UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEF 44903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	DECEMBER 2019/ JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FOURTEEN (14)** PAGES

Q1 (a) (i) Name **two (2)** main purposes of distribution system planning.

(2 marks)

(ii) Explain the main protection problem that might face by substation with two transformers which operate in parallel on the same busbar.

(1 mark)

(b) A 4,000 kVA, 11 kV / 6.6 kV with 7 % impedance distribution transformer is to be installed to serve an industrial motor pump as illustrated in **Figure Q1(b)**.

(i) Identify the percentage voltage drop at power transformer secondary terminal during the starting of the large motor.

(6 marks)

(ii) Choose the proper size 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 %.

(6 marks)

(c) The distribution transformer in **Q1(b)(ii)** is to be protected using a differential protection scheme against overcurrent. The step-down transformer is connected in '*Delta-Grounded Star*' configuration. A percentage differential relay with 8 % slope setting is utilised for this overcurrent protection scheme. The primary side current transformer ratio is given as 10 : 1.

(i) Investigate the appropriate secondary current transformer ratio.

(4 marks)

(ii) Analyse the differential percentage between the incoming current and the outgoing current with the proposed current transformer ratio as given in **Q1(c)(i).**

(4 marks)

(iii) Predict the minimum secondary current that can activate the differential relay if the primary current is assumed to be constant.

(2 marks)

Q2 (a) Define the cooling method designations of *ONAF* and *ODWF* used in distribution transformer.

(2 marks)

(b) **Figure Q2(b)** shows a simplified industrial installation for a motor loading. The resistance and reactance for *Cable 1* and *Cable 2* is given in **Table Q2(b)**.

(i) Investigate the short circuit current using per unit approach if a symmetrical three-phase fault occurred at "*Fault A*". Take the calculation base as 10 MVA and the asymmetrical factor is corresponding to the following expression:

$$\kappa = 1.02 + 0.98e^{-3\frac{R}{X}}$$

(10 marks)

(ii) Plan a proper protective device for the motor terminal based on the result obtained in **Q2(b)(i)**.

(2 marks)

(c) **Table Q2(c)** depicts the loads of *Motor Control Centre (MCC)* in an electronic factory. The loads consist of normal, *N* and standby, *S* duty cycle. The standby loads should be considered as 50 % of its nominal rating. The *MCC* is served with a three-phase cable installed from the 415 V main switchgear feeder. The insulation and the conductor type of the cable are *EPR* and copper, respectively. The short circuit current capacity is to be assumed as 100 times of the *MCC* load current and the fault clearing time is taken as 0.5 second.

(i) Analyse the minimum size of the cable required based on the short circuit withstand capacity criteria.

(8 marks)

(ii) Evaluate again the cable size obtained in **Q2(c)(i)** for continuous current carrying capacity criteria based on **Appendix A**. The cable is directly clipped on the wall with the ambient temperature of 30°C. The cable is laid on 2 cable rack with the number of cables / rack is to be 3. Recommend the new cable size if necessary.

(3 marks)

Q3 (a) List **two (2)** monitoring types perform by voltage control relay.

(2 marks)

(b) Consider a feeder supply at 6.35 kV line to neutral voltage, $\overline{E}$ with short circuit level of 200 MVA and X_S/R_S ratio of 5 as depicted in **Figure Q3(b)**. The feeder is supplying a star connected inductive load of $S_L = 10\ MW + j\ 20\ MVAr$ per phase.

(i) Examine the load bus voltage, $\overline{V}$.

(7 marks)

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

(1 mark)

(iii) If the load bus voltage is to be maintained as at the supply bus voltage $\overline{E}$, analyse the reactive power that should be supplied by the compensator (Comp.).

(6 marks)

(c) A small scale industrial plant is designed to having load shedding scheme activated when its lines are overloaded based on the parameters as shown in **Table Q3(c)**. The plant corresponded main power distribution circuit is shown in **Figure Q3(c)**.

(i) Plot a graph that outlining the timeline cycle as pickup by *'Relay 81'* in **Figure Q3(c)** to activate load shedding procedure by conventional frequency monitoring device.

(4 marks)

(ii) On the same answered graph, plot another timeline cycle that indicate load shedding response procedure as pickup by an *'Intelligent Load Shedding (ILS)'* monitoring device.

(2 marks)

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

(3 marks)

Q4 (a) Summarise **one (1)** variable that can give direct impact to the magnitude of the capacitor switching transient.

(2 marks)

(b) A proper starting method is important on the industrial scale motor in order to reduce excessive overcurrent that could jeopardise the winding and insulation in the motor itself. The *STAR-DELTA* circuit configuration in **Figure Q4(b)** is the most commonly favourable by industry.

