculating the ' R_c ' value, ohms law can be used to find the current within the core ' I_c '. (See appendix 'Equation 2')

After the value of ' I_c ' has been calculated the magnetising current ' I_m ' can then be calculated in order for ' X_m ' to be calculated. (See appendix 'Equation 3')

4.3 Short circuit test

A short circuit test was carried out on the transformer, The parameters measured were the input voltage, input current, input power, and the frequency. (See appendix 'Task 3- short circuit test')

This experiment is carried out to be able to calculate the resistance and the reactance in both the primary and secondary coil. ' R_{1E} ' and ' X_{2E} ' are used to indicate resistance and reactance for the primary coil where ' R_{2E} ' and ' X_{2E} ' are used to indicate the secondary coil.

Firstly, the primary coil impedance, resistance, and reactance was calculated using the values measured from the experiment. (See appendix 'Equation 4')

Secondly, the secondary coil impedance, resistance, and reactance was calculated from using the values measured and the previous calculated values. From the past calculations the secondary coil current was able to be calculated, which was a current draw of 3.58A. (See appendix 'Equation 5')

4.4 Equivalent circuit

Figure 1 in the appendix Shows the equivalent circuit drawn from the calculations carried out on the transformer.

4.5 Voltage Regulation

$$V_1=229.8V \quad V_2=114V$$

$$I_1=0.47A \quad I_2=1.65A$$

$$P_1=80W \quad P_2=60W$$

$$P.F=0.757 \quad P.F=0.3$$

$$\%reg = \frac{(E_2 - V_2)}{V_2} \times 100 = \frac{(112.6 - 114)}{114} \times 100 = -1.2281$$

$$\%reg = \frac{I_2(R_2 \cos \phi_2 - X_2 E \sin \phi_2)}{V_2} \times 100 = \frac{1.65(0.7227 \times 0.3 - 1.0295 \times 0.95)}{114} = 1.4396$$

$$\%reg = \frac{1.65(0.7227 \times 0.3 - 1.295 \times 0.95)}{114} \times 100 = -1.102$$

regulation should not be negative for a resistive load

4.6 R1 circuit

	simulated	practical	calculated
% Regulation	1.2	-	-1.2281
Power factor	1	1	0.757

4.7 R2 circuit

	simulated	practical	calculated
% Regulation	1.4	-	1.4396
Power factor	1	1	0.871

4.8 RC circuit

	simulated	practical	calculated
% Regulation	1.1	-	-1.102
Power factor	1	1	0.75

4.9 RL circuit

	simulated	practical	calculated
% Regulation	0.5	-	0.491
Power factor	1	1	0.95

5. Three-phase Induction Motor Investigation

5.1 introduction

Three distinct tests were carried out on a three-phase induction motor. The motor was located in the same room as the previously tested transformer, the risk assessment for this room has been completed. (See appendix Page 16) As a group the motor was wired up to perform a stator resistance test, no-load test, and blocked rotor test. Before any of the tests were carried out suitable PPE was worn. As the motor is a moving part a shield was put in place so there was no potential of direct contact to the rotating motor. After connecting the motor up to the supply the tester Chauvin Arnoux power & quality analyser Was put in place and connected to the motor, there was also a rpm meter directed to measure the speed of the rotating shaft. To measure the torque of the motor a torque meter was used.

5.2 Stator Resistance Test

$$I = \frac{10V}{R_t}$$
$$R_t = \frac{10}{I} = \frac{2R_1}{3}$$
$$R_1 = \frac{3 \times 10}{2I} = \frac{15}{I}$$
$$\frac{15}{0.438} = 34.25\Omega$$

5.3 No Load Test

$$V_o = 124.4V$$
$$124.4 \times \sqrt{3} = 215.5V$$
$$I_o = 0.56A \quad \text{these calculations belong in the appendix}$$
$$I_o = 0.56A \div \sqrt{3} = 0.32A$$
$$P_o = 25W = P_o = 25 \div 3 = 8.3W$$
$$\cos \theta_o = 0.11$$
$$\theta_o = \cos^{-1}(0.11) = 83.68^\circ = \sin \theta_o = \sin(83.68) = 0.99$$
$$R_c = \frac{V_o}{I_o \cos \theta_o} = \frac{215.5}{0.32 \times 0.11} = 6122.16\Omega$$
$$X_m = \frac{V_o}{I_o \sin \theta_o} = \frac{215.5}{0.32 \times 0.99} = 680.24\Omega$$

