00180

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX6832/ECX6332 Power Systems Planning**
Academic Year	: 2019/2020
Date	: 11th August2020
Time	: 1330-1630hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8) questions** in **Nine (09)** pages.
3. Answer **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts/codes are provided.
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear hand writing.
8. Do not use red colour pen.

1. a. Briefly explain five forecasting techniques widely use in and compare usability of each in current electric utility practice. **[5 marks]**

   b. A trend analysis performed on electricity sales (S) and generation (G) of a developing country gave the following statistical results from a least-square method.

$$\ln(S) = -114.36 + 0.0623 \times t$$

$$\ln(G) = -124.11 + 0.067 \times t$$

   S is the sales in GWh and G is the generation in GWh and t is the time in year (such as 2019, 2020.... etc.)

   If the annual growth rate of sales in year t is defined as,

$$growth_t = \frac{S_t - S_{t-1}}{S_{t-1}} \times 100\%$$

   Calculate the annual growth rates for sales and similarly for the generation indicated by the results of this analysis. Also, comment on the losses in the network. **[8 marks]**

   c. The demand growth for electricity is expected to change from 2020 onwards. If the sales are expected to reach 124,500 GWh per year by the year 2038, develop a model of the form,

$$S^2 = k_1(T + k_2)$$

   to forecast the sales in the period 2020-2038, k_1 and k_2 are constants to be derived. T is the year (such as 2020, 2021, etc.). S is the sales in GWh. Results of historic trend analysis may be used to calculate the sales in the year 2019. Using the forecast model, estimate the sales in the year 2030. **[4 marks]**

   d. As per the records, sales in 2001 was 29,802 GWh. Compute and comment the compound growth rates for 2001 to 2019 and 2020 to 2038 periods. **[3 marks]**

2. A power system is served by four generators where the installed capacities and forced outage rates are given in Table Q2.

Table Q2

Merit order loading	Plant ID.	Installed Capacity (MW)	F.O.R	Average Cost (US$/MWh)
2	A	100	0.2	3,000
1	B	100	0.1	2,000
3	C	100 200	0.7 0.4	6,000

If the generating system above is serving a load described by the chronological load curve shown in Figure Q2, do the followings:

