

Excitation Control for a Synchronous Generator

Group:

Three Phase

Members:

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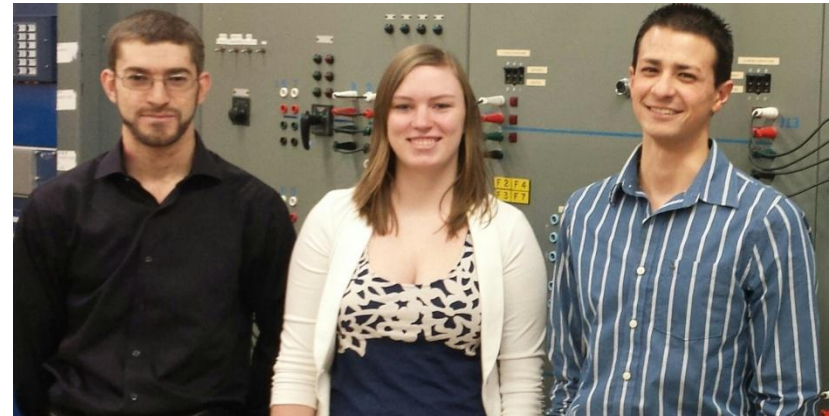
Norman Fischer
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Sponsor:

SEL

The goal of this project is to equip a generator used in the BEL Power Lab with a static exciter. The exciter should support a continuous operating mode and a three to four second burst.

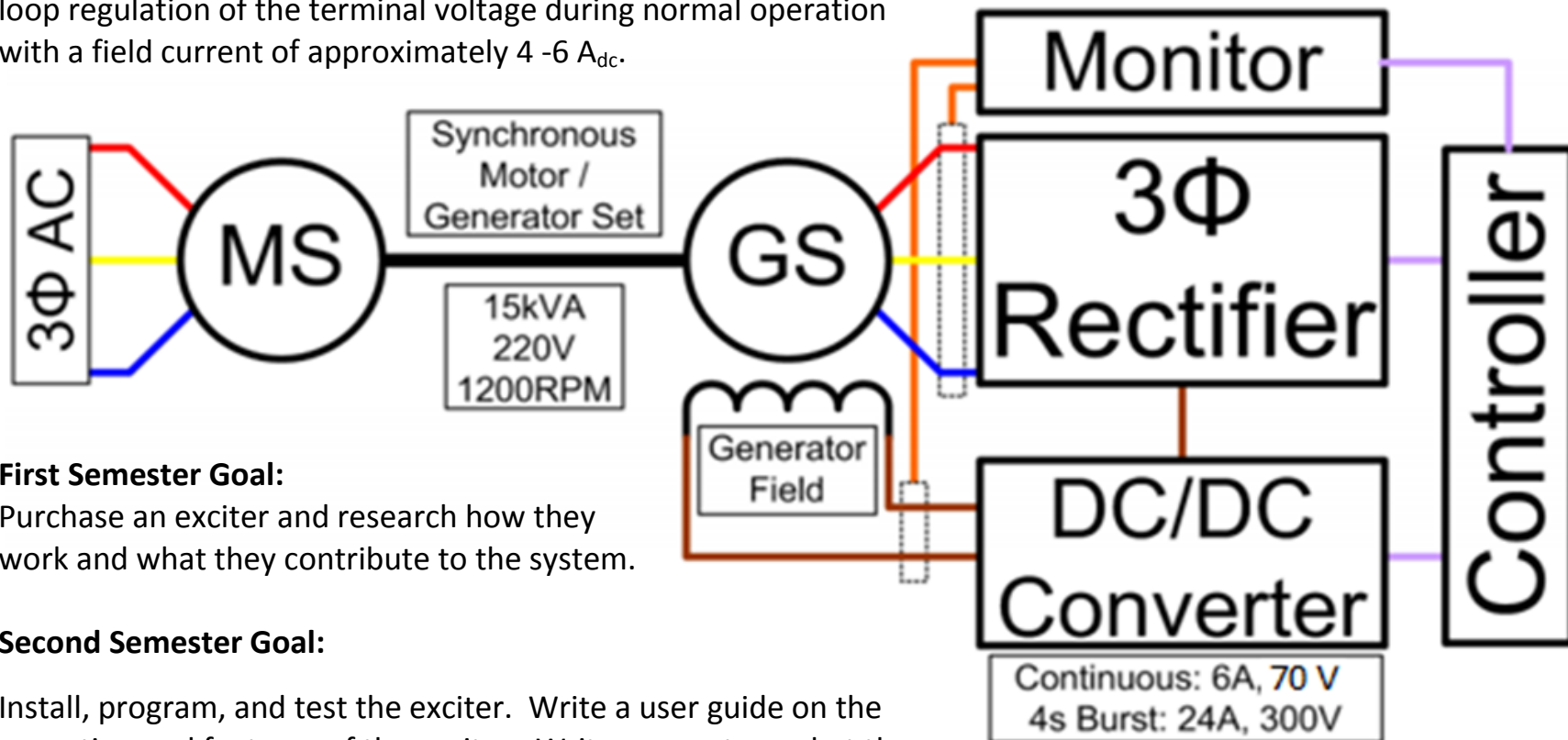
The objective of this project is to make a more industrially realistic system for use with fault simulations. In addition the exciter will enhance the quality upper division labs that may use this system.



