Ac dc three phase generators

Aims and Objectives

The main objective of this report is to describe the investigation into operating characteristics of AC-DC Three-Phase generators and motors.

The following subjects must be covered in this report for it to successfully document the investigation, these subjects will be constructed using a series of lab experiments and learner comments:-

Operating characteristics of DC and AC generators supplying resistive, capacitive and inductive loads.

Relationship between speed, current, power factor, and efficiency of a cage induction motor, capacitor start induction motor, synchronous motor and DC motor.

Analyse the results from each of the experiments done and provide graphical analysis of the results.

Introduction/ Background

It is well known that the most regular type of power to be generated around the world is three phase AC. The reasons being are:-

Three phase power is needed for the use of the most efficient types of industrial motors.

It is considered to be the most efficient form of electrical energy to generate and distribute.

Due to the performance of three phase, the size and weight of devices using it such as generators and motors are lower compared to devices using other power systems.

Although it should be noted that the performance of an AC system is dependant on the power factor, not just the load in terms of current.

In-order to successfully investigate the subject of AC vs. DC a total of six practical tests were completed, the practical tests will be documented in the following report and analysed.

The tests completed:-

AC induction motor torque-speed characteristics

AC synchronous motor torque-speed characteristics

AC capacitor start induction motor torque-speed characteristics

DC motor torque-speed characteristics

DC generator output characteristics

AC generator output characteristics

AC Induction Motor Test

An induction motor is an asynchronous motor where through electromagnetic induction power is supplied to the rotating device. In some contexts an induction motor can be described as a “ rotating transformer” because the stator can be shown to be the primary winding and the rotor as the secondary winding. Induction motors can be found regularly in industrial situations.

Induction motors get their popularity from being rugged in construction, and from not having brushes.

There is more than one design of induction motor a few examples are:-

Squirrel Cage Rotor Motor

Wound Rotor Motor

Double Cage Rotor Motor

Each of the above motor designs has its own merits; the type of motor to be used in this experiment is the cage rotor motor.

Squirrel Cage Rotor Motor:-

A cage induction motor rotor shown in the illustration below consists of a series of conducting bars laid into slots carved into the face of the rotor and shorted at either end by large shorting rings. The design is known as the cage rotor because of the conducting bars, if examined they can be seen to look like a squirrel or hamsters exercise wheel.

1Squirrel Cage Motor Construction

Test

The purpose of this test was to find the torque-speed characteristics of an AC induction motor.

The characteristics that will be analysed against torque are:-

Speed

Current

Output Power

Power Factor

Efficiency

The basic idea behind the test, the motor is run at full speed and is connected to a brake unit. The brake unit can be adjusted to make the motor produce more or less amounts of torque. Starting at low motor torque, readings of current voltage and power are taken, then readings continue to be taken all they way to near stalling point.

The test equipment is as follows:-

Circuit Diagram for Cage Rotor Induction Motor Test:-

Block Diagram

To further explain and simplify, a block diagram of the test is included below. This shows exactly how the system operates.

Brake

Motor

Three Phase Supply

Torque Control

Speed (rev/min)

Ammeter, volt meter, watt meter

Test Procedure

A completely extensive test procedure can be found in the appendix taken from the Student Guide of TecQuipment Electrical Machines FH2 refer to appendix !!!.

Results Table T. 1

Torque (Nm)

Speed (rev/min)

Output Power (W)

Wattmeter Wa (W)

Wattmeter Wb (W)

Input Power (W)

Line Current (A)

Line Voltage (V)

Volt-Amperes (VA)

Power Factor

Efficiency (p. u.)

