

- Announcements
- SYNCH homework posted, due latest Mon 9am
- Office hrs: EERC 123 4:05-5:55pm W,F (online connect via Zoom)
- Office: EERC 614. Phone: 906.487.2857
- Recommended problems from Ch.3, solutions posted
- Next: Transmission Line Parameters, Chapters 4,5,6

Synchronous Machines - Chapter 3.

- Concepts behind SYNCH exercise set.
- S-S behavior - X_d ; Dynamic behavior - X_d'
- Short-circuit behavior - X_d'' ; s-s, transient, subtransient

Chapter 4 - Series Resistance of Transmission Lines

- Series Resistance, temperature correction
- Basic stranding, conductor types, ACSR is most common
- Series Resistance, temperature correction

Chapter 5 - Series Inductance of Transmission Lines

- Self inductance, mutual inductance

Example of full set of machine parameters, req'd for transient simulation:

**Name : SM59_FC - Synchronous Machine. 8 TACS control. TYPE 59.
Balanced steady-state. No saturation. Single mass.**

Card : SOURCE

**Data : Volt= Steady-state voltage magnitude in [V]
at the terminals of the machine.**

Freq= The electrical frequency of the machine in [Hz]. Steady-state.

Angle= The steady-state voltage phasor angle phase A in [deg.]

Poles= Number of poles.

**SMOVTP= Proporsjinality factor which is used only to split the real
power among multiple machines in parallel during initialization.
No machines in parallel: SMOVTP=1.**

**SMOVTQ= Proporsjinality factor which is used only to split the reactive
power among multiple machines in parallel during initialization.
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Machines in parallel: Requires manually input file arranging.

RMVA= The three-phase volt-ampere rating of the machine in [MVA].

RkV= The rated line-to-line voltage of the machine in [kV].

**AGLINE= Value of field current in [A] which will produce rated
armature voltage on the d-axis.**

Indirect specification of mutual inductance.

RA= Armature resistance in [pu]. RA>0!

XL= Aramture leakage reactance in [pu].

Xd= D-axis synchronous reactance in [pu].

Xq= Q-axis synchronous reactance in [pu].

Xd'= D-axis transient reactanse in [pu].

Xq'= Q-axis transient reactanse in [pu].

Xd''= D-axis subtransient reactanse in [pu].

Xq''= Q-axis subtransient reactanse in [pu].

Tdo'= D-axis transient time constant in [sec.]

Tqo'= Q-axis transient time constant in [sec.]

Tdo''= D-axis subtransient time constant in [sec.]

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Xo= Zero-sequence reactance in [pu]

RN= Real part of neutral grounding impedance [pu].

XN= Imaginary part of neutral grounding impedance [pu].

XCAN= Canay's characteristic reactance in [pu].

Unknown: Use XCAN=XL.

HICO= Moment of inertia of mass.

In [million pound-feet²] if MECHUN=0.

In [million kg-m²] if MECHUN=1.

DSR= Speed-deviation self-damping coefficient for mass.

T=DSR(W-Ws) where W is speed of mass and Ws is synchronous speed.

In [(pound-feet)/(rad./sec)] if MECHUN=0.

In [(N-m)/(rad./sec)] if MECHUN=1.

DSD= Absolute-speed self-damping coefficient for mass.

T=DSD(W) where W is speed of mass.

In [(pound-feet)/(rad./sec)] if MECHUN=0.

In [(N-m)/(rad./sec)] if MECHUN=1.

FM= <=2: Time constants based on open circuit measurements.

>2: Time constants based on short circuits measurements.
MECHUN= 0: English units.
1: Metric units.

Control I/O:

Node : OUT= Aramture node. 3-phase. Phase A: Angle.
Phase B: Angle-120.
Phase C: Angle+120.

TACS1= TACS node. Type of control: 0..22.

TACS2= TACS node. Type of control: 0..22.

TACS3= TACS node. Type of control: 0..22.

TACS4= TACS node. Type of control: 0..22.

TACS5= TACS node. Type of control: 0..22.

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TACS nodes : Click directly on these to specifiy type of control.

Control type: 0= No Control.

1= D-axis armature current. Out.

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4= Field winding current. Out.

5= D-axis damper current. Out.

6= current in eddy-current winding. Out.

7= Q-axis damper current. Out.

8= Voltage applied to d-axis. Out.

9= Voltage applied to q-axis. Out.

