



REQUIREMENTS FOR GENERATING FACILITY INTERCONNECTION TO THE LIPA TRANSMISSION SYSTEM

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1.0 Introduction

This document has been prepared to identify the technical requirements for connecting a Producer generation facility to the LIPA transmission system. It applies to new connections or substantial modifications of existing generators. This document is written to comply with NERC Standard, FAC-001, Facility Connection Requirements, which requires entities responsible for the reliability of the interconnected transmission systems to maintain and make available a Facility Connections Requirements document. The NERC standards require those entities seeking to add facilities or connect to the interconnected transmission system to comply with the Facility Connection Requirements document. The NERC Planning Standards are posted on NERC's web site (www.nerc.com/standards).

Rather than give detailed technical specifications this document provides a general overview of the functional objectives and requirements to be met in the design of facility connections. These requirements are written to establish a basis for maintaining reliability, power quality, and a safe environment for the general public, power consumers, maintenance personnel and the equipment. This Facility Connection Requirements document is revised from time to time to reflect changes or clarifications in planning, operating, or interconnection policies.

The Producer should also refer to the following LIPA documents for information concerning the functional objectives and requirements when designing interconnections:

- Bulk Power System Facility and End User Interconnection Requirements to the LIPA Transmission System
- LIPA Transmission and Distribution Planning Criteria and Guidelines
- LIPA Revenue Metering Requirements For Generating Facilities Interconnecting to the LIPA Transmission System

Any Producer seeking to connect to the Bulk Power System in New York should review the NYISO interconnect documents and tariffs. All Generators connecting to the New York Transmission System must follow the NYISO Generator Interconnection Procedures. Generators connecting to the LIPA distribution system must follow the LIPA Generator Interconnection Procedures appropriate for the size generator being connected.

Nothing in this document is intended to supersede LIPA's Small Generator Interconnection Procedures or Agreement, or the LIPA Transmission and Distribution Planning Criteria and Guidelines Document. If there is a conflict, LIPA's Small Generator Interconnection Procedures or Agreement or the NYISO Large Facility Interconnection Procedures or Generator Agreement, as applicable, will control.

All Producers operating generators rated 10 MVA or greater must adhere to the requirements outlined in this document. LIPA shall evaluate each installation to determine the maximum Producer MVA which can be connected to the LIPA system at a particular location without exceeding the load carrying capability, fault duty, and interrupting capability of the LIPA equipment.

Control and protection requirements as well as specific electrical requirements for parallel operation with the LIPA system are provided for transmission interconnections of synchronous generators.

Should a Producer desire to interconnect induction generators and D.C. generators with inverters to LIPA's transmission system, then engineering studies shall be performed, at Producer's expense, to determine specific interconnection requirements.

Appendix C is an application form to be used by the Producer and LIPA to document the specific characteristics of the installation. This application shall be coordinated by LIPA's Distributed Resource Management group.

Responsibility for protection of the Producer's generating system against possible damage resulting from parallel operation lies with the Producer.

The LIPA transmission lines have automatic instantaneous reclosing with a dead time as short as 12 cycles. It is the Producer's responsibility to protect its equipment from being reconnected out-of-synchronism with the LIPA system after automatic reclosing of a LIPA circuit breaker. It is also the Producer's responsibility to protect its equipment from these reclosures. The Producer shall provide high speed protective relaying to remove its equipment from the utility circuit prior to the automatic reclosure.

2.0 General Requirements

Producer generators shall be connected to the transmission system rated 23 kV and above. This connection can be made at the LIPA substation or at a point on a transmission line. A substation connection shall require a dedicated circuit breaker. A system or bus configuration could require more than one dedicated circuit breaker. All dedicated circuit breakers shall be sized to meet the voltage, load current, and short circuit interrupting requirements at the substation.

A connection to a point on a transmission line shall require the installation of a substation at the point of connection. The substation shall have at least two circuit breakers equipped with high speed line relaying as specified by LIPA. Three terminal line configurations are not acceptable. The design of the substation should conform to the requirements in the LIPA Transmission and Distribution Planning Criteria and Guidelines.

LIPA shall evaluate and analyze each proposed installation prior to accepting any interconnection configuration.

Each Producer facility which is to be operated in parallel with the LIPA system shall submit its control and protection designs to LIPA for review and acceptance.

The specific design requirements of the protection system depend on the generator type, size, and other site specific considerations. The Producer shall meet LIPA's "Specifications and Requirements for Electric Installations"; latest revision) and all local and municipal codes. To eliminate unnecessary costs and delays, a facility substation one-line drawing and relay functional diagram(s) should be submitted to LIPA for acceptance prior to the commencement of construction and ordering of equipment. Seven (7) copies of the following must be submitted by the Producer:

- A. Substation one-line drawing.
- B. Relay functional diagram showing all current transformer (CT) and potential transformer (PT) circuits, relay connections, and protective control circuits. All interconnections with LIPA's circuits should be clearly labeled (See **Appendix E** for an example of an acceptable relay functional).
- C. Three line AC schematic diagrams of transmission lines, transformers and bus relay protection.
- D. Interconnection breaker AC and DC schematics.
- E. Protective relay equipment list including manufacturer model number, relay ranges, manufacturer's bulletins, curves and proposed settings.
- F. Generator, transformer, and breaker nameplate information including generator transient, subtransient, and synchronous impedances with time constants and transformer positive and zero sequence impedances.
- G. Producer generator protection scheme.
- H. Interconnection breaker speed curve.
- I. All drawings should incorporate LIPA's requirements for name and number description of the major equipment (switches, breakers, etc.).

If the Producer installs equipment without prior written acceptance of the equipment by LIPA, it shall be done at the Producer's own risk. The Producer shall be solely responsible for all costs associated with the replacement of any equipment that has not been accepted by LIPA. Final acceptance of the interconnection by LIPA will be contingent upon LIPA's acceptance of all of the facility's interconnection equipment.

If the Producer makes changes in the design of the project, any previous information furnished by LIPA shall be subject to review and possible changes.

At the completion of construction, a qualified testing company acceptable to LIPA shall perform functional tests of all protective equipment. LIPA reserves the right to witness such tests. The functional tests of all protective equipment include, but are not limited to, trip tests and relay calibrations. If these tests are successful, and the protective relay settings have been correctly applied, LIPA shall permit the interconnection to be energized.

3.0 Generating Criteria

It is the policy of LIPA to permit any applicant to operate generating equipment in parallel with the LIPA electric system whenever such operation can take place without adversely affecting other LIPA customers, the general public, LIPA equipment and LIPA personnel. To minimize this interference, the Producer's generation shall meet the following criteria:

A. Voltage

Nominal voltages on the LIPA transmission system are 345, 138, 69, 34.5 and 23.38 kV.

B. Flicker

The Producer shall not cause voltage variations on the LIPA system exceeding those defined on the Border Line of Visibility in **Appendix D** - Voltage Flicker Curves.

C. Frequency

The Project will meet the NPCC under frequency guidelines specified in NPCC's Emergency Criteria Document A-3, Section 4.9. The over-frequency trip setting of the Protective Functions shall be 60.5 Hertz. The final time delay will be determined by LIPA based on review of the Project design.

D. Harmonics

The total harmonic voltage or current distortion created by a Producer-owned generator must not exceed 5% of the fundamental 60 Hz voltage or current waveform. Any single harmonic shall not exceed 3% of the fundamental frequency.

$$\% \text{ Total Harmonic Distortion (THD)} = \frac{\sqrt{\sum_{i=2}^{\infty} h_i^2}}{h_1} \times 100 \quad 1$$

$$\text{While a Single Component \% Distortion} = \frac{h_i}{h_1} \times 100 \quad 2$$

Where:

h_i = The magnitude of the i^{th} harmonic of either voltage or current.

h_1 = the magnitude of the fundamental voltage or current.

E. Power Factor

Synchronous generators produce or absorb VARS such that the power factor at the delivery point (location of LIPA's revenue metering equipment) is between 0.90 and 1.0 leading or 0.90 and 1.0 lagging. LIPA's system operator may request Producer to adjust the power factor at the delivery point, within the above stated limits.

