


## 2.5. Evaluation Process and Reforms Metric (2.5.1)

  
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No.	Key Indicator- 2.5. Evaluation Process and Reforms Metric
2.5.1. QIM	<p data-bbox="323 259 1417 338"><i>Mechanism of internal assessment is transparent and robust in terms of frequency and mode</i></p> <ul style="list-style-type: none"> <li data-bbox="411 394 1425 674">• Internal assessment tests are conducted by the institute's exam cell as per the academic calendar. The time tables, seating arrangements for internal tests are informed through circulars and displayed in notice boards well in advance.</li> <li data-bbox="411 696 1425 1536">• Once the examinations are conducted, the answer scripts of students are evaluated by concerned course instructor and distributed to the students. Answers to all the questions given in the examinations are discussed with students during the distribution of answer scripts. The system is made transparent by providing the scheme of evaluation and answer key to the students so that they verify the marks awarded and understand their mistakes committed by them in the examination. Grievances in the evaluation process made by the students are addressed and modifications of marks are carried out, if necessary. Answer scripts are verified by the HoD to ensure that there is no discrepancy in the evaluation.</li> <li data-bbox="411 1559 1425 1693">• The internal test marks of the students are disseminated in the notice board to ensure transparency.</li> <li data-bbox="411 1715 1457 1850">• The internal assessment and end semester examination marks are communicated to the parents through post and SMS.</li> </ul>

  
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# EXAMCELL NOTICE BOARD

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**TIME TABLE**

Sl. No.	Branch	Exam Date	Exam Time	Exam Venue	Exam Subjects
1	Civil Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	CIVIL ENGINEERING
2	Computer Science	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	COMPUTER SCIENCE
3	Electrical Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	ELECTRICAL ENGINEERING
4	Information Technology	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	INFORMATION TECHNOLOGY
5	Management Studies	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	MANAGEMENT STUDIES
6	Chemical Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	CHEMICAL ENGINEERING
7	Biotechnology	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	BIO TECHNOLOGY
8	Food Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	FOOD ENGINEERING
9	Textile Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	TEXTILE ENGINEERING
10	Environmental Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	ENVIRONMENTAL ENGINEERING
11	Metallurgical Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	METALLURGICAL ENGINEERING
12	Production Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	PRODUCTION ENGINEERING
13	Automotive Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AUTOMOTIVE ENGINEERING
14	Marine Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	MARINE ENGINEERING
15	Aviation Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AVIATION ENGINEERING
16	Space Technology	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	SPACE TECHNOLOGY
17	Energy Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	ENERGY ENGINEERING
18	Biomedical Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	BIO MEDICAL ENGINEERING
19	Robotics Engineering	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	ROBOTICS ENGINEERING
20	Artificial Intelligence	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	ARTIFICIAL INTELLIGENCE
21	Blockchain Technology	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	BLOCKCHAIN TECHNOLOGY
22	Quantum Computing	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	QUANTUM COMPUTING
23	Augmented Reality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AUGMENTED REALITY
24	Virtual Reality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	VIRTUAL REALITY
25	Internet of Things	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	INTERNET OF THINGS
26	Big Data Analytics	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	BIG DATA ANALYTICS
27	Cloud Computing	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	CLOUD COMPUTING
28	Machine Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	MACHINE LEARNING
29	Deep Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	DEEP LEARNING
30	Reinforcement Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	REINFORCEMENT LEARNING
31	Generative Adversarial Networks	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	GENERATIVE ADVERSARIAL NETWORKS
32	Transfer Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	TRANSFER LEARNING
33	Domain Adaptation	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	DOMAIN ADAPTATION
34	Multi-Task Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	MULTI-TASK LEARNING
35	Meta-Learning	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	META-LEARNING
36	Neuro-Symbolic AI	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	NEURO-SYMBOLIC AI
37	Explainable AI	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	EXPLAINABLE AI
38	AI Ethics	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ETHICS
39	AI Law	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI LAW
40	AI Policy	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI POLICY
41	AI Governance	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI GOVERNANCE
42	AI Safety	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI SAFETY
43	AI Security	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI SECURITY
44	AI Privacy	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI PRIVACY
45	AI Accountability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ACCOUNTABILITY
46	AI Transparency	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI TRANSPARENCY
47	AI Auditability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI AUDITABILITY
48	AI Reliability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RELIABILITY
49	AI Robustness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ROBUSTNESS
50	AI Resilience	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RESILIENCE
51	AI Flexibility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI FLEXIBILITY
52	AI Scalability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI SCALABILITY
53	AI Portability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI PORTABILITY
54	AI Interoperability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI INTEROPERABILITY
55	AI Compatibility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI COMPATIBILITY
56	AI Conformance	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI CONFORMANCE
57	AI Compliance	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI COMPLIANCE
58	AI Validity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI VALIDITY
59	AI Soundness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI SOUNDNESS
60	AI Consistency	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI CONSISTENCY
61	AI Coherence	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI COHERENCE
62	AI Logicality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI LOGICALITY
63	AI Rationality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RATIONALITY
64	AI Objectivity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI OBJECTIVITY
65	AI Impartiality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI IMPARTIALITY
66	AI Neutrality	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI NEUTRALITY
67	AI Fairness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI FAIRNESS
68	AI Equity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI EQUITY
69	AI Justice	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI JUSTICE
70	AI Integrity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI INTEGRITY
71	AI Honesty	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI HONESTY
72	AI Truthfulness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI TRUTHFULNESS
73	AI Sincerity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI SINCERITY
74	AI Candor	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI CANDOR
75	AI Openness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI OPENNESS
76	AI Transparency	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI TRANSPARENCY
77	AI Accountability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ACCOUNTABILITY
78	AI Responsibility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RESPONSIBILITY
79	AI Reliability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RELIABILITY
80	AI Trustworthiness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI TRUSTWORTHINESS
81	AI Credibility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI CREDIBILITY
82	AI Reputability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI REPUTABILITY
83	AI Respectability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RESPECTABILITY
84	AI Estimability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ESTIMABILITY
85	AI Honorability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI HONORABILITY
86	AI Nobility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI NOBILITY
87	AI Magnanimity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI MAGNANIMITY
88	AI Generosity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI GENEROSITY
89	AI Kindness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI KINDNESS
90	AI Goodness	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI GOODNESS
91	AI Virtue	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI VIRTUE
92	AI Integrity	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI INTEGRITY
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99	AI Accountability	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI ACCOUNTABILITY
100	AI Responsibility	18.11.2023	10:00 AM - 12:00 PM	NEW LAB	AI RESPONSIBILITY