(i) Explain how the excessive start-up time and locked rotor current can contribute to overheated condition.

(4 marks)

(ii) Analyse in brief *STAR-DELTA* circuit in terms of the principles used when starting the motor, the voltages, resultant currents and torques.

(5 marks)

(c) **Table Q4(c)** depicts the average measurement results for an industrial electric pump with variable speed control.

(i) Analyse the percentage different between the three-phase fundamental active power, P_{fund} and the three-phase average active power, P_{avg}.

(4 marks)

(ii) Determine the percentage of total harmonic distortion, $\%THD$ for three-phase voltage and current.

(4 marks)

(iii) Derive the formulae that show relationship between $\%THD$ and total RMS voltage, V_{rms} and total RMS current, I_{rms}.

(4 marks)

(iv) Compare the true three-phase power factor, PF_{true} and the harmonic displacement three-phase power factor, PF_{dis}.

(2 marks)

– END OF QUESTIONS –

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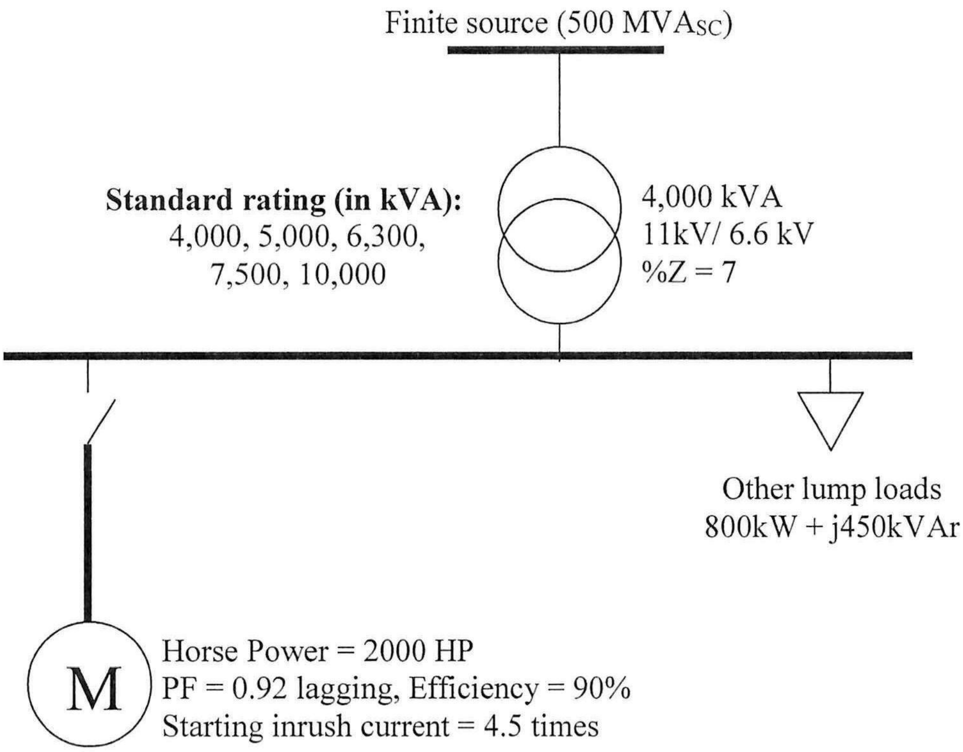

Figure Q1(b)

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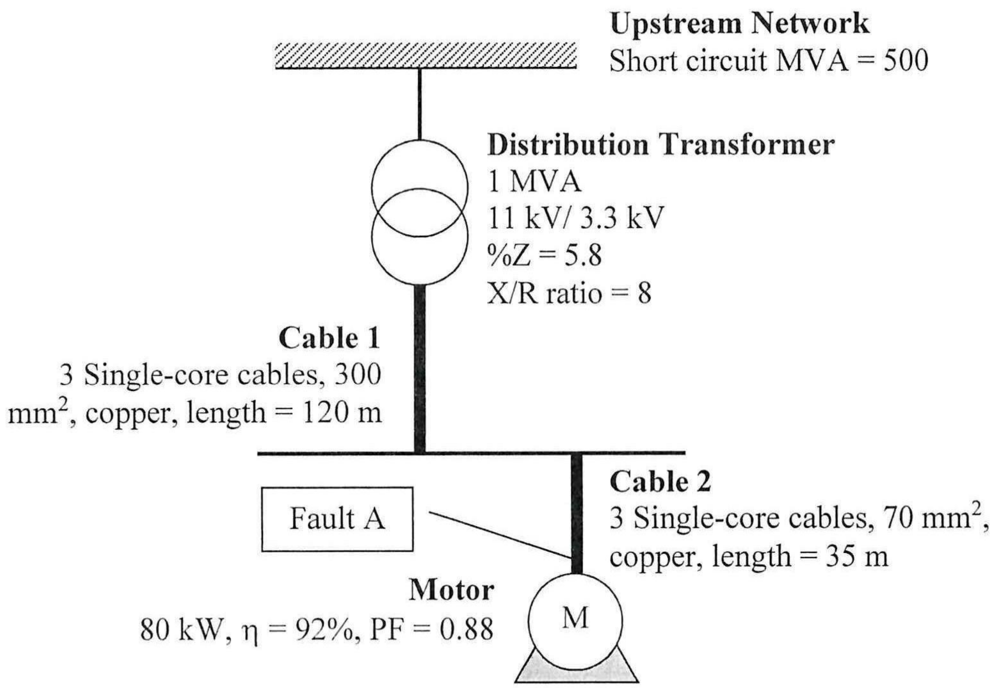