10= Zero-sequence voltage. Out.

11= Voltage applied to field winding. Out.

12= Total mmf in the machines air-gap. Out.

13= Angle between q- and d- axis component of mmf. Out.

14= Electromagnitic torque of the machine. Out.

15= Not in use.

16= d-axis flux linkage. Out.

17= q-axis flux linkage. Out.

18= Angle mass. Out.

19= Angular velocity mass. Out.

20= Shaft torque mass. Out.

21= Field voltage. In.

22= Mechanical power. In.

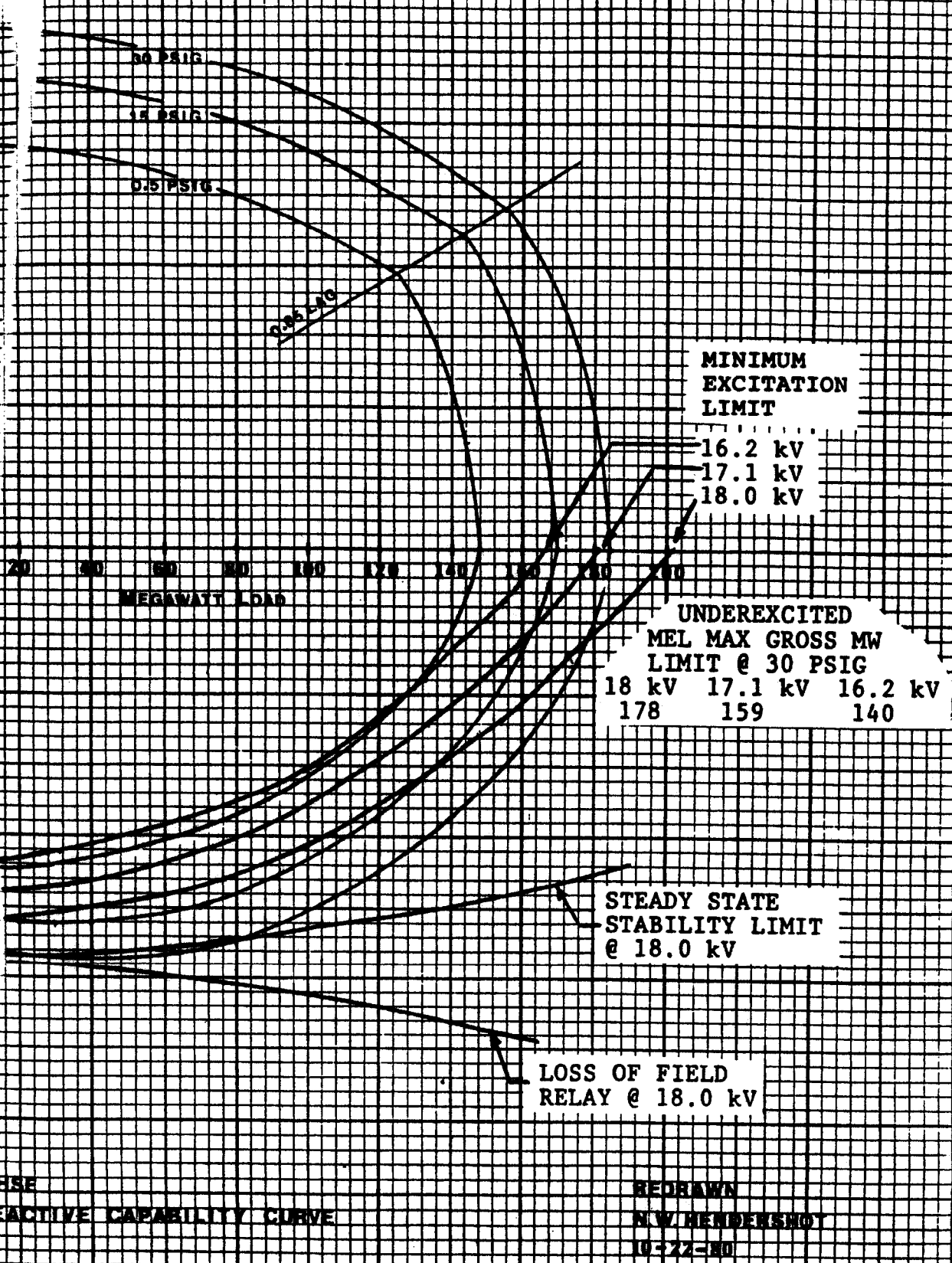
RuleBook: VIII.