F. External Fault and Line Clearing

For interconnections at voltages up to and including 69 kV, the Producer shall be responsible for disconnecting its generating equipment from the LIPA system within 6 cycles of the occurrence of a fault on a LIPA transmission line connected directly to the interconnect breaker using its primary relaying. Backup relaying must clear this fault in 18 cycles. A similar type fault with a 138 kV connection shall be cleared in 4 cycles using dual primary relaying.

The short circuit currents on the transmission system are available from LIPA on request.

4.0

System Planning and Engineering Studies

A. Coordination with NYISO

1. The NYISO Open Access Transmission Tariff (OATT) describes the process for a generator to apply for connection to the New York State Bulk Power system. The NYISO process ensures compliance with NERC Reliability standards, NPCC Criteria, NYSRC, and NYISO requirements.
2. The NYISO process allows for LIPA to review and comment on all studies evaluating the impact of the proposed facility on the interconnected transmission system.
3. Metering requirements are described in LIPA's Revenue Metering Requirements For Generating Facilities Interconnecting To The LIPA Transmission System.

B. Engineering Studies

Engineering studies shall be performed by LIPA to determine the exact electrical configuration of the interconnection installation and to identify any required additions, changes, or modifications to the LIPA system. Major equipment requirements such as circuit breakers and special protective relaying shall also be studied. Items requiring investigation are as follows:

1. Equipment short circuit duty.
2. Impact on electric system stability.
3. Breaker Failure requirements.
4. Deadline Operating restraints.
5. VAR requirements for induction generators.
6. MVA limitations of generation because of location on the LIPA system.
7. Protective relay coordination for three phase and line to ground faults on the LIPA system and the Producer's generator installation.

5.0

Control and Protection Requirements

The following requirements apply to the interconnection equipment of all generators operating in parallel with the LIPA transmission system:

1. All additions or changes required to protective relay and control equipment on the LIPA system shall be installed by LIPA at the Producer's expense. All additions or changes to relay and control equipment required at the point of interconnection shall be paid for and installed by the Producer.
2. The Producer shall be solely responsible for synchronizing its generator(s) with the LIPA system.
3. All Producer-owned generators shall be isolated from the LIPA system by means of an isolating transformer. All installations shall have a wye grounded/delta or a wye grounded/delta/wye transformer with the wye grounded winding configuration on the LIPA side. See **Appendix B** for the technical explanation of this requirement. A ground fault current limiting neutral reactor shall be installed if required by LIPA.
4. LIPA shall install, own, control, operate and maintain (at the Producer's expense) a visible manual load break or motor-operated disconnecting device on LIPA's side of the point(s) of interconnection. Devices shall be capable of being padlocked.
5. A SCADA (Supervisory Control and Data Acquisition) system RTU (Remote Terminal Unit) purchased by LIPA, and paid for by the Producer, shall be required at each generating site. The RTU shall provide LIPA with supervisory trip control of the interconnection breaker(s). It shall also provide telemetry of key operating parameters of the Producer's facility which shall include, but not be limited to:
 - a. Status indication of interconnection breaker(s), generator breaker(s), and all other devices that are in series with these breakers.
 - b. Status indication of various alarms such as loss of DC to interconnection breaker(s), loss of DC to RTU, loss of AC to RTU battery charger, loss of relaying communication channel, etc.
 - c. Telemetry of current, voltage, watts, VARS, power factor for all interconnection breakers.

- d. Pulse accumulation of MWHR (in/out) and MVARHR (in/out) for the facility.
- e. The RTU will be equipped with analog output capabilities if it is determined that the generator set point is to be transmitted from the NYISO to the Producer via the LIPA Control Room.

The location of the RTU shall depend on the proximity of the Producer to the LIPA interconnecting substation. The Producer shall not be allowed to operate in parallel if the RTU or its associated communications channels are out of service. The RTU shall be maintained and repaired by LIPA at the Producer's expense.

All costs for additional hardware and software for LIPA's mainframe supervisory computer that are necessary for its interconnection shall be charged to the Producer.

Whether the RTU is purchased by the Producer or by LIPA (at the Producer's expense), it shall be delivered to LIPA for testing and programming. At this time, loss of DC/AC relays, fuses, and various terminal blocks will be installed within the RTU cabinet by LIPA at the Producer's expense.

The Producer shall make provisions adjacent to the RTU to terminate the fiber optic cable in a wall mounted fiber patch panel adjacent to the RTU equipment. The communications channels shall be ordered by LIPA. Installation, maintenance and subsequent monthly charges shall be charged to the Producer.

- 6. All Producers shall provide an interconnection breaker on LIPA's side of their isolation transformer. The breaker shall be located in the Producer's substation. A disconnecting switch in series with the Producer's circuit breaker shall be installed as a visible disconnect. The circuit breaker and switch shall be installed at the Producer's expense.

7. The Producer shall be responsible for tripping its interconnection breaker if a fault occurs on the electric facilities serving its installation, thereby disconnecting its generation and isolating transformer as a source of fault current within 6 cycles after the occurrence of a fault for interconnections up to and including 69 kV, and within 4 cycles after the occurrence of a fault for 138 kV interconnections. Whenever the LIPA supply is de-energized, the Producer's interconnection breaker shall be tripped by voltage and/or frequency relays and transfer tripped from LIPA's interconnection substation. The interconnection breaker shall be automatically locked out and prevented from closing into a de-energized or partially de-energized (loss of one phase) LIPA system. The interconnection breaker close circuit shall include a synch check and an over/under voltage permissive contact to prevent closing the breaker when unfavorable voltage conditions exist.
8. The following are the minimum relay requirements for the interconnection breaker:

 - a. Dual primary transmission line relaying systems using fiber optic cables as the pilot channels are required. The line differential relays shall include directional phase and ground impedance elements (21 and 21G) and ground directional overcurrent elements. CT's for this relaying shall be on the generator side of the interconnect breaker. LIPA shall specify the type of relays and CT ratios.
 - b. Back-up phase overcurrent with instantaneous and time delay functions are required as well as one ground overcurrent relay with instantaneous and time delay functions connected on the transformer neutral.
 - c. Over/under frequency protection is required.
 - d. Over/under voltage protective functions are required.
 - e. Directional power relays may be required to limit power flow to contractual agreements.
 - f. Directional overcurrent relays shall be required at sites where the Producer's load requirements from LIPA exceed the Producers generating capability. Any exceptions to this requirement must be approved by LIPA.
 - g. Breaker failure relaying is required to trip all breakers in the zones of protection adjacent to the interconnection breakers.

All interconnection breaker relays and required generator breaker relays must be utility grade. Interconnection breaker relays will require Flexitest Switches for current, voltage, output and input connections to facilitate maintenance, inspection, testing, and adjustments.

- 9.** Direct transfer trip, independent of any permissive transfer trip, is required. Should the transmission line primary relaying system(s) not provide this capability, separate equipment will be required. The communication medium shall be determined by LIPA.

LIPA shall specify and order the transfer trip communications channels. Installation, maintenance, and subsequent monthly charges shall be charged to the Producer. A loss of transfer trip alarm point shall be wired to the RTU.

The Producer shall terminate fibers adjacent to the transfer trip equipment in a wall mounted fiber patch panel. The Producer shall not be allowed on line if the transfer trip or associated communication medium is out of service.

- 10.** All breakers shall be D.C. trip and close. Trip and close circuits of the interconnection breaker shall be separately fused. A loss of D.C. alarm shall be wired to the RTU.
- 11.** A visible disconnect is required at the Producer's equipment on the generator side of the interconnection breaker.
- 12.** Control, CT, and telemetering leads which interconnect to LIPA shall have a minimum size and stranding of 19/25, 19/22, and #18 STP, respectively. All control, CT and telemetering leads shall be terminated using ring type connectors.
- 13.** The station battery shall be sized for an eight hour duty cycle in accordance with IEEE Standard 485-1983. At the end of the duty cycle the battery shall be capable of tripping and closing all breakers. A low voltage D.C. alarm shall be wired to the RTU.
- 14.** All relaying CTs shall have a minimum ANSI accuracy of C800, at the selected tap. The Producer shall provide a CT shorting block for each CT circuit.
- 15.** All microprocessor relays requiring an auxiliary power source shall be powered from the station battery. AC to DC converters are not acceptable.