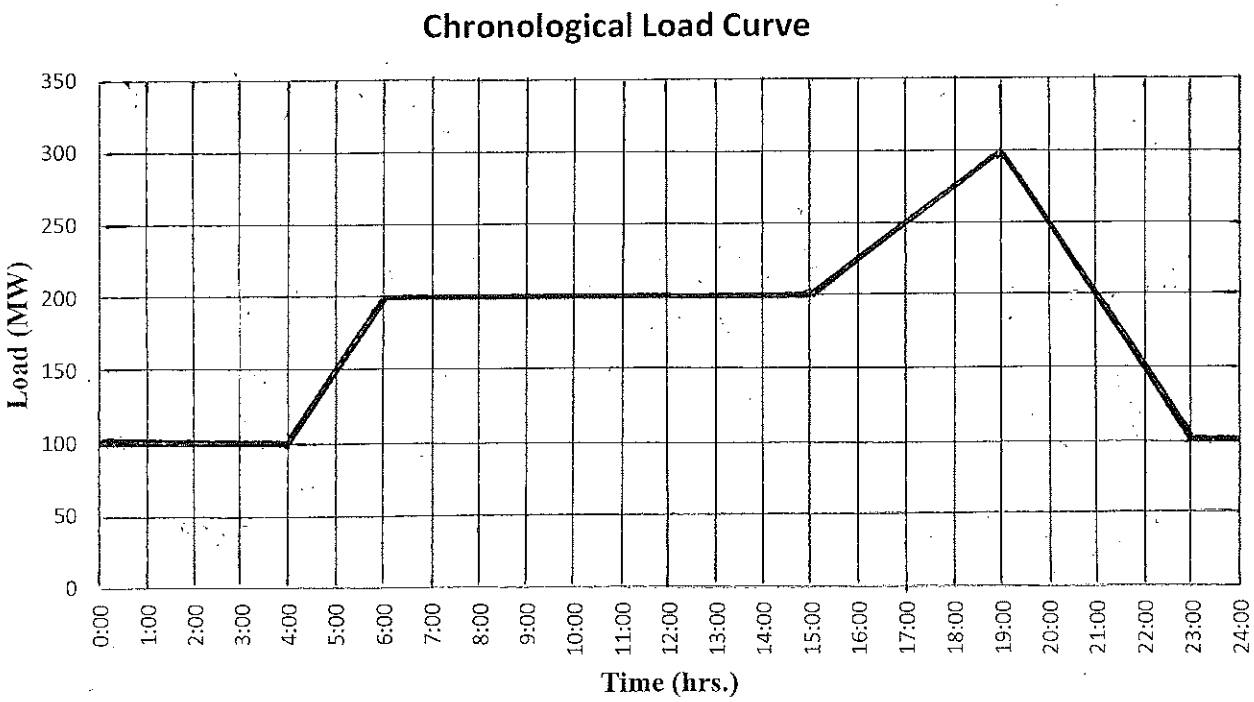


Figure Q2

a. Sketch: Load duration curve of the system **[5 marks]**

b. Calculate: Daily energy to be served **[3 marks]**

c. Develop the Remaining Load Duration Curves (RLDCs) for each generator and estimate: Energy served, plant factor and expected production costs for each generator **[8 marks]**

d. Loss of Load Probability index (LOLP) & (LOLE) **[2 marks]**

e. Energy Not Served (ENS) **[2 marks]**

3. a. Define the term "DSM" elaborating its objectives and purpose. Also list out strategies of load shape objectives. **[4 marks]**

b. An electric utility is planned to implement summer peaking TOU (Time-Of-Use) metering project for 25,000 residential customers. The peak load pricing period would apply from April through June, six hours per day. Residential consumers have the following characteristics:

Energy consumed during summer peak hours: 1,000 kWh/yr./customer

Energy consumed during summer off-peak hours: 4,500 kWh/yr./customer

Energy consumed during non-summer period: 9,500 kWh/yr./customer

Estimated summer peak load price elasticity: -0.4

Estimated summer off-peak price elasticity: -0.15

The marginal cost of operation and the existing and proposed tariff rates are tabulated in table Q3.

Table Q3

Description	**Existing Tariff**	**Proposed TOD Tariff**	**Marginal cost of operation**
	(LKR/kWh)		
Summer peak rate	12.00	27.00	32.5
Summer off-peak rate	12.00	*See the note*	10.0
Non-summer period	8.00	8.00	6.0

Note: The proposed TOD rate structure summer off-peak is designed as such annual customer bill is the same as the existing tariff if the customer does not alter the usage profile.

The failure rate of the TOU meter is estimated at 0.25% per year and repair cost is LKR 3,000 LKR. Take levelized annual fix charge rate as 16%.

Evaluate the cost benefit of this project. **[16 marks]**

4. **a.** For a uniformly distributed load on a distribution feeder, show that the total voltage drop along the full length of the line can be represented by the expression $I_s.z(l/2)$ where I_s is the rms current at the sending end and z is the impedance per unit length. l is the total length of the line. **[3 marks]**

   b. Also, for a line loaded with uniformly increasing load show that the above voltage drop could be represented as $I_s.z(2l/3)$. **[5 marks]**

   c. A pentagonal shaped urban residential area is to be fed with a distribution transformer located at the center of the area (see figure Q4).

   Five main feeders will run along the roadways at an angle 72^0 to each other as shown in thick lines. Four lateral feeders connected to each main feeder run parallel to reach side of the pentagon. The arrangement of the housing scheme is expected to impose an area load density of 1.23 MW/km^2.

   The operating voltage is 400V, three phase four wire type. If the impedance per unit length of a lateral is twice the impedance per unit length of the main feeder, calculate the impedance per unit length of the main feeder, such that the voltage drop anywhere in the residential area will be within 4% of the nominal voltage.

