Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEF 44903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

Q1 (a) List **two (2)** main criteria of cable sizing that to be implemented in an industrial power system.

(4 marks)

(b) A 1600 kVA, 11 kV / 400 V with 5 % impedance distribution transformer is to be installed to serve an industrial motor pump as illustrated in **Figure Q1(b)**.

(i) Analyse the percentage voltage drop, V_{drop} at the line distribution network during the starting of industrial motor.

(8 marks)

(ii) Analyse the proper size of the transformer from its standard ratings if the voltage variation during the starting industrial motor is be limited to a maximum value of 10 %.

(4 marks)

(c) Consider a feeder serving large motor which is being fed from 400 V, 50 Hz having a circuit breaker with separate multifunction motor protection relay. The motor is rated at 50 kW with 0.85 power factor lagging and efficiency of 95 %. Power cables laid between the feeder and the motor are 3-core copper, XLPE type. The cables are laid 75 cm underground in horizontal formation with 30 cm spacing to each other. The number of cables in group is 3 Nos. The ground ambient temperature is 32°C and its thermal resistivity of soil is 100°C cm / Watt.

(i) If the fault clearing time for the circuit breaker is 7 cycles and the motor short circuit current is 75 times of its rated value, determine the initial size of the standard cable based on the short circuit current withstand capacity criteria. Refer to **Appendix A**.

(7 marks)

(ii) Analyse again the cable size as obtained in **Q1(c)(i)** by considering the continuous current carrying capacity criteria. Decide either the cable size suitable to serve the large motor or not? Refer to **Appendix A** and **Appendix B**.

(7 marks)

Q2 (a) Explain the function of shunt capacitor in improving the bus voltage on receiving-end feeder.

(4 marks)

(b) Sketch a circuit connection of an online type UPS and describe in brief its working principle.

(8 marks)

(c) A solar power system is to be installed in a factory as depicted in **Figure Q2(c)(1)** as power backup for important loads. The loads and their autonomy time are shown **Figure Q2(c)(2)** The characteristics of the proposed solar system is given in **Table Q2(c)**.

(i) Determine the total energy demand, E_t and design energy demand, E_d if the future load growth and design margin are both considered as 12%.

(2 marks)

(ii) Recommend the appropriate minimum and maximum number of cells required for the battery bank.

(4 marks)

(iii) Recommend the minimum battery capacity required for this solar power system.

(4 marks)

(iv) Determine the current rating for the battery charger.

(4 marks)

(v) Recommend the minimum size (in kW) of the solar panel that should be installed if the daily sunny period is assumed as 7.5 hours.

(4 marks)

Q3 (a) Consider a three-phase feeder supply a voltage, $\overline{E} = 6.6$ kV with X_S/R_S ratio of 5 and short circuit level, $S_c = 180$ MVA as depicted in **Figure Q3(a)**. The feeder is supplying a star connected inductive load of $S_L = 10\ kW + j\ 25\ kVAr$.

(i) Analyse a feasible value for the load bus voltage, $\overline{V}$.

(6 marks)

(ii) Conclude the result obtained in **Q3(a)(i)**.

(2 marks)

(b) An industrial motor is to be protected against overload. Its nameplate details are three-phase 3.3 kV, 500 kW, 75% efficiency and 0.85 power factor. The motor can withstand 15% overload continuously. The time constant of heat withstand characteristic is 10 minutes. A thermal relay is connected across a C.T. of 120/1 ratio. The time constant of the relay is also 10 minutes. The range of settings is 70% to 150% of 1 A in step of 5%. Suggest the proper relay setting for this application.

(6 marks)

(d) A 10 units, 5 steps power factor corrector (PFC) is to be installed in the electronics factory having active and reactive power of 120 kW and 90 kVAr, respectively under voltage supply of 400 V. The voltage rating of the capacitors used in the power factor corrector is 550 V. The PFC has the step arrangement of 1 : 1 : 2 : 3 : 3 with 17 kVAr for each unit of capacitor. With this system in place, the total power factor is targeted to be improved to 95 %.

(i) Determine the average power factor and the minimum effective reactive power, Q_s injected into supply system.

