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CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION

SEPTEMBER 2014 SESSION

SUBJECT CODE	:	**FED20203**
SUBJECT TITLE	:	**INDUSTRIAL MOTOR CONTROL**
LEVEL	:	**DIPLOMA**
TIME / DURATION	:	**9.00 AM – 11.00 AM (2 HOURS)**
DATE	:	**2 JANUARY 2015**

INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **Answer four (4) questions only.**
6. **Answer all questions in English.**
7. **Do not open the question paper until instructed to do so.**

THERE ARE 5 PAGES OF QUESTIONS, EXCLUDING THIS PAGE AND APPENDIX.

INSTRUCTION: Answer four (4) questions only.

Please use the answer booklet provided.

Question 1

(a) Draw the circuit symbol of the components as listed below:

(i) Thermal Overload Relay

(ii) Isolator

(4 marks)

(b) The installation of a motor control needs to be protected against short circuit and overload current. Define:

(i) Short circuit

(ii) Overload current.

(4 marks)

(c) Explain briefly two (2) differences between contactor and control relay.

(4 marks)

(d) **Figure 1** shows the stator windings connection of a three phase motor. Determine:

(i) The connection as shown in **Figure 1**.

(ii) The phase voltage, $\mathbf{V_P}$, if the line voltage, V_L = 240 V.

(iii) The phase current, $\mathbf{I_P}$, if the line current, I_L = 3.35 A.

(5 marks)

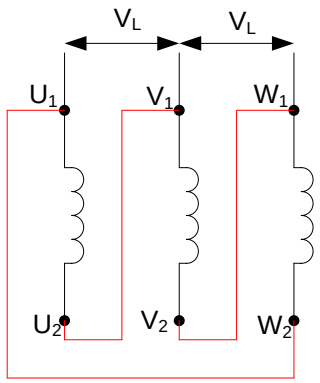


Figure 1

(e) A 3-phase, 6 poles, 50 Hz induction motor take 60 A at full-load speed 940 RPM and develop a torque of 150 Nm. The starting current at rated voltage is 300 A.

(i) Determine the starting torque

(ii) If star-delta starter is used, determine the starting torque and starting current.

(8 marks)

Question 2

(a) Describe the function of control circuit and power circuit.

(4 marks)

(b) **Figure 2** shows a control diagram for a conveyor system using forward-reverse Direct On Line (D.O.L) starter.

(i) Identify the components F1, S1, F2, and KM2

(4 marks)

(ii) Describe the functions of KM1 (13-14).

(2 marks)

(iii) Explain the principle operation of the diagram in Figure 4

(6 marks)

(iv) Identify "**X**" and describe its function.

(3 marks)

(v) Draw the power diagram for forward-reverse Direct On Line (D.O.L)Starter

(6 marks)

