Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEV 40203
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 (a) Primary distribution systems consist of feeders that deliver power from distribution substations to distribution transformers. List **three (3)** different ways in which the primary distribution lines can be laid.

(3 marks)

(b) The common types of power transformer used in a distribution system are oil-filled, non-flammable liquid-filled and dry-type transformer. Explain **two (2)** differences between dry-type transformer and oil-filled transformer.

(4 marks)

(c) X kVA, 11 kV / 6.6 kV with 6.8% impedance distribution transformer is to be installed to serve an industrial motor pump as depicted in **Figure Q1(c)**. Choose the proper size (X) of the transformer from its standard ratings if the voltage variation during the motor starting is to be limited to a maximum value of 10%.

(8 marks)

(d) Consider a feeder serving large motor which is being fed from 3.3 kV, 50 Hz switchgear having a circuit breaker with separate multifunction motor protection relay. The motor is rated at 150 kW with 0.85 power factor lagging and efficiency of 92%. Power cables laid between the feeder and the motor are 3-core copper, PVC type. The cables are laid 105 cm underground in horizontal formation with 30 cm spacing to each other. The number of cables in group is 2 Nos.

(i) If the fault clearing time for the circuit breaker is 7 cycles and the motor short circuit current is 200 times of its rated value, determine the initial size of the cable based on the short circuit current withstand capacity criteria. Refer to **Appendix A**.

(5 marks)

(ii) Analyse the value of thermal resistivity if the ground ambient temperature is 45°C and the continuous current carrying capacity criteria value is 75.42 A based on the cable size obtained in **Q1(d)(i)**. Refer to **Appendices A** and **B**.

(5 marks)

Q2 (a) An uninterruptible power supplies (UPS) is an electrical apparatus that provides emergency power to a load when the input power source or mains power fails.

(i) State **three (3)** general types of UPS systems.

(3 marks)

(ii) With the aid of figure, sketch and explain any **two (2)** of the mentioned types of UPS in **Q2(a)(i)**.

(4 marks)

(b) A 50, Hz 11 kV industrial feeder is serving by 0.75 km 3-core armoured XLPE 120 mm^2 underground cable to its Motor Control Centre (MCC) with the resistance of 0.25 Ω / km. The average monthly power consumption for this MCC is depicts in **Table Q2(b)**. The loss constant, k is assumed as 0.2 and the average power factor is 0.85 lagging. By applying the estimated losses calculation approach, determine the Load Loss Factor (LLF) and yearly technical energy loss in kWh for this feeder.

(8 marks)

(c) A UPS system is proposed to be installed in a factory as depicted in **Figure Q2(c)(i)** with its main configuration as power backup for critical loads. The loads and their autonomy time are shown **Figure Q2(c)(ii)**. The characteristics of the proposed solar system is given in **Table Q2(c)**.

(i) Analyse the total energy demand, (E_t) and design energy demand, (E_d) if the future load growth and design margin are both considered as 15%.

(3 marks)

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

(3 marks)

(iii) Recommend a minimum battery capacity (in AH) required for this proposed system.

(2 marks)

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

(2 marks)

Q3 (a) State **two (2)** motor starting methods that producing high voltage and current harmonics.

(2 marks)

(b) Describe the impact of active power balance on system frequency deviation. Explain **two (2)** consequences of system frequency deviation on industrial activities.

(4 marks)

(c) A 415 V three-phase supply is connected to three star-connected loads in parallel, through a feeder of impedance (0.1 + j0.5) Ω/phase. Determine the voltage (in line-to-line) at load terminal where the loads are as follows:

15 kW + j15 kVAr; 12 kW + j6 kVAr; 30 kW + j6 kVAr

(7 marks)

(d) Measurements of harmonics component have been performed at load terminal of **Q3(c)** and the results are tabulated in **Table Q3(d)**.

(i) Compare the displacement power factor and the true power factor of this installation. X and Y should be obtained from **Q3(c)**.

