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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2017/2018

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEF 44903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	DECEMBER 2017/JANUARY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

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Q1 (a) (i) List down **three (3)** types of primary distribution lines in power system.

(2 marks)

(ii) Briefly explain the most reliable primary distribution line in **Q1(a)(i).**

(1 mark)

(b) (i) Instrument transformers (IT) are high accuracy class electrical devices used to isolate or transform voltage or current levels. Write the primary applications of instrument transformer in industrial power systems.

(2 marks)

(ii) Oil-filled, non-flammable liquid-filled and dry type are the commonly power transformer used in distribution system. Show **two (2)** differences between oil-filled and dry type power transformer.

(4 marks)

(c) **Figure Q1(c)** shows single line diagram of small industrial plant. A distribution transformer is to be installed to serve a motor loading. The transformer will be connected to a finite bus that having a short circuit capacity of 500 MVA.

(i) Analyse the short circuit capacity of the transformer (in kVA).

(4 marks)

(ii) Calculate the voltage variation during the motor starting.

(5 marks)

(iii) The fault clearing time (t_c) of the circuit breaker/ fuse is to be assumed as 10 cycles for low voltage breakers with intermediate/short time delay. The conductor type for marked as "*Cable A*" is copper with XLPE insulation. The final (T_2) and initial temperatures (T_1) are given in **Table Q1(c)(iii)**. Identify the constant K for *Cable A* based on the *Equation (1)* in *Appendix A.*

(2 marks)

(iv) If the standard rating for Circuit Breaker 1 (CB 1) to be chosen as 45 kA, select the minimum size (in mm^2) of *Cable A* due to short circuit temperature rise and *Equation (2)* in *Appendix A.*

(3 marks)

(v) With standard rating of 45 kA for Circuit Breaker 1 (CB 1), estimate the total short circuit kVA to protect the transformer.

(2 marks)

Q2 (a) Name **two (2)** benefits of improving energy efficiency in industrial power systems.
(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. A XLPE cable with resistance of 0.128 Ω/km is laid from the feeder to the load point with the cable length of 0.6 km. The loss constant, k is assumed as 0.15 and the average power factor is 0.85 lagging.

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

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

(c) A solar power system, as depicted in **Figure Q2(c)**, is to be installed in a factory power backup for important loads. The list of the loads and its autonomy time is given in **Table Q2(c)(i)**. The characteristics of the proposed solar system is given in **Table Q2(c)(ii)**.

(i) Survey the load profile (VA versus period in hour) of the loading.
(4 marks)

(ii) Point out the peak design load (in kVA) and design energy demand (kVAh) if the future load growth and design margin are both considered as 10%
(4 marks)

(iii) Investigate the maximum and minimum number of cells required for the battery bank if the desired nominal battery voltage is 125 V.
(2 marks)

(iv) Analyse the minimum battery capacity required for this solar power system.
(2 marks)

(v) Point out the current rating for the battery charger.
(2 marks)

(vi) Predict the minimum size (in kW) of the solar panel that should be installed if the daily sunny period is assumed as 5 hours.
(3 marks)

Q3 (a) Explain technically how the power factor correction (PFC) installed in industrial power system might reduce the demand charges.

(3 marks)

(b) Identify three common issues in power factor corrector.

(6 marks)

(c) A 12 units, 6 steps power factor corrector is to be installed in the milling factory having active and reactive power of 100kW and 59.33kVAr, respectively under voltage supply of 415V. The voltage rating of the capacitors used in the power factor corrector is 515 V. The power factor corrector has the step arrangement of 1 : 1 : 2 : 2 : 3 : 3 with 5kVAr for each unit of capacitor.

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

(4 marks)

(ii) Examine the effective reactive power (Q_{Ceff}) to be supplied by capacitor bank and the steps that the power factor corrector to be switched ON.

(4 marks)

(iii) Estimate the actual average power factor for the system.

(6 marks)

(iv) Recommend a new system if 3.3kVAr per unit of capacitor is to be used in the factory.