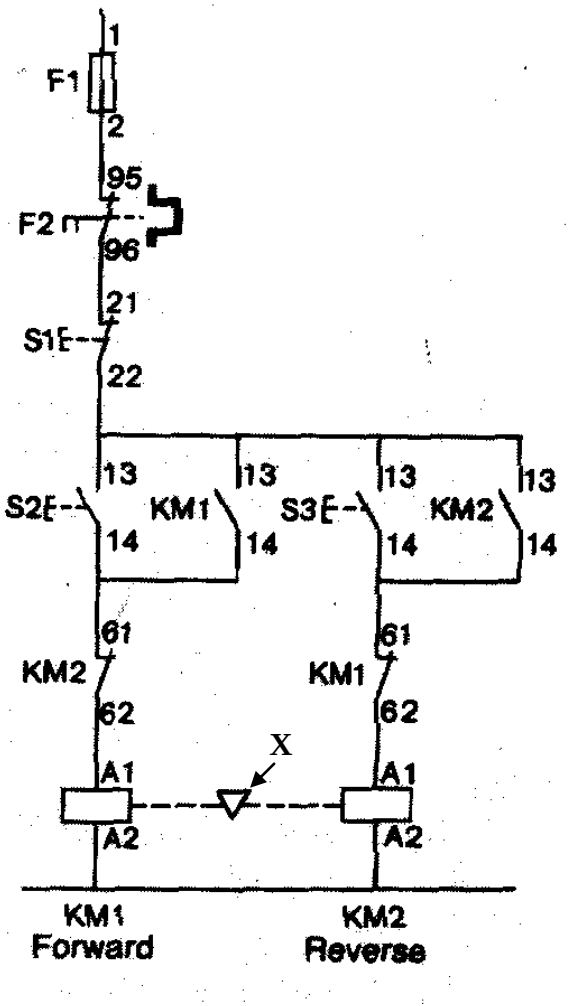


Figure 2

Question 3

(a) Briefly explain the basic construction of an Induction Motor.

(10 marks)

(b) A conveyor system that uses a three-phase induction motor as its main actuator is connected in DELTA with 415 V voltage supply. **Figure 3** shows the name plate of the motor. Determine:

(i) Line voltage, V_L and the phase voltage, V_P.

(ii) The electrical power, P_e of the motor (input power drawn from the supply).

(iii) The efficiency of the motor, η.

(iv) The torque produced by the motor, T.

(15 marks)

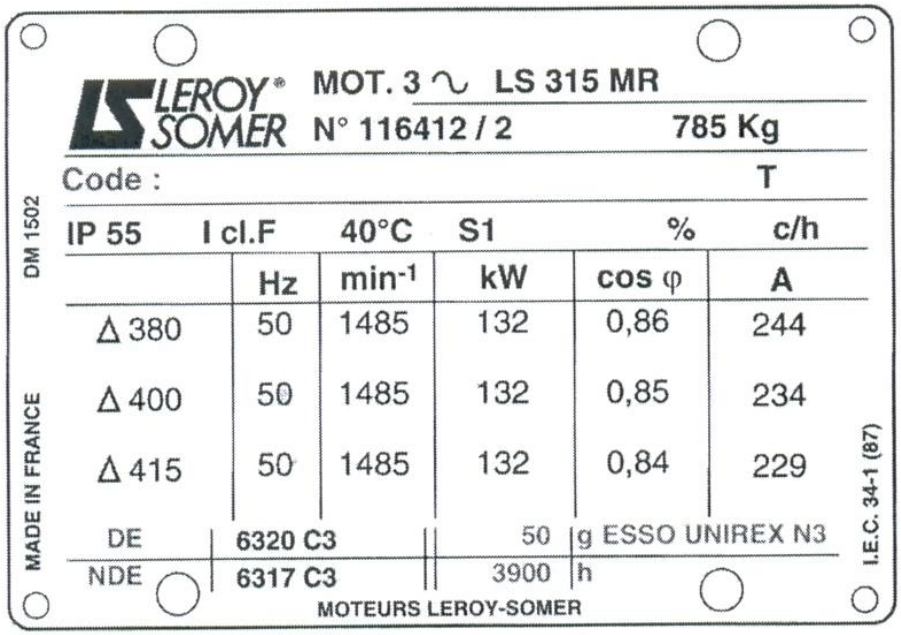


Figure 3

Question 4

(a) **Figure 4** shows the power diagram of an Autotransformer starter. Design the control diagram for an Autotransformer starter.

(7 Marks)

(b) List three (3) advantages and three (3) disadvantages of Autotransformer starting method.

(6 Marks)

(c) Draw the characteristics graph of current versus speed for Autotransformer starting method.

(4 Marks)

(d) An Induction motor with short-circuit current at normal voltage is 6 times the full load current and the full load slip is 4 %. If magnetizing current is neglected, determine the starting torque in terms of full load torque when started with:

(i) Star-Delta starting method.

(ii) Autotransformer starting method, with 70.7% tapping.

