

1809806

by Richard Harrison

RESEARCH COULD HAVE BEEN MORE VARIED AND CITATIONS
MORE CONSISTENT. ADEQUATE KNOWLEDGE DEMONSTRATED
WITH SOME VALID CONCLUSIONS AND EVIDENCE OF
CRITICAL ANALYSIS.

MARK ASREED


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1. Executive summary

The following assignment/paper documents research done into power converters of various types (including single and three phase voltage controllers for both AC and DC induction machines) used for speed control within industry. Further research was done into how these induction machines are used within industry and the power delivery systems which supply industries and factories.

Experiment 1 took place on a single-phase transformer. 230V was applied then open and short circuit tests were carried out to catalogue the equivalent circuit parameters so the circuit could be re-created in a computer simulation. The test was then repeated on the simulation circuit to see if the results were the same. A datasheet for the non-simulation transformer was used to aid in comparison. *how close were they?*

Punctuation Error

Experiment 2 involved testing a 3-phase asynchronous motor's stator resistance and its wattage, volt and current readings when there was either no load or a blocked rotor. Then finally a test was performed to drive the motor past synchronous speed and record the results. The results produced parameters for an equivalent circuit which was created on the Multi-Sim circuit simulation suite. Using excel, a spreadsheet and graph was created to mimic the motor's performance.

2. Research

2.1 Power electronic converters

Power electronic converters are used to refine and regulate the electrical energy/power. The voltage and current supplied will depend upon the equipment and the task. Possible tasks include electric vehicles, power supplies, filters, renewable sources, speed control and the transmission of electricity since these converters can be used in applications where the voltages and current are also used to transmit data. Domestic applications include DC/DC used in phones and AC/DC converters which are used in PC power supplies.

Electronic converters are commonly used with renewable energy sources such as wind turbines and photo-voltaic cells. Solar panel farms with hundreds of panels all connected in a grid use AC/DC converter in order for the power to be stored in batteries. A DC/AC transistor setup will then supply AC current for transmission or for on-site AC consumers.

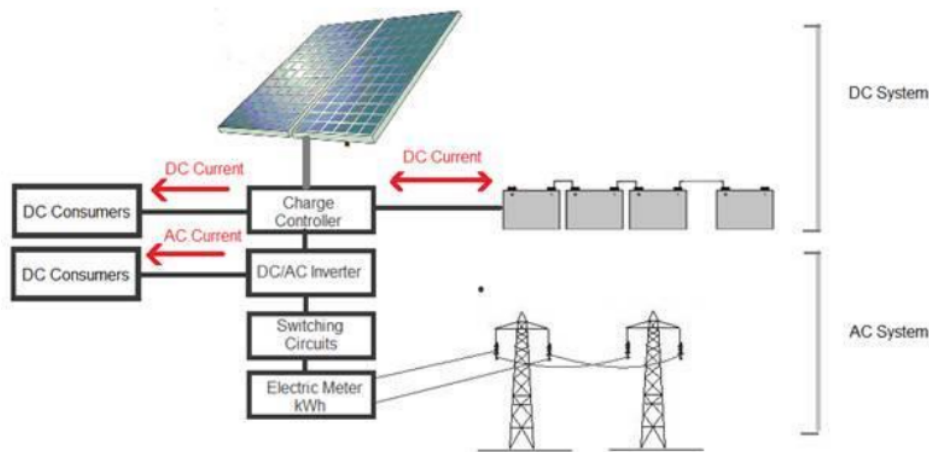


Figure 1 - Power converters for renewable sources (Osmanbasic, 2018)

For DC drives, power electronic converters such as a controlled rectifier or a chopper can be used to adjust the DC power. In contrast, AC drives mostly use an inverter to adjust the voltage and frequency in the AC power. In this case, a rectifier is often included to convert the AC power in the mains power system into the DC power. (Kim, 2017)

Direct quotes must be contained with .in "" marks and preceded by the author's surname. In the citation, the name is then suppressed and the page number included.

Converters such as this use various types of transistors (Insulated Gate Bipolar, Bipolar Junction, Metal Oxide Semiconductor Field Effect) and thyristors (Gate Turn Off, Integrated Gate Commutated). Thyristors are used for rectifying, changing AC to DC since they can block the negative part of the waveform to help produce direct current. Whereas transistors can change the DC into AC.

2.2 AC Induction machine speed control methods using power electronic converters

For machine speed control using AC, two types of AC-to-AC controllers are used. These are three phase and single-phase voltage controllers. These controllers output regulate the voltage, current and overall power sent to the AC load.

2.2.1 single phase voltage controllers

This controller takes a single-phase input source and adapts it to suit the load by changing the voltage to a specified level at a specified frequency. There are three sub-categories of this converter. Two, three and four legged converters. Two and four require more hardware and have decreased efficiency compared to the three-legged converter. Figure 2 shows a basic three-legged converter. The circuit uses transistors as switches to change single phase DC input into 3-phase output. In order to control the output voltage the transistor timings and the pulse width need to be changed.

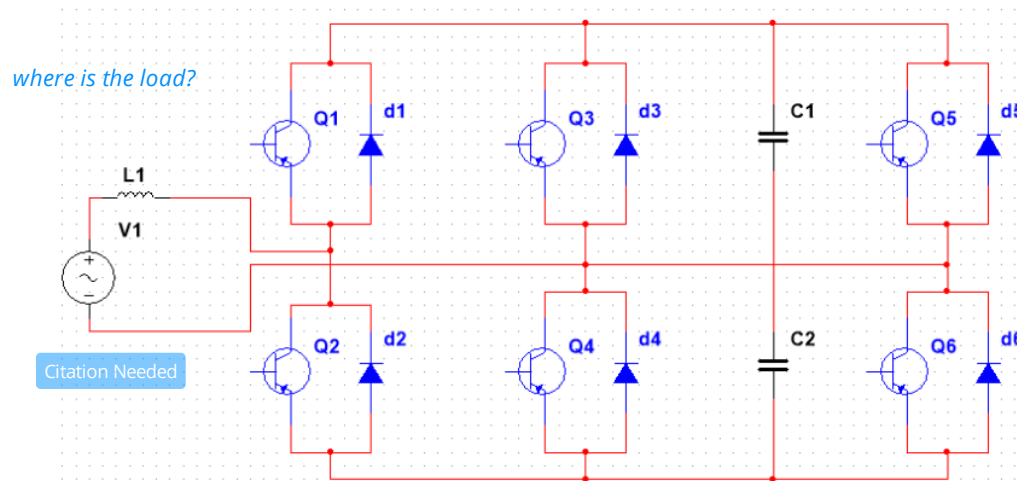


Figure 2 - single phase three-legged converter

Where is the output connected?

This converter uses PWM to control the output. For rectification during the first half of the cycle, Q1 and Q4 conduct and the output travels across their capacitor. To invert, Q1, Q4 and Q5 activate to give AC to the load. Then for the second half, Q3 and Q2 conduct and give a rectified output. Then Q6 is activated as well to create an AC output to the load, which can be connected to the negative rail of the circuits power supply.