(2 marks)

Q4 (a) Describe **two (2)** monitoring systems that should be placed at the incoming switchgear.

(2 marks)

(b) A simplified power system for a manufacturing plant is depicted in **Figure Q4(b)**. The priority of the load block is defined as follows:

- Vital load block – L A1, L B1
- Semi-vital load block – L A2, L B2, L C2
- Non-vital load block – L A3, L B3, L C1, L C3

Prepare appropriate load shedding scheme for this plant. Show all design steps systematically.

(6 marks)

(c) A factory is having a load shedding scheme with load reduction factor (d) of 2. The MVA base for the load shedding calculation is taken as 10 MVA and the standard frequency variation (f) is 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:

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

Predict the relative overload (ΔP) that to be shed in kW.

(3 marks)

(d) **Figure Q4(d)** illustrates a differential protection scheme for a packaging factory. A 50 Hz, 1.5 MVA step-down transformer is connected in Delta-Grounded Star configuration with voltage level of 11 kV – 415 V. A percentage differential relay with 10% slope setting is utilised for this overcurrent protection scheme. The primary side current transformer ratio is given as 10 : 1.

(i) Point out proper value for secondary current transformer ratio.

(5 marks)

(ii) Analyse the differential percentage between the incoming current and the outgoing current with the proposed current transformer ratio as given in Q4(d)(i).

(5 marks)

(iii) Select the minimum secondary current to activate the percentage differential relay if the primary current is assumed to be constant.

(4 marks)

– END OF QUESTIONS –

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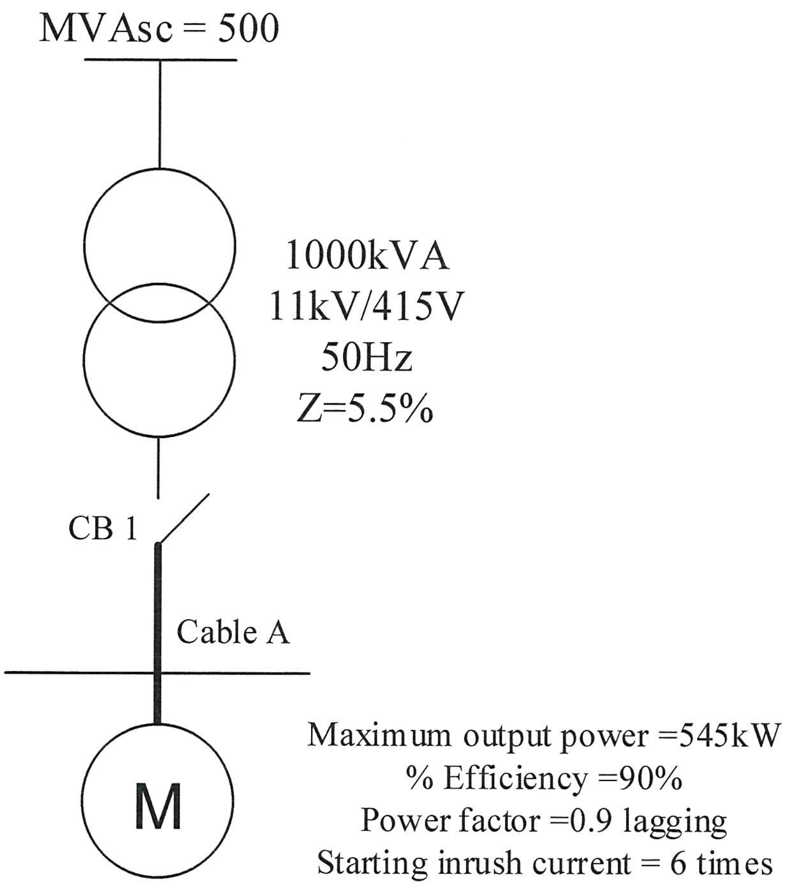

Figure Q1(c)

Table Q1(c)(iii): Boundary conditions of initial (T_1) and final (T_2) temperature for XLPE/EPR insulation:

Insulation material	Final temperature, T_2 (°C)	Initial temperature, T_1 (°C)
XLPE/ EPR	250	90

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Table Q2(b)

Month	Monthly Average Consumption (kW)
January	60
February	45
March	50
April	48
May	56
June	52
July	62
August	65
September	68
October	72
November	75
December	64

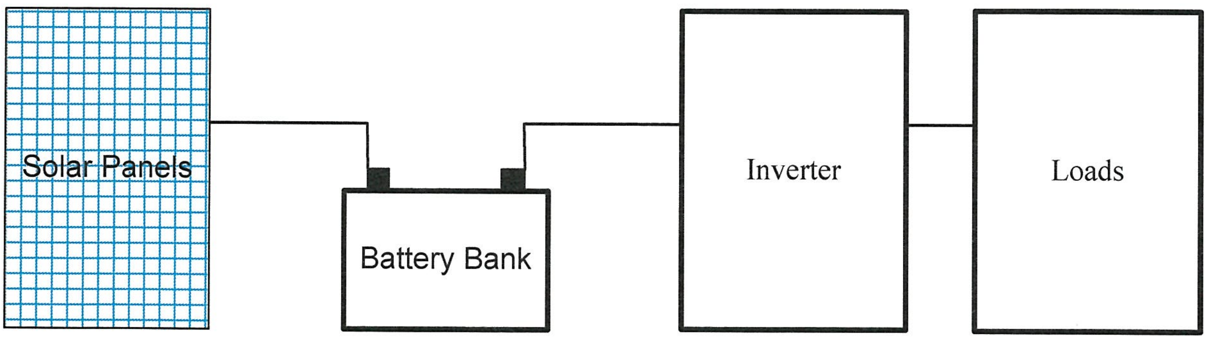

Figure Q2(c)

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Table Q2(c)(i)

Loading	Rating (VA)	Nos (Unit)	Autonomy Time (Hours)
Lighting	20	50	8
Telecommunication Cabinet	200	5	24
Distributed Control System Cabinet	400	8	5
Computer Console	150	12	3

Table Q2(c)(ii)

Item	Value
Output Voltage	125 V_{dc}
Load voltage tolerance	± 10 %
Cell charging voltage	2.25 V_{dc}
Cell end of discharge voltage	2.00 V_{dc}
Depth of discharger (k_{dod})	85%
Battery ageing factor (k_a)	25%
Temperature correction factor at 35°C (k_t)	0.93
Capacity rating factor (k_c)	10%
Recharge efficiency factor	1.1
Recharge time (T)	10 hours
Continuous load current (L)	20 A

