Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	INDUSTRIAL POWER SYSTEM
COURSE CODE	:	BNE 43203
PROGRAMME CODE	:	BNE
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) A distribution transformer is to be installed at the basement area of Factory X. Recommend proper type of the distribution transformer that will be suitable for this installation by discussing **THREE (3)** main technical aspects.

(3 marks)

(b) **Table Q1(b)** depicts the load utilisation in a manufacturing factory with its utilisation factor (*ku*). Demand estimation has to be made for these loads based on proper utilisation factor (*ku*) and diversity factor (*ks*). Three (3) levels of diversity factor needs to be assumed which are at the distribution box (DB), plant distribution box (PDB) and main general distribution board (MGDB) before connecting to the distribution transformer.

(i) Complete the electrical block diagram for the installation by determining the diversity factor, *ks* using **Table Q1(b)(i)**.

(5 marks)

(ii) Analyse the estimated demand at each PDB in **Table Q1(b)(i)**.

(3 Marks)

(iii) Decide the total estimated demand to be connected at the distribution transformer.

(2 marks)

(iv) Propose the minimum supply scheme for the total demand in **Q3(b)(iii)**.

(2 marks)

(c) The installed distribution transformer as mentioned in **Q1(b)** is rated at 11 kV/ 400 V and operating at 50 Hz. 3-core copper, XLPE power cables are laid from the distribution transformer to the MGDB. The cables are laid 120 cm underground in horizontal formation with 60 cm spacing to each other. The number of cables in a group is 2 Nos. The ground ambient temperature is 40 °C and the thermal resistivity of soil is 150 °C cm/Watt.

(i) If the fault clearing time of the network is 8 cycles with the short circuit capacity (kVASC) of 200 times the loading, select the initial size of the cable based on the short circuit current withstand capacity criteria.

(4 marks)

(ii) Evaluate again the cable size as identified in **Q1(c)(i)** by considering the continuous current carrying capacity criteria.

(6 marks)

Q2 (a) A 50 Hz 11 kV industrial feeder is serving by 0.5 km 3-core armoured XLPE 120 mm2 underground cable to its Motor Control Centre (MCC). The average power consumption and maximum power in a month for this MCC are 1943 kW and 2915 kW respectively. The power factor for this installation is assumed as 0.85 lagging. Assume the total day for a month is 30 days.

(i) Apply estimated losses calculation approach to detemine the monthly power losses for this feeder. Consider k=0.2 and the conductor resistance for 120 mm^2 cable is 0.196 Ω/km.

(3 marks)

(ii) Evaluate again the monthly power losses if the feeder loading is being split evenly using **TWO (2)** cables of 35mm^2. Formulate the percentage different between the results in **Q2(i)** and **Q2(ii)**. Assume the conductor resistance for 35 mm^2 cable is 0.668 Ω/km.

(5 marks)

(iii) Conclude the impact on power losses for both installation methods as in **Q2(i)** and **Q2(ii)**.

(1 mark)

(b) The critical load for an industrial packaging plant supplied by uninterruptable power supplies (UPS) during power outage period is given in **Table Q2(b)(i)**. The block diagram of the proposed UPS and its main configuration is shown in **Figure Q2(b)**. The characteristics of the proposed UPS is given in **Table Q2(b)(ii)**.

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

(4 marks)

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

(4 marks)

(iii) Construct an UPS system that consists of battery bank, rectifier, static switch and inverter systems if the desired AC voltage output is 415V.

(7 marks)

(iv) Summarise typical consequences when having improper battery sizing.

(1 mark)

Q3 (a) State **THREE (3)** benefits of load shedding scheme to industrial consumers.