(6 marks)

(ii) Analyse the effective reactive power, Q_{Ceff} to be supplied by capacitor bank and the total unit steps of power factor corrector to be switched *'ON'*.

(6 marks)

(iii) Analyse the actual average power factor for the system based on the unit step recommended in **Q3(d)(ii)**.

(8 marks)

(iv) Justify the implication of total unit steps of power factor corrector if 7 kVAr per unit of capacitor is to be used in the factory.

(6 marks)

– END OF QUESTIONS –

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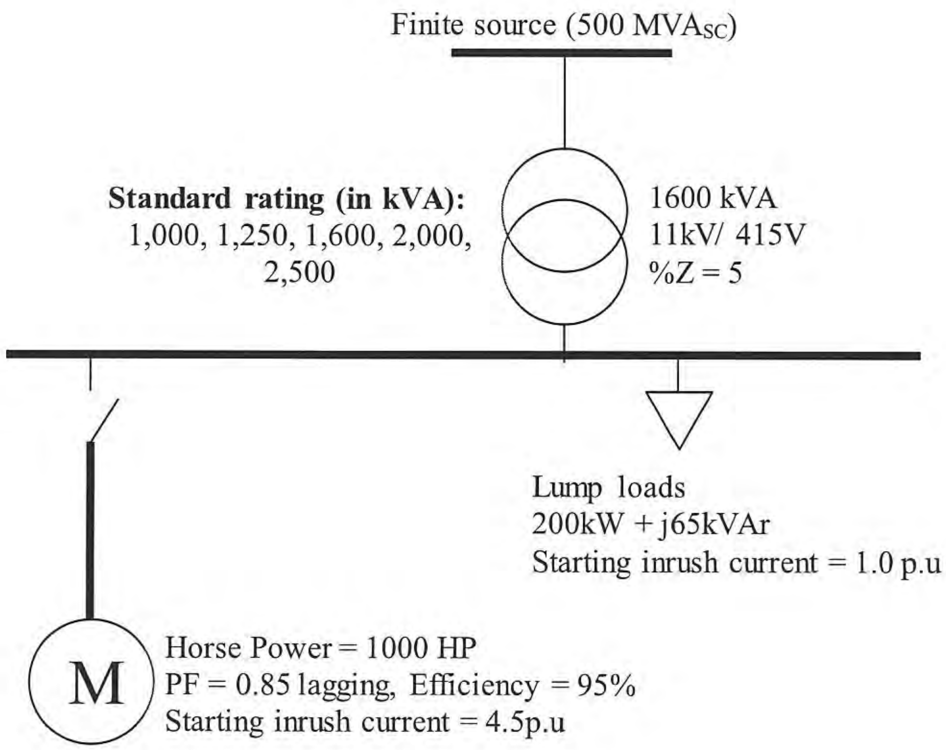

Figure Q1(b)

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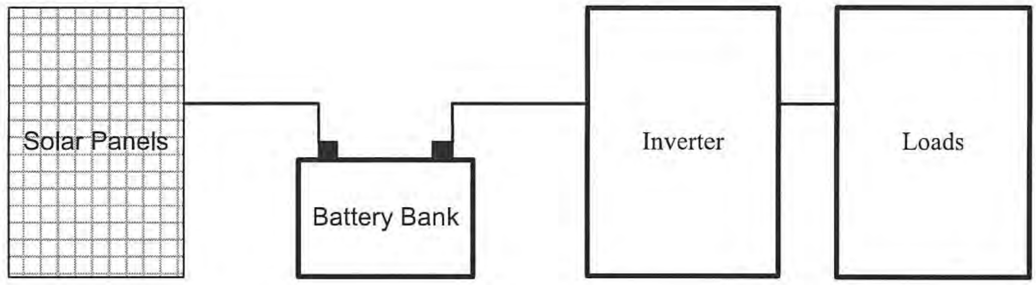

Figure Q2(c)(1)

