



**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER I  
SESSION 2017/2018**

COURSE NAME : POWER QUALITY  
COURSE CODE : BEF 44803  
PROGRAMME CODE : BEV  
EXAMINATION DATE : DECEMBER 2017/JANUARY 2018  
DURATION : 3 HOURS  
INSTRUCTION : 1. ANSWER FIVE (5) QUESTIONS ONLY  
2. CHOOSE ANYONE OF Q3 OR Q4

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

- Q1** (a) Mark and write names of **four (4)** regions of operation of the ITIC curve shown in **Figure Q1(a)**.  
(4 Marks)
- (b) A switchgear busbar is subjected to voltage variations of +19% and -21% from its nominal value lasting for up to 0.40 seconds due to the operation of an automatic welding machine.
- (i) Argue, whether a device that is compliant with the ITIC curve shown in **Figure Q1(a)** tolerate these voltage deviations.  
(2 Marks)
- (ii) By referring to the ITIC curve as shown in **Figure Q1(a)**, deduce the impact if the duration of the voltage swings lasts for 9 seconds.  
(2 Marks)
- (c) Deduce the effects of voltage imbalance on three-phase induction motors.  
(2 Marks)
- (d) Calculate the percent voltage unbalance, if Voltage measurements carried out between the different phases of a three-phase supply gave the following readings:  
R-Y = 470 V  
Y-B = 472 V  
B-R = 450 V  
(10 Marks)
- Q2** (a) Draw step by step (from load to source) distortion in voltage waveform caused by nonlinear loads (drawing non-linear current waveform) in an electrical distribution system (supplying pure sinusoidal voltage).  
(8 Marks)

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- (b) **Figure Q2(b)** shows the single line diagram of a small industrial plant. Where a variable speed drive of 100 HP is supplied by a transformer at 415 V, 50 Hz. The transformer is rated at 500 kVA and 5.75% impedance. The line current drawn by the load is given by the expression:

$$i = 100\cos(\omega t - 30.37^\circ) + 20\cos(5\omega t + 28.08^\circ) + 14\cos(7\omega t - 32.66^\circ) + 8\cos(11\omega t + 25.78^\circ) + 6\cos(13\omega t - 34.78^\circ) + 3\cos(17\omega t + 23.49^\circ) + \cos(19\omega t - 37.24^\circ)$$

Calculate the percent total voltage harmonic distortion (THD<sub>v</sub>) at the point of common coupling (PCC).

(12 Marks)

- Q3** (a) Explain with neat diagrams any **two (2)** of the following harmonic mitigation techniques.

(i) Line reactors.

(4 Marks)

(ii) Isolation transformers.

(4 Marks)

(iii) Tuned harmonic filters.

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(4 Marks)

(iv) 12 & 18 pulse rectifiers.

(4 Marks)

(v) Active harmonic filters.

(4 Marks)

- (b) **Figure Q3(c)** shows the single-line diagram of an industrial plant. The plant is supplied by 11 kV, 50 Hz three-phase distribution feeder from the utility. The short-circuit data on the 11 kV system indicates a three-phase short circuit availability of 20 MVA at 11 kV with an 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 R<sub>TR</sub> = 1% and X<sub>TR</sub> = 6.5%, respectively. A Y-connected 200 kVAR capacitance bank is connected to the 415 V busbar for power factor correction. Determine the parallel resonant frequency of the system.

(12 Marks)

- Q4** (a) (i) Briefly explain passive filter. (4 Marks)
- (ii) Draw a simple power system circuit by showing passive filter applied in it. (4 Marks)
- (b) Calculate L and C parameters of a simple 5<sup>th</sup> harmonic notch filter for a 415 V, 3- $\Phi$ , 50 Hz power system, where harmonics are produced due to a 5 converted supplied load. The power factor correction approach indicates a need for 40 kVAR shunt capacitors. (12 Marks)
- Q5** (a) With the help of a waveform, explain any two (2) of the following the terms:
- (i) Voltage sag. (3 Marks)
- (ii) Voltage interruption. (3 Marks)
- (iii) Voltage swell. (3 Marks)
- (b) Explain the principle of operation of any two (2) of the following sag mitigation technologies.
- (i) Stativ VAR Compensator (SVC). (2 Marks)
- (ii) Uninterruptible Power Supply (UPS). (2 Marks)
- (iii) Static Transfer Switch (STS). (2 Marks)

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- (c) Assume that the motor depicted in **Figure Q5(c)** drives an air compressor in a manufacturing plant. Find the instantaneous voltage drop at the motor terminals any time the compressor starts. Motor data is given as:

- 3000 HP, 3-phase, 4000 V, squirrel cage induction motor
- Full-load current: 377 A
- Locked rotor current: 2070 A

(10 Marks)

- Q6** (a) Give **two (2)** indicators that are used to quantify and evaluate the harmonic distortion in current and voltage waveforms. Illustrate how these indicators are used to determine any necessary corrective action.

(4 Marks)

- (b) Two of the power electronic devices used for voltage sag mitigation are: PWM Shunt Compensator and Dynamic Voltage Restorer.

- (i) Draw their respective appropriate diagrams.

(4 Marks)

- (ii) Write their corresponding relevant equations.

(4 Marks)

- (iii) Examine their own principles of operation.

