Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEV40203/ BEF44903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY/ AUGUST 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 NINE (9) PAGES

Q1 (a) (i) Sketch and label the primary distribution line of the industrial distribution system which has the most reliable for continuity of supply.

(3 marks)

(ii) Explain the working concept of the primary distribution line named in **Q1(a)(i)** in **two (2)** points.

(4 marks)

(b) 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(b)**. 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)

(c) Consider a feeder serving a large motor which is being fed from 3.3kV, 50 Hz switchgear having a circuit breaker with a 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, suggest 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 in **Q1(c)(i)**. Refer to **Appendix A** and **Appendix B**.

(5 marks)

Q2 (a) To ensure that the battery system is capable of meeting the required objectives, it is important to size the battery correctly.

(i) List the steps to be considered in battery sizing.

(5 marks)

(ii) Explain the effects of improper battery sizing.

(2 marks)

(b) **Table Q2(b)** depicts the average monthly power consumption for a single-phase feeder which is energised by three-phase 415 V, 50 Hz supply. An XLPE cable with resistance of 0.25 Ω/ km is laid from the feeder to the load point with the cable length of 0.75 km. The loss constant, k is assumed as 0.15 and the average power factor is 0.80 lagging.

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(i) By applying the estimated losses calculation approach, determine the Load Loss Factor (LLF) for the feeder.

(6 marks)

(ii) Solve for yearly technical energy loss for this feeder in kWh.

(4 marks)

(c) The critical loads for an industrial packaging plant that are to be supplied by Uninterruptible Power Supplies (UPS) during power outage period is given in **Table Q2(c)**.

(i) Investigate the load profile (kVA versus period in hour) of the UPS loading.

(6 marks)

(ii) Produce the peak design load (in kVA) if the future load growth and design margin are both considered as 10%.

(2 marks)

Q3 (a) Explain in brief the function of transducers and relays.

(2 marks)

(b) A 5 MVA, 11 kV/ 400 V, Y-connected step-down transformer has been installed to serve an industrial plant. The total inductance produced in the system is calculated as 10.79 μH. The power system is operating at 50 Hz. Predict the harmonic order when the installed capacitor bank as power factor corrected is rated at 500 kVAr and 800 kVAr.

(4 marks)

(c) 12 units, 6 steps power factor corrector 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 power factor corrector has the step arrangement of 1 : 1 : 2 : 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 98%.

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

(3 marks)

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

(4 marks)

(d) An industrial feeder rated at 1.91 kV line-to-neutral voltage ($\overline{E}$) with short circuit level of 20 MVAsc and X_S/R_S ratio of 4 as depicted in **Figure Q3(d)** is supplying power to a star connected inductive load of $S_L = 1.5\ MW + j\ 1.8\ MVAr$ per phase. Analyse the load bus voltage ($\overline{V}$) and determine the percentage of voltage drop caused by the inductive load.

(10 marks)

(e) A small scale industrial plant is designed to have load shedding scheme that will be activated when its lines are overloaded. The plant corresponded main power distribution circuit is shown in **Figure Q3(e)**. Plot a graph to outline the timeline cycle as pickup by 'Relay 81' and 'Intelligent Load Shedding (ILS)' to activate the load shedding procedure.

(2 marks)

Q4 (a) List **three (3)** potential underlying factors that could lead to a malfunction occurring in an industrial power system.

(3 marks)

(b) In the industrial setup depicted in **Figure Q4(b)**, there are two incoming sources and several protective devices (PD) in place. To reduce the area where tripping occurs in the event of **Fault** ***A***, select the appropriate type of protective device for PD 1 through PD 4. Additionally, create a diagram and describe the flow of short circuit current as well as the functioning of the protective devices.

(7 marks)

(c) In **Figure Q4(c)**, a protective arrangement is demonstrated for a food processing factory using differential protection. The configuration involves a 1 MVA step-down transformer connected in a Delta-Grounded Star pattern, operating at voltage levels of 11 kV - 415 V. To implement an overcurrent protection system, a percentage differential relay with a slope setting of 15% is employed. The current transformer ratio on the primary side is specified as 10:1.

(i) Suggest an appropriate secondary current transformer ratio value.

(6 marks)

(ii) Examine the percentage difference in the current between the incoming and outgoing currents using the suggested current transformer ratio mentioned in **Q4(c)(i)**.

(5 marks)

(iii) Analyse the minimum secondary current required to activate the percentage differential relay, assuming that the primary current remains constant.

(4 marks)

– END OF QUESTIONS –

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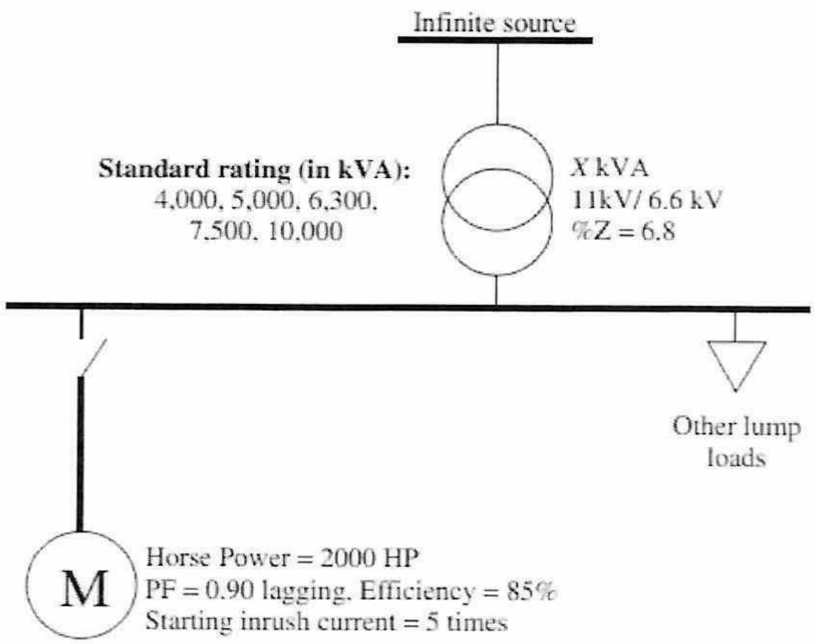

