EXCITATION SYSTEMS

OUTLINE

- Functions and Performance Requirements
- Elements of an Excitation System
- Types of Excitation Systems
- Control and Protection Functions
- Modeling of Excitation Systems

Functions of the excitation system

- **The functions of an excitation system are**
  - ☞ **to provide direct current to the synchronous generator field winding, and**
  - ☞ **to perform control and protective functions essential to the satisfactory operation of the power system**

The performance requirements of the excitation system are determined by

a) Generator considerations:

- supply and adjust field current as the generator output varies within its continuous capability
- respond to transient disturbances with field forcing consistent with the generator short term capabilities:
  - rotor insulation failure due to high field voltage
  - rotor heating due to high field current
  - stator heating due to high VAR loading
  - heating due to excess flux (volts/Hz)

b) Power system considerations:

- contribute to effective control of system voltage and improvement of system stability

Elements of an Excitation System

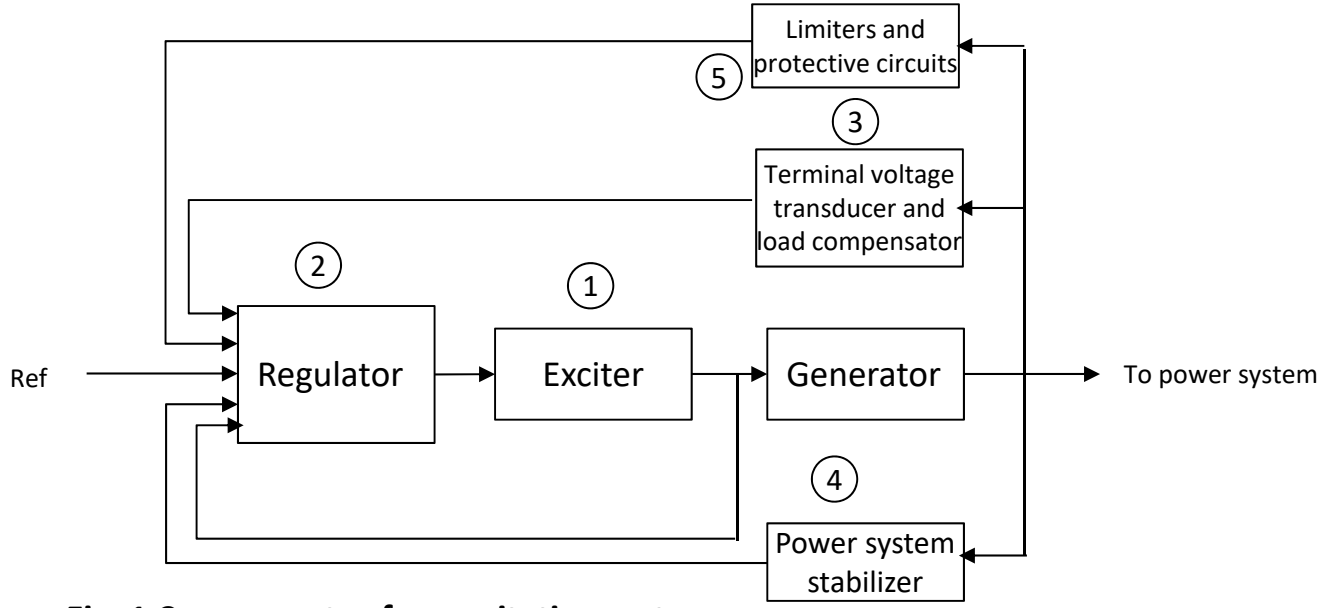

Fig. 1 Components of an excitation system

1. ***Exciter***: **provides dc power to the generator field winding**
2. ***Regulator***: **processes and amplifies input control signals to a level and form appropriate for control of the exciter**
3. ***Terminal voltage transducer and load compensator***: **senses generator terminal voltage, rectifies and filters it to dc quantity and compares with a reference; load comp may be provided if desired to hold voltage at a remote point**
4. ***Power system stabilizer:*** **provides additional input signal to the regulator to damp power system oscillations**
5. ***Limiters and protective circuits***: **ensure that the capability limits of exciter and generator are not exceeded**

Types of Excitation Systems

Classified into three broad categories based on the excitation power source:

- **DC excitation systems**
- **AC excitation systems**
- **Static excitation systems**