Semester Goals

Problem:

Design and implement a solid state exciter and related controls for a 15 kVA, 220V, 1200 RPM synchronous machine in UI Model Power System lab. The exciter should be capable of supporting fast field forcing to temporarily increase ac output voltage for voltage sags during simulated faults. The exciter should be capable of driving $24 A_{dc}$ at $300 V_{dc}$ for 3-4 seconds as well providing closed loop regulation of the terminal voltage during normal operation with a field current of approximately 4 -6 A_{dc} .



First Semester Goal:

Purchase an exciter and research how they work and what they contribute to the system.

Second Semester Goal:

Install, program, and test the exciter. Write a user guide on the operation and features of the exciter. Write a report on what the exciter is used for, how it works, and what it adds to the system.

ABB Unitrol 1020



Unitrol 1020 Key Advantages:

- **Upgrade Options**
Upgradable with a power system stabilizer and a PM40 module
- **High short term overload current**
40 Amps for 10 seconds
With PM40 option: 80 Amps for 10 seconds.
- **Wide operating temperature range**
-40°C to +70°C
- **Superior Voltage Regulation**
 $\pm 0.10\%$ from rated
- **High Continuous Output Current**
Up to 20 Adc
With PM40 option: 40 Adc
- **Wide Input Voltage Range**
9-300 Vac

Disadvantages of the Competitors

Basler DECS-200

- 15 Adc maximum continuous output
- $\pm 0.25\%$ voltage regulation
- 56-277 Vac input range
- -40°C to +60°C
- No Ethernet ports

Basler DECS-250

- 15 Adc maximum continuous output
- $\pm 0.25\%$ voltage regulation
- 56-277 Vac input range
- -40°C to +60°C

Product Comparison

Features	<u>ABB Unitrol -1020 Basic</u>	<u>Basler DECS-200</u>	<u>Basler DECS-250</u>
Exciter Output	Up to 20 Adc	< 15 Adc < 125 Vdc	< 15 Adc < 125 Vdc
Exciter Input	9-300 Vac	56-277 Vac	56-277 Vac
VR accuracy	±0.10%	±0.25%	±0.25%
Size	6.69" x 11.89" x 6.69"	8.08" x 7.32" x 12"	8.08" x 8.62" x 12"
Short Term Overload	< 40 Adc 10 seconds	< 300 Vdc < 30 Adc 10 seconds	< 300 Vdc < 30 Adc 10 seconds
Commissioning software	CMT1000 PC Software	BESTCOMSPlus PC Software	BESTCOMSPlus PC Software
Interface	USB, Ethernet, RS485, CAN bus, Front Panel HMI.	RS232, RS485 Modbus, Front Panel HMI.	USB, Ethernet, RS232, RS485 w/ options, J1939 CAN bus, IRIG-B, Front Panel HMI.
Optional Interface	Not Specified	DB9 for External Tracking	Profibus, RS232 and DB9 (ExternalTracking)
Maximum Burden	Not specified	3,070 VA	3,070 VA
Operating Temperature	-40 to 70 °C	-40 to 60 °C	-40 to 60 °C
Cost	Between \$5,000 and \$6,000	Between \$5,000 and \$6,000	Between \$4,000 and \$5,000