0. 1

1500

15. 708

80

0

80

0. 35

245

148. 52336

0. 5386

0. 1963495

0. 2

1450

30. 369

85

10

95

0. 38

245

161. 25393

0. 5891

0. 3196708

0. 3

1450

45. 553

95

20

115

0. 4

245

169. 74098

0. 6775

0. 3961139

0. 4

1440

60. 319

100

30

130

0. 42

245

178. 22803

0. 7294

0. 4639891

0. 5

1425

74. 613

110

40

150

0. 45

245

190. 9586

0. 7855

0. 4974188

0. 6

1400

87. 965

120

50

170

0. 5

245

212. 17622

0. 8012

0. 5174388

0. 7

1390

101. 89

130

60

190

0. 55

245

233. 39385

0. 8141

0. 5362754

0. 8

1360

113. 94

145

65

210

0. 57

245

241. 8809

0. 8682

0. 5425481

0. 9

1350

127. 23

160

80

240

0. 65

245

275. 82909

0. 8701

0. 5301438

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The values for output power, volt-amperes, input power, power factor and efficiency were calculated using the following relationships:-

Problems:-

Before the results are expressed in graphical form and commented on, the report discusses any problems that occurred during the lab experiment. Only one major issue occurred during the induction motor test. The fault was due to a wiring error. A link was missing on one of the watt meters which caused the motor to “ single phase” and not rotate. It was easy to see that it was “ single phasing” because the current measured for one of the phases was zero, indicating an open circuit somewhere. The link was quickly replaced and the test could begin.

Graphical Analysis:-

Now the report illustrates the results in the table T. 1 in a graphical form, to make comparison the results from the test equipment manufacture have been included as a guide.

Speed vs. Torque

The above graph shows the relationship between speed and torque, it shows that at a low torque the speed is at its maximum but as the torque increases the adverse happens to the speed. This is expected because increasing the torque of the motor is adding more mechanical load, thus slowing the motor down.

2Manufactures graph of Speed versus Torque (Cage Induction Motor)

The graph above is a representation of the results that the manufacturer of the test machines gives as a guide. It is possible to see that from a torque of 0. 1Nm to 0. 9Nm the results are similar to the report author’s. The torque was not taken any higher than 0. 9Nm in the authors test as stalling the motor was not a desired outcome.

Output Power vs. Torque

This graph shows the relationship of output power versus torque taken from the lab results in table T. 1; it has an obvious linear upward trend. It is expected that the output power increases as more load is put on the motor, because the motor has to work harder to maintain rotation.

3Manufactures graph of Output Power versus Torque (Cage Induction Motor)

The manufactures results also share the same upward trend as the authors, but again the manufacture has taken the results past 0. 9Nm and taken the motor into a stalling condition.

Line Current versus Torque

The graph above shows the results of torque against line current, a good upward trend is visible. This indicates that as the torque increases so does the line current, this again is due to the increase in load on the motor.

4Manufactures graph of Line Current versus Torque (Cage Induction Motor)

The guide results from the manufacture complement the results that the author recorded. A steady rise is shown from around 0. 35-0. 4A to 0. 6-0. 7A at about 0. 9Nm.

Power Factor versus Torque

The graph is showing the results from the practical lab experiment, the calculated power factor versus the torque. It can be seen from the upward trend of the graph that as the torque of the motor increases, so does the power factor. It will be later seen in the report that because the power factor increases with torque so will the efficiency.

5Manufactures graph of Power Factor versus Torque (Cage Induction Motor)

The guide results above show similarities with the results gained through practical lab experiments.

Torque vs. Efficiency

The graph is showing the relationship between efficiency and torque, the efficiency increases as the torque does, this is expected because the output power increases with the torque. The peak efficiency occurs at around 0. 75-0. 8Nm after which the efficiency starts to reduce.

6Manufactures graph of Efficiency versus Torque (Cage Induction Motor)

The graph above shows the relationship of torque and efficiency, the manufactures results show a similar trend to that of the author's. The results from the manufactures show more of the downward trend after 0. 8Nm to eventually stalling point.

Conclusion

Overall the results acquired through practical experiment show encouraging results, both towards theory and also towards the manufactures guide results. Some of the graphs could have been a more steady results but it is not possible to get perfect results on something like this without doing the test many more times and taking average values. The trends do illustrate what is expected, so this means the equipment was set up correctly, and the test was carried out uniformly to manufactures guidelines. The induction motor is capable of supplying torque when needed but it will not maintain a constant speed.

