IES MASTER
PUBLICATION

# ELECTRICAL ENGINEERING

# GATE 2018

# GATE SOLUTIONS

**ELECTRICAL ENGINEERING**

From (1991 - 2017)

IES MASTER PUBLICATION

**Office :** F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016 • **Phone :** 011-26522064
**Mobile :** 8130909220, 9711853908 • **E-mail:** info@iesmasterpublications.com, info@iesmaster.org
**Web :** iesmasterpublications.com, iesmaster.org

**IES MASTER PUBLICATION**

F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016

**Phone :** 011-26522064, **Mobile :** 8130909220, 9711853908

**E-mail :** info@iesmasterpublications.com, info@iesmaster.org

**Web :** iesmasterpublications.com, iesmaster.org



**Second Edition : 2017**

**Typeset at : IES Master Publication, New Delhi-110016**

# PREFACE

It is an immense pleasure to present topic wise previous years solved paper of GATE Exam. This booklet has come out after long observation and detailed interaction with the students preparing for GATE exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

GATE exam now a days has become more important because it not only opens the door for higher education in institutes like IIT, IISC, NIT's but also many of the PSUs have started inducting students on the basis of GATE score. In PSU’s, which are not inducting through GATE route, the questions in their exams are asked from GATE previous year papers. Thus, availability of authentic solutions to the students is the need of the day. Towards this end this booklet becomes indispensable.

I am thankful to IES master team without whose support, I don't think, this book could have been flawlessly produced.

Every care has been taken to bring an error free book. However comments for future improvement are most welcome.

**Mr. Kanchan Kumar Thakur**
Director Ex-IES

GATE
GATE
GATE
GATE

# CONTENTS

# Power Systems

Unit 1

## Syllabus

*Power generation concepts, ac and dc transmission concepts, Models and performance of transmission lines and cables, Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Bus admittance matrix, Gauss Seidel and Newton-Raphson load flow methods, Voltage and frequency control, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential and distance protection; Circuit breakers, System stability concepts, Equal area crterion.*

## Contents

*Chapter*

# Generating Power Stations and Per Unit System

# 1

## 1 – Mark

**1.** A 500 MVA, 11 KV synchronous generator has 0.2 p.u. synchronous reactance. The p.u. synchronous reactance on the base values of 100 MVA and 22 KV is

(a) 0.16 (b) 0.01

(c) 4.0 (d) 0.25 ***[GATE-1991]***

**2.** In order to have a lower cost of electrical energy generation

(a) The load factor and diversity factor should be low

(b) The load factor should be low but diversity factor should be high

(c) The load factor should be high but diversity factor should be low

(d) The load factor and diversity factor should be high. ***[GATE-1995]***

**3.** Which material is used in controlling chain reaction in a nuclear reactor?

(a) Thorium (b) Heavy water

(c) Boron (d) Beryllium

***[GATE-1996]***

**4.** In a thermal power plant, the feed water coming to the economiser is heated using

(a) H.P. Steam

(b) L.P. Steam

(c) Direct heat in the furnace

(d) Flue gases ***[GATE-2000]***

**5.** The rated voltage of a 3-phase power system is given as

(a) rms phase voltage

(b) peak phase voltage

(c) rms line to line voltage

(d) peak line to line voltage. ***[GATE-2004]***

**6.** In thermal power plants, the pressure in the working fluid cycle is developed by

(a) condenser (b) super heater

(c) feed water pump (d) turbine

***[GATE-2004]***

**7.** For harnessing low variable waterheads, the suitable hydraulic turbine with high percentage of reaction and runner adjustable vanes is

(a) Kaplan (b) Francis

(c) Pelton (d) Impeller

***[GATE-2004]***

**8.** Out of the following plant categories :

(i) Nuclear (ii) Run-off-river

(iii) Pump Storage (iv) Diesel

The base load power plants are

(a) (i) and (ii) (b) (ii) and (iii)

(c) (i), (ii) and (iv) (d) (i), (iii) and (iv)

***[GATE-2009]***

**9.** A three phase star-connected load is drawing power at a voltage of 0.9 pu and 0.8 power factor lagging. The three phase base power and base current are 100 MVA and 437.38.A respectively. The line-to-line load voltage in kV is _________. ***[GATE-2014]***

**10.** Base load power plants are

P: wind farms

Q: run-off-river plants

R: nuclear power plants

S: diesel power plants

Choose the correct answer :

(a) P, Q and S only (b) P, R and S only

(c) P, Q and R only (d) Q and R only

***[GATE-2015]***


IES MASTER
Institute for Engineers (IES/GATE/PSUs)
CE
ME
EE
ECE
Computer Based Test at 35 Centres
MTRE Scholarship
For ESE & GATE Aspirants
Session 2018-19
Get up to
100% Scholarship
in each branch
Master Talent Reward Exam
Registration Open
Last Date of Registration
18th Dec
Exam Date
24th Dec
Visit iesmaster.org/master-talent-reward-exam or Call on +91 8010009955 | +91 9711853908

## 2 – Marks

**1.** The synchronous reactance of a 200 MVA, 10kV, 3-phase, 50 Hz generator is 1.0 p.u. at its own base. Its p.u. reactance at 100 MVA, 20 kV base will be _________.

