NINE MILE POINT NUCLEAR STATION

UNIT II OPERATIONS

LESSON PLAN

02-LOT-001-245-2-02 (OPS) 0S-STC-001-245-2-02 (NON-OPS)

MAIN GENERATOR & EXCITER

Prepared By: Unit #2 Training Department

DATE AND INITIALS

APPROVALS

SIGNATURES

REVISION 5

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Summary of Pages

Revision <u>5</u> (Effective Date: _

6/12/90)

Number of Pages: 25

Da to Da II

June 1988

THIS LESSON REAN SUPERCEDES LESSON PLAN #N3-OUR-46:4

NIAGARA MOHAWK POWER CORPORATION

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OBJECTIVE APPLICABILITY MATRIX

OBJECTIVE NUMBER	LICENSE CLASS	NON-OPS
TO-1	X	
TO-2		X
10-2		
EO-1	X	X
E0-1	X	X
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E0-3		
E0-4	X	<u> </u>
E0-5	X	
E0-6	X	X
E0-7	X	X
E0-8	X	
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I. TRAINING DESCRIPTION

- A. Title: N2-OLP-46, Main Generator and Exciter
- B. <u>Purpose</u>: In a lecture presentation, the instructor shall present information for the student to meet each Student Learning Objective. Additionally, he shall provide sufficient explanation to facilitate the student's understanding of the information presented.
- C. Estimated Duration: 2.5 hours
- D. Training Methods:
 - 'Classroom Lecture
 - Assign the Student Learning Objectives as review problems with the students obtaining answers from the text, writing them down and handing them in for grading.

E. References:

- 1. Technical Specification None
- 2. Procedures
 - a. N2-OP-24, Generator Isolated Phase Bus Duct Cooling
 - N2-OP-68, Main Generator, Exciter, Main Transformer,
 325KV Yard, and Generator/Unit Protection
- 3. NMP-2 FSAR
 - a. Vol. 23 Chap. 10, pg. 10.2.1

II. REQUIREMENTS/PREREQUISITES

- A. Requirements for Class:
 - 1. AP-9, Rev. 2, "Administration of Training"
 - 2. NTP-10, Rev. 4, "Training of Licensed Operator Candidates"
 - 73. NTP-11, Rev. 5, "Licensed Operator Retraining and Continuing Training"
 - 4. NTP-12, Rev. 3, "Unlicensed Operator Training"

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B. Prerequisites:

- 1. Instructor
 - a. Demonstrated knowledge and skills in the subject, at or above the level to be achieved by the trainees, as evidenced by previous training or education, or
 - b. SRO license for Nine Mile Point Unit II, or a similar plant, or successful completion of SRO training including simulator certification at the SRO level for Nine Mile Point Unit II, and
 - c. Qualified in instructional skills as certified by the Training Analyst Supervisor.

2. Students

- a. Meet eligibility requirements per 10CFR55, or
- b. Be recommended for this training by Operations Superintendent, his designee, or Training Superintendent.

III. TRAINING MATERIALS

- A. Instructor Materials
 - 1. Transparency Package
 - 2. Overhead Projector
 - 3. Whiteboard and Felt Tip Markers
 - 4. N2-OLP-46
 - 5. N2-OLT-46
 - 6. See Section I.E.1
 - 7. See Section I.E.2
- B. Student Materials
 - 1. N2-OLT-46
 - 2. Section I.E.1
 - 3. Section I.E.2

IV. QUIZZES, TEST, EXAMS AND ANSWER KEYS

A. Will be generated and administered as necessary. They will be on permanent file in the Records Room.

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- TO-1 To provide the trainee with knowledges of the following that will allow safe and efficient operation of the Main Generator and Exciter System:
 - a. System purpose
 - b. Indications
 - c. Alarms
 - d. Major components
 - e. Normal and abnormal operation
 - f. Operator responsibilities according to procedures
 - g. Technical Specifications
 - h. Normal precautions and limitations
- TO-2 To provide the trainee with a basic knowledge of the Main Generator and Exciter System.

Upon completion of this chapter, mastery of the required system knowledge will be demonstrated by performing the Enabling Objectives listed below.

- EO-1 State the purpose of the Main Generator and Exciter.
- EO-2 State the function of the following generator components
 - a. Stator frame
 - b. Stator bars and liquid connections
 - c. Field winding
 - d. Rotor fans
 - e. Collector rings
- EO-3 Describe how the generator field is cooled.
- EO-4 State the function of the following alternator components:
 - a. Stator
 - b. Stator winding
 - c. Alternator armature bus bars
 - d. Rotor
 - e. Alternator collector
 - f. Alternator brush rigging
 - g. Air coolers
- EO-5 State the six (6) systems that must be in operation to support operation of the main generator.

- EO-6 Describe how the isolated phase bus ducts are cooled.
- EO-7 Describe the operation of the AC and DC voltage regulator. Include the parameter varied by the control switch before and after being paralleled to the grid.
- EO-8 Given N2-OP-24, 68, Identify the appropriate actions and/or locate information related to:
 - a. Startup
 - b. Normal operations
 - c. Shutdown
 - d. Off Normal operations
 - e. Procedures for correcting alarm conditions

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Fig. Page

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I. INTRODUCTION

Student Learning Objectives

Purpose Α.

- 1. Main Generator converts the rotational mechanical energy of the Main Turbine into 25kv. 3 phase, 60Hz electrical energy.
- 2. Excitation System provides and controls DC excitation current to the rotor field windings of the Main Generator to regulate Main Generator output voltage.
- Isolated Phase Bus Duct Cooling 3. System provides cool forced air flow to both the indoor and outdoor sections of the isolated phase bus duct so that the bus can carry full generator load without exceeding allowable bus temperature limits.

System Overview/General Description В.

1. Main Generator and Exciter System consists of the major electrical equipment and interconnections associated with Generation and Transmission of Electrical Energy to the 345kv system and to the Normal Station Service Transformer.

VI. LESSON CONTENT

Text Text Ref. Ref. Page Fig.

II. DETAILED DESCRIPTION

2

A. Main Generator

- Located in turbine building at 306 ft. elevation.
- Hydrogen cooled, synchronous, direct driven from 14-stage tandem compounded steam turbine. Generator supplies 3 phase power at the following rating:

Rated KVA 1,348,400kva
Rated Voltage 25 kv
Pf 0.90 lagging
Speed 1,800 RPM
Max H₂ Pressure 75 psig
Frequency 60 Hz

B. Generator Construction

1. Stator Frame

2a

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- a. Welded gas tight generator casing and end shield. Supports and encloses stator winding and core.
- b. Cooled principally by hydrogen gas circulated by fans. Deionized water cools stator windings.

2. Stator Core

- a. Built of thousands of segmental, oriented-grain silicon steel punchings.
- b. Punchings are annealed and insulated with varnish.
- c. The punchings are assembled in an 2 interleaved manner on keys machined on key bars to form a cylindrical—shaped core for the stator winding.

