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by Jason Booth

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Name: Jason Booth

University number: 1302736

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1. Executive Summary

Investigation was carried out into 4 different methods of speed control to an induction motor using advanced electronic circuitry that produces different waveforms. Experiments ^{were} conducted on a single-phase transformer and a three-phase induction motor so that parameters can be found to produce a simplified equivalent circuit. This was then used to predict the performance and efficiency of the transformer and motor. The equivalent circuit was then built on simulation software to compare with theory and measured values to prove the mathematical theory is correct. Open circuit, short-circuit and load tests were carried out on the transformer. The open and short-circuit test were used to gain the equivalent circuit, whereas the load tests were used to predict the voltage regulation and efficiency. The equivalent circuit of the motor was created by carrying out blocked rotor test, no-load test and stator resistance test. The motor was also tested under load by driving it faster than synchronous speed using a VSD for generating. Also, further tests were made by connecting the motor to an inverter and a pony brake taking accurate readings of stator voltage, stator frequency and rotor speed under a small friction load for a range of speeds demonstrating the inverter's performance. All results gathered were compared with expected values from theory obtained by research.

A good summary but it does contain repetition and does not include the overall conclusions

2. Work plan for Life-long Learning

A methodical approach will be carried out throughout the assignment starting with research on the topic area before carrying out any practical experiments to gain an understanding of what is being or must be done. Technical analysis of experiments will be conducted and compared with theoretical results to prove the theory and conclusions drawn in a summarized format. A risk assessment is carried out to highlight any hazard or where there is potential for something to become hazardous and for colleagues to understand the risks involved and what can be done to counteract them to provide safe working activities. The risk assessment can be seen in appendix 9.13 towards the back of the report.

excellent work plan

3. Research

3.1 Phase angle control (soft starter)

According to Hughes, a soft starter is the most widely used method to start up large AC motors that generates a lot of torque which in result causes a massive inrush of current at start-up. A soft-starter device “provides a smooth build-up of current and torque, the maximum current and acceleration time are easily adjusted, and it is particularly valuable where the load must not be subjected to sudden jerks.” Hughes mentions “the real drawback over conventional starters is that the mains currents during start-up are not sinusoidal, which can lead to interference with other equipment on the same supply.” (2006, p. 204)

Hughes illustrates the circuit in figure 1 below which comprises of three back-to-back thyristors connected in series with three phase supply. Each thyristor is fired once per half cycle, the firing is synchronised with the mains and the firing angle is varied so that each pair conducts for a varying proportion of a cycle. The current waveforms are shown in figure on the following page. (2006, p. 204)

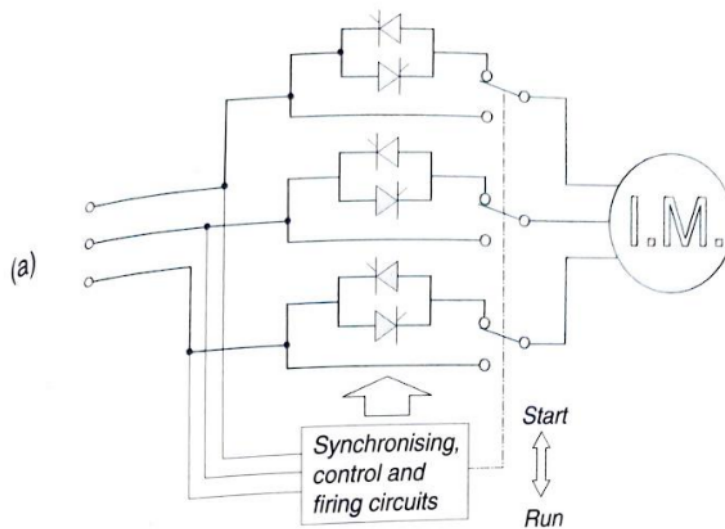


Figure 1 - Phase angle controller

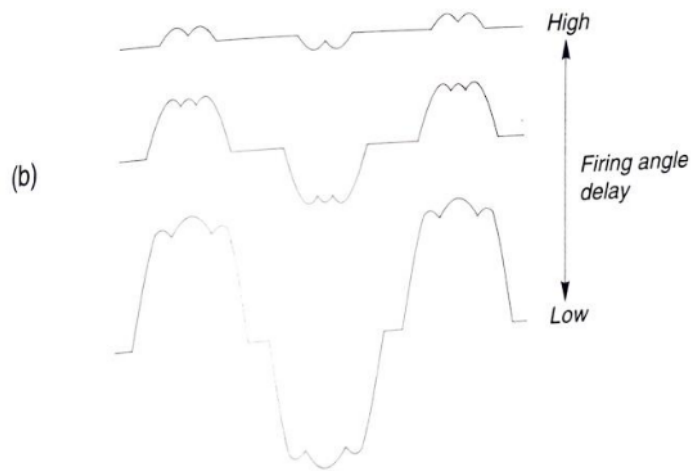


Figure 2 - Phase angle waveform

(2019)

According to Control Concepts, each of the back-to-back SCR pair is switched on for a portion of the half-cycle that it conducts. Power is controlled by increasing/decreasing the point at which the SCR is switched ON within each half cycle. The author also mentions that phase-angle control is required if the load is transformer-coupled or inductive. (2019) *Not quite Harvard*



Figure 3 - Soft-starter waveform

According to Power Products International, phase angle control allows an extremely tight, accurate and smooth control of the load but will generate a significant amount of electrical noise unless substantial filter networks are employed. The author mentions that the level of electrical interference increases when the switch on point reaches maximum peak voltage of the waveform. (2020)

3.2 Cycloconverter

According to Cyril W. Lander, cycloconverters are composed of two converters connected back-to-back as shown in figure 4 below. (1993, p. 181)

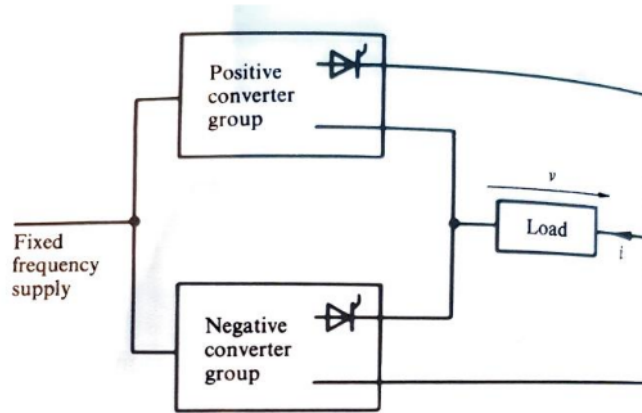
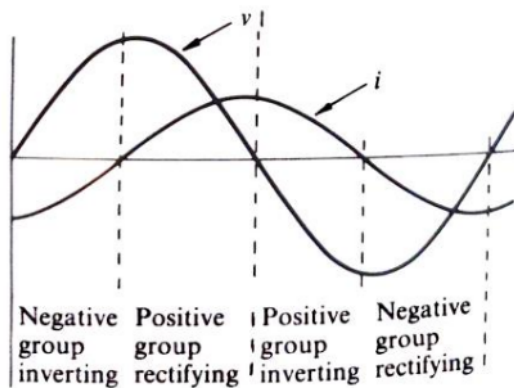


Figure 4 – Cycloconverter

Lander states that Analysing the waveforms on figure 5, Lander explains that “the instantaneous power flows in the load fall into one of four periods. The two periods, when the product of load voltage and current is positive, require power flow into the load, dictating a situation where the converter groups rectify, the positive and negative load current periods.” *Citation belongs here* The other two periods represent times when the product of load voltage and current is negative; hence the power flow is out of the load, demanding that the converters operate in the inverting mode. (1993, p. 181)



(b)

Figure 5 - Cycloconverter waveform

Cycloconverters are not very widespread but ^{are} is used in very large induction motors or synchronous motor drives where the speed is very low. This is because cycloconverters produce waveforms that are only acceptable at frequencies well below the mains frequency. Hughes mentions that it is feasible that very large induction or synchronous motors with high pole numbers meaning the motor has a very low speed direct (gearless) drive such as a cycloconverter becomes practicable. (Hughes, 2006, p. 300)

Good explanation given

In contrast to most converters, the cycloconverter is a direct converter as it does not have a d.c. stage like most inverters do, this process is known as AC-AC conversion. (Science Direct, 2017)

Correctly cited

3.3 Quasi square Inverter

Quasi-square inverters are commonly called quasi sine wave inverters or modified sine wave inverters. The output signal produces a square waveform that increases/decreases stepwise with positive and negative polarity. Figure 6 below shows the waveform of a quasi-square inverter. (Electrical Technology, 2019) Correctly cited

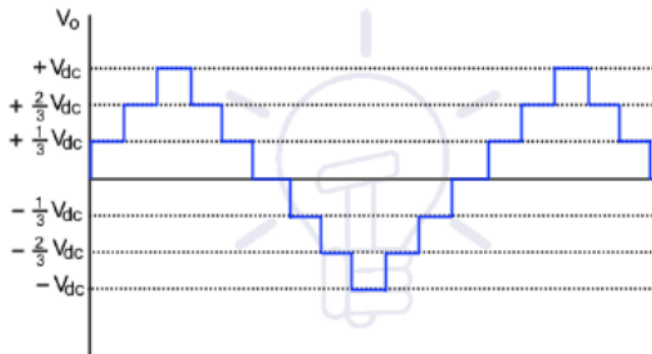


Figure 6 - Quasi-square waveform

(2019)