- 16.** Three PTs with dual secondary windings shall be installed on the Producer side of the interconnection breaker and shall be connected wye grounded/wye grounded-open delta. The open delta secondary winding is required for ground fault protection on the 138 kV system. Three red indicating lights, one per phase, connected phase to ground in the PT secondary, shall be installed to provide visual verification of potential on each phase.
- 17.** During emergency conditions, all interconnection breakers shall be capable of being tripped by LIPA via supervisory control. LIPA will consider tripping the generator breaker instead of the interconnection breaker if the system configuration permits. Interconnection breaker and generator breaker(s) status shall be transmitted to LIPA via the RTU. The supervisory equipment shall be installed and paid for by the Producer. A digital meter connected to the CTs and PTs through Flexitest switches shall be used to provide MWs, MVARs, Amps and Volts to the RTU. The RTU connection shall be made by means of a 485 port. The make and model number for the meter shall be provided by LIPA. This equipment will be procured by the Producer at the Producer's expense.
- 18.** Synchronous generators shall be equipped with synchronizing capability across the generator breaker. A total of four potential transformers shall be required on the interconnection breaker, one on LIPA's side of the breaker (as specified in #16) and three on the Producer's side. Synch check relays shall be installed for manual synchronizing. Closing into the LIPA system without a functioning synch check relay is not permitted. Automatic synchronizing equipment shall be optional.
- 19.** Voltage and frequency relays are required at the LIPA substation to disconnect the Producer's generator from the LIPA bus in the event that this bus becomes isolated from the LIPA system and the Producer's generator continues to carry the connected LIPA load. These relays shall be installed at the Producer's expense.
- 20.** Additional control and protection equipment that, depending on the parameters of each interconnection, could be required for installation on the LIPA system include, but are not limited to:

 - a.** Digital transient recorder for 138 kV interconnections.
 - b.** Sequence of event recorder for 138 kV interconnections.
 - c.** Additional primary relaying systems to existing LIPA transmission line to ensure fault clearing within "new" stability parameters resulting from the Producer's generation.
 - d.** Expansion/addition of SCADA RTUs on the LIPA side of the interconnection.
 - e.** Upgrade of breaker failure relaying protection.

- f. Recloser blocking of transmission line breakers.
- g. Zero sequence voltage relaying

6.0 Maintenance and Operating Requirements

The following requirements apply to all Producer-owned installations.

- A. The protective devices (relays, circuit breakers, etc.) required to disconnect the Producer's generation shall be owned, operated, and maintained by the Producer at its expense.
- B. All final relay setting calculations for the Producer's interconnection breaker shall be submitted for review and acceptance by LIPA to assure protection of LIPA equipment and reliability of service to the adjacent LIPA customers. The Producer shall be required to change relay settings, if necessary, to accommodate changes in the LIPA system.
- C. It shall be the Producer's responsibility to have calibration and functional trip tests performed on its fault and isolation protection equipment. These tests shall be performed prior to placing equipment in service and once every two (2) years thereafter. Copies of these test results shall be submitted to LIPA no later than five working days after completion of tests. All the testing and calibration shall be performed by a qualified independent testing organization acceptable to LIPA, in accordance with industry standards. Interconnection breaker speed curves shall be verified using a Cincinnati Analyzer or an equivalent. Battery tests shall meet the requirements of IEEE Standard 450-1987. LIPA reserves the right to witness and accept or reject the result of all tests. LIPA shall be notified of the date of testing two (2) weeks in advance.
- D. After the Producer's equipment is in service, LIPA reserves the right to test or review on request the calibration and operation of all protective equipment including relays, circuit breakers, batteries, etc. at the interconnection as well as review the Producer's complete maintenance records. A review of the calibration and operation of protective equipment may include LIPA-witnessed trip testing of the interconnection breaker from its associated protective relays.

The failure of the Producer to maintain its equipment in a manner acceptable to LIPA or to furnish maintenance records on demand shall result in the Producer being prevented from operating in parallel with the LIPA system.

- E. If LIPA is requested to work at the Producer's generating site, LIPA operating and maintenance personnel shall inspect the site to insure that all LIPA safety requirements have been met. If not, commencement of the requested work will be delayed until conditions are deemed safe by LIPA.
- F. LIPA reserves the right to test for or to request the Producer to supply certified test reports for harmonic content at the point of interconnection. The % Total Harmonic Distortion (THD) measurements shall be taken with a spectrum analyzer.

Inverter installations shall be required to take two sets of measurements; one with the inverter isolated and the other with the inverter connected to the LIPA system. The current harmonic levels should be observed and recorded at 0, 1/2, 3/4, and full power measurements.

If the % THD exceeds the limits outlined in Section II Part D the Producer shall install filters to meet the required limits.

If at any time during parallel operation harmonic distortion problems affecting other customers' equipment can be traced to the Producer's generator, the Producer's generating equipment shall be immediately disconnected from the LIPA system and shall remain disconnected until the problem is corrected.

- G. The Producer shall close the interconnection circuit breaker only after obtaining approved switching orders from the responsible LIPA operator as defined in the Operating Agreement. LIPA reserves the right to open the disconnecting device to the Producer for any of the following reasons:
 - 1. System Emergency or System Pre-Emergency
 - 2. Substandard conditions existing with the Producer's generating and/or protective equipment.
 - 3. Failure of the Producer to maintain its equipment in accordance with the agreed upon schedule.
 - 4. Failure of Producer to make maintenance records available to LIPA on request.
 - 5. Interference by the Producer's generation system with the quality of service rendered by LIPA to its customers.
 - 6. Personnel safety.
 - 7. To eliminate conditions that constitute a potential hazard to the general public.
 - 8. Loss of communications medium for Direct Transfer Trip or SCADA.

