# Excitation System Upgrade

**Richard C. Schaefer, Basler Electric**

**Frame 6 Users Conference**
**June 11, 2009**

Basler Electric

# Outline

1) Specifying Excitation Systems for Procurement

2) Alternate Solutions to Replacing Aged Static Exciter Systems

3) Retrofitting SCT-PPT Excitation Systems with Digital Control

# Introduction

**Consider all factors**

- **Environment**
- **Excitation location**
- **Applicable specs**
- **Agency requirements**
- **Performance**
- **Ratings**

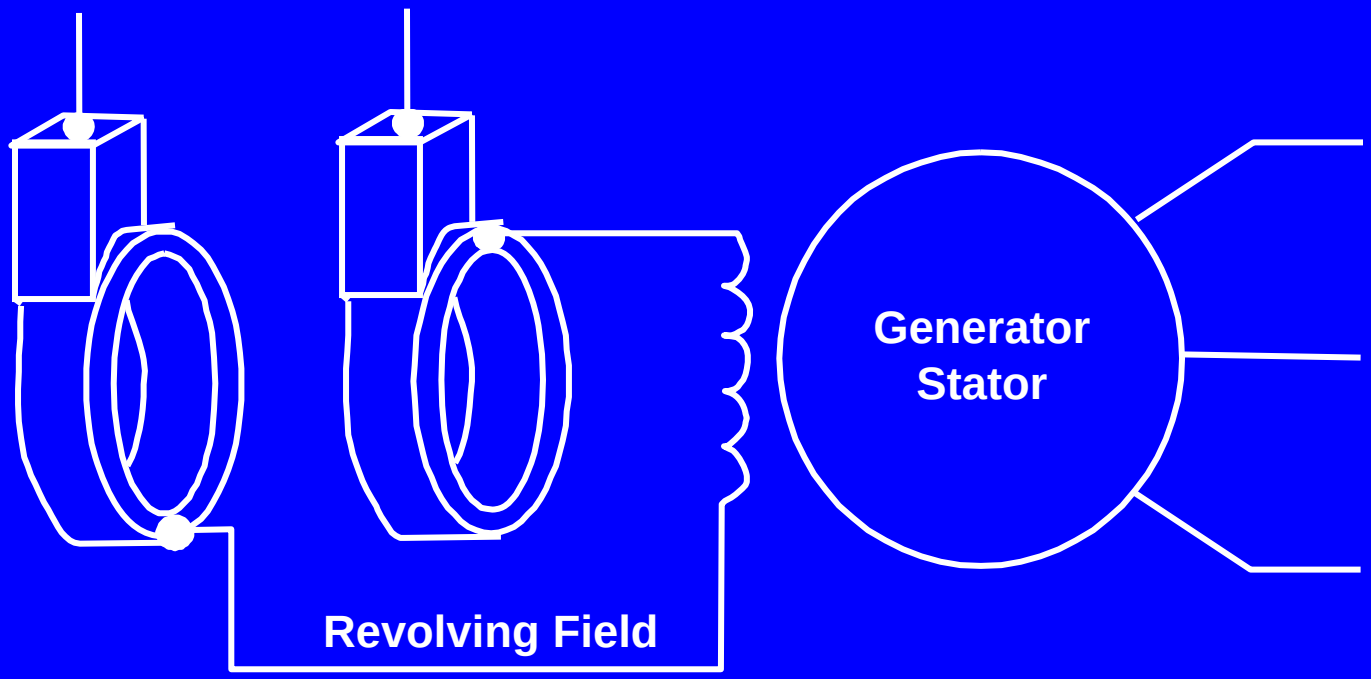
# Identify the Application

- For the generator main field?

OR

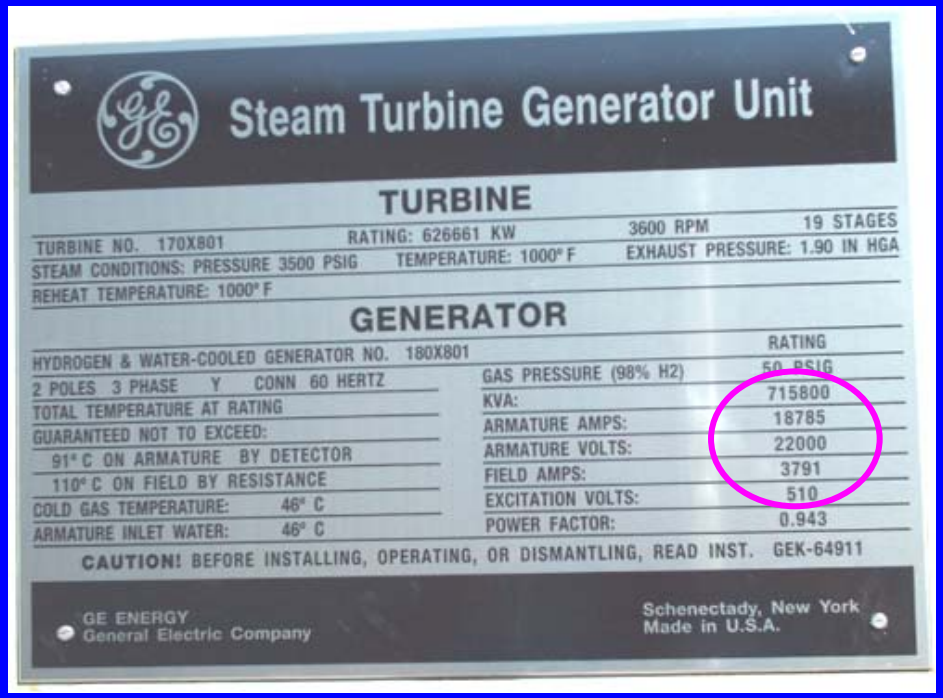
- For the shunt field of the rotating exciter?

# Slip-Ring Generator



# Sizing the Excitation System

- From the generator nameplate
- 115% the rated kVA at 105% rated generator voltage
- Future consideration for generator rewind requiring higher field current and higher field voltage



# Field Forcing Concerns

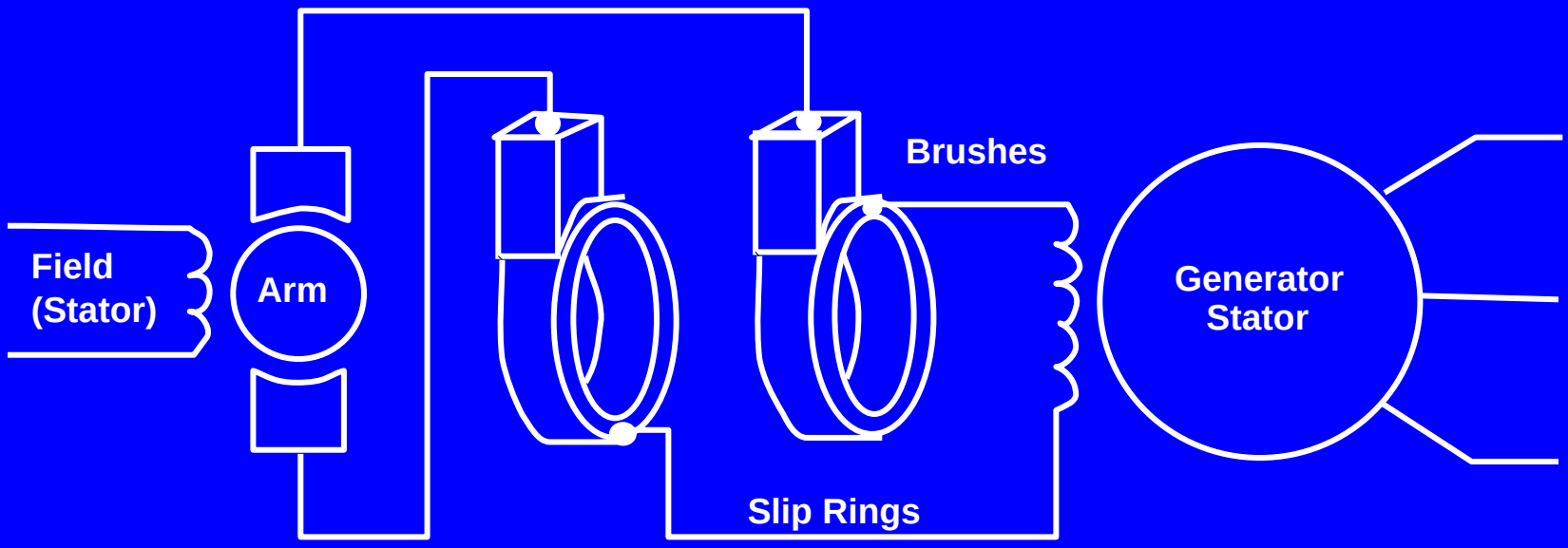
- Magnitude can vary 150-200% of full load
- Can go higher if there are special requirements

Field forcing also called “Response Ratio”.