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DATE/TIME	VENUE	11:00-11:30	11:30-12:00	12:00-12:30
18.11.23(MON)	NEW LAB	CIVIL & E	CIVIL, EEE & MECH	EEE & AEE
19.11.23(TUE)	NEW LAB	CIVIL & E	CIVIL, EEE & MECH	EEE & AEE
20.11.23(WED)	NEW LAB	CIVIL & E	CIVIL, EEE & MECH	EEE & AEE
21.11.23(THU)	NEW LAB	CIVIL & E	CIVIL, EEE & MECH	EEE & AEE
22.11.23(FRI)	NEW LAB	CIVIL & E	CIVIL, EEE & MECH	EEE & AEE

COORDINATOR OF EXAMS  
 PRINCIPAL

CIRCULAR FROM UNIVERSITY REGARDING I MID EXAMINATIONS FOR II B. TECH/MBA ONLINE EXAMINATION TIME TABLE AND DESCRIPTIVE TIME TABLE WITH SUBJECTS AND CODES

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# EXAMCELL NOTICE BOARD

**II B. TECH I SEM I MID EXAMINATION TIME TABLE**  
**I. M. TECH II MID EXAMINATION TIME TABLES**  
**III MBA I MID EXAMINATION TIME TABLE**  
**IV B. TECH I SEM I MID EXAMINATION TIME TABLE**

*blae*

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# EXAMCELL NOTICE BOARD

The notice board contains several documents, including:

- M.TECH I SEM TIME TABLE**
- III B.TECH I SEM I MID EXAMINATION TIME TABLE FROM UNIVERSITY**
- II M.B.A TIME TABLE**

**M.TECH I SEM TIME TABLE**

**III B.TECH I SEM I MID EXAMINATION TIME TABLE FROM UNIVERSITY**

**II M.B.A TIME TABLE**

*Blane*

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# VIKAS COLLEGE OF ENGINEERING AND TECHNOLOGY



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 NUNNA-521212, Vijayawada Rural, Krishna Dt., A.P. India.

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## DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

III- II - Sem, II - Mid Exam

		SET	B
ACADAMIC YEAR:	2023-24	Year-Semester:	III-II
COURSE NAME:	Power System Analysis		
Faculty Name:	B. Lakshmana Nayak	Date:	01-05-2024.
Duration :	90 mins	Max Marks:	45 M

### Course Outcomes:

- CO3 Able to form a Zbus for a power system networks. Able to find Symmetrical fault analysis for power systems.
- CO4 Able to find the sequence components of currents for unbalanced power system network. Find the fault currents for all types faults to provide data for the design of protective devices.
- CO5 Able to analyze the steady state, transient and dynamic stability concepts of a power system.