AC Synchronous Motor Test

The major characteristic of a synchronous motor is that it stays at a constant speed regardless of no load or full load. Under certain conditions they can produce a power factor that is capable of correcting a low power factor from an inductive load. A common use for a synchronous motor is to drive a DC generator. They come in all sizes from small to thousands of horsepower.

The synchronous motor works by the application of three-phase AC power to the stator which causes a rotating magnetic field. The rotor sits inside this magnetic field, and is energised with a DC voltage. The rotating magnetic field of the stator attracts the rotor magnetic field caused by the DC voltage, and a strong rotating force is then imposed on the rotor shaft.

This is one of the disadvantages of the synchronous motor, it needs a DC excitation voltage to start without this the rotor will not start turning. This characteristic causes the motor to have poor starting torque, most of its torque is when it is running at synchronous speed.

7Showing the parts making up a synchronous motor

Test

The purpose of this test was to find the torque-speed characteristics of an AC synchronous motor.

The characteristics that will be analysed against torque are:-

Current

Output Power

Power Factor

Efficiency

Speed has not been considered because of the way the motor operates, a constant speed should be apparent throughout the test.

In the test the motor is ran at full speed, and an adjustable brake unit will control the levels of torque the motor produces. Measurements of current, voltage and power are taken at low to high torque points to get the torque characteristics of the motor.

Test Equipment:-

Circuit Diagram for Synchronous Motor Test:-

Block Diagram

To further explain and simplify, a block diagram of the test is included below. This shows exactly how the system operates.

Three Phase Supply

Brake

Motor

DC Rotor Supply

Torque Control

Speed (rev/min)

Ammeter, volt meter, watt meter

Test Procedure

The test procedure that was followed can be found in the appendix taken from the Student Guide of TecQuipment Electrical Machines FH2, refer to appendix!!!.

Results Table T. 2

Torque (Nm)

Speed (rev/min)

Output Power (W)

Wattmeter Wa (W)

Wattmeter Wb (W)

Input Power (W)

Line Current (A)

Line Voltage (V)

Volt-Amperes (VA)

Power Factor

Effieciency (p. u.)

0

1500

0

0

4

4

0. 05

245

21. 21762

0. 1885

0

0. 05

1500

7. 854

0

8

8

0. 05

245

21. 21762

0. 377

0. 981748

0. 1

1500

15. 71

0

10

10

0. 05

245

21. 21762

0. 4713

1. 570796

0. 2

1500

31. 42

10

12

22

0. 05

245

21. 21762

1. 0369

1. 427997

0. 3

1500

47. 12

20

20

40

0. 1

245

42. 43524

0. 9426

1. 178097

0. 4

1500

62. 83

30

30

60

0. 15

245

63. 65287

0. 9426

1. 047198

0. 5

1500

78. 54

38

39

77

0. 2

245

84. 87049

0. 9073

1. 019998

0. 6

1500

94. 25

50

46

96

0. 25

245

106. 0881

0. 9049

0. 981748

0. 7

1500

110

55

52

107

0. 25

245

106. 0881

1. 0086

1. 027624

0. 8

1500

125. 7

60

65

125

0. 3

245

127. 3057

0. 9819

1. 00531

0. 9

1500

141. 4

70

72

142

0. 35

245

148. 5234

0. 9561

0. 995575

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The values for output power, volt-amperes, input power, power factor and efficiency are calculated using the following relationships:-

Graphical Analysis:-

The report now includes graphical representation of the results table T. 2; the guide graphs from the TecQuipment the machine manufacture have been included to compare result reliability.

Output Power vs. Torque

The above shows the relationship between torque and output power, it can be seen that as the torque produced increases so does the output power. This outcome is expected because the motor has to turn a greater load and remain at a constant speed.

8Manufactures graph of Output Power versus Torque (Synchronous Motor)

The manufactures graph also shows the output power increasing with the torque.

Line Current versus Torque

The line current in this graph is taking an upwards trend indicating as the torque produced is increased so does the line current. The motor is working harder to produce more torque and therefore putting more load on the line.

9Manufactures graph of Line current versus Torque (Synchronous Motor)

The manufactures graph shows a smoothing increase in line current against torque but does compare with the results gained from the test.