DC Excitation Systems

- utilize dc generators as source of power; driven by a motor or the shaft of main generator; self or separately excited
- represent early systems (1920s to 1960s); lost favor in the mid-1960s because of large size; superseded by ac exciter
- voltage regulators range from the early non-continuous rheostatic type to the later system using magnetic rotating amplifiers

DC Excitation System

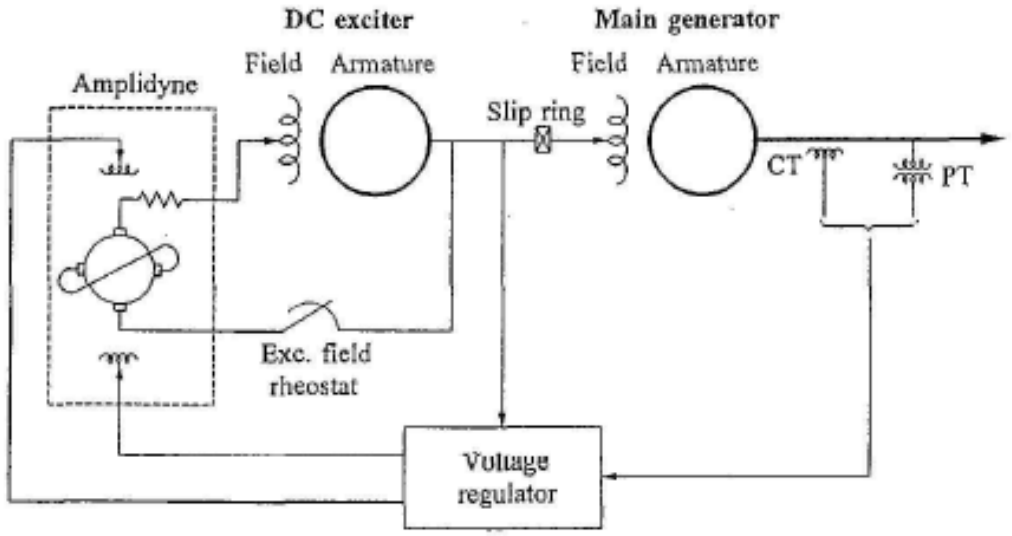

Fig. 2 DC excitation system with amplidyne voltage regulators

- An amplidyne is an electromechanical amplifier.
- It consists of an electric motor driving a DC generator.
- The signal to be amplified is applied to the generator's field winding, and its output voltage is an amplified copy of the field current.
- The amplidyne is used in industry in high power servo and control systems, to amplify low power control signals.
  - It is now mostly obsolete.

Fig. 2 shows a simplified schematic of a typical dc excitation system with an amplidyne voltage regulator

- **self-excited dc exciter supplies current to the main generator field through slip rings**
- **exciter field controlled by an amplidyne which provides incremental changes to the field in a buck-boost scheme**
- **the exciter output provides rest of its own field by self-excitation**

AC Excitation System

- use ac machines (alternators) as source of power
- usually, the exciter is on the same shaft as the turbine-generator
- the ac output of exciter is rectified by either controlled or non-controlled rectifiers
- rectifiers may be stationary or rotating
- early systems used a combination of magnetic and rotating amplifiers as regulators; most new systems use electronic amplifier regulators

AC Excitation System

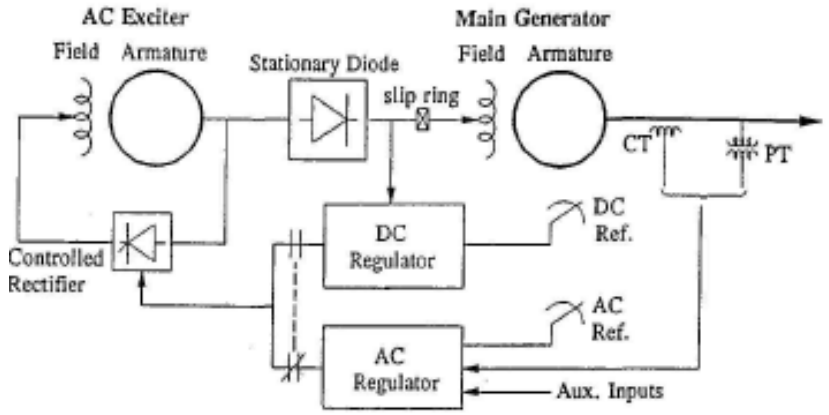

Fig. 3 Field controlled alternator rectifier excitation system

- **dc output to the main generator field supplied through slip rings**
- **when non-controlled rectifiers are used, the regulator controls the field of the ac exciter;**