### Answer the Following Questions:

Q. N	Question	Marks	CO	BL
1.A	Explain the three phase short circuit currents on unloaded synchronous generator with neat diagrams.	7	CO3	L2
1.B	What do you understand by short circuit MVA? Explain.	8	CO3	L1
2.A	What are sequence impedances? Obtain expression for sequence impedances in a balanced static 3-phase circuit.	7	CO4	L1
2.B	Derive an expression for the fault current for a double line fault as an unloaded generator and draw its equivalent diagram.	8	CO4	L2
3.A	Describe the methods of improving the transient stability limit of a power system.	7	CO5	L2
3.B	Derive swing equation for a single machine connected to infinite bus system. State the assumptions if any and state the usefulness of this equation.	8	CO5	L2

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## DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

III - II - Sem, II - Mid Exam

		SET	B
ACADAMIC YEAR:	2023-24	Year-Semester:	III- II
COURSE NAME:	Power System Analysis		
Faculty Name:	B. Lakshmana Nayak	Date:	01-05-2024.
Duration :	90 mins	Max Marks:	45 M


### ANS KEY:

1. Explain the three phase short circuit currents on unloaded synchronous generator with neat diagrams?

DEFINITION:2M, DIAGRAM:2M, DERIVATION:3M

A. Short Circuit of a Synchronous Machine on No Load:

Short Circuit of a Synchronous Machine on No Load – Under steady state short circuit conditions, the armature reaction of a synchronous generator produces a demagnetizing flux. In terms of a circuit this effect is modelled as a reactance  $X_a$  in series with the induced emf. This reactance when combined with the leakage reactance  $X_l$  of the machine is called synchronous reactance  $X_d$  (direct axis synchronous reactance in the case of salient pole machines). Armature resistance being small can be neglected. The steady state short circuit model of a Synchronous Machine on No Load is shown in Fig. 9.3a on per phase basis.

  
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- $X_d$  = direct axis synchronous reactance
- $X'_d$  = direct axis transient reactance
- $X''_d$  = direct axis subtransient reactance
- $|E_g|$  = per phase no load voltage (rms)
- $O_a, O_b, O_c$  = intercepts shown in Figs. 9.4a and b.

The intercept  $O_b$  for finding transient reactance can be determined accurately by means of a logarithmic plot. Both  $\Delta i''$  and  $\Delta i'$  decay exponentially as

$$\Delta i'' = \Delta i''_0 \exp(-t/\tau_{dw})$$

$$\Delta i' = \Delta i'_0 \exp(-t/\tau_f)$$

where  $\tau_{dw}$  and  $\tau_f$  are respectively damper, and field winding time constants with  $\tau_{dw} \ll \tau_f$ . At time  $t \gg \tau_{dw}$ ,  $\Delta i''$  practically dies out and we can write

$$\log(\Delta i'' + \Delta i')|_{t \gg \tau_{dw}} = \log \Delta i' = -\Delta i'_0 / \tau_f$$

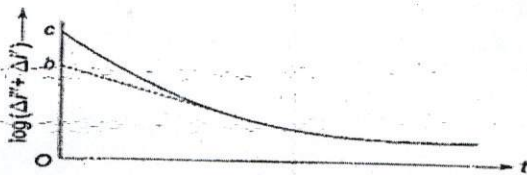


Fig. 9.5

The plot of  $\log(\Delta i'' + \Delta i')$  versus time for  $t \gg \tau_{dw}$  therefore, becomes a straight line with a slope of  $(-\Delta i'_0 / \tau_f)$  as shown in Fig. 9.5. As the straight-line portion of the plot is extrapolated (straight line extrapolation is much more accurate than the exponential extrapolation of Fig. 9.4), the intercept corresponding to  $t = 0$  is

$$\Delta i'|_{t=0} = \Delta i'_0 \exp(-t/\tau_f)|_{t=0} = \Delta i'_0 = ob$$

where

- $r_a$  = AC resistance of the armature winding per phase.

Though the machine reactance's are dependent upon magnetic saturation (corresponding to excitation), the values of reactance's normally lie within certain predictable limits for different types of machines. Table 9.1 gives typical values of machine reactance's which can be used in fault Calculations and in stability studies.

Normally both generator and motor sub transient reactance's are used to determine the momentary current flowing on occurrence of a short circuit. To decide the interrupting capacity of circuit breakers, except those which open instantaneously, sub transient reactance is used for generators and transient reactance for synchronous motors

2. What do you understand by short circuit MVA? Explain.

DEFINITION:4M, EXPLANATION:4M

A. Short Circuit Current Calculation:

What is the importance of short circuit current calculation?