Power Factor versus Torque

The power factor in this graph is shown to increase to a level above 0. 8 very quickly and stays there till the end of the test (0. 9Nm). Synchronous motors normally run at a very good power factor close to unity, and this is represented in the results from the test.

10Manufactures graph of Power Factor versus Torque (Synchronous Motor)

The manufactures guide graph shows a similar trend to that of the report authors.

Efficiency vs. Torque

The above graph showing the relationship of torque and efficiency shows a really good level of efficiency produced by the motor, but the trend is not very reliable as it would not be expected to go past 1. Synchronous motors do have good efficiency higher than that of induction motors.

11Manufactures graph of Efficiency versus Torque (Synchronous Motor)

The manufactures graph shows a much more reliable trend of efficiency of the synchronous motor, but it does still show that the motor is very efficient.

Conclusion

The results for this test could have been better and if the test was to be repeated then more effort would be made to get better measurements. Although with this in mind the graphs do show what is expected from a synchronous motor in terms of torque characteristics.

In comparison to the induction motor, the synchronous motor has improved characteristics of:-

Less load in terms of current on the line.

Better Power factor (closer to unity)

Better Efficiency

It would be interesting to find out the difference in starting torque capacity of the two motors because the induction motor would be expected to have a greater starting torque than the synchronous, based on the research into the operation of these two types of motor.

AC Capacitor Start Induction Motor Test

The most common AC induction motor in use today is probably the single phase induction motor. The reasons for this are that they require little maintenance, and are the least expensive. In the single phase AC induction motor the stator magnetic field does not rotate, it simply alternates polarity as a result of the AC voltage changing polarity. Through magnetic induction a voltage is induced in the rotor, however this alone will not cause the motor to turn. This is why starting methods are needed for single phase AC induction motors.

Capacitor Start

In this type of induction motor the stator is made up of a main winding and a starting winding. The starting winding is connected in series with a capacitor, which offers between the two windings a phase difference of 90 degrees. The result when the motor is started is that between the two windings a rotating magnetic field is created and is enough to start the motor. Once nearly full speed occurs then a speed sensitive switch cuts out the starting winding and the motor runs as a single phase motor. In this way of starting the starting winding is not designed to give the motor high starting torque and so only small motors can use this system.

Test

The purpose of this test was to find the torque-speed characteristics of an AC induction motor.

The characteristics that will be analysed against torque are:-

Speed

Current

Output Power

Power Factor

Efficiency

The basic idea behind the test, the motor is run at full speed and is connected to a brake unit. The brake unit can be adjusted to make the motor produce more or less amounts of torque. Starting at low motor torque, readings of current voltage and power are taken, then readings continue to be taken all they way to near stalling point.

Test Equipment:-

Circuit Diagram for Synchronous Motor Test:-

Block Diagram

To further explain and simplify, a block diagram of the test is included below. This shows exactly how the system operates.

Brake

Motor

Three Phase Supply

Torque Control

Speed (rev/min)

Ammeter, volt meter, watt meter

Test Procedure

An extensive test procedure can be found in the appendix taken from the Student Guide of TecQuipment Electrical Machines FH2 refer to appendix !!!.

Results Table T. 3

Torque (Nm)

Speed (rev/min)

Output Power (W)

Input Power (W)

Supply Current (A)

Line Voltage (V)

Volt-Amperes (VA)

Power Factor

Effieciency (p. u.)

0. 1

1450

15. 18

250

1. 7

245

416. 5

0. 6

0. 0607375

0. 2

1450

30. 37

290

1. 75

245

428. 75

0. 676

0. 1047198

0. 3

1450

45. 55

310

1. 8

245

441

0. 703

0. 1469455

0. 4

1448

60. 65

330

1. 81

245

443. 45

0. 744

0. 183799

0. 5

1425

74. 61

355

1. 9

245

465. 5

0. 763

0. 210177

0. 6

1400

87. 96

390

1. 97

245

482. 65

0. 808

0. 2255502

0. 7

1390

101. 9

421

2. 05

245

502. 25

0. 838

0. 2420245

0. 8

1350

113. 1

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2. 2

245

539

0. 872

0. 2406326

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The values for output power, volt-amperes, input power, power factor and efficiency were calculated using the following relationships:-

Problems:-

Before the results are expressed in graphical form and commented on, the report discusses any problems that occurred during the lab experiment. Only one major issue occurred during the induction motor test. The fault was due to a wiring error. A link was missing on one of the watt meters which caused the motor to “ single phase” and not rotate. It was easy to see that it was “ single phasing” because the current measured for one of the phases was zero, indicating an open circuit somewhere. The link was quickly replaced and the test could begin.

