Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	POWER QUALITY
COURSE CODE	:	BEV 40603
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS TEST IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE TEST CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) **Figure Q1(a)** shows a typical three - phase distribution system. The voltage source is sinusoidal and the system impedance $\mathbf{Z_{sysh}}$ comprises of the source transformer, cable, and any other inductive impedance are present between the voltage source and the point of common coupling (PCC). A nonlinear load is connected to the distribution system at PCC.

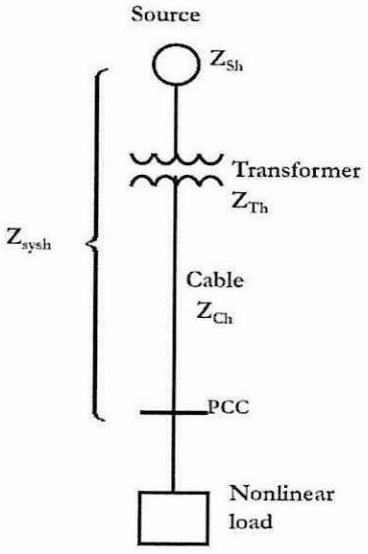

Figure Q1(a): Typical three-phase distribution system

(i) Draw a per phase equivalent circuit to represent the power distribution system.

(4 marks)

(ii) Explain the relationship between the level of voltage distortion and the location in the three-phase distribution system, by considering the effects of harmonic currents generated from the nonlinear load.

(3 marks)

(iii) Based on the answer in **Q1(a)(ii)**, sketch the system voltage in relation with the answer of **Q1(a)(i)** for the following:

(a) at the source (1 marks)
(b) at the cable point (1 marks)
(c) at the load (1 marks)

(b) A variable speed drive (VSD) is rated at 100 HP, 480 V, 50 Hz is supplied by a transformer which is rated at 500 kVA and has 5.75% impedance as shown in **Figure Q1(b)**. The load current is non-sinusoidal and comprises the following harmonic constituents as shown in **Table Q1(b)**.

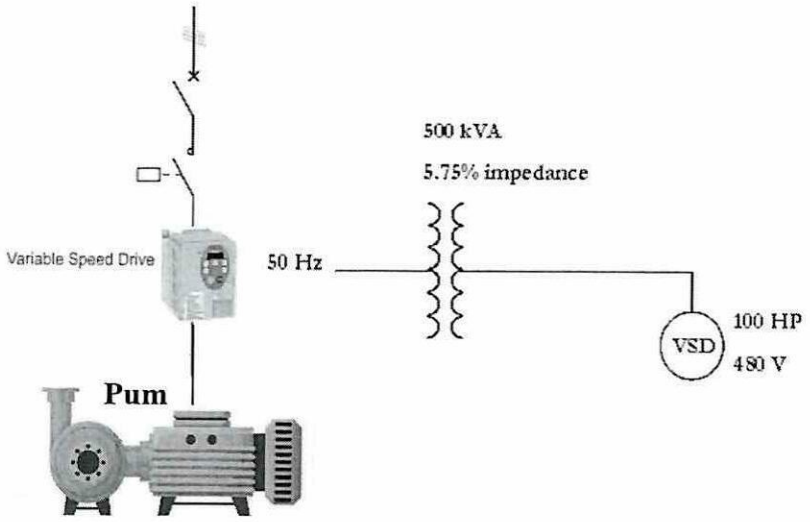

Figure Q1(b): Three-phase distribution system with pump application

Table Q1(b): List of harmonic current.

Harmonic Order	Harmonic Currents
1	124
5	80
7	45
11	18
13	12
17	9
19	5.5

(i) Calculate the actual transformer impedance (Z) on the fundamental frequency. (2 marks)

(ii) Calculate the voltage drop at the transformer impedance (Z) due to the harmonic current for each harmonic order. (9 marks)

(iii) Determine the percentage (%) of load voltage harmonic at the PCC. (4 marks)

Q2 (a) There is concern that may arise from utilizing capacitor in an electrical power system is the possibility of system resonance. Explain with the help of neat diagrams the following resonance phenomenon.

(i) Series resonance (4 marks)

(ii) Parallel resonance (4 marks)

(b) **Figure Q2(b)** shows the example of single-line diagram for an industrial plant. The plant is supplied by 11kV, 50 Hz three-phase distribution feeder from the utility source. The short-circuit happen on the 11 kV system indicates a three-phase short circuit rated at 20 MVA at 11 kV with and X/R ratio of 2.4. The step-down transformer is rated 2000 kVA, 11 kV/415 V and has percentage resistance and reactance of RTR = 1% and XTR = 6.5% respectively. A Y-connected 200 kVAR capacitance bank is connected to the 415 V busbar for power factor correction.