MEL curves are for 16.2 kV, 17.1 kV & 18 kV
 the generator bus. The machine capability
 will also be reduced as the generator
 voltage is reduced. This effect is not
 Operation of the generator below maximum
 may require a change in the MEL setting.

J.C. WEADOCK
UNIT 7
 147.055MVA, 18KV
 3600 RPM, 0.85 P.F.

180
 120
 100
 80
 60
 40
 20

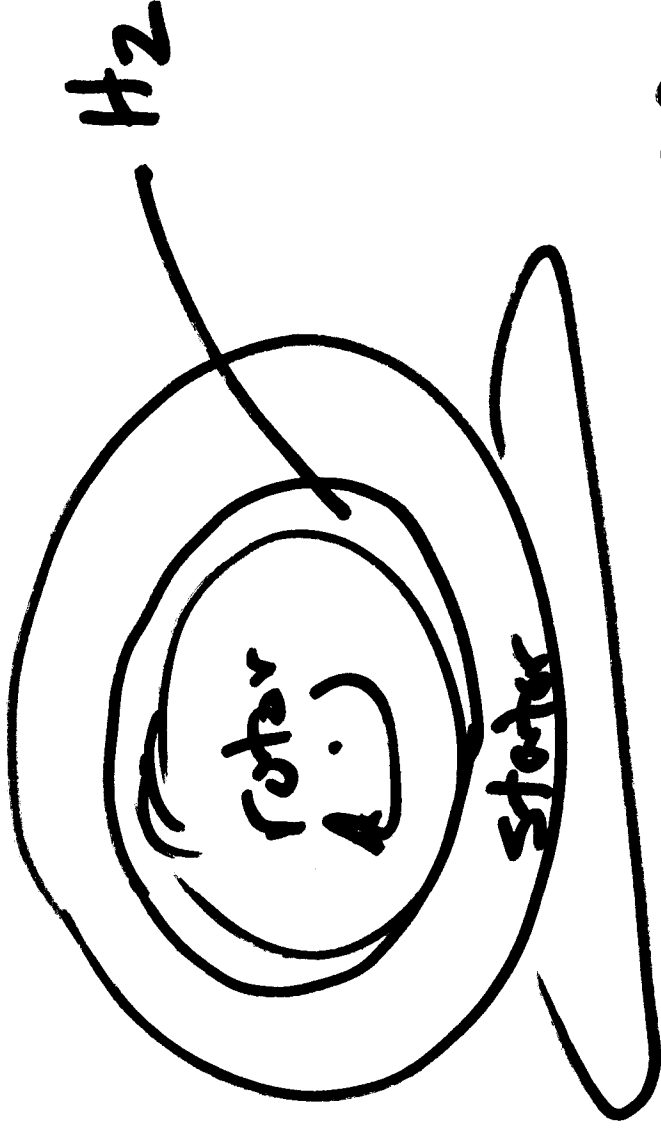
20
 40
 60
 80
 100
 120
 140
 160



WHSE
 REACTIVE CAPABILITY CURVE

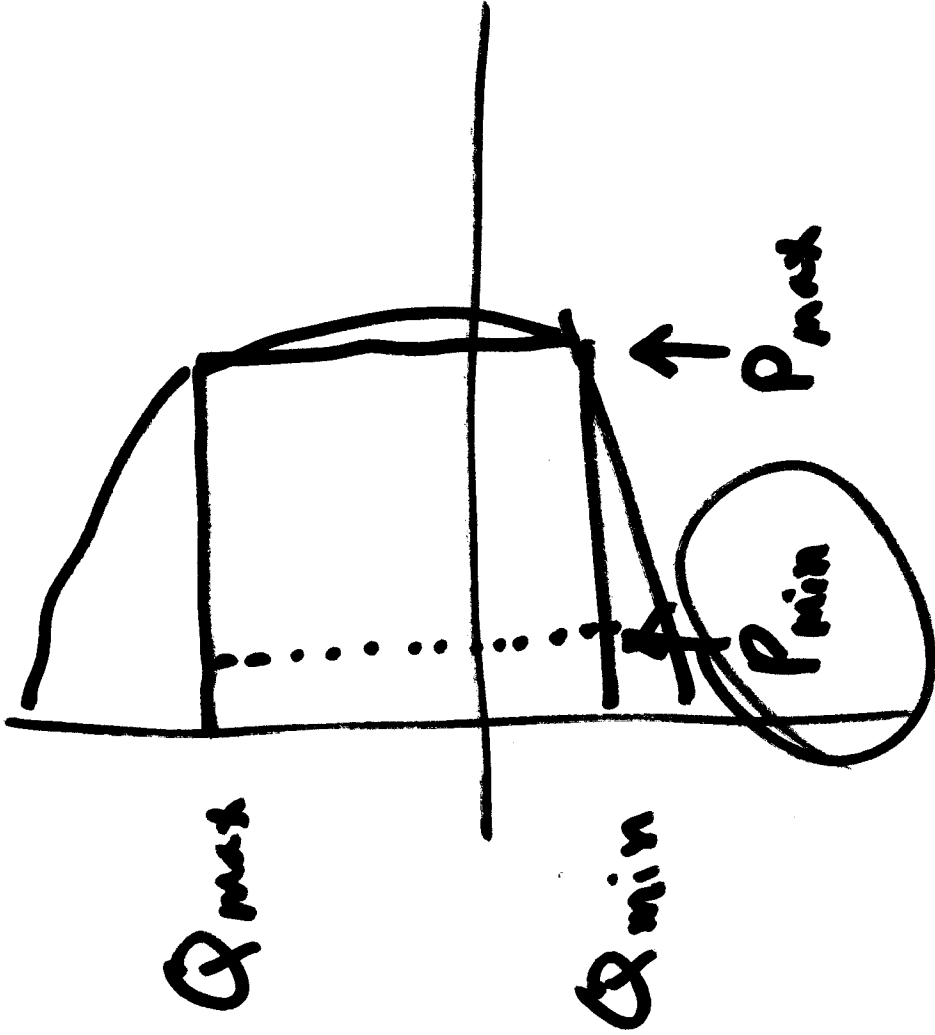
REDRAWN
 N.W. HENBERSHOT
 10-22-80

H₂ inside Gen

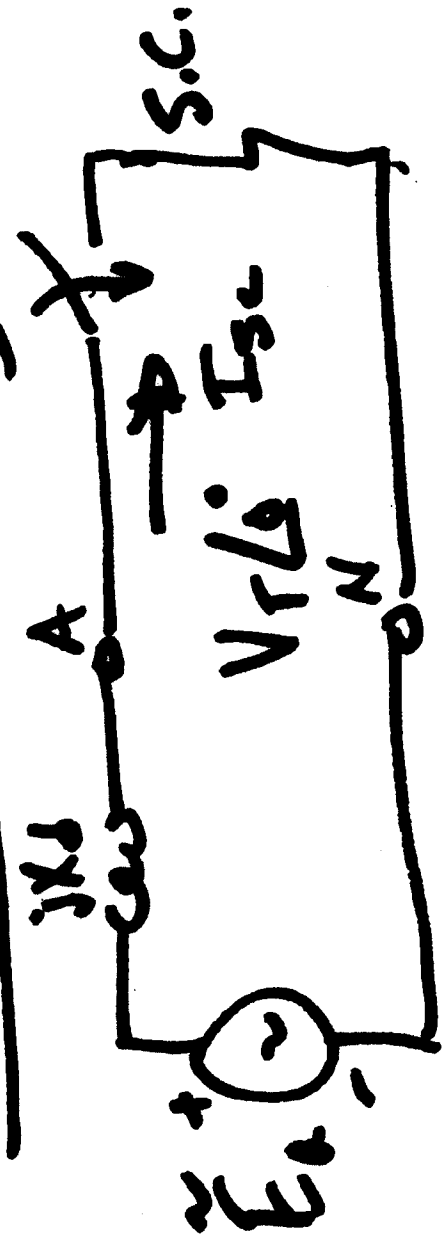


(P_{mech loss})

- Reduce windage losses
- Reduce H₂O vapor
- Heat transfer / cooling.