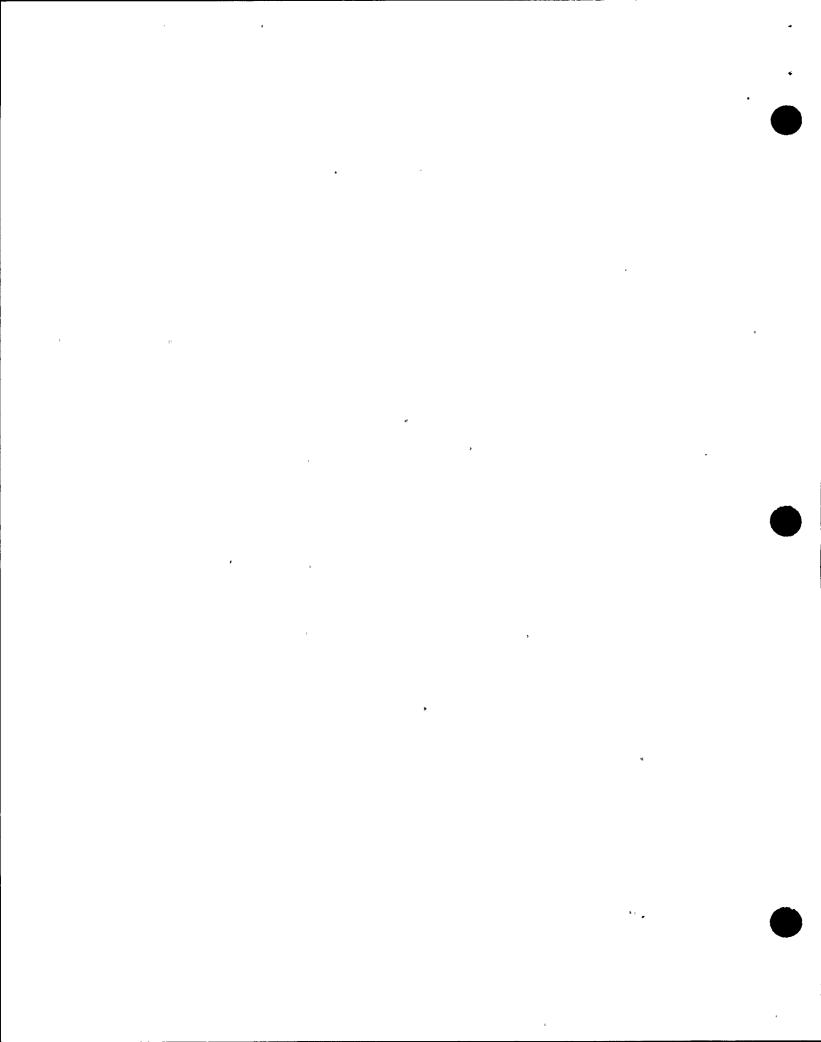
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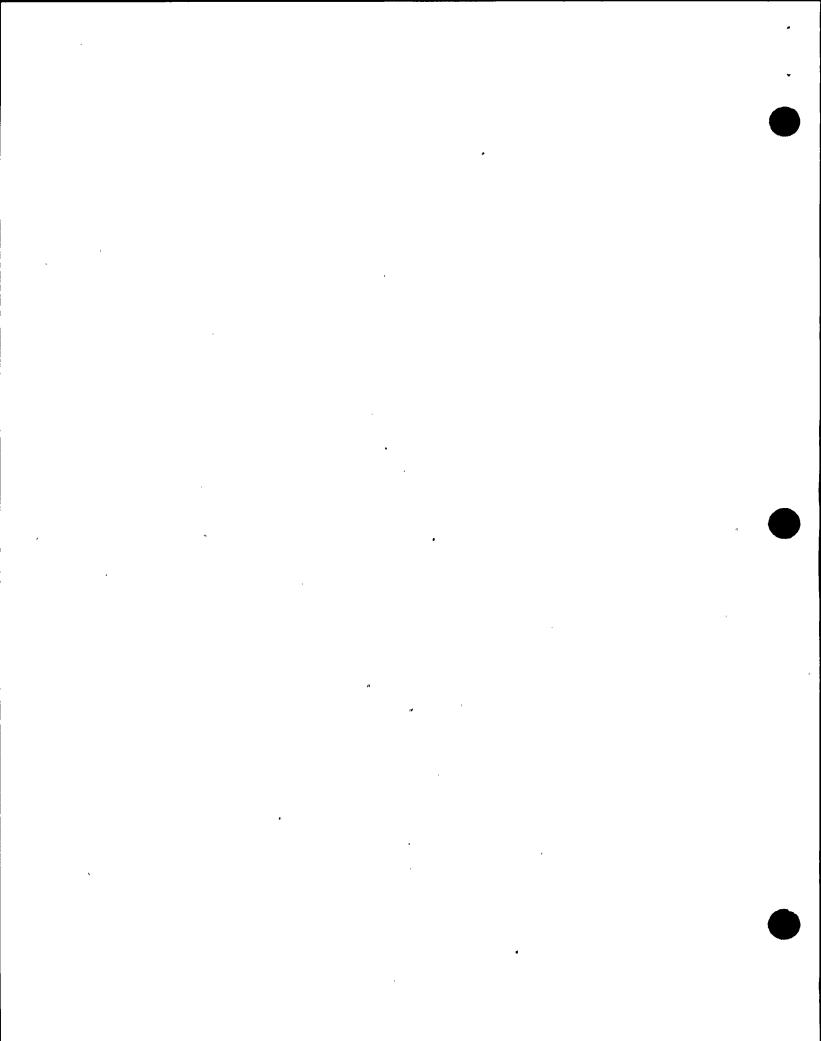
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	3.	Stat	tor Bars		1	
	٠.	a.	Armature Winding formed by		•	2b
			inserting insulated bars into			
			core slots. Ends are joined			
			to form coils which are connected	Đ.		
			by rings.			
		b.	Each bar is composed of hollow	3		
			copper conductors. Strands are		4	
		•	spiral or transposed to share			
			load current and minimize losses			
F			due to flux distribution.			
		с.	Each strand is insulated with low		4	
			voltage insulation.			
		d.	Strands are hollow to carry		1	
			deionized water for cooling.			
	4.	Stat	tor Liquid Connections			
			a. Stator Bar Strands are manifolded			
		i.	at each end by a clip assembly.			
			Clip assembly has one tube			
		,	connection.			
			b. Flexible heavy wall teflon hoses	į		
			connect tube fittings to annular			
•			manifold (header). Inlet header is			
			at one end and outlet header is			
			at opposite end.		•	
		5.	Stator End Winding Support	3		2b
			a. Stator bar ends are rigidly			
			supported to avoid vibrations.			
			b. System of anchoring called Tetra-			
			Loc due to the four-way support			
			provided.	•		
		ı	c. Resin impregnated glass roving			
			used to hold bars'and groups of			
			bars. Allows flexibility and			
			custom fit. 02-LOT-001-245-2-02 -7 June	1990		
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			•	<u> </u>
6.	Rotor (Field) Winding			2c
	a. A multi-coil, single circuit			
	winding produces the magnetic			
	field in the rotor.			
	b. The exciter feeds DC voltage on to	l		
	the rotor winding via collector			
	rings and carbon brushes.			
	c. The field winding consists of			
	four poles 90° apart. The			
	conductor is rectangular in		•	
	cross-section with holes for		•	
	hydrogen circulation and is			
	insulated from other conductors.			
	d. All turns are connected in series			
	to form a one-circuit winding.			
7.	Rotor Cooling	4	2	3
	a. Cooled by hydrogen gas flow in			
	direct contact with the copper			
	windings.			
	b. Gas is forced into rotor subslots			2d
	then flows outward through the			
	winding by fans on each end.			
	c. Hydrogen cooled in heat exchangers			
	mounted on top of generator.			
8.	Collector and Collector Connections			2e
	a. Collector rings shrunk on end of			
	rotor shaft, provide contact	ę.		
	surface for brushes.			
	b. The collector rings are connected			
	to connection bars in the bore			
	hole in the center of the -			
	rotor.shaft.			
	c. The connection bars connect to			
	rotor windings via terminal studs.			



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VI. LESSON CONTENT

9. Couplings

- a. Coupling faces are bolted together with enough friction between the coupling faces to transmit the normal shaft torque.
- b. Coupling bolts also absorb the torsional stresses at the coupling and are tightly fitted so that the shear forces are absorbed uniformly in the bolts.