AC Excitation System

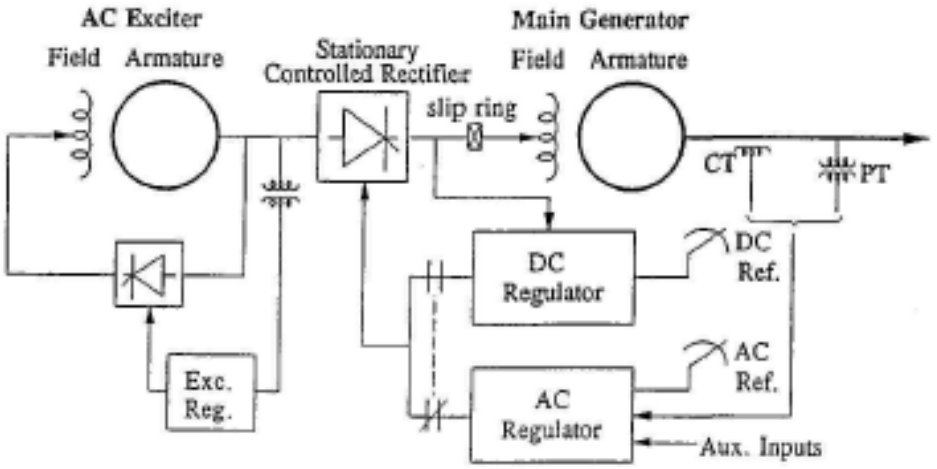

Fig. 4 Alternator supplied controlled-rectifier excitation system

- **When controlled rectifiers are used, the regulator directly controls the dc output voltage of the exciter**

Rotating Excitation System

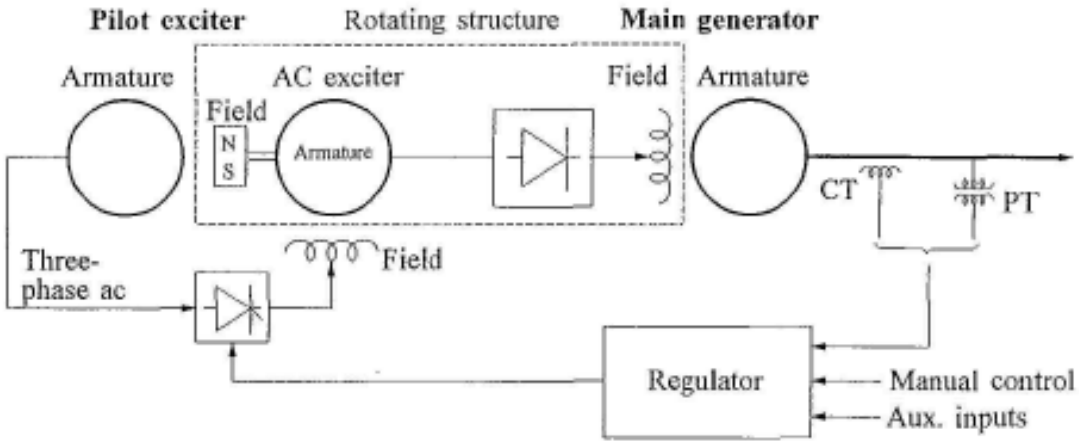

Fig. 5 Brushless excitation system

- **the need for slip rings and brushes is eliminated; such systems are called *brushless excitation systems***
- **they were developed to avoid problems with the use of brushes perceived to exist when supplying the high field currents of large generators**
- **they do not allow direct measurement of generator field current or voltage**

Static Excitation System

- all components are static or stationary
- supply dc directly to the field of the main generator through slip rings
- the power supply to the rectifiers is from the main generator or the station auxiliary bus