Fault Current: § 3.9



S-S: $jX_d \approx jX_s$

transient: jX_d — a few seconds

subtransient jX_d'' — up to a few cycles (fault)

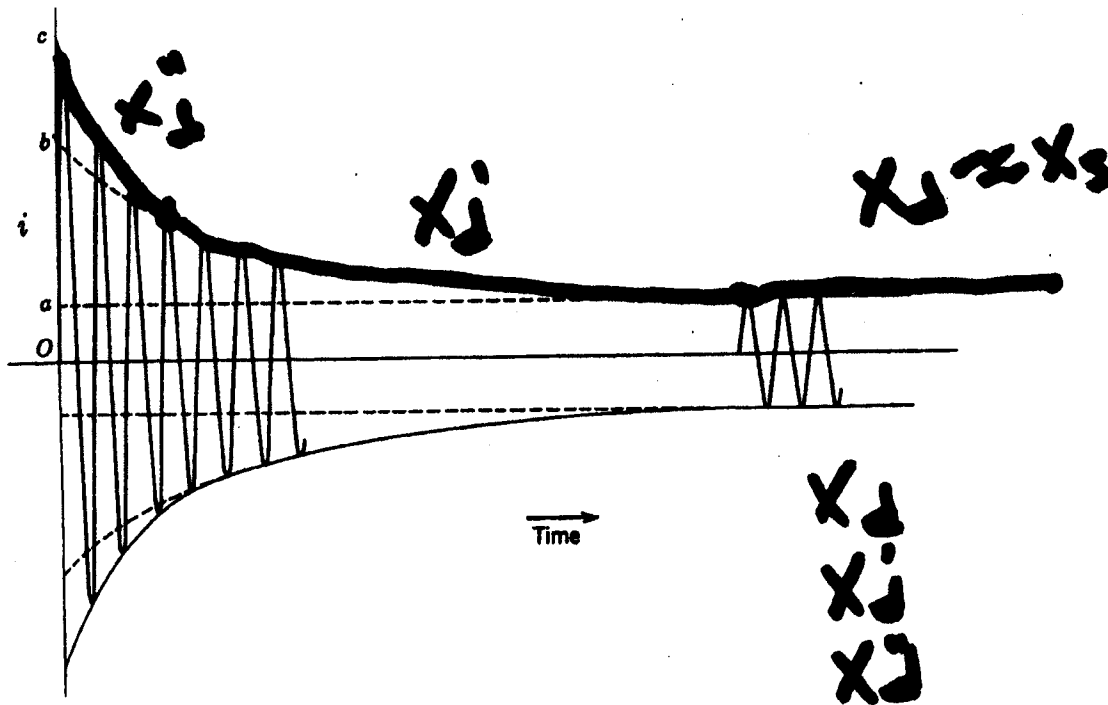


FIGURE 3.19
Current as a function of time for a synchronous generator short-circuited while running at no load. The unidirectional transient component of current has been eliminated in redrawing the oscillogram.

intercept is the distance $o-b$. The rms value of the current represented by this intercept is known as the *transient current* $|I'|$, defined by

$$|I'| = \frac{o-b}{\sqrt{2}} = \frac{|E_i|}{X'_d} \quad (3.59)$$

The rms value of the current determined by the distance $o-c$ in Fig. 3.19 is called the *subtransient current* $|I''|$, given by

$$|I''| = \frac{o-c}{\sqrt{2}} = \frac{|E_i|}{X''_d} \quad (3.60)$$

Subtransient current is often called the *initial symmetrical rms current*, which is more descriptive because it conveys the idea of neglecting the dc component and taking the rms value of the ac component of current immediately after the occurrence of the fault. Equations (3.59) and (3.60) can be used to calculate the parameters X'_d and X''_d of the machine when an oscillographic record such as Fig. 3.19 is available. On the other hand, Eqs. (3.59) and (3.60) also indicate the

3.9 SHORT-CIRCUIT CURRENTS

When an ac voltage is applied suddenly across a series $R - L$ circuit, the current which flows generally has two components—a dc component, which decays according to the time constant L/R of the circuit, and a steady-state sinusoidally varying component of constant amplitude. A similar but more complex phenomenon occurs when a short circuit appears suddenly across the terminals of a synchronous machine. The resulting phase currents in the machine will have dc components, which cause them to be offset or *asymmetrical* when plotted as a function of time. In Chap. 10 we shall discuss how the *symmetrical* portion of these short-circuit currents is used in the ratings of circuit breakers. For now let us consider how short circuits affect the reactances of the machine.