10. Shaft voltages

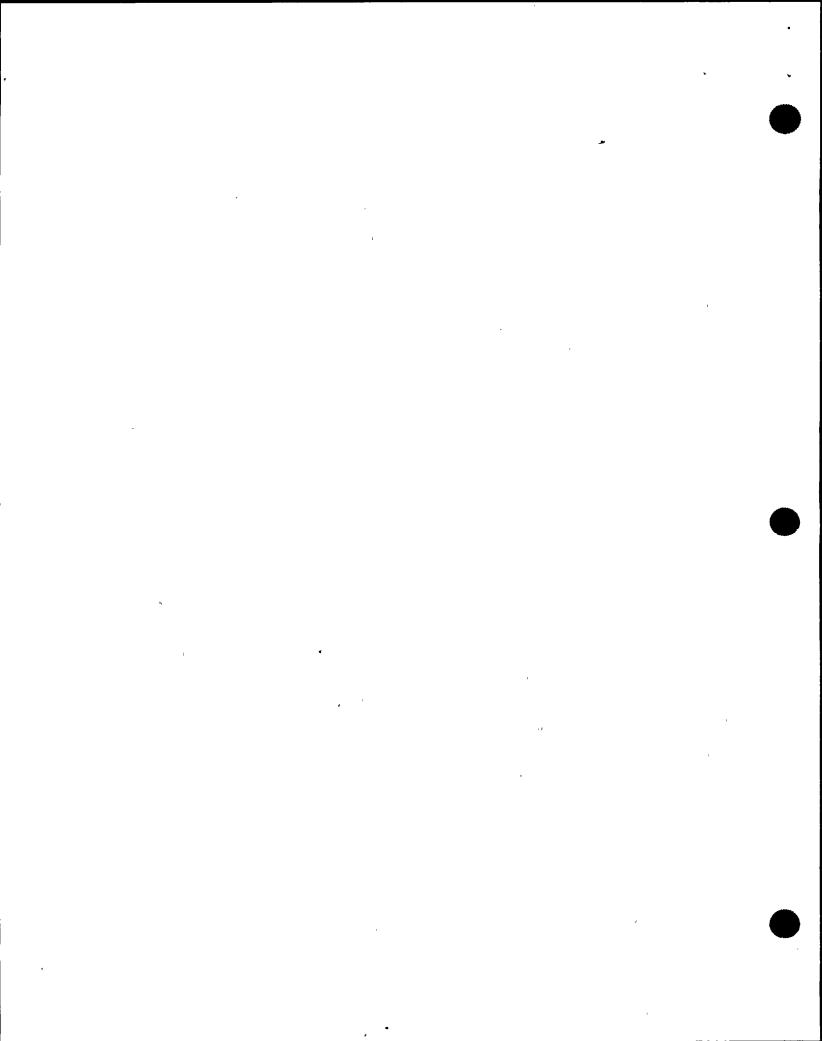
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- a. Voltages may be induced in generator rotor due to stray magnetic flux.
- b. Normally 5-10 volts RMS AC, peaks may be 150 volts peak-to-peak.
- c. Arcing across the oil film could cause pitting of bearing and shaft.
- d. The rotor is grounded to the casing through the use of grounding brushes. Electrical insulation is also used to minimize the conduction of the voltage which will generate shaft currents.

11. End Shields and Bearings

- a. End Shields are reinforced fabrications designed to support the weight of the rotor and contain hydrogen within the generator.
- b. Rotor bearing, hydrogen shaft seals, and seal oil passages are contained and supported by end shields

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<u>Page</u>	Fig.

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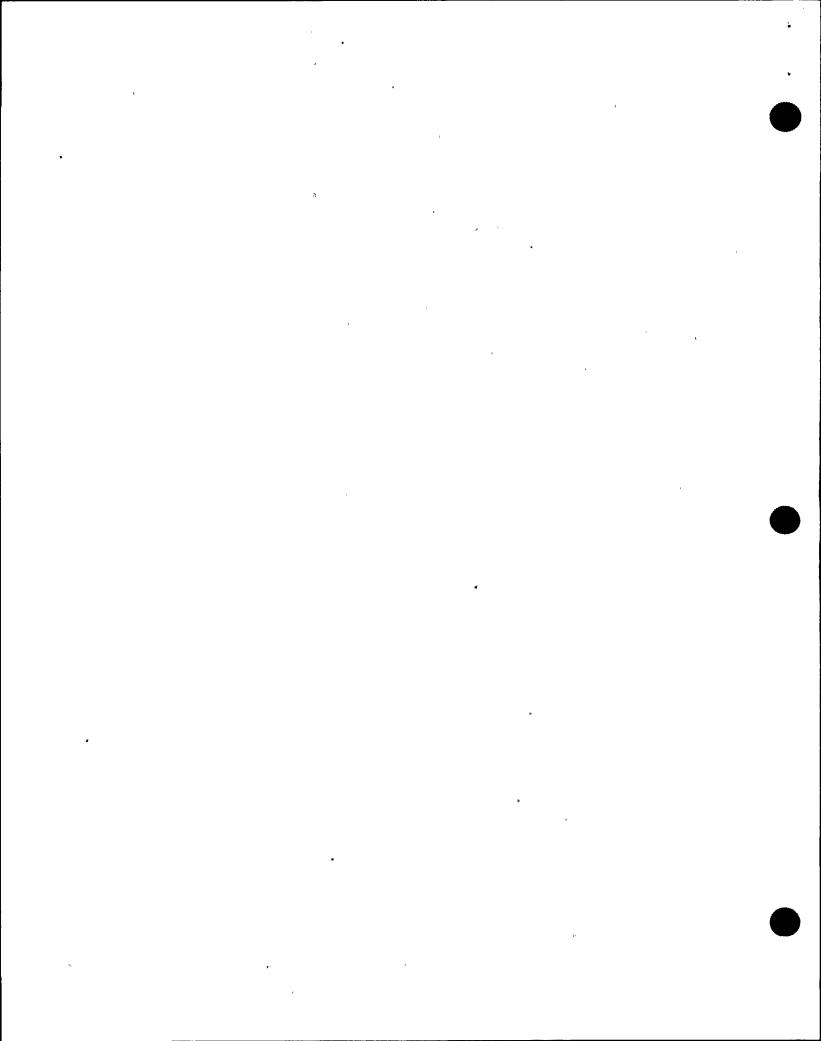
VI. LESSON CONTENT

- c. Outer end shield can be removed for bearing inspection without loss of hydrogen.
- d. Shields are split on horizontal centerline to facilitate removal.
- e. The inner end shields help separate 5 the hydrogen fans' suction from the discharge to improve the flow through the generator.
- 12. Lower Frame Extension and High Voltage Bushing
 - a. Provides passage of the main power leads (from the armature windings) via porcelain insulated high-voltage bushings
 - b. The armature windings terminate at 6 bushings on the lower frame extension at the collector end of the generator.
 - c. 18 current transformers are fedby the high voltage bushings-15 for relaying, 3 for metering.