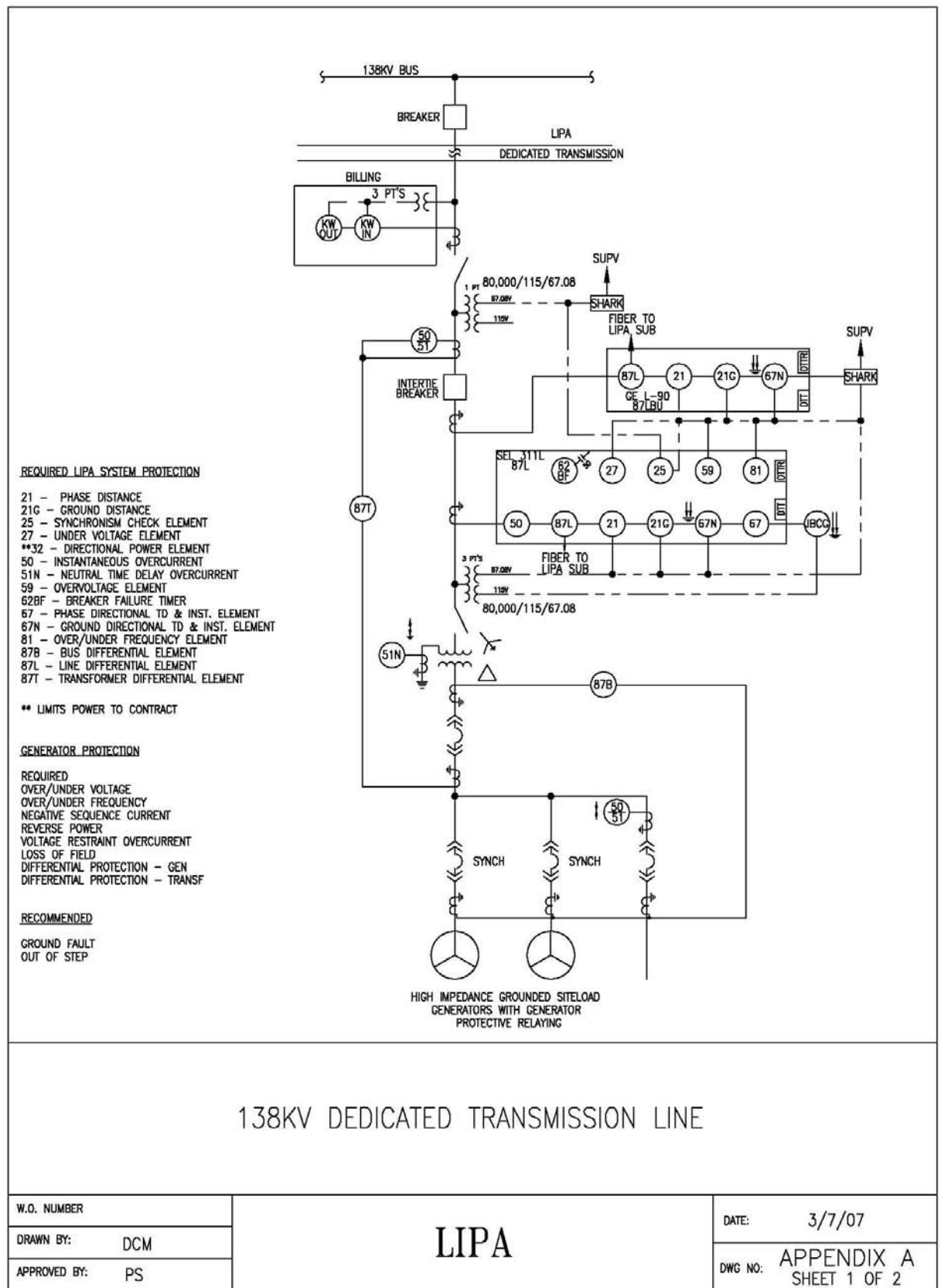
- H.** To accomplish the interconnection and to provide for continuing operations in a safe, economical and efficient manner, LIPA shall prepare and deliver Operating Instructions to the Producer prior to interconnecting the facility. The Operating Instructions shall include but not be limited to, defining requirements for:
- 1.** Maintaining proper voltage and frequency and for putting into effect voltage changes as required from time to time.
 - 2.** Phasing and synchronizing the facility and LIPA's system (if a synchronous generator).
 - 3.** Taking transmission lines out of service for maintenance during a system emergency or system pre-emergency conditions and restoring such lines to service.
 - 4.** Controlling the flow of real and reactive power.
 - 5.** Periodic maintenance of the interconnection circuit breaker and related facilities.
 - 6.** Procedure for communication between electrical operations personnel of the Producer and LIPA.
- I.** The Producer shall also ensure the availability of a telephone handset for use by LIPA personnel during testing and maintenance of the Producer's equipment.
- J.** The Producer shall be required to have a qualified testing company acceptable to LIPA, perform maintenance, trip tests, and recalibration tests on its protective relaying devices once every two (2) years. A copy of the test results shall be sent to LIPA for review, comment, and acceptance, no later than five (5) working days after completion of tests.
- K.** The producer will notify LIPA whenever equipment modifications are made that change ratings or performance characteristics of the Producer's equipment.

Appendix A

Drawing List

1. 138 kV Dedicated Transmission Line
2. 69 kV or Less Dedicated Transmission

These drawings are examples of typical interconnections. Each project is site specific and may have different requirements.



Appendix B

Explanation of the Requirement for A Wye Grounded Transformer

All Producer generation interconnections with LIPA must be grounded sources. During a phase to ground fault on the LIPA system, the Producer's generator can be isolated with the phase to ground fault if the LIPA source opens before the Producer's protective equipment detects the fault condition and isolates from the LIPA system. If the generator is not grounded during the period that it is isolated with the phase to ground fault, the neutral can shift resulting in overvoltage on the two remaining unfaulted phases. This overvoltage can reach 173% of normal and will damage LIPA phase to ground connected load or equipment isolated with the generator. To avoid the possibility of an overvoltage due to a neutral shift, LIPA requires that the Producer's generator interconnect into the LIPA system as a grounded source.

The designer of the generation installation should be aware that the isolation transformer provides a path for zero sequence fault current for all phase to ground faults on the circuit. In order to limit the ground fault current from the Producer's equipment, LIPA may require that the system be designed to limit the zero sequence current (large zero sequence impedance) and still meet the grounding requirements.

There are several methods to ground a source. The accepted method is to use a wye grounded-delta step-up transformer with the generator grounded.

Appendix C

Date _____

GENERATOR DATA

Preliminary ____ Final ____

Name of Company _____

Station _____ Unit # _____

Manufacturer _____

Generator Nameplate Number _____

Expected In-Service Date _____

Rated Mva at Rated H psig _____

Rated kV _____

Rated P.F. _____

Max Turbine kW Capability
(Utilizing Overpressure, etc.) _____

Field Amperes for Rated Conditions _____

Field Amperes at Rated Generator
Volts & Amps. @ O-P.F. Overexcited _____

Field Resistance _____ Ohms @ 125°C _____ Ohms @ 25°C
Full Load Field Voltage, $E_{FD,FL}$ (per unit)

Short Circuit Ratio

	In Per Unit on Rated Machine
MVA	_____ and kV _____
Direct Axis Unsaturated Synchronous Reactance	X_d
Quadrature Axis Unsaturated Synchronous Reactance	X_q
Direct Axis Transient Reactance at Rated Current	X'_{di}
Direct Axis Transient Reactance at Rated Voltage	X'_{dv}
Quadrature Axis Transient Reactance at Rated Current (where applicable)	X'_{qi}
Direct Axis Subtransient Reactance at Rated Current	X''_{di}

Appendix C CONTINUED

Quadrature Axis Subtransient Reactance at Rated Current	X''_{qi}
Direct Axis Subtransient Reactance at Rated Voltage	X''_{dv}
Quadrature Axis Subtransient Reactance at Rated Voltage	X''_{qv}
Negative Sequence Reactance	X_2
Zero Sequence Reactance	X_o
Stator Leakage Reactance at Rated Voltage	X_{lv}
Stator Leakage Reactance at Rated Current	X_{li}
Potier Reactance	X_p
Armature D.C. Resistance	R_a ____ @ ____ °C
Positive Sequence Resistance	R_l ____ @ ____ °C
Zero Sequence Resistance	R_o ____ @ ____ °C
Negative Sequence Resistance	R_2 ____ @ ____ °C
Direct-Axis Transient Open-Circuit Time Constant	T'_{do} ____ Sec. @ ____ °C
Direct-Axis Subtransient Open-Circuit Time Constant	T''_{do} ____ Sec. @ ____ °C
Quadrature-Axis Subtransient Open-Circuit Time Constant (where applicable)	T'_{qo} ____ Sec. @ ____ °C
Quadrature-Axis Subtransient Open-Circuit Time Constant	T''_{qo} ____ Sec. @ ____ °C
Short-Circuit Time Constant of Armature Winding	T_a ____ Sec. @ ____ °C
Generator + Turbine Inertia (including all on Generator Shaft)	WR^2 ____ Lb. Ft. ²
Rated Speed	____ R.P.M.
Inertia Constant on Machine Base	H_c ____ MW Sec./MVA
Saturation Curve No. On Open Circuit (Attach)	
Saturation Curve No. for Rated Stator Current at 0 P.F. lag (Attach)	
"V" Curve No. (Attach)	
Reactive Capability Curve No. (Attach)	

The above resistances, reactances and time constants are defined in ASA Standards-Definitions of Electrical Terms (Group 10-Rotating Machinery, Section 31.)

Appendix C CONTINUED

GENERATOR STEP-UP TRANSFORMER

Transformer MVA Rating

Transformer Voltage Rating

Available Taps

Connection of Windings
(e.g., wye, delta)

Transformer Leakage Impedance for
Positive and Zero Sequence
on the transformer base between
each pair of windings and for
each available tap.

