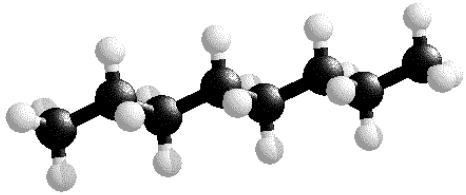
Basics of Paralleling

Revised: February 1, 2017

Course Objectives

Participants will be able to:

- Discuss basic paralleling control functions to gain a better understanding of how paralleling is accomplished
- Explain the advantages of paralleling to enhance the overall system reliability, performance and flexibility
- Describe how generator set control functions are provided in a distributed logic architecture to improve paralleling reliability
- Recognize the common building blocks of a backup power system and their functionalities



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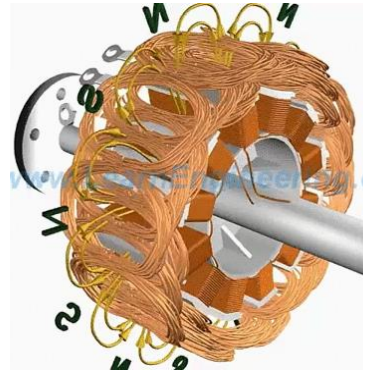

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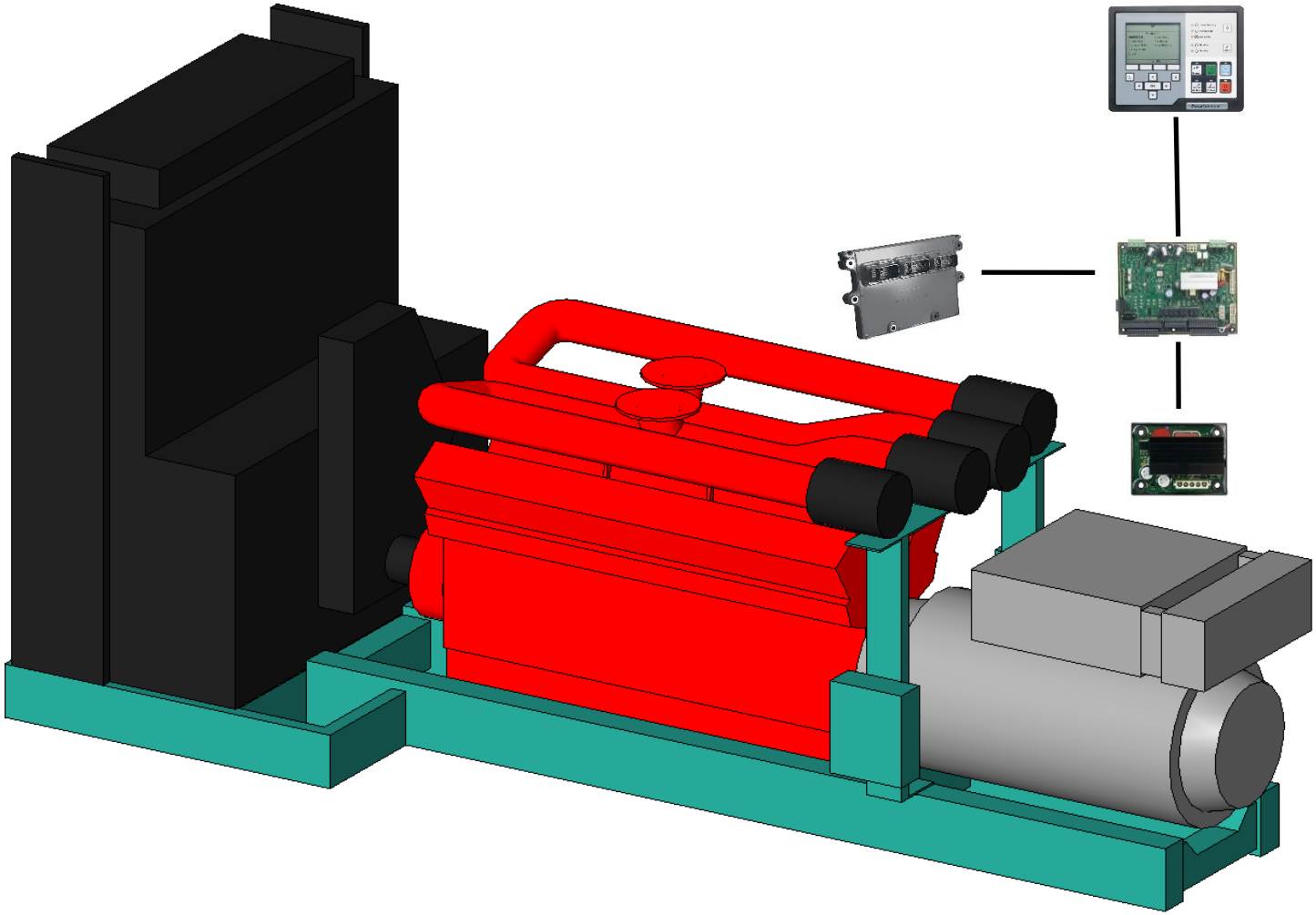
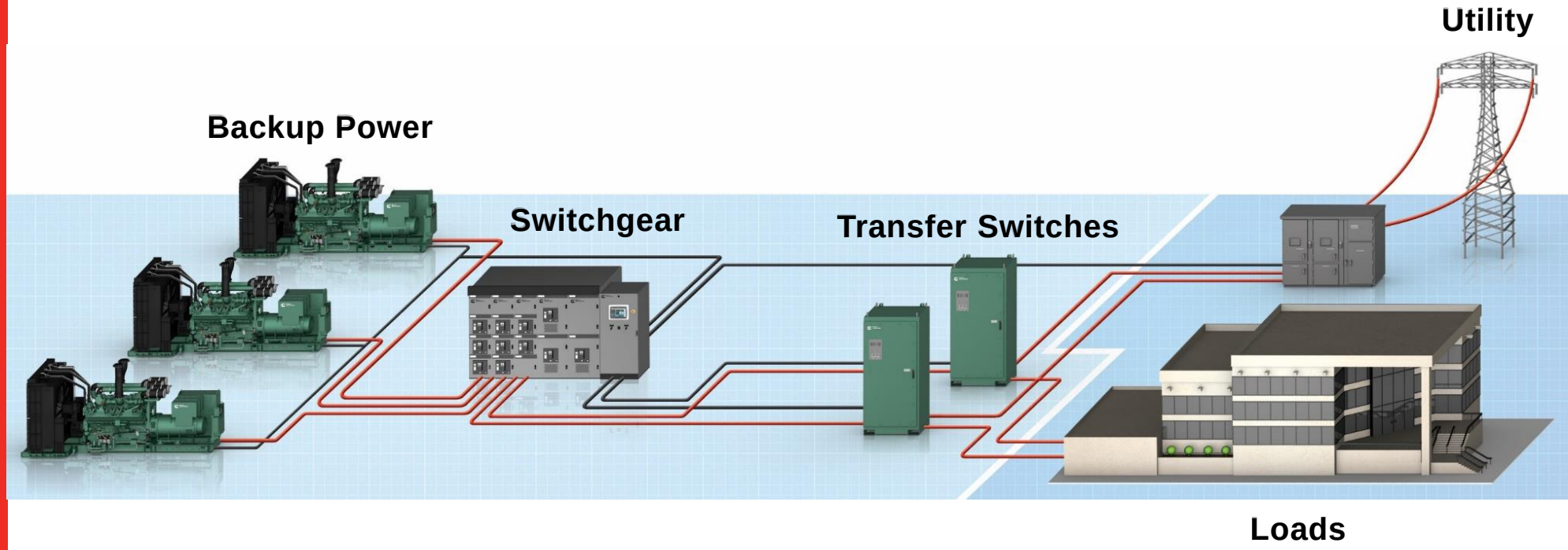
Generator Set