$$\boxed{f_{se} = \frac{n_m P}{120}} \quad (3-34)$$

where f_{se} = electrical frequency, in Hz
 n_m = mechanical speed of magnetic field, in r/min (equals speed of rotor for synchronous machines)
 P = number of poles

$$\boxed{P = s_p(f_{nl} - f_{sys})}$$

where P = power output of the generator
 f_{nl} = no-load frequency of the generator
 f_{sys} = operating frequency of system
 s_p = slope of curve, in kW/Hz or MW/Hz

$$P_{max} = \frac{3V_\phi E_A}{X_S}$$

and the corresponding maximum torque is

$$\tau_{max} = \frac{3V_\phi E_A}{\omega_{nr} X_S}$$

$$P_{out} = \sqrt{3} V_L I_L \cos \theta$$

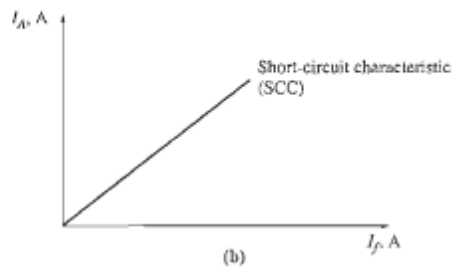
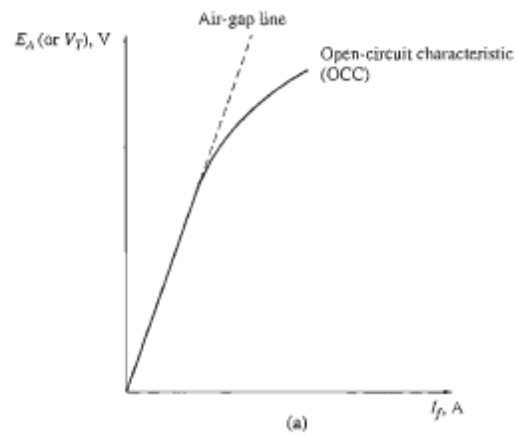


FIGURE 4-17
 (a) The open-circuit characteristic (OCC) of a synchronous generator. (b) The short-circuit characteristic (SCC) of a synchronous generator.

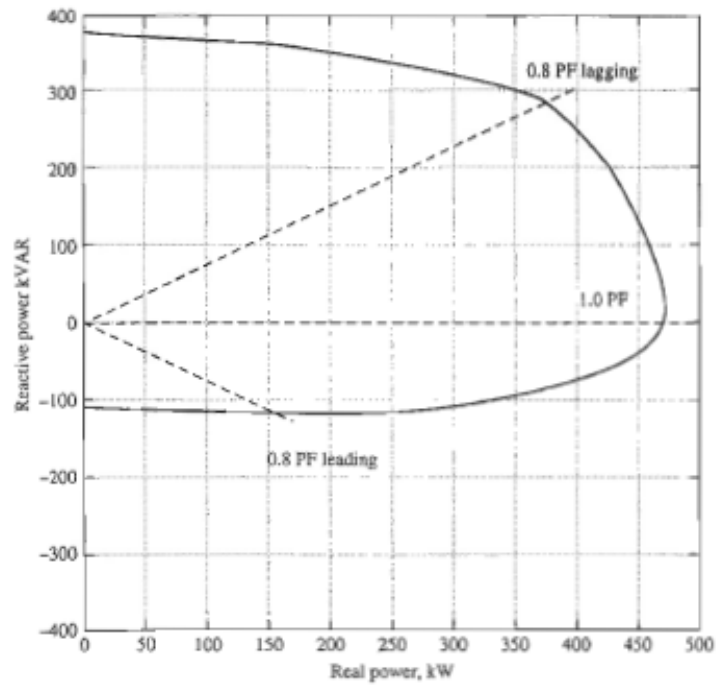


FIGURE 4-52
 Capability curve for a real synchronous generator rated at 470 kVA. (Courtesy of Marathon Electric Company.)