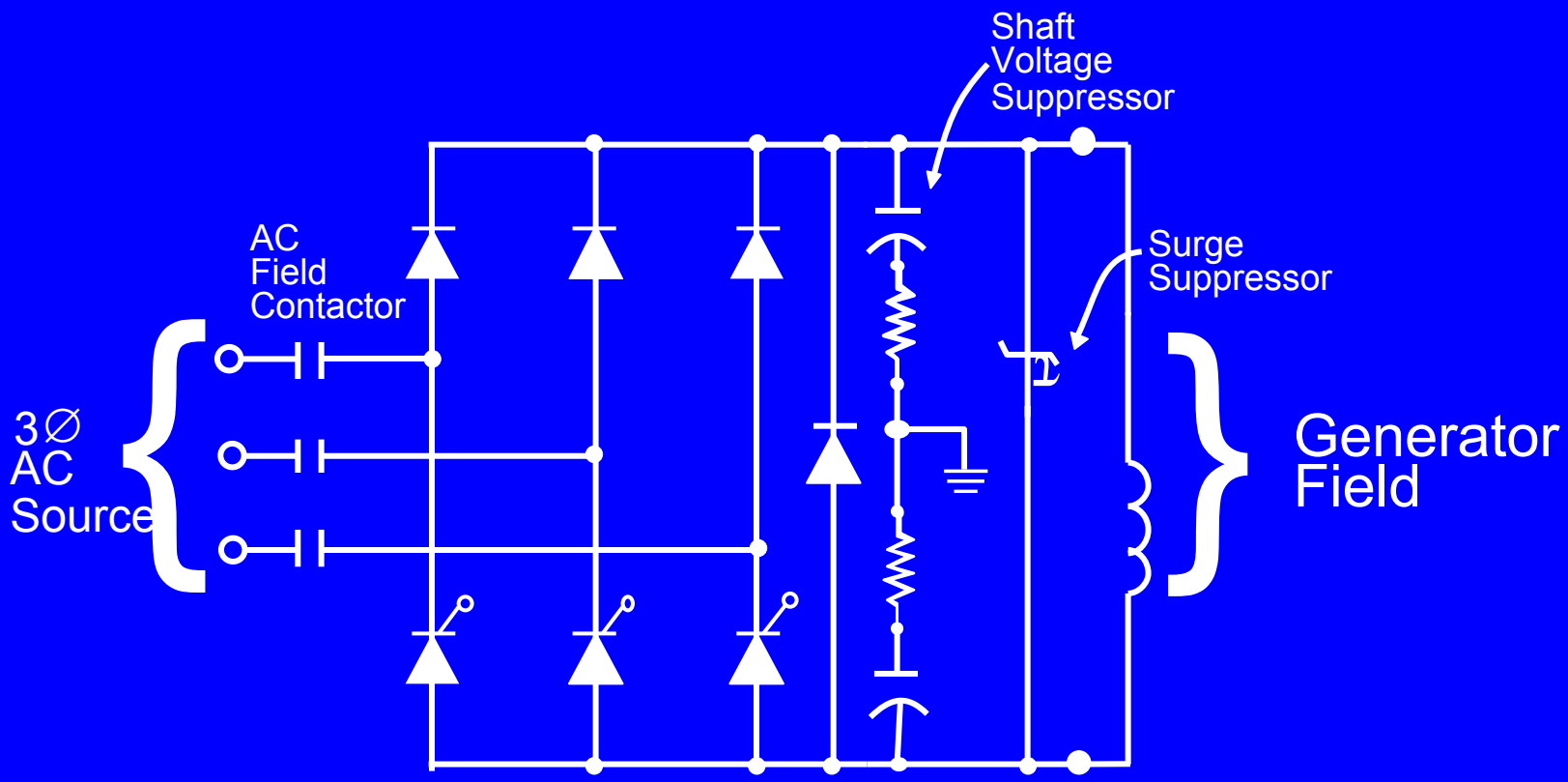
# The PPT

- Most are convection cooled, dry type
- Most designed with anticipated harmonic content
- Other considerations:
  - higher than normal BIL ratings
  - epoxy cast or resin core coils (depending on transformer location)

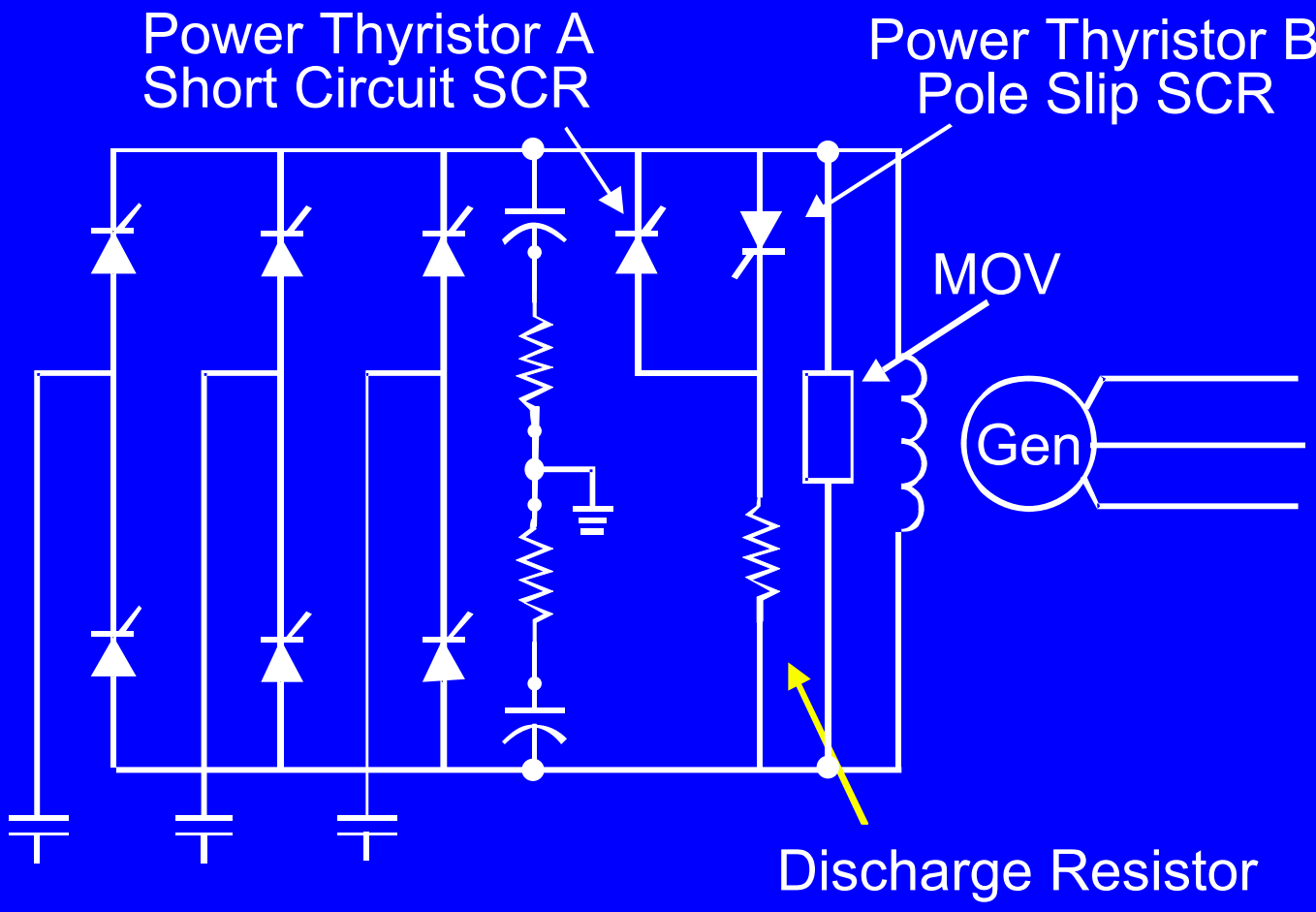
# Rotary-Excited Brush Type Generator



# 3 SCR Half Wave Bridge



# 6 SCR Bridge with Crowbar Fast De-excitation Circuit



# Rotating Exciter Voltage Regulator Applications

# Excitation Field Requirements

- Range from 10A – 200A
- Voltage Regulator works directly into exciter shunt field
- Eliminates various types of pilot exciters
- Information not obvious (need measurements)
- Use 6 SCR bridge