A good way to analyze the effect of a three-phase short circuit at the terminals of a previously unloaded generator is to take an oscillogram of the current in one of the phases upon the occurrence of such a fault. Since the voltages generated in the phases of a three-phase machine are displaced 120 electrical degrees from each other, the short circuit occurs at different points on the voltage wave of each phase. For this reason the unidirectional or dc transient component of current is different in each phase.⁴ If the dc component of current is eliminated from the current of each phase, the amplitude of the ac component of each phase current plotted versus time, shown in Fig. 3.19, varies approximately according to

$$I(t) = |E_i| \frac{1}{X_d} + |E_i| \left(\frac{1}{X_d'} - \frac{1}{X_d} \right) e^{-t/T_d'} + |E_i| \left(\frac{1}{X_d''} - \frac{1}{X_d'} \right) e^{-t/T_d''} \quad (3.57)$$

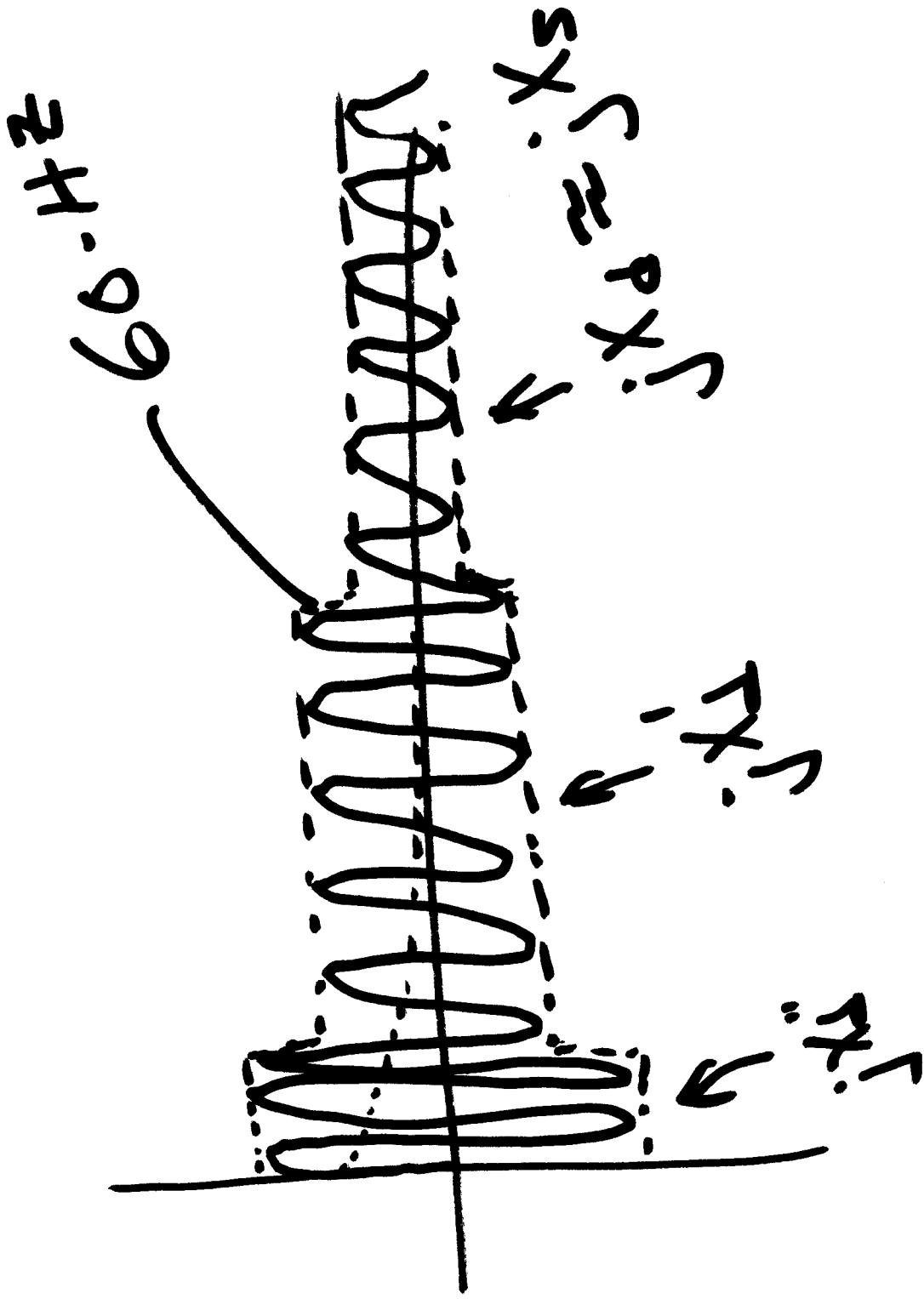
where $e_i = \sqrt{2} |E_i| \cos \omega t$ is the synchronous internal or no-load voltage of the machine. Equation (3.57) clearly shows that the armature phase current, with the dc removed, has three components, two of which decay at different rates over the subtransient and transient periods. Neglecting the comparatively small resistance of the armature, the distance $o-a$ in Fig. 3.19 is the maximum value of the sustained short-circuit current, with the rms value $|I|$ given by