_____ p.u. on _____ tap

_____ p.u. on _____ tap

etc. as needed

_____ p.u. on _____ tap

_____ p.u. on _____ tap

_____ p.u. on _____ tap

_____ p.u. on _____ tap

Transformer Saturation Curve No.
(Attach)

Appendix C CONTINUED

EXCITATION SYSTEM DATA

Name of Company _____

Station _____ Unit # _____

Manufacturer _____

Expected In-Service Date _____

Type of Excitation System IEEE Type 1 _ 2 _ 3 _ 4

Voltage Response _____

Mfr. Exciter Type _____

Mfr. Regulator Type _____

Exciter Saturation Curve No. on Open Circuit (Attach) _____

Exciter Saturation Curve No. for Rated Armature Current (Attach) _____

Appendix C CONTINUED

EXCITATION SYSTEM DATA FOR COMPUTER STABILITY PROGRAMS

Universal Representation as defined by: IEEE 31TP-67-424 paper entitled, "Computer Representation of Excitation Systems"

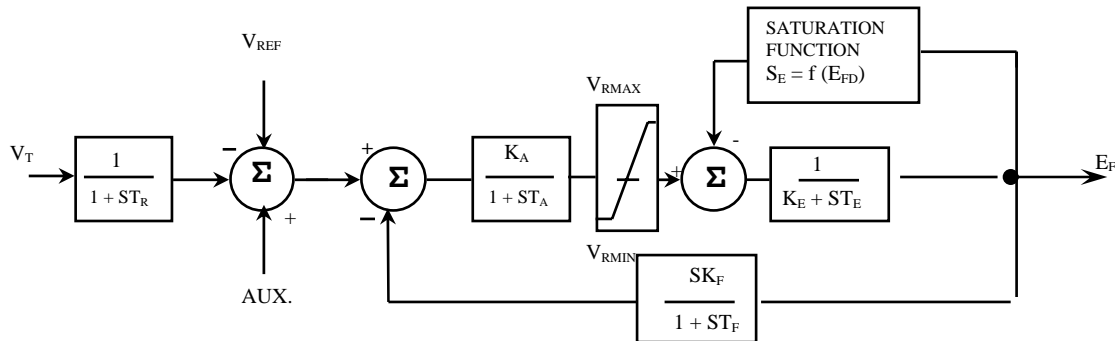
Type 1. Excitation System - Continuously Acting Regulator & Exciter		Type 2. Excitation System - Rotating Rectifier System		Type 3. Excitation System-Static With Terminal Potential & Current Supplies		Type 4. Excitation System - Non-continuously Acting	
K_A		K_A		K_A		-	
K_E		K_E		K_E		K_E	
K_F		K_F		K_F		-	
T_A	Sec.	T_A	Sec.	T_A	Sec.	-	
T_E	Sec.	T_E	Sec.	T_E	Sec.	T_E	Sec.
T_F	Sec.	T_{F1}, T_{F2}	Sec.	T_F	Sec.	-	
T_R	Sec.	T_R	Sec.	T_R	Sec.	-	
E_{FDMAX}	p.u.	E_{FDMAX}	p.u.	E_{FDMAX}	p.u.	E_{FDMAX}	p.u.
E_{FDMIN}	p.u.	E_{FDMIN}	p.u.	E_{FDMIN}	p.u.	E_{FDMIN}	p.u.
S_{EMAX}		S_{EMAX}		-		S_{EMAX}	
SE.75 MAX		SE.75 MAX		-		SE_{MIN}	
V_{RMAX}	p.u.	V_{RMAX}	p.u.	V_{RMAX}	p.u.	V_{RMAX}	p.u.
V_{RMIN}	p.u.	V_{RMIN}	p.u.	V_{RMIN}	p.u.	V_{RMIN}	p.u.
-		-		-		K_V	
-		-		-		T_{RH}	Sec.
-		-		K_P		-	
-		-		K_I		-	
-		-		X_I		-	
-		-		V_{BMAX}	p.u.	-	

Definitions of the above terms and associated block diagrams are on the following 3 pages.

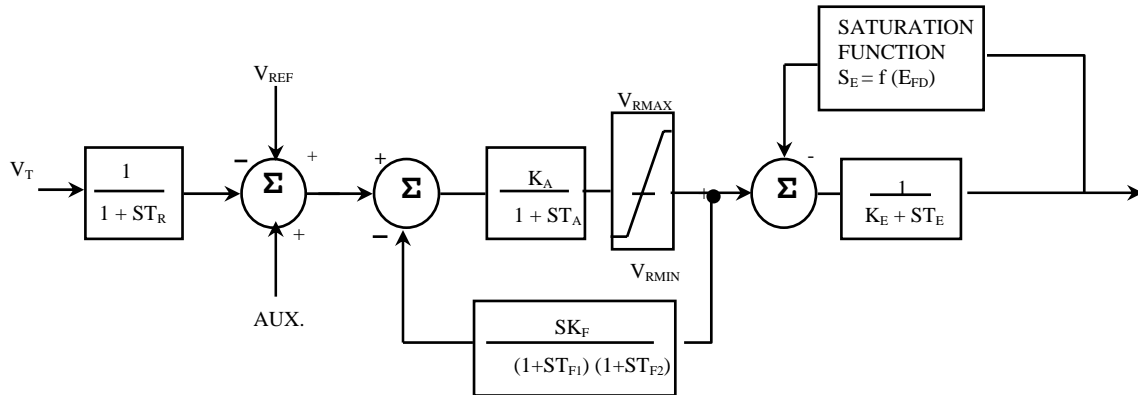
EXCITATION SYSTEMS

For a detailed discussion of voltage regulator representations for computer studies, see "Computer Representation of Excitation Systems," IEEE Committee Report, Excitation Systems Subcommittee, Power Generation Committee, presented at the IEEE Summer Meeting, July 9-14, 1967.

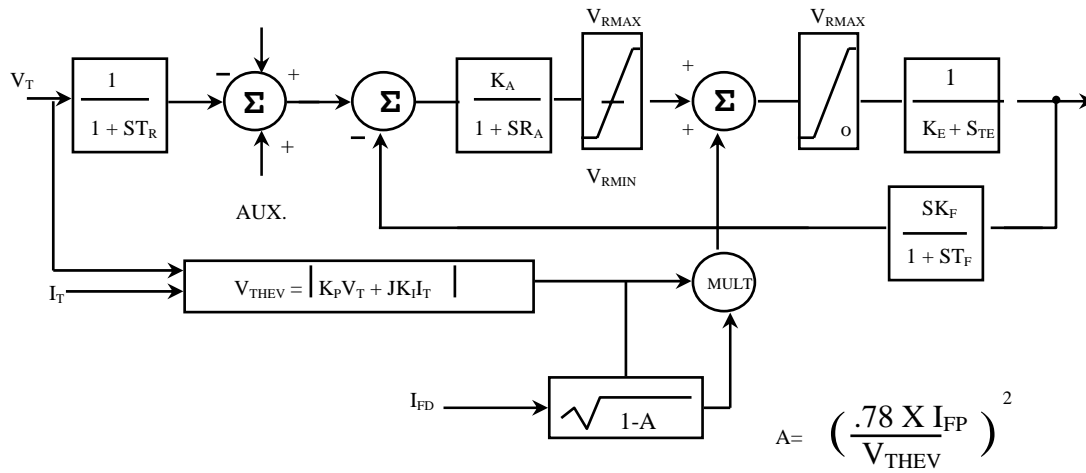
Voltage regulator representations shown in the attached sketches resemble frequently-encountered actual excitation systems. The type 1 block diagram is used for a conventional rotating exciter and continuously acting regulator.