2.2.2 Three phase voltage controllers

This controller achieves the same goal as its single-phase counterpart except with a three phase supply. Instead of switching for each half cycle, the thyristors are connected back-to-back since the current flows bi-directionally and the thyristors only work in one direction. Shown in figure 3.

Research should involve sources

Citation Needed

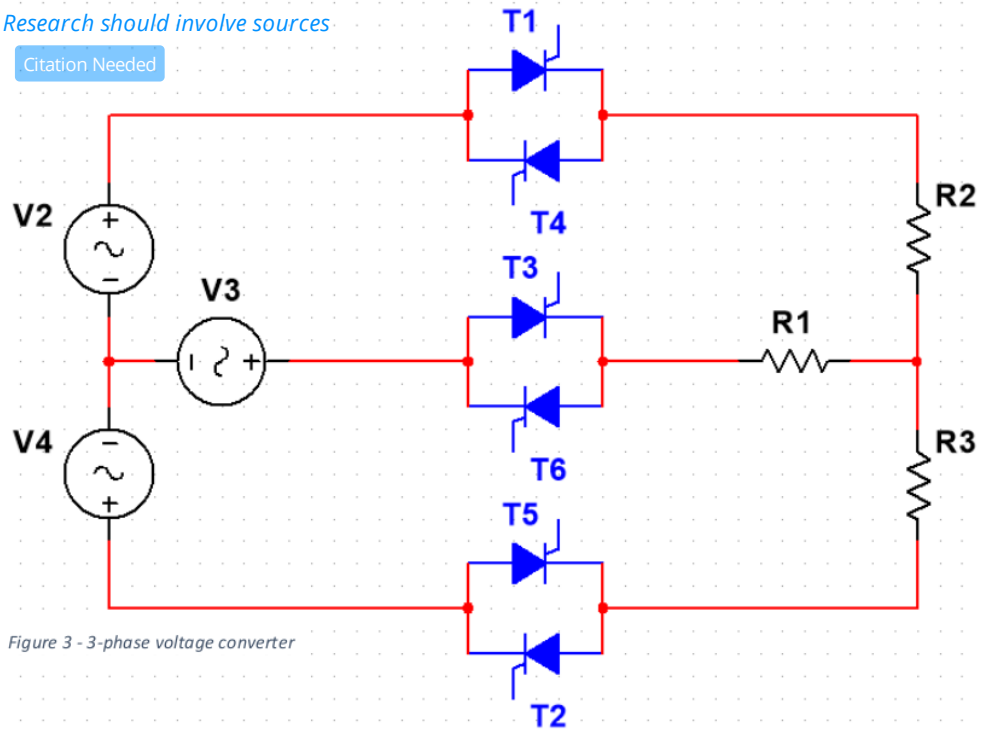


Figure 3 - 3-phase voltage converter

The thyristors activate in a sequence according to their number at 60° intervals along the full wavelength cycle with the first half positive (one direction) and the second half negative (opposing direction) hence, the two parallel thyristors on each of the three rails. The output voltage can be controlled by triggering the thyristors at different points.

Induction machines work with AC not DC. There is no such thing as a DC induction motor

2.3 DC Induction machine speed control methods using power electronic converters

2.3.1 Three phase Dual voltage converter

A dual voltage converter can run off a single or three phase source and is both a rectifier and an inverter by converting the supply to DC and then back to AC. The DC load, which could be a variable speed DC motor used in industry, is connected in between. As shown in figure 4 and 5.

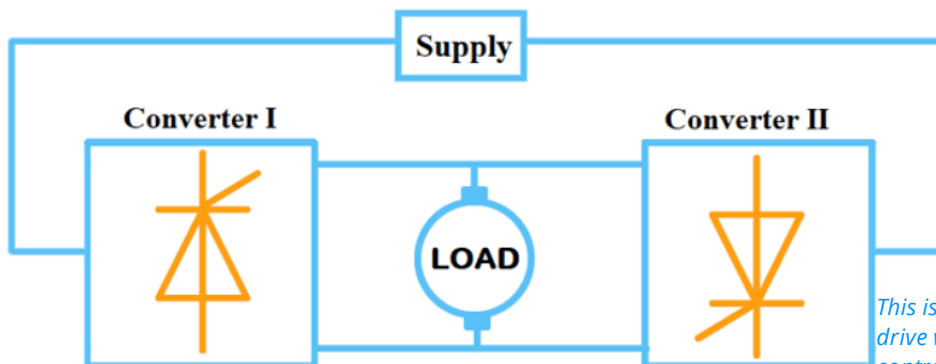


Figure 4 - Dual voltage converter (Kansagara, 2019)

This is a 4 quadrant DC drive which cannot control an induction motor. If fed into the stator of a 3 phase induction motor, nothing would happen

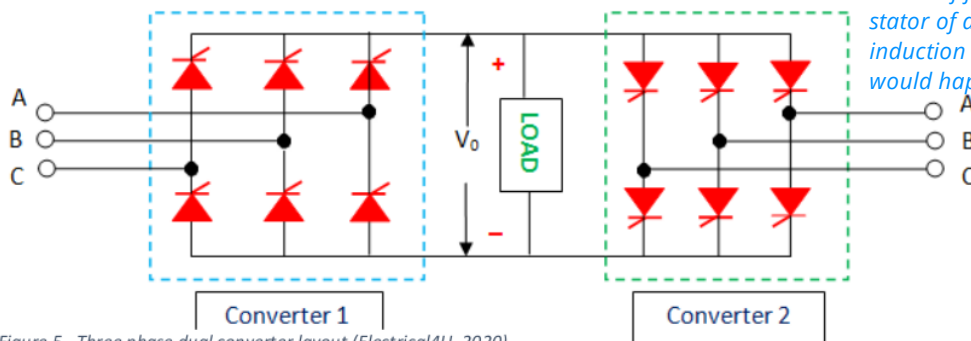


Figure 5 - Three phase dual converter layout (Electrical4U, 2020)

This type of converter has four quadrants of operation which are 90° apart:

- Quadrant 1: Forward motoring (current and voltage positive)
- Quadrant 2: Regenerative braking (voltage positive, current negative)
- Quadrant 3: Reverse motoring (current and voltage are negative)
- Quadrant 4: regenerative braking (current positive, voltage negative)

For the two converters to work together, their outputs must be both equal and opposite. Therefore, a control circuit is used to synchronise the two. However, in the real world the voltages produced by the two converters contain ripples which destabilise the system. Therefore, a time delay of approximately 10ms is needed between the switching of the two converters to keep the system stable.

Figure 5 shows how a three-phase supply with re-circulating current is used, one set of forward and reverse biased thyristors is used per converter. One a rectifier, the other an inverter.

*Again, this is the wrong type of drive, it
converts AC into DC*

2.3.2 single phase dual voltage converter

The architecture of this converter is like the three-phase Dual converter. The method is different. A single-phase AC supply is sent to converter 1 and DC is produced using forward biased thyristors while an inductor blocks converter 2 entirely meaning this converter operates without the re-circulating current. The positive half of the cycle is produced, and negative biased thyristors produce the other half.