(6 marks)

(b) A factory having a load shedding scheme with the load reduction factor (d) of 2. The MVA base for the load shedding calculation is 10 MVA and the standard frequency variation (f) is $\pm 1\%$. The factory is fed with 50 Hz (f_0) supply and the overall power factor is to be assumed as 0.85. The frequency variation during the load shedding is given as:

$$f = \frac{1 + \frac{d-1}{d}\Delta P}{1 + \Delta P} f_0$$

Determine the relative overload (ΔP) to be shed in kW based on the frequency tolerance set by the plant.

(5 marks)

(c) Discuss the drawbacks of Breaker Interlock Scheme in load shedding system.

(4 marks)

(d) Typically, the load shedding scheme in industry can be managed either via the conventional Programmable Logic Controller (PLC) Based or the new-tech Intelligent Load Shedding (ILS) method.

(i) Explain the Intelligent Load Shedding (ILS) in terms of the working concept, necessity and response parameters.

(6 marks)

(ii) Construct the recommended operation logic flow chart of expert system considerations for the load shedding procedure.

(4 marks)

Q4 (a) A large industrial plant receives 3-phase electric power from the local utility. The following loads are being fed in the plant at 11.0 kV:

- 1.2 + j 1.2 MVA
- 2.0 MW at 0.8 (lag) power factor
- 800 kW of pure heating and lighting (negligible reactive power) load
- A number of induction motors: total power output of 3,000 HP, with a composite efficiency of 0.85 and power factor of 0.88 (lag)

(i) Analyse the total active power, reactive power and apparent power.

(5 marks)

(ii) Compute the overall (composite) load power factor and the full load current.

(3 marks)

(iii) Plan the capacitive VAR requirements for the capacitor bank if the overall plant power factor is to be improved to 0.95 lag.

(2 marks)

(iv) Draw the phasor diagram of the power triangle for the power factor correction.

(2 marks)

(b) Give **THREE (3)** possible root causes of fault to be happened in industrial power system.

(3 marks)

(c) **Figure Q4(c)** shows a partial industrial installation with two incoming sources and its appropriate protective devices (PD).

(i) Choose proper type of protective device for PD 1 to PD 4 in order to minimise the tripping area with the occurrence of Fault A as shown in the **Figure Q4(c)**.

(2 marks)

(ii) Sketch and explain the circulation of short circuit current and the operation of the protective devices.

(5 marks)

(d) Typically during motor starting, there is high induced current that builds-up in the rotor which results excessive current peak that could jeopardise the winding and insulation in the motor itself. Thus, a proper starting method is normally used on the industrial scale motor in order to reduce this problem. Analyse the typical star-delta motor starting circuit in terms of the principles used when starting the motor.

(3 marks)

- END OF QUESTIONS –

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Table Q1(b)

Load utilisation	Apparent power (kVA)	Utilisation factor (ku)
Plant A		
Lathe No. 1	8	0.8
Lathe No. 2	10	0.8
Lathe No. 3	15	0.8
10 Socket Outlets, 16/ 20A	43	1.0
40 Fluorescent Lamps	2	1.0
Plant B		
Compressor	25	0.8
Heater	15	1.0
5 Socket Outlets, 16/ 20A	20	1.0
15 Fluorescent Lamps	1	1.0
10 Motors, each rating at 10 kW	120	0.8
Plant C		
Ventilation	4.5	1.0
Oven	20	1.0
40 Socket Outlets, 16/ 20A	170	1.0
25 Fluorescent Lamps	1.5	1.0

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Table Q1(b)(i)

Load Utilisation	S	ku	Sku	ks 1	SDB	ks 2	SPDB	ks 3	SMGDB
Plant A									
Lathe No. 1	8	0.8							
Lathe No. 2	10	0.8							
Lathe No. 3	15	0.8							
10 Socket Outlets, 16/ 20A	43	1							
40 Fluorescent Lamps	2	1							
Plant B									LV/MV
Compressor	25	0.8							
Heater	15	1							
5 Socket Outlets, 16/ 20A	20	1							
15 Fluorescent Lamps	1	1							
10 Motors, each rating at 20 kW	120	0.8							
Plant C									
Ventilation	4.5	1							
Oven	20	1							
40 Socket Outlets, 16/ 20A	170	1							
25 Fluorescent Lamps	1.5	1							