- Skid
- Engine
- Alternator
- Cooling
- Control

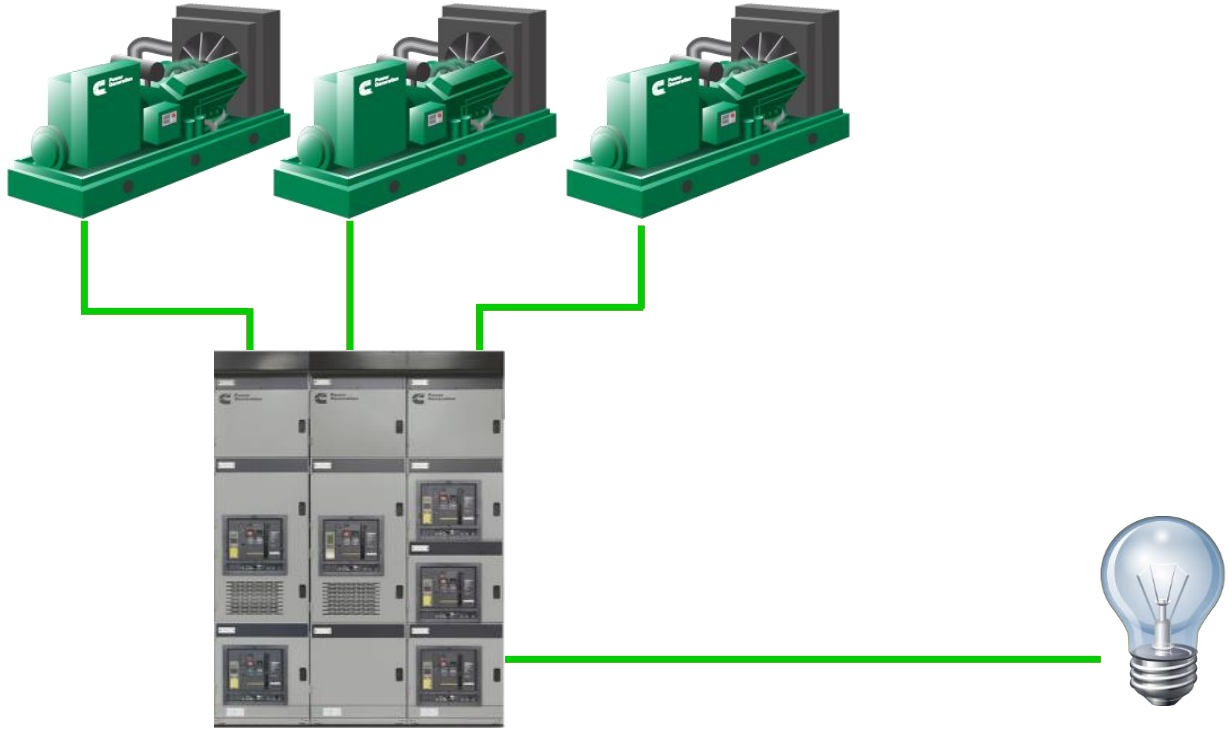


Power System



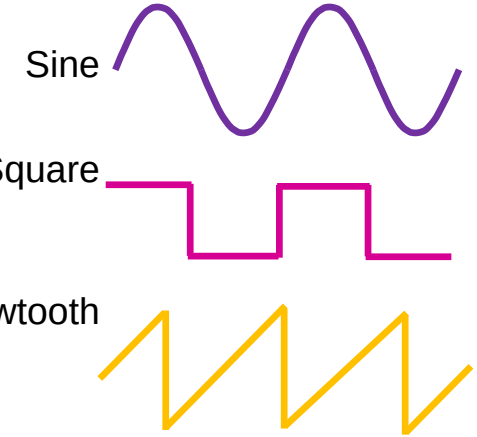
Paralleling

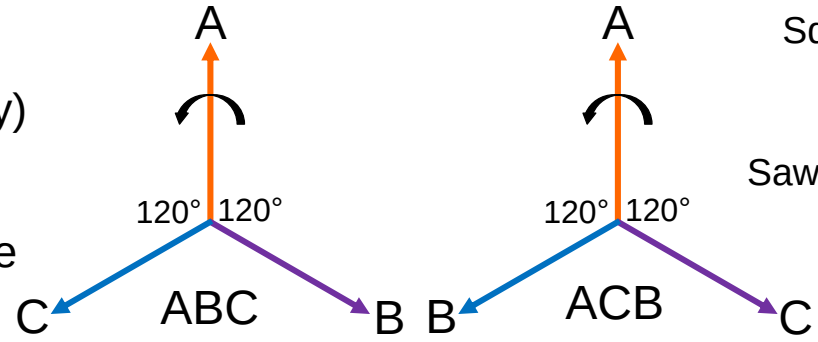
- Synchronous operation of two or more generator sets connected together on a paralleling bus in order to provide power to common loads

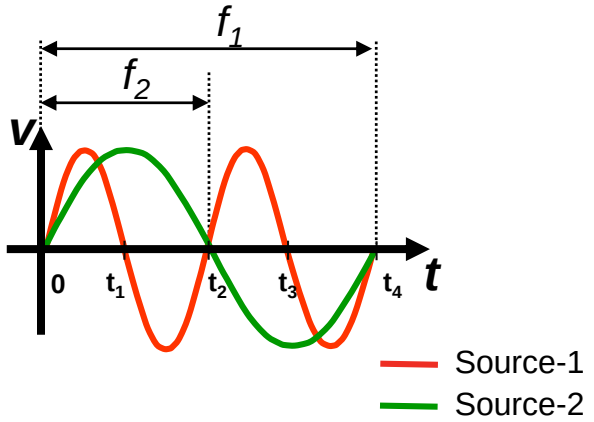


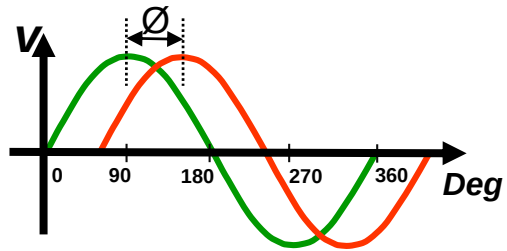
Paralleling Operation

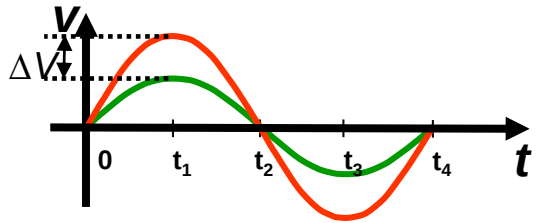
- Generators can be connected to a power plant or another generator source only when the following conditions are met:
  - Waveform
  - Phase Sequence
  - Speed difference (frequency)
  - Phase angle difference
  - Voltage amplitude difference











Synchronization

- Synchronization is the mechanism of matching frequency, phase and voltage of AC power sources