C. ALTERNATOR CONSTRUCTION

- 1. Generator Exciter
 - a. "Alterrex" excitation system manufactured by General Electric
 - Consists of Alternator, Static
 Voltage Regulator and Power
 Rectifier Assembly.
 - c. 4 pole AC synchronous generator driven from main generator shaft. Air cooled with air-to-water heat exchanger. Cooling water provided by TBCLCW.
 - d. 3-phase power at the following ratings:

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VI. <u>LESSON CONTENT</u>	Text Ref. <u>Page</u>	Text Ref. Fig.	<u>SL0</u>
Rated kva 3595 kva			
· Rated voltage 436 vac			
PF 0.95 Lagging			
Speed 1800 RPM			
Frequency 60 Hz			
e. Alternator output is controlled			*
by static voltage regulator	,		
which controls the alternator			
field current.	'		
f. Alternator Exciter output is			
rectified by Main Generator			
field rectifier assembly			
then fed to Main Generator			
field through the field breaker			
and collector assembly.			
2. Alternator Stator	7		4a
a. Stator consists of 3 main elements:	ı		4b
Fabricated Steel Frame, Laminated	1		
Core, and Armature Winding.			
 Stator frame is designed to support 			
the stator punchings (laminations)			
 c. Laminations are thin, high-grade, 			
non-aging low-loss silicone sheet			
steel. A coating of insulating			
enamel helps minimize core eddy	•		
currents.			
Alternator Armature Bus Bars	7		4c
a. Purpose: carry the alternator-			
exciter output to the power			
rectifier assembly.			
b. Power rectifier consists of five		,	
three-phase full wave rectifiers,			
mounted on alternator-exciter			
housing. 02-LOT-001-245-2-02 -11 June 1	990		
UNIT 2 OPS/552			

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- the field windings
- The collector is opposite the b. coupling end.

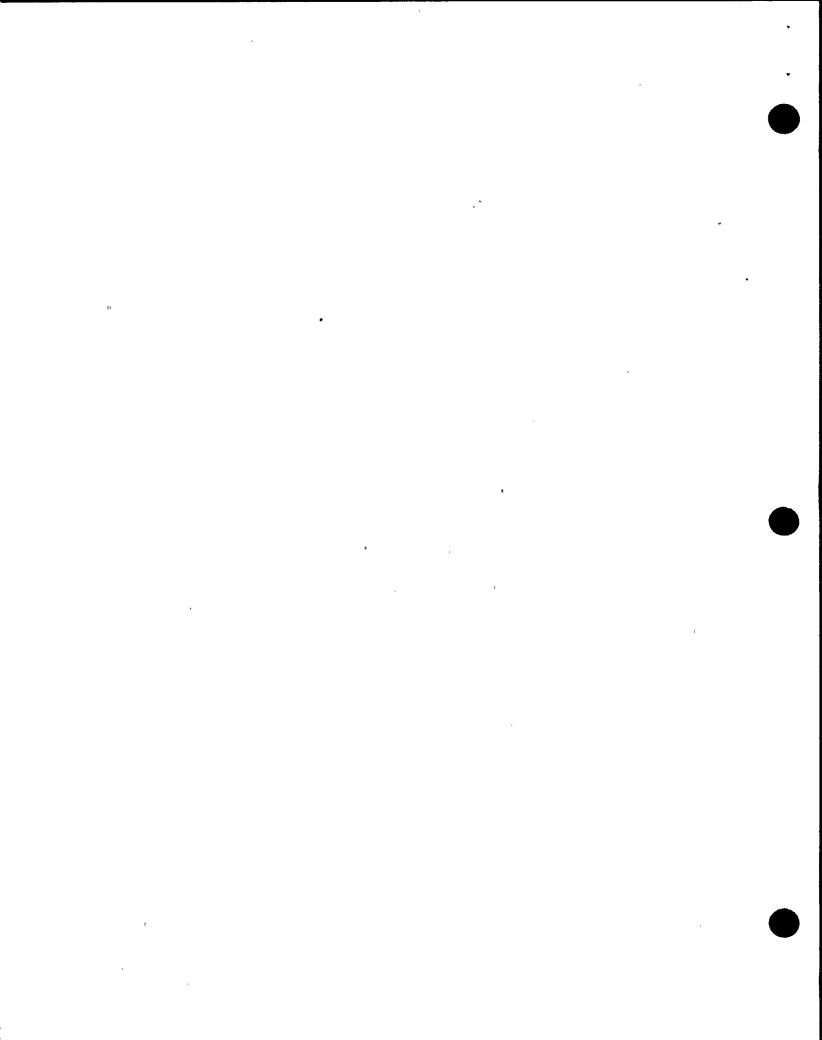
The alternator brush rigging С. consists of 8 spring-loaded brush holders clamped on to an insulated steel stud; they transmit the excitation voltage onto the rotor.

Alternator bearings are forcedd. oil lubricated from the main turbine lube oil system; they provide radial support for the alternator shaft.

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6. Air Coolers

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- a. Horizontally mounted above alternator
- b. The Cooler is a single pass heat exchanger. Cooler removes heat from alternator closed air circulation cooling system.
 Cooled by TBCLCW system.

D. GENERATOR ISOLATED PHASE BUS DUCT COOLING SYSTEM

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- 1. Isolated Phase Bus Duct Cooling System
 - a. Each phase from generator to transformer is enclosed in two separate ducts referred to as the isolated phase bus duct.
 - Two 100% capacity, forced draft, cooling units, cooling water supplied from TBCLCW system.
- 2. Cooling Units
 - a. Cooling unit consists of fan, cooling coil section, motoroperated inlet damper and a back draft discharge damper.
 - Normally, one unit fan is running;
 other in standby. Air cooled by
 TBCLCW.
- 3. Flow Path
 - a. Air flows from cooling unit to center phase of bus duct. Air travels in both directions along center phase. Splits and flows through crossover ducts to other two bus ducts. Air returns toward cooling unit through other two ducts.

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Text Text Ref. Ref. <u>Page</u> Fig.

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VI. LESSON CONTENT

b. Return air ducts tap off the outer two bus ducts above the cooling unit and connect to the commom return air plenum.

III.INSTRUMENTATION, CONTROLS AND INTERLOCKS

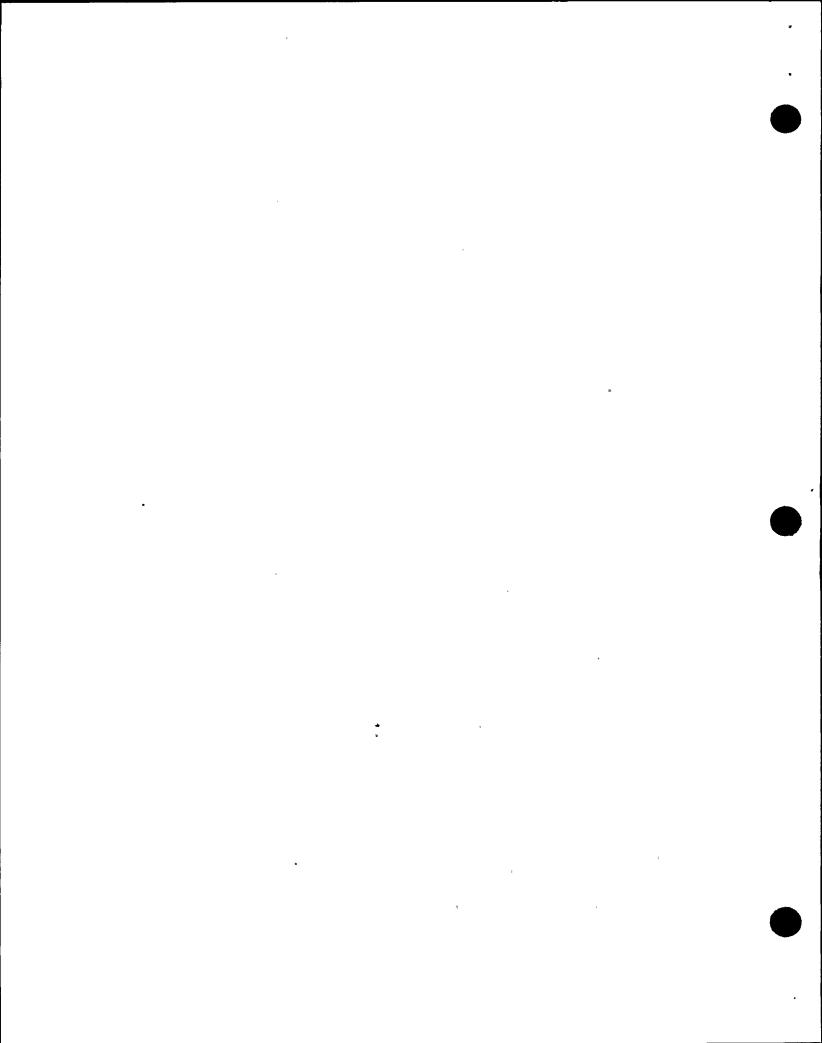
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- A. The following <u>instrumentation</u> is located in the control room on panel 2CEC-PNL852:
 - Main Generator Field Current, dc ammeter, scale 0--8,000 dc amps, indicates Main Generator field current.
 - Main Generator Field Volts, dc voltmeter, scale 0-600 dc volts, indicates Main Generator field voltage.
 - Voltage Regulator Amplidyne Meter (Boost-Buck), dc voltmeter, scale -10/0/+10 dc volts, indicates differential voltage between the auto and manual voltage regulators.
 - Main Generator Current Ph. 1-3 ac ammeter, scale 0-45 ac kiloamperes, indicates Main Generator phase current (one meter per phase).
 - 5. Main Generator Megavars, varmeter, scale 1500-0-1500 ac megavars marked to GEN on left and TO BUS on right, indicates Main Generator reactive power.
 - Main Generator Megawatts, wattmeter, 10
 scale 0-1,500 ac megawatts indicates
 Main Generator output power.