Potential source for controlled rectifier

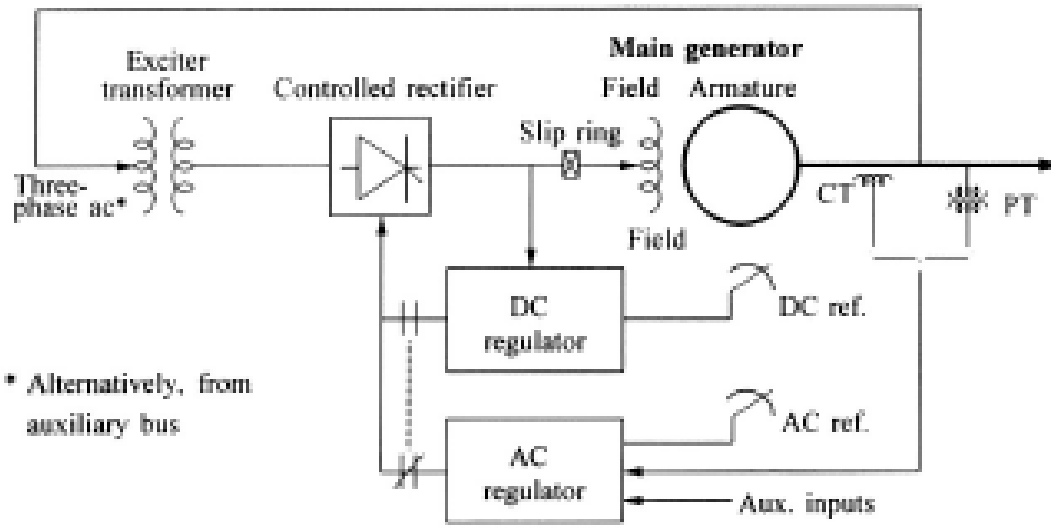

Figure 6: Potential-source controlled-rectifier excitation system

- **excitation power is supplied through a transformer from the main generator terminals**
- **regulated by a controlled rectifier**
- **commonly known as bus-fed or transformer-fed static excitation system**
- **very small inherent time constant**
- **maximum exciter output voltage is dependent on input ac voltage; during system faults the available ceiling voltage is reduced**

Compound-source rectifier system

- power to the exciter is formed by utilizing current as well as voltage of the main generator
- achieved through a power potential transformer (PPT) and a saturable current transformer (SCT)
- the regulator controls the exciter output through controlled saturation of excitation transformer
- during a system fault, with depressed generator voltage, the current input enables the exciter to provide high field forcing capability

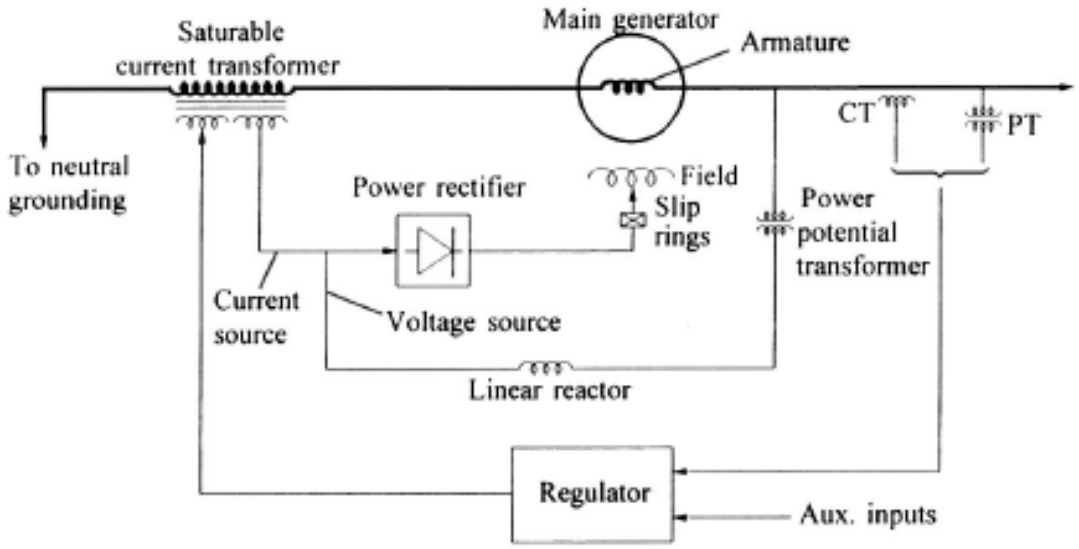

Fig. 7: Compound-source rectifier excitation system

Compound-controlled rectifier system

- utilizes controlled rectifiers in the exciter output circuits and the compounding of voltage and current within the generator stator
- result is a high initial response static system with full "fault-on" forcing capability