According to Electrical Technology, the construction of a quasi-square inverter is much simpler than pure sine wave inverter but is more complex than a pure square wave inverter. (2019)

A report by NASA states that, "a Q-S wave is inherently generated in a three-phase inverter bridge (Fig. 7) by switching the transistors on and off in the sequence shown in figure 8. Note that the transistors are on for only 120 degrees. A similar waveform is also produced if the transistors are on for 180 degrees. However, the potential problem of having two transistors in series on simultaneously is eliminated by switching for only 120 degrees. Thus, this method has been used in inverters used in this study. The disadvantage of switching for only 120 degrees is that the waveforms and voltage regulation are dependent on the load power factor. By taking the necessary precautions to prevent short circuit current through the series transistor, this disadvantage is overcome" (1977) This quotation is far too long

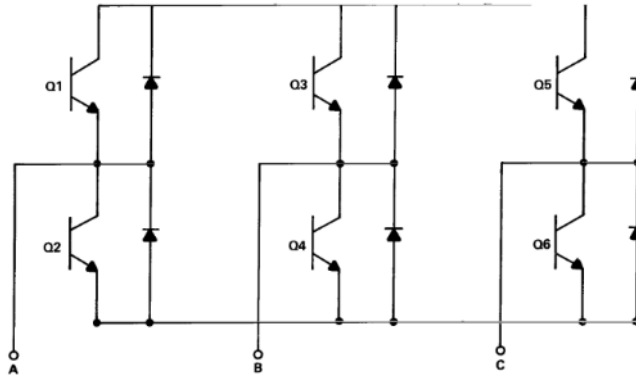


Figure 7 - Quasi-square transistor stack

Q	120° DRIVE						180° DRIVE					
1	1	1	0	0	0	0	1	1	1	0	0	0
2	0	0	0	1	1	0	0	0	0	1	1	1
3	0	0	1	1	0	0	0	0	1	1	1	0
4	1	0	0	0	0	1	1	1	0	0	0	1
5	0	0	0	0	1	1	1	0	0	0	1	1
6	0	1	1	0	0	0	0	1	1	1	0	0
Degrees 0 60 120 180 240 300 360 												

Note: 1 indicates transistor is driven on, 0 indicates transistor is driven off.

Figure 8 - Quasi-square inverter firing sequence

You must always explain your figures or leave them out

3.4 PWM Inverter – flux vector drive

Elprocus states that PWM inverters can maintain the output voltage as the rated voltages depending on the country irrespective of the type of load connected. It is achieved by varying the switching frequency width at the oscillator. (Elprocus, 2018) [Correctly cited](#)

Rockwell Automation provides a block diagram below in figure 9 which illustrates the power conversion unit in PWM drives. A diode bridge rectifier produces the intermediate DC circuit voltage. The DC voltage is filtered in a LC low-pass filter. Output voltage and frequency is controlled electronically by varying the width of the pulses of voltage to the motor. This technique utilizes switching of insulated gate bipolar transistors (IGBTs) on and off at a very fast speed to generate the proper RMS voltage levels. (2000)

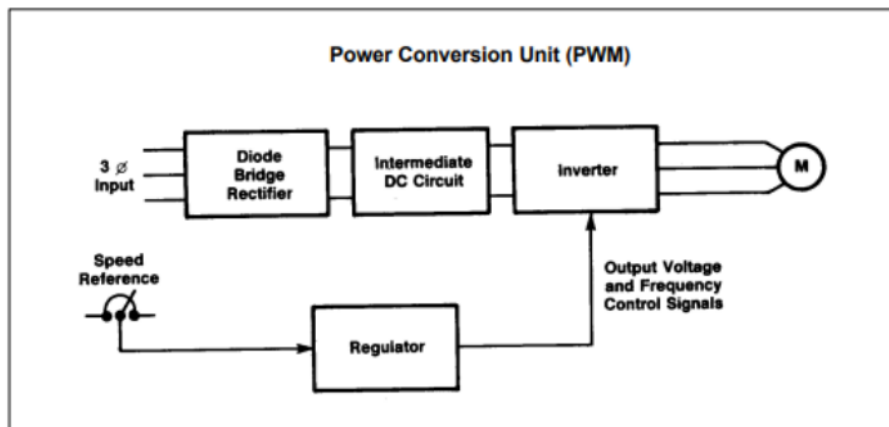


Figure 9 - PWM power conversion [Citation Needed](#)

Flux vector control is often referred to AC motor control technique that uses fast switching IGBTs operating at carrier frequencies of several kilohertz, in conjunction with high-speed computers. (Wildi, 2013) [Correctly cited](#)

3.5 Power Systems required to deliver a three phase AC supply

In an industrial electric power system, electrical power is transmitted from the electricity grid. The supplied voltage is in the high range of 11KV, 33KV, 66KV or 132KV. These voltages are then stepped down using a step-down transformer so it can be supplied to industrial premises. (Electrical Technology, 2017) Correctly cited

According to Wildi, there are power blocks that give rise to three types of generating stations which are:

1. Base-power stations – delivers full power at all times (Nuclear and coal-fires stations).
2. Intermediate-power stations – responds quick to sudden changes in demand by adding or removing one or more generating units (Hydropower stations).
3. Peak-generating stations – delivers power for brief intervals during the day which requires stations to be put into service quickly. Consequently, they use prime movers such as gas turbines, diesel engines, pumped-storage turbines that can be started up in a few minutes. (2013, pp. 676-677)

The figure below shows the load duration curve of a large electric utility system.

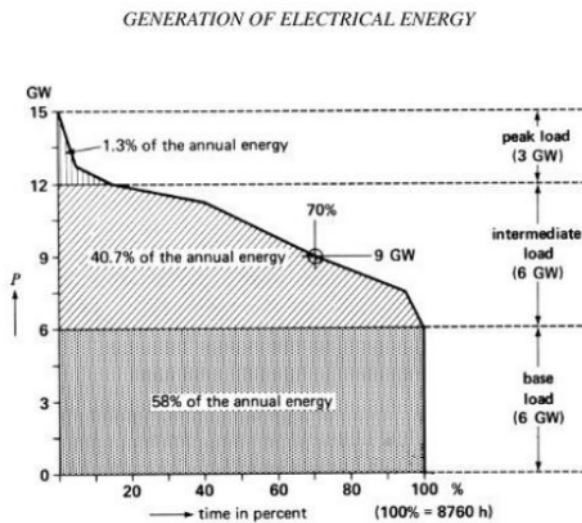


Figure 10 – Load duration curve

The figure below shows a diagram of a transmission and distribution system. It consists of generating stations, substations, an interconnecting substation and several loads being commercial, industrial and residential. (Wildi, 2013, pp. 718-719)

page numbers are only needed for direct quotations

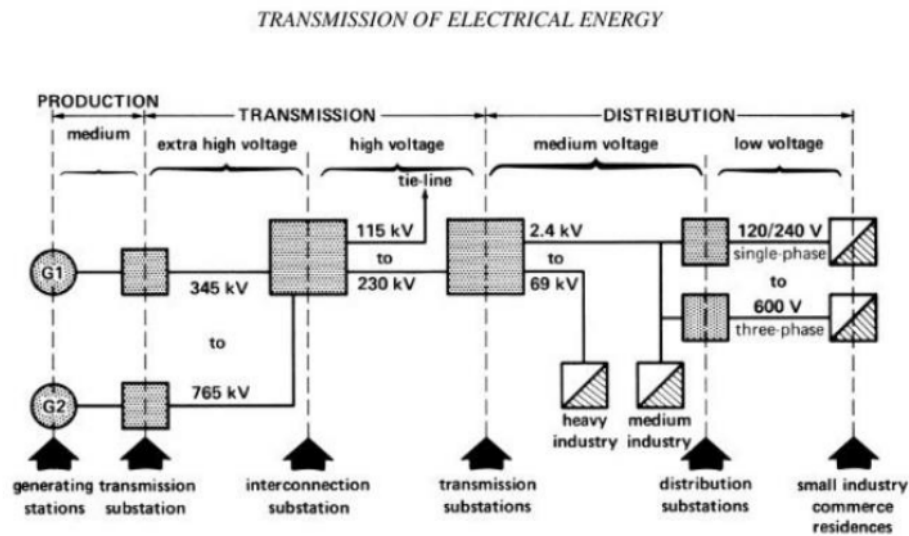


Figure 11 - Generation, transmission & distribution system

Interconnecting substations tie different power systems together, to enable power exchanges between them, and to increase the stability of the overall network. (Wildi, 2013, p. 719)

4. Transformer Investigation

This experiment is carried out to gain the equivalent circuit parameters to predict the performance of the transformer at varied levels of load. To gain the equivalent circuit parameters an open circuit and short circuit tests are carried out. Analysing the test results are used to determine the equivalent circuit parameters. These tests are carried out on a step-down transformer with a turns ratio of 2:1. The data sheet can be found in appendix 9.1. An open circuit test is performed to determine the core losses and no-load current I_0 . The short circuit test is used to determine the copper losses in the transformer.

4.1 Open Circuit Test

With this test, the low-voltage (secondary) side of the transformer is kept open, and the high-voltage (primary) side is connected to the supply voltage from the variac. A voltmeter, ammeter and wattmeter are connected to the primary side. These measuring instruments are used to record the values of the readings to determine the and calculate the equivalent circuit.

Voltage is applied to the LV side of the transformer and is steadily increased until the voltmeter reads the rated input voltage of the transformer. At this point readings are taken.

Open Circuit Test			
Primary Voltage	Secondary Voltage	Current	Input Power
230.8V	112.9V	0.55A	28.8W

Figure 12 - Open Circuit Test Table

The input power is also known as the no load current, as it is quite small the voltage drops due to this current is negligible. The input power drawn is considered to be the core losses as the output is left open circuit so there is no output power. As mentioned, the no load current is quite small, so the copper losses are negligible, therefore the input power is almost equal to the core losses of the transformer.

With these parameters the equivalent circuit can be produced by calculating R_c and X_m , which the calculations can be found in appendix 9.2.

$$Power\ lost = \frac{V^2}{R_c}$$

these equations and calculations should be in the appendix, your reader is only interested initially in the results in comparison with theory

$$28.8 = \frac{230.8^2}{R_c}$$

$$R_c = \frac{53268.64}{28.8} = 1849.61 \text{ Ohms}$$

$$I_c = \frac{230.8}{1849.61} = 124.78 \text{ mA}$$

Since,

$$I_o = \sqrt{I_c^2 + I_m^2}$$

$$0.55^2 = 124.78^2 + I_m^2$$

$$I_m^2 = 0.3025 - 15.571m$$

$$I_m = 738.887m$$

$$X_m = \frac{230.8}{738.887 * 10^{-3}} = 312.36$$

4.2 Short Circuit Test

A short circuit test is carried out with the supply voltage from the variac connected to the HV side of the transformer with the same instruments in the circuit as the open-circuit test. The LV side of the transformer is short-circuited. To limit the high current caused by the short circuit, the primary winding is energized with a small voltage which is enough to produce the rated current of the transformer.

Short Circuit Test			
Primary Voltage	Primary Current	Secondary Current	Input Power
9.4V	1.69A	3.48A	9.12W

Figure 13 - Short Circuit Test Table

With these values the series branch parameters of the equivalent circuit of the transformer can be determined by doing the following calculations:

Primary

$$Z_{1E} = \frac{V_1}{I_1} = \frac{9.4}{1.69} = 5.562 \text{ Ohms}$$

$$R_{1E} = \frac{Pin}{I_1^2} = \frac{9.192}{1.69^2} = 3.218 \text{ Ohms}$$

$$X_{1E} = \sqrt{5.562^2 - 3.218^2} = 4.537 \text{ Ohms}$$

Secondary

$$Z_{2E} = \left(\frac{N_2}{N_1}\right)^2 Z_{1E}$$

$$Z_{2E} = \left(\frac{112.9}{230.8}\right)^2 * 5.562 = 1.331 \text{ Ohms}$$

$$R_{2E} = \left(\frac{N_2}{N_1}\right)^2 R_{1E}$$

$$R_{2E} = \left(\frac{112.9}{230.8}\right)^2 * 3.218 = 0.77 \text{ Ohms}$$

$$X_{2E} = \left(\frac{N_2}{N_1}\right)^2 X_{1E}$$

$$X_{2E} = \left(\frac{112.9}{230.8}\right)^2 * 4.537 = 1.086 \text{ Ohms}$$

$$I_2 = \frac{N_1}{N_2} * I_1$$

$$I_2 = \frac{230.8}{112.9} * 1.69$$

$$I_2 = 3.455 \text{ Amps}$$

Full calculations can be found in appendix A9. The equivalent circuit of the transformer can be seen in appendix 9.3.

4.3 Transformer Load Tests & Simulation

The transformer was subjected to load tests which values were recorded. Using simulation software, the circuit was built for open circuit, short circuit and each of the load tests to compare between measured, simulated and calculated. The simulation circuits can be seen in appendix 9.7, 9.8, 9.9 & The table for this can be seen in appendix 9.11.

Open Circuit Test				
	Primary Voltage (V)	Secondary Voltage (V)	Primary Current (A)	Input Power (W)
Measured	230.8	112.9	0.55	28.8
Simulated	230.8	N/A	548.895×10^{-3}	28.8

Figure 14 - OC Test Table

Short Circuit Test				
	Primary Voltage (V)	Primary Current (A)	Secondary Current (A)	Input Power (W)
Measured	9.4	1.69	3.48	9.12
Simulated	9.4	1.707	N/A	9.198

Figure 15 - SC Test Table

As can be seen in the table above, simulation and measured values compare almost identical proving theory and calculations are correct.

Table in appendix 9.11 compares measured, simulated & calculated values for the load tests. Analysing the table, it can be said that almost all results closely match indicating theory and calculation to be correct and proving that gaining the equivalent circuit parameters is useful in determining the performance of the transformer.

where are your load test results?

5. Three-phase Induction Motor Investigation

Tests were carried out on a three-phase induction motor using suitable measuring equipment to carry out stator resistance, no-load and blocked-rotor tests, to determine the approximate per-phase equivalent circuit parameters for the motor.



Figure 16 - Induction motor test setup

The setup of the experiment can be seen in the image above.

5.1 Stator Resistance Test

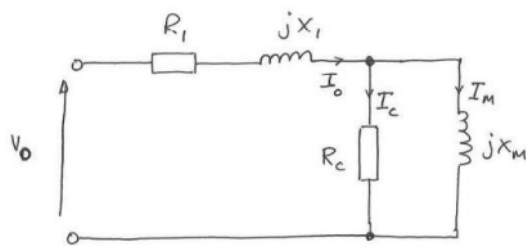
Stator resistance test was performed by locking the rotor and applying dc to the stator. Voltage and current are measured to calculate R.

5.2 No-Load Test

No-load test was carried out by coupling the motor shaft to a VSD and driven past synchronous speed, then applying rated voltage to the stator and measuring the voltage, current and power.

Since fractional slip (S) = 0, the rotor is open ($\frac{R_2^1}{S} = \infty$).

The equivalent circuit for the no-load test can be seen below.



it is not appropriate to use course notes as figures

Figure 17 - No-load motor equivalent circuit

5.3 Blocked Rotor Test

The blocked rotor test is carried out by preventing the rotor from turning ($S=1$). A low voltage is applied to the stator so that rated current flows. From here, voltage, current and power is recorded. It is noted that since the voltage is small and the current is very large, the core and magnetizing component can be ignored. The equivalent circuit for this test can be seen below.

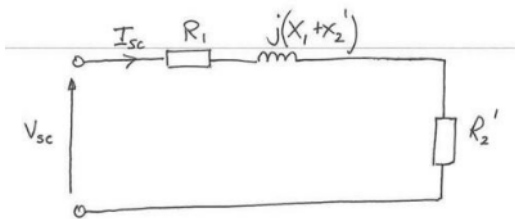


Figure 18 - Blocked rotor equivalent circuit

The table below shows the measured results of the three tests carried out on the motor.

Induction Motor Testing			
Stator Test	Resistance	Stator Resistance	34.25Ω
No Load Test	Line Voltage		215V
	Line Current		0.56A
	Total Power		25W
Blocked Rotor Test	Line Voltage		178.4V
	Line Current		1.95A

	Total Power	303W
--	-------------	------

Figure 19 - Induction motor test table

Using the recorded measurements in the table above, the parameters per phase was calculated and from there the equivalent circuit parameters was gained by using mathematical equations which can be seen in appendices 9.12, 9.13, 9.14.

From the circuit parameters calculated from the tests conducted on the motor, a spreadsheet is produced that simulates the performance of the motor in terms of torque and stator current. The spreadsheet values can be seen in appendix 9.15. A graph is produced from the data and can be seen in figure 20 below.

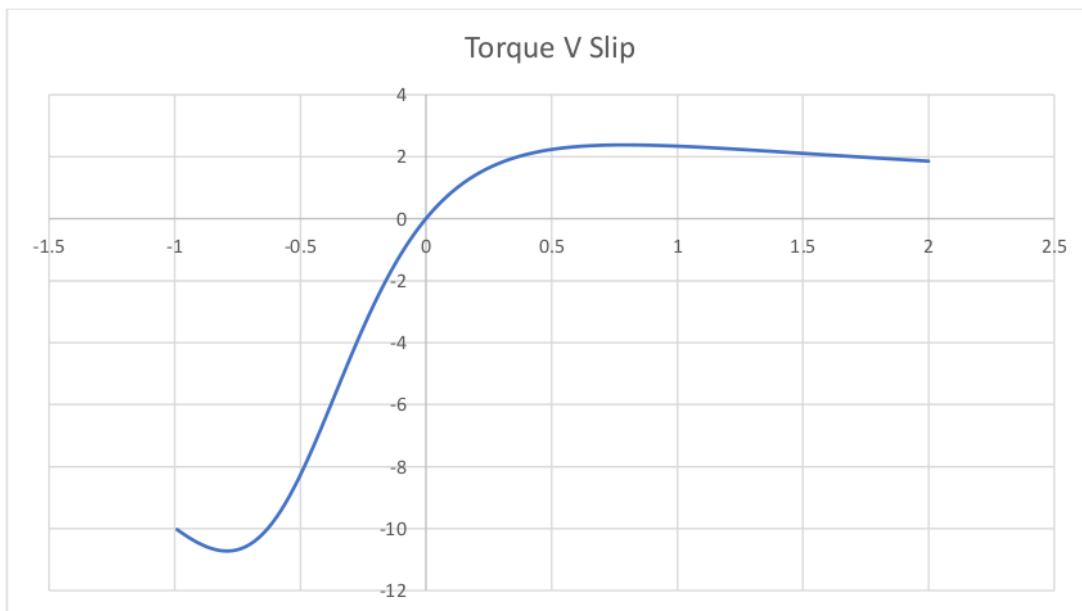


Figure 20 - Torque Vs Slip Graph

Analysing the graph it can be seen that the motor is generating in the left-hand plane as the fractional slip is between 0 and -1. It is seen that negative slip produces negative torque causing a braking effect and peaked at -10.7262 Nm at a speed of 5370 rpm and fractional slip of -0.79.

The motor is said to be motoring when fractional slip is between 0 and 1. Looking at this section of the graph, positive torque is developed and peaks at 2.379714 Nm, 0.79 fractional slip, 630 rpm.

The motor is braking when fractional slip is between 1 and 2. This produces positive torque in negative direction which therefore acts as a brake.

The motor was driven under load, measuring the rotor speed, torque and fractional slip. The table and graph results can be seen below.

Motor Under Load					
Measured			Predicted		
Rotor Speed Nr (RPM)	Torque	Fractional Slip S	Rotor Speed Nr (RPM)	Torque	Fractional Slip S
2850	0.1	0.05	2850	0.453728	0.05
2800	0.2	0.0667	2800	0.53566	0.06
2750	0.4	0.083	2750	0.691233	0.08
2700	0.5	0.1	2700	0.836198	0.1
2650	0.6	0.1167	2650	0.971092	0.12
2600	0.7	0.13	2600	1.034929	0.13
2550	0.8	0.15	2550	1.15571	0.15
2500	0.9	0.1667	2500	1.26773	0.17

Figure 21 - motor under load

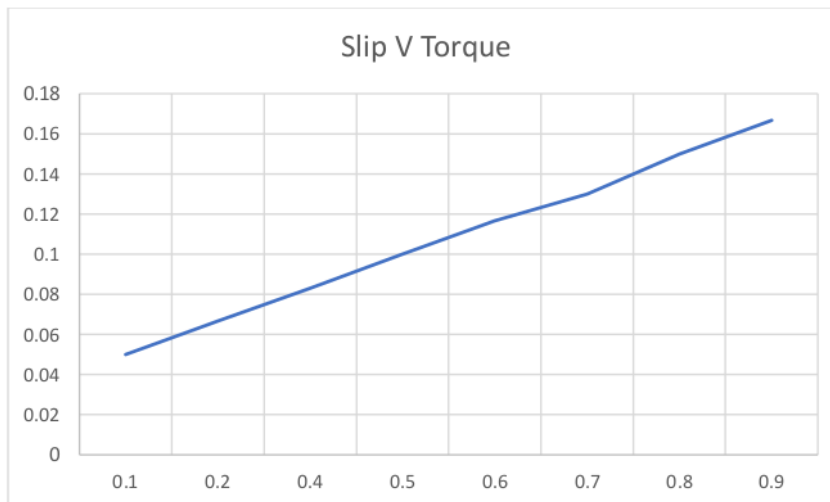


Figure 22 - Slip v torque under load

The motor was connected to a VSD to drive it faster than synchronous speed. The results from this test can be seen in the table below.

Faster than Synchronous Speed		
Rotor Speed Nr (RPM)	Power (Hz)	P.F
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

power is measured in watts not Hz

Figure 23 - Faster than sync speed table

The power recorded went negative, indicating that power is being generated instead of wasted.

A load test was carried out on a 4-pole induction motor connected to an inverter and a pony brake to measure the inverter's performance. The results can be seen in the table below.

Motor Connected to an Inverter				
Power (Hz)	Rotor Speed Nr (RPM)	Vline (V)	Stator Speed Ns (RPM)	Fractional Slip
5	102.5	111	150	0.3167
10	256	117	300	0.1467
15	418.5	121	450	0.07
20	568	125	600	0.0533
25	721.1	129	750	0.0385
30	871.1	133	900	0.0321
35	1018	137	1050	0.0305
40	1171	140	1200	0.0242
45	1322	144	1350	0.0207
50	1473	150	1500	0.018

Figure 24 - motor connected to inverter table

what is the relationship between stator voltage and frequency as a gradient?

Analysing the data, as the frequency increases, the voltage rises proportionally. As the speed increases, the fractional slip decreases.

6. Conclusions and Recommendations

From carrying out extensive research in different methods of electronic speed control, it can be concluded that there are many ways speed control can be achieved. The most efficient method of speed control is by variable frequency drives (VFD) or more commonly known as inverters. They offer excellent speed control by adjusting the voltage and frequency which enables direct regulation of torque. The drawback VFDs is that they need to be implemented in a control system and is expensive as they are relatively new in the market. *incorrect, VFDs have been around for a long time*

Soft starters do not offer good speed control however it reduces the stress placed on the motor at start-up by ramping the voltage up slowly to limit the inrush current which can be extremely high if starting loads with high inertia torque. This would be suitable for conveyors to prevent jerks which can cause spillage of material.

Quasi-square inverters are smaller, simpler, and provides better reliability and efficiency than a sine wave inverter due to having 60% of components compared to a sine wave inverter. *the sinewave inverter was not part of your research, the PWM was* The advantage however is somewhat offset by the 3-5% lower motor efficiency. However, it can be improved by including a regulator to help maintain the voltage to the Q-S inverter. It is better to use the Q-S inverter on motors with a power factor of 0.7 or less to allow the waveform to maintain its fundamental voltage.

Performing open and short-circuit tests on a transformer was needed to gain the equivalent circuit parameters from which the circuit can be drawn in a simplified manner, that can be used in simulations and experiments to predict the efficiency and voltage regulation of the transformer.

From the open circuit test, the no-load power was recorded which was found out to be the core losses in the transformer as the primary current is very small, thus the copper loss in the primary winding is negligible. Since the iron losses are at rated voltage, the power input is drawn to supply the iron losses of the transformer under no load.

In the short-circuit test, the applied voltage to the primary winding is very low at 9.4 volts so the flux level in the core is very small, so the core loss is negligible. Therefore, the no-load shunt branch is considered as absent in equivalent circuit of this test. As the core losses are determined by voltage, the losses are negligible. Therefore, the power loss measured is equal to the full load copper losses of the transformer.

load regulation test results were not commented on

The parameters gained from the transformer tests proved helpful in predicting the performance as an equivalent circuit was created on multisim to simulate the circuit which looking at the tables provided matched very closely with measured and calculated values. This proved the research, theory and calculations to be correct and accurate, therefore an excellent tool to predict the performance. Looking at the table for the load tests, the different between measured, calculated and simulated values for efficiency and voltage regulation are nearly identical.

The motor tests is crucial to gain the motor equivalent circuit parameters, which like the transformer, can be used to predict the performance, torque, etc. The graph generated proved useful as it shows when the motor is generating, motoring and braking. Motoring occurs when S is between 0 and 1, which looking at the graph it proves correct. Generating is when S is between 0-1 which looking at the graph it does this and provides negative torque. Braking occurs when S is between 1 and 2, which looking at the graph the torque starts to decrease indicating to be correct. So, it can be said that the graph indicates the performance of the motor in all three regions.

Comparing the predicted and measured tables and graphs it shows that the fractional slip is near identical which is to be expected, slight discrepancies can be from rounding to the nearest number, not accurately recording measurements from the motor and the simulation does not consider real life factors where the motor is subjected to a physical load. The difference between measured and predicted torque is somewhat high which can again be due to simulation errors *incorrect, physical load is represented by fractional slip* where it does not consider real life factors such as motor drag, physical load, etc.

When the motor was driven past synchronous speed, the power measured became negative indicating the motor is generating which as the speed further increases past synchronous speed, so does power generated, therefore increasing the power factor.

Using an inverter to drive a motor proved excellent in speed control. As frequency was increased, so did the line voltage on the motor, this backs up theory learned about inverters. As frequency increases it allows the voltage to be on for a longer period which imagining a sine waveform, the higher the frequency, the higher the voltage can reach its peak.

7. Team Working

Experiments carried out in this report was conducted by a group of students which all had separate roles in the experiments. As part of this project, team working was needed and carried out for the transformer and induction motor tests. The team consisted of three members which were Jason Booth, Matthew Perry and Harri Jones. Each member had their own roles and responsibilities. During the testing of the induction motor, Matthew Perry was responsible for increasing the speed of the motor, Jason Booth was responsible for measuring the values displayed and Harri was responsible for recording the results to a spreadsheet so graphs can be generated for analysing. During the transformer tests, each member was responsible for recording assigned values such as current, voltage, power, etc. During these tests, all health and safety precautions were taken by carrying out a risk assessment and wearing the correct PPE. Also, the equipment is protected by a circuit breaker so if there were accidental actions that would cause a short-circuit or a large increase of current drawn, it would trip the breaker removing power from the circuit. The motor was securely clamped to avoid falling over on start-up and irrational movement of the motor under load/speed and the motor shaft protected by a steel cage to prevent items/clothing to be caught.

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Portable Safety Isolating Transformers



RS Part No	260-4244	260-4250	260-4272	260-4288	260-4294	260-4301	399-6140	310-2171
Transformer Type	CM7501	CM10001	CM15002	CM22502	CM33002	CM40002	CMH13	CMH1200110
Continuous Output Rating (VA)	375	500	750	1125	1650	2000	3000	600
Intermittent, 5 mins on 15 mins off, (VA)	750	1000	1500	2250	3300	4000		1200
Primary Voltage (V)	230	230	230	230	230	230	230	230
Frequency	50/60Hz	50/60Hz	50/60Hz	50/60Hz	50/60Hz	50/60Hz	50/60Hz	50/60Hz
Off Load Secondary Volts (V)	113.8	114.6	113.8	112	111.5	112.5	113.5	112.5
Full Load secondary Volts (V)	109.6	110	109.6	108.4	108.3	108.9	109.9	109.5
Regulation at Continuous Rating	4%	4%	4%	3%	3%	3%	3%	4%
Efficiency at Continuous Rating	90%	90%	93%	93%	95%	93%	96%	94%
Iron Loss (Watts)	20.16	23.5	18	18.4	22.7	30	40	17.3
Copper Loss at Continuous Rating	9.05	14.8	18.4	21	22.7	30	42.9	38
Insulation Resistance at 2kV for 1 Minute	10.74	17	21	29	30	58	30	10
Flash Test Voltage for 1 minute	2kV	2kV	2kV	2kV	2kV	2kV	2kV	2kV
Primary Winding Resistance at 20 °C	1.79Ω	1.3Ω	0.93Ω	0.53Ω	0.53Ω	0.24Ω	0.216Ω	1.79Ω
Secondary Winding Resistance at 20 °C	0.52Ω	0.37Ω	0.25Ω	0.16Ω	0.16Ω	0.075Ω	0.04Ω	0.91Ω
Winding Temperature Rise	96	90	92	95	98	98	92	84
Primary Thermal Circuit Breaker Rating	3Amp	4Amp	6Amp	8Amp	10Amp	15Amp	15Amp	6Amp
Dimensions, Width x Depth x Height (mm)	160x210x220	160x210x220	160x210x220	190x240x260	190x240x260	270x320x280	230x300x370	175x75x175
Weight (Kg)	9	10.5	11.5	16	18	30	32	7
Output Sockets	1x16A BS EN 60309	1x16A BS EN 60309	2x16A BS EN 60309	2x16A BS EN 60309	2x16A BS EN 60309	2x16A BS EN 60309	1x32A BS EN 60309	1x16A BS EN 60309

Materials and Construction

The enclosure is moulded from DMC (Dough moulded compound) which is fibre glass with a Flame retardant compound and is self extinguishing (not 399-6140). The enclosure for 399-6140 is sheet steel ventilated to IP22 and finished in golden yellow to BS4800 shade 08 E 51. The encapsulant used to retain the transformer is a flame retardant Polyurethane resin which incorporates a silica sand filler. The bobbin is manufactured in nylon and is rated for operation at 140 °C. The interwinding and screen insulation is nomen/polyester composite. The winding wire is dual coated polyester , grade 2 rated for 200 °C. The mains cable fitted on the 500-3300 VA range has fitted a moulded 13 Amp plug with a 13 Amp fuse. The mains cable fitted on 260-4301 & 399-6140 is supplied untermminated to allow the user to fit the required style of plug.

9. Appendix

9.1 Transformer Datasheet

do not include datasheets, quote from them instead and cite your source

9.2 Transformer Open-circuit Calculation

Open Circuit Test Results

$$P_V = 230.8 \text{ V} \quad P_I = 0.55 \text{ A} \quad \text{Power loss} = 23.8 \text{ W}$$

$$E_2 = 112.6 \text{ V}$$

$$R_c = \frac{V^2}{\text{Power loss}} = \frac{230.8^2}{23.8} = 1849.61 \Omega$$

$$I_c = \frac{V}{R_c} = \frac{230.8}{1849.61} = 124.78 \text{ mA}$$

$$\text{Since } I_o = \sqrt{I_c^2 + I_m^2}$$

$$0.55^2 = 124.78 \text{ mA}^2 + I_m^2$$

$$I_m^2 = 0.3025 - 15.571 \text{ mA}$$

$$I_m = \sqrt{286.429 \text{ mA}}$$

$$I_m = 535.658 \text{ mA}$$

$$\therefore X_m = \frac{V}{I_o} = \frac{230.8}{535.658 \text{ mA}} = \frac{430.872 \Omega}{0.535658} = 804.42 \Omega$$

9.3 – Transformer Short-circuit Calculation

Short Circuit Test

$$P_V = 9.4 \text{ V}, P_I = 1.69 \text{ A}, S_I = 3.43 \text{ A}, \text{Power loss} = 9.192 \text{ W}$$

Transformer rated values are: 3.41 A, 375 VA, 110 V.

$$Z_{1E} = \frac{9.4}{1.69} = 5.562 \Omega$$

$$R_{1E} = \frac{9.192}{1.69^2} = 3.213 \Omega$$

$$X_{1E} = \sqrt{5.562^2 - 3.213^2} = 4.537 \Omega$$

$$Z_{2E} = \left(\frac{N_2}{N_1}\right)^2 \times Z_{1E} = \left(\frac{112.9}{230.8}\right)^2 \times 5.562 = 1.331 \Omega$$

$$R_{2E} = \left(\frac{N_2}{N_1}\right)^2 \times R_{1E} = \left(\frac{112.9}{230.8}\right)^2 \times 3.213 = 0.77 \Omega$$

$$X_{2E} = \left(\frac{N_2}{N_1}\right)^2 \times X_{1E} = \left(\frac{112.9}{230.8}\right)^2 \times 4.537 = 1.086 \Omega$$

9.4 – Transformer Load Test 1

Load Test 1 @ 50 Hz

Recorded values are:-

$$\begin{aligned} P_V &= 230 \text{ V}, \quad S_V = 111.6 \text{ V}, \quad P_{in} = 292.1 \text{ W} \\ P_I &= 1.33 \text{ A}, \quad S_I = 2.31 \text{ A}, \quad P_{out} = 255.2 \text{ W} \\ \text{Load P.F.} &= 1. \end{aligned}$$

$$\% \text{ reg} = \left(\frac{E_2 - V_2}{V_2} \right) \times 100\% = \frac{112.6 - 111.6}{111.6} \times 100 = 0.99\%$$

↑ ↑ ↑
MEASURED

$$\begin{aligned} \% \text{ reg} &= \frac{I_2 (R_{2e} \cos \theta_2 + X_{2e} \sin \theta_2)}{V_2} \times 100 \\ &= \frac{2.31 (0.77 \times 1 + 1.086 \times 0)}{112.6} \times 100 \\ &= 1.57\% \quad \text{— Calculated} \end{aligned}$$

Measured efficiency:

$$\begin{aligned} \% \eta &= \frac{\text{output power}}{\text{input power}} \times 100 \\ &= \frac{255.2}{292.1} \times 100 = 87.37\% \end{aligned}$$

Calculated

$$\begin{aligned} \% \eta &= \frac{\text{output VA} \times \text{P.F.} \times 100}{\text{output VA} \times \text{P.F.} + \text{iron losses} + \text{copper losses}} \\ &= \frac{257.565 \times 1 \times 100}{257.565 \times 1 + 28.8 + 4.109} \\ &= 87.35\% \quad 85.67 \end{aligned}$$

$$\begin{aligned} \text{Copper loss} &= I_2^2 R_{2e} = 2.31^2 \times 0.77 \\ &= 4.109 \end{aligned}$$

Load Test 1 Continued

Simulated

$$\begin{aligned} \% \text{ reg} &= \frac{2.217 (0.77 \times 1 + 1.086 \times 0)}{110.866} \times 100 \\ &= 1.54\% \end{aligned}$$

$$\begin{aligned} \% \eta &= \frac{245.79 \times 1}{245.79 \times 1 + 28.8 + 4.109} \times 100 \\ &= 88.19\% \end{aligned}$$

9.5 – Transformer Load Test 2

Load Test 2 @ $R = 20\ \Omega$, $L = 85\ \mu\text{H}$

$$\begin{aligned} P_V &= 230\ \text{V} & S_V &= 108.6\ \text{VA} & P_{in} &= 210\ \text{W} \\ P_Z &= 30.9\ \text{V} & S_Z &= 3.24\ \text{A} & P_{out} &= 175.3\ \text{W} \\ \text{Load pf} &= 0.499 \end{aligned}$$

Measured

$$\% \text{ reg} = \frac{112.6 - 108.6}{108.6} \times 100 = 3.68\%$$

$$\% \eta = \frac{175.3}{210} \times 100 = 83.48\%$$

Calculated

$$\% \text{ reg} = \frac{3.24(0.17 \times 0.499 + 1.086 \times 0.867)}{108.6} \times 100$$

$$= 3.95\%$$

$$\text{Copper loss} = \frac{3.24^2 \times 0.17}{2} = 0.928$$

$$\begin{aligned} \% \eta &= \frac{351.864 \times 0.499}{351.864 \times 0.499 + 28.8 + 0.088} \times 100 \\ &= 92.64\% \end{aligned}$$

Simulated

$$\% \text{ reg} = \frac{3.238(0.17 \times 0.59823 + 1.086 \times 0.9)}{108.246} \times 100$$

$$= 3.98\%$$

$$\begin{aligned} \% \eta &= \frac{350.5 \times 0.59823}{350.5 \times 0.59823 + 28.8 + 0.07} \times 100 \\ &= 95.04\% \end{aligned}$$

9.6 – Transformer Load Test 3

Load Test 3 (a) $R = 20.27, C = 48.18 \mu F$

$$\begin{aligned} P_v &= 229.8 \text{ V} & S_v &= 114 \text{ V} & P_{in} &= 30 \text{ W} \\ P_i &= 0.47 \text{ A} & S_i &= 1.65 \text{ A} & P_{out} &= 60 \text{ W} \\ \text{Load pf} &= 0.3 \end{aligned}$$

Measured

$$\% \text{ reg} = \frac{112.6 - 114}{114} \times 100 = 1.23\%$$

$$\% \eta = \frac{60}{30} \times 100 = 75\%$$

Calculated

$$\begin{aligned} \% \text{ reg} &= \frac{1.65(0.77 \times 0.3 - 1.056 \times 0.95)}{114} \times 100 \\ &= 1.15\% \end{aligned}$$

$$\text{Copper loss} = 1.65^2 \times 20.27 = 2.1$$

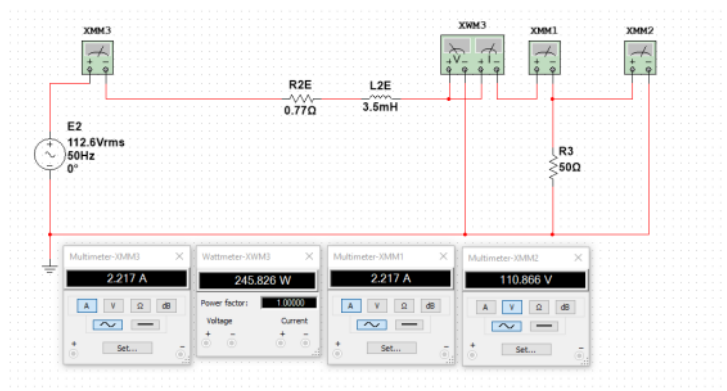
$$\begin{aligned} \% \eta &= \frac{188.1 \times 0.3}{188.1 \times 0.3 + 23.8 + 2.1} \times 100 \\ &= 59.52\% \quad 64.62\% \end{aligned}$$

Simulated

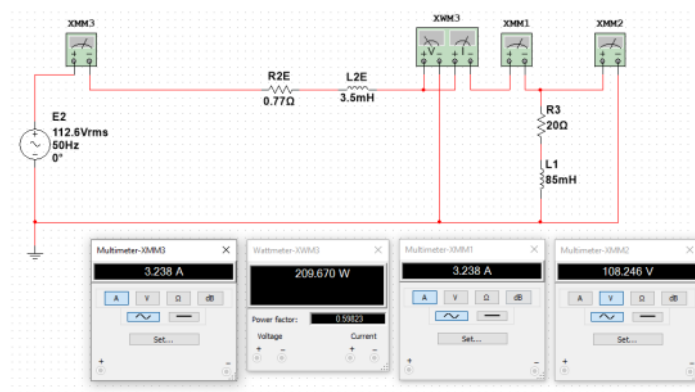
$$\begin{aligned} \% \text{ reg} &= \frac{1.654(0.77 \times 0.29418 - 1.056 \times 0.96)}{113.955} \times 100 \\ &= 1.13\% \end{aligned}$$

$$\begin{aligned} \% \eta &= \frac{188.48 \times 0.29418}{188.48 \times 0.29418 + 23.8 + 2.1} \times 100 \\ &= 64.21\% \end{aligned}$$

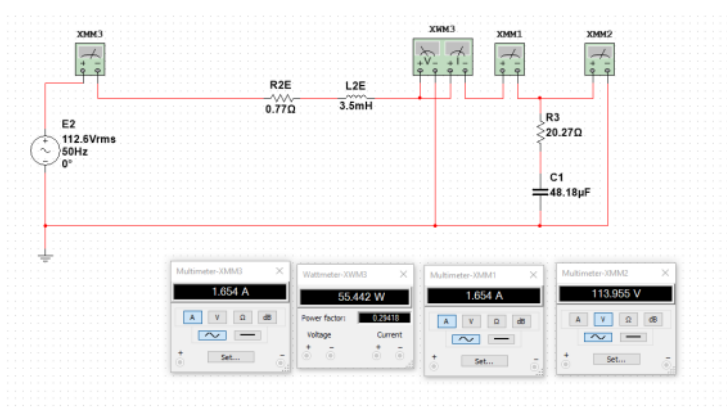
9.7 – R Load Test Multisim



9.8 – RL Load Test Multisim

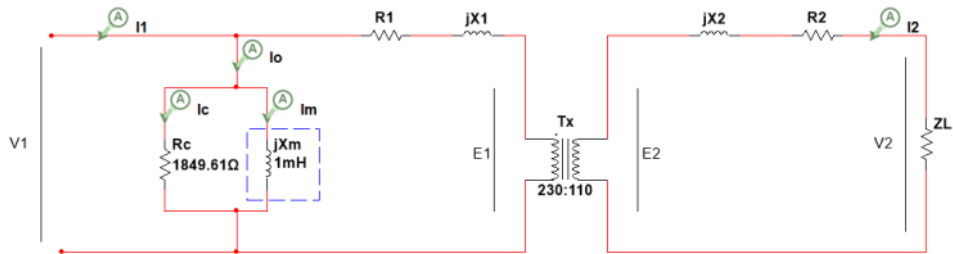


9.9 – RC Load Test Multisim



9.10 – Transformer Equivalent Circuit

what values were used?



there should be no ideal transformer in it

9.11 – Transformer Load Test Results

these results should be in the main report and explained

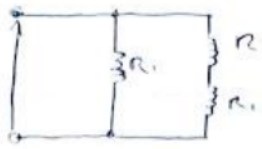
Transformer Test Results										
		Primary Voltage (V)	Primary Current (A)	Secondary Voltage (V)	Secondary Current (A)	Power In (W)	Power Out (W)	Load P.F	Efficiency	Voltage Regulation
Load Test 1 R	Measured	230	1.38	111.5	2.31	292.1	255.2	1	87.37%	0.99%
	Calculated	N/A	N/A	N/A	N/A	N/A	N/A	N/A	88.67%	1.57%
	Simulated	N/A	N/A	110.866	2.217	N/A	245.826	1	88.19%	1.54%
Load Test 2 RL	Measured	230	3.09	108.6	3.24	210	175.3	0.499	83.48%	3.68%
	Calculated	N/A	N/A	N/A	N/A	N/A	N/A	N/A	82.64%	3.95%
	Simulated	N/A	N/A	108.246	3.238	N/A	209.67	0.59823	85.04%	3.98%
Load Test 3 RC	Measured	229.8	0.47	114	1.65	80	60	0.3	75%	1.23%
	Calculated	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64.62%	1.15%
	Simulated	N/A	N/A	113.066	1.654	N/A	55.442	0.29418	64.21%	1.18%

voltage regulation should be negative for RC

9.12 – Induction Motor Stator Resistance Test

Stator Resistance Test

$I = 0.438$



10V DC

~~$I = \frac{V_{DC}}{2R_1}$~~

~~$R_1 = \frac{V_{DC}}{2I}$~~

$$I = \frac{10}{R_1 + 2R_1} \quad \frac{R_1 + 2R_1}{R_1 + 2R_1} = \frac{2R_1}{3}$$

$$\therefore R_1 = \frac{10}{I} = \frac{2R_1}{3} \quad R_1 = \frac{2R_1}{3}$$

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

9.13 – Induction Motor No-load Test

Motor Testing

No Load Test

$$V_0 = 215 \text{ V}$$

$$I_0 = 0.32 \text{ A}$$

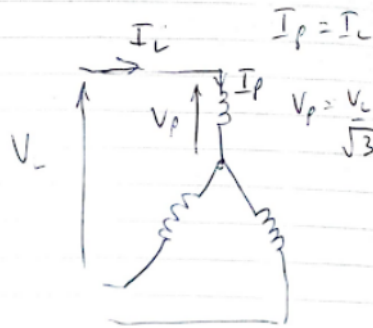
$$P_0 = 25 \text{ W Total Power} = 25 \text{ W}$$

$$V_0 = V_{\text{line}}$$

$$215 \text{ V} / \text{per phase}$$

$$0.32 \times \sqrt{3} = 0.56 \text{ A / per phase}$$

$$25 \div 3 = 8.3 \text{ W per phase}$$



$$\text{pf} = \cos \phi_0 = \frac{P_0}{V_0 I_0} = \frac{8.3}{215 \times 0.32} = 0.12$$

$$\therefore \phi_0 = 83.11^\circ$$

$$\therefore R_c = \frac{V_0}{I_0 \cos \phi_0} = \frac{215}{0.32 \times 0.12} = 5594 \Omega$$

$$X_m = \frac{V_0}{I_0 \sin \phi_0} = \frac{215}{0.32 \times 0.99} = 673.66 \Omega$$

$$I_c = I_0 \cos \phi_0 \quad I_m = I_0 \sin \phi_0$$

$$I_c = 0.32 \times 0.12 = 38.4 \text{ mA} \quad I_m = 0.32 \times 0.99 = 316.8 \text{ mA}$$

$$R_c = \frac{V_0}{I_c}$$

$$R_c = \frac{215}{38.4 \text{ mA}} = 5594 \Omega$$

$$X_m = \frac{V_0}{I_m}$$

$$= \frac{215}{316.8 \text{ mA}} = 673.66 \Omega$$

9.14 – Induction Blocked Rotor Test

$$V_L = 103 \text{ V}$$

$$P_0 = 303 \text{ W}, \quad 303 \div 3 = 101 \text{ W}$$

$$I_L = \frac{1.95}{\sqrt{3}} = 1.13 \text{ A / phase}$$

$$V_{sc} = 103 \text{ V / phase}$$

$$I_{sc} = 1.13 \text{ A / phase}$$

$$P_{sc} = 101 \text{ W / phase}$$

$$\therefore \cos \phi_{sc} = \frac{P_{sc}}{V_{sc} I_{sc}} = \frac{101}{103 \times 1.13} = 0.87 \text{ (lagging)}$$

$$\therefore \sin \phi_{sc} = 0.49$$

$$Z_{sc} = \frac{V_{sc}}{I_{sc}} = \frac{103}{1.13} = 91.15 \Omega$$

$$R_1 + R_2' = Z_{sc} \cos \phi_{sc}$$

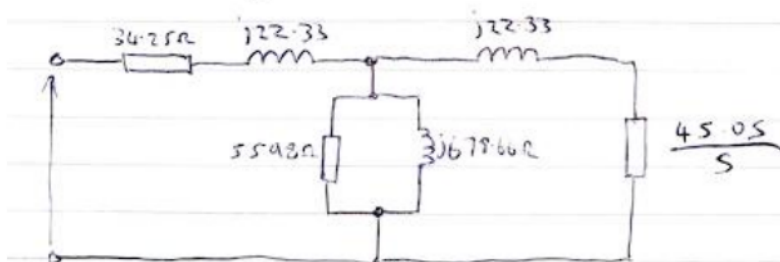
$$\therefore R_2' = Z_{sc} \cos \phi_{sc} - R_1$$

$$R_2' = 91.15 \times 0.87 - 34.25 \\ = 45.05$$

$$X_1 + X_2' = Z_{sc} \sin \phi_{sc}$$

$$= 91.15 \times 0.49 = 44.66 \Omega$$

$$X_1 = X_2' = \frac{1}{2} \times 44.66 = 22.33$$



9.15 – Torque v Slip Table Results

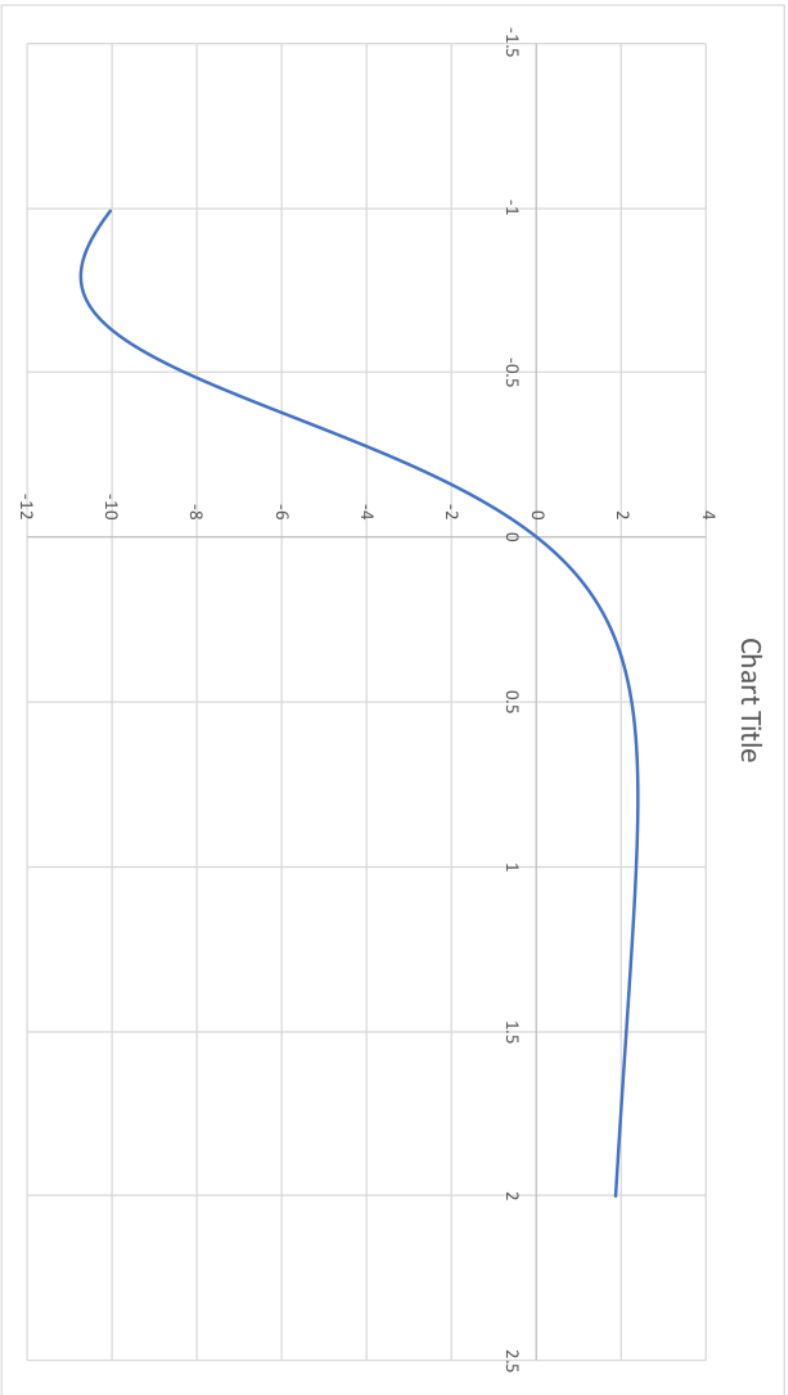
s	T	Speed rpm		1.72	1.994167	-2160		1.43	2.143981	-1290	
	2	1.856694	-3000		1.71	1.999254	-2130		1.42	2.149147	-1260
1.99	1.861416	-2970			1.7	2.004351	-2100		1.41	2.154304	-1230
1.98	1.866152	-2940			1.69	2.009457	-2070		1.4	2.159452	-1200
1.97	1.870904	-2910			1.68	2.014572	-2040		1.39	2.16459	-1170
1.96	1.87567	-2880			1.67	2.019695	-2010		1.38	2.169718	-1140
1.95	1.880451	-2850			1.66	2.024827	-1980		1.37	2.174832	-1110
1.94	1.885247	-2820			1.65	2.029967	-1950		1.36	2.179934	-1080
1.93	1.890058	-2790			1.64	2.035114	-1920		1.35	2.185021	-1050
1.92	1.894883	-2760			1.63	2.040268	-1890		1.34	2.190092	-1020
1.91	1.899722	-2730			1.62	2.045429	-1860		1.33	2.195146	-990
1.9	1.904576	-2700			1.61	2.050596	-1830		1.32	2.200182	-960
1.89	1.909443	-2670			1.6	2.055768	-1800		1.31	2.205197	-930
1.88	1.914325	-2640			1.59	2.060945	-1770		1.3	2.210192	-900
1.87	1.91922	-2610			1.58	2.066127	-1740		1.29	2.215164	-870
1.86	1.924129	-2580			1.57	2.071313	-1710		1.28	2.220111	-840
1.85	1.929051	-2550			1.56	2.076503	-1680		1.27	2.225033	-810
1.84	1.933986	-2520			1.55	2.081695	-1650		1.26	2.229927	-780
1.83	1.938935	-2490			1.54	2.08689	-1620		1.25	2.234792	-750
1.82	1.943896	-2460			1.53	2.092086	-1590		1.24	2.239626	-720
1.81	1.94887	-2430			1.52	2.097283	-1560		1.23	2.244428	-690
1.8	1.953857	-2400			1.51	2.10248	-1530		1.22	2.249194	-660
1.79	1.958855	-2370			1.5	2.107678	-1500		1.21	2.253925	-630
1.78	1.963866	-2340			1.49	2.112873	-1470		1.2	2.258616	-600
1.77	1.968888	-2310			1.48	2.118068	-1440		1.19	2.263267	-570
1.76	1.973922	-2280			1.47	2.123259	-1410		1.18	2.267875	-540
1.75	1.978967	-2250			1.46	2.128447	-1380		1.17	2.272438	-510
1.74	1.984023	-2220			1.45	2.13363	-1350		1.16	2.276954	-480
1.73	1.98909	-2190			1.44	2.138809	-1320		1.15	2.28142	-450

1.14	2.285833	-420		0.85	2.376045	450		0.56	2.294864	1320
1.13	2.290192	-390		0.84	2.377165	480		0.55	2.286061	1350
1.12	2.294493	-360		0.83	2.378091	510		0.54	2.276693	1380
1.11	2.298734	-330		0.82	2.378818	540		0.53	2.266737	1410
1.1	2.302912	-300		0.81	2.379336	570		0.52	2.256173	1440
1.09	2.307023	-270		0.8	2.379637	600		0.51	2.244977	1470
1.08	2.311066	-240		0.79	2.379714	630		0.5	2.233128	1500
1.07	2.315036	-210		0.78	2.379557	660		0.49	2.220601	1530
1.06	2.318931	-180		0.77	2.379158	690		0.48	2.207371	1560
1.05	2.322747	-150		0.76	2.378507	720		0.47	2.193413	1590
1.04	2.32648	-120		0.75	2.377595	750		0.46	2.1787	1620
1.03	2.330128	-90		0.74	2.376411	780		0.45	2.163205	1650
1.02	2.333685	-60		0.73	2.374946	810		0.44	2.146901	1680
1.01	2.337149	-30		0.72	2.373188	840		0.43	2.129757	1710
1	2.340515	2.66E-12		0.71	2.371126	870		0.42	2.111743	1740
0.99	2.343779	30		0.7	2.368749	900		0.41	2.092829	1770
0.98	2.346936	60		0.69	2.366045	930		0.4	2.072982	1800
0.97	2.349983	90		0.68	2.363002	960		0.39	2.052168	1830
0.96	2.352915	120		0.67	2.359606	990		0.38	2.030354	1860
0.95	2.355726	150		0.66	2.355845	1020		0.37	2.007505	1890
0.94	2.358412	180		0.65	2.351705	1050		0.36	1.983582	1920
0.93	2.360968	210		0.64	2.347172	1080		0.35	1.95855	1950
0.92	2.363389	240		0.63	2.34223	1110		0.34	1.932368	1980
0.91	2.365668	270		0.62	2.336865	1140		0.33	1.904997	2010
0.9	2.3678	300		0.61	2.331061	1170		0.32	1.876396	2040
0.89	2.36978	330		0.6	2.324802	1200		0.31	1.846521	2070
0.88	2.371601	360		0.59	2.318071	1230		0.3	1.815329	2100
0.87	2.373256	390		0.58	2.310849	1260		0.29	1.782776	2130
0.86	2.37474	420		0.57	2.30312	1290		0.28	1.748814	2160

0.27	1.713396	2190	-0.02	-0.20323	3060	-0.31	-4.66048	3930
0.26	1.676473	2220	-0.03	-0.30973	3090	-0.32	-4.85559	3960
0.25	1.637995	2250	-0.04	-0.41956	3120	-0.33	-5.05187	3990
0.24	1.597911	2280	-0.05	-0.53277	3150	-0.34	-5.24904	4020
0.23	1.556166	2310	-0.06	-0.64941	3180	-0.35	-5.44682	4050
0.22	1.512708	2340	-0.07	-0.7695	3210	-0.36	-5.64494	4080
0.21	1.467481	2370	-0.08	-0.89309	3240	-0.37	-5.84309	4110
0.2	1.420428	2400	-0.09	-1.02021	3270	-0.38	-6.04097	4140
0.19	1.371491	2430	-0.1	-1.15088	3300	-0.39	-6.23827	4170
0.18	1.320612	2460	-0.11	-1.28511	3330	-0.4	-6.43466	4200
0.17	1.26773	2490	-0.12	-1.42292	3360	-0.41	-6.62982	4230
0.16	1.212783	2520	-0.13	-1.56431	3390	-0.42	-6.82343	4260
0.15	1.15571	2550	-0.14	-1.70926	3420	-0.43	-7.01515	4290
0.14	1.096446	2580	-0.15	-1.85777	3450	-0.44	-7.20466	4320
0.13	1.034929	2610	-0.16	-2.0098	3480	-0.45	-7.39162	4350
0.12	0.971092	2640	-0.17	-2.16533	3510	-0.46	-7.57572	4380
0.11	0.904871	2670	-0.18	-2.32431	3540	-0.47	-7.75663	4410
0.1	0.836198	2700	-0.19	-2.48667	3570	-0.48	-7.93405	4440
0.09	0.765008	2730	-0.2	-2.65235	3600	-0.49	-8.10767	4470
0.08	0.691233	2760	-0.21	-2.82126	3630	-0.5	-8.2772	4500
0.07	0.614806	2790	-0.22	-2.99332	3660	-0.51	-8.44237	4530
0.06	0.53566	2820	-0.23	-3.1684	3690	-0.52	-8.6029	4560
0.05	0.453728	2850	-0.24	-3.3464	3720	-0.53	-8.75855	4590
0.04	0.368945	2880	-0.25	-3.52717	3750	-0.54	-8.90908	4620
0.03	0.281245	2910	-0.26	-3.71055	3780	-0.55	-9.05428	4650
0.02	0.190562	2940	-0.27	-3.89639	3810	-0.56	-9.19395	4680
0.01	0.096834	2970	-0.28	-4.08451	3840	-0.57	-9.32792	4710
0	0	3000	-0.29	-4.2747	3870	-0.58	-9.45602	4740
-0.01	-0.1	3030	-0.3	-4.46677	3900	-0.59	-9.57812	4770

-0.6	-9.6941	4800	-0.89	-10.5273	5670
-0.61	-9.80387	4830	-0.9	-10.4883	5700
-0.62	-9.90736	4860	-0.91	-10.4466	5730
-0.63	-10.0045	4890	-0.92	-10.4023	5760
-0.64	-10.0953	4920	-0.93	-10.3556	5790
-0.65	-10.1797	4950	-0.94	-10.3066	5820
-0.66	-10.2577	4980	-0.95	-10.2555	5850
-0.67	-10.3294	5010	-0.96	-10.2024	5880
-0.68	-10.3948	5040	-0.97	-10.1475	5910
-0.69	-10.4539	5070	-0.98	-10.0909	5940
-0.7	-10.5069	5100	-0.99	-10.0328	5970
-0.71	-10.5539	5130	-1		
-0.72	-10.5948	5160			
-0.73	-10.63	5190			
-0.74	-10.6594	5220			
-0.75	-10.6832	5250			
-0.76	-10.7017	5280			
-0.77	-10.7149	5310			
-0.78	-10.723	5340			
-0.79	-10.7262	5370			
-0.8	-10.7246	5400			
-0.81	-10.7185	5430			
-0.82	-10.708	5460			
-0.83	-10.6933	5490			
-0.84	-10.6746	5520			
-0.85	-10.652	5550			
-0.86	-10.6258	5580			
-0.87	-10.5962	5610			
-0.88	-10.5633	5640			

9.12 – Motor Graph



9.13 – Risk Assessment

What are the hazards?	Who might be harmed and how?	What are you already doing to control the risks?	Who needs to carry out the action?	When is the action needed by?	Done
Electricity	Students in classroom. Direct contact with bare conductors.	Isolate source of electricity at all times expect when in use. Supervisory maintained at all times by competent person. Electrical connections protected by a non-conductive junction box.	Students and lecturer.	24/11/2022	Yes
Moving object	All personnel in 1m vicinity of the motor. Clothing can be caught by the motor shaft and cause individuals to be dragged in causing bodily damage.	Point of motion i.e. motor shaft to be shrouded in metal cage. The motor base will be secured by appropriate fixings to prevent accidental movement.	Lecturer.	24/11/2022	Yes
Sharp objects	Anyone carrying out wiring to electrical equipment. Stripping insulation exposing bare conductors can cause cuts and lacerations to body and hands.	Personal protective equipment to be used at all times which include safety gloves and safety goggles. Lecturer to supervise the activity.	Students and lecturer.	24/11/2022	Yes
Slips, trips and falls	Everyone. Electrical cables are used during this activity which are often laid across flooring. This poses risk of tripping.	All cable runs are to be appropriately covered using rubber cable matting. Correct classroom gangways are to be identified before starting work activities.	Students and lecturer.	24/11/2022	Yes

FINAL GRADE

GENERAL COMMENTS

Instructor

40/100

PAGE 1

Text Comment. This date is incorrect

Text Comment. Word count exceeded, limit is 2500 + 10%

Text Comment. Mark capped to 40%, original mark = 61

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. were

Text Comment. A good summary but it does contain repetition and does not include the overall conclusions

PAGE 6

Text Comment. excellent work plan

PAGE 7

PAGE 8

Text Comment. (2019)

Text Comment. ^

Text Comment. Not quite Harvard

PAGE 9

Text Comment. Lander states that

Text Comment. citation belongs here

PAGE 10

Text Comment. are

QM

Good explanation given

You have clearly put much effort into this explanation, well done.

QM

Correctly cited

PAGE 11

QM

Correctly cited

Text Comment. (2019)

Text Comment. ^

Text Comment. This quotation is far too long

PAGE 12

Text Comment. You must always explain your figures or leave them out

PAGE 13

QM

Correctly cited

QM

Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:



Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 14



Correctly cited

PAGE 15

Text Comment. page numbers are only needed for direct quotations

PAGE 16

Text Comment. You do need need to include datasheets, there are no marks for doing so

Text Comment. What does the datasheet say?

Text Comment. power and current are different quantities

Text Comment. these equations and calculations should be in the appendix, your reader is onoly interested initially in the results in comparison with theory

PAGE 17

PAGE 18

PAGE 19

Text Comment. where are your load test results?

PAGE 20

PAGE 21

Text Comment. it is not appropriate to use course notes as figures

PAGE 22

PAGE 23

PAGE 24

Text Comment. power is measured in watts not Hz

Text Comment. what is the relationship between stator voltage and frequency as a gradient?

PAGE 25

Text Comment. incorrect, VFDs have been around for a long time

Text Comment. the sinewave inverter was not part of your research, the PWM was

PAGE 26

Text Comment. load regulation test results were not commented on

Text Comment. incorrect, physical load is represented by fractional slip

PAGE 27

PAGE 28

QM

Good range of sources

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

QM

Correct method of listing.

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

PAGE 29

PAGE 30

Text Comment. do not include datasheets, quote from them instead and cite your source

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

Text Comment. what values were used?

Text Comment. there should be no ideal tranaformer in it

Text Comment. these results should be in the main report and explained

Text Comment. voltage regulation should be negative for RC

GRADING FORM: NEW CSG-RUBRIC

JASON BOOTH

61

1. ENGAGEMENT WITH LITERATURE



A good research section with evidence of reading from a wide range of sources cited correctly sometimes and listed correctly using the Harvard method. 13/20

13

2. KNOWLEDGE AND UNDERSTANDING

- 

Good knowledge demonstrated in your research findings, transformer and motor investigation explanations. However there are some misconceptions (see comments within) 13/20
- 13

3. COGNITIVE AND INTELLECTUAL

- 

Some analysis of transformer and motor investigation results analysis and good conclusions/recommendations. However, there are more things you could have looked at such as transformer regulation and motor inverter V/f ratio. 13/20
- 13

4. PRACTICAL APPLICATION

- 

Good use of equipment for transformer and motor experiments and presentation of results in many cases yet some results are consigned to the appendix with little explanation. 13/20
- 13

5. TRANSFERABLE SKILLS

- 

A good executive summary, work plan, risk assessment and explanation of team working. Report is well structured, written and presented with some (but not all) clear diagrams. Word count has been exceeded. 9/20
- 9