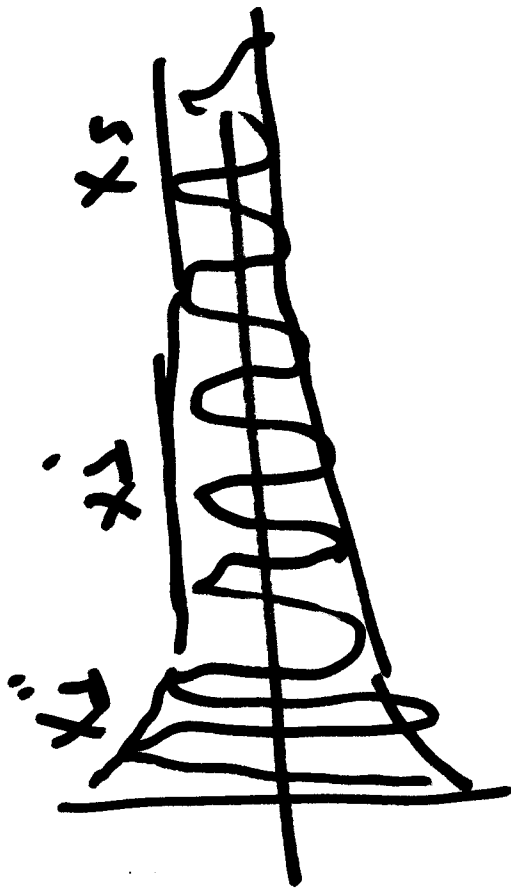
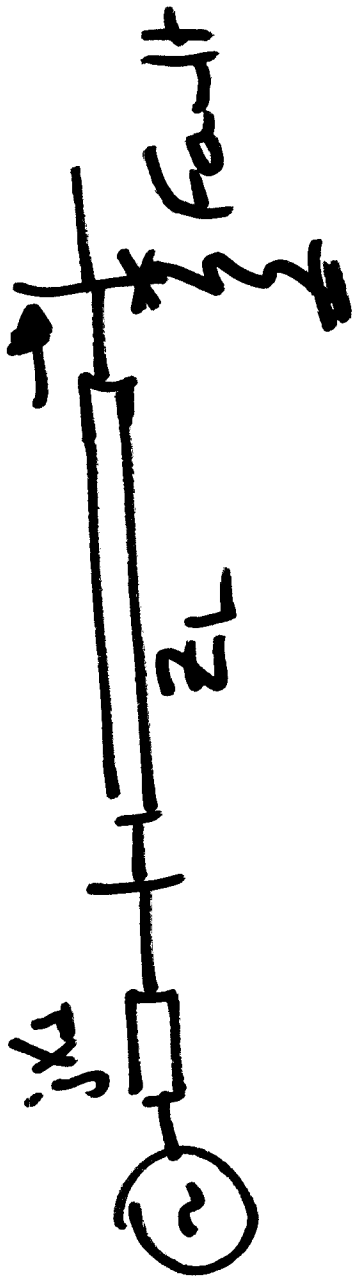
$$|I| = \frac{o-a}{\sqrt{2}} = \frac{|E_i|}{X_d} \quad (3.58)$$

If the envelope of the current wave is extended back to zero time and the first few cycles where the decrement appears to be very rapid are neglected, the

⁴For further discussion of the dc components see A. E. Fitzgerald et al., *Electric Machinery*, 4th ed., McGraw-Hill, Inc., New York, 1983 and Chap. 10 of this book.