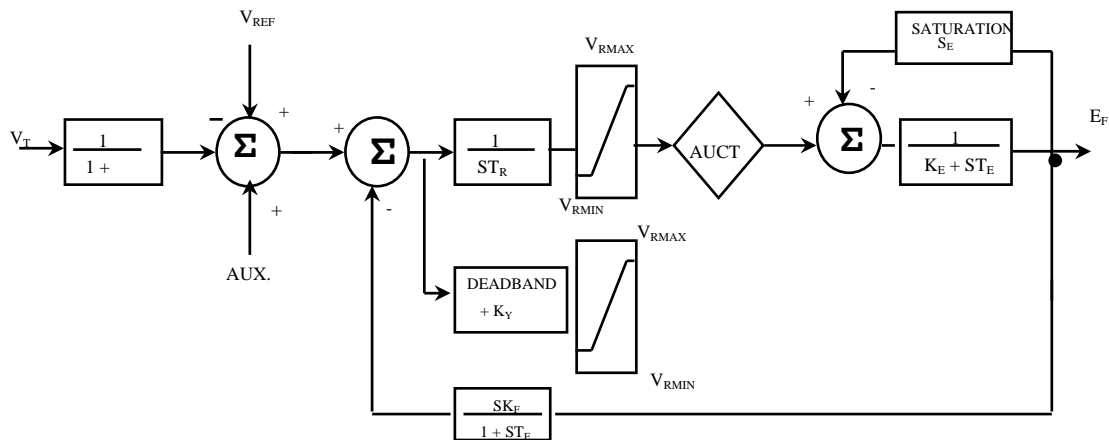
The type 2 block diagram is for those Westinghouse brushless systems which derive damping signals from the regulator terminals.



Type 3 is for a static system using both current and potential transformers for power sources, specifically the General Electric SCPT.



The type 4 block diagram is for rheostatic systems with contacts for fast response. The Westinghouse BJ-30 is such a system.



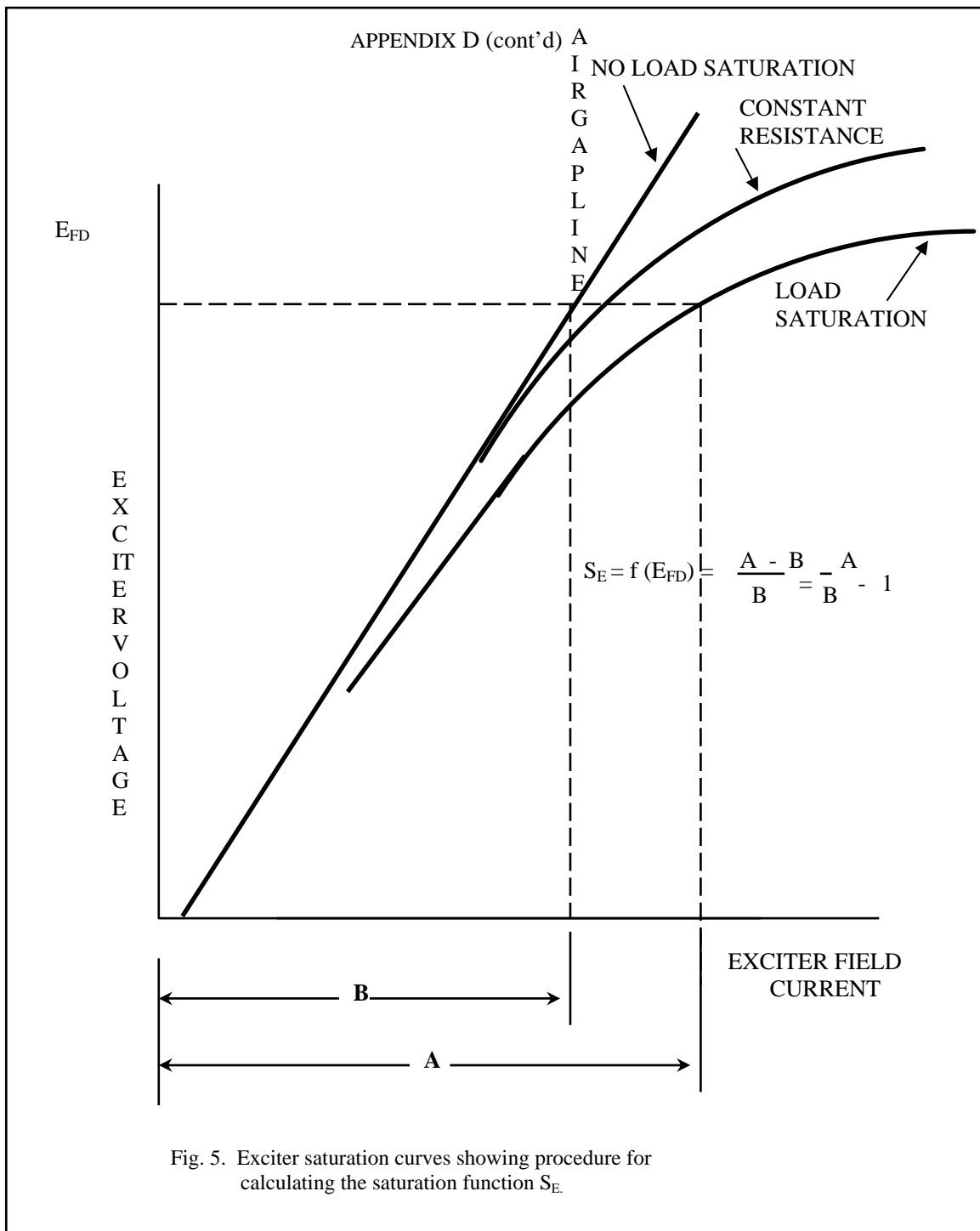


Fig. 5. Exciter saturation curves showing procedure for calculating the saturation function S_E .

Fig. 5. Exciter saturation curves showing procedure for calculating the saturation function

TURBINE AND GOVERNOR DATA FOR THERMAL UNITS

_____ Fossil Fired

_____ Nuclear

Name of Company

Station _____ Unit #

Manufacturer

Expected In-Service Date

Unit Rated MVA

Max. Turbine MW

Turbine Serial No.

Type of Prime Mover

Type of Governor

_____ Reheat

_____ Non-reheat

Tandem Compound Single Reheat

Tandem Compound Double Reheat

Cross Compound Single Reheat with
HP-IP Shaft and Separate LP Shaft

Cross Compound Single Reheat with
HP-LP Shaft and IP-LP Shaft

Straight Condensing

K_1

T_1 _____ Sec.

T_2 _____ Sec.

T_3 _____ Sec.

P_{Max} _____ p.u.

P_{Min} _____ p.u.

K_2

T_4 _____ Sec.

T_5 _____ Sec.

K_3

K_4

T_6 _____ Sec.

The definitions of the above terms are shown on the attached pages.

GOVERNORS AND ENERGY SYSTEMS

Linearized, simplified mathematical models of energy systems, governors, and prime movers are used in stability studies. A single block diagram is sufficient to represent a variety of steam turbine systems. This block diagram is shown below.