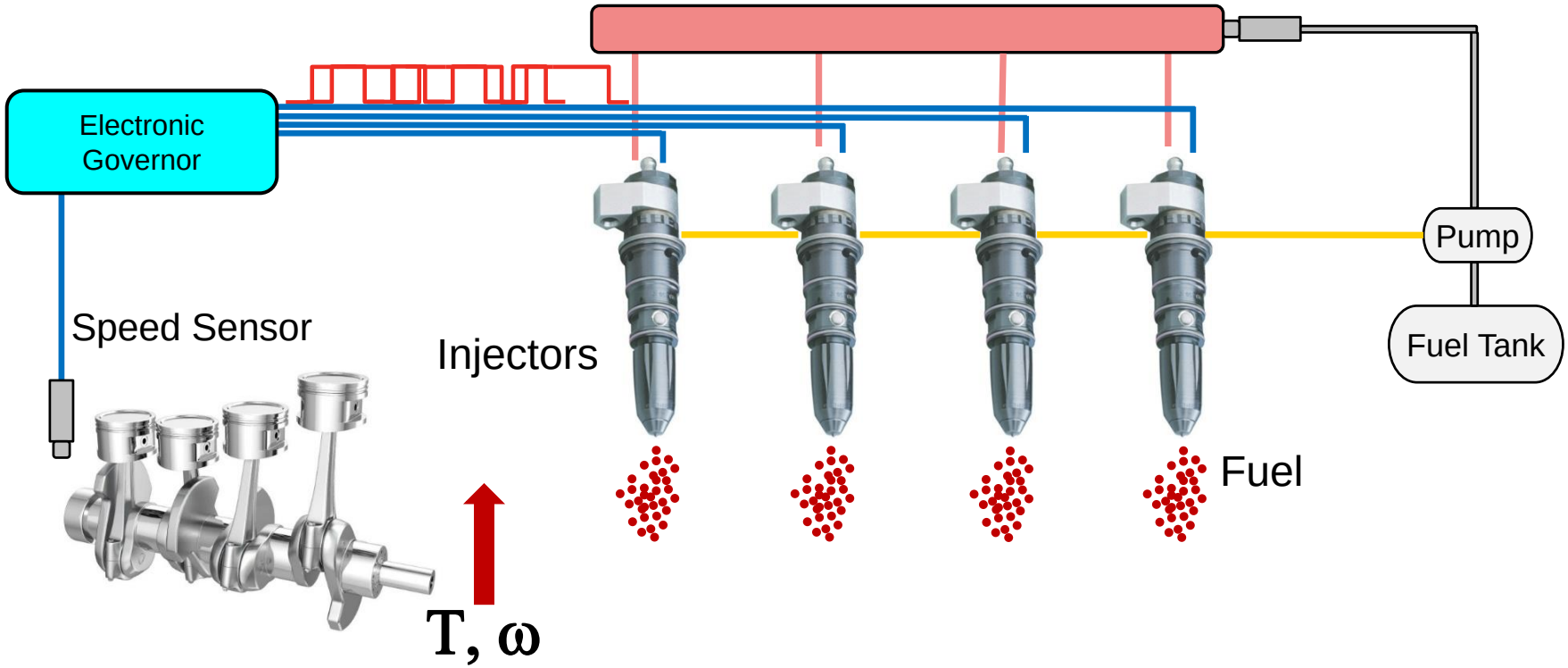
Electronic Governor

Maintains engine output speed

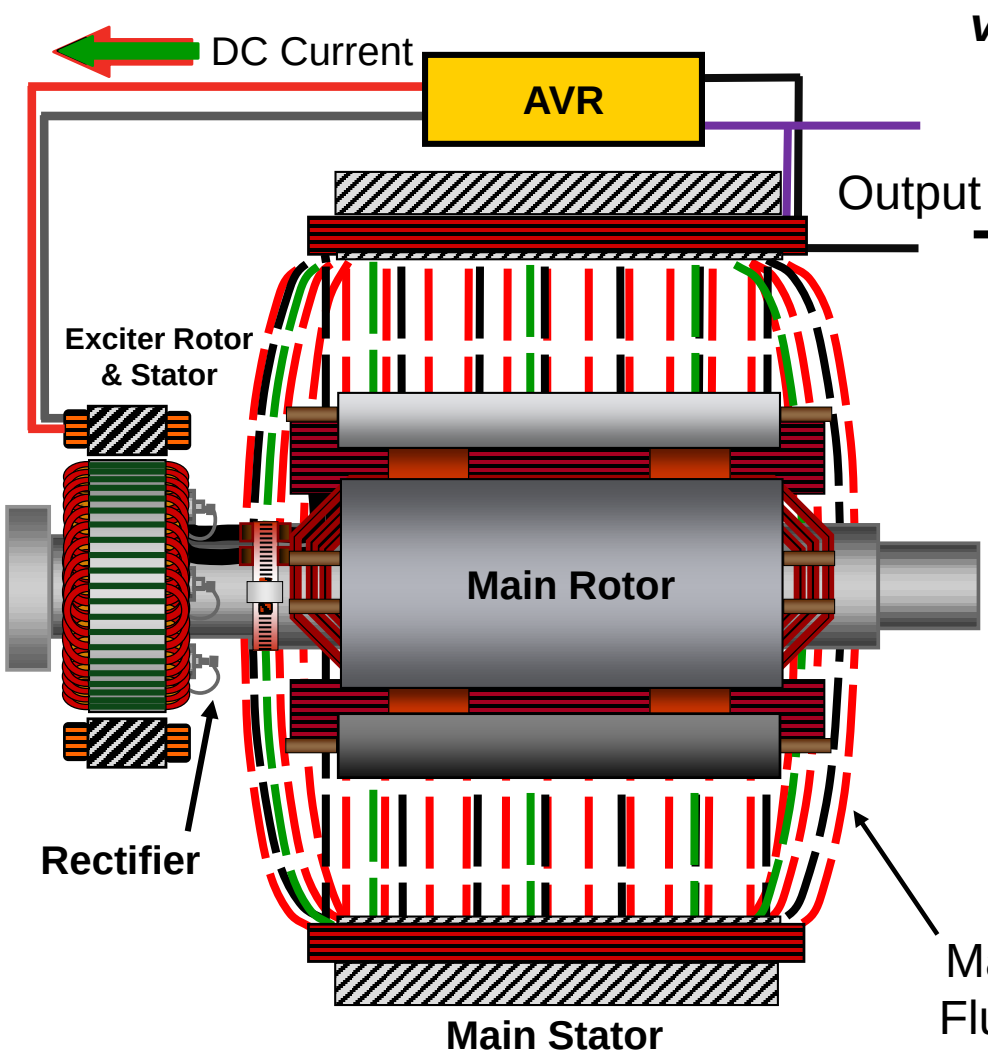
Automatic Voltage Regulator

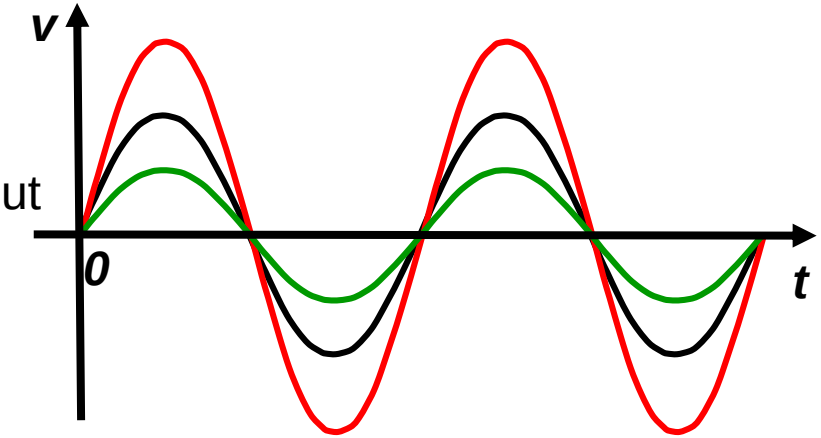
Maintains generator output voltage

Electronic Governor (GOV)



Automatic Voltage Regulator (AVR)



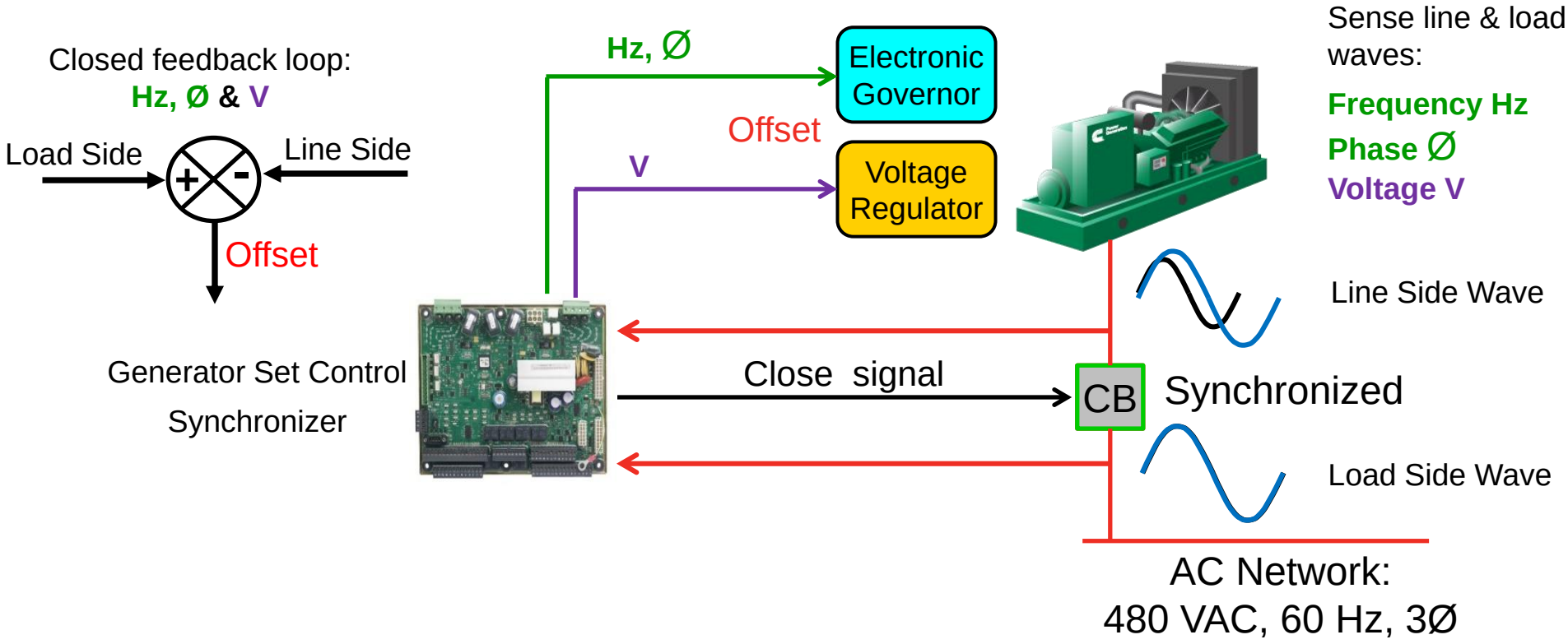


- The output voltage can be increased or decreased by altering the strength of the magnetic field

$$\nabla \times \boldsymbol{E} = -\frac{\delta \boldsymbol{B}}{\delta t} \ (Faraday's\ Law)$$