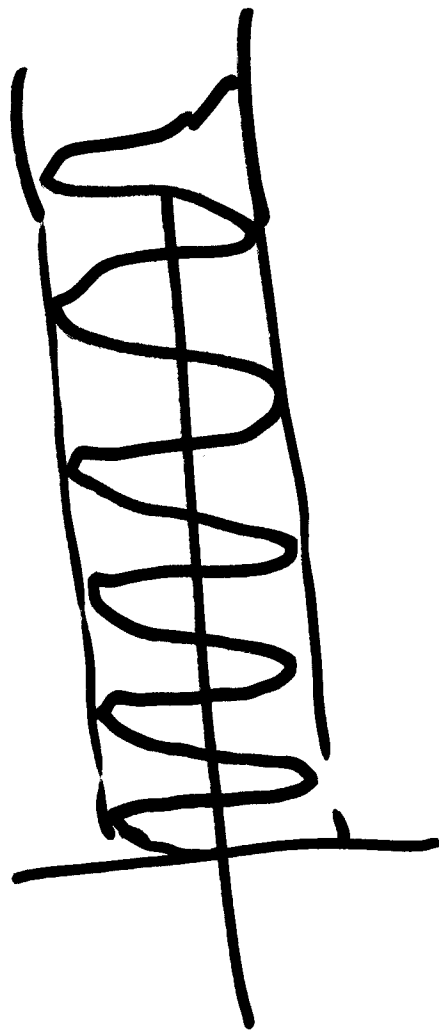
Approximation





if $Z_L < Z_j$

if $Z_L > Z_j$

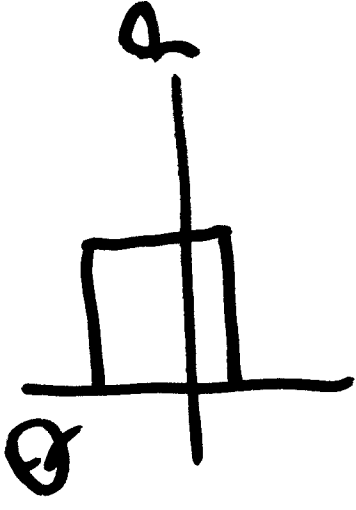


Parameters

- P_{SCHED}

- Q_{min} / Q_{max}

- V_{BUS}



Short-Circuit:

- X_dⁱ, X_d^j, X_d^k

- T_{d0}ⁱ, T_{d0}^j, T_{d0}^k

- X_N



Stability,

Transients

: See help screen
from ATP.

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14= Electromagnetic torque of the machine. Out.

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20= Shaft torque mass. Out.

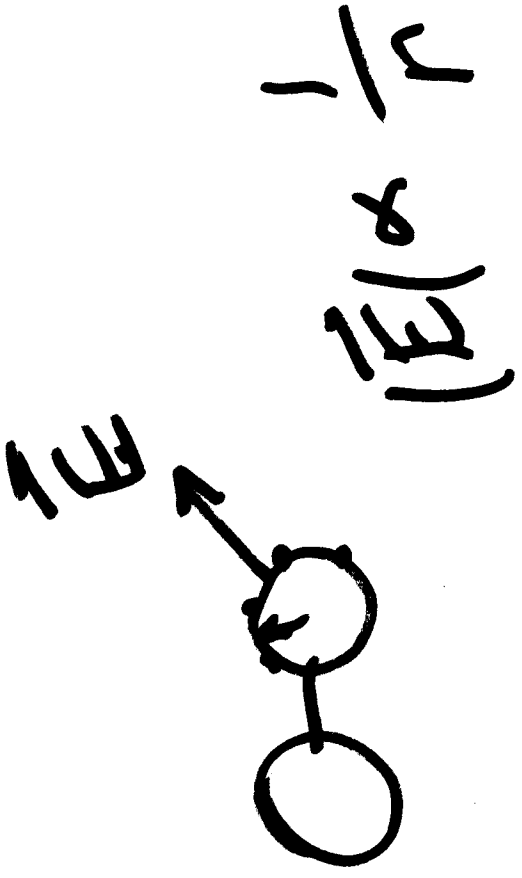
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RuleBook: VIII.

Aluminum Bare Transmission and Distribution Cable

-  AAAC-6201 
-  AAC 
-  ACSR 
-  ACSR/AW 
-  ACAR 
-  ACSR/TW 
-  AAC/TW 
-  Motion-Resistant Conductor 
-  VR2 Cable 
-  ACSS 
-  ACSS/AW 
-  ACSS/TW 
-  Armor Wire/Binder Tape 
-  Tie & Ground Wire 



\uparrow
 \uparrow
 \uparrow
 \uparrow
 Reolpary
 Viberaters