The following general definitions apply to the servo for steam systems:

P_o = initial turbine power, p.u. on system base

$\Delta\omega$ = electrical speed deviation, radians per second

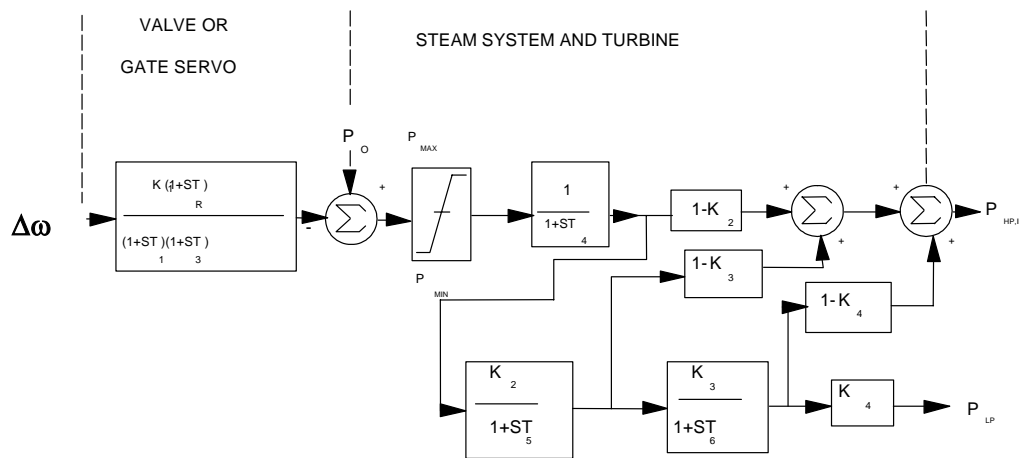
K_1 = $\frac{\text{Megawatts rating}}{\text{Per unit regulation}} \times \frac{1}{377} \times \frac{1}{\text{System Base}}$

T_1, T_3 = controller and governor lags, seconds

T_2 = controller lead compensation, seconds

P_{\max} = upper power limit, p.u. on system base

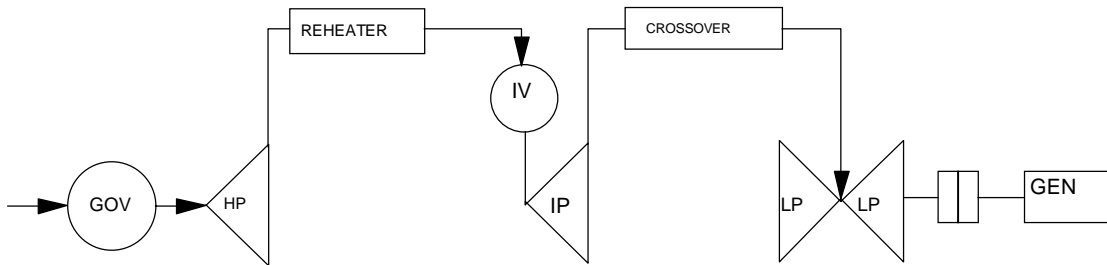
P_{\min} = lower power limit, p.u. on system base



Steam Systems

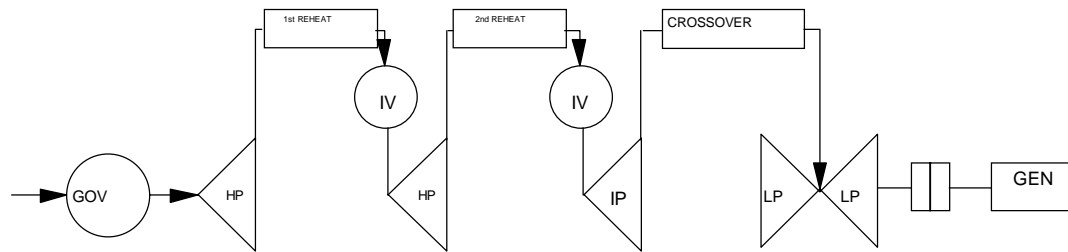
A number of steam systems may be approximated by this block diagram, some of which are described in the following paragraphs with block diagram symbols related to physical equipment.

Tandem Compound Single Reheat Configuration



- K_2 - fraction of total power developed downstream from reheater
- K_3 - fraction of reheat power developed by LP turbines
- K_4 - 0
- T_4 - delay due to steam inlet volumes associated with steam chest and inlet piping
- T_5 - reheater delay, including HP turbine, hot & cold leads up to intercepter valves
- T_6 - delay associated with IP-LP turbines, including crossover pipes and LP end hoods

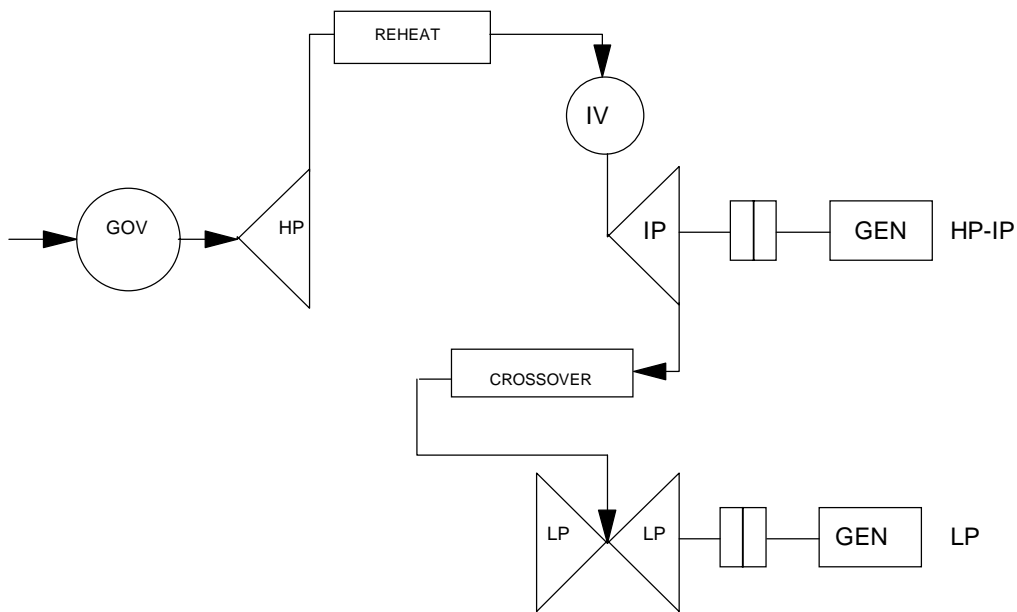
Tandem Compound Double Reheat Configuration



- K_2 - fraction of total power downstream from VHP turbine
- K_3 - fraction of first reheater power developed downstream of HP turbine
- K_4 - 0
- T_4 - delay due to steam inlet volumes associated with steam chest and inlet piping
- T_5 - first reheater delay including hot and cold leads and VHP turbine
- T_6 - second reheater, IP - LP turbines, crossover pipes, and LP end hood delays

Cross Compound Single Reheat Configuration with HP - IP

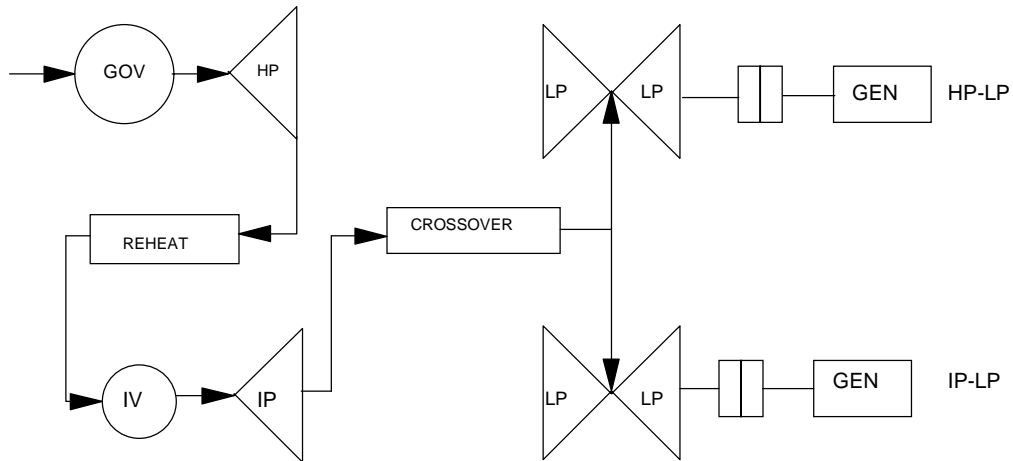
Shaft and Separate LP Shaft



- K_2 - fraction of total power developed downstream of HP turbines
- K_3 - fraction of reheat power developed by LP shaft turbines
- K_4 - 1
- T_4 - delay due to steam inlet volumes associated with steam chest and inlet piping
- T_5 - reheater delay, including HP turbine hot and cold leads, up to inteceptor valves
- T_6 - delay due to IP turbine, crossover pipes, and LP end hoods