(9 marks)

(ii) Estimate the three-phase reactive power (Qc) required to correct the true power factor in **Q3(d)(i)** to 0.98 lagging if the harmonics are **NOT** being eliminated.

(3 marks)

Q4 (a) Motor protection is provided by a set of devices ensuring that deterioration due to abnormal supply, motor or load operating conditions is avoided. List **two (2)** main faults that might affecting an induction motor.

(2 marks)

(b) Capacitor bank energisation causes current and voltage transient operating states. Thus, the maximum inrush peak current due to the switching of capacitor bank should be carefully determined. A fixed 300 kVAr capacitor bank with line-to-line voltage of 6.6 kV is fed by a 50 Hz network with short circuit capacity of 200 MVA. Estimate the maximum inrush peak current ratio as compared to its nominal current.

(3 marks)

(c) An industrial motor is to be protected against overload. Its nameplate details are three-phase 3.3 kV, 300 kW, 70% efficiency and 0.8 power factor. The motor can withstand 10% 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 130% of 1 A in steps of 5%. Calculate the proper relay setting for this application.

(7 marks)

(d) A three-phase 11 kV, 10 MVA, star-connected generator is protected by an earth fault relay having 10% setting. The C.T. ratio is 200 / 1 A.

(i) If the neutral resistance limits the maximum earth-fault current to 40% of full load value, analyse the percentage of the protected winding.

(11 marks)

(ii) Evaluate the maximum earth-fault current if only 5% of the winding is to be left unprotected.

(2 marks)

– END OF QUESTIONS –

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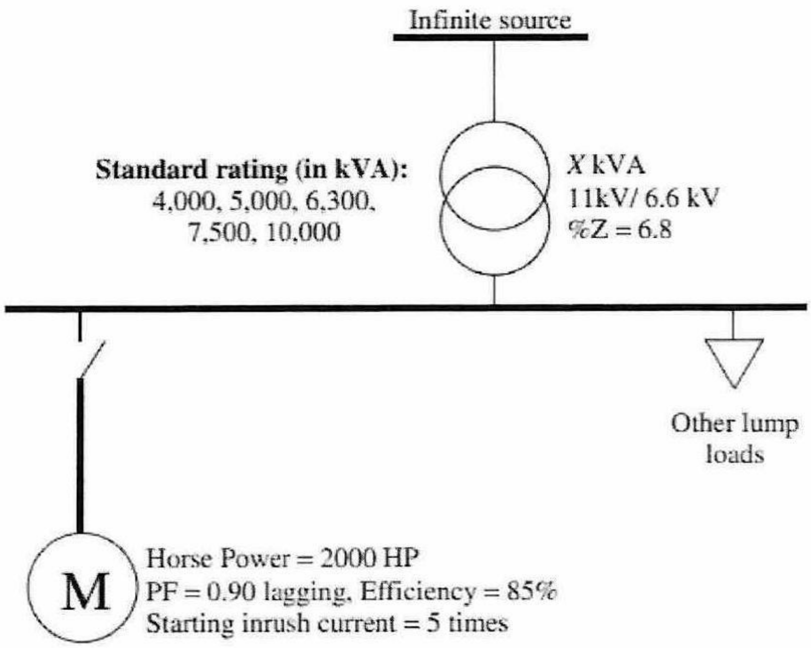

Figure Q1(c)

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Table Q2(b)

Month	Monthly Average Consumption (kW)
January	1850
February	2210
March	1750
April	1910
May	2000
June	1850
July	1970
August	1900
September	2130
October	1940
November	1800
December	2010