   Assume the loads on the laterals are uniformly distributed along the lines. **[12 marks]**

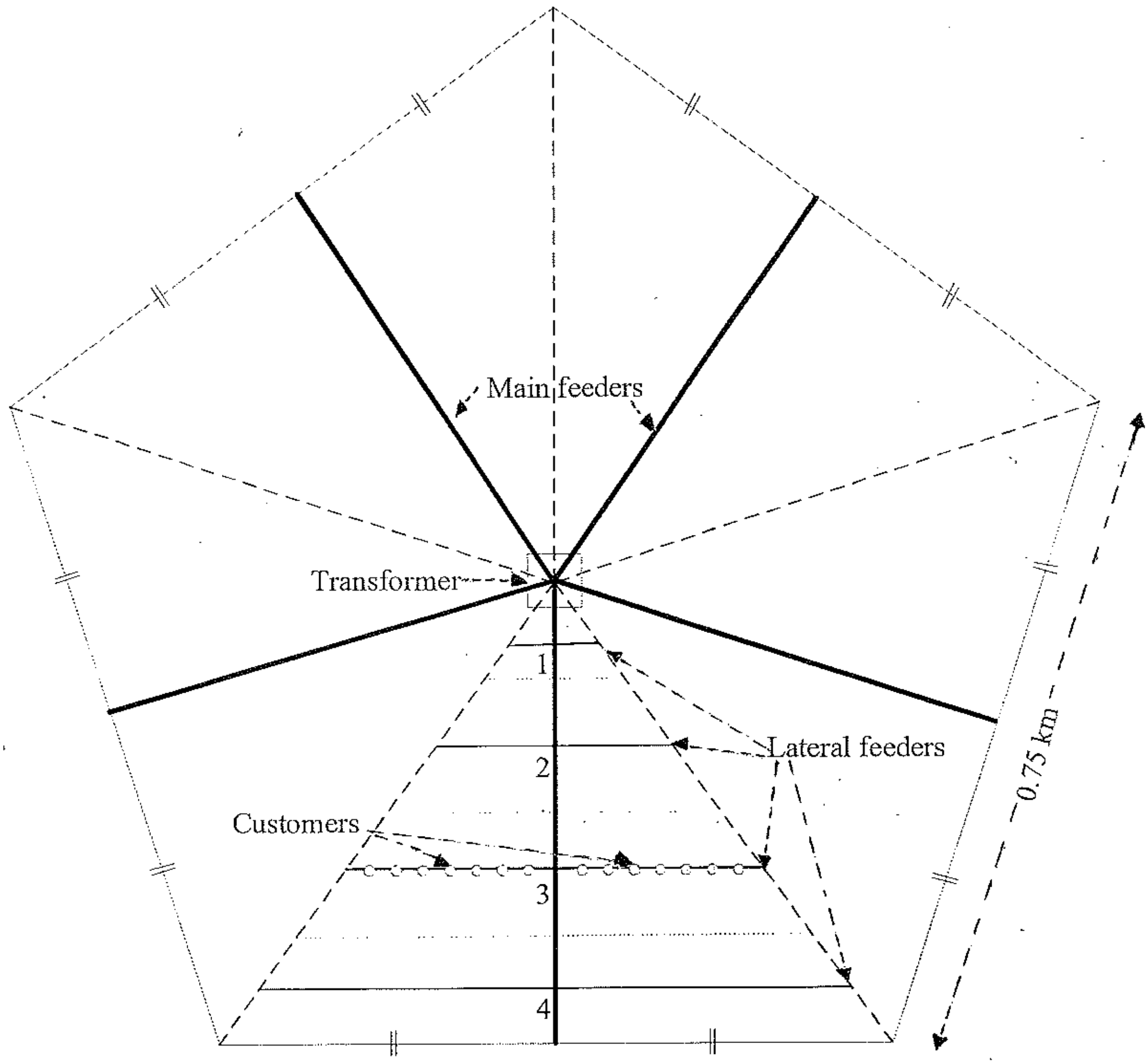


Figure Q4

5. An isolated power system can be represented as shown in figure Q5 below:

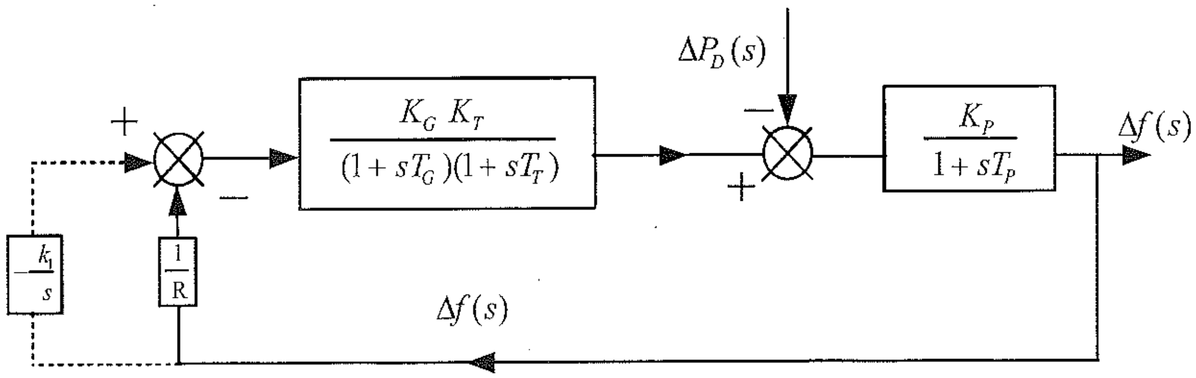


Figure Q5

Show that the Area Control Error (ACE), i.e. $\Delta f(s)$ is given by the following equation for a ΔP_D step disturbance: **[15 marks]**

$$\Delta f(s) = -\frac{\Delta P_D}{s}\left[\frac{Rk_p s(1+sT_G)(1+sT_T)}{s(1+sT_G)(1+sT_T)(1+sT_p)R + k_p(Rk_1 + s)}\right]$$

If $T_P = 10.0$ sec. $T_G = T_T = 0.0$ $k_P = 100$ Hz/p.u. MW

$R = 3$ Hz/p.u. MW $\Delta P_D = 0.1$ p.u. MW and $k_I = 0.1$

Compute the time error, caused by the above step disturbance, in seconds. **[5 marks]**

6. Consider the typical substation configurations Figure Q6.1 & Figure Q6.2 shown below and the reliability data given in the table for each component:

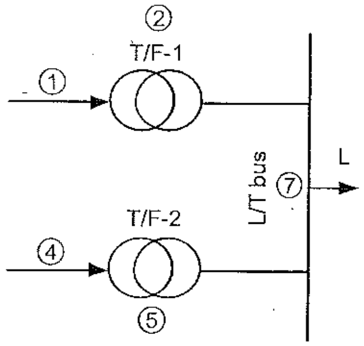


Figure Q6.1

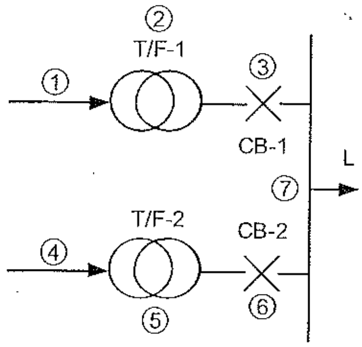


Figure Q6.2

Table Q6

Component	**λ(f/yr)**	**r (hours)**	**λ_a (f/yr)**	**S (hours)**
Line - 1	0.1	10	0.1	1.0
Line - 4	0.12	8	0.12	1.0
Transformer - 2 & 5	0.01	50	0.01	1.0
7 (L/T bus bar)	0.05	2	0.05	-
Breaker 3	0.03	3	0.02	1.0
Breaker 6	0.04	6	0.03	1.5

λ_a= Active failure rate s = Switching time

a. Neglecting any coordinated/un-coordinated maintenance work performed in this system, Evaluate the failure rate (λ), average outage duration (r), annual outage time (Unavailability) at load point L for both substation configurations. If the average load connected at bus #7 is L=50 MW, calculate the total energy not served for both the configurations. **[15 marks]**

b. If the un-served energy cost is estimated to be 80 LKR/kWh and the extra cost involved in converting the substation shown in Figure Q6.1 to Figure Q6.2 is estimated to be 1.2 million LKR, what would be the simple pay-back period of the extra cost involved in converting the substations? **[5 marks]**

7. a. Over a period of one year, the following performance has been recorded in the log sheet of a 120 MW generating unit in a large power system.