***[GATE-1997]***

**2.** An industrial consumer has a daily load pattern of 2000 kW, 0.8 lag for 12 hrs and 1000 kW UPF for 12 hrs. The load factor is

(a) 0.5 (b) 0.6

(c) 0.75 (d) 2.0 ***[GATE-1999]***

**3.** The plug setting of a negative sequence relay is 0.2A. The current transformer ratio is 5 : 1. The minimum value of line to line fault current for the operation of the relay is

(a) 1 A (b) $\frac{1}{1.732}$A

(c) 1.732 A (d) $\frac{0.2}{1.732}$A

***[GATE-2000]***

**4.** A 3-phase transformer has rating of 20 MVA, 220 kV (star)-33 kV (delta) with leakage reactance of 12%. The transformer reactance (in ohms) referred to each phase of the L.V. delta-connected side is

(a) 23.5 (b) 19.6

(c) 18.5 (d) 8.7 ***[GATE-2001]***

**5.** A 75 MVA, 10 kV synchronous generator has $X_d$ = 0.4 pu. The $X_d$ value (in pu) to a base of 100 MVA, 11 kV is

(a) 0.578 (b) 0.279

(c) 0.412 (d) 0.44 ***[GATE-2001]***

**6.** A hydraulic turbine having rated speed of 250 rpm is connected to a synchronous generator. In order to produce power at 50 Hz, the number of poles required in the generator are

(a) 6 (b) 12

(c) 16 (d) 24 ***[GATE-2004]***

**7.** A generator is connected through a 20 MVA, 13.8/138 kV step down transformer, to a transmission line. At the receiving end of the line a load is supplied through a step down transformer of 10 MVA, 138/69 kV rating. A 0.72 p.u. load, evaluated on load side transformer ratings as base values, is supplied from the above system. For system base value of 10 MVA and 69 kV in load circuit, the value of the load (in per unit) in generator circuit will be -

(a) 36 (b) 0.144

(c) 0.72 (d) 0.18 ***[GATE-2006]***

**8.** For the power system shown in the figure below, the specifications of the components are the following :

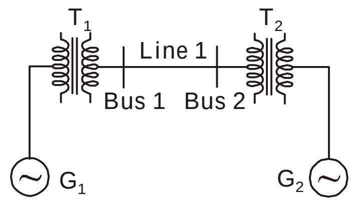
$G_1$ = 25 kV, 100 MVA, X = 9%

$G_2$ = 25 kV, 100 MVA, X = 9%

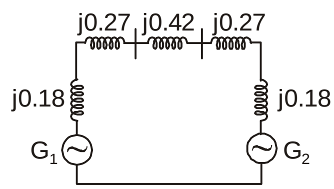
$T_1$ = 25 kV/220 kV, 90 MVA, X = 12%

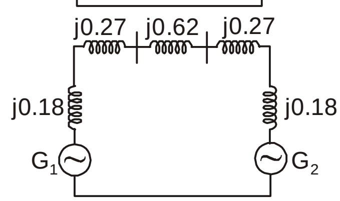
$T_2$ = 220 kV/25kV, 90 MVA, X = 12%

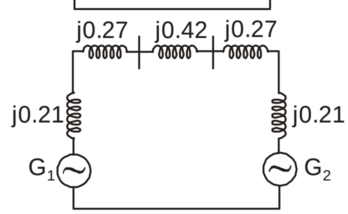
Line 1 : 220 kV, X = 150 ohms.