5.4 Blocked Rotor Test

$$V_{sc} = 103V$$
$$I_{sc} = 1.95A \quad I_{sc} = 1.95 \div \sqrt{3} = 1.13A$$
$$I_{sc} = 1.95 \div \sqrt{3} = 1.13A$$
$$P_{sc} = 303W = P_{sc} = 303 \div 3 = 101W$$
$$\cos \theta_{sc} = \frac{P_{sc}}{V_{sc} \times I_{sc}} = \frac{101}{103 \times 1.13} = 0.87 = \theta_{sc} = \cos^{-1}(0.87) = 29.54^\circ$$
$$\sin \theta_{sc} = \sin(29.54) = 0.49$$
$$Z_{sc} = \frac{V_{sc}}{I_{sc}} = \frac{101}{1.13} = 91.15\Omega$$
$$R_1 + R_2' = Z_{sc} \times \cos \theta$$
$$R_1 + R_2' = 91.15 \times 0.87 = R_2' = 79.3 - 34.25 = R_2' = 45.05\Omega$$
$$R_2' = 45.05\Omega \quad X_1 + X_2' = Z_{sc} \times \sin \theta_{sc} = 91.15 \times 0.49 = 44.66\Omega$$

5.5 Table of results

a good graph

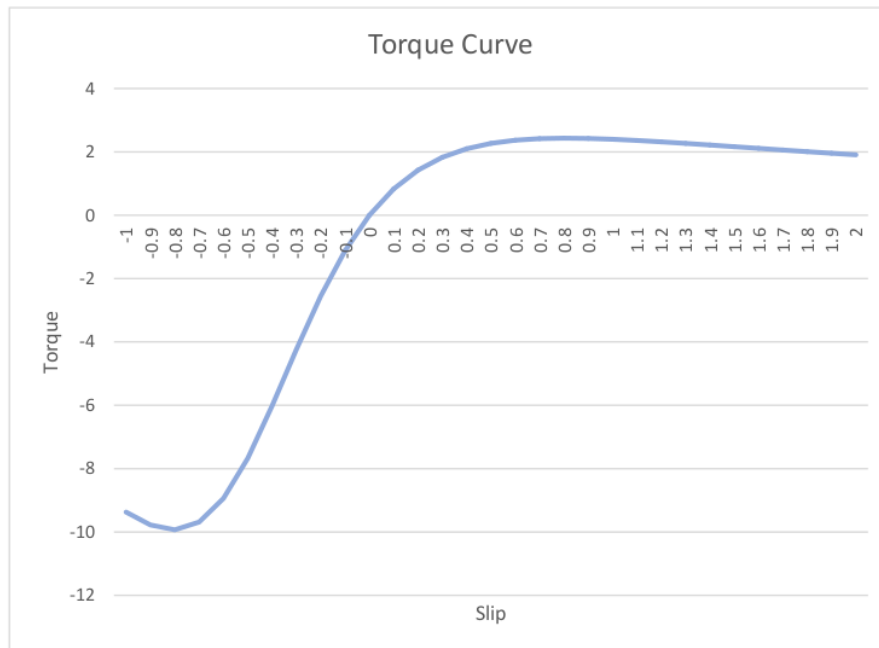


Table 1

Table 1 shows the values simulation of how the motor performed in the reversing, motoring and braking aspects. As the curve gradually increases that is the generating region where the gradual settling of the line is the motoring of the motor. And finally, the motor when braking shows between regions 1 and 2 of the table.

When the motor is in its generating state the curve and values are accurate. Where the torque is at -8 the slip is around -0.6- -0.4. The generating curve was what was expected but where there is no obvious peak of motoring at torque 2.5-3. Where a peak was expected to be found. The braking region has a small drop off but nothing that of which stands out where it ranges from 3 down to about 1.9 Nm.

5.6 Motor performance.

Actual			Predicted		
Nr	T	S	Nr	T	S
2850	0.1	0.05	2850	0.45	0.05
2800	0.2	0.067	2800	0.61	0.07
2750	0.4	0.083	2750	0.69	0.08
2700	0.5	0.1	2700	0.83	0.1
2650	0.6	0.12	2650	0.97	0.12
2600	0.7	0.13	2600	1.03	0.13
2550	0.8	0.15	2550	1.16	0.15
2500	0.9	0.17	2500	1.27	0.17

Table 2 slip speed

Table 2 shows similarity between the predicted and actual values where the torque varies when speed is changed. The torque values are different, but they still increase as predicted.

