07-188-91

NINE MILE POINT NUCLEAR STATION

UNIT II OPERATIONS

LESSON PLAN

02-LOT-001-245-2-02 (OPS)
OS-STC-001-245-2-02 (NON-OPS)

MAIN GENERATOR & EXCITER

Prepared By: Unit #2 Training Department

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Summary of Pages

Revision 5 (Effective Date: 6/12/90)

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THIS LESSON PLAN SUPERCEDES LESSON PLAN #N2-OLP-46

NIAGARA MOHAWK POWER CORPORATION

5/3/326 26pp.

OBJECTIVE APPLICABILITY MATRIX

OBJECTIVE NUMBER	LICENSE CLASS	NON-OPS
TO-1	X	
TO-2		X
EO-1	X	X
EO-2	X	X
EO-3	X	X
EO-4	X	X
EO-5	X	
EO-6	X	X
EO-7	X	X
EO-8	X	

I. TRAINING DESCRIPTION

A. Title: N2-OLP-46, Main Generator and Exciter

B. Purpose: 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
   b. 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"
3. NTP-11, Rev. 5, "Licensed Operator Retraining and Continuing Training"
4. NTP-12, Rev. 3, "Unlicensed Operator Training"

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.

V. LEARNING OBJECTIVES FOR MAIN GENERATOR AND EXCITER

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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

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
I. INTRODUCTION			
Student Learning Objectives	i		
A. Purpose			1

I. INTRODUCTION

Student Learning Objectives

A. Purpose

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.
3. Isolated Phase Bus Duct Cooling 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.

B. System Overview/General Description

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 Ref. Page	Text Ref. Fig.	SLO
II. DETAILED DESCRIPTION	2		
A. Main Generator			
1. Located in turbine building at 306 ft. elevation.			
2. 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 H_2 Pressure 75 psig Frequency 60 Hz			
B. Generator Construction			
1. Stator Frame			2a
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 interleaved manner on keys machined on key bars to form a cylindrical-shaped core for the stator winding.	2		

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
3. Stator Bars		1	2b
a. Armature Winding formed by inserting insulated bars into core slots. Ends are joined to form coils which are connected by rings.			
b. Each bar is composed of hollow copper conductors. Strands are spiral or transposed to share load current and minimize losses due to flux distribution.	3		
c. Each strand is insulated with low voltage insulation.			
d. Strands are hollow to carry deionized water for cooling.			
4. Stator Liquid Connections			
a. Stator Bar Strands are manifolded at each end by a clip assembly. Clip assembly has one tube connection.			
b. Flexible heavy wall teflon hoses 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.			
c. Resin impregnated glass roving used to hold bars and groups of bars. Allows flexibility and custom fit.			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
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 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 then flows outward through the winding by fans on each end.			2d
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 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.			

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 5
    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

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
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 the hydrogen fans' suction from the discharge to improve the flow through the generator.	5		
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 fed by the high voltage bushings-15 for relaying, 3 for metering.			

C. ALTERNATOR CONSTRUCTION

1. Generator Exciter
   a. "Alterrex" excitation system manufactured by General Electric
   b. 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: — Text Ref. Page 6

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 — Text Ref. Page 7 — SLO 4a

a. Stator consists of 3 main elements: Fabricated Steel Frame, Laminated Core, and Armature Winding. — SLO 4b

b. 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.

3. Alternator Armature Bus Bars — Text Ref. Page 7 — SLO 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.

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
4. Alternator Rotor			4d
a. The rotor consists of a shaft, laminated spider, field poles, and field coils.			
b. The spider consists of a stack of thin laminations riveted together. It has dovetail slots in which the field poles are keyed			
c. Field poles consist of thin laminations riveted together, keyed into spider.			
d. Field coils are copper strip insulated by asbestos and moisture-resistant binder. Coils are series-connected around the rotor			
e. Air circulation fans are mounted on rotor ends.			
5. Alternator Collector and Collector Connections	8		4e
a. Collector rings carry current to the field windings			
b. The collector is opposite the coupling end.			
c. The alternator brush rigging consists of 8 spring-loaded brush holders clamped on to an insulated steel stud; they transmit the excitation voltage onto the rotor.			4f
d. Alternator bearings are forced-oil lubricated from the main turbine lube oil system; they provide radial support for the alternator shaft.			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
6. Air Coolers 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.			4g
D. GENERATOR ISOLATED PHASE BUS DUCT COOLING SYSTEM	9	6	6

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.
   b. 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, motor-operated inlet damper and a back draft discharge damper.
   b. 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.