Short circuit current calculation studies are important for every Electrical engineer to estimate the value of fault currents and hence to find the following details.

1. To determine the switchgear rating for protective relaying
2. To determine the voltage, drop during the starting of large motors.
3. To determine the rating of the protective equipment, MCCs, and Breaker panels.

Why MVA method is preferable compared to other methods?

We can also find the short circuit parameters using Ohmic and Per Unit Methods. The conversion formulas used for both these methods are complex and not easy to memorize.

In the MVA method, it is not necessary to convert impedances from one voltage to another as in the Ohmic method. And it is not required any base MVA value as in the Per Unit method. So, the calculations using MVA Method are simple hand calculations and also quick.

Short circuit current calculation using MVA method:

The following is the procedure

1. Convert the typical single line diagram to an equivalent MVA diagram.
2. Simplification of an equivalent MVA diagram into a single short-circuits MVA value at the point of fault.

This can be easily achieved with the following three steps.

Step-1: Convert all single line components to short circuit MVA's.

In practice, the MVA method is used by separating the circuit into components and calculating each component with its own infinite bus. Equipment such as generators, motors, transformers, etc., is normally given their own MVA and impedance or reactance ratings.

The short circuit MVA of each component in the given SLD is equal to its MVA rating divided by its own per unit impedance or reactance.

Step-2: Combine individual MVA values.

- 1) Series MVA's are combined as resistances in parallel.
- 2) Parallel MVA's are added arithmetically.


Step-3: Reduce MVA diagram into a single short-circuits MVA value at the point of fault.

Reduce MVA diagram by simplifying the equivalent MVA diagram using the MVA quantities obtained in the previous step.

3. What are sequence impedances? Obtain expression for sequence impedances in a balanced static 3-phase circuit.

DEFINITION:2M, DIAGRAM:2M, DERIVATION:3M

Sequence Impedance

  
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Step-2: Combine individual MVA values.

- 1) Series MVA's are combined as resistances in parallel.
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Step-3: Reduce MVA diagram into a single short-circuits MVA value at the point of fault.

Reduce MVA diagram by simplifying the equivalent MVA diagram using the MVA quantities obtained in the previous step.

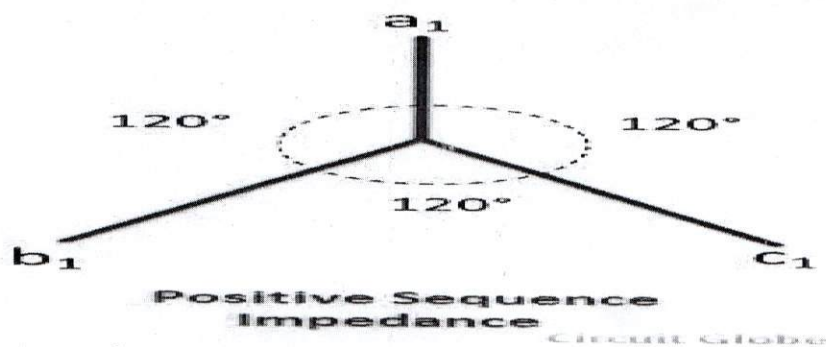
3. What are sequence impedances? Obtain expression for sequence impedances in a balanced static 3-phase circuit.

DEFINITION:2M, DIAGRAM:2M, DERIVATION:3M

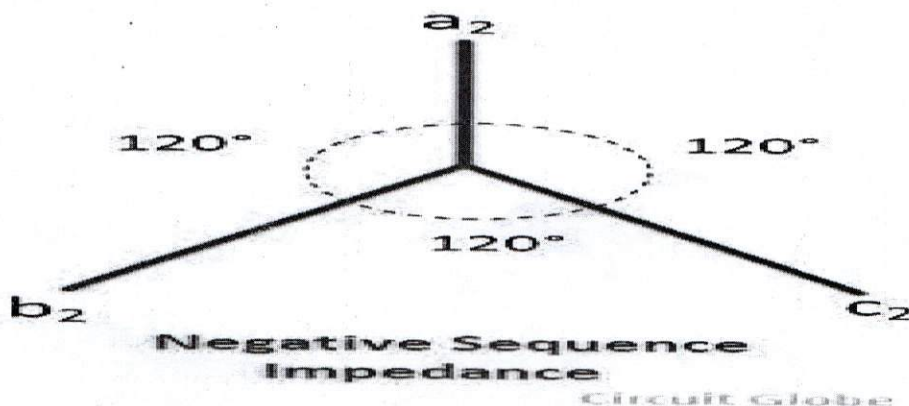
Sequence Impedance

The sequence impedance of the network describes the behaviour of the system under asymmetrical fault conditions. The performance of the system determines by calculating the impedance offered by the different element of the power system to the flow of the different phase sequence component of the current. Every power system component (static or rotating) has three values of impedance one for each symmetrical value of current. The sequence impedance of power system is of three types namely positive sequence impedance, negative sequence impedance and zero sequence impedance.