Nr	P	PF
3000	7.5	0.03
3050	-25	0.113
3100	-71.5	0.298
3150	-135	0.476
3200	-193	0.587
3250	-248	0.655
3300	-313	0.708

Table 3

Hz	Nr	V Line	S	Ns
5	102.5	111	0.317	150
10	256	117	0.147	300
15	418.5	121	0.07	450
20	568	125	0.053	600
25	721.1	129	0.039	750
30	871.1	133	0.032	900
35	1018	137	0.03	1050
40	1171	140	0.024	1200
45	1322	144	0.02	1350
50	1473	150	0.018	1500

Table 4

Table 4 shows the Voltage and Frequency increase, when the V/F ratio stays constant as the frequency is increased. when the V/F ratio stays as a constant, when they are increased as individuals, the speed increases, as expected from the research carried out. With an increase in speed, a smaller fractional slip error. The fractional slip decreases from a lowest speed to the base speed. The line voltage increases as an constant as with each step up of 5Hz was a around about 5V increase where the average increase was 4.7V.

6. Conclusions and Recommendations

This report included various tasks where understanding was improved of single-phase transformers and three phase induction motors. The research task in this report researched in depth into a numerous amount of motor controls where a wealth of information was found read and transferred into the report. Writing the research task made big improvement on the knowledge of induction motors speed control. The practical/theoretical aspect of the report consisted of testing a single phase transformer and a three phase induction motor. Where results were gathered and from them results calculations were carried out which are included in this report.

The knowledge gathered from researching the control methods of a induction motor were shared between four control methods which were the cycloconverter, vector control, Voltage/frequency inverter control, and the soft start. Where the vector controller was preferred and found to be most practical in a wide range of areas where speed control and precision control of an AC induction motor was found to be accurate.

From researching a complete power station it was found that there are many small components included in the generation distribution and consumption of electricity. And setting up factories and power plants can revolve around weather or not power is able to arrive the location and is a vital aspect to the project.

Recommendation would be to introduce a vector controller inverter for the speed control of a the phase AC induction motor, where accuracy tests could be carried out where stop and start times could also be tested. This would be an interesting factor as if the application would be accurate enough for specific CNC applications but not all.

7. Team Working

Team working was an important part of the report where teamwork was required in each practical task. A team of 3 was made where each person had a individual role to participate. One team member would read the oscilloscope, speed dial, torque, tachometer operator, and one would take the readings.

For the motor test the tachometer operator would point a laser slightly to the left of the motor to take a speed reading of the motor. As and when we needed to change the wiring/ practical we would try and keep the same personnel on the same sort of instruments.

8. Citation List

Good range of sources

Correct method of listing.

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9. Appendix

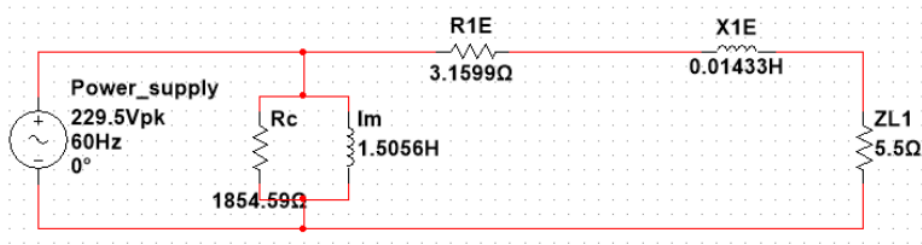


Figure 1 Task 3 equivalent circuit.

$$V=229.5V$$

$$I=0.54A$$

$$P_{in}=28.4W$$

$$F=50HZ$$

Results from open-circuit test.