# Equipment Features

# Specify all features
## Prevent misinterpretation:

- Features are integrated into a single controller with microprocessor architecture
- Software can enable and disable features
- Typical features included,
  listed on following 3 slides

# Redundant Digital Excitation Control Systems

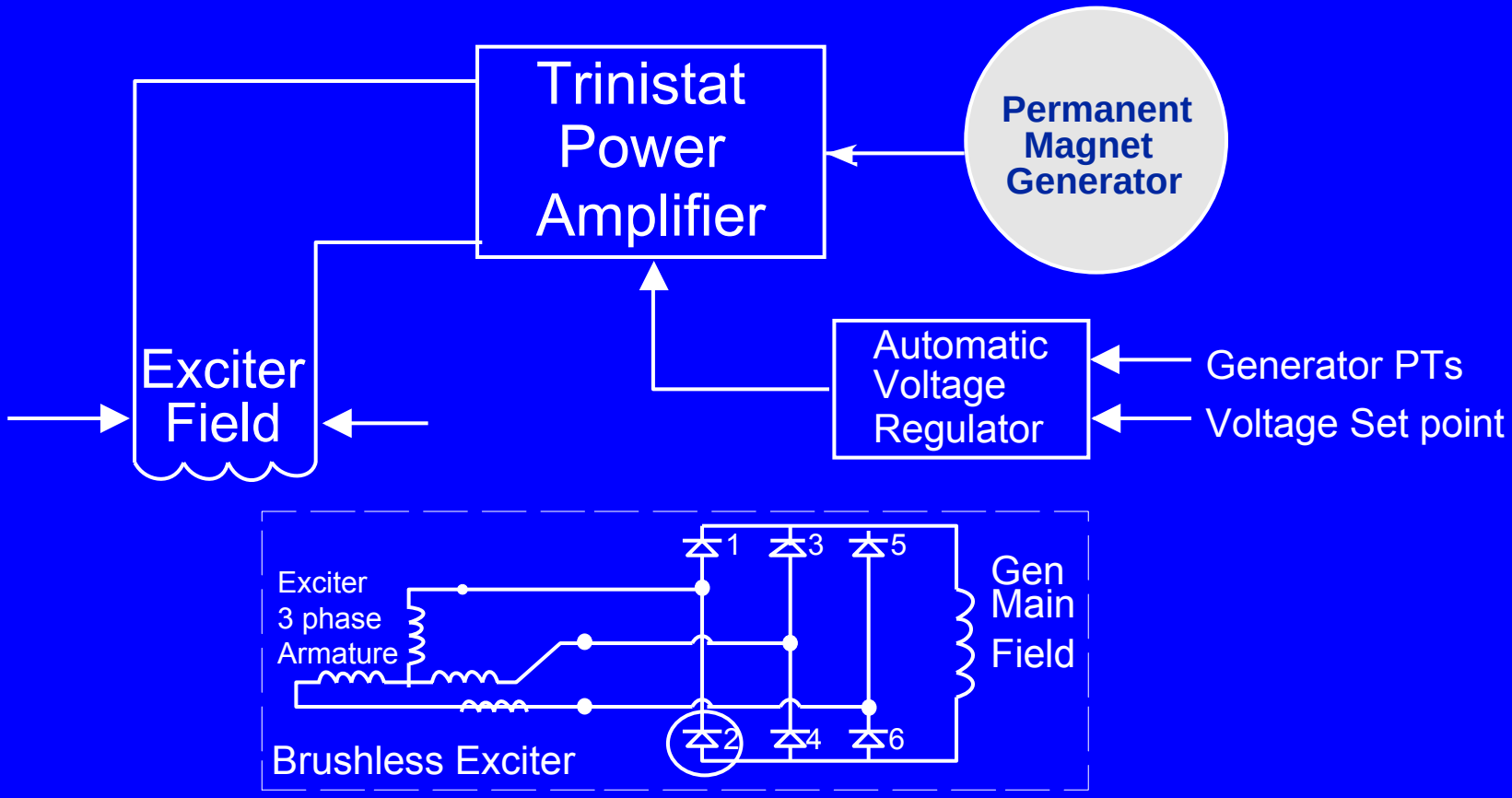
FEATURES
- Voltage regulation
- Manual control
- var/PF control
- Excitation limiters
- Power system stabilizers

- **Bumpless transfer**
- **Drawout or fixed mounted**

# Power Input Options

- PMG
- Station power
- Generator output

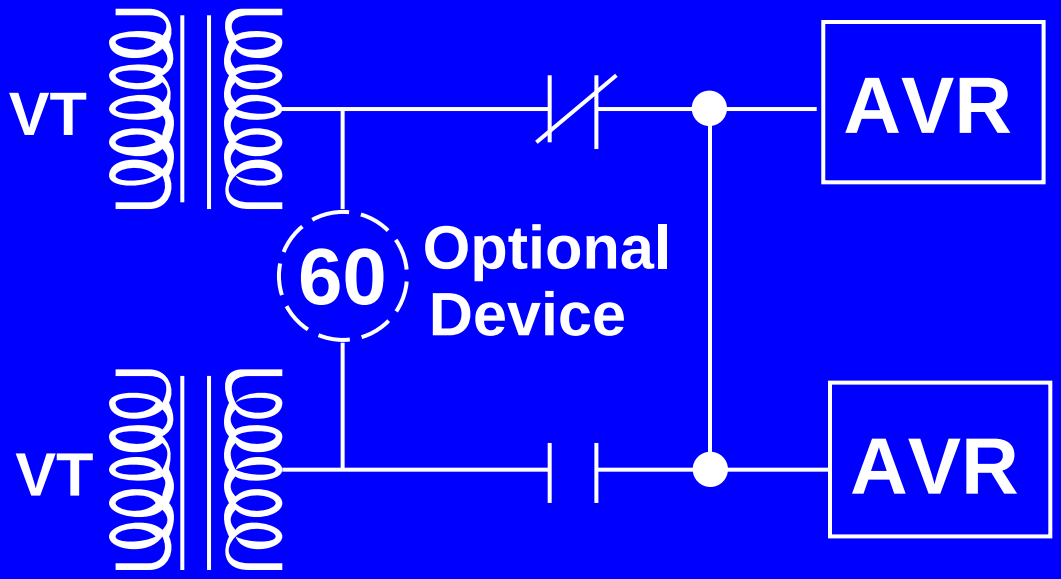
# Permanent Magnet Generator (PMG)



# Special Feature Considerations

- Power System Stabilizer
- Redundant Digital Controllers
- Backup Instrument Transformers
- Redundant Bridge