Positive Sequence Impedance – The impedance offered by the network to the flow of positive sequence current is called the positive sequence impedance. The positive sequence means all the electrical quantities are numerically equal and displaces each other by  $120^\circ$ .



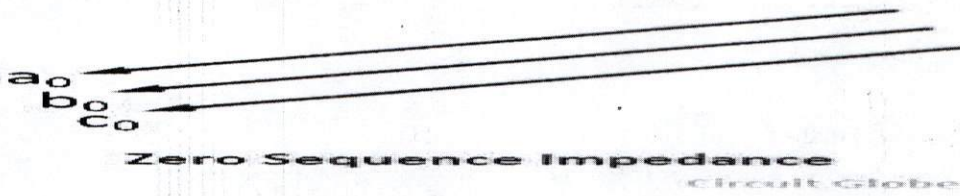
Negative Sequence Impedance – The negative sequence impedance means the impedance offered by the network to the flows of negative sequence current.



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Zero Sequence Impedance – The impedance offered to zero sequence current is called the zero-sequence impedance.



The impedance of the positive, negative and zero sequence component is given by the ratio of the phase sequence voltage to the phase sequence current of the system.

$$\text{Positive Sequence Impedance } Z_1 = \frac{V_1}{I_1}$$

$$\text{Negative Sequence Impedance } Z_2 = \frac{V_2}{I_2}$$

$$\text{Zero Sequence Impedance } Z_3 = \frac{V_3}{I_3}$$

4. Derive an expression for the fault current for a double line fault as an unloaded generator and draw its equivalent diagram

DEFINITION:2M, DIAGRAM:2M, DERIVATION:3M

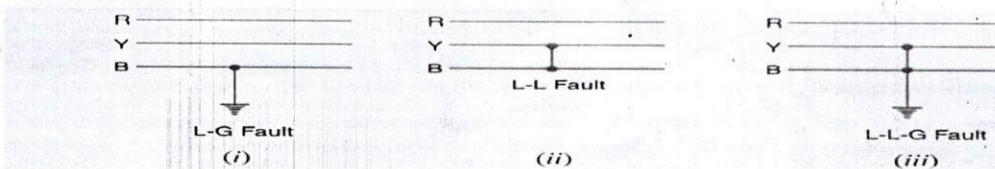
Unsymmetrical Faults on 3-Phase System

Those faults on the power system which give rise to unsymmetrical fault currents (i.e., unequal fault currents in the lines with unequal phase displacement) are known as unsymmetrical faults. On the occurrence of an unsymmetrical fault, the currents in the three lines become unequal and

so is the phase displacement among them. It may be noted that the term 'unsymmetry' applies only to

the fault itself and the resulting line currents. However, the system impedances and the source voltages are always symmetrical\* through its main elements viz. generators, transmission lines, synchronous reactors etc. There are three ways in which unsymmetrical faults may occur in a power system (see Fig. 18.1).

- (i) Single line-to-ground fault (L — G)
- (ii) Line-to-line fault (L — L)
- (iii) Double line-to-ground fault (L — L — G)



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The solution of unsymmetrical fault problems can be obtained by either (a) Kirchhoff's laws or (b) Symmetrical components method. The latter method is preferred because of the following reasons:

- (i) It is a simple method and gives more generality to be given to fault performance studies.
- (ii) It provides a useful tool for the protection engineers, particularly in connection with tracing out of fault currents.

### Double Line-To-Ground Fault

Figure 10.14 shows a three-phase generator with a fault on phases b and c through an impedance Zf to ground. Assuming the generator is initially on no-load, the boundary conditions at the fault point are

$$V_b = V_c = Z_f(I_b + I_c) \quad (10.15)$$

$$I_b + I_c = 0 \quad (10.16)$$

From (10.16), the phase voltages  $V_b$  and  $V_c$  are



5. Describe the methods of improving the transient stability limit of a power system.

DEFINITION: 2M, DIAGRAM: 2M, DERIVATION: 3M

A. Here are some methods to improve the transient stability of a power system:

- Increase voltage: Increasing the voltage profile of the system increases its power transfer ability. This also increases the difference between the critical clearance angle and the initial angle.
- Use high-speed circuit breakers: High-speed circuit breakers help clear faults as quickly as possible.
- Use STATCOMs: STATCOMs can provide active and reactive power independently, and can provide inductance and capacitance for voltage support.
- Use high-speed governors: High-speed governors can be used on machines.
- Use turbine fast valving: Turbine fast valving can be used to improve transient stability.
- Use high-speed excitation: High-speed excitation can be used to improve transient stability.
- Use auto re-closing breakers: Auto re-closing breakers can be used to improve transient stability.