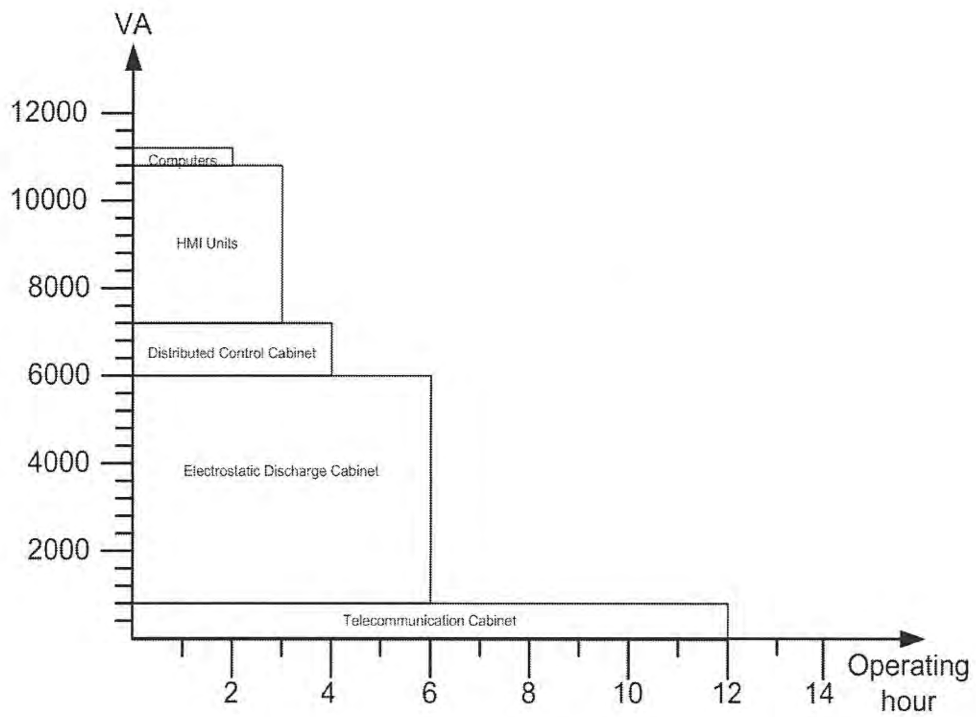

Figure Q2(c)(2)

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Table Q2(c)

Item	**Value**
Battery Output Voltage	120 V_{dc}
Load voltage tolerance	± 5 %
Cell charging voltage	2.5 V_{dc}
Cell end of discharge voltage	5.0 V_{dc}
Depth of discharger	90 %
Battery ageing factor	30 %
Temperature correction factor at 35°C	0.90
Altitude correction factor	1.0
Capacity rating factor	15 %
Recharge efficiency factor	1.1
Recharge time	3 hours
Continuous load current	20 A

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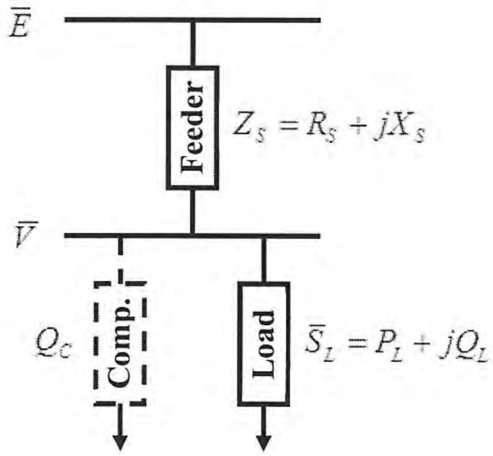

Figure Q3(b)

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Appendix A

$$K = 148\sqrt{In\left(1+\frac{T_2 - T_1}{228.1+T_1}\right)}\ ,\ K = 226\sqrt{In\left(1+\frac{T_2 - T_1}{234.5+T_1}\right)},\ A = \frac{\sqrt{I_{SC}^2 t}}{K}$$

Insulation material	Final temperature, T_2 (°C)	Initial temperature, T_1 (°C)
PVC	160	70
Butyl Rubber	220	85
XLPE/ EPR	250	90

TABLE 4D4A – Multicore 70 °C armoured thermoplastic insulated cables (COPPER CONDUCTORS)