$$p = \frac{V_1^2}{R_c} = 28.4 = \frac{229.5^2}{R_c}$$

$$R_c = \frac{229.5^2}{28.4} = 1854.59\Omega$$

Equation 1

$$I_c = \frac{V_1}{R_c} = \frac{229.5}{1854.59} = 0.1237A$$

Equation 2

$$I_0 = \sqrt{I_c^2 + I_m^2} = \sqrt{0.1237^2 + 0.4852^2} = 0.5007A$$

$$I_0^2 = I_c^2 + I_m^2 = 0.54^2 = 0.1237^2 + I_m^2$$

$$I_m^2 = 0.54^2 - 0.1237^2$$

$$I_m^2 = 0.2916 - 0.0562 = 0.2354$$

$$I_m = \sqrt{0.2354} = 0.4852A$$

$$X_m = \frac{V_1}{I_m} = \frac{229.5}{0.4852} = 473\Omega$$

Equation 3

$$V1=9.4$$

$$I1=1.71$$

$$P_{in}=9.24$$

$$F=50HZ$$

Task 3- short circuit test.

$$Z_1 E = \frac{9.4}{1.71} = 5.5\Omega$$

$$R_1 E = \frac{9.24}{1.71^2} = 3.1599\Omega$$

$$X_1 E = \sqrt{5.5^2 - 3.1599^2} = 4.5017\Omega$$

Equation 4

$$Z_2 E = \left(\frac{N_2}{N_1}\right)^2 Z_1 E \left(\frac{110}{230}\right)^2 \times 5.5 = 1.25785\Omega$$