(8 Marks)

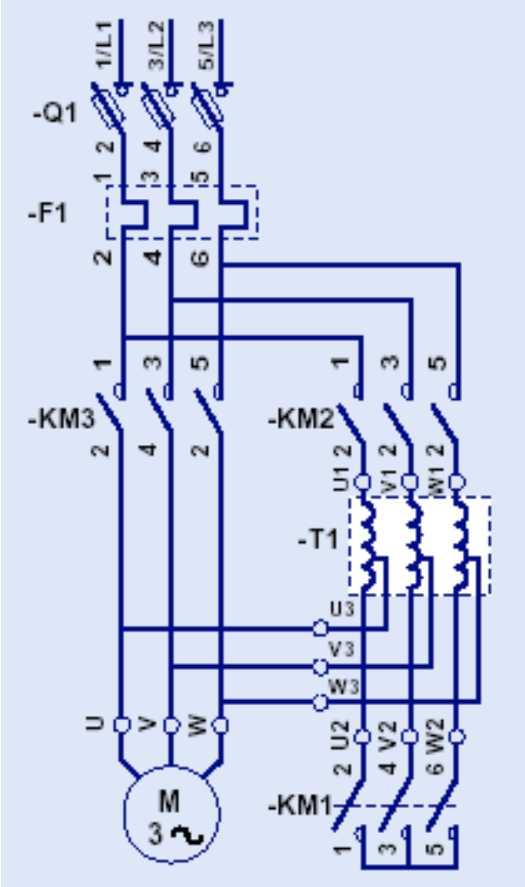


Figure 4

Question 5

(a) List three (3) types of stopping method for variable speed drives (VSD).

(3 marks)

(b) Explain briefly three (3) main parts of Variable Speed Drives (VSD).

(i) Rectifier

(ii) Three phase inverter

(iii) DC line filter

(6 marks)

(c) Explain briefly two (2) types of errors that will cause failure to variable speed drives (VSD).

(6 marks)

(d) The specifications of a conveyor belt system (multi-motor) are given in **Table 1**.

(i) Calculate the total power consumed by 5 motors having a derating factor of 0.8

(ii) Select the appropriate motor and Variable Speed Drives (VSD) for the system (refer to Appendix)

(10 marks)

Table 1

System load:	Fairly Constant load
Speed range:	1 to 3
Motor speed:	480 to 1440 (rev/min)
Resistance torque:	7 Nm
No. of load:	5 motors

END OF QUESTION PAPER

APPENDIX

Useful formula:

1. Electrical Power:
   $P_e = V_L I_L \sqrt{3} \cos \varphi$

2. Mechanical Power:
   $P_m = T\Omega$

3. Rotor Speed (Motor Speed)
$$N_r = \frac{120(1-s)f}{p}$$

4. Direct On Line Starting Method:
$$\frac{T_{st}}{T_f} = \left(\frac{I_{sc}}{I_f}\right)^2 .s_f$$

5. Star-Delta Starting Method
$$\frac{T_{st}}{T_f} = \frac{1}{3}\left(\frac{I_{sc}}{I_f}\right)^2 .s_f$$

6. Auto-Transformer Starting Method
$$\frac{T_{st}}{T_f} = K^2\left(\frac{I_{sc}}{I_f}\right)^2 .s_f$$

APPENDIX

EleDelta – EF1

High Efficiency Motor CEMEP–EU Standard

TECHNICAL DATA

415V 50Hz Synchronous Speed 3000 r/min (2 poles)

Type	Rated Output kW	Rated Output HP	Full Load Speed r/min	Full Load Current A	Full Load Eff %	Full Load Power factor cosØ	1st/IN Locked current / Rated current	Tst/TN Locked torque / Rated torque	TM/TN Max torque / Rated torque	Weight kg
EF1–80M1–2	0.75	1	2900	1.70	76.0	0.83	7.0	2.2	2.3	17
EF1–80M2–2	1.1	1.5		2.39	78.0	0.84	7.9			18
EF1–90S–2	1.5	2	2840	3.16	79.0					22
EF1–90L–2	2.2	3		4.45	81.4	0.85				25
EF1–100L–2	3	4	2870	5.81	83.1	0.87	8.1			28
EF1–112M–2	4	5.5	2880	7.51	84.3	0.88				45
EF1–132S1–2	5.5	7.5	2900	10.1	85.8					59
EF1–132S2–2	7.5	10		13.6	87.3					64
EF1–160M1–2	11	15	2940	19.5	88.6	0.89				109
EF1–160M2–2	15	20		26.2	90.0					121
EF1–160L–2	18.5	25		31.8	90.5	0.90				136
EF1–180M–2	22	30		37.6	91.0			2.0		180
EF1–200L1–2	30	40	2950	50.7	92.0					246
EF1–200L2–2	37	50		62.2	92.5					256
EF1–225M–2	45	60	2960	75.2	93.0					328
EF1–250M–2	55	75	2970	89.9	93.5	0.91				433
EF1–280S–2	75	100	2960	121	94.0	0.92				572
EF1–280M–2	90	125		144	94.4					632
EF1–315S–2	110	150	2975	178	94.5	0.91	7.7	1.8	2.2	950
EF1–315M–2	132	180		212	95.0					1080
EF1–315L1–2	160	220		257	95.1	0.92				1210
EF1–315L2–2	200	270		321	95.2					1240
EF1–355M–2	250	340	2980	397				1.6		1970
EF1–355L–2	315	430		500						2000