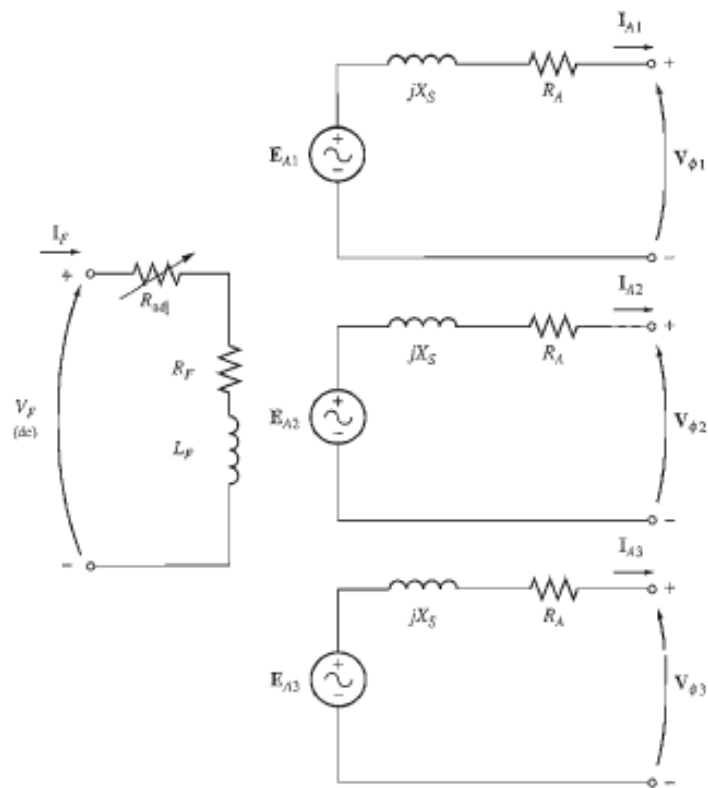


FIGURE 4-10
The full equivalent circuit of a three-phase synchronous generator.