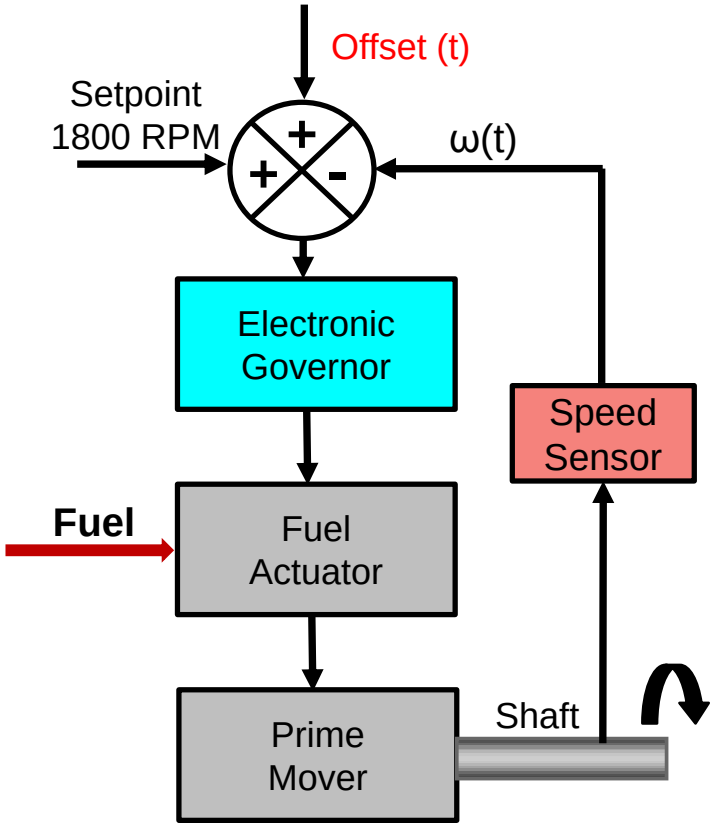
Synchronizer

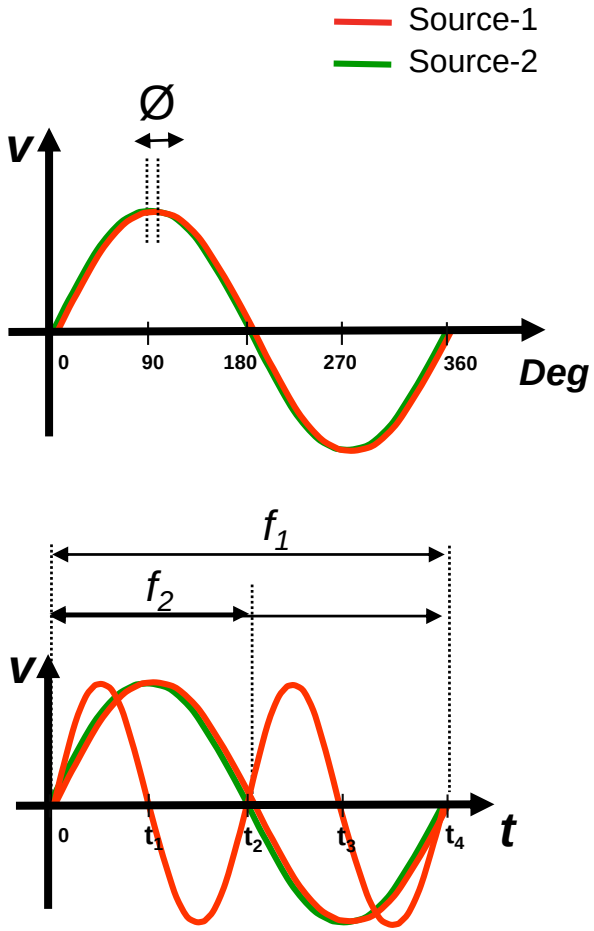
- Match Frequency, Phase and Voltage



Synchronizing: Phase and Frequency

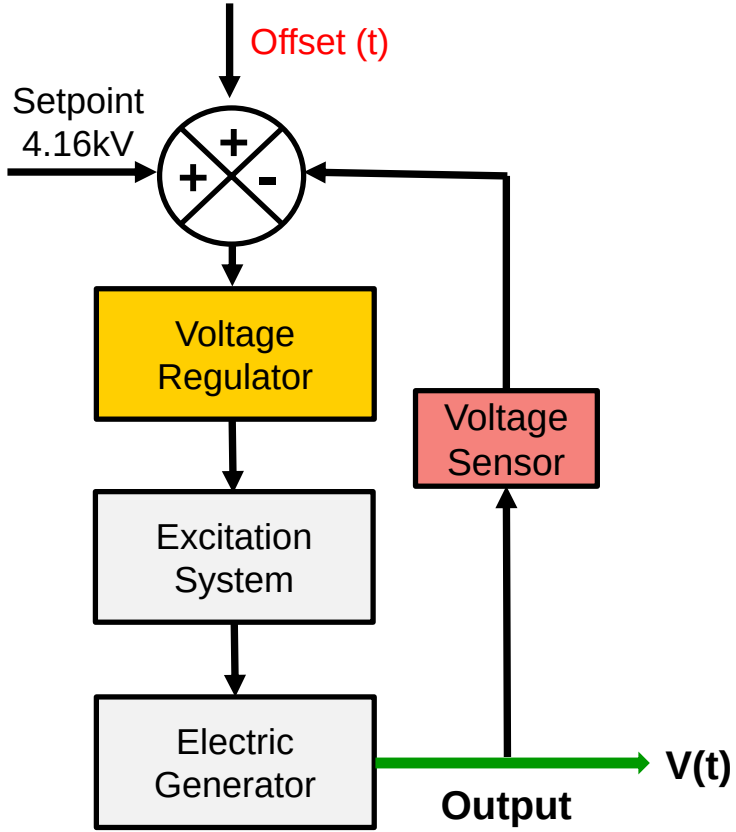
- Adjusting the governor fuel set point

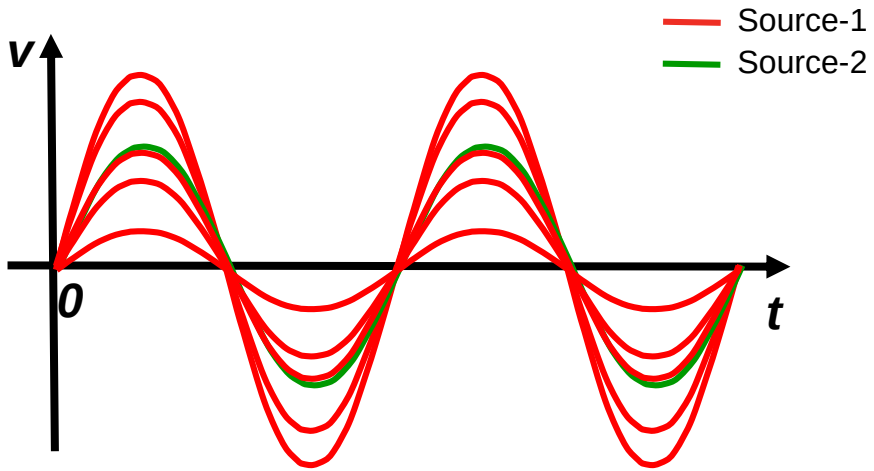




Synchronizing: Voltage Amplitude

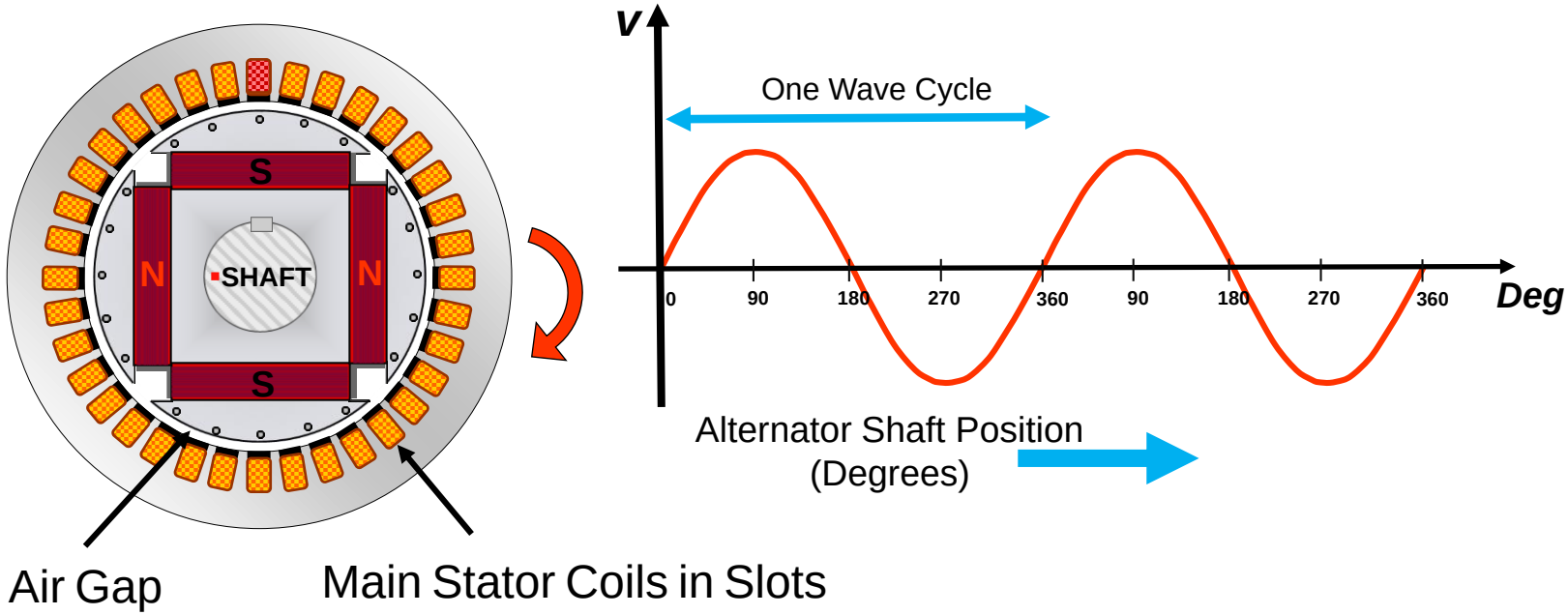
- Adjusting the field excitation



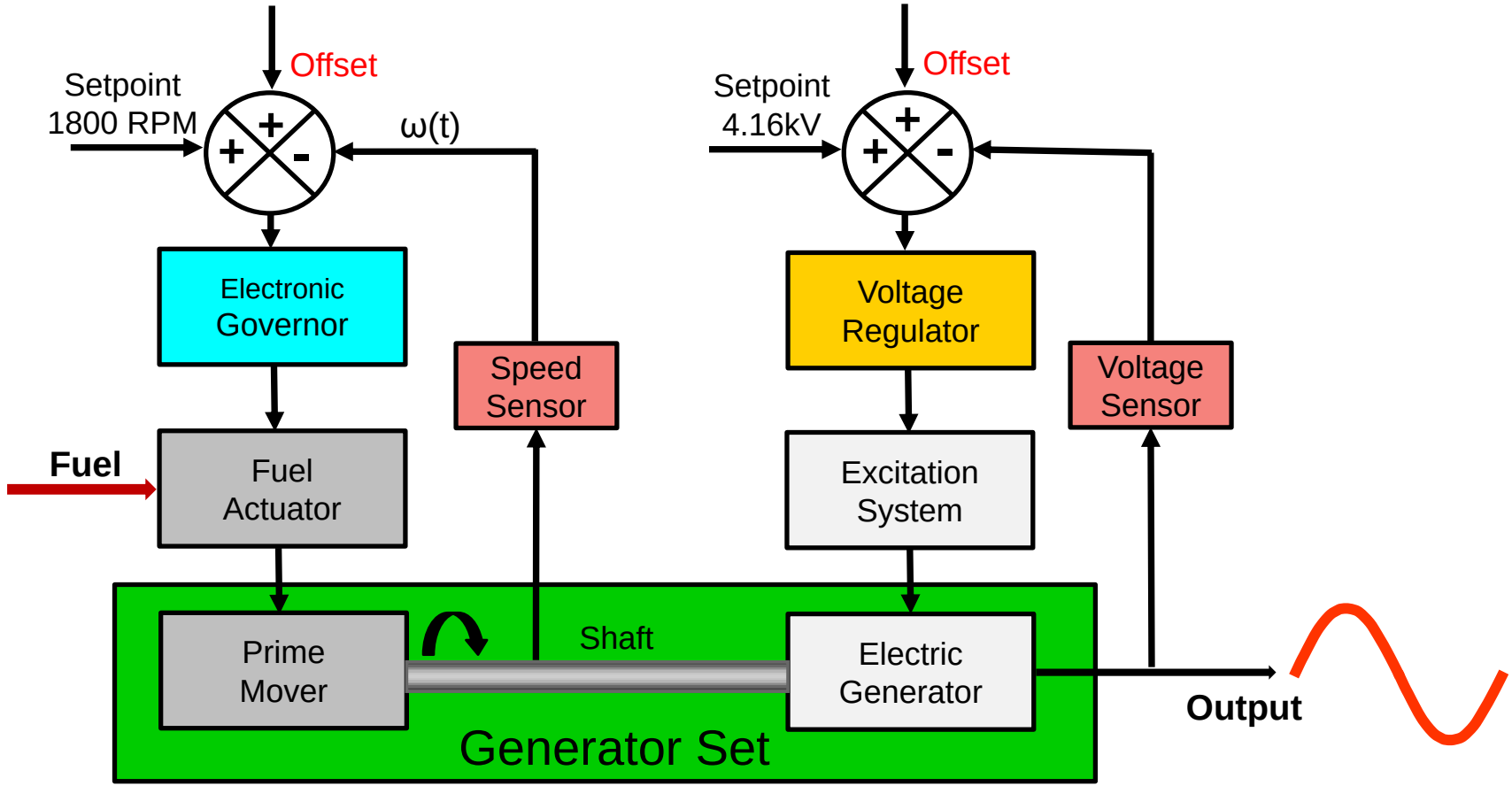