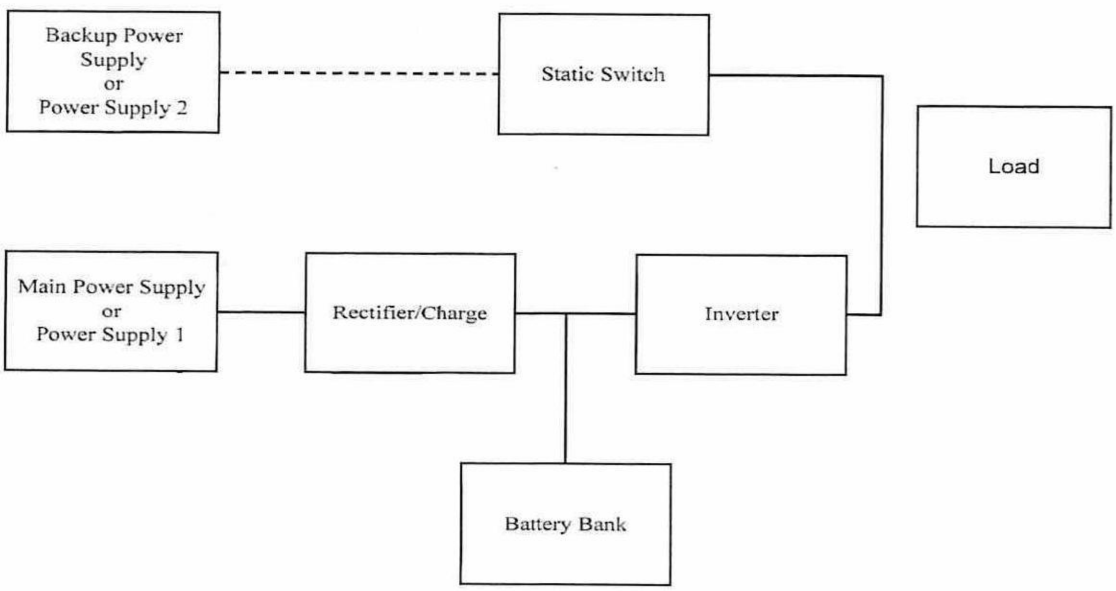

Figure Q2(c)(i)

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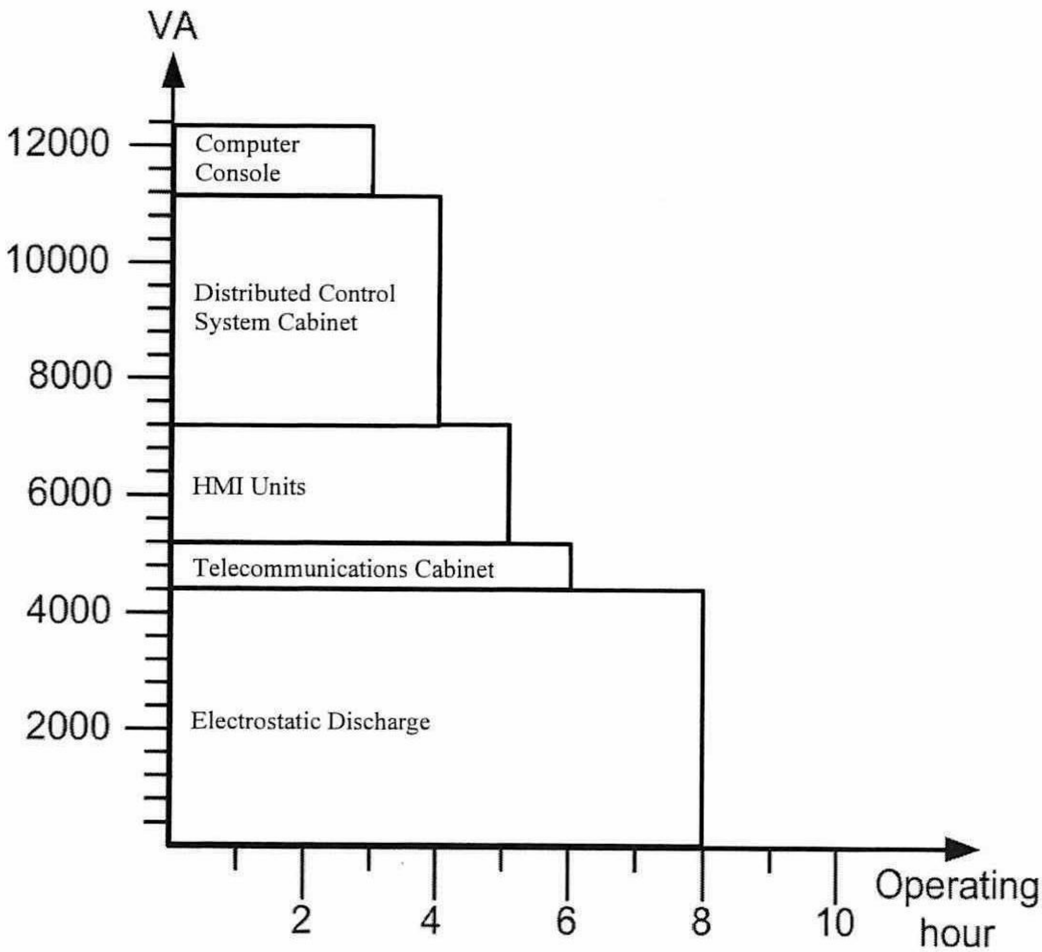