Graphical Analysis:-

Now the report illustrates the results in the table T. 1 in a graphical form, to make comparison the results from the test equipment manufacture have been included as a guide.

Speed vs. Torque

Supply Current versus Torque

Power Factor versus Torque

Efficiency vs. Torque

Conclusion

Overall the results acquired through practical experiment show encouraging results, both towards theory and also towards the manufactures guide results. Some of the graphs could have been a more steady result but it is not possible to get perfect results on something like this without doing the test many more times and taking average values. The trends do illustrate what is expected, so this means the equipment was set up correctly, and the test was carried out uniformly to manufactures guidelines.

DC Motor Test

The working principle behind any DC motor is the attraction and repulsion of magnets. The simplest motors use electromagnets on a shaft, with permanent magnets in the case of the motor that attract and repel the electromagnets. The reason for using electromagnets is so that it is possible to flip their magnetic field (their north and south poles).

So the electromagnet is attracted to one of the permanent magnets. As soon as it reaches the permanent magnet, it's north and south poles flip so that it is repelled from that magnet and attracted to the other permanent magnet. This video shows you the parts and how they fit together:

Test

The purpose of this test was to find the torque-speed characteristics of an AC induction motor.

The characteristics that will be analysed against torque are:-

Speed

Current

Efficiency

The basic idea behind the test, the motor is run at full speed and is connected to a brake unit. The brake unit can be adjusted to make the motor produce more or less amounts of torque. Starting at low motor torque, readings of current voltage and power are taken, then readings continue to be taken all they way to near stalling point.

Test Equipment:-

Circuit Diagram for DC Motor Test:-

Block Diagram

To further explain and simplify, a block diagram of the test is included below. This shows exactly how the system operates.

Brake

Motor

Three Phase Supply

Torque Control

Speed (rev/min)

Ammeter, volt meter, watt meter

Test Procedure

An extensive test procedure can be found in the appendix taken from the Student Guide of TecQuipment Electrical Machines FH2 refer to appendix !!!.

Results Table T. 4

Torque (Nm)

Speed (rev/min)

Voltage (V)

Current (A)

Input Power (W)

Output Power (W)

Efficiency (p. u.)

0. 05

4600

104

0. 55

57. 2

24. 085544

0. 421075938

0. 1

3900

104

0. 65

67. 6

40. 840704

0. 604152433

0. 15

3200

104

0. 75

78

50. 265482

0. 644429262

0. 2

2800

104

0. 9

93. 6

58. 643063

0. 626528449

0. 25

2600

104

1

104

68. 067841

0. 654498469

0. 3

2300

104

1. 15

119. 6

72. 256631

0. 604152433

0. 35

2100

104

1. 2

124. 8

76. 96902

0. 616738942

0. 4

1900

104

1. 35

140. 4

79. 587014

0. 566859073

0. 45

1800

104

1. 5

156

84. 823002

0. 54373719

0. 5

1600

104

1. 6

166. 4

83. 775804

0. 503460361

0. 55

1500

104

1. 7

176. 8

86. 393798

0. 488652703

0. 6

1400

104

1. 85

192. 4

87. 964594

0. 457196436

0. 65

1300

104

1. 9

197. 6

88. 488193

0. 447814742

0. 7

1250

104

2. 1

218. 4

91. 629786

0. 419550301

0. 75

1200

104

2. 15

223. 6

94. 24778

0. 421501698

The values for output power, volt-amperes, input power, power factor and efficiency were calculated using the following relationships:-

Problems:-

Before the results are expressed in graphical form and commented on, the report discusses any problems that occurred during the lab experiment. Only one maj