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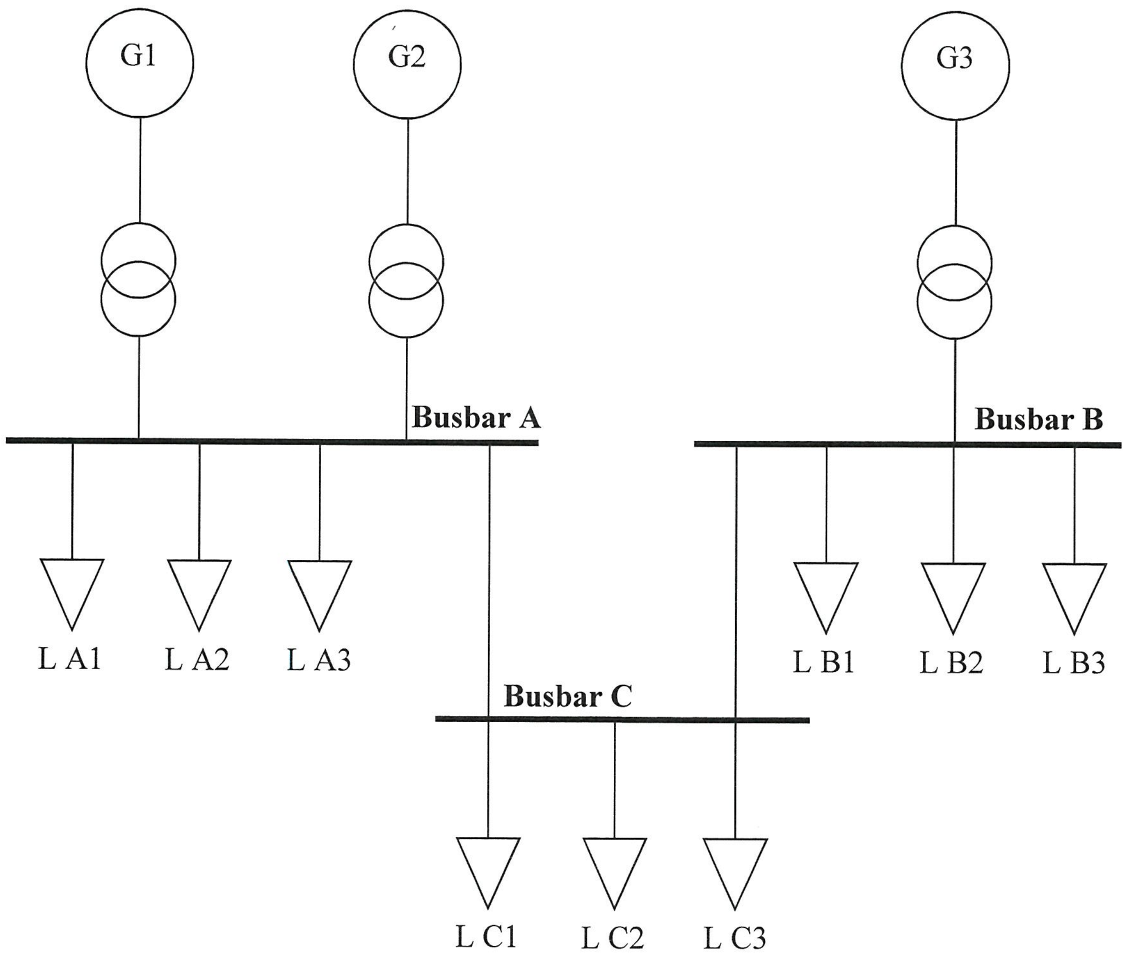

Figure Q4(b)