Figure Q2(c)(ii)

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Table Q2(c)

Item	Value
Battery Output Voltage	120 Vdc
Load voltage tolerance	± 10 %
Cell charging voltage	2.25 V_{dc}
Cell end of discharge voltage	5.0 V_{dc}
Depth of discharger	85%
Battery ageing factor	35%
Temperature correction factor at 35°C	0.9
Altitude correction factor	0.95
Capacity rating factor	12%
Recharge efficiency factor	1.1
Minimum recharge time	5 hours
Continuous load current	35A

Table Q3(d)

Frequency (Hz)	Line-to-line Voltage (V)	Line Current (A)
50	$X\angle 0°$	$103\angle -Y°$
250	$18\angle 15°$	$20\angle -15°$
350	$9\angle 35°$	$13\angle +60°$
550	$5\angle 45°$	$8\angle -15°$
650	$3\angle 25°$	$2\angle -20°$

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Appendix A

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

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. (^oC)	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

$$C_{min} = \frac{E_d \ x\ (1 + K_a)\ x\ (1 + K_c)\ x\ K_t}{V_{dc}\ x\ K_{dod}}$$

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

$$E_d = E_t\ (1 + K_a)(1 + K_c)$$

$$THD_V = \frac{\sqrt{\sum_{k=2}^{\infty} V_{krms}^2}}{V_{1rms}} \times 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} V_k^2}}{V_1} \times 100\%$$

$$THD_I = \frac{\sqrt{\sum_{k=2}^{\infty} I_{krms}^2}}{I_{1rms}} \times 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \times 100\%$$

$$V_{rms} = V_{1rms}\sqrt{1 + (THD_V/100)^2}$$

$$I_{rms} = I_{1rms}\sqrt{1 + (THD_I/100)^2}$$

$$PF_{true} = \frac{P_{avg}}{V_{1rms} I_{1rms}} \times \frac{1}{\sqrt{1 + (THD_V/100)^2}\sqrt{1 + (THD_I/100)^2}}$$

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

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

$$\frac{\hat{I}_{rush}}{I_{ncapa}} = \sqrt{2} \times \frac{1}{\omega\sqrt{L_{up}C}}$$

$$L_{up}\omega = \frac{V_n^2}{S_{SC}}$$

$$Q = C\omega V_n^2$$

$$I_{fmax} = \frac{3E_{ph}}{Z_1 + Z_2 + Z_3 + 3Z_n} \approx \frac{E_{ph}}{Z_n} = \frac{V_{LL}}{\sqrt{3} \times R_n}$$