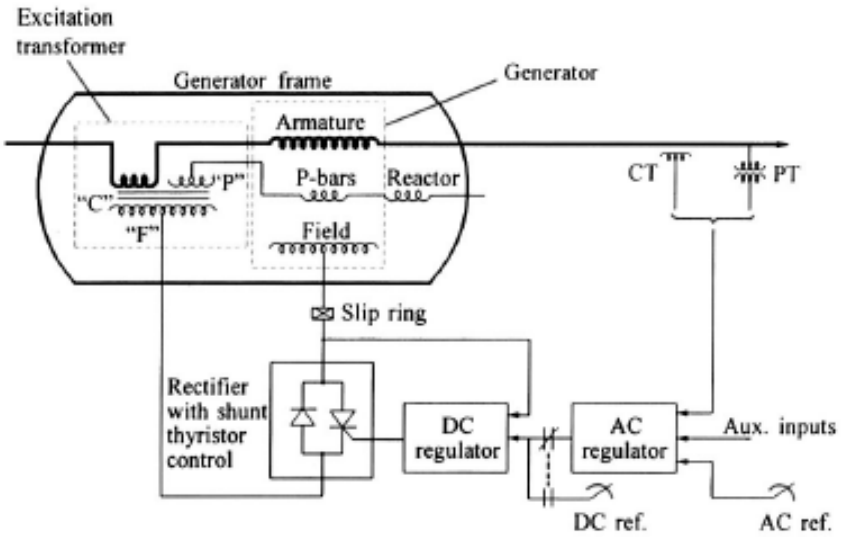

Figure 8: GENERREX compound-controlled rectifier excitation system
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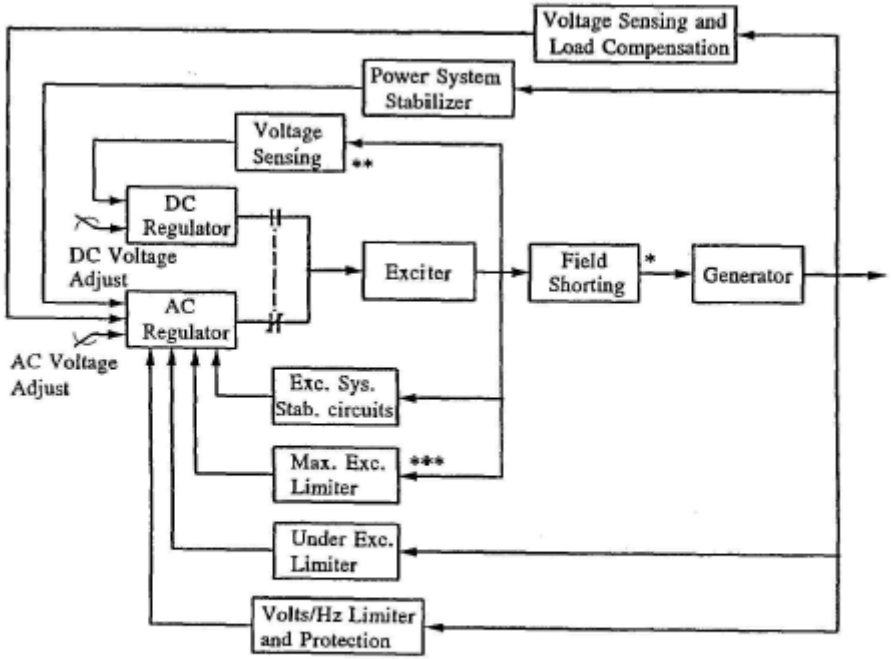
Control and Protective Functions

- **A modern excitation control system is much more than a simple voltage regulator**
- **It includes a number of control, limiting and protective functions which assist in fulfilling the performance requirements identified earlier**
- **Figure 9 illustrates the nature of these functions and the manner in which they interface with each other**



* Field shorting circuits are applicable to ac and static exciters only
** Some systems have open loop dc regulator
*** Max. exc. limiter may also be used with dc regulator

Figure 9: Excitation system control and protective circuits

Control and Protective Functions

Control, limiting and protective functions:

- **any given system may include only some or all of these functions depending on the specific application and the type of exciter**
- **control functions regulate specific quantities at the desired level**
- **limiting functions prevent certain quantities from exceeding set limits**
- **if any of the limiters fail, then protective functions remove appropriate components or the unit from service**

AC Regulator:

- **basic function is to maintain generator stator voltage**
- **in addition, other auxiliaries act through the ac regulator**

DC Regulator:

- **holds constant generator field voltage (manual control) used for testing and startup, and when ac regulator is faulty**

Modeling of Excitation Systems

IEEE Recommended Practice for Excitation System Models for Power System Stability Studies