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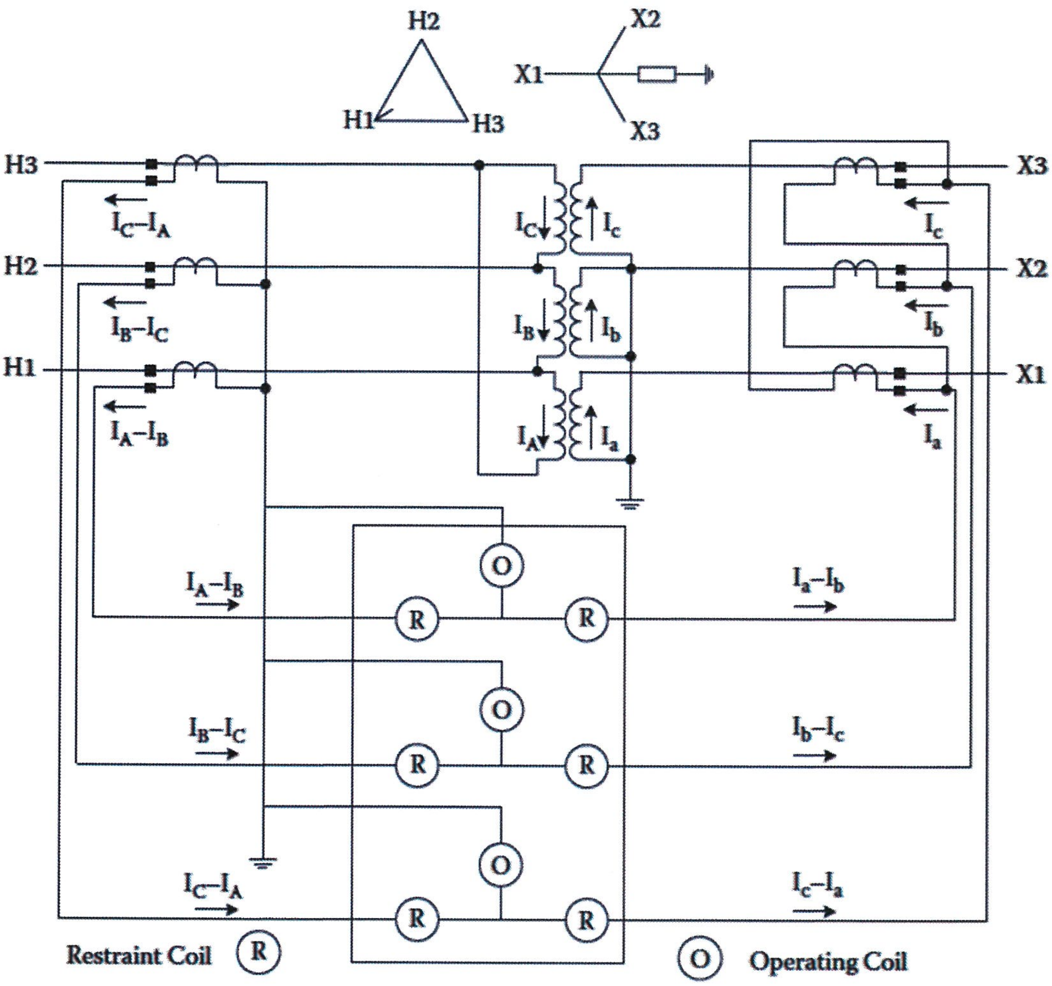

Figure Q4(d)

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Appendix A

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

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

where,

T_1 = initial conductor temperature in °C
T_2 = final conductor temperature in °C

The minimum cable size due to short circuit temperature rise:

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

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

Load Loss Factor:

$$LLF = k * LF + (1-k) * LF^2 \qquad (3)$$

where,

LF = Load Factor
k = loss constant

Number of cells:

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$$N_{max} = \frac{V_{DC}(1+V_{l,max})}{V_c} \qquad (4)$$

$$N_{min} = \frac{V_{DC}(1-V_{l,min})}{V_{eod}} \qquad (5)$$

where,

N_{max}/ N_{min} = maximum or minimum of cells
V_{DC} = nominal battery voltage
$V_{l,max}$ = maximum load voltage tolerance (%)
$V_{l,min}$ = minimum load voltage tolerance (%)
V_c = cell charging voltage (charge cycle)
V_{eod} = cell end of discharge voltage

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Frequency variation:

$$f = \frac{1 + \frac{d-1}{d}\Delta P}{1 + \Delta P} \qquad (6)$$

where,

d	=	load reduction factor
ΔP	=	relative overload
f	=	frequency variation
f_0	=	system frequency

Minimum battery capacity:

$$C_{\min} = \frac{E_d \times (1 + k_a) \times (1 + k_c) \times k_t}{V_{DC} \times k_{dod}} \qquad (7)$$

where,

C_{min}	=	minimum battery capacity (Ah)
E_d	=	design energy over autonomy time (VAh)
V_{DC}	=	nominal battery voltage
k_a	=	battery ageing factor (%) (25%)
k_c	=	capacity rating factor (%) (10%)
k_t	=	temperature correction factor
k_{dod}	=	maximum depth of discharge (%) (80%)

DC current rating of the battery charger:

$$A = \left[\frac{1.1 \times AH}{T} + L\right] \times \frac{1}{C1} \times \frac{1}{C2} \qquad (8)$$

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where,

AH	=	recharge in ampere-hours
T	=	recharge time [T]
L	=	DC continuous load current [amperes]
$C1$	=	temperature correction (from manufacturer)
$C2$	=	altitude correction factor (from manufacturer)