APPENDIX

EleDelta – EF1

High Efficiency Motor CEMEP–EU Standard

TECHNICAL DATA

Type	Rated Output kW	Rated Output HP	Full Load Speed r/min	Full Load Current A	Full Load Eff %	Full Load Power factor cosØ	Ist/IN Locked current / Rated current	Tst/TN Locked torque / Rated torque	TM/TN Max torque / Rated torque	Weight kg
415V 50Hz Synchronous Speed 1500 r/min (4 poles)										
EF1–80M1–4	0.55	0.75	1440	1.37	75.0	0.75	5.7	2.4	2.3	18
EF1–80M2–4	0.75	1		1.82	74.6	0.77	6.5	2.3		19
EF1–90S–4	1.1	1.5	1400	2.61	76.2					23
EF1–90L–4	1.5	2		3.37	78.5	0.79				27
EF1–100L1–4	2.2	3	1430	4.67	81.5	0.81	7.5			37
EF1–100L2–4	3	4		6.16	82.6	0.82				40
EF1–112M–4	4	5.5	1435	8.06	84.4					43
EF1–132S–4	5.5	7.5	1440	10.8	86.7	0.83				65
EF1–132M–4	7.5	10		14.3	88.0	0.84				78
EF1–160M–4	11	15	1470	20.6	88.6		8.9	2.2		118
EF1–160L–4	15	20		27.5	90.1	0.85				138
EF1–180M–4	18.5	25		33.3	90.4	0.86	7.9			177
EF1–180L–4	22	30		39.3	90.7					203
EF1–200L–4	30	40		53.1	91.6					243
EF1–225S–4	37	50	1475	63.6	92.6	0.88				305
EF1–225M–4	45	60		75.2	93.0	0.89				328
EF1–250M–4	55	75	1480	90.4	93.5					452
EF1–280S–4	75	100	1475	121	94.1					592
EF1–280M–4	90	125		143	94.3					672
EF1–315S–4	110	150	1480	182	94.6		7.6	2.1	2.2	980
EF1–315M–4	132	180		217	94.9					1040
EF1–315L1–4	160	220		262	95.3					1180
EF1–315L2–4	200	270		328						1260
EF1–355M–4	250	340	1485	415		0.88				1810
EF1–355L–4	315	430		517		0.89				1910
EF1–400M1–4	400	545	1490	662	95.5	0.88	6.9	1.4	3.0	3000
EF1–400M2–4	450	610		737		0.89				3100
EF1–400L1–4	500	680		818	95.6		7.0	1.3		3200
EF1–400L2–4	560	760		912	96.0		6.5	1.4		3400
EF1–400L3–4	630	855		1026			7.1	1.5	3.1	3500