Figure Q2(b)

Table Q2(b)

LOW VOLTAGE XLPE INSULATED POWER CABLES

TABLE 1B SINGLE-CORE 600/1000V ARMOURED CABLES (COPPER CONDUCTOR)

Conductor Nominal Area	Conductor Shape	Thickness of Insulation	Thickness of Extruded Bedding	Nominal of Armour Diameter	Thickness of Outer Sheath	Overall Diameter	Approx. Weight	Current Rating In Air at 40ºC	Current Rating In Ground at 25ºC	Conductor Resistance dc at 20ºC	Conductor Resistance 50Hz at 90ºC	Reactance at 50Hz	Short Circuit Current for 1 sec
sq. mm		mm	mm	mm	mm	mm	kg/km	amp	amp	Ω/km	Ω/km	Ω/km	kA
50		1.0	0.8	0.9	1.5	17.3	740	200	205	0.387	0.494	0.113	7.15
70		1.1	0.8	1.25	1.5	19.8	1020	255	250	0.268	0.342	0.107	10.0
95	circular	1.1	0.8	1.25	1.6	21.9	1330	310	300	0.193	0.247	0.102	13.5
120	stranded	1.2	0.8	1.25	1.6	24.0	1610	365	340	0.153	0.196	0.101	17.1
150		1.4	1.0	1.6	1.7	27.1	2030	415	385	0.124	0.159	0.0999	21.4
185	or	1.6	1.0	1.6	1.8	29.6	2460	480	435	0.0991	0.128	0.0975	26.4
240		1.7	1.0	1.6	1.8	32.4	3080	570	500	0.0754	0.0982	0.0946	34.3
300	circular	1.8	1.0	1.6	1.9	35.2	3750	650	565	0.0601	0.0793	0.0920	42.9
400	compacted	2.0	1.2	2.0	2.0	40.0	4830	760	635	0.0470	0.0632	0.0923	57.2
500		2.2	1.2	2.0	2.1	44.1	6040	870	715	0.0366	0.0509	0.0903	71.5
630		2.4	1.2	2.0	2.2	48.3	7430	995	800	0.0283	0.0415	0.0878	90.0
800		2.6	1.4	2.5	2.4	54.8	9550	1150	890	0.0221	0.0347	0.0863	114.0
1000		2.8	1.4	2.5	2.5	60.0	11750	1250	940	0.0176	0.0300	0.0847	143.0

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Table Q2(c)

Load description	Duty cycle (N or S)	Motor rating (kW)	Operating motor power (kW)	Power Factor	Efficiency (%)
Hoist system	N	64	56	0.80	88
Cooling tower fan 1	N	20	17	0.86	92
Cooling tower fan 2	S	20	17	0.86	92
Heater	N	35	-	-	-
Water pump	N	65	58	0.82	94
Future pump	S	10	8.8	0.90	85
Compressor	N	25	22	0.88	90

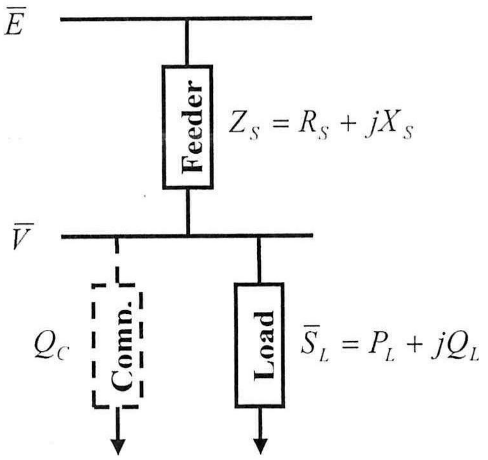

Figure Q3(b)

