



**Power  
Generation**

# A Distributed Logic Approach to Reliable Embedded Power Generation Systems



# Reliable Emergency Power Systems

- “Demystify” Paralleling Equipment
- Why Paralleling is Used
- Review Major System Components and Functions.
- Conclusions

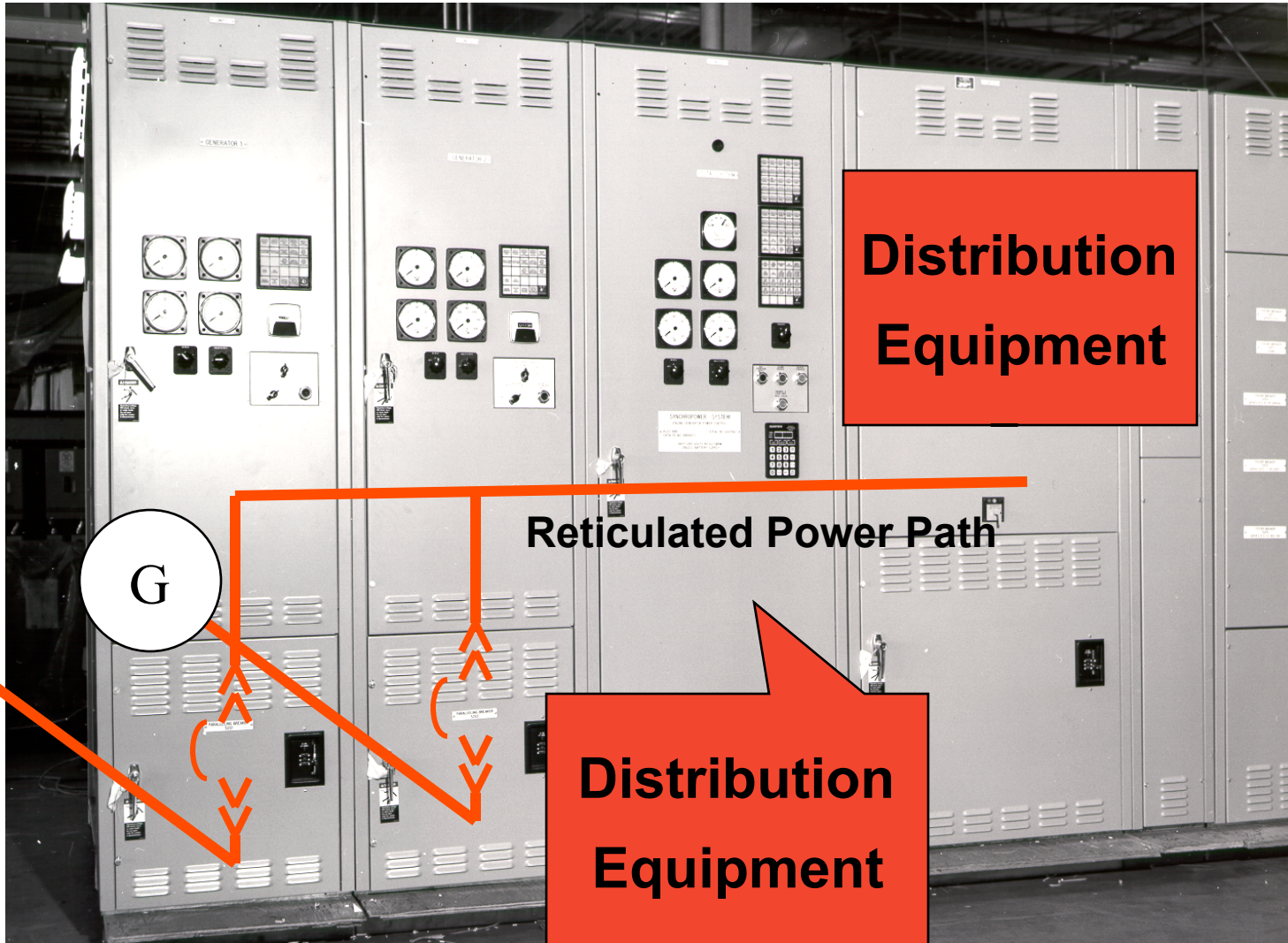
# What is Paralleling?

- A generator set control system that functions to allow two or more small generator sets to work together as if they were one large set.