(8 Marks)

- END OF QUESTIONS -

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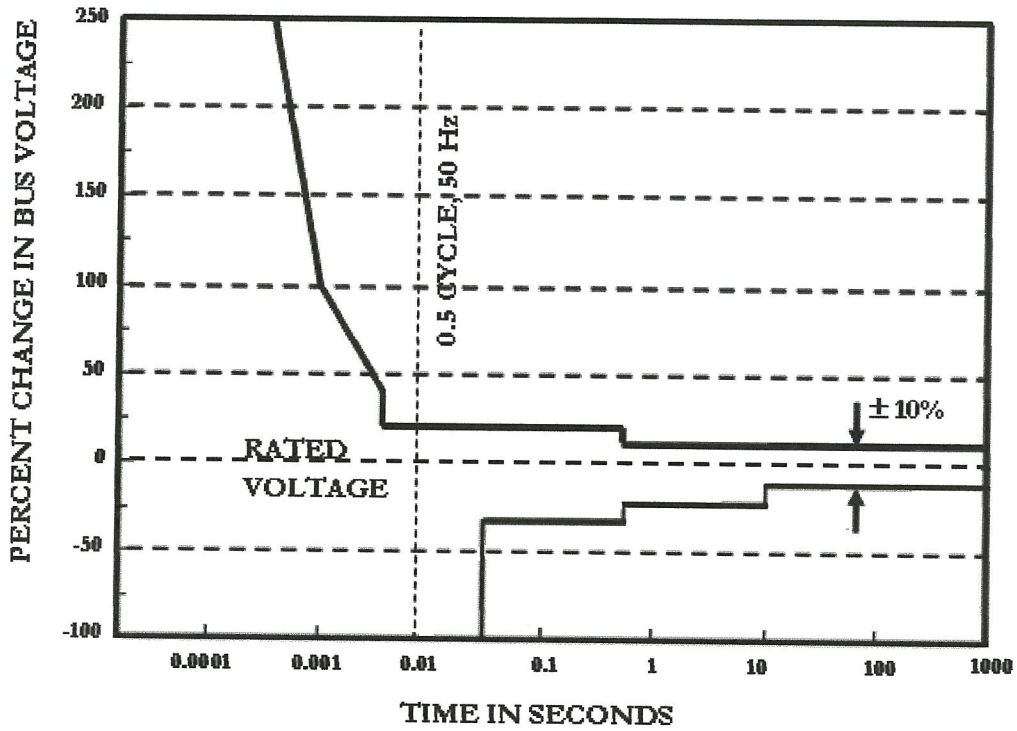


Figure Q1(a)

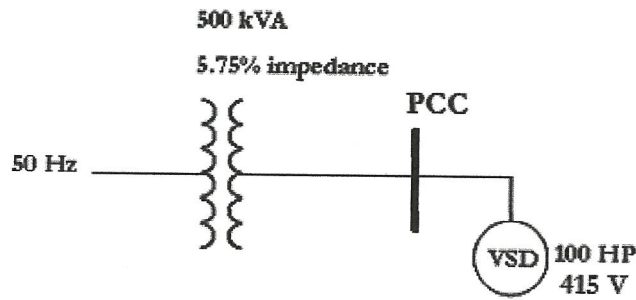


Figure Q2(b)

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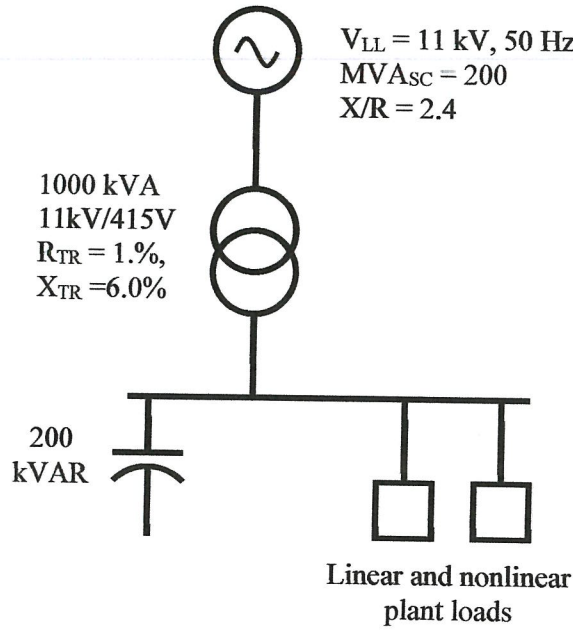


Figure Q3(c)

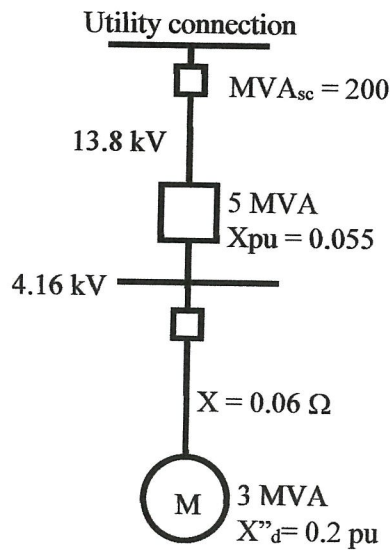


Figure Q5(c)

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