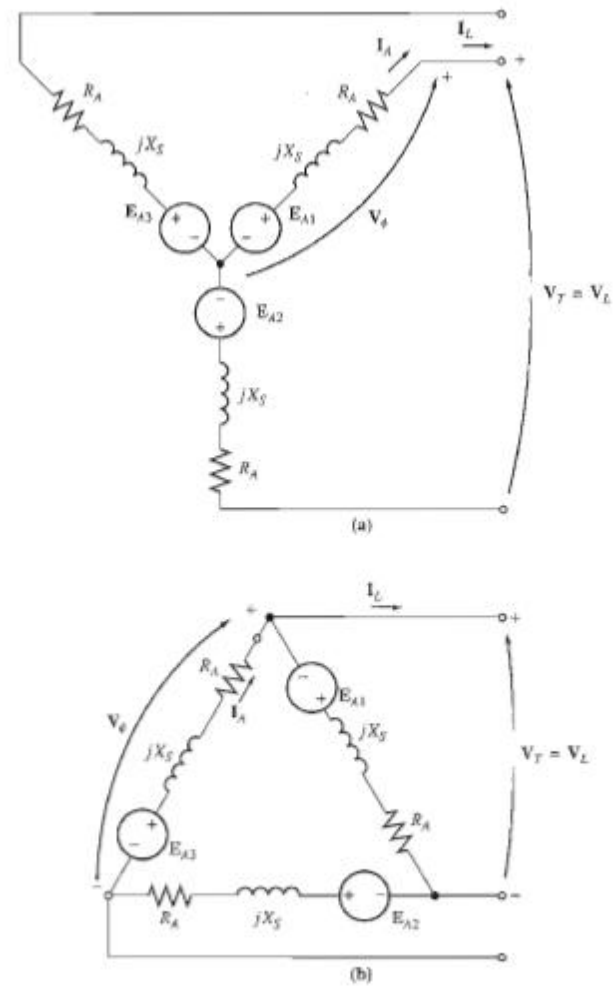


FIGURE 4-11
The generator equivalent circuit connected in (a) Y and (b) Δ .

Tentative Schedule

December	
05	Snapshot II
10	Finish and Submit Cost Comparison
10	Order Exciter

January	
02	Connect Exciter
03	Commission Exciter

February	
02	Begin Tests

March	
02	Test for Requirements
11	Snapshot III

April	
02	Test for Failure
17	Write Test Procedures

May	
01	Write User Manual
02	Engineering Design Expo
10	Order Exciter

Excitation Control for a Synchronous Generator

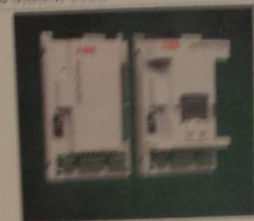
- Group: [Name]
- Members: [List of names]
- Advisor: [Name]
- Monitor: [Name]
- Client: [Name]
- Project: [Name]

The goal of this project is to design a generator excitation control system for a synchronous generator. The monitor should support a continuous operating mode and a three-to-four second time constant.

The algorithm of this project is to make a state machine controller for the generator excitation. In addition, the monitor will enhance the quality of the control loop that may use the system.



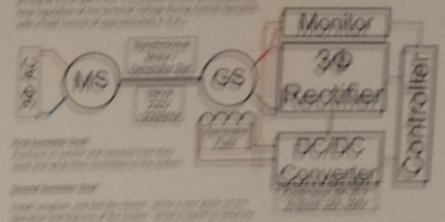
ABB Control 1020



- ABB Control 1020 features include:
 - High performance
 - Wide operating range
 - Low power consumption
 - High reliability
 - Easy installation
 - Low maintenance
 - High accuracy
 - Wide operating range
 - Low power consumption
 - High reliability
 - Easy installation
 - Low maintenance
 - High accuracy

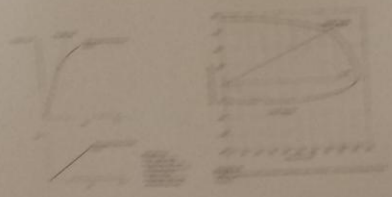
Semester Goals

Design and implement a control system for a synchronous generator excitation system. The system should be capable of supporting the generator's continuous operating mode and a three-to-four second time constant. The monitor should support a continuous operating mode and a three-to-four second time constant.



- First Semester Goal: [Text]
- Second Semester Goal: [Text]

Handwritten notes and equations, including the formula $P_{out} = \sqrt{3} V_L I_L \cos \phi$.



Product Comparison

Product	Price	Performance	Reliability	Support
ABB Control 1020	1000	High	High	Good
ABB Control 1030	1200	High	High	Good
ABB Control 1040	1500	High	High	Good
ABB Control 1050	1800	High	High	Good
ABB Control 1060	2000	High	High	Good
ABB Control 1070	2200	High	High	Good
ABB Control 1080	2500	High	High	Good
ABB Control 1090	2800	High	High	Good
ABB Control 1100	3000	High	High	Good

Excitation System

Handwritten notes and diagrams related to the excitation system, including a block diagram of the excitation system and a graph showing the system's response to a step change in load.

Tentative Schedule

Week	Task
Week 1	Project Introduction
Week 2	System Requirements
Week 3	System Design
Week 4	System Implementation
Week 5	System Testing
Week 6	System Deployment
Week 7	System Maintenance
Week 8	System Evaluation