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 9

A. The following instrumentation is located in the control room on panel 2CEC-PNL852:

1. Main Generator Field Current, dc ammeter, scale 0--8,000 dc amps, indicates Main Generator field current.
2. Main Generator Field Volts, dc voltmeter, scale 0-600 dc volts, indicates Main Generator field voltage.
3. Voltage Regulator Amplidyne Meter (Boost-Buck), dc voltmeter, scale -10/0/+10 dc volts, indicates differential voltage between the auto and manual voltage regulators. 10
4. 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.
6. Main Generator Megawatts, wattmeter, scale 0-1,500 ac megawatts indicates Main Generator output power. 10

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, Esterline-Angus recording frequency meter, single channel for Main Generator frequency.
9. 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 <u>control switches and position indicators</u> are located in the control room on Panel 2CEC-PNL852:

1. 41ECS-2EXCX03, control switch for 2GMS-G1 exciter field breaker (41E). — Text Ref. Page 10
2. 41MCS-2EXSX03, control switch for 2GMS-G1 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.
5. 90CS-2EXSX03, control switch for adjusting the exciter AC voltage regulator.

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
C. Stator Ground Fault	11		
1. 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.			
3. Stator ground fault relay will trip unit (simultaneous trip) if single fault occurs.	11		
D. Stator Phase-to-Phase Fault			
1. 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			
1. Permissible voltage limits are listed in the Generator Instruction Book. Also found in Generator Operating Procedure.			
2. Extended operation at overvoltage condition leads to excessive heating in stator caused by I^2R losses. May damage insulation.			
3. If voltage regulator fails, overvoltage relay will protect the generator and exciter			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
F. Over-volts per Hertz	11		
1. Volts per hertz means percent voltage divided by percent frequency			
2. 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			
1. Field is isolated from ground so single ground fault will not usually cause damage.			
2. 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	12		
1. Results in operation of generator as an induction motor.			
2. May cause severe overheating and pulsating rotor torque leading to electrical and/or mechanical damage			
3. Protected by loss of excitation relays and Out-of-Step Relays which trip generator.			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
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)			
3. If generator motoring occurs as a result of a failure to complete a sequential (generator and turbine) trip, protection from the fault is lost.	12		
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			
1. 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.			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
K. Accidental Energization			
1. If generator is energized at standstill or reduced speed, it will behave and accelerate as an induction motor.			
2. This may result in high currents and rapid damage.	12		
3. Protected by phase instantaneous over-current 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			5
1. H_2 system maintains 75 psig H_2 in generator with Seal Oil System in operation.			
2. TBCLCW is supplied to H_2 coolers.			
3. Stator Cooling Water System is in operation.			
4. All electrical lockout relays reset.	13		
B. Normal Operation			
1. With generator at rated speed and field flashed, either regulator will vary generated voltage if it is selected (AC should be used).			
2. Once loaded, use AC regulator to vary VARS as requested by load dispatcher.			

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
3. Generator capabilities curve	13		
a. Curve AB limited by field heating due to large field current. Since field is H_2 cooled, limit varies with H_2 press.			
b. Curve BC limited by armature heating. Although bars are water cooled, stator punchings are H_2 cooled. Limit varies with H_2 press.			
c. Curve CD limited by stator end heating grid stability limits may be reached first.			
4. The AC regulator is operated with the feedback signal controlling the regulator. This enables the regulator to respond to system transients. The limiting signals are set for a generator with a full complement of hydrogen and stator coolers in service.	14		7
5. Paralleling prerequisites			
a. Voltages match			
b. incoming frequency slightly higher			
c. 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. 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.	14		

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
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	15		

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:
    1. Stator punching insulation may break down
    2. Insulation gaps may not be sufficient
    3. Higher field current may cause rotor overheating.

D. Frequency Variations

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

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
V. SYSTEM INTERRELATIONS	16		5

A. Generator Stator Cooling

1. 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 CO_2 Purge System

The Generator is cooled by H_2 gas circulated around the stator punchings and rotor windings. The H_2 is circulated by shaft driven fans and cooled by Turbine Building Closed Loop Cooling Water. Because of the explosive nature of H_2 in air, a CO_2 purge system is used to displace the H_2 in the generate when maintenance needs to be done on the system.

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

Reduction in H_2 pressure in the generator reduces the heat removal capability of this system and thus limits the allowable generator load. Loss of one H_2 cooler reduces load carrying capability to 80%. The generator should be taken off line if H_2 pressure falls below 30 psig.

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
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 H_2 pressure in the generator and prevent it from escaping. Loss of seal oil pressure will allow H_2 pressure to decrease due to leakage from the generator.	16		5
D. Turbine EHC System 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. Turbine Building Closed Loop Cooling Water System 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. Technical Specifications None	17		

VI. LESSON CONTENT	Text Ref. Page	Text Ref. Fig.	SLO
B. Procedures			8
1. 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

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

VIII. SYSTEM HISTORY

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

IX. WRAP-UP

A. Review the Student Learning Objectives