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Table Q3(c)

Plant Parameter	Value
Load reduction factor	1.5
Fundamental frequency	60 Hz
Frequency tolerance	± 1.5 %
Base apparent power	1.5 MVA
Overall p.f	0.85

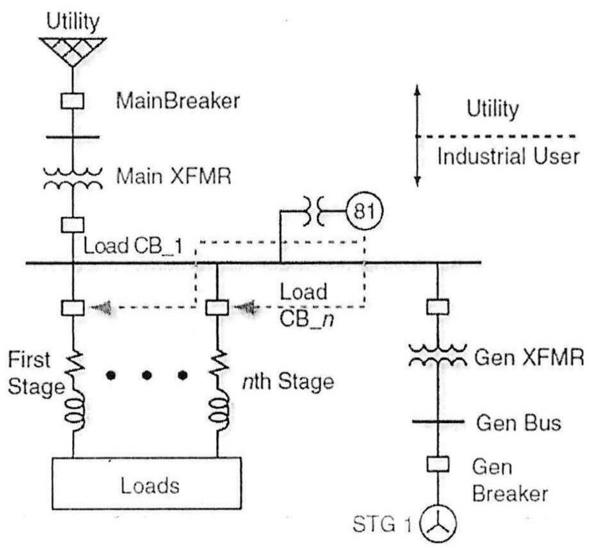

Figure Q3(c)

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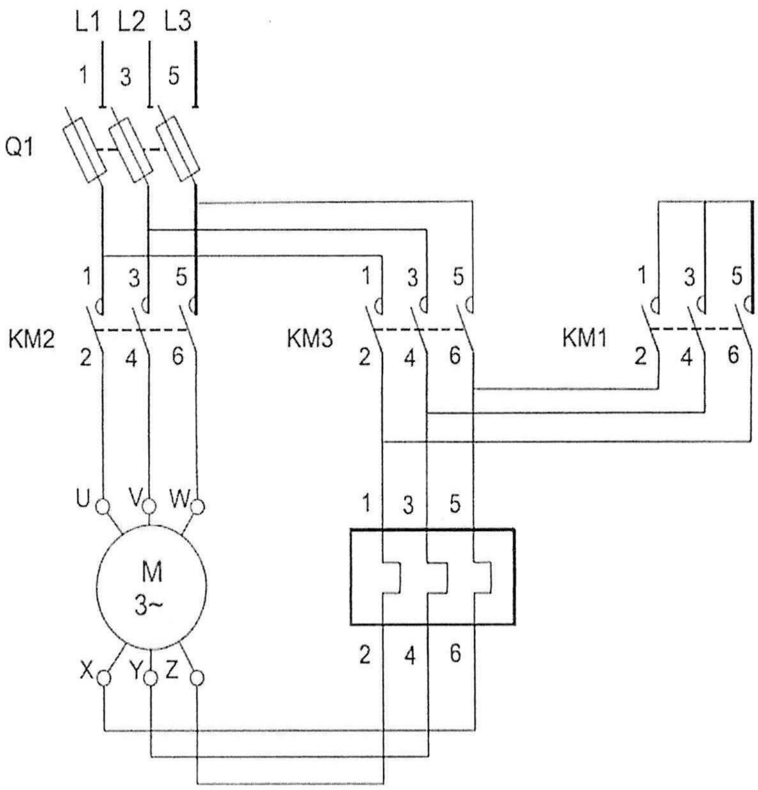

Figure Q4(b)

Table Q4(c)

Frequency (Hz)	Voltage (V)	Current (A)
50	412∠0°	29∠-27°
250	85∠10°	5.8∠-10°
350	31∠25°	3.2∠80°
550	12∠6°	1.3∠-50°
650	7∠15°	0.03∠-30°

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Appendix A

Air Temp. (°C)	20	25	30	35	40	45	50	55
Rating Factor	1.81	1.41	1.10	1.05	1.00	0.95	0.89	0.84

No. of racks	No. of cables per rack				
	1	2	3	6	9
1	1.00	0.84	0.80	0.75	0.73
2	1.00	0.80	0.76	0.71	0.69
3	1.00	0.78	0.74	0.70	0.68
6	1.00	0.76	0.72	0.68	0.66

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
(mm²)	(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	-	-

TERBUKA

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Appendix B

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

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

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

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Appendix C: Formulae

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$Q_N = Q_L + Q_C$$

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

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

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

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

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

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