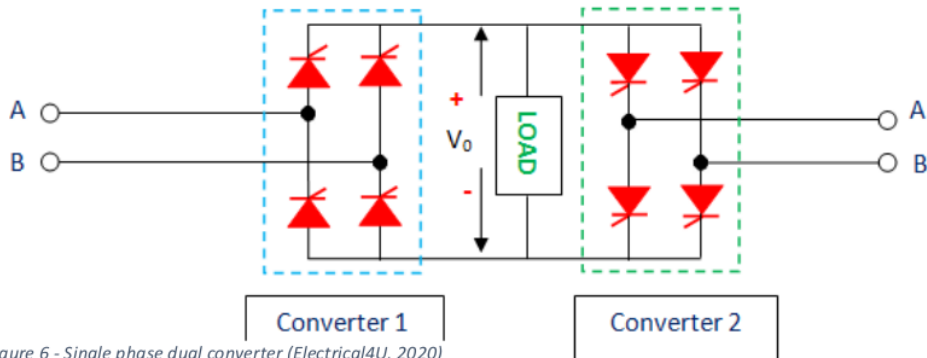


Figure 6 - Single phase dual converter (Electrical4U, 2020)

By blocking conductor 1 and removing the inductor from conductor 2 the motor/load can be reversed. Controlling the switching of the two converters can be achieved by using control circuits which monitor load current, control voltage or polarity.

Direct quotes must be contained with .in " " marks and preceded by the author's surname. In the citation, the name is then suppressed and the page number included.

2.4 Industrial applications of induction machines

All types of industries are invariably required to install different types of electric motors as prime mover for driving process equipment participating in their respective production line up. The continuous process of technical development has resulted into availability of highly diversified types of electric motors. (Parikh, 2013)

2.4.1 Advantages and Disadvantages:

Asynchronous motor	
Advantages	Disadvantages
simple construction	
Higher starting torque	Single phase induction motor produces no starting torque
Good overload capacity	Higher input surge currents
Good speed regulaton	Difficult to alter the speed greatly
85-97% efficiency	During lighter loads the efficiency decreases
Can operate more extreme conditions compared to other motors	
Cost is low	
Reliable and long lasting	

Table 1 - Advantaqes and Disadvantaqes of

2.4.2 Applications:

1. Drilling machines
2. Lathes
3. Drives for large machinery such as grinders and blenders
4. Vacuum and water pumps

As a result of the huge variety of applications for electric motors, they have been developed to have a vast number of different qualities. The abilities of these motors can be further enhanced and tuned using controllers and converters like the ones talked about earlier. Others include types of starter include DOL, soft and star/delta starters. Controllers help regulate speed and motor direction by controlling the voltage, current and frequency sent to the windings. Different starters can help the motor start if a load is pre-applied and different starters are used depending upon the load, motor and application. Different types of motor have different qualities and induction motors can be wired in different configurations (mainly star and delta to produce different characteristics like increased starting torque. Single or three phase motors are also used and they come in big or small with respective ratings.

2.4.3 Types of electric motor:

1. Synchronous
2. Induction
3. Stepper
4. Brushless DC
5. Hysteresis
6. Universal
7. Reluctance
8. DC shunt
9. DC series
10. Separately excited
11. PMDC
12. Compound DC

However, all motors still have a few things in common. A field and stator winding and a rotor.

Every sector of industry will use at least one type of these motors. Renewable energy, Food production and processing, manufacturing (vehicles, appliances etc), entertainment and tourism to name a few.

Read the brief more carefully next time, much of the above is irrelevant to this assignment.

2.5 Power Systems required to deliver a three-phase, 415VAC supply to a typical factory

As shown in figure 7, Electrical power is produced at a power station at approximately 25KV (renewable, coal, gas etc) and is stepped up at a local substation to a range of 275-400KV for long range transmission on overhead/underground power lines to reduce power loss through heat and high currents. Once in the region of the consumer, the voltage needs to be stepped down again.

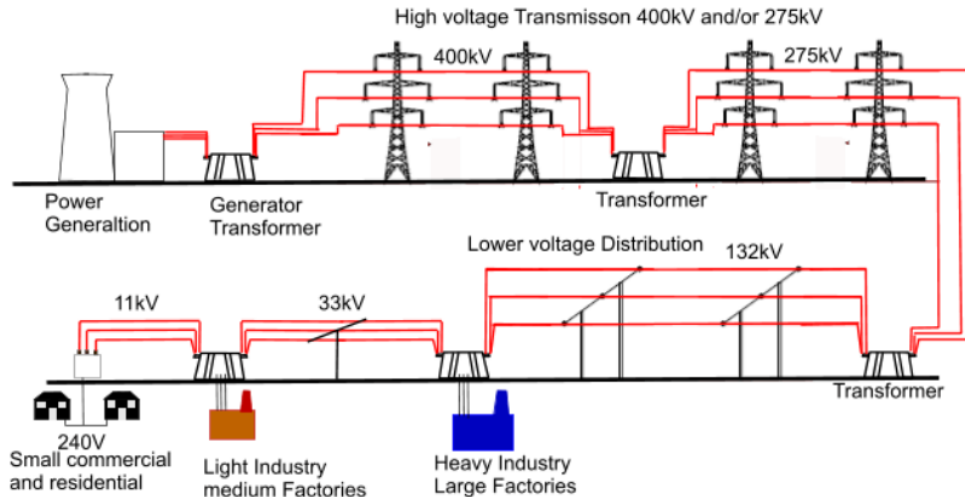


Figure 7 - Power transmission (Sreenivasa, 2015)

Heavy industry is supplied with 132KV and lighter industries are supplied with 33KV or even 450V power which will be fed into a substation and transformer on-site that would either be the property of the supplier or the industry in question. The power would be stepped down to the required voltage which is often 415V. Higher voltages could be used within the factory grounds depending upon the application.

3. Transformer Investigation

In order to obtain the equivalent circuit parameters, open and short circuit tests must be carried out to calculate/predict the iron and copper losses. The appendix includes class-notes taken during the experiment and the transformer datasheet used.

The transformer datasheet states a total iron loss of 20.16 Watts.

Table 2 - All transformer test results

Open circuit test		short circuit test		Load tests			
				Test 1		Test 2	
Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
230V	112V	8.87V	N/A	230V	109V	230V	108V
0.542A	N/A	1.69A	3.41A	1.8A	3.24A	2.86A	5.44A
34W	N/A	7.98W	N/A	389W	355W	634W	588W
p.f. 0.27	N/A	p.f. 0.53	N/A	p.f. 0.94	p.f. 1.01	p.f. 0.96	p.f. 1

The table above shows the results of the transformer practical group tests. With these results calculations could be done to determine the required values for the RL and RC circuit equivalents. The notes on which are shown in the appendix.

Working safely as a group

In order to work safely as a group, only one person changed the circuit at a time and only when the equipment was isolated. Checks were done to ensure before tuning on the power that the circuit was correct and that no-one was in contact with the circuit physically. The circuit was also suitably grounded.