Cross Compound Single Reheat Configuration with HP-LP

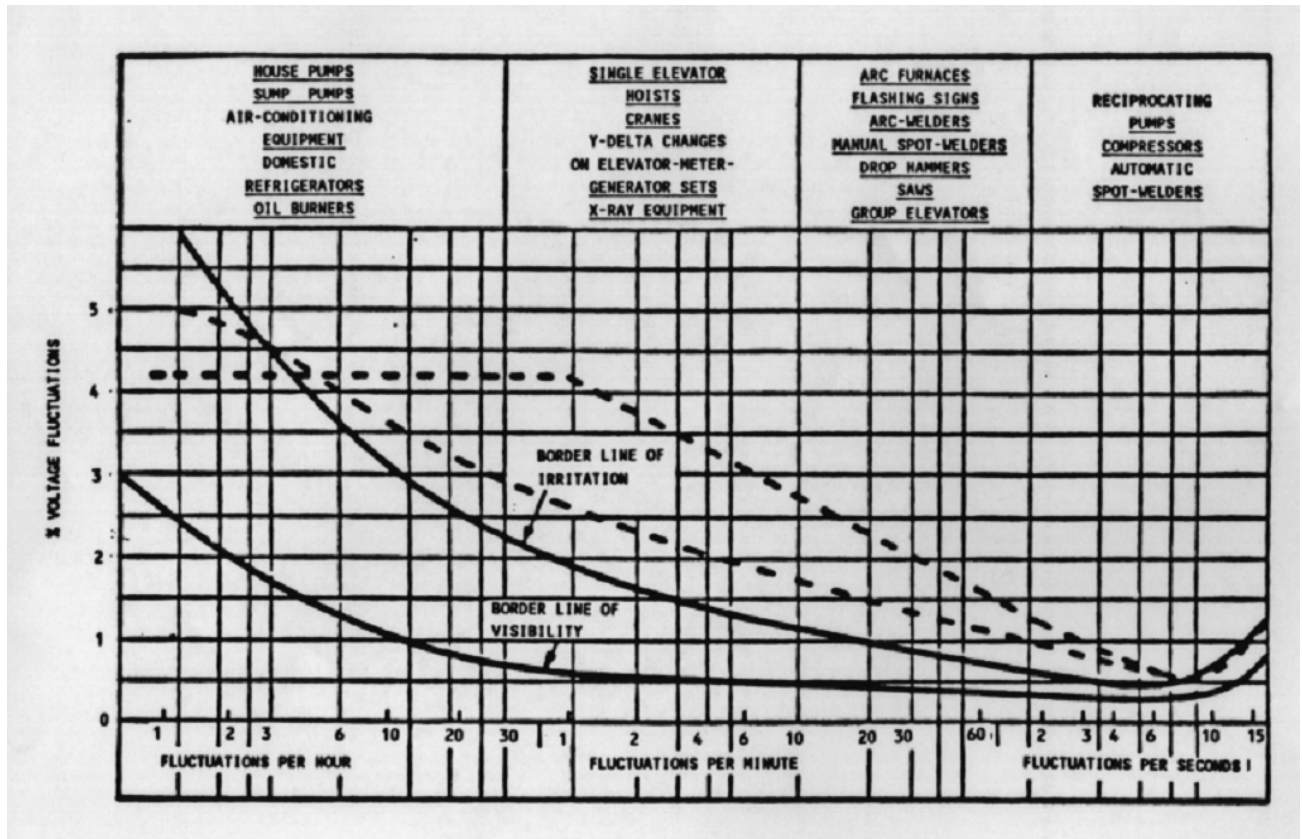
Shaft and IP-LP Shaft

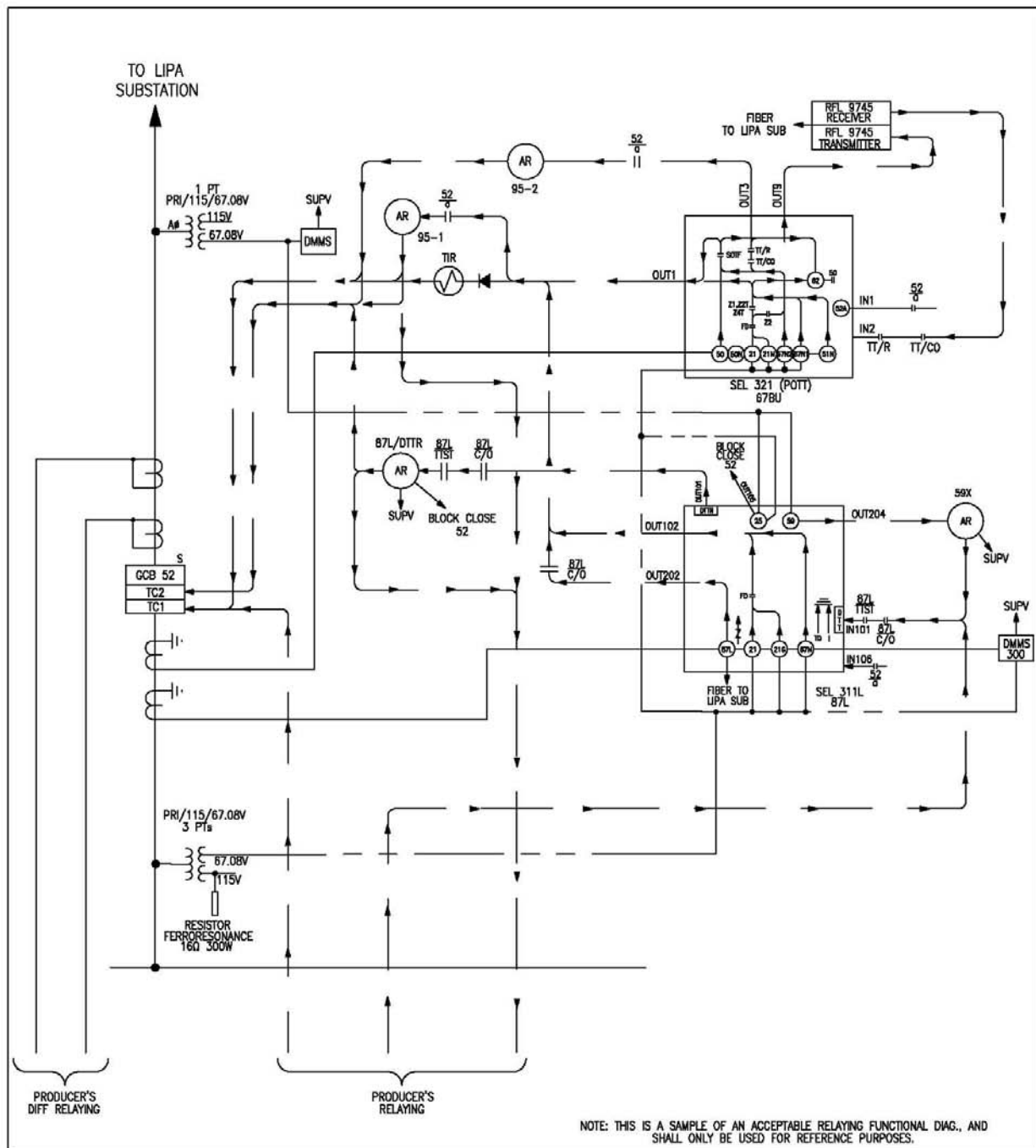


- K_2 - fraction of total power developed downstream from HP turbine
- K_3 - 0
- K_4 - fraction of reheat power developed by IP-LP shaft
- T_4 - delay due to steam inlet volumes associated with steam chest and inlet piping
- T_5 - delay due to reheater, HP turbine, and hot and cold leads up to interceptor valves
- T_6 - delay due to crossover pipes, IP-LP turbines, and LP end hoods

APPENDIX D

Flicker Curve





RELAY FUNCTIONAL DIAGRAM

W.O. NUMBER	LIPA	DATE: 3/6/07
DRAWN BY: DCM		DWG NO: APPENDIX E
APPROVED BY: PS		