The equal area criterion is a method that can be used to quickly predict the stability of a power system. It's based on the graphical interpretation of the energy stored in the rotating mass.

2 Basics of Transient Stability Assessment and Improvement 2.1 Nomenclature  $P_{e, pre}(W)$  - Active power transfer capability before the fault.  $P_{e, f}(W)$  - Active power transfer capability during the fault.  $P_{e, post}(W)$  - Active power transfer capability after the

$P_m(W)$  - Mechanical power supplied to the turbine.  $P_a(W)$  - Acceleration/deceleration power defined as difference between mechanical and electrical power.  $J(kgm^2)$  - Moment of inertia.

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$\delta_0$  (rad) - Steady-state rotor angle before the fault.  $\delta_1$  (rad) - Steady-state rotor angle after the fault.  $\delta_c$  (rad) - Critical rotor angle which defines stability limit during fault.  $\delta_m$  (rad) - Maximum permissible rotor angle perturbation after fault clearance. A1, A2 - Acceleration and deceleration areas.

**2.2 Transient Stability Mechanism** In order to understand the different effects of the improvement techniques, the basics of transient stability assessment are briefly summarized by means of the well-known equal area criterion (EAC) [12, 13]. The EAC determines the transient stability limit according to the acceleration and deceleration area A1 and A2, respectively. The corresponding P -  $\delta$  diagram is shown in Fig. 1. The physical relation between the mechanical and electrical quantities is given by the equation of motion shown in (1). Generators are accelerating or decelerating once there is a mismatch between mechanical power supplied to the turbine and electrical power delivered to the grid.  $P_a = P_m - P_e = J\omega_0 \frac{d^2\delta}{dt^2}$  (1) The stability limit is derived by calculating the maximum clearing angle and, based on that, the critical clearing time (CCT) which describes the time that the generator takes to advance from the initial rotor angle to the critical rotor angle. Hence, the greater the CCT, the more severe disturbances the generator (system) can withstand.

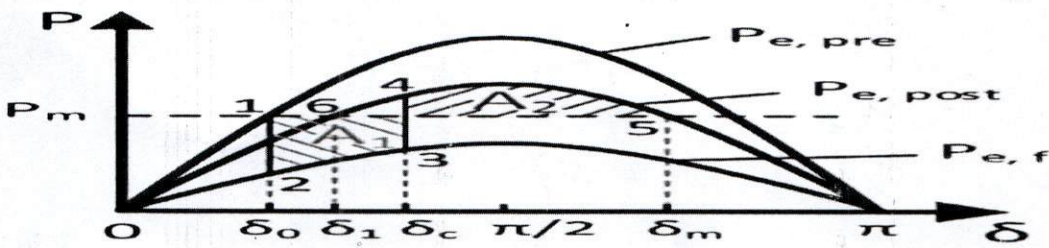


Fig. 1: P- $\delta$  curve

6. Derive swing equation for a single machine connected to infinite bus system. State the assumptions if any and state the usefulness of this equation.

DEFINITION: 2M, DIAGRAM: 2M, DERIVATION: 3M

A. Swing equation for a SMIB (Single machine connected to an infinite bus bar) system.

$$\frac{H}{\pi f} \frac{d^2\delta}{dt^2} = P_m - P_e$$

Since M in p.u =  $H/\pi f$

$$M \frac{d^2\delta}{dt^2} = P_m - P_e$$


Where H = inert a constant in MW/MVA

f = frequency in Hz

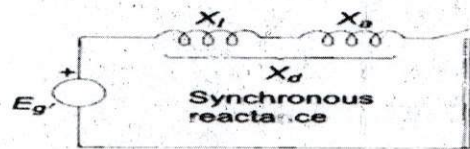
M = inert a constant in p.u

Swing curve

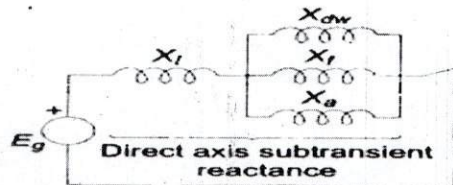
The swing curve is the plot or graph between the power angle  $\delta$  and time t. From the nature of variations of  $\delta$  the stability of a system for any disturbance can be determined.