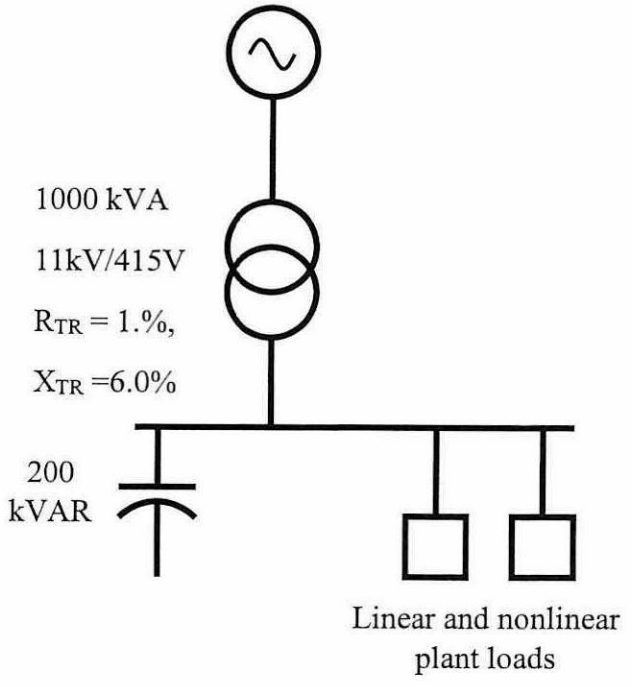

Figure Q2(b)

(i) Determine the parallel resonant frequency of the system. (12 marks)

(ii) Suggest **FIVE (5)** methods of harmonic mitigation to limit the propagation of harmonic current in **Q2(b)(i).** (5 marks)

Q3 (a) The purpose of a harmonic filter is to reduce the harmonic distortion and its adverse effects on the motors and other nearby electronics.

(i) Briefly explain on passive filter and its usage in power quality. (4 marks)

(ii) Sketch a simple power system circuit by showing a passive filter is been applied to reduce the harmonics in the power system network. (4 marks)

(b) **Figure Q3(b)** shows a 2000 kVA, 13.8 kV/480 V transformer with a leakage reactance of 6% and feeding a bus containing two 500 HP variable speed drives. A 750 kVAR Y – connected capacitor bank is installed on the 480 V bus for power factor correction (PFC) mitigation. It is proposed that the capacitor bank is to a detuned 5th harmonic filter.

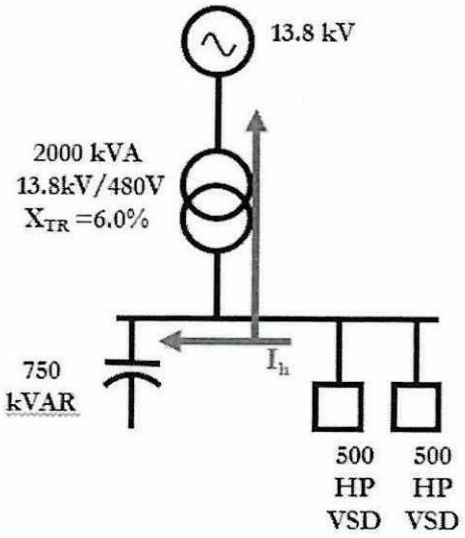

Figure Q3(b)

(i) Calculate and analyze the value of inductor to tune the bank to 4.7th harmonic order. (12 marks)

(ii) Sketch the new 3-phase configuration of tuning inductor with the capacitor bank. (5 marks)

Q4 (a) The main impact of voltage fluctuations is dimming of lights and potential tripping of equipment.

(i) Explain what is a voltage fluctuation. (4 marks)

(ii) State **THREE (3)** main causes of voltage fluctuation. (3 marks)

(iii) Describe the effects of voltage fluctuation on a distribution or transmission line. (3 marks)

(iv) Give **FOUR (4)** examples of loads that are likely to produce voltage fluctuations in the supply voltage. (2 marks)

(v) List **THREE (3)** types of voltage sag and state their durations and magnitudes. (4 marks)

(b) An uninterruptible power supply (UPS) is supplying to a 900 W load which has a lagging power factor of 0.9. The efficiency of the UPS is 90% with an input battery of 12-volt DC. Assume there is a separate charger for the battery. Evaluate the following:

(i) kVA rating of the inverter used in the UPS (3 marks)

(ii) Wattage (W) of the rectifier in the UPS (3 marks)

(iii) Amp hour rating of the battery assuming the backup time is 45 minutes. (3 marks)

- END OF QUESTIONS –

FORMULA

$$R_{sys} = \left[\frac{kV_{LL}^2}{MVA_{SC}}\right] cos\left\{tan^{-1}\left(\frac{X}{R}\right)\right\}$$

$$X_{TR} = X_{pu}\frac{1000(kV_{LL})^2}{kVA_{TR}}$$

$$X_{CAP} = \frac{1000(kV_{CAP})^2}{kVA_{CAP}}$$

$$Z_{base} = \frac{V_{base}^2}{S_{base}}$$

$$\text{Rectifier Wattage} = \frac{\text{kVA rating of inverter} \times \text{P.F}}{\text{Inverter efficiency}}$$

$$\text{I}_{\text{dc}} = \frac{\text{Battery (kW) rating}}{\text{Battery voltage}}$$