Rotor Position and Output Voltage

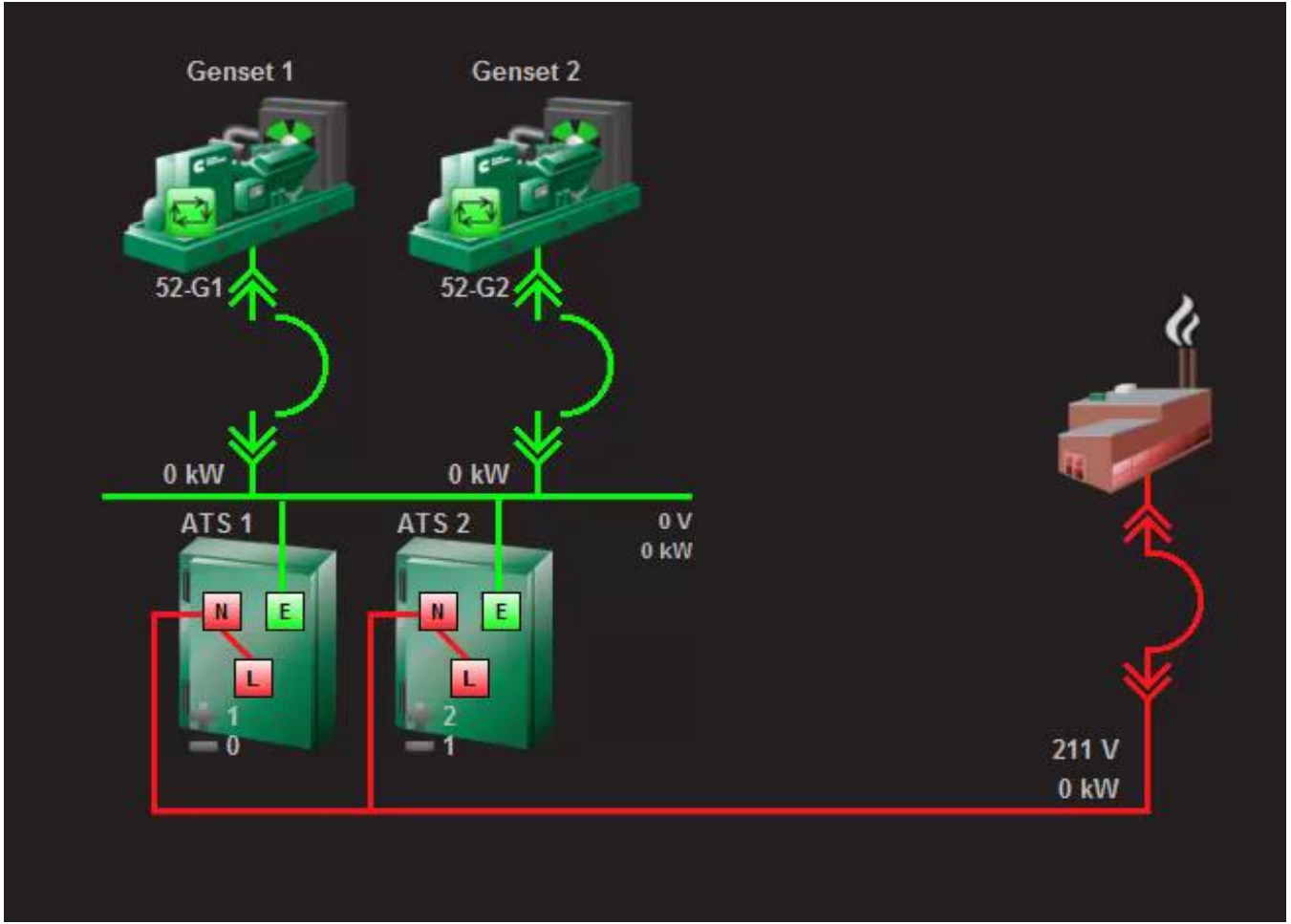
- $Electrical_{Degrees} = P/2 * Mechanical_{Degrees}$ *P: Number of poles*



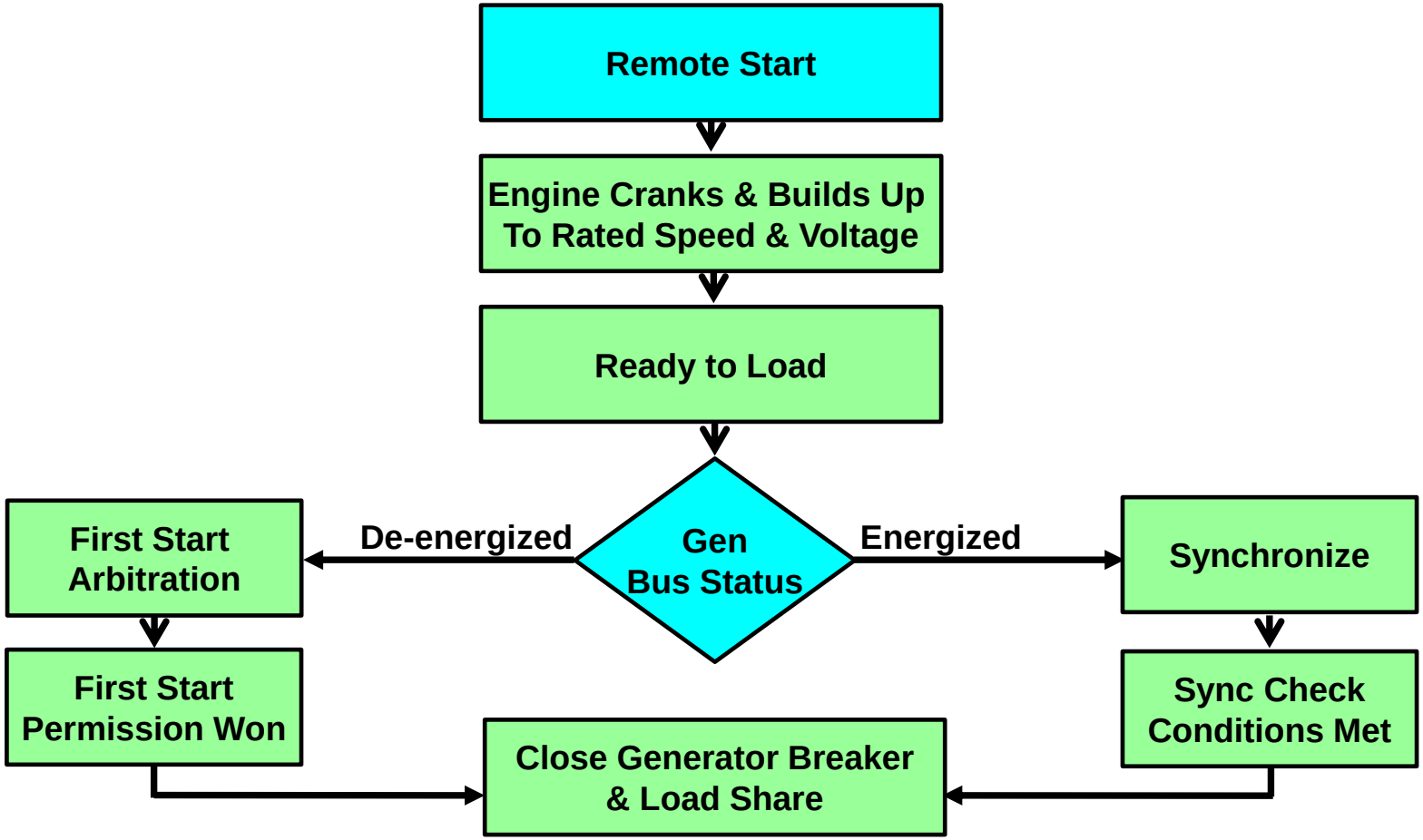
Controlling Speed, Phase and Voltage



Standby System Simulation: Isolated Bus

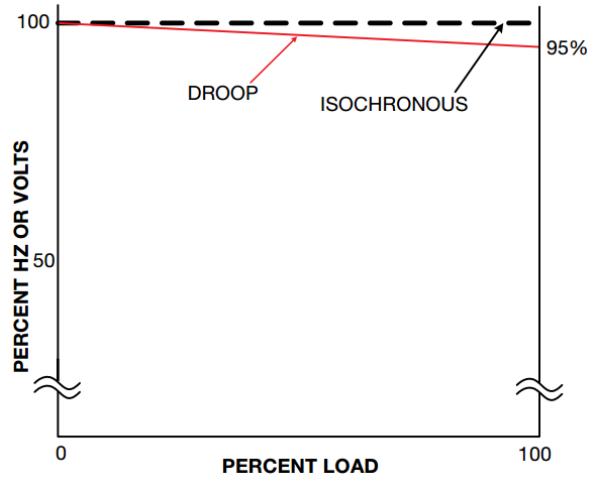


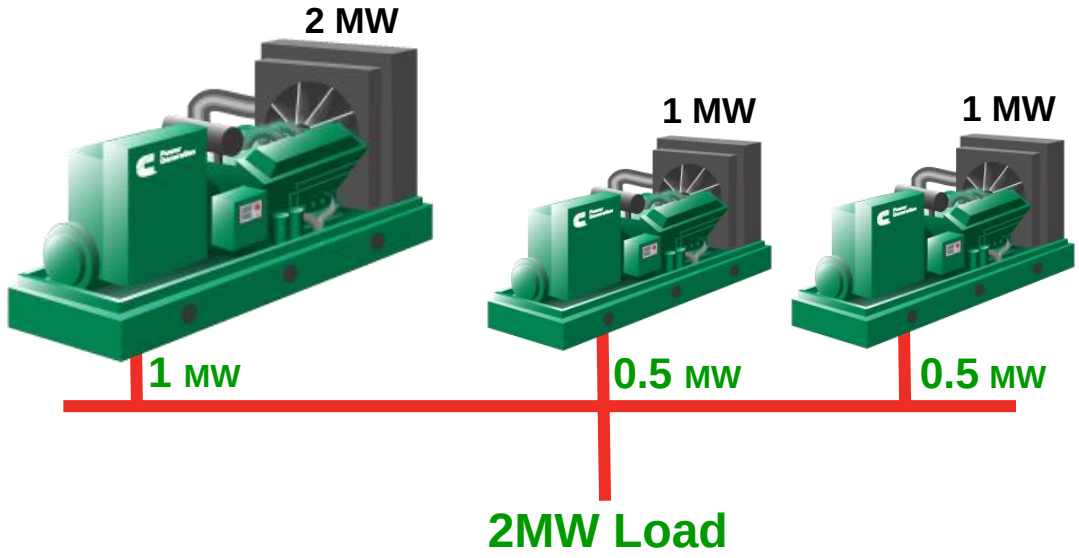
Paralleling Sequence of Operation: Isolated Bus