$$R_2 E = \left(\frac{110}{230}\right)^2 \times 3.1599 = 0.7227\Omega$$

$$X_2 E = \left(\frac{110}{230}\right)^2 \times 4.5017 = 1.0295\Omega$$

Equation 5



Figure 2



Figure 3



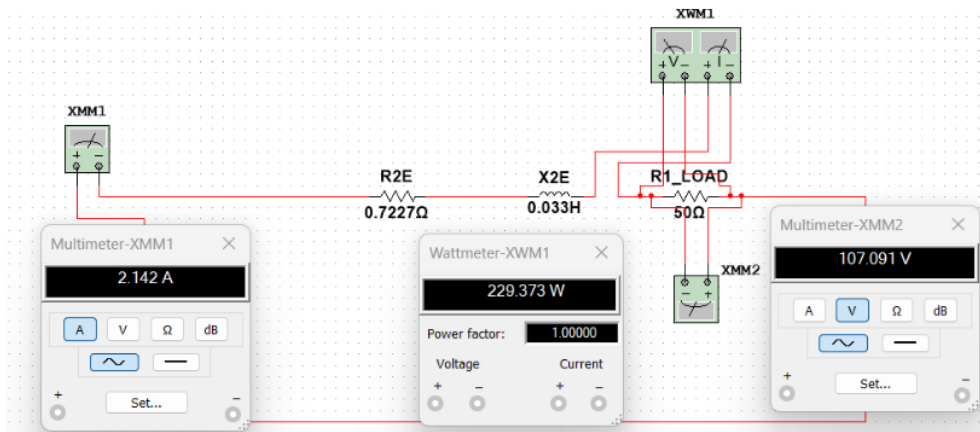


Figure 7 R1 load

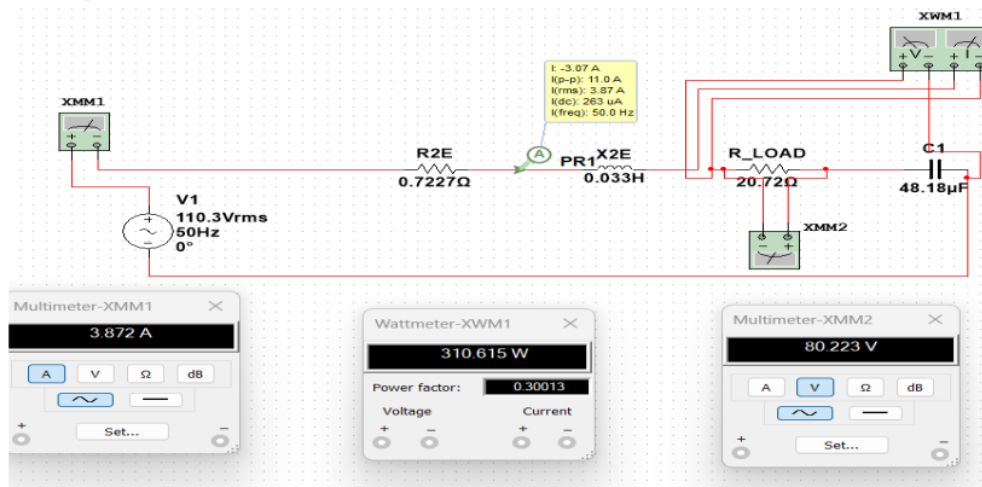


Figure 6 RC circuit

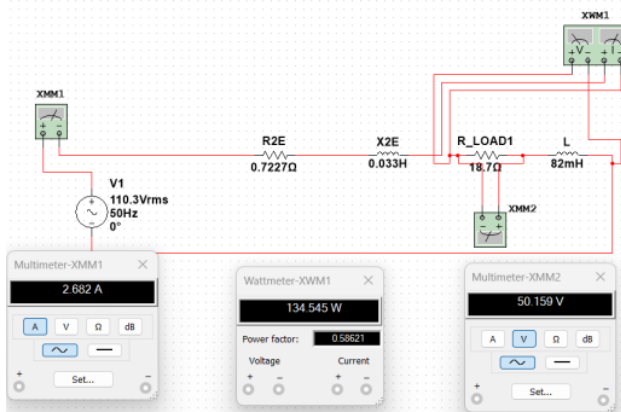


Figure 5 RL circuit

Hazards.	People at Risk.	Controls in place currently.	Risk rating.			High, Medium, Low	Additional control measures
			Probability	sternness	Final Risk score		
Heavy objects	Operator & public	Secure on a workbench	6	4	10	Medium	Steel toed boots to be worn
Electric shock	Operator & public	Isolators and E-stops in place	2	9	11	Medium	Only competent personnel to be using machinery
Moving Parts	Operator & public	Guards in place over top of moving parts	2	3	5	Low	Keep fingers out of moving parts and more stickers should be used to raise awareness to the hazard
Loud machinery	Operator & public	Rubber shoes to absorb the shock from moving parts	5	3	8	Medium	Ear defenders to be worn when the machinery is in operation

Table 1 – G22a Risk assessment table.

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this belongs after the title page

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FINAL GRADE

GENERAL COMMENTS

40 /100

CAP LIFTED.
54/100

Instructor

PAGE 1

Text Comment. Mark capped to 40% due to late submission

Text Comment. Original mark = 54

Text Comment. table of contents shoul follow on next page

PAGE 2**QM**

Line spacing should be 1.5

This allows the marker to put comments in between your lines

Text Comment. What were your findings?

PAGE 3**QM**

Line spacing should be 1.5

This allows the marker to put comments in between your lines

QM

Spelling

Spelling error

PAGE 4**QM**

Line spacing should be 1.5

This allows the marker to put comments in between your lines

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 5

QM

Line spacing should be 1.5

This allows the marker to put comments in between your lines

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Spelling

Spelling error

PAGE 6

QM

Line spacing should be 1.5

This allows the marker to put comments in between your lines

PAGE 7

Text Comment. regulation should not be negative for a resistive load

PAGE 8

Text Comment. these calculations belong in the appendix

PAGE 9

Text Comment. a good graph

Text Comment. generating

PAGE 10

PAGE 11

QM

Line spacing should be 1.5

This allows the marker to put comments in between your lines

PAGE 12

PAGE 13

QM

Correct method of listing.

You have listed your sources correctly according to the Harvard method.

QM

Good range of sources

You have demonstrated reading from a good range of sources shown by your list below

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

QM

Good Structure

Report is structured exactly as stated in the assignment brief.

Text Comment. this belongs after the title page

PAGE 20

GRADING FORM: NEW CSG-RUBRIC

HEFIN WILLIAMS

54

1. ENGAGEMENT WITH LITERATURE

-  A good research section with evidence of reading from a wide range of sources cited and listed correctly using the Harvard method. 12/20 **12**

2. KNOWLEDGE AND UNDERSTANDING

-  Satisfactory knowledge and understanding demonstrated in your research findings, transformer and motor investigation explanations. 10/20 **10**

3. COGNITIVE AND INTELLECTUAL

-  Satisfactory analysis of transformer and motor investigation results analysis and conclusions/recommendations 10/20 **10**

4. PRACTICAL APPLICATION

-  Good use of equipment for transformer and motor experiments and presentation of results . 12/20 **12**

5. TRANSFERABLE SKILLS

-  A brief executive summary, work plan, risk assessment and explanation of team working. Report is well structured, and presented with clear diagrams. Word count not exceeded. However, **10**

text format is incorrect, should be 1.5 line spacing.

10/20