# Single or Dual Channel AVR with Dual Instrument Transformers



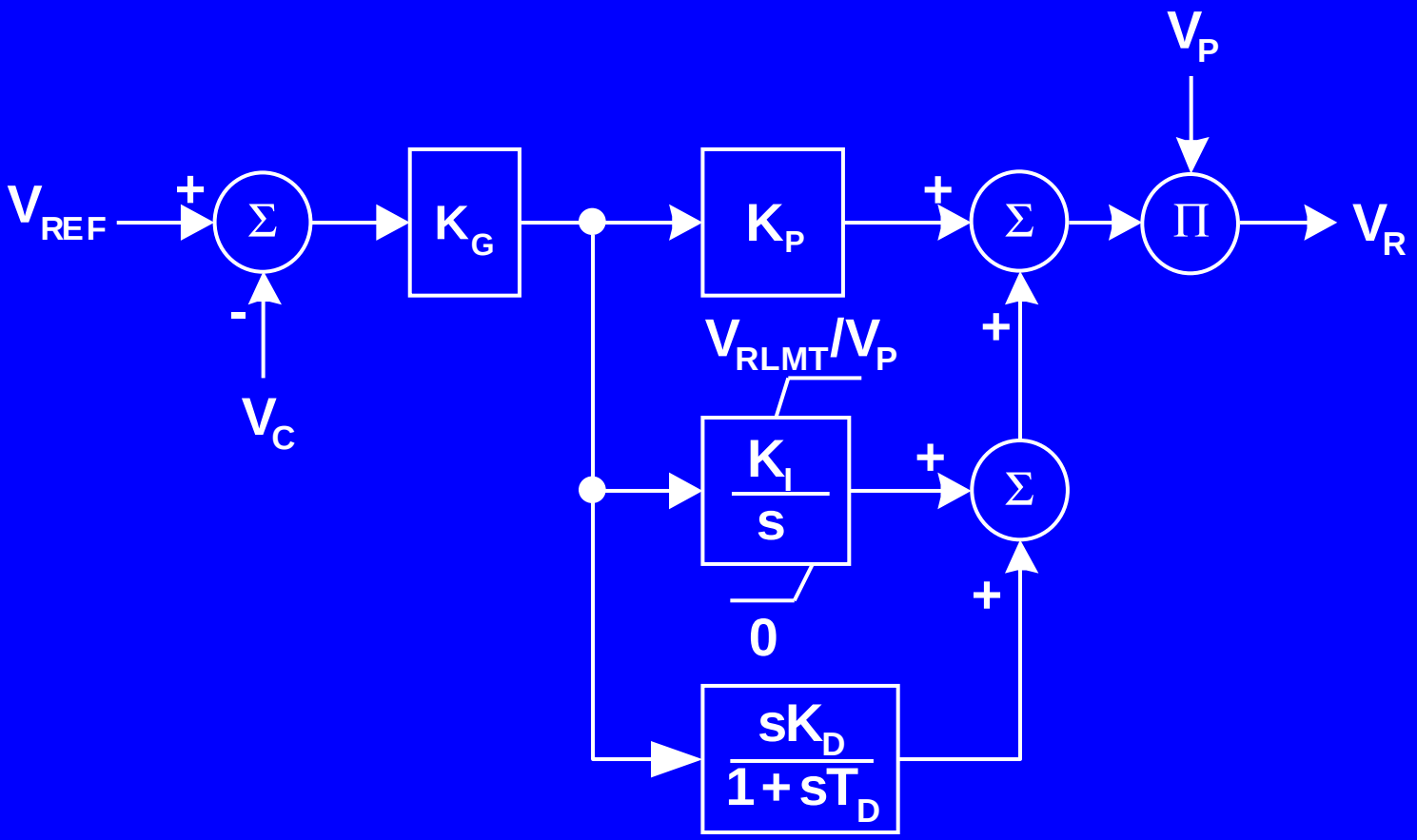
# Environment

## Know the issues involved:

- Dripping water
- Temperature concerns
- Salt air spray damage
- Adequate working space
- Safety

# PID Exciter Model

## IMPORTANT TODAY



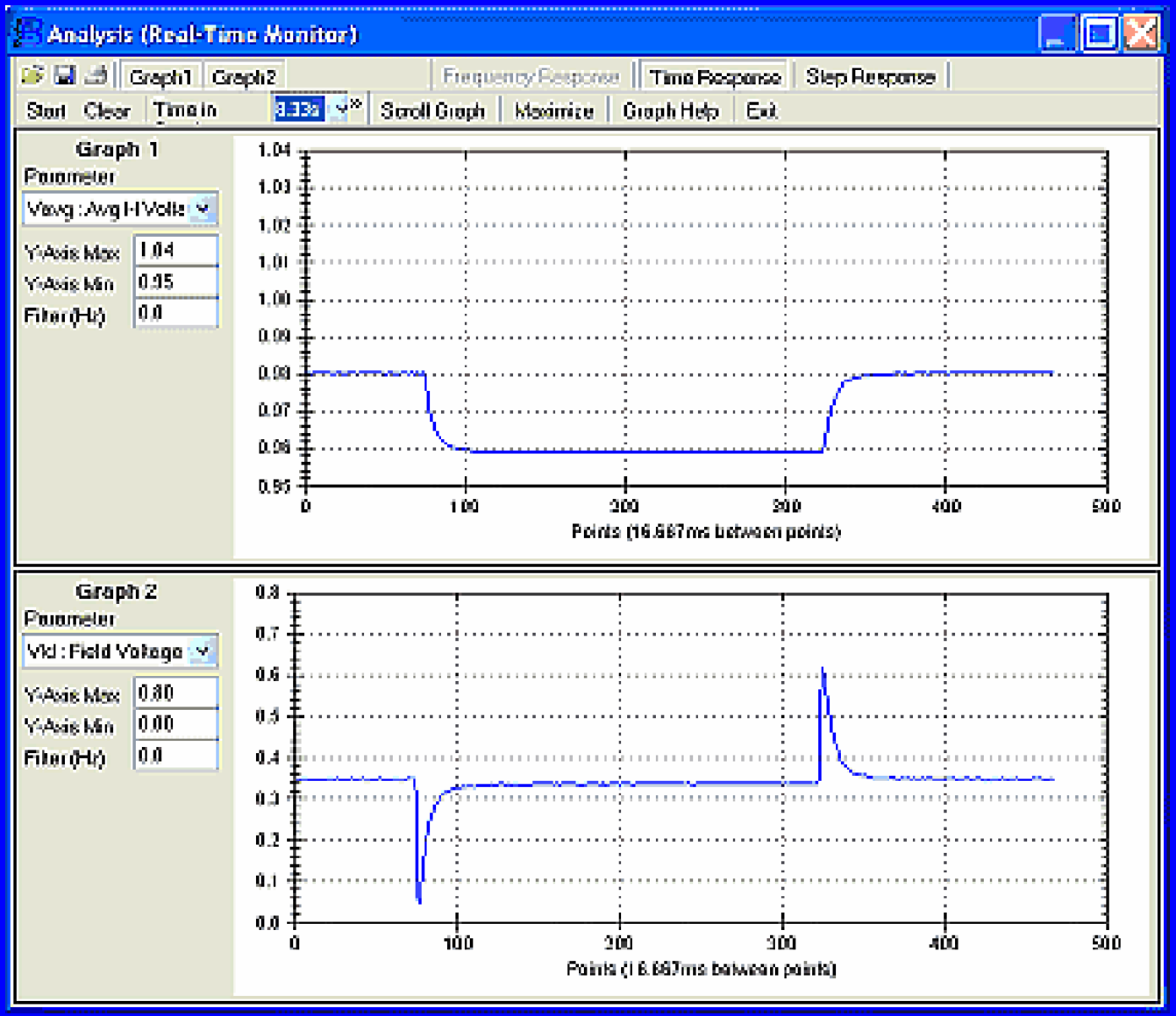
# Define the project for vendor

- Defined schedules
- Drawings of the existing system
- Generator design data and curves
- Availability of cable and conduits
- Development of interface
- Documentation
- Technical training schedule
- Technical spec