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UNIT 2 OPS/552



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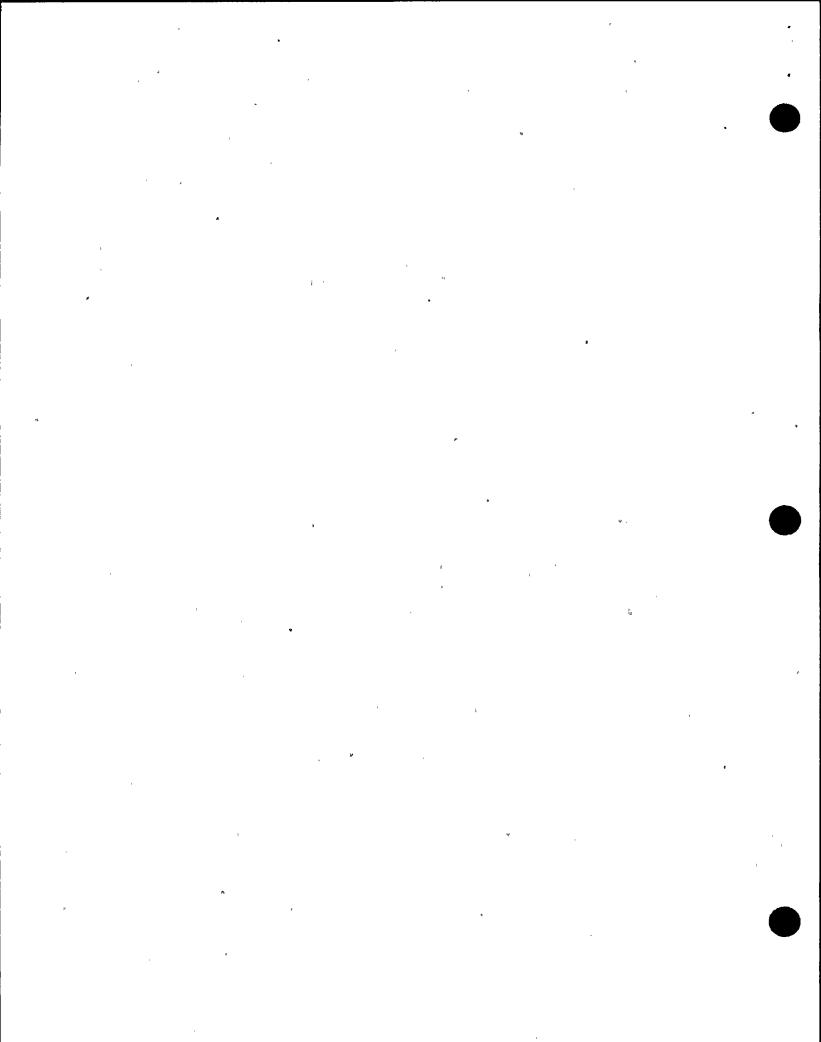
VI. LESSON CONTENT

7. Main Generator Frequency, frequency meter, scale 55-65 Hz, indicates main generator line frequency.

- 8. Main Generator Frequency Chart
 Recorder, scale 55-65 Hz, EsterlineAngus recording frequency meter,
 single channel for Main Generator
 frequency.
- Main Generator Kilovolts, ac voltmeter, scale 20-30-kV, indicates Main Generator phase-to-phase voltage.
- 10. 345kV line Main Generator Volts,
 Esterline-Angus recording voltmeter.
 Channel 1 records 345-kV line voltage
 (0-875kV) and Channel 2 records Main
 Generator phase-to-phase voltage
 (0-30kV).
- B. The following control switches and position indicators are located in the control room on Panel 2CEC-PNL852:
 - 1. 41ECS-2EXCX03, control switch for 2GMS-G1 exciter field breaker (41E).
 - 2. 41MCS-2EXSX03, control switch for 2GMS-Gl field breaker (41M).
 - 3. 43CS--2EXSX03, control switch for selecting manual or automatic generator voltage regulation.
 - 4. 70CS-2EXSX03, control switch for adjusting the exciter DC voltage regulator.
 - 90CS-2EXSX03, control switch for adjusting the exciter AC voltage regulator.

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C. Stator Ground Fault

 Stator neutral is normally close to ground potential through a high impedance grounding transformer.

- 2. Single fault may not cause immediate damage but stator has tough, high voltage insulation so a ground fault may be indicative of a larger, more serious problem. Second fault could cause serious damage.
- Stator ground fault relay will trip 11 unit (simultaneous trip) if single fault occurs.