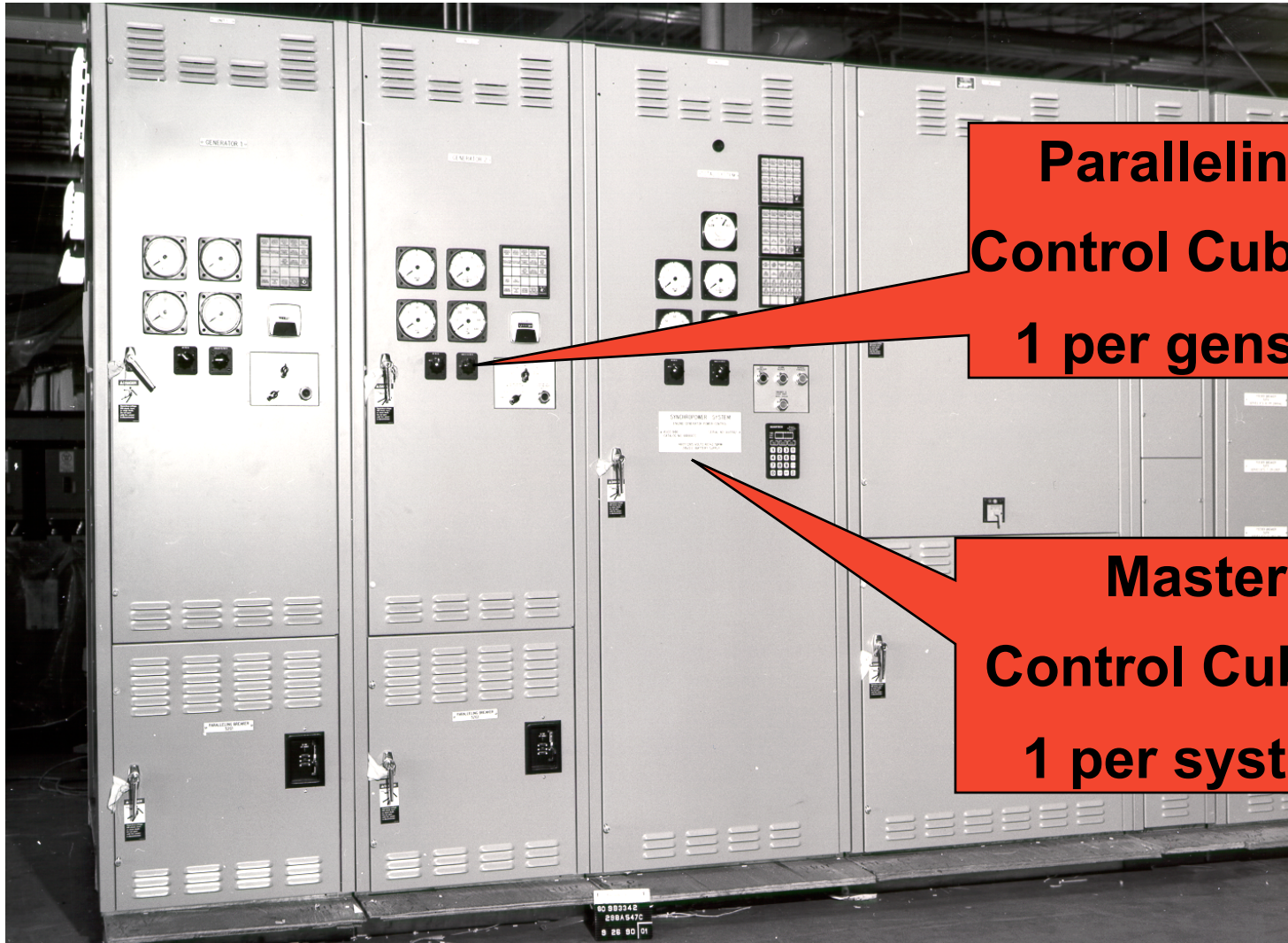
# Why Parallel?

- Reliability
  - It's better to have two or more gensets to serve a critical load than one.
- Flexibility
  - It's easy to add capacity with a paralleling system.
- Economy
  - For large systems (>2000kW), it's cheaper to use several 1500RPM sets, than to use a single slow speed set.
- Service Convenience
  - With a parallel system you can take a generator set down for service/repairs and still have emergency standby power in place for critical loads.