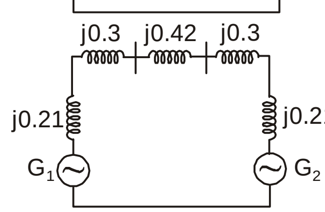



Choose 25 kV as the base voltage at the generator $G_1$ and 200 MVA as the MVA base. The impedance diagram is

(a)



(b)



(c)



(d)



***[GATE-2010]***

## ANSWER KEY

**:: 1 MARK ::**

1. (b)
2. (d)
3. (c)
4. (d)
5. (c)
6. (c)
7. (a)
8. (a)
9. (118.8kV)
10. (d)

**:: 2 MARKS ::**

1. (0.125 p.u.)
2. (c)
3. (c)
4. (b)
5. (d)
6. (d)
7. (b)
8. (b)

## SOLUTION...

### 1 – Mark

**Sol–1: (b)**

$$Z(p.u.)_{new} = Z(p.u.)_{old} \times \left(\frac{KV_{old}}{KV_{new}}\right)^2 \times \left(\frac{MVA_{new}}{MVA_{old}}\right)$$

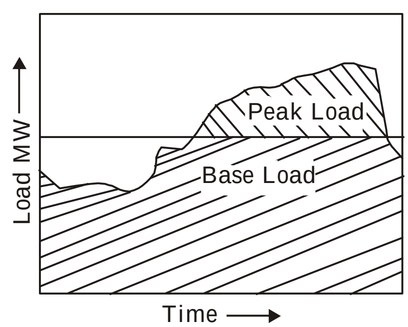
$$= 0.2 \times \left(\frac{11}{22}\right)^2 \times \frac{100}{500}$$

$$= \frac{0.2}{20} = 0.01$$

**Sol–2: (d)**

In order to have a lower cost of electric energy generation the Load factor should be high.

$$\text{Load factor} = \frac{\text{Average load}}{\text{Peak load}}$$




To economize generation, the load is divided into the two parts, base load and peak load. These two loads are supplied from seperate plants called the base load plant and the peak load plant.

A base load plant operates at a high load factor.

$$\text{Group divesity factor} = \frac{\text{Sum of individual maximum demand}}{\text{Maximum demand of the group}}$$

Daily load diversity results in reduced operating expenses.

**Sol–3: (c)**

Control rods are used to control the chain reaction in a nuclear reactor. Control rods are made up of materials having high absorption cross section. Such materials are Boron, Hafnium and Cadmium.

**Sol–4: (d)**

Flue gases coming out of the boilers carry lot of heat. An economiser extracts a part of this heat from the flue gases and uses it for heating feed water.

**Sol–5: (c)**

The rated voltage of a 3-phase power system is always rms line to line voltage.

**Sol–6: (c)**

In thermal power plants, heaters bleed steam from the main turbine and use it for feed water heating. The feed water is heated, put under pressure by feed water pump and then further heated so that its temperature approaches and pressure exceeds that of water in the boiler.

**Sol–7: (a)**

- Propeller turbine is a reaction turbine suitable for low head and large quantity of water. It is suitable for heads below 30m.
- A Kaplan turbine is a propeller turbine with adjustable blades, the advantage of adjustable blades being that a Kaplan turbine operates at high efficiency even under part load conditions.

**Sol–8: (a)**

Nuclear and Run-off-river plants are the base load plant and Pumped Storage and Diesel plants are peak load plants.

**Note :** A base load plant operates at a high load factor and should be one which has low operating costs.

The peak load plant operates at a low load factor.

**Sol–9: (118.8kV)**

$$\text{Base kV} = \frac{\text{Base kVA}}{\sqrt{3}\times\text{Base current, A}}$$

$$= \frac{100\times10^3}{\sqrt{3}\times437.38} = 132\ \text{kV}$$

$\therefore$ Actual line to line voltage

= (p.u. value) × Base voltage

= 0.9 × Base voltage

= 0.9 × 132 = 118.8kV

**Sol–10: (d)**

Diesel plants are very costly and thus not used as base load plants.

Wind plants are intermittent and hence they can't serve as base load plants.

**Run off river** plants are base load plants.

**Nuclear plants** aren't turned on/off frequently due to safety and economic reasons hence used as base load plants.

## 2 – Marks

**Sol–1: (0.125 p.u.)**

$$Z_{p.u.,new} = Z_{p.u.,old}\cdot\left(\frac{kV_{old}}{kV_{new}}\right)^2\cdot\left(\frac{MVA_{new}}{MVA_{old}}\right)$$

$$= 1.\left(\frac{10}{20}\right)^2.\left(\frac{100}{200}\right)$$

$$= \frac{1}{8}\text{p.u.} = 0.125\ \text{p.u.}$$

**Sol–2: (c)**

$$\text{Load factor} = \frac{\text{Average Demand}}{\text{Maximum Demand}}$$

Average demand in 24 hrs.

$$= 12\times2000+\frac{12\times1000}{24}$$

$$= 24000+\frac{12000}{24}$$

$$= \frac{36000}{24}\text{kW}$$

$$= 1500\ \text{kW}$$

Maximum demand in 24 hrs is given as 2000 kW

$$\therefore \text{Load factor} = \frac{\text{Average Demand}}{\text{Maximum Demand}}$$

$$= \frac{1500}{2000}$$

$$= \frac{3}{4} = 0.75$$

**Sol–3: (c)**

The given is a L-L fault

Here $I_f = \sqrt{3}I_{R1} = \sqrt{3}I_{R2}$

and $I_{R1} = -I_{R2}$

Plug setting of the negative sequence relay is 0.2A.