APPENDIX

EleDelta – EF1

High Efficiency Motor CEMEP–EU Standard

TECHNICAL DATA

Type	Rated Output kW	Rated Output HP	Full Load Speed r/min	Full Load Current A	Full Load Eff %	Full Load Power factor cosØ	1st/IN Locked current / Rated current	Tst/TN Locked torque / Rated torque	TM/TN Max torque / Rated torque	Weight kg
415V 50Hz Synchronous Speed 1000 r/min (6 poles)										
EF1–90S–6	0.75	1	910	1.99	72.7	0.72	5.9	2.0	2.1	23
EF1–90L–6	1.1	1.5		2.78	75.4	0.73				25
EF1–100L–6	1.5	2	940	3.59	77.5	0.75				33
EF1–112M–6	2.2	3		5.04	79.9	0.76	6.9			45
EF1–132S–6	3	4	960	6.73	81.6			2.1		63
EF1–132M1–6	4	5.5		8.79	83.3					73
EF1–132M2–6	5.5	7.5		11.7	85.0	0.77				84
EF1–160M–6	7.5	10	970	15.7	86.5			2.0		119
EF1–160L–6	11	15		22.3	87.9	0.78				147
EF1–180L–6	15	20		28.9	89.0	0.81	7.5			195
EF1–200L1–6	18.5	25		35.4	89.7			2.1		235
EF1–200L2–6	22	30		40.8	90.3	0.83				256
EF1–225M–6	30	40	980	54.3	91.5	0.84		2.0		306
EF1–250M–6	37	50		64.8	92.3	0.86		2.1		416
EF1–280S–6	45	60		78.6	92.6				2.0	546
EF1–280M–6	55	75		95.7	93.0					614
EF1–315S–6	75	100	985	126	93.8	0.88		2.0		970
EF1–315M–6	90	125		151	94.2					1180
EF1–315L1–6	110	150		184	94.4		7.3			1240
EF1–315L2–6	132	180		223	94.7	0.87				1300
EF1–355M1–6	160	220	990	267	94.9	0.88		1.9		1740
EF1–355M2–6	200	270		333						1945
EF1–355L–6	250	340		416						2070
EF1–400M1–6	315	430		526	95.8	0.87	6.1	1.4	2.9	3100
EF1–400M2–6	355	475		593			6.5			3200
EF1–400L–6	400	545		659	96.0	0.88	7.5	1.5	3.5	3400

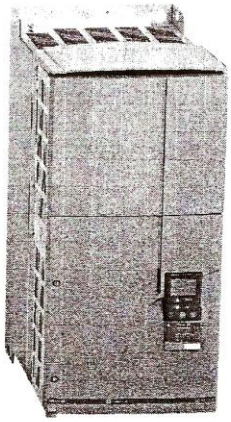
APPENDIX

Variable speed controllers for asynchronous motors

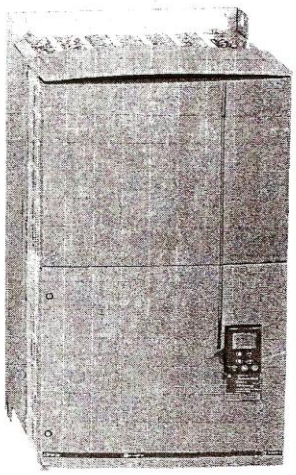
Altivar 58
with integrated heatsink and EMC filters
for asynchronous motors from 0.37 to 75 kW or 0.5 to 100 HP

References

ATV-58HU18M2



ATV-58HD28N4



ATV-58HD54N4

High torque applications (170 % Tn)