Table Q2(b)(i)

Load Description	Ratings (VA)	Nos (Unit)	Autonomy Time (Hours)
Distributed Control System Cabinet	400	10	5
Electrostatic Discharge	450	10	6
Telecommunications Cabinet	200	4	8
Computer Console	120	6	3
HMI units	200	10	5

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Table Q2(b)(ii)

Characteristics	Value
Output voltage	120 Vdc
Depth of discharge	85%
Battery ageing factor	25%
Temperature correction factor for vented cell at 30°C	0.93
Capacity rating factor	8%
Recharge efficiency factor	1.1
Minimum recharge time	3 hours

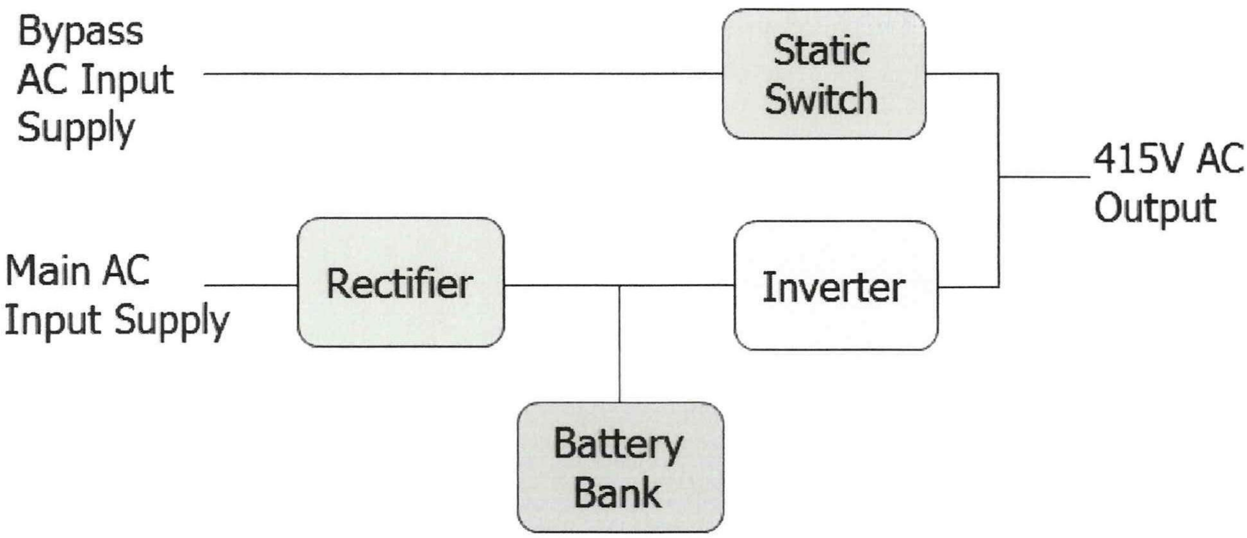

Figure Q2(b)