Pick up current = Plug setting × CT ratio

$$= 0.2\times\frac{5}{1} = 1\ \text{Amp.}$$

1 Amp. is the negative sequence current.

So, $I_f = \sqrt{3}\,I_{f2}$

$= \sqrt{3}\times1$

$= 1.732$ Amp.

**Sol–4: (b)**

$\because$ Base impedance on L.V. side

$$= \frac{(kV)^2}{(MVA)_B} = \frac{33^2}{20}$$

$$= 54.45\Omega$$

$\therefore$ Leakage reactance in $\Omega$ (on LV side)

$= 54.45 \times 0.12$

$= 6.534\Omega$

$\Rightarrow$ So reactance per phase = $6.35\Omega$

In $\Delta$ connection, if the impedance in each arm is $Z_1$, then per phase impedance (i.e. between phase and neutral) can be determine by converting equivalent star (Y).

$$Z_{ph} = \frac{Z_1}{3} \quad \therefore \; Z_1 = 3.Z_{ph}$$

$$= 3 \times 6.534$$

$$= 19.6\Omega$$

**Sol–5: (d)**

$X_d$ (in pu) on new base

$$= X_d.\text{old}\frac{(MVA)_{new}}{(MVA)_{old}} \times \frac{(kV_{old})^2}{(kV_{new})^2}$$

$$= 0.4 \times \frac{100}{75} \times \left(\frac{10}{11}\right)^2 = 0.44 \text{ p.u.}$$

**Sol–6: (d)**

$\because$ Rated speed of hydraulic turbine = 250 rpm

$\because$ Output frequency of generator = 50 Hz

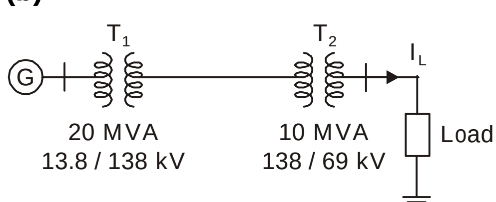
If no of pole = P, then

$$N = \frac{120f}{P}$$

or $$P = \frac{120f}{N} = \frac{120 \times 50}{250} = 24$$

$\therefore$ No. of pole required = 24

**Sol–7: (b)**




Base current on load side

$$(kA)_B = \frac{(MVA)_B}{\sqrt{3}(kV)_B}$$

$\Rightarrow$ ($I_L$ = 0.72 is given on 69 kV)

$(kA)_B$ on Generator side,

$$\Rightarrow (kA)_{B\ new} = \frac{(MVA)_B}{\sqrt{3}.(kV)_{new}} = \frac{(MVA)_B}{\sqrt{3} \times 13.8}$$

Actual load current, $I_L = I_{L\,pu} \times (kA)_{B\ old}$

pu current on generator side;

$$\Rightarrow I_{p.u.new} = I_{p.u.old} \times \frac{(kA)_{B-old}}{(kA)_{B-new}}$$

$$= 0.72 \times \frac{13.8}{69}$$

$$= 0.144$$

**Sol–8: (b)**

Given, $kV_{base} = 25kV$, $MVA_{base} = 200$ MVA

Per unit reactance of

$$G_1 = j0.09 \times \left(\frac{200}{100}\right) \times \left(\frac{25}{25}\right)^2$$

$$= j0.18$$

Per unit reactance of

$$G_2 = j0.09 \times \left(\frac{200}{100}\right) \times \left(\frac{25}{25}\right)^2$$

$$= j0.18$$

Per unit reactance of

$$T_1 = j0.12 \times \left(\frac{200}{90}\right) \times \left(\frac{25}{25}\right)^2$$

$$= j0.27$$

Per unit reactance of line = $\frac{X_{actual}}{X_{base}}$

$$= \frac{150}{(220)^2} \times 200$$

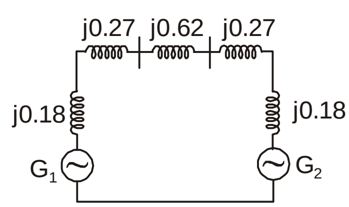
$$= j0.62$$

Per unit reactance of

$$T_2 = j0.12 \times \left(\frac{200}{90}\right) \times \left(\frac{220}{220}\right)^2$$

$$= j0.27$$

The impedance diagram of the power system is



IES MASTER
PUBLICATION

# ELECTRICAL ENGINEERING

# GATE 2018