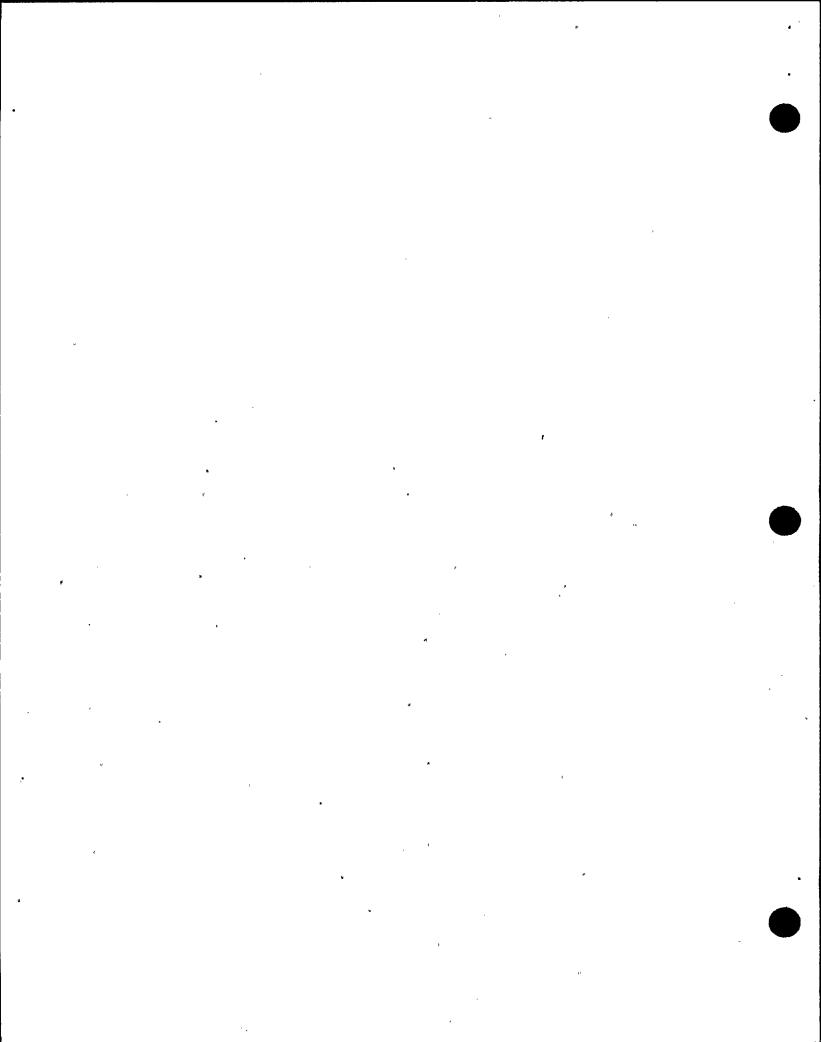
D. Stator Phase-to-Phase Fault

- This is an electrical fault between any two phases of Armature.
- 2. It is very serious due to the potential for very large current flow
- 3. Protected by the generator differential protective relay, will trip generator

E. Overvoltage

- Permissible voltage limits are listed in the Generator Instruction Book.
 Also found in Generator Operating Procedure.
- Extended operation at overvoltage condition leads to excessive heating in stator caused by I²R losses. May damage insulation.
- 3. If voltage regulator fails, overvoltage relay will protect the generator and exciter

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F. Over-volts per Hertz

- Volts per hertz means percent voltage divided by percent frequency
- Proportional to flux in the generator and step up transformer cores.
 Excessive flux may cause overheating.
- 3. May be caused by regulator failure, load rejection, or manual regulator operation with a turbine trip.
- 4. Dual level protection (on or off line) trips within 2 seconds at 118% or 30 seconds at 110% to 118%.
- 5. Will trip immediately on load reject at 110% if regulator in manual

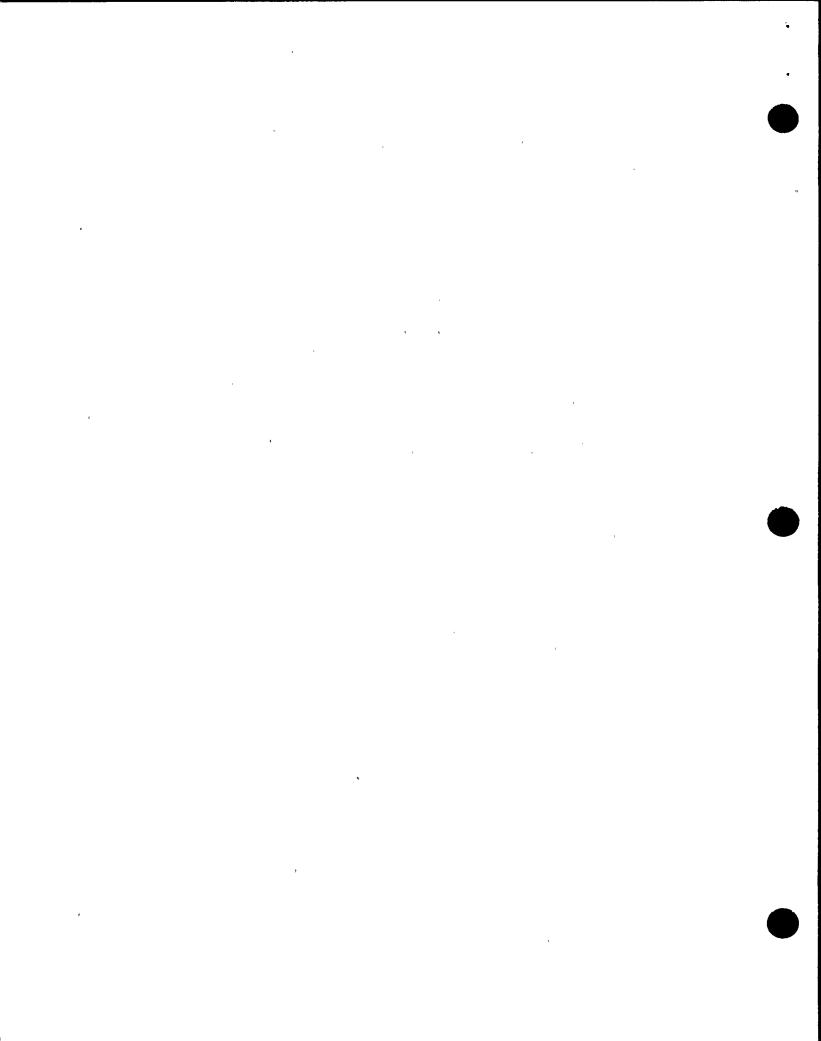
G. Field Ground

- Field is isolated from ground so single ground fault will not usually cause damage.
- Presence of the first ground makes the second fault difficult to detect. The second ground may cause extensive damage.
- 3. Field Ground Protective Relay will trip generator on single field ground fault.

H. Loss of Excitation and Loss of Synchronism

- 1. Results in operation of generator as an induction motor.
- May cause severe overheating and pulsating rotor torque leading to electrical and/or mechanical damage
- Protected by loss of excitation relays and Out-of-Step Relays which trip generator.

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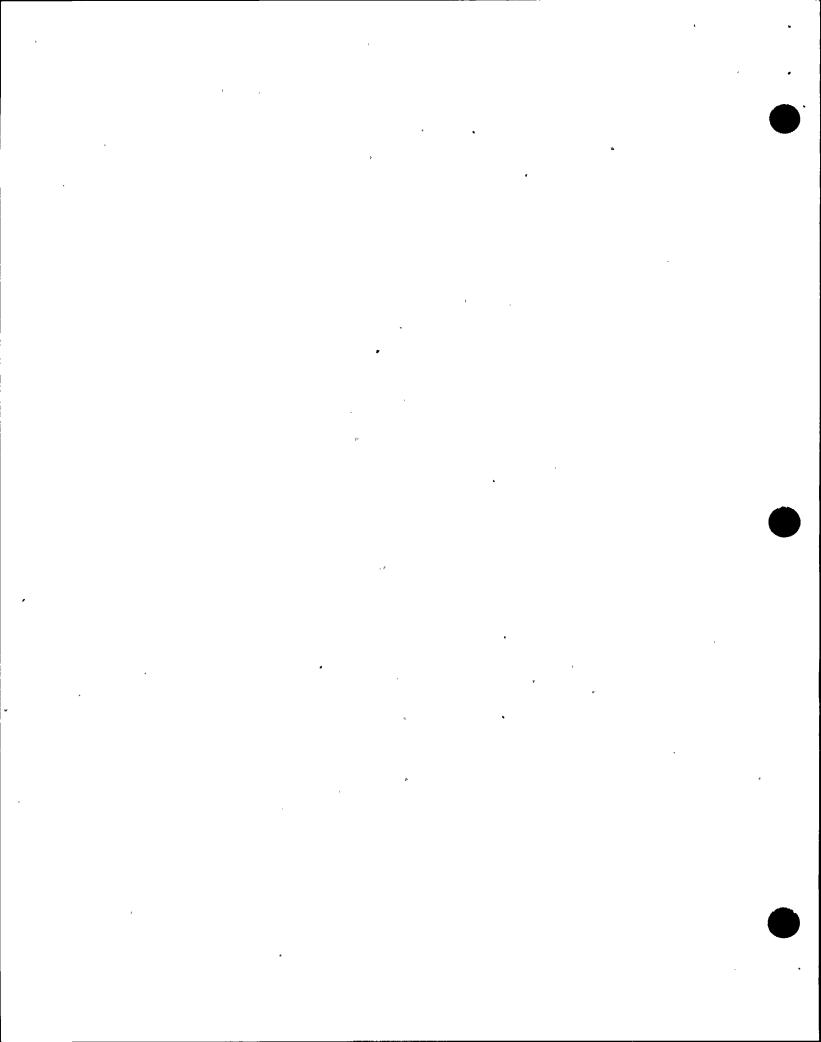
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I. Generator Motoring