  
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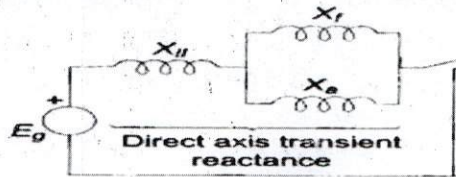




(a) Steady state short circuit model of a synchronous machine



(b) Approximate circuit model during subtransient period of short circuit



(c) Approximate circuit model during transient period of short circuit

Consider now the sudden short circuit (three-phase) of a synchronous generator initially operating under open circuit conditions. The machine undergoes a transient in all the three phase finally ending up in steady state conditions described above.

The circuit breaker must, of course, interrupt the current much before steady conditions are reached. Immediately upon short circuit, the DC off-set currents appear in all the three phases, each with a different magnitude since the point on the voltage wave at which short circuit occurs is different for each phase. These DC off-set currents are accounted for separately on an empirical basis and, therefore, for short circuit studies, we need to concentrate our attention on symmetrical (sinusoidal) short circuit current only.

Immediately in the event of a short circuit, the symmetrical short circuit current is limited only by the leakage reactance of the machine. Since the air gap flux cannot change instantaneously (theorem of constant flux linkages), to counter the demagnetization of the armature short circuit current, currents appear in the field winding as well as in the damper winding in a direction to help the main flux. These currents decay in accordance with the winding time constants.

The time constant of the damper winding which has low leakage inductance is much less than that of the field winding, which has high leakage inductance. Thus, during the initial part of the short circuit, the damper and field windings have transformer currents induced in them so that in the circuit

model their reactances— $X_f$  of field winding and  $X_{dw}$  of damper winding—appear in parallel with  $X_a$  as shown in Fig. 9.3b. As the damper winding currents are first to die out,  $X_{dw}$  effectively becomes open circuited and at a later stage  $X_f$  becomes open circuited. The machine reactance thus changes from the parallel combination of  $X_a$ ,  $X_f$  and  $X_{dw}$  during the initial period of the short circuit to  $X_a$  and  $X_f$  in parallel (Fig. 9.3c) in the middle period of the short circuit, and finally to  $X_a$  in steady state (Fig. 9.3a). The reactance presented by the machine in the initial period of the short circuit, i.e.

$$X_l + \frac{1}{(1/X_a + 1/X_f + 1/X_{dw})} = X_d'' \quad (9.5)$$

is called the subtransient reactance of the machine. While the reactance effective after the damper winding currents have died out, i.e.

$$X_d' = X_l + (X_a \parallel X_f) \quad (9.6)$$

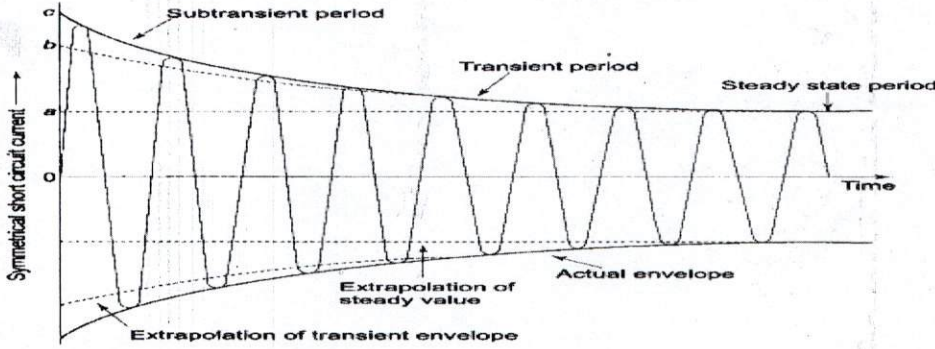
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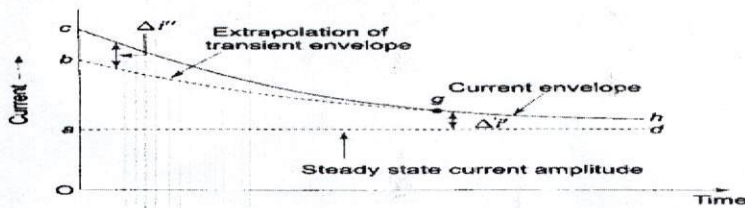
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is called the transient reactance of the machine. Of course, the reactance under steady conditions is the synchronous reactance of the machine. Obviously  $X''_d < X'_d < X_d$ . The machine thus offers a time varying reactance which changes from  $X''_d$  to  $X'_d$  and finally to  $X_d$ .