Load Sharing

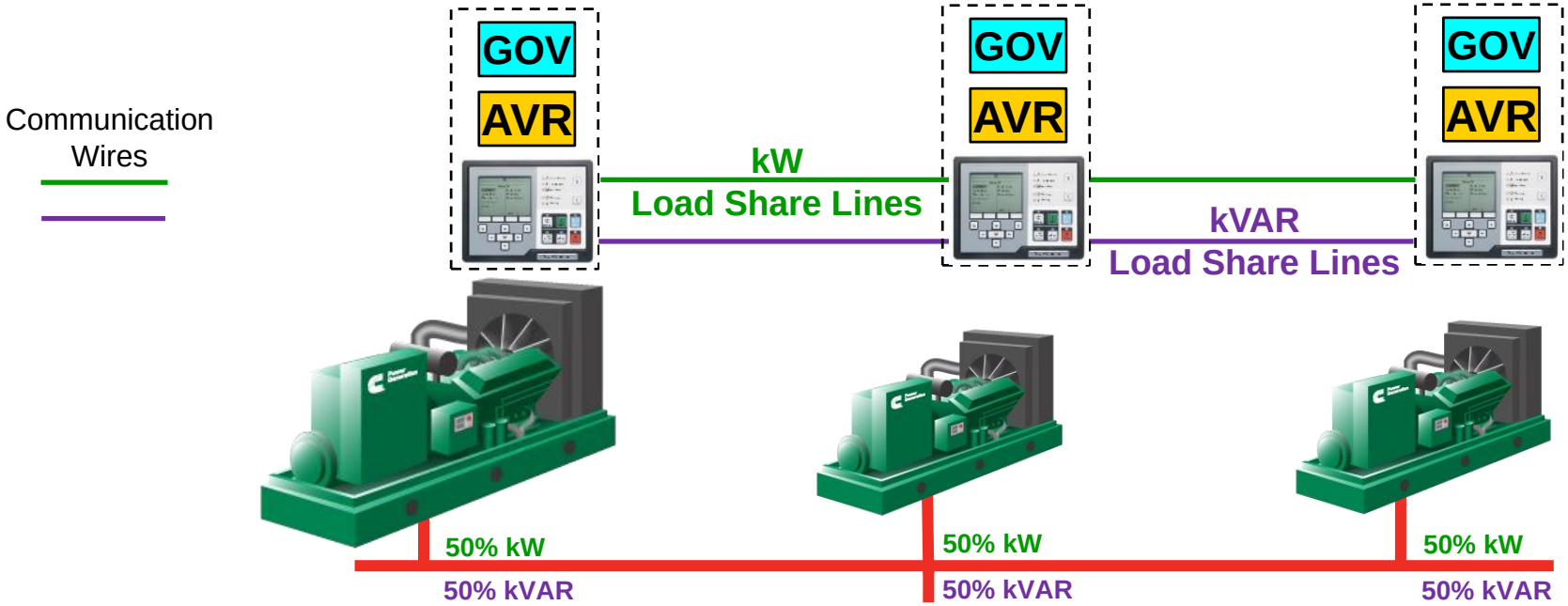
- The proportional division of the kW and kVAR total load between multiple generator sets in a paralleled system
  - Load sharing is essential to avoid overloading and stability problems on the generator sets
- Load share can be Isochronous or Droop





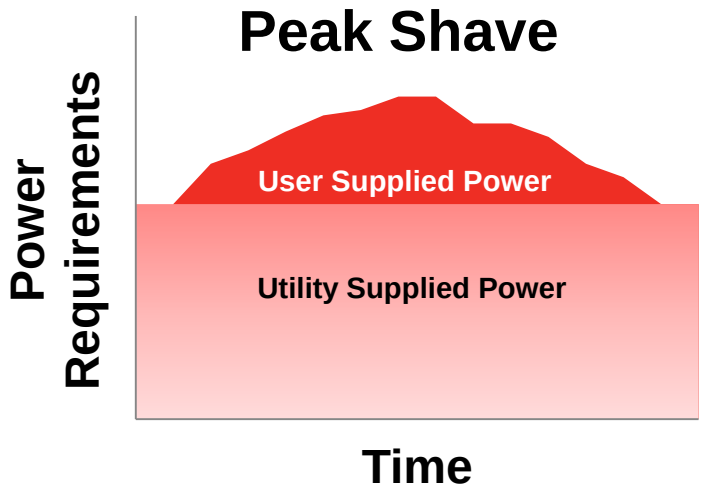
Load Sharing

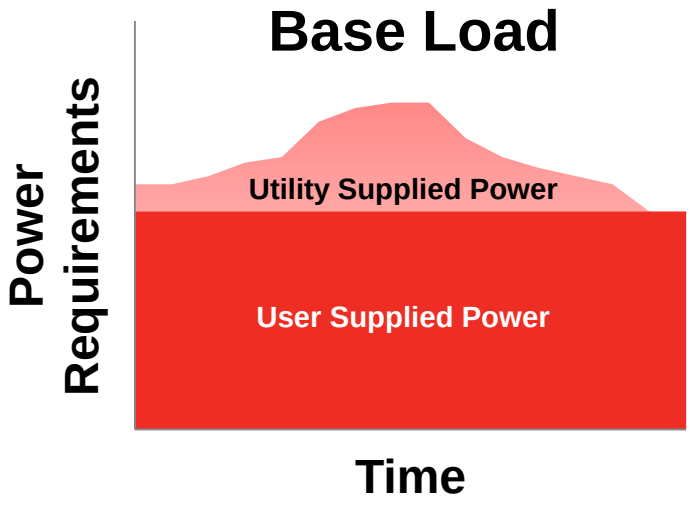
- The kW load sharing is achieved by increasing or decreasing fuel to the engines
- The kVAR load sharing is achieved by increasing or decreasing the field excitation to the alternators



Energy Management

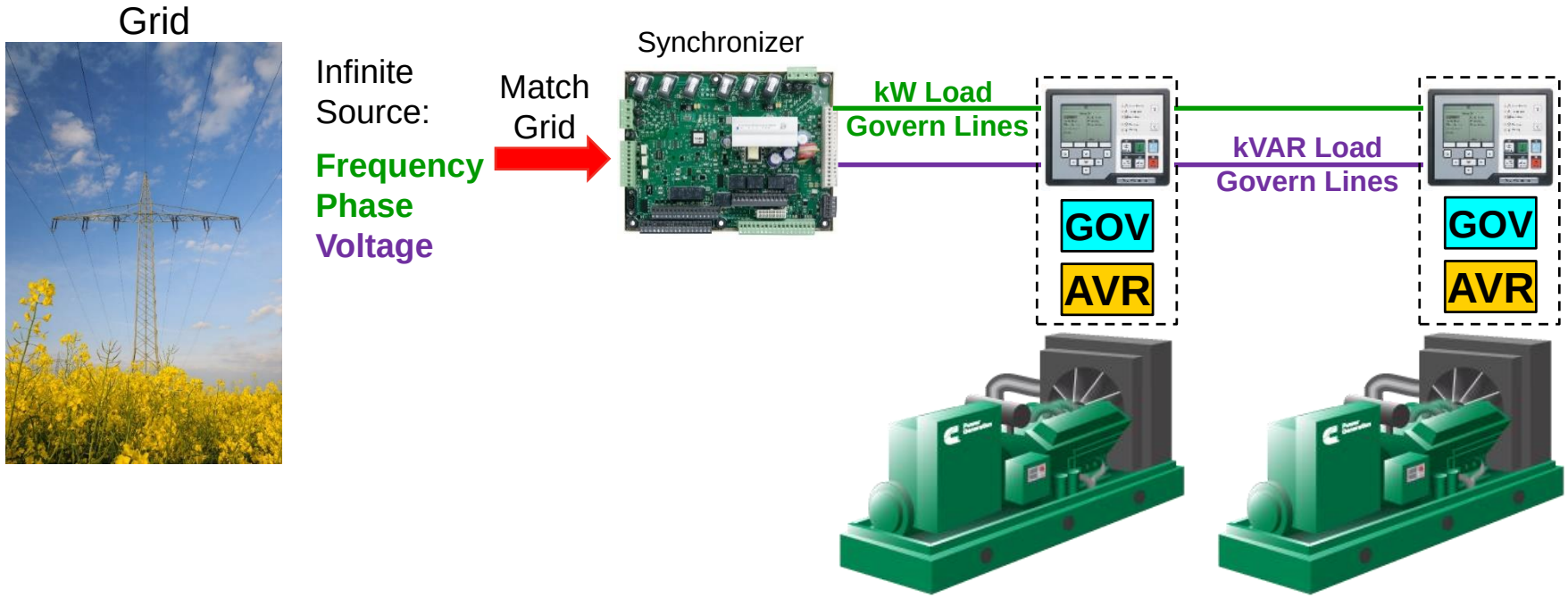
- Peak Shave
- Base Load





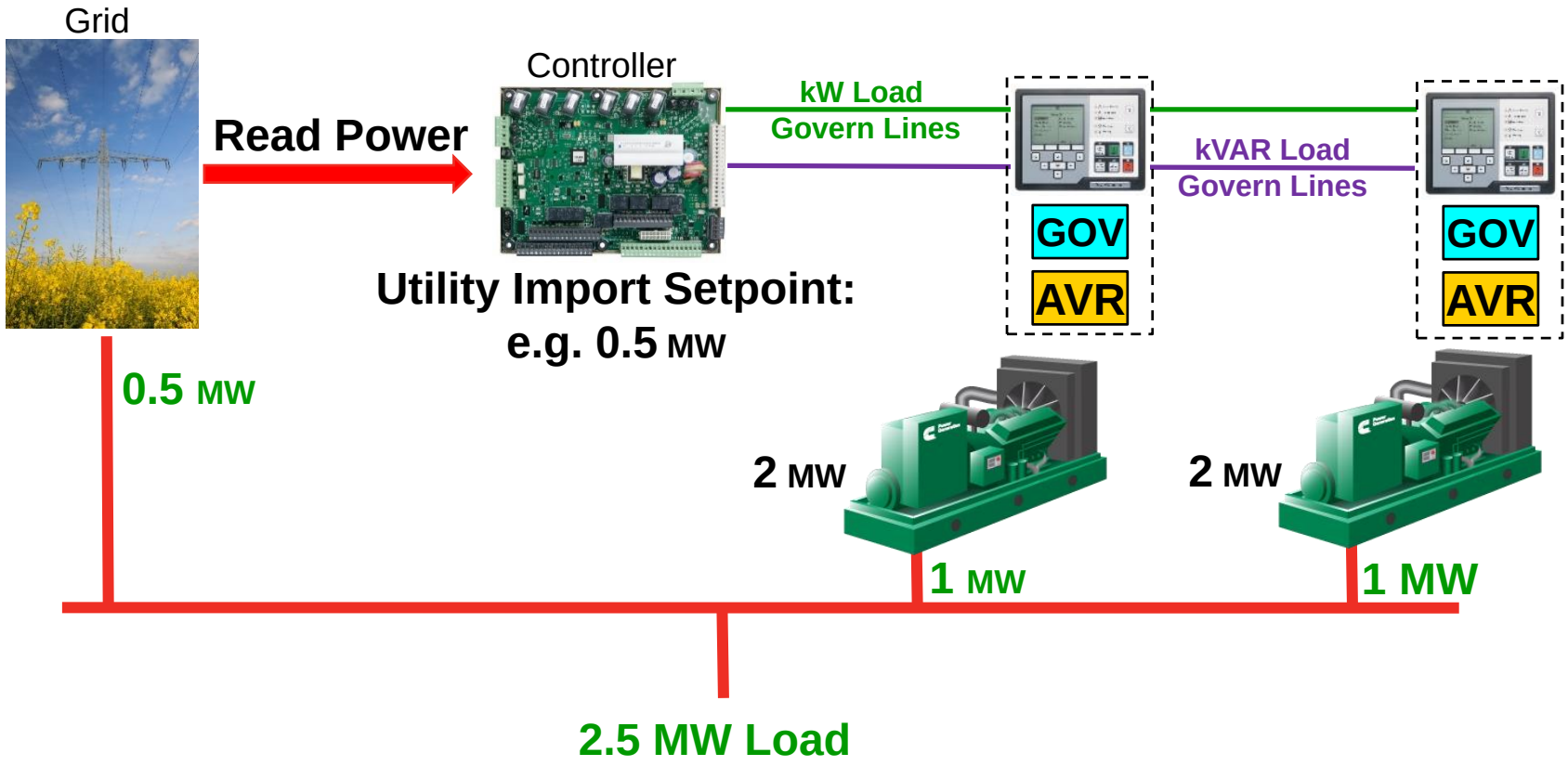
Connecting to the Grid

- Base load, peak shave, extended paralleling
- Cannot change the grid voltage and frequency
- Drive generator sets to match the grid