Extracted from log-sheet data

- Plant operates full load for 6,040 hours
- Forced to shut down completely six times for 700 total hours
- The plant has been taken for 250 hours to conduct planned maintenance
- The plant was available but not called for 1,100 hours
- Plant de-rated twice to 30% of maximum capacity for 100 hours and de-rated once to 40% for 50 hours

Estimate:

1. Planned outage rate **[2 marks]**
2. Forced outage rate **[2 marks]**
3. Equivalent average repair time **[3 marks]**
4. Equivalent availability **[3 marks]**
5. Maximum energy production for the period **[2 marks]**

b. Table Q7 is a re-production of a part of typical interruption data from a power utility for a feeder circuit. It serves for 2,200 customers with a total load of 5 MW. Excluding momentary interruption events and major events, which are omitted from the Table Q7, calculate the SAIFI, SAIDI, CAIDI and ASAI for this feeder. **[8 marks]**

Table Q7

Date	Time (hrs.: min.)		No. of Customers.
	Start	End	interrupted
17-Jan-19	1:11 AM	3:11 AM	155
18-Jan-19	12:23 AM	1:25 AM	60
3-Feb-19	7:32 PM	8:24 PM	60
21-Feb-19	9:30 AM	10:15 AM	75
5-Mar-19	11:26 AM	12:45 PM	652
5-Mar-19	1:13 PM	1:42 PM	745
6-Mar-19	10:10 AM	10:12 AM	100
10-Apr-19	8:55 AM	9:15 AM	390
22-May-19	4:51 AM	8:01 AM	450
6-Jul-19	9:20 PM	10:33 PM	1,500
8-Jul-19	3:20 AM	3:25 AM	255
20-Aug-19	8:20 AM	8:45 AM	365
14-Sep-19	8:00 PM	8:27 PM	930
14-Oct-19	3:45 PM	4:14 PM	1,048
14-Oct-19	11:01 PM	11:55 PM	100
15-Oct-19	10:11 AM	5:00 PM	120
16-Oct-19	9:14 PM	9:15 PM	2,000
10-Nov-19	3:45 AM	9:00 AM	950
5-Dec-19	7:30 AM	8:00 AM	670
12-Dec-19	6:10 AM	1:52 PM	1,480

8. Following are the 16 multiple type questions which will cover most of your course content. Questions carry **1.25** mark each. Underline the correct answer and attach the three (7 to 9) pages to your answer script.

a. Energy that ultimately available for work is refers to as,

1. Useful energy **2.** Primary energy **3.** Final energy **4.** Secondary energy

b. Identify the wrong statement in respect of typical electric utility planning

1. Load forecast and investment plans are essential outputs of the planning process
2. Expansion planning utilizes the available manpower and other resources
3. Generation expansion planning use the longest planning window compared to transmission and distribution planning
4. Sensitivity studies are essential in planning studies

c. Find the wrong statements of the following:

i. Hydropower plants use both reaction and impulse turbines
ii. Economizers are used to pre-heat in take air in coal power stations
iii. Gas turbines have high thermal efficiency ranging to 50% – 60 %
iv. Graphite and heavy water commonly use as moderators in nuclear power plants

1. (i) & (iii) **2.** (i), (vi) **3.** (ii) & (iv) **4.** (ii) & (iii)

d. A power system has two generating stations P_1 and P_2. The incremental production cost characteristics are,

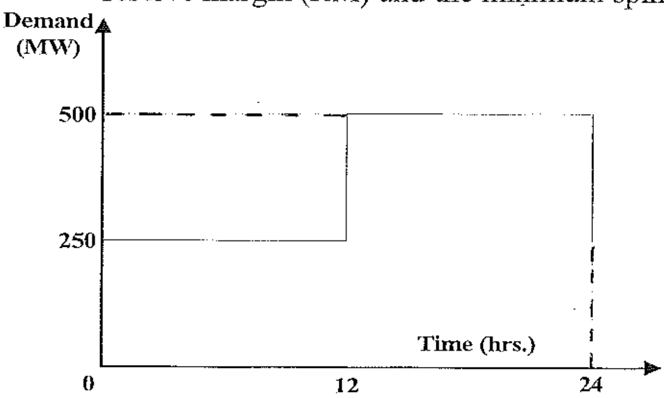
$$\frac{\partial F_1}{\partial P_1} = 30.25 + 0.65\,P_1 \frac{LKR}{MWhr}; \qquad where\ 10\ MW \leq P_1 \leq 100\ MW$$

$$\frac{\partial F_2}{\partial P_2} = 19.5 + 0.26\,P_2 \frac{LKR}{MWhr}; \qquad where\ 10\ MW \leq P_2 \leq 100\ MW$$