- 1. Occurs when steam flow to the turbine is lost with generator on line.
- 2. Generator operates as a sychronous motor driving the turbine (with Excitation)
- If generator motoring occurs as a result of a failure to complete a sequential (generator and turbine) trip, protection from the fault is lost.
- 4. If excitation is also lost, generator acts as induction motor and may be damaged by high slip-frequency currents.
- 5. Protected by antimotoring relay and directional power relay. A 30 second T.D. prevents false trips.

J. Unbalanced Armature Currents

- Caused by an unbalanced load such as an open in a single phase.
- 2. Results in excessive heating due to negative sequence current.
- 3. Protected by Reverse Phase relay which trips generator on unbalanced armature current or negative phase sequence.



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K. Accidental Energization

- If generator is energized at standstill or reduced speed, it will behave and accelerate as an induction motor.
- This may result in high currents and 12 rapid damage.
- Protected by phase instantaneous overcurrent relay and unit online relay.
- 4. If overcurrent conditions occurs with online relay denergized, an instantaneous trip of generation lockout relays will occur.

IV. SYSTEM OPERATION

A. Startup Operation

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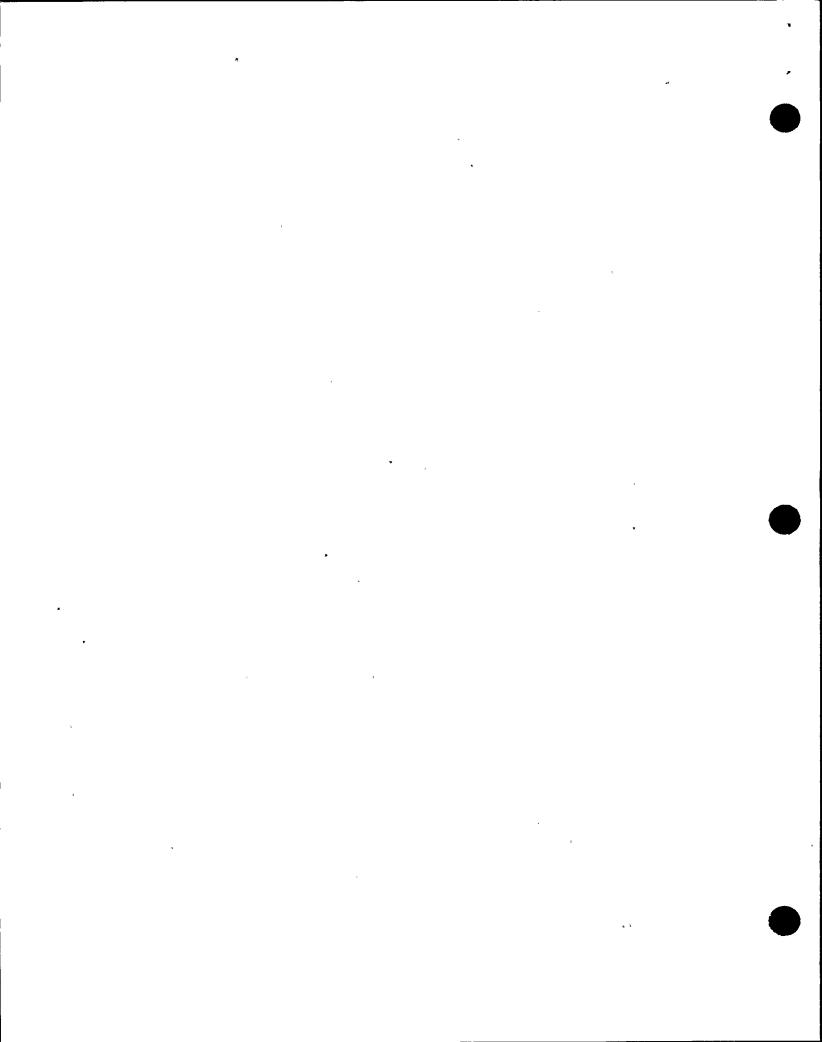
- 1. H_2 system maintains 75 psig H_2 in generator with Seal Oil System in operation.
- 2. TBCLCW is supplied to H₂ coolers.
- Stator Cooling Water System is in operation.
- 4. All electrical lockout relays 13 reset.

B. Normal Operation

- With generator at rated speed and field flashed, either regulator will vary generated voltage if it is selected (AC should be used).
- Once loaded, use AC regulator to vary VARS as requested by load dispatcher.

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Text Text Ref. Ref. VI. LESSON CONTENT **Page** Fig. SLO 3. 13 Generator capabilities curve Curve AB limited by field a. heating due to large field current. Since field is H₂ cooled, limit varies with H₂ press. Curve BC limited by armature b. heating. Although bars are water cooled, stator punchings are H₂ cooled. Limit varies with Ho press. Curve CD limited by stator end С. heating grid stability limits may be reached first. 4. The AC regulator is operated with the 14 7 feedback signal controlling the regulator. This enables the regulator to respond to system transients. limiting signals are set for a generator with a full complement of hydrogen and stator coolers in service. Paralleling prerequisites 5. Voltages match a. b. incoming frequency slightly higher proper phase relationship 6. Following synchronization, the operator varies real load with the turbine load set control and reactive load with the voltage control. 7. Load set varies steam flow to turbine. 14 When generator load equals steam flow available, the bypass valves will be shut. Load is then limited by the reactor's ability to supply steam. 02-L0T-001-245-2-02 -20 June 1990

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VI. LESSON CONTENT

8. The unit can be tripped from any load but in all cases it is preferred to reduce load gradually and trip the circuit breaker a few seconds after the turbine is tripped.

C. Voltage Variations

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- 1. Rated KVA at 95% and 105% voltage
- 2. If lagging power factor reduce KVA proportionally with volt. (i.e. 90% KVA at 90% volt)
- 3. If leading power factor, reduce KVA by square of percent voltage (i.e. 81% KVA at 90% volt)
- 4. This limit prevents generator instability.
- 5. Operation above 105% rated voltage is avoided because:
 - Stator punching insulation may break down
 - Insulation gaps may not be sufficient
 - Higher field current may cause rotor overheating.

D. Frequency Variations

- 1. Turbine is limiting factor
- 2. Hi/Lo frequency may cause blade damage.