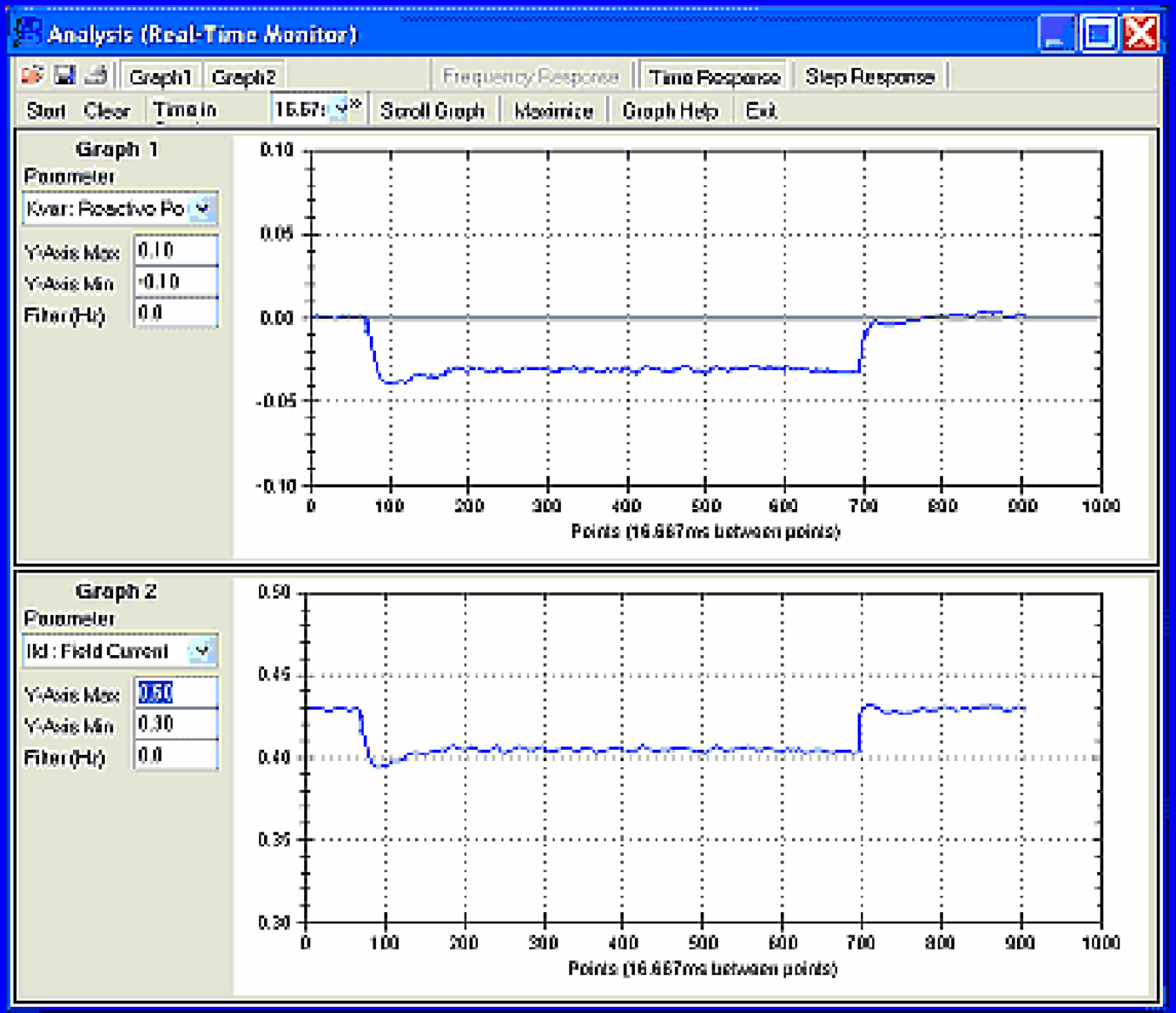
# Startup and Commissioning Tests

- Startup and Sequence Logic checkout
- Off-line and on-line voltage step responses
- Under Excitation and Over Excitation Limiter
- Volts/Hertz Limiter
- Autotracking verification
- Frequency Response
- Power System Stabilizer

# 5% Voltage Step Change in Voltage Regulator Mode



# Under Excitation Limit Dynamic Step Test



# IEEE Standards as Applicable

- 421.1 Standard Definitions for Excitation Systems for Synchronous Machines
- 421.2 Identification, Testing, and Evaluation of Dynamic Performance of Excitation Control System
- 421.3 Hipot Test Requirements for Excitation Systems for Synchronous Machines
- 421.4 Preparation of Excitation System Specs
- 421.5 Recommended Practice for Excitation System Models for Power System Stability Studies

# Appendix

## MACHINE DATA

| | | | | | |
|---|---|---|---|---|---|
| Turbine-Generator Size & Mfg: | _____MW | _____Manufacturer | | | |
| Turbine Drive Type: | | ____Steam | ____Gas | ____Hydro | ____Diesel |
| Is this a *Voltage Regulator* System Retrofit project? | | | _____yes | | _____no |
| Is this a *Static Excitation* System Retrofit project? | | | _____yes | | _____no |
| What is the environment at the Exciter Cubicle (dry, wet, dirty, etc.)? | _____ | | | | |
| Describe Conditions | _____ | | | | |
| What is the Ambient Temperature of the equipment location? | _____ | | | | |
| Does system have a *Main Rotating Exciter*? | | | _____yes | | _____no |
| What is the existing *System Control* Power? | | | _____125VDC | | _____250VDC |
| Is 120VAC *Control* Power available in the exciter cubicle? | | | _____yes | | _____no |
| **What is the Excitation Power Source?** | | | | | |
| Static Exciter: | | | | | |
| Generator Output | | | _____yes | | _____no |
| Station Power | | | _____yes | | _____no |
| Rotating Exciter Voltage Regulator Applications | | | | | |
| Generator Output | | | _____yes | | _____no |
| PMG (Permanent Magnet Generator) | | | _____yes | | _____no |
| Station Power | | | _____yes | | _____no |
| Specify Station Power Voltage: | _____ | | | | |
| Where Station Power is used, is backup ac Station with power transfer switch required? | | | | _____yes | _____no |

## GENERATOR DATA

| | | | |
|---|---|---|---|
| Manufacturer: | _____ | | |
| Frequency: | _____ | | |
| MW: | _____ | MVA: | _____ |
| Voltage: | _____ | Power Factor: | _____ |
| Stator Amps: | _____ | Generator Full Load Field Amps: _____ | Field Volts: _____ |
| Generator at 115% MVA at 105% generator voltage | | Field Amps: _____ | Field Volts: _____ |
| Rated Generator Field Voltage: | _____ | Generator Field Ohms: | _____ |
| RPM: | _____ | Coolant Type: | _____ |

## MAIN ROTATING EXCITER DATA

| | | | |
|---|---|---|---|
| Armature Voltage: | _____ | Armature Amps: | _____ |
| KW: | _____ | | |
| Exciter Shunt Field Ohms: | _____ | Rated Exciter Shunt Field Voltage: | _____ |
| Full Load Exciter Shunt Field Amps: | _____ | | |

| | | | | |
|---|---|---|---|---|
| Is this a *Brush Type* Exciter? | _____yes | | | _____no |
| Is this a *Brushless* Exciter? | _____yes | | | _____no |
| What are the ratings of the Permanent Magnet Generator? | ____Volts | ____Amps | ____Hz | ____# of phases |

## ADDITIONAL FEATURE CONSIDERATIONS BEYOND THOSE SPECIFIED IN TABLE 1

| | | |
|---|---|---|
| Is a redundant *digital controller* needed? | _____yes | _____no |
| Are redundant *SCR Bridges* required? | _____yes | _____no |
| Will a *Power System Stabilizer* be required? | _____yes | _____no |
| Will a *PSS Tune-up* be required as part of this project? | _____yes | _____no |
| Is automatic transfer to redundant instrument PTs required? | _____yes | _____no |
| Is turnkey install required? | _____yes | _____no |
| Is commissioning required by manufacturer? | _____yes | _____no |
| Special Field Forcing Requirements? | _____yes | _____no |
| Define: _____ | | |
| Special Power Potential Transformer Consideration? | _____yes | _____no |
| Define: _____ | | |
| Is Excitation Model Information required? | _____yes | _____no |
| Field Ground Relay? | _____yes | _____no |
| Automatic Synchronization? | _____yes | _____no |

## DRAWING DOCUMENTATION

| |
|---|
| Schematic Interconnect Drawing |
| Outline Drawings |
| Other Special Drawing Considerations |

# Outline

1) Specifying Excitation Systems for Procurement

2) Alternate Solutions to Replacing Aged Static Exciter Systems

3) Retrofitting SCT-PPT Excitation Systems with Digital Control

# Retrofit Approaches

1. Replace complete static exciter system, including PPT.
2. Keep PPT and replace VR control and power rectifier bridge(s).
3. Retrofit only the analog controls and keep the power rectifier bridge(s), breaker, contactors and PPT.