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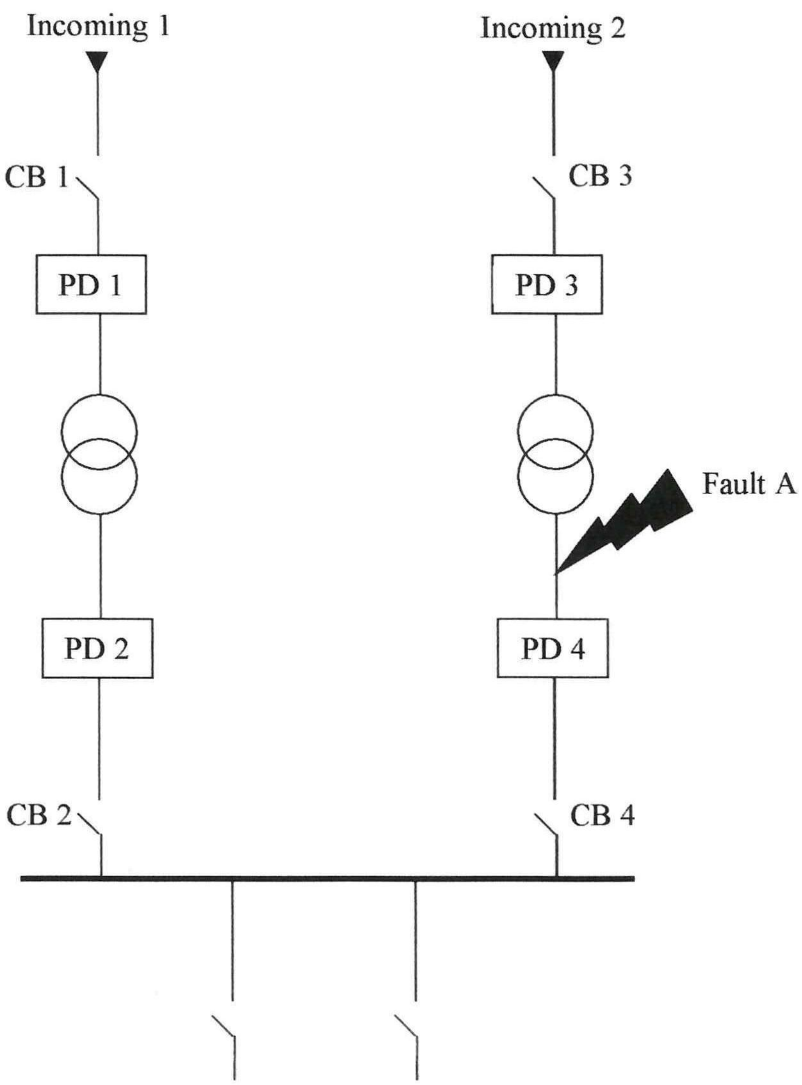

Figure Q4(c)

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APPENDIX A

The minimum cable size due to short circuit temperature rise:

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

where,
A = Minimum required cross section area in mm^2
t = The duration of the short circuit in second
K = Short circuit temperature rise constant

The temperature rise constant (K) according to IEC 60364-5-54:

$$K = 226\sqrt{In\left(1+\frac{T_2 - T_1}{234.5 + T_1}\right)} \quad \text{.....(for copper conductors)}$$

$$K = 148\sqrt{In\left(1+\frac{T_2 - T_1}{228.1 + T_1}\right)} \quad \text{.....(for aluminium conductors)}$$

where,
T_1 = the initial conductor temperature in °C
T_2 = the final conductor temperature in °C

Table A1: Boundary conditions of initial (T_1) and final (T_2) temperature for different insulation:

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

Standard Cable Size (mm^2):

1, 1.5, 2.5, 4, 6, 10, 16, 25, 35, 50, 70, 95, 120, 150, 185, 240, 300, 400.

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APPENDIX B

TABLE 4E4A – Multicore 90 °C armoured thermosetting insulated cables (COPPER CONDUCTORS)

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 90 °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 1 four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or 1 four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or 1 four-core cable, three-phase a.c.
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	27	23	29	25	25	21
2.5	36	31	39	33	33	28
4	49	42	52	44	43	36
6	62	53	66	56	53	44
10	85	73	90	78	71	58
16	110	94	115	99	91	75
25	146	124	152	131	116	96
35	180	154	188	162	139	115
50	219	187	228	197	164	135
70	279	238	291	251	203	167
95	338	289	354	304	239	197
120	392	335	410	353	271	223
150	451	386	472	406	306	251
185	515	441	539	463	343	281
240	607	520	636	546	395	324
300	698	599	732	628	446	365
400	787	673	847	728	-	-

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APPENDIX C

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