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V. SYSTEM INTERRELATIONS

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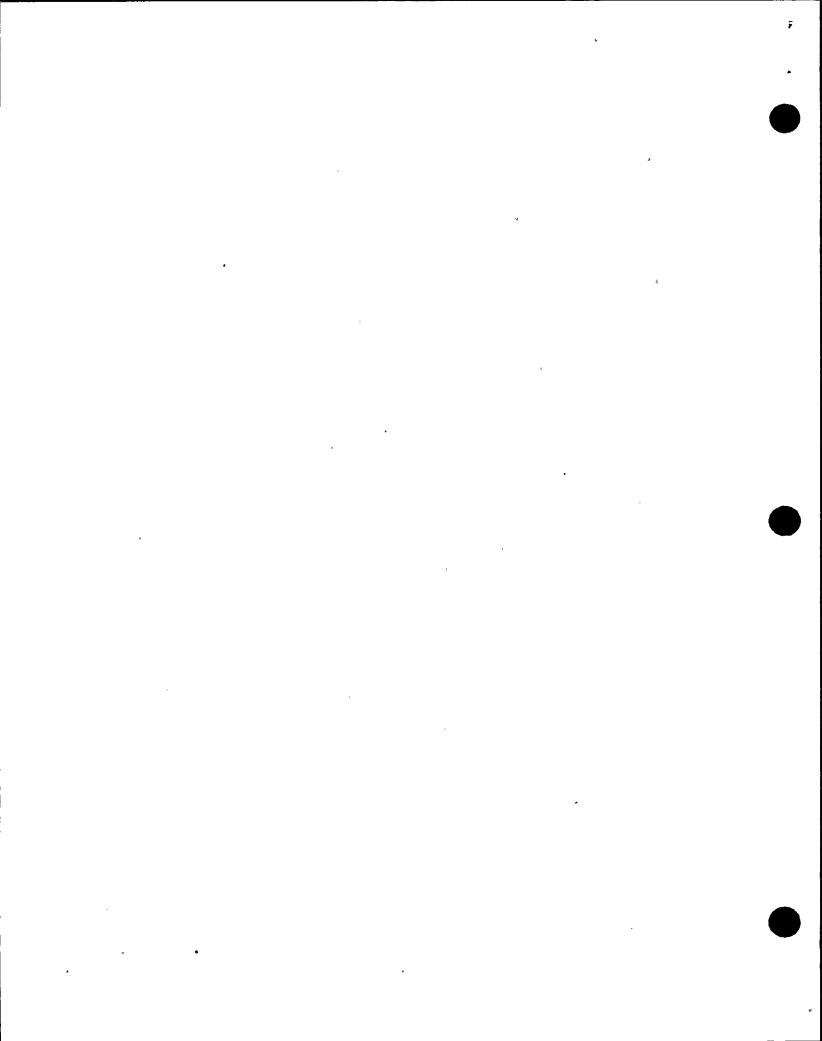
A. Generator Stator Cooling

- The Stator Winding Cooling system supplies cool deionized water to cool the generator stator and static field rectifier. Reduction in the cooling capability of this system limits the amount of power the Main Generator can safely generate.
- 2. Total loss of stator cooling results in a runback of the Main Turbine and generator to the no flow limit (7006 amps).
- B. Hydrogen Cooling and CO₂ Purge System
 The Generator is cooled by H₂ gas circulated around the stator punchings and rotor windings. The H₂ is circulated by shaft driven fans and cooled by Turbine Building Closed Loop Cooling Water.

 Because of the explosive nature of H₂ in air, a CO₂ purge system is used to displace the H₂ in the generate when maintenance needs to be done on the system.

Hydrogen is supplied through the $\rm H_2$ supply system from banks of $\rm H_2$ bottles. $\rm CO_2$ is supplied from the Cardox unit of the fire protection system.

Reduction in H₂ pressure in the generator reduces the heat removal capability of this system and thus limits the allowable generator load. Loss of one H₂ cooler reduces load carrying capability to 80%. The generator should be taken off line if H₂ pressure falls below 30 psig.



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C. Hydrogen Seal Oil System

The Hydrogen Seal Oil system supplies sealing oil to the generator "end shields" at a pressure sufficient to oppose the $\rm H_2$ pressure in the generator and prevent it from escaping.

Loss of seal oil pressure will allow H₂ pressure to decrease due to leakage from the generator.

D. <u>Turbine EHC System</u>

The Generator Electrical System is connected to the EHC System through the generator lockout relays which produces a cross trip to the turbine.

E. Main Turbine Lube Oil System The main turbine lube oil system provides the oil supply for the generator and alternator bearings.

F. <u>Turbine Building Closed Loop Cooling</u> <u>Water System</u>

The TBCLCW System provides cooling water for the generator hydrogen coolers, alternator air coolers, and isolated phase bus duct coolers.

VI. DETAILED SYSTEM REFERENCE REVIEW

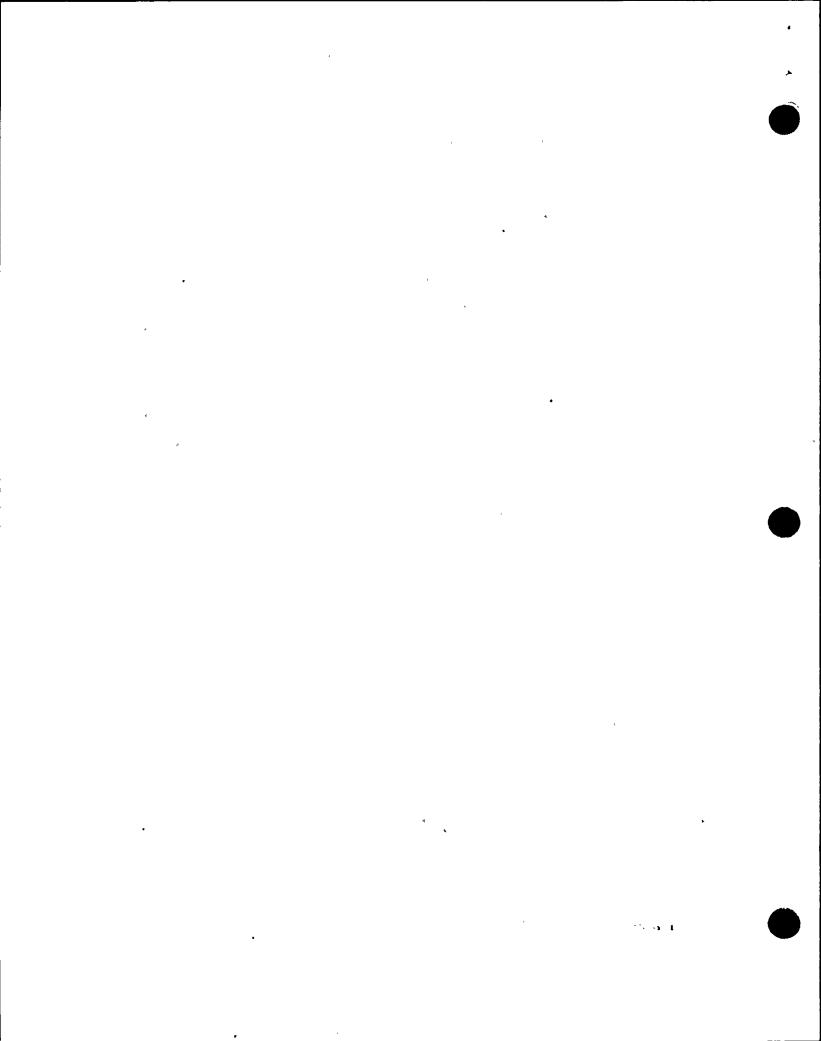
Review each of the following referenced documents with the class.

A. <u>Technical Specifications</u>
None

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Fig. Page

В. **Procedures** 8

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- N2-OP-24 Generator Isolated Phase Bus Duct Cooling
- 2. N2-OP-68 Main Generator, Exciter, Main Transformer, 345 KV yard, and Generator/Unit Protection.

VII.RELATED PLANT EVENTS

Refer to Addendum "A" and review related events with class (if applicable)

VIII.SYSTEM HISTORY

Refer to Addendum "B" and review related modifications with class (if applicable)

IX. WRAP-UP

Α. Review the Student Learning Objectives

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