# Factors that influence re-evaluation of existing system's ability to comply

1. 2005 Energy Act put emphasis on:
   - generator excitation model validation
   - performance testing
   - limiter coordination w/protective relaying
2. Need to add power system stabilizer

# THE RETROFIT

- Eliminated all analog controls except
  - Two SCR bridges
  - AC field molded case breaker
  - DC field flash contactor
  - Field Flash resistor
  - DC control interface
  - PPT
- NEW Digital Controller mounted on front door replaced old AVR rack
- NEW Programmable digital firing module programmed for 3 SCR application
- NEW Gate amplifier board
- EXISTING balance reactors used for the SCR bridges

# Original OEM Analog Voltage Regulator

# Existing 3 SCR, 3 Diode Half-Wave Bridge

# Original equipment parts removed during demolition

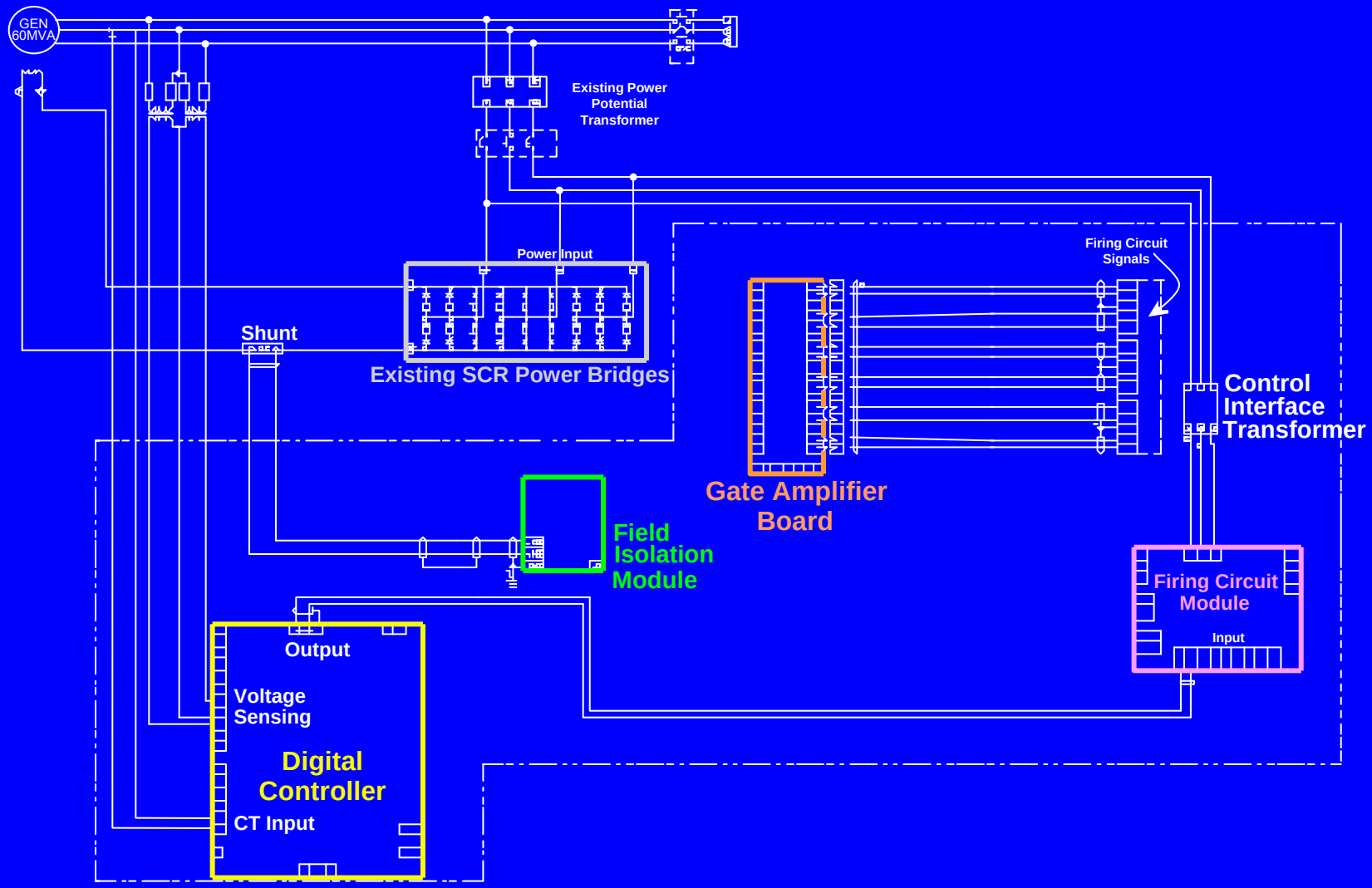
# Digital Controller Installed in Cabinet Door

- Voltage Regulator
- Field Current Regulator
- Var/PF Control
- Nulling
- Excitation Limiters
- Autovoltage Matching
- Oscillography
- Real Time Monitoring Testing Tools
- Built-in Dynamic System Analyzer Testing Tools
- Protection
- Optional Power System Stabilizer

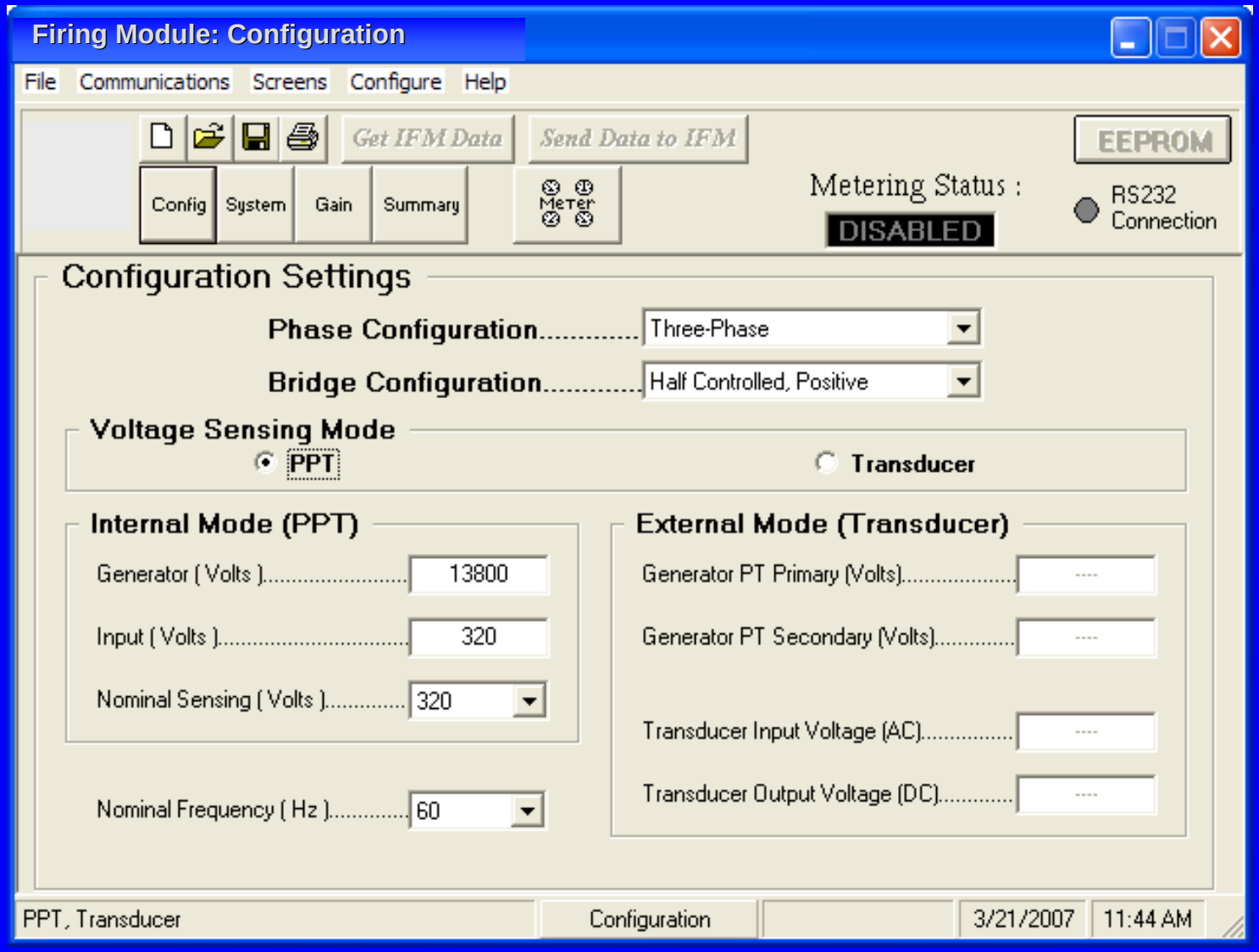
# Back door of digital controller panel showing firing circuit and related hardware