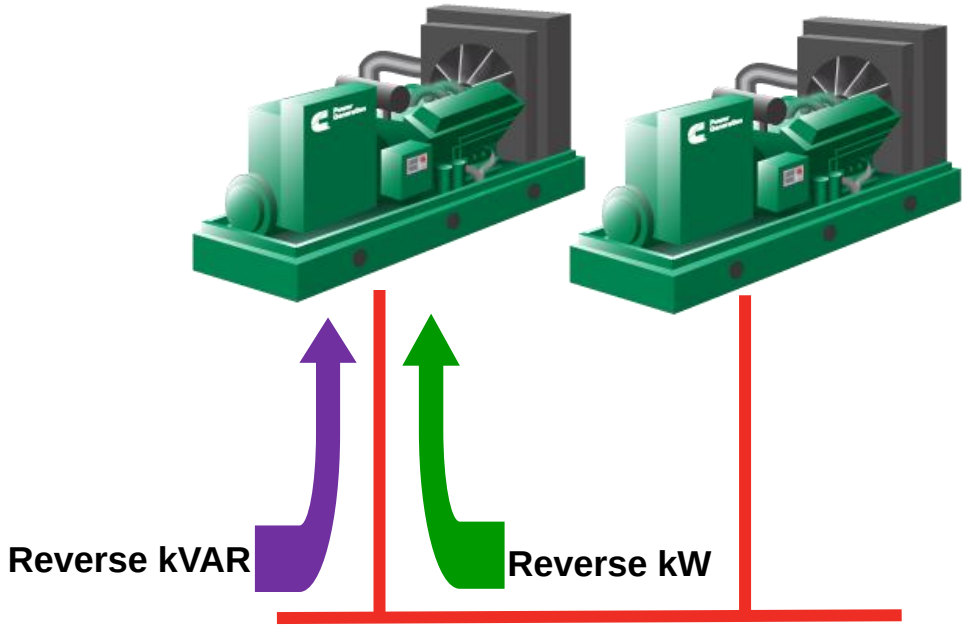
Grid Connecting Example

- Peak Shave Mode - Extended Paralleling



Typical Generator Protection Elements

- 15 – Synchronizer
- 24 – Volts/Hertz
- 25 – Synch Check
- 27 – Undervoltage
- 32 – Directional Power
- 40 – Loss of Excitation/Reverse kVAR
- 46 – Phase Balance Current
- 47 – Phase Sequence Voltage
- 50 – Instantaneous overcurrent
- 51 – Time Overcurrent
- 59 – Overvoltage
- 81U/O – Under/Over Frequency



Paralleling Control

Data Link

Data Link

Human Machine Interface ↔ **Generator Set Controller** ↔ **Engine Control Module**

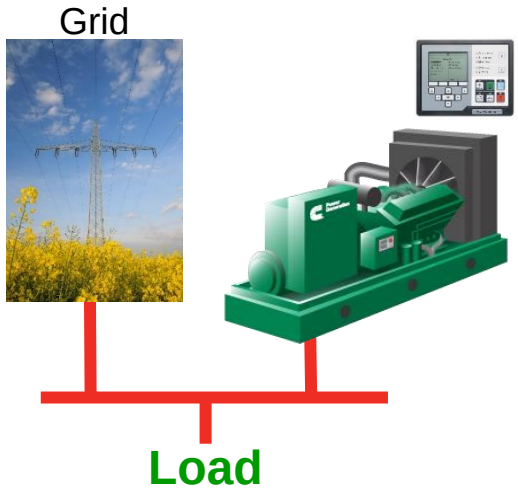
- User Interface
- Configurations/Settings
- Alarms
- Start/Stop
- Manual Paralleling

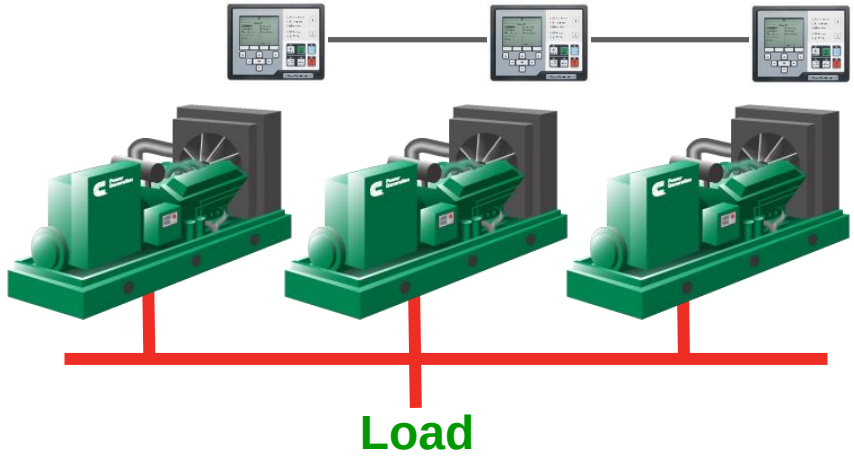
- Paralleling
- Genset Protection
- Voltage Regulation
- Load Sharing
- Generator Metering

- Engine Protection
- Governing
- Engine metering

Generator Set Paralleling Controls Capabilities

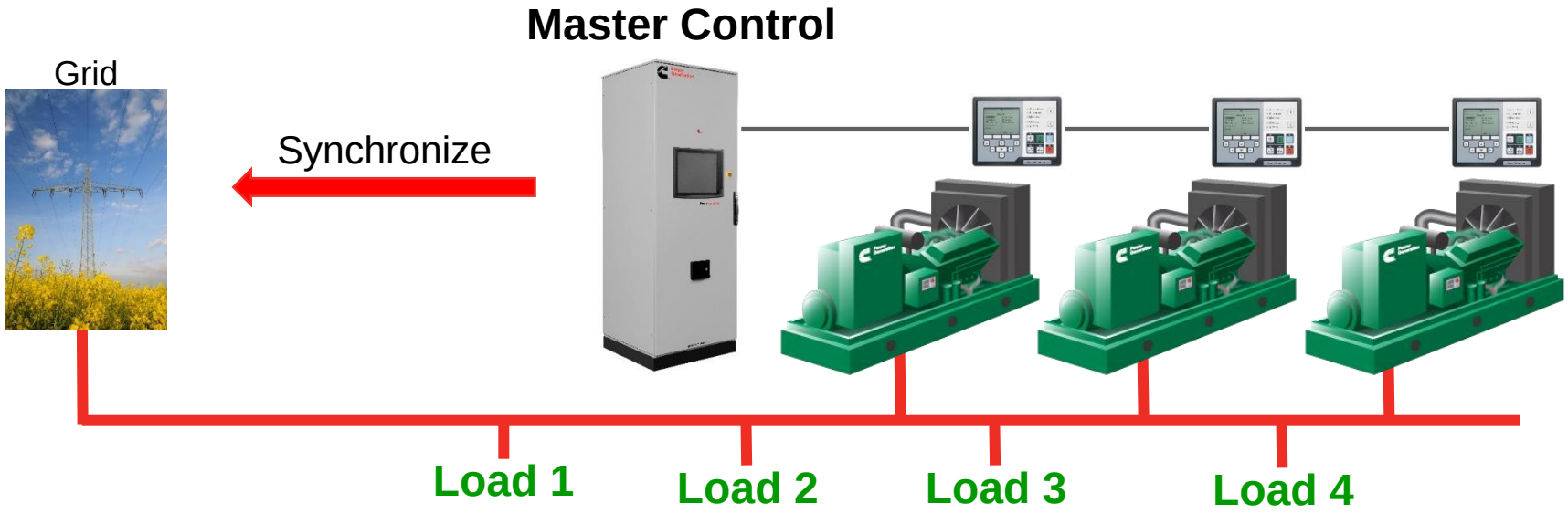
- Without a Digital Master Control, generator set control can:
  - Parallel with each other
  - Synchronize with the grid (single genset) - Base Load/Peak Shave
  - Single Load Add/Shed Scheme
  - Perform Load Demand