Figure Q1(b)

Table Q2(b)

Month	Monthly Average Consumption (kW)
January	70
February	45
March	45
April	48
May	60
June	52
July	72
August	65
September	68
October	80
November	75
December	60

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Table Q2(c)

Load Description	**Ratings (VA)**	**Nos (Unit)**	**Autonomy Time (Hours)**
Distributed Control System Cabinet	400	12	5
Electrostatic Discharge	460	10	6
Telecommunications Cabinet	200	5	9
Computer Console	140	6	3
HMI Units	200	10	5

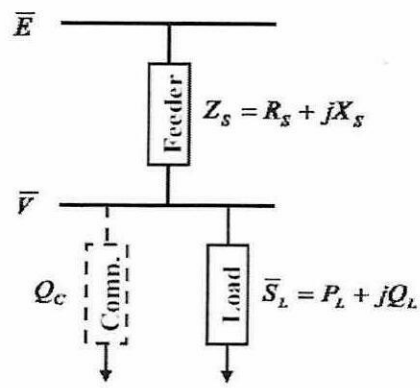

Figure Q3(d)

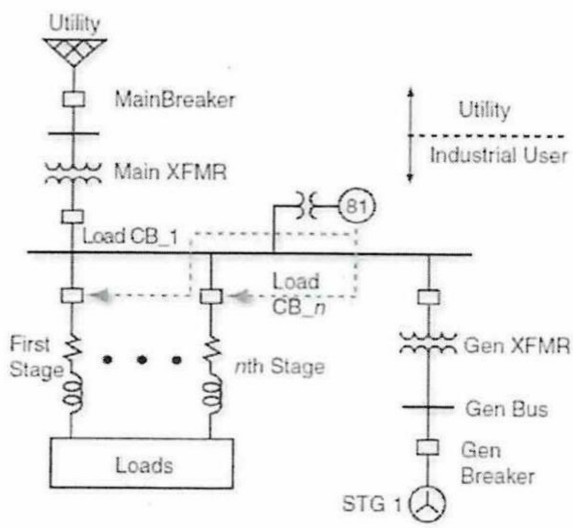

Figure Q3(e)

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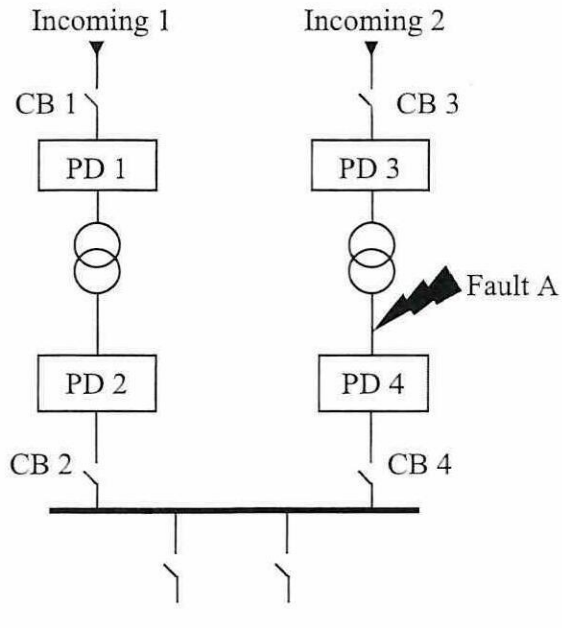

Figure Q4(b)

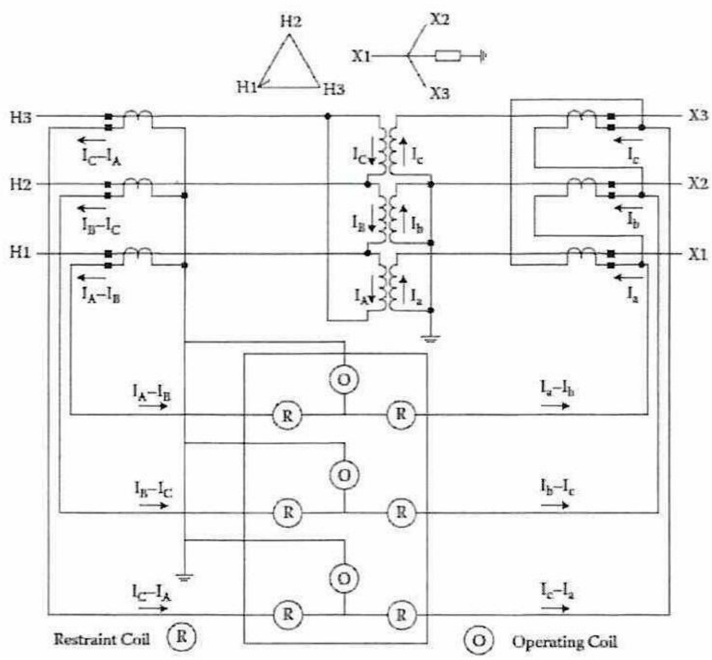

Figure Q4(c)

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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. (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