# Exciter cabinet lineup with digital controller installed

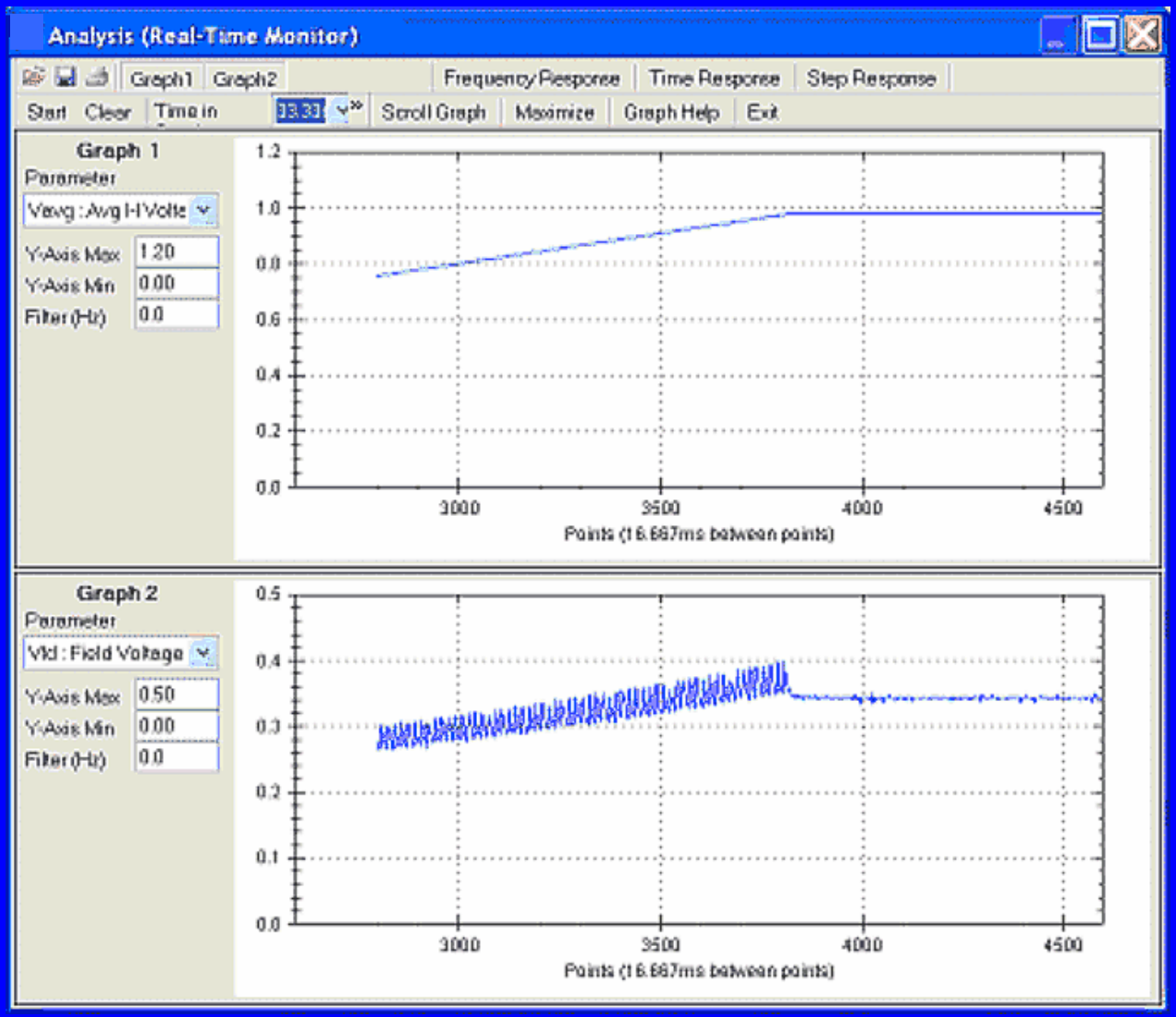
# Partial schematic of the new interconnected system



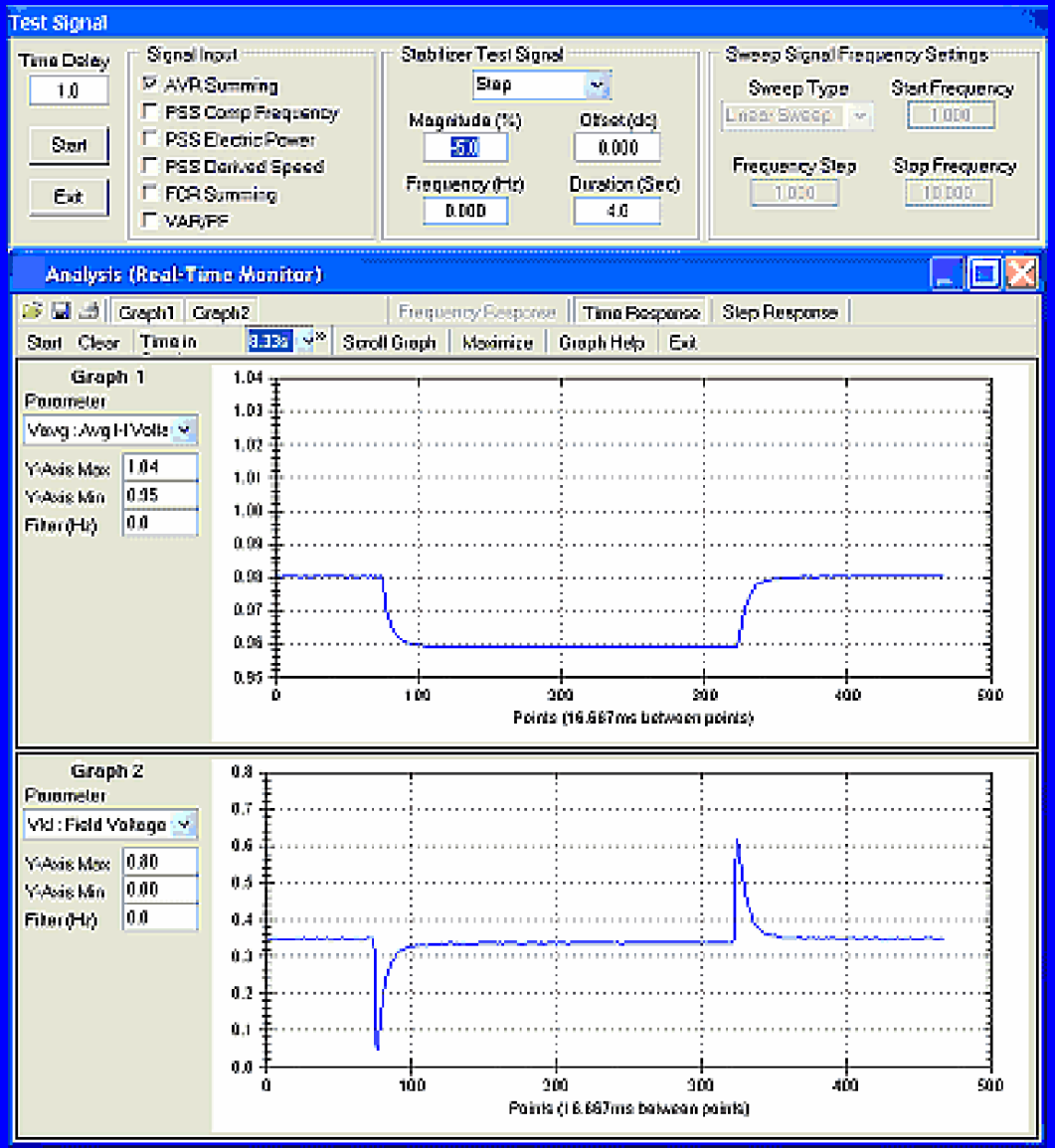
# Firing circuit setup for half-wave bridge