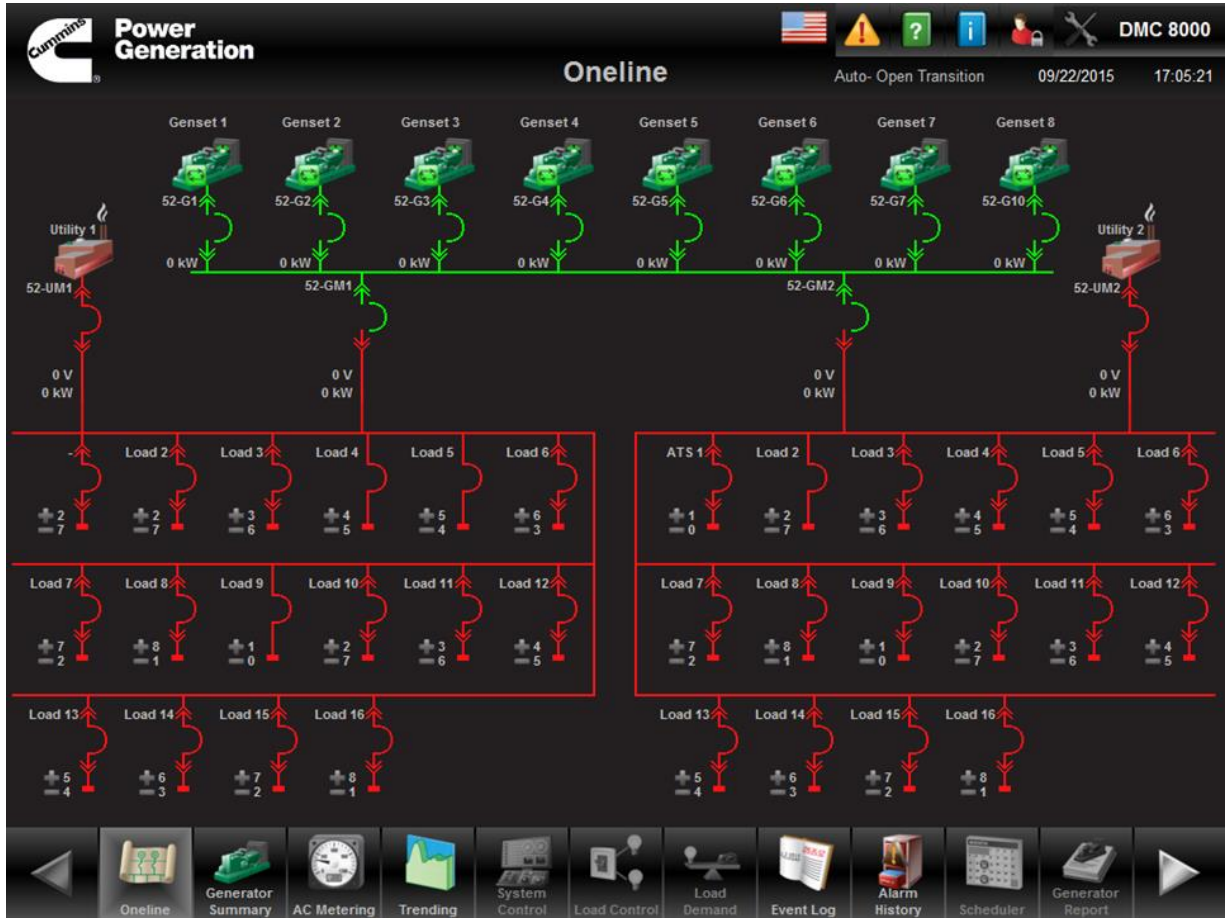


Master Control

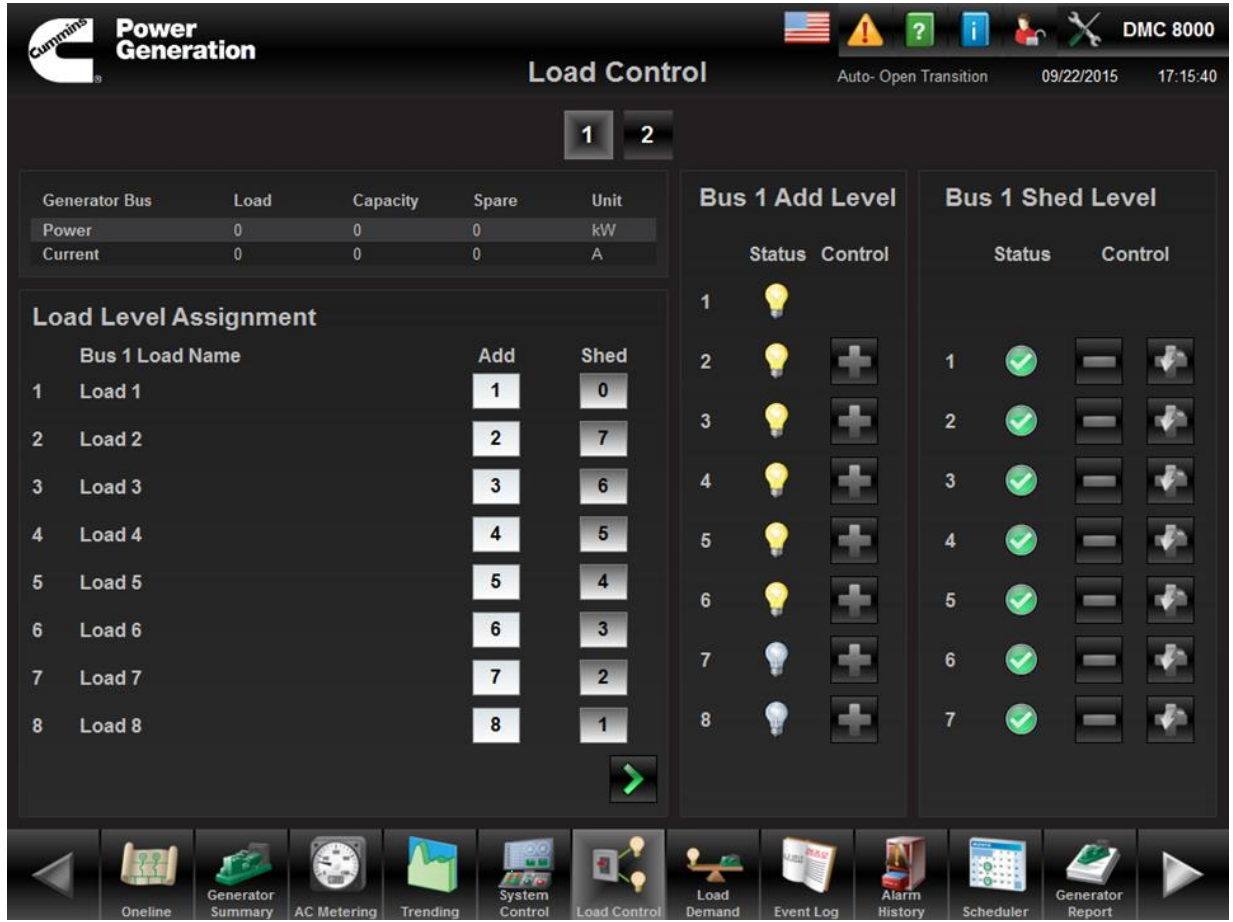
- Is required when:
  - Synchronizing multiple generator sets with the utility or multiple utility feeds
  - Load and capacity management
  - System monitoring and control
  - Complex sequence of operation



Digital Master Control



Digital Master Control



Summary

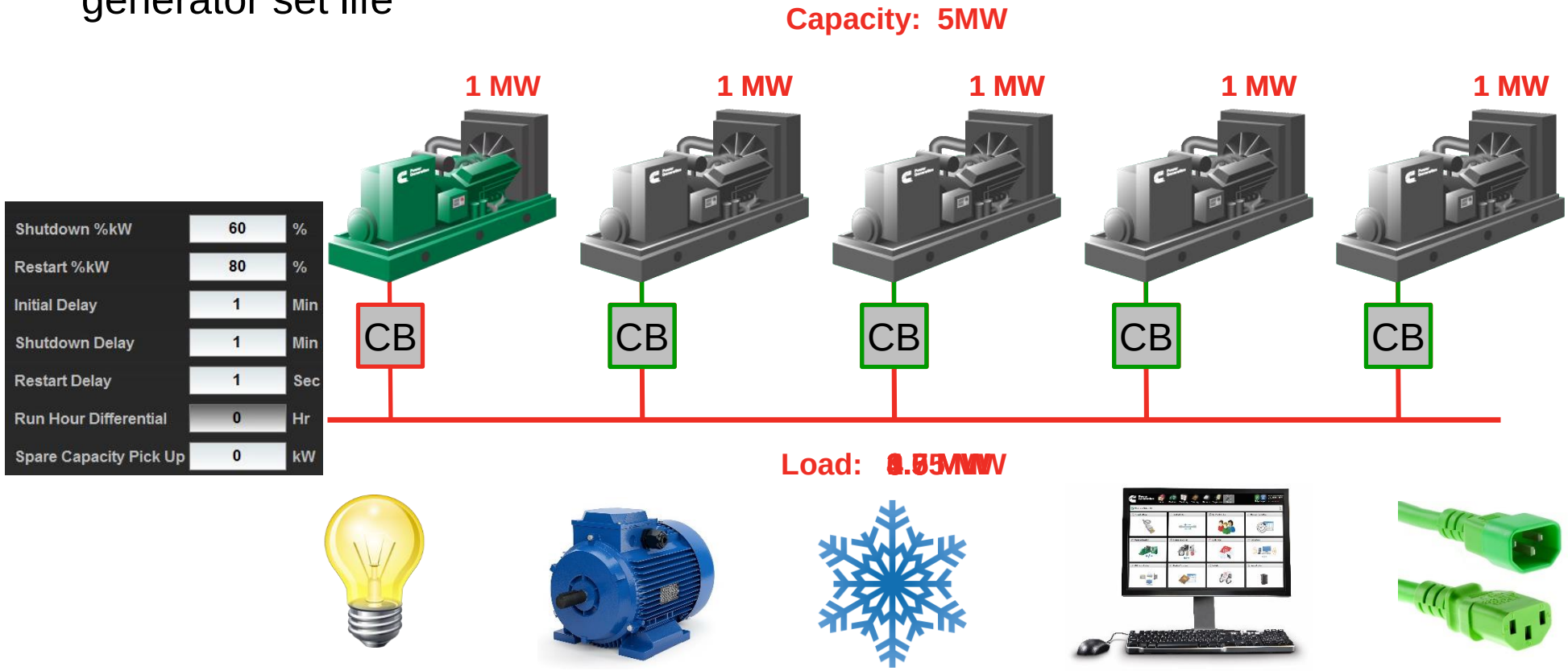
- Governor and AVR are the basic functions on every genset and the synchronizer, load share and load govern simply adjust the reference point to them
- Paralleling enhances the overall system reliability, performance and flexibility
- Distributed logic architecture in a paralleling system improves the overall reliability by eliminating single points of failure

Thank You!

Please share your feedback by completing the Power Seminar evaluation form.

Load Demand

- Match generating capacity to the load to optimize fuel efficiency and prolong generator set life



Reference Material:
Load Demand

- The load demand feature is used to match generating capacity to the load to optimize fuel efficiency and prolong generator set life while maintaining correct reserve capacity for the customer’s application
- Shutdown sequence can either be a fixed sequence or can be based on running hours
  - Fixed sequence: the sequence can be changed while the system is in operation
  - Running hours: attempts to equalize generator set hours over time by exchanging stopped and running generator sets
- To protect system integrity, load demand will restart all generator sets whenever an overload condition is detected
- The minimum amount of capacity to maintain online is adjustable