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc. horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase a.c. or d.c.	1 three- or four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or four-core cable, three-phase a.c.
1	2	3	4	5	6	7
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	21	18	22	19	22	18
2.5	28	25	31	26	29	24
4	38	33	41	35	37	30
6	49	42	53	45	46	38
10	67	58	72	62	60	50
16	89	77	97	83	78	64
25	118	102	128	110	99	82
35	145	125	157	135	119	98
50	175	151	190	163	140	116
70	222	192	241	207	173	143
95	269	231	291	251	204	169
120	310	267	336	290	231	192
150	356	306	386	332	261	217
185	405	348	439	378	292	243
240	476	409	516	445	336	280
300	547	469	592	510	379	316
400	621	540	683	590	-	-

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Appendix B

Ground Temp. (°C)	20	25	30	35	40	45	50
Rating Factor	1.12	1.08	1.04	0.96	0.91	0.87	0.82

Spacing	No. of cables in group				
	2	3	4	6	8
Touching	0.79	0.69	0.62	0.54	0.50
15 cm	0.82	0.75	0.69	0.61	0.57
30 cm	0.87	0.79	0.74	0.69	0.66
45 cm	0.90	0.83	0.79	0.75	0.72
60 cm	0.91	0.86	0.82	0.78	0.76

Cable size	Depth of laying (cm)					
	75	90	105	120	150	180 ≥
up to 25 sq. mm.	1.00	0.99	0.98	0.97	0.96	0.95
25 to 300 sq. mm	1.00	0.98	0.97	0.96	0.94	0.93
above 300 sq. mm.	1.00	0.97	0.96	0.95	0.92	0.91

Nominal area of conductor in sq. mm	Rating factors for value of Thermal Resistivity of Soil in °C cm / Watt					
	100	120	150	200	250	300
25	1.24	1.08	1.00	0.91	0.84	0.78
35	1.15	1.08	1.00	0.91	0.84	0.77
50	1.15	1.08	1.00	0.91	0.84	0.77
70	1.15	1.08	1.00	0.90	0.83	0.76

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Appendix C: Formulae

$$A = \frac{\sqrt{I_{SC}^2 t}}{K}$$

$$LLF = k * LF + (1-k) * LF^2$$

$$N_{\max} = \frac{V_{DC}(1 + V_{l,\max})}{V_c}$$

$$N_{\min} = \frac{V_{DC}(1 - V_{l,\min})}{V_{eod}}$$

$$f = \frac{1 + \frac{d-1}{d}\Delta P}{1 + \Delta P}$$

$$C_{\min} = \frac{E_d \times (1 + k_a) \times (1 + k_c) \times k_t}{V_{DC} \times k_{dod}}$$

$$A = \left[\frac{1.1 \times AH}{T} + L\right] \times \frac{1}{C1} \times \frac{1}{C2}$$

$$I_{L,DC} = \frac{S}{V_{DC}}$$

$$I_C = \frac{C(k_t)}{t_C}$$

$$E_d = E_t(1 + k_g)(1 + k_C)$$

$$Z_S = \frac{E^2}{S_{SC}}$$

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$$\tan\phi_{SC} = \frac{X_S}{R_S}$$

$$R_S = Z_S \cos\phi_{SC}$$

$$X_S = Z_S \sin\phi_{SC}$$

$$V^4 + \{2(R_S P_L + X_S Q_L) - E^2\}V^2 + (R_S^2 + X_S^2)(Q_L^2 + P_L^2) = 0$$

$$X = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$$Q_N = Q_L + Q_C$$

$$(R_S^2 + X_S^2)Q_N^2 + 2V^2 X_S Q_N + (V^2 + R_S P_L)^2 + X_S^2 P_L^2 - E^2 V^2 = 0$$

$$P_{3\phi} = \sqrt{3} \times V_L \times I_L \times \cos\theta$$

$$V_{rms} = \sqrt{\sum_{k=1}^{\infty} V_{krms}^2} = \sqrt{V_{1rms}^2 + \sum_{k=2}^{\infty} V_{krms}^2}$$

$$I_{rms} = \sqrt{\sum_{k=1}^{\infty} I_{krms}^2} = \sqrt{I_{1rms}^2 + \sum_{k=2}^{\infty} I_{krms}^2}$$

$$THD_V = \frac{\sqrt{\sum_{k=2}^{\infty} V_{krms}^2}}{V_{1rms}} \times 100\%$$

$$THD_I = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \times 100\%$$

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