# Voltage buildup in Voltage Regulator Mode



# 5% Voltage Step Change in Voltage Regulator Mode



# Outline

1) Specifying Excitation Systems for Procurement

2) Alternate Solutions to Replacing Aged Static Exciter Systems

3) Retrofitting SCT-PPT Excitation Systems with Digital Control

# Retrofitting SCT-PPT Excitation Systems with Digital Control

## Main field static excitation systems

- 1970’s vintage
- 5 - 295 MVA generators
- Gas turbines

# Main field-excited gas turbine-generator (Frame 5 and Frame 7)

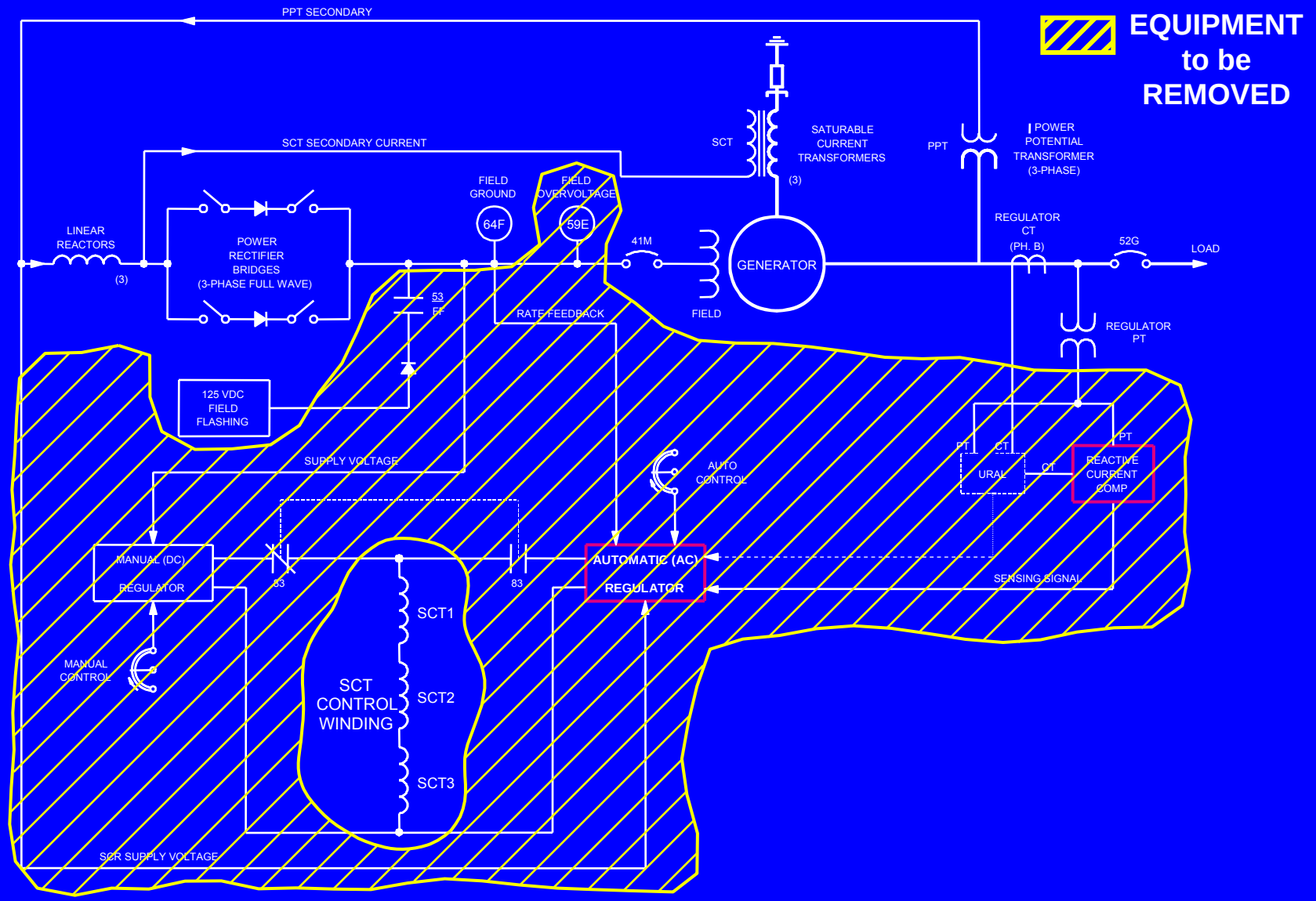
# SCT-PPT equipment

- SCT
- PPT
- Linear reactors
- Power rectifier bridge(s)
- Automatic (AC) voltage regulator
- Manual (DC) voltage regulator
- Signal transformers (CT and PT)
- 41M generator field breaker
- Protection modules
- Auxiliary control systems


Dual power rectifier bridge assembly

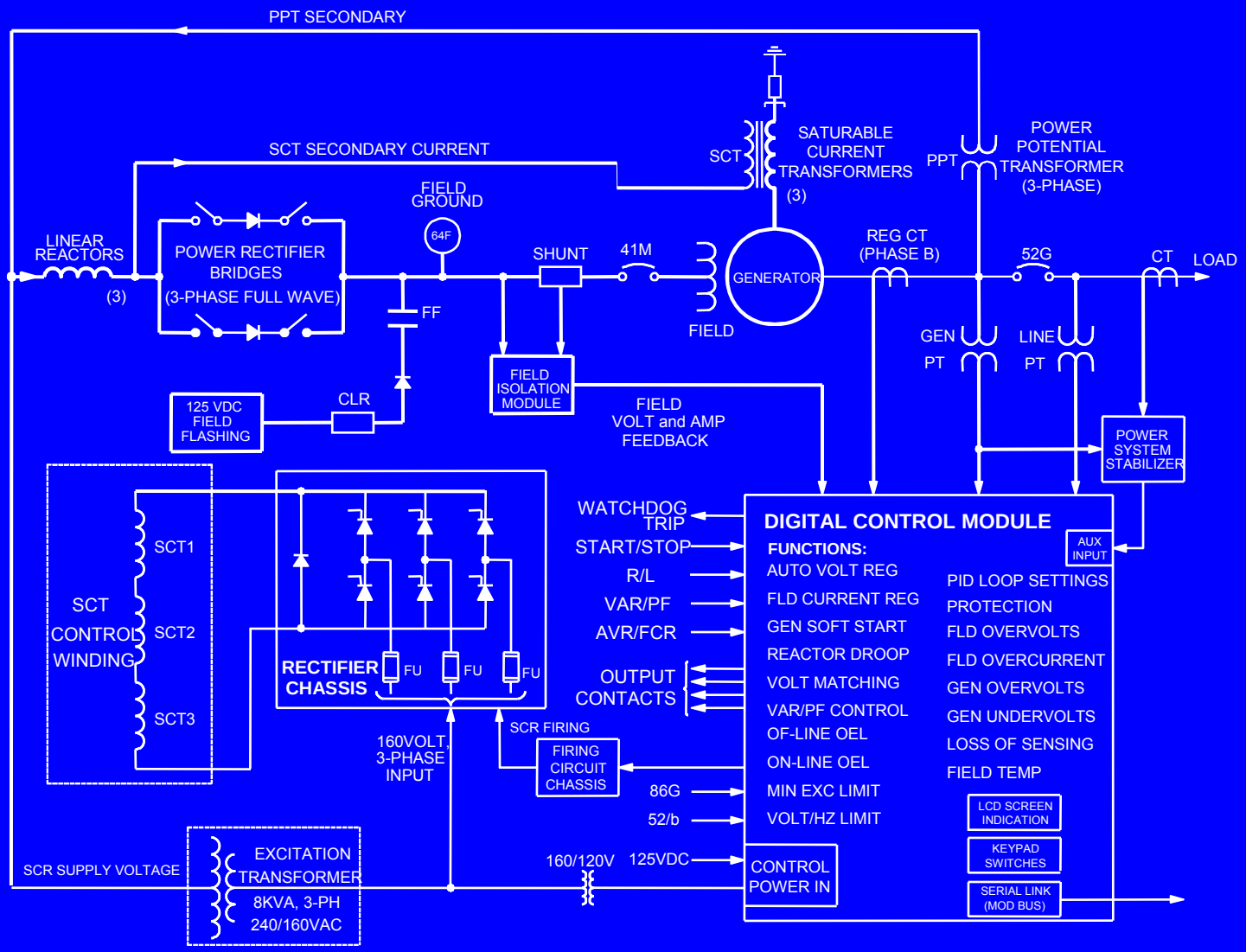

SCTs and linear reactors

# Component parts to be removed for the retrofit



# Start-up and commissioning of new digital voltage regulator system

# New retrofit digital voltage regulator on SCT-PPT system (steam turbine)



# Gas turbine-generator system

**(New pans into existing generator control panel with “middle door”)**

- **Demolition and installation**
- **System testing**
- **System startup  (Off-line and on-line testing)**
- **Technical training**

# CONCLUSION

- **Guidelines for specifying**
- **Options**
  - Replace entire excitation system
  - Replace analog portion only for digital front end, keeping rectifier bridges
  - SCT/PPT AVR replacement for digital, keeping power magnetics

# Questions