# Traditional Equipment Construction

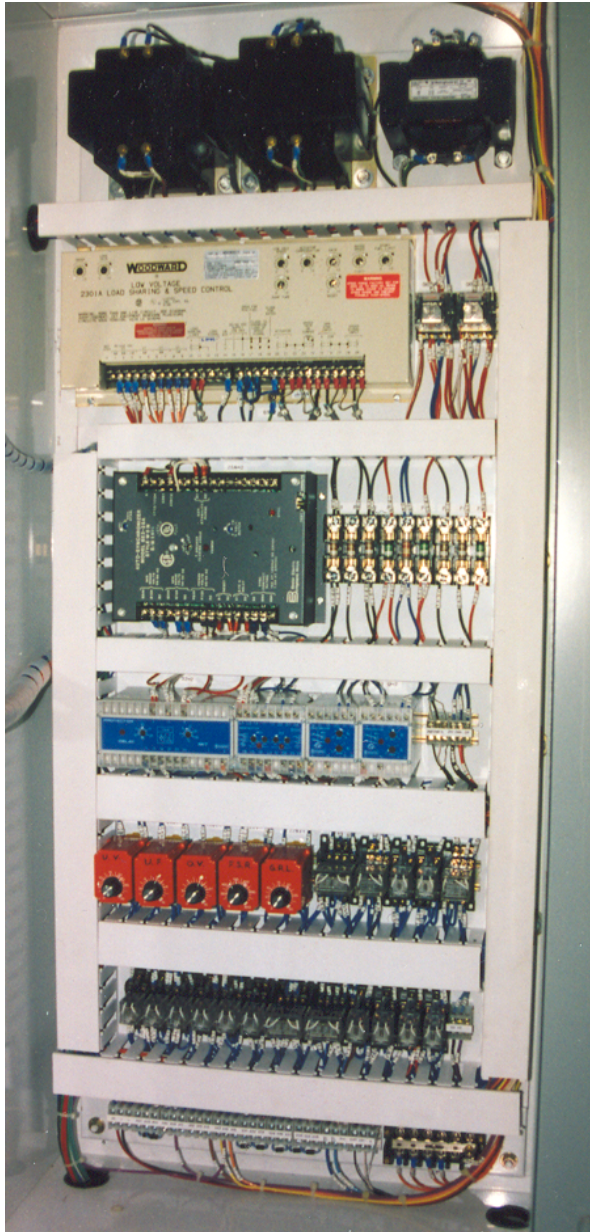


# Traditional Equipment Construction



**Paralleling  
Control Cubicle  
1 per genset**

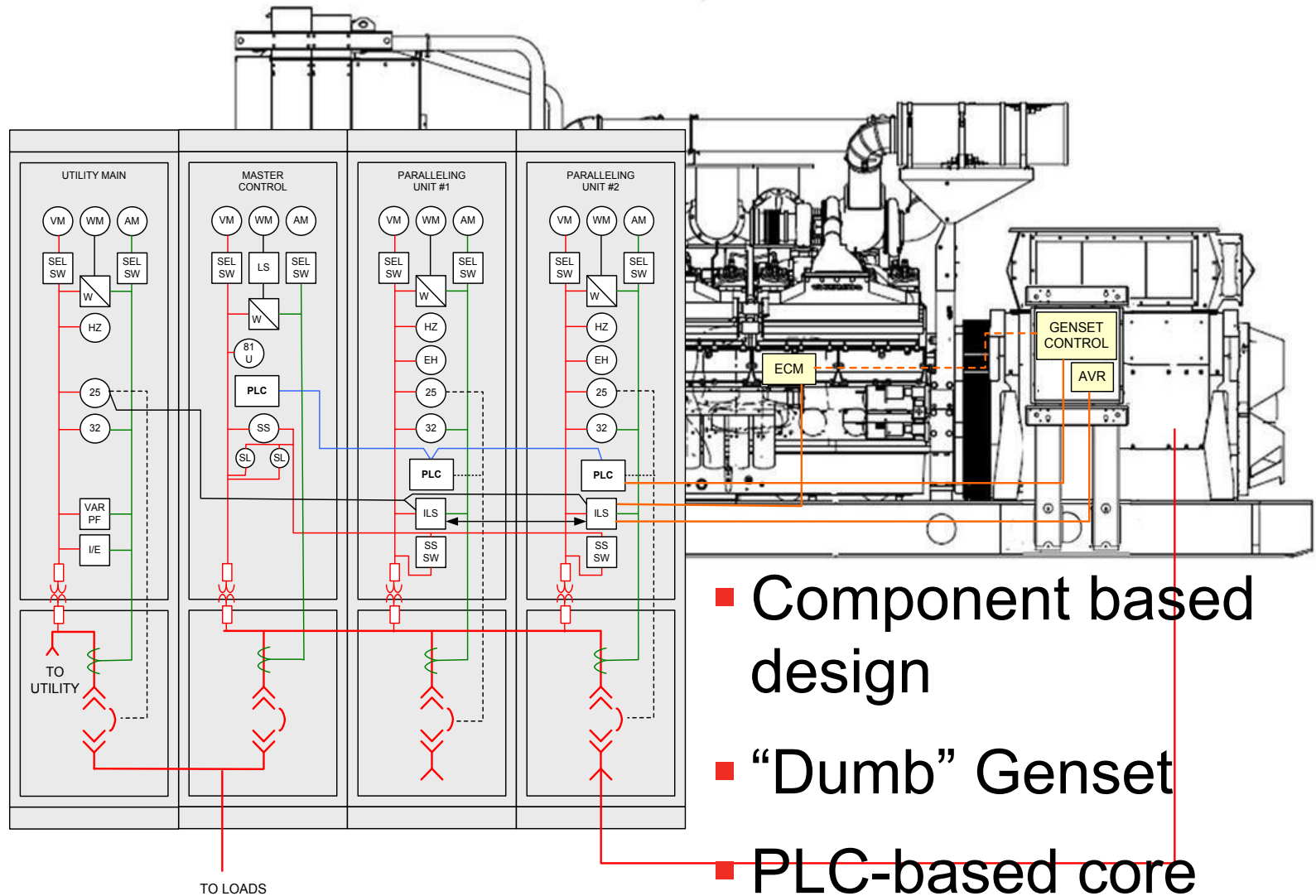
**Master  
Control Cubicle  
1 per system**