If two power stations are suppling150 MW demand, the possible optimum dispatch schedule of P_2 and P_1 would be,

1. 65, 85 MW **2.** 50, 100 MW **3.** 100, 50 MW **4.** 85, 65 MW

e. Five power stations are available to cater a load demand profile given in the figure below. The basic characteristics of the five power plants are given in the table below. The system reserve margin (RM) and the minimum spinning reserve (SR) is:



Plant ID	Capacity (MW)	Avg. Cost (LKR/MWh)	F.O.R.
A	50	2,700	0.1
B	100	2,500	0.07
C	150	2,300	0.1
D	150	2,200	0.08
E	150	2,000	0.05

1. 20%, 10% **2.** 16.7%, 20% **3.** 20%, 20% **4.** 16.7%, 10%

f. Suppose that \$100 is saved on the last day of the year for 10 years in a savings account that pays 6% interest. What is the approximate present worth equivalent amount?

1. \$186 2. \$56 3. \$736 4. \$ 856

g. Following data is gathered from a 300 MW coal power plant.

- All-inclusive cost 360,360 LKR/kW
- Economic life 30 yrs.
- Cost of annual maintenance 10,282 LKR/kW
- Fuel cost 1.9 LKR/kWh
- Variable maintenance cost 1.2 LKR/kWh

The life cycle costs of the plant in LKR/kWh for 0.2 and 0.8 plant factors respectively at the discount rate of 10% would be:

1. 12, 34 2. 29, 20 3. 18, 29 4. 31, 10

h. Check the following five statements

i. Cascading outages may lead loss of network integrity and islanding a power system
ii. Voltage, thermal, contingency, stability, short circuit are some widely used criteria in transmission planning process
iii. Receiving end voltage is always less than the sending end voltage
iv. At surge impedance loading, the voltage throughout the length of the line is the same
v. Interposition of lines has no impact on minimizing low voltage interferences

1. Statements ii, iii, iv are correct
2. Statements iv, v, i are correct
3. Statements i, ii, iv are correct
4. Statements iii, iv, ii are correct

i. Synchronous generators are used to control sending end voltage. Check the following statements:

i. When a synchronous generator is under excited it delivers lagging reactive power
ii. Lower excitation limit of a synchronous generator is governed by the over-heating of the rotor
iii. When synchronous generators are over excited it draws lagging reactive power
iv. Upper excitation limit of a synchronous generator is governed by the stability of the system

1. Statements i, ii, iii, iv are correct
2. Statements i & ii are correct, and statement iii & iv are incorrect
3. Statements i, ii, iii, iv are incorrect
4. Statements i & ii are incorrect, and statement iii & iv are correct

j. Find the required capacity of a static VAR compensator to be installed at a bus with ± 5% voltage fluctuation. Take the short circuit capacity as 7,000MVA.

1. ±350 MVAr   2. ±1400 MVAr   3. ±140 GVAr   4. ±35 MVAr

k. The permissible variation of frequency in Sri Lanka power system is

1. ±1%   2. ±2.5%   3. ±5%   4. ±10%

l. What is the standard ACSR conductors used in high voltage transmission systems (132 kV & 220 kV) in Sri Lanka?

1. Horse   2. Lynx   3. Zebra   4. Dove

m. Justifying the choice of HVDC transmission are:

i. Economic transmission over long distance
ii. Generation of less harmonics
iii. Increased transmission capacity within a fix corridor
iv. Frequency and phase dependent power transfer

1. Statements i & ii are acceptable
2. Statements i & iii are acceptable
3. Statements i & iv are acceptable
4. All statements are acceptable

n. In what bus bar configuration that requires a separate bus coupler?

1. Mesh bus configuration
2. Breaker-and-a-half configuration
3. Double bus bar single breaker configuration
4. Double bus bar double breaker configuration

o. A 3-ϕ, 11 kV, 50 Hz, 200 kW load has a pf of 0.8 lag. A Δ-connected 3-ϕ capacitor is used to improve the pf to unity. The capacitance per phase of the capacitor in microfarads is:

1. 3.948   2. 1.315   3. 0.439   4. 11.844

p. FACTS controllers can be used to control power flow by controlling:

1. Impedance or voltage
2. Capacity factor or load angle
3. Impedance and phase angle
4. Power and voltage