(a) Symmetrical short circuit armature current in synchronous machine



(b) Envelope of synchronous machine symmetrical short circuit current

Fig. 9.4

If we examine the oscillogram of the short circuit current of a Synchronous Machine on No Load after the DC off-set currents have been removed from it, we will find the current wave shape as given in Fig. 9.4a. The envelope of the current wave shape is plotted in Fig. 9.4b. The short circuit current can be divided into three periods—initial subtransient period when the current is large as the machine offers subtransient reactance, the middle transient period where the machine offers transient reactance, and finally the steady state period when the machine offers synchronous reactance.

If the transient envelope is extrapolated backwards in time, the difference between the transient and subtransient envelopes is the current  $\Delta i''$  (corresponding to the damper winding current) which decays fast according to the damper winding time constant. Similarly, the difference  $\Delta i'$  between the steady state and transient envelopes decays in accordance with the field time constant.

In terms of the oscillogram, the currents and reactances discussed above, we can write

$$|I| = \frac{oa}{\sqrt{2}} = \frac{|E_g|}{X_d} \quad (9.7a)$$

$$|I'| = \frac{ob}{\sqrt{2}} = \frac{|E_g|}{X'_d} \quad (9.7b)$$

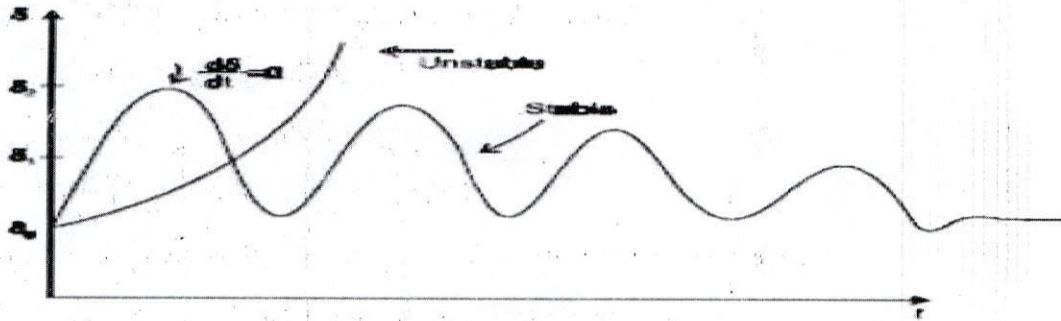
$$|I''| = \frac{oc}{\sqrt{2}} = \frac{|E_g|}{X''_d} \quad (9.7c)$$

where

- $|I|$  = steady state current (rms)
- $|I'|$  = transient current (rms) excluding DC component
- $|I''|$  = subtransient current (rms) excluding DC component

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3 machine system having ratings  $G_1, G_2$  and  $G_3$  and inertia constants  $M_1, M_2$  and  $M_3$ . What is the inertia constant  $M$  and  $H$  of the equivalent system.

$$M_{eq} = \frac{M_1 G_1}{G_b} + \frac{M_2 G_2}{G_b} + \frac{M_3 G_3}{G_b}$$

$$H_{eq} = \frac{\pi f M_{eq}}{G_b}$$

Where  $G_1, G_2, G_3$  – MVA rating of machines 1, 2, and 3

$G_b$  = Base MVA or system MVA

Assumptions made in stability studies.

- (i). Machines represented by classical model
- (ii). The losses in the system are neglected (all resistance are neglected)
- (iii). The voltage behind transient reactance is assumed to remain constant.
- (iv). Controllers are not considered (Shunt and series capacitor)
- (v). Effect of damper winding is neglected.

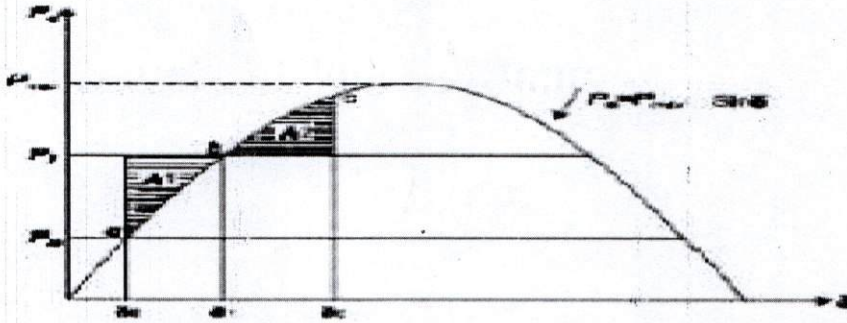
Equal Area Criterion

The equal area criterion for stability states that the system is stable if the area under  $P - \delta$  curve reduces to zero at some value of  $\delta$ .

This is possible if the positive (accelerating) area under  $P - \delta$  curve is equal to the negative (decelerating) area under  $P - \delta$  curve for a finite change in  $\delta$ . Hence stability criterion is called equal area criterion.

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