Motor Power indicated on rating plate (1)		Mains supply Line current (2)		Max. prospective line Isc		Altivar 58 Max. speed controller nominal current	Max. transient current (3)	Power dissipated at nominal load (4)	Reference (5)	Weight
		at	at	at	at					
kW	HP	U min A	U max A	U min kA	U max kA	A	A	W		kg
Single phase supply voltage : 200...240 V (6) 50/60 Hz										
0.37	0.5	5.6	4.7	2	2	2.3	3.1	42	**ATV-58HU09M2**	2.200
0.75	1	9.8	8.3	2	2	4.1	5.6	64	**ATV-58HU18M2**	2.200
1.5	2	18.5	15.6	5	5	7.8	10.6	107	**ATV-58HU29M2**	3.800
2.2	3	24.8	21.1	5	5	11	15	145	**ATV-58HU41M2**	3.800
3	–	24.7	21.3	5	5	13.7	18.6	220	**ATV-58HU72M2** (7)	6.900
4	5	35	30	22	22	18.2	24.7	235	**ATV-58HU90M2** (7)	13.000
5.5	7.5	46	39.4	22	22	24.2	32.9	310	**ATV-58HD12M2** (7)	13.000
3-phase supply voltage : 200...240 V (6) 50/60 Hz										
1.5	2	9.7	8.3	5	5	7.8	10.6	107	**ATV-58HU29M2**	3.800
2.2	3	13.4	11.4	5	5	11	15	145	**ATV-58HU41M2**	3.800
3	–	17.2	15	5	5	13.7	18.6	170	**ATV-58HU54M2**	6.900
4	5	22.4	19.5	5	5	18.2	24.7	220	**ATV-58HU72M2**	6.900
5.5	7.5	34.7	30	22	22	24.2	32.9	235	**ATV-58HU90M2**	13.000
7.5	10	44.4	38.2	22	22	31	42.2	310	**ATV-58HD12M2**	13.000
3-phase supply voltage : 380...500 V (6) 50/60 Hz										
0.75	1	3.4	2.6	5	5	2.3	3.1	55	**ATV-58HU18N4**	3.800
1.5	2	6	4.5	5	5	4.1	5.6	65	**ATV-58HU29N4**	3.800
2.2	3	7.8	6	5	5	5.8	7.9	105	**ATV-58HU41N4**	3.800
3	–	10.2	7.8	5	5	7.8	10.6	145	**ATV-58HU54N4**	6.900
4	5	13	10.1	5	5	10.5	14.3	180	**ATV-58HU72N4**	6.900
5.5	7.5	17	13.2	5	5	13	17.7	220	**ATV-58HU90N4**	6.900
7.5	10	26.5	21	22	22	17.6	24	230	**ATV-58HD12N4**	13.000
11	15	35.4	28	22	22	24.2	32.9	340	**ATV-58HD16N4**	13.000
15	20	44.7	35.6	22	22	33	44.9	410	**ATV-58HD23N4**	15.000
18.5	25	43	35	22	65	41	55	670	**ATV-58HD28N4**	34.000
22	30	51	41	22	65	48	66	780	**ATV-58HD33N4**	34.000
30	40	68	55	22	65	66	90	940	**ATV-58HD46N4**	34.000
37	50	82	66	22	65	79	108	940	**ATV-58HD54N4**	57.000
45	60	101	82	22	65	94	127	1100	**ATV-58HD64N4**	57.000
55	75	121	98	22	65	116	157	1475	**ATV-58HD79N4**	57.000

Standard torque applications (120 % Tn)

3-phase supply voltage : 380...500 V (6) 50/60 Hz										
22	30	51	41	22	65	44	55	750	**ATV-58HD28N4**	34.000
30	40	67	53	22	65	60	66	925	**ATV-58HD33N4**	34.000
37	50	82	66	22	65	72	90	1040	**ATV-58HD46N4**	34.000
45	60	99	79	22	65	85	108	1045	**ATV-58HD54N4**	57.000
55	75	121	97	22	65	105	127	1265	**ATV-58HD64N4**	57.000
75	100	160	130	22	65	138	157	1730	**ATV-58HD79N4**	57.000

(1) These powers are given for the maximum switching frequency permitted by the speed controller (2 or 4 kHz depending on rating), in continuous operation with no derating. For higher switching frequencies, the controller must be in intermittent operation or the speed controller must be set one rating lower. See special uses on the previous pages.
(2) Typical value without additional choke for a 4-pole motor. Exceptions : ATV-58HU72M2, HU90M2 and HD12M2 (single phase) (7).
(3) For 60 seconds.
(4) These powers are given for the maximum switching frequency permitted by the speed controller in continous operation (2 or 4 kHz depending on rating).
(5) Speed controller supplied with an operator terminal mounted on it. To obtain a speed controller without an operator terminal, add the letter **Z** at the end of the reference.
Example : **ATV-58HU09M2** without operator terminal, the reference is **ATV-58HU09M2Z**.
(6) Nominal supply voltage, U min...U max.
(7) A line choke must be used if these speed controllers are connected to a single phase supply.