3.1 Open circuit calculations and experiment

Transformer ratio 2:1, 230V 50Hz, input current = 542mA at 34 W

This will determine the core losses.

$$Power\ loss = \frac{230V^2}{R_c}$$

$$R_c = \frac{230V^2}{34W}$$

$$R_c = 1555.9\Omega$$

Therefore:

$$|I_c| = \frac{230}{1555.9\Omega} = 0.148A$$

$$|I_0| = \sqrt{|I_c|^2 + |I_m|^2}$$

$$|I_m|^2 = 0.54A^2 - 0.149A^2$$

$$|I_m| = 0.519A$$

Then:

$$X_m = \frac{230}{0.519} = 443.16\Omega$$

$$L_m = \frac{443.16}{100\pi} = 1.411H$$

Shown above are the results for the open circuit calculations which were then used to create the equivalent circuit with the test results. As shown in the Multi-sim equivalent circuit, figure 8 (page 13) the results shown by the program probes looking at input current give the similar readings as the test results with minor discrepancies which can be expected from a simulation. Meaning the calculations are correct.

The practical experiment was done by leaving the high voltage side of the transformer open or disconnected and powering the low voltage side. The low voltage side then had ammeters, voltmeters and a wattmeter connected. Throughout the experiment the voltage to the LV side was gradually increased from zero until the normal rated value was reached. Once there, readings were recorded.

The core losses are given by the wattmeter, the ammeter records the no-load current

3.1.1 Equivalent circuit

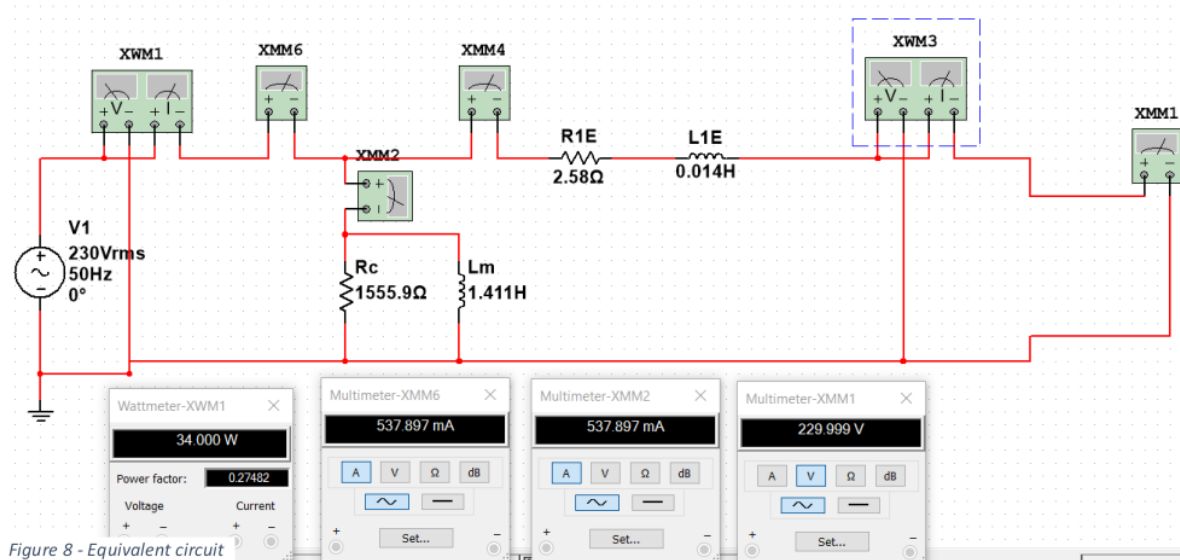


Figure 8 - Equivalent circuit

Readouts labelled XMM6 and XMM2 in figure 8 give the readings that we are looking for.

If you are using the equivalent circuit, you must refer to either the primary or the secondary

3.2 short circuit calculations and experiment

Using information provided by the data sheet and the results from the group tests:

230 : 110V 50Hz, Primary V1 = 8.87V, I1 = 1.69A, Pin = 7.98W

$$|Z_{1E}| = \frac{8.87}{1.69} = 5.25\Omega$$

$$|R_{1E}| = \frac{7.98}{1.69^2} = 2.79\Omega$$

$$|X_{1E}| = \sqrt{5.25^2 - 2.79^2} = 4.447\Omega$$

$$|L_{1E}| = \frac{4.447}{100\pi} = 0.014\Omega$$

$$|Z_{2E}| = \left(\frac{110}{230}\right)^2 \times 5.25 = 1.2\Omega$$

$$|R_{2E}| = \left(\frac{110}{230}\right)^2 \times 2.79 = 0.64\Omega$$

$$|X_{2E}| = \left(\frac{110}{230}\right)^2 \times 4.447 = 1.017\Omega$$

$$|L_{2E}| = \frac{1.017}{100\pi} = 0.00324H$$

$$I_2 = \frac{230}{110} \times 1.69 = 3.53A$$

$$L_m = \frac{443.16}{100\pi} = 1.41H$$

For the practical experiment, the LV side of the transformer was short circuited. Voltmeters, ammeters and watt meters were connected on the HV side. The voltage was increased on the HV side until the ammeter readings matched the rated current for the transformer. Then, the readings were all recorded.

The wattmeter is recording the copper losses from the transformer windings and the ammeter is recording the primary full load current equivalent.

	RL 36.5Ω	RC 28.3Ω		RL 36.5Ω	RC 28.3Ω
Units	93mH	48μF	Units	93mH	48μF
Primary			Secondary		
V	230	230	V	109	114
A	1.55	0.469	A	2.26	1.58
W	208	86.3	W	177	68.8
P.f	0.58	-0.8	P.f	0.72	0.38

Table 3 - R, RC and RL calc results

Table 3 shows the expected results from the calculations while the RC and RL circuits shown in figures 9 and 10 show the simulated results. The simulation results match the calculations very well with minor discrepancies except for the wattage recorded in the RL circuit with a discrepancy of 32W. This error could be the result of a miscalculation by the simulator software since the other readings match the calculations with only minor discrepancies, and no calculation errors can be found. However, a mistake with the practical experiment may have caused the issue since the results from it were used to create the equivalent circuits.

3.2.1 RL circuit

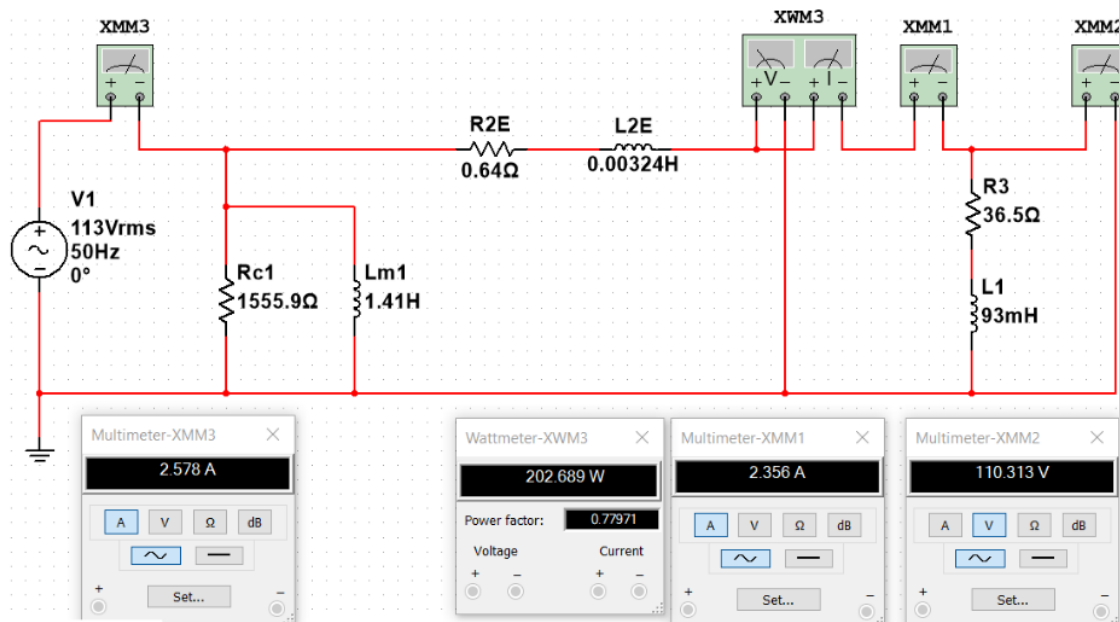


Figure 9 - RL circuit

Using table 2:

$$\sin(\phi_2) = \sin(\cos^{-1}(0.72)) = 0.694$$

$$V_2 = 113 - 2.26(0.64 \times 0.72 + 1.017 \times 0.694) = 110.36V$$

Calculation matches M-sim V2 result.

3.2.2 RC circuit

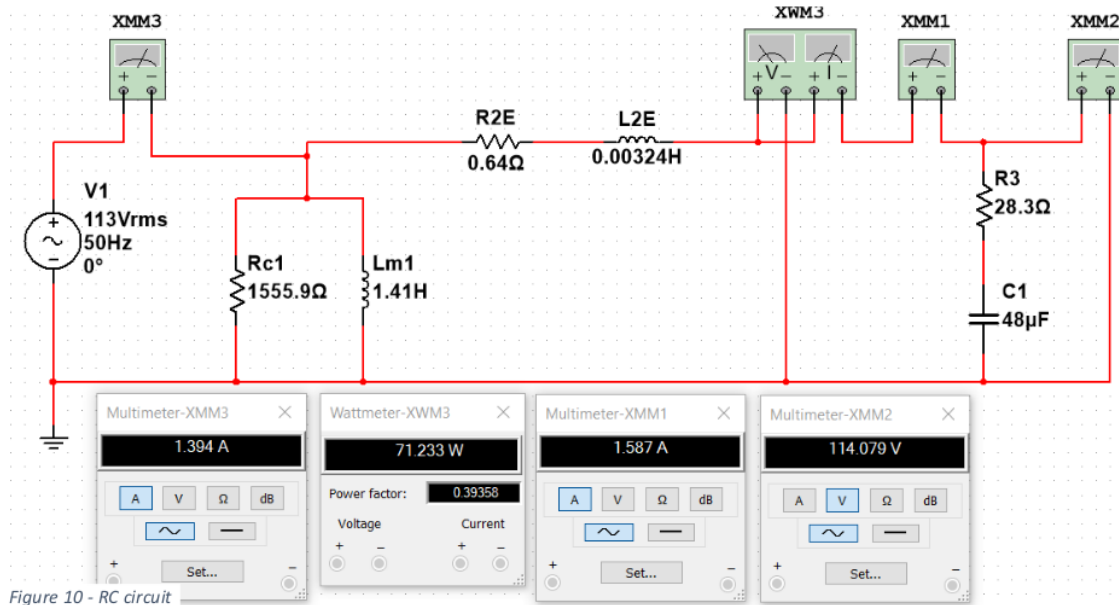


Figure 10 - RC circuit

Using table 2:

$$\sin(\phi_2) = \sin(\cos^{-1}(0.38)) =$$

$$V_2 = 113 - 1.58(0.64 \times 0.38 + 1.017 \times 0.925) = 111.13V$$

incorrect, the sign inside the brackets changes when the power factor is leading

Calculation is close to M-sim result with a small 3V discrepancy which could be because the simulation does not account for the resistance within the cables and degradation within the transformer itself.

The answer should be 112.6 which is must closer but there is still

something wrong as the answer should be nearer 114

3.3 Load testing

3.3.1 R circuit

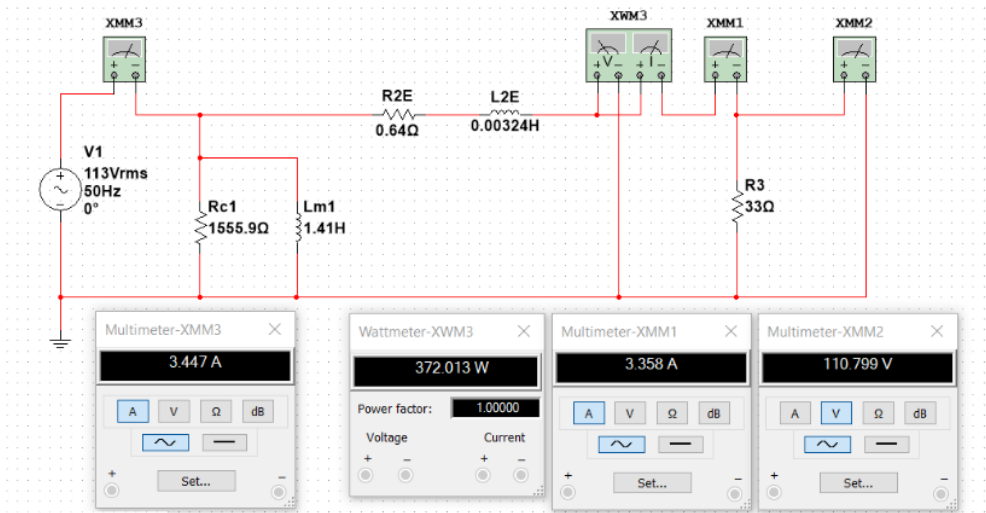


Figure 11 - R circuit

Load tests			
Test 1		Test 2	
Primary	Secondary	Primary	Secondary
230V	109V	230V	108V
1.8A	3.24A	2.86A	5.44A
389W	355W	634W	588W
p.f. 0.94	p.f. 1.01	p.f. 0.96	p.f. 1

Table 4 - Load and overload test results

Regarding the datasheet shown in the appendix (figure 17) the secondary voltage at full load is stated to be 109.6V and the off load secondary voltage is stated as 133.8V. Given the results of the RC circuit testing. It can be concluded that the RC test is an "off-load" test.

Full load test 1 results (shown in table 4) are proven accurate as they correspond to the datasheet with a similar secondary voltage reading of 109V.

Also:

$$\text{Stated losses} = 20.16 + 10.74 = 30.9W$$

As of load test 1 (Full load):

$$\text{Test 1 primary} - \text{secondary wattage} = 389 - 355 = 34W$$

The difference in losses from datasheet to experiment is 3.1W which is acceptable. However, from the Multi-sim simulation (figure 11) it can be seen that the simulation does not account for the iron losses. There is a voltage difference of nearly 3V

3.3.2 Regulation

$$\cos(\phi_2) = 0.96 \quad \sin(\phi_2) = 0.28$$

$$I_2 = 3.24, R_{2E} = 0.64, X_{2E} = 1.017$$

$$V_2 = 113 - 3.24(0.64 \times 0.96 + 1.017 \times 0.28) = 110.09V$$

3.2.3 overload (test 2)

$$\cos(\phi_2) = 0.96 \quad \sin(\phi_2) = 0.28$$

$$I_2 = 5.44$$

$$V_2 = 113 - 5.44(0.64 \times 0.96 + 1.017 \times 0.28) = 108.12V$$

4. Three-phase Induction Motor Investigation

Working safely as a group

In order to work safely as a group, only one person changed the circuit at a time and only when the equipment was isolated. Checks were done to ensure before tuning on the power that the circuit was correct and that no-one was in contact with the circuit physically. The circuit was also suitably grounded.

4.1 Motor testing and calculations:

For each test, the motor as wired in delta.

4.1.1 Stator resistance calcs:

$$R_1 = \frac{11.7V}{0.33A \times 2} = 17.72\Omega$$

For this test, a DC voltage of approximately 12V was applied to the stator. Then readings for voltage and amps were recorded. Wattage was divided by three since there are three phases.

Motor testing results			
Units	Stator resistance	No-load/Sync speed	Locked rotor
Volts	11.7	214	25.7
Amps	0.33	0.534	0.491
Watts		20.3	6.36
P.f.		0.32	0.88

Table 5 - Motor testing results

4.1.2 No load test calcs:

$$V_0 = \frac{V_{nl}}{\sqrt{3}} = \frac{214}{\sqrt{3}} = 123.6V$$

$$I_0 = V_{nl} = 0.534A$$

$$P_0 = \frac{1}{3}P_{nl} = \frac{61}{3} = 20.3W$$

$$P.f.(\phi_0) = \cos(\phi_0) = \frac{P_0}{V_0 I_0} = \frac{20.3}{123.6 \times 0.534} = 0.308$$

$$\cos^{-1}(0.308) = 72.06^\circ$$

$$R_c = \frac{123.6V}{0.534 \times 0.308} = 751.5\Omega$$

$$I_m = I_0 \sin(\phi)$$

$$\sin(\phi) = \sin(72.06) = 0.951$$

$$X_m = \frac{123.6V}{0.534 \times 0.951} = 243.39$$

Approximately 400V was applied to the motor and an external variable speed drive was fitted to push the rotor speed past that of the rotating magnetic field. Once reached, the readings were recorded for Volts, Amps, Watts and power factor.

4.1.3 Locked rotor test calculations:

$$\cos(\phi_{sc}) = \frac{6.36}{25.7 \times 0.491} = 0.504$$

$$Z_{sc} = \frac{V_{sc}}{I_{sc}} = \frac{25.7}{0.491} = 52.34$$

$$R_1 + R_2' = Z_{sc} \cos(\phi_{sc}) = 52.34 \times 0.504 = 26.38$$

$$R_2' = 26.38 - 17.72 = 8.66\Omega$$

$$\sin(\phi_{sc}) = \sin(\cos^{-1}(0.504)) = 0.864$$

$$x_1 + x_2' = Z_{sc} \sin(\phi_{sc}) = 52.34 \times 0.864 = 45.22\Omega$$

For the final test, a low AC voltage was applied to the motor to produce a reading for full load current to the stator. Volts, Amps, Wattage and power factor were recorded. This was done so that the short circuit current at a normal running voltage could be found. Leakage impedance can also be found in this test.

4.1.4 For 50Hz operation

$$x_1 + x_2' @ 50Hz = 45.22 \times \frac{50}{15} = 150.73\Omega$$

$$\text{assuming } x_1 + x_2' = \frac{150.73}{2} = 75.365\Omega$$

$$N_s = \frac{50 \times 60}{2} = 1500rpm$$

Since the motor used is rated at 30KW:

$$P = \sqrt{3} \times 214 \times I_L \times 0.504$$

$$I_L = \frac{30,000KW}{\sqrt{3} \times 214 \times 0.504} = 160.59A$$

4.1.5 Motor equivalent circuit and calculation predictions

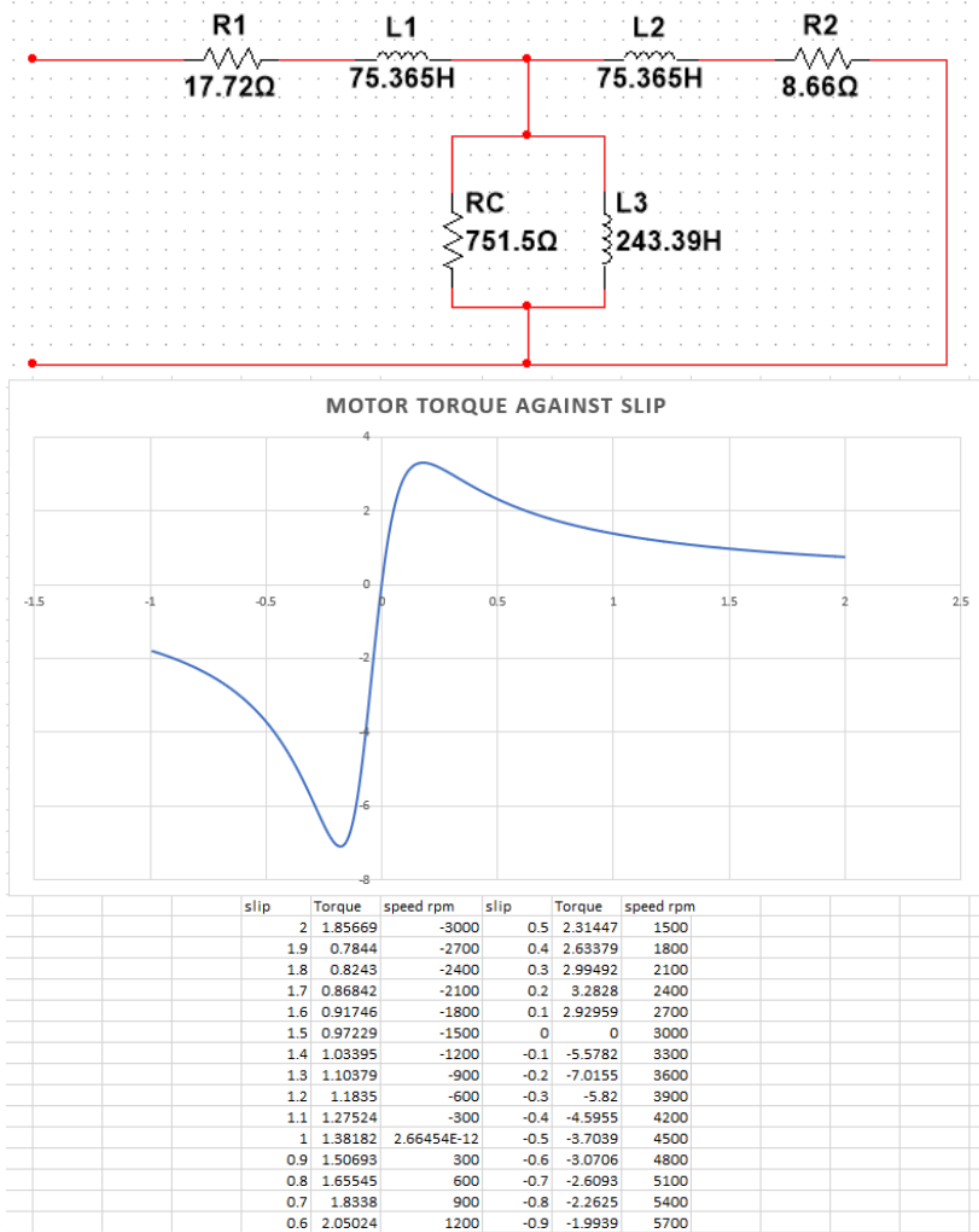


Figure 12 - Motor equivalent circuit and predicted values

Figure 12 shows how the torque produced is directly proportional to slip and as the torque increases so does the slip. The graph also shows how slip bears little relation to the actual speed of the rotor. There are two instances where the speed hits 3000rpm. However, the value of slip is zero in one instance and as high as it ever gets in the other instance.

5. Conclusions and Recommendations

The practical results matched the predicted values from both the calculations and the simulation results most of the time but not always. The practical results for the RL circuit corresponded well except for the wattage on the secondary. This may be the result of an error in the simulator since there was a 35W difference, but human error cannot be ruled out. However, all other results matched with minor discrepancies. If the experiment were to be redone, more accurate and re-calibrated equipment could be used, and a different simulator could be used. Research done into converters, motors and controllers helped build understanding on how each result from the calculations and the experiments affected each other and what they really meant.

As shown in the discrepancies between the experiment results, calculated results and the simulated results there will often be errors, but simulators and calculated values do not account for real world interference. Things like corrosion, heat loss and human error are not accounted for since they cannot be predicted in a “perfect world” scenario where things like efficiency are 100%.

Also, the transformers copper losses depend upon the current going through it, while the iron losses are directly linked to the voltage. *Useful point made*

6. Works Cited

Correct method of listing.

Good range of sources

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7. Appendix

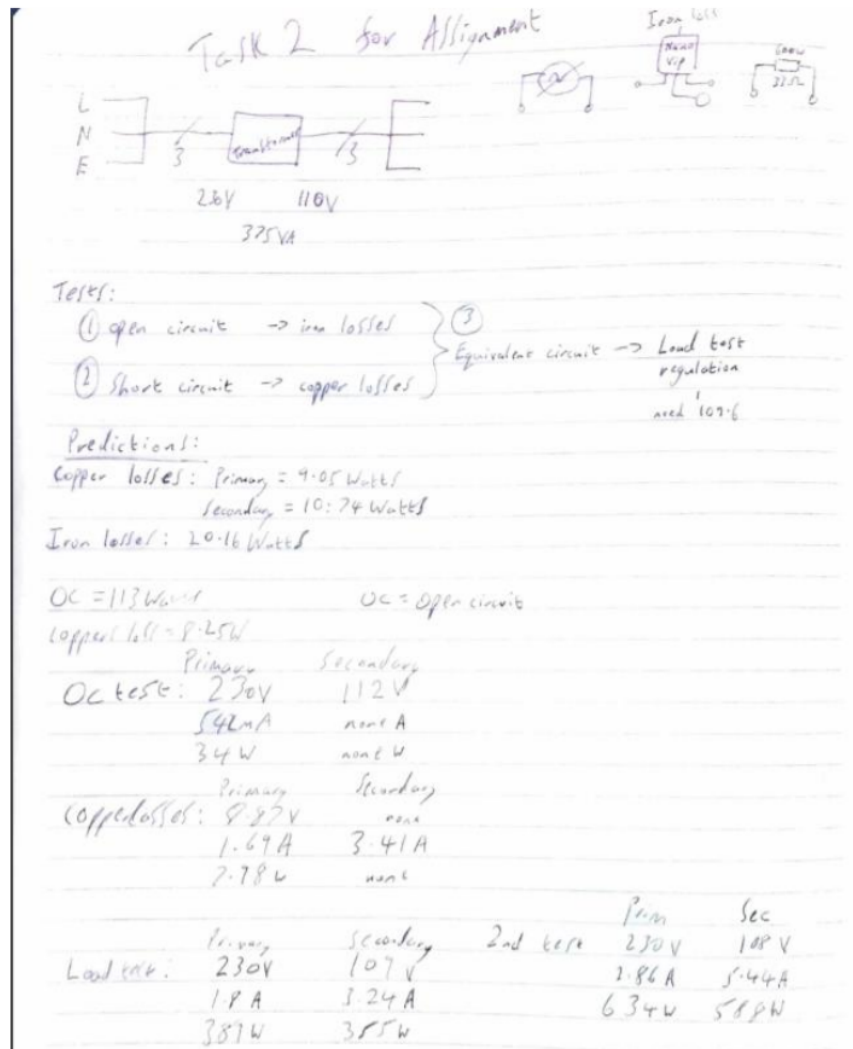


Figure 13 - Notes 1

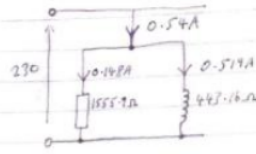
Primary on open circuit test:

Input current = 542 mA 34 Watts

$$\text{Power loss} = \frac{|V_1|^2}{R_c}$$

$$34W = \frac{230V^2}{R_c}$$

$$R_c = \frac{52900}{34} = 1555.9 \Omega$$



Therefore:

$$|I_c| = \frac{|V_1|}{R_c} = \frac{230}{1555.9} = 0.148A$$

Also:

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

$$|I_o|^2 = |I_c|^2 + |I_m|^2$$

$$0.54A^2 = 0.148A^2 + |I_m|^2$$

$$|I_m|^2 = 0.2916 - 0.0222$$

$$|I_m| = \sqrt{0.2694} = 0.519A$$

$$X_m = \frac{|V_1|}{|I_m|} = \frac{230}{0.519} = 443.16 \Omega$$

Short CCT calcs:

230:110V 50Hz

Primary $V_1 = 8.87V$, $I_1 = 1.69A$, $P_{in} = 7.98W$

$$|Z_{se}| = \frac{|V_1|}{|I_1|} = \frac{8.87}{1.69} = 5.25 \Omega$$

$$|R_{se}| = \frac{P_{in}}{|I_1|^2} = \frac{7.98}{1.69^2} = 2.79 \Omega$$

$$|X_{se}| = \sqrt{5.25^2 - 2.79^2} = 4.447 \Omega$$

OPEN CCT
Calcs

Turn over →

Figure 14 - Notes 2

$$|Z_{2E}| = \left(\frac{N_1}{N_2}\right)^2 |Z_{1E}| = \left(\frac{110}{230}\right)^2 \times 5.25 = 1.2 \Omega$$

$$R_{1E} = \left(\frac{110}{230}\right)^2 \times 2.79 = 0.64 \Omega$$

$$|X_{2E}| = \left(\frac{110}{230}\right)^2 \times 4.447 \Omega = 1.017 \Omega$$

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

$$= \frac{230}{110} \times 1.69$$

$$= 3.53 \text{ A}$$

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

$$L_m = \frac{X_m}{100\pi} = \frac{443.16}{100\pi} = 1.41 \text{ H}$$

$$L_{1E} = \frac{X_{1E}}{100\pi} = \frac{4.447}{100\pi} = 0.014 \text{ H}$$

	RL	36.5 Ω	RL	28.3 Ω
		93 mH		48 mF
Primary		~~W~~		~~W~~
V		230		230
A		1.55		0.469
W		208		86.3
P.f.		0.58		-0.80
Secondary		~~W~~		~~W~~
V		109		114
A		2.26		1.58
W		177		68.8
P.f.		0.72		-0.38

$\div 4$ for second test

Figure 15 - Notes 3

Task 3 for assignment

Motor open circuit test: Drive it at synchronous speed

DC test: Stator resistance

Stator test
11.7V 0.33A
across each phase

Stator resistance test calcs
 $R_s = \frac{11.7V}{0.33A} = 35.45 \Omega$

Syn speed
Volts 214
mA 534
Watts 61
P.f. 0.32

No load test calcs

P.f. (ϕ_0) = $\cos \phi_0 = \frac{P_0}{V_0 I_0}$

$\cos \phi_0 = \frac{61}{214 \times 0.534} = 0.534$

$\phi = \cos^{-1}(0.534)$

$\phi = 57.7^\circ$ degrees

Therefore: $I_c = I_0 \cos \phi_0$
 $I_m = I_0 \sin \phi_0$

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

or $R_c = \frac{V_0}{I_0 \cos \phi}$

$R_c = \frac{214}{0.534 \times 0.534}$

$R_c = 750.47 \Omega$

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

or $X_m = \frac{V_0}{I_0 \sin \phi}$

$X_m = \frac{214}{0.534 \times 0.845}$

$X_m = 474.26$

copper loss

out test

25.7V

4.91mA

19.1W

0.88pf

$\cos \phi_{sc} = \frac{19.1}{25.7 \times 0.491} = 1.51$

$Z_{sc} = \frac{V_{sc}}{I_{sc}} = \frac{25.7}{0.491} = 52.34$

$R_1 + R_2' = Z_{sc} \cos \phi_{sc} = 52.34 \times 1.51 = 79.03$

$R_2' = 79.03 - 35.45 = 43.58 \Omega$

Figure 16 - Notes 4

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	CMHT3	CMH1200/110
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	28	35	40	48	17.3
Copper Loss at	9.05	14.8	18.4	22.7	30	42.9	38	13
Continuous rating	10.74	17	21	29	30	58	30	10
Insulation Resistance at 2kV for 1 Minute	>200MΩ	>200MΩ	>200MΩ	>200MΩ	>200MΩ	>200MΩ	>200MΩ	>200MΩ
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	1.73Ω
Secondary Winding Resistance at 20°C	0.52Ω	0.37Ω	0.25Ω	0.16Ω	0.16Ω	0.075Ω	0.04Ω	0.91Ω
Winding	96	90	92	95	98	98	84	80
Temperature Rise	89	85	88	89	96	92	86	75
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 nomex/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 unterminated to allow the user to fit the required style of plug.

RS Tech - PPT Rev3.doc 14/12/2011

Figure 17 - Transformer datasheet

Instructor

54/100

PAGE 1

PAGE 2

QM

Good Structure

Report is structured exactly as stated in the assignment brief.

PAGE 3

PAGE 4

Text Comment. how close were they?

QM

Punctuation Error

Punctuation error

PAGE 5

QM

Improper Citation

Improper citation:

Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

Text Comment. Direct quotes must be contained with ".in " " marks and preceded by the author's surname. In the citation, the name is then suppressed and the page number included.

PAGE 6

Text Comment. where is the load?

QM

Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:
http://www.plagiarism.org/plag_article_citation_styles.html

Text Comment. Where is the output connected

PAGE 7

Text Comment. Research should involve sources

QM

Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:
http://www.plagiarism.org/plag_article_citation_styles.html

PAGE 8

Text Comment. Induction machines work with AC not DC. There is no such thing as a DC induction motor

Text Comment. Converter turn AC into DC, you need to look at inverters or phase controllers instead.

Text Comment. This is a 4 quadrant DC drive which cannot control an induction motor. If fed into the stator of a 3 phase induction motor, nothing would happen

PAGE 9

Text Comment. Again, this is the wrong type of drive, it converts AC into DC

PAGE 10

Text Comment. Direct quotes must be contained with .in " " marks and preceded by the author's surname. In the citation, the name is then suppressed and the page number included.

QM

Improper Citation

Improper citation:

Improperly cited material. Please use the link below to find links to information regarding specific citation styles: http://www.plagiarism.org/plag_article_citation_styles.html

Text Comment. You need to focus on AC induction motors in your research

Text Comment. Read the brief more carefully next time, much of the above is irrelevant to this assignment.

Text Comment. If you are using the equivalent circuit, you must refer to either the primary or the secondary

Text Comment. incorrect, the sign inside the brackets changes when the power factor is leading

Text Comment. The answer should be 112.6 which is must closer but there is still something wrong as the answer should be nearer 114

Text Comment. Useful point made



Good range of sources

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



Correct method of listing.

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

GRADING FORM: NEW CSG-RUBRIC

RICHARD HARRISON**54****1. ENGAGEMENT WITH LITERATURE**



Engagement with an appropriate range of literature, including sources retrieved independently. Some over-reliance on texts. Referencing may show minor inaccuracies or inconsistencies. However, some of the material research was not relevant. (10/20)

10**2. KNOWLEDGE AND UNDERSTANDING**



Limited but adequate knowledge and critical understanding of the well-established concepts and principles within the subject area, with a few gaps in the selection of material. A narrow critical understanding of the main methods of enquiry. Concern should be expressed over your confusion of AC and DC motors and controls. (9/20)

9**3. COGNITIVE AND INTELLECTUAL**



A good and appropriate application of established methods, materials, tools and/or techniques. Clear appreciation of the context of the application. Mainly consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose mostly appropriate solutions outside the context in which they were first studied. (11/20)

11

4. PRACTICAL APPLICATION



A very good application of a range of established methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive insights. Consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose appropriate solutions outside the context in which they were first studied. Evidence of some creativity. (12/20)

12

5. TRANSFERABLE SKILLS



Can communicate well, confidently and consistently in a suitable medium for the audience. Work is coherent, fluent, well-structured and organised. Can work very well autonomously and/or as part of a team, with very good contribution to group activities. Demonstrates very good skills for employment requiring the exercise

12

of personal responsibility and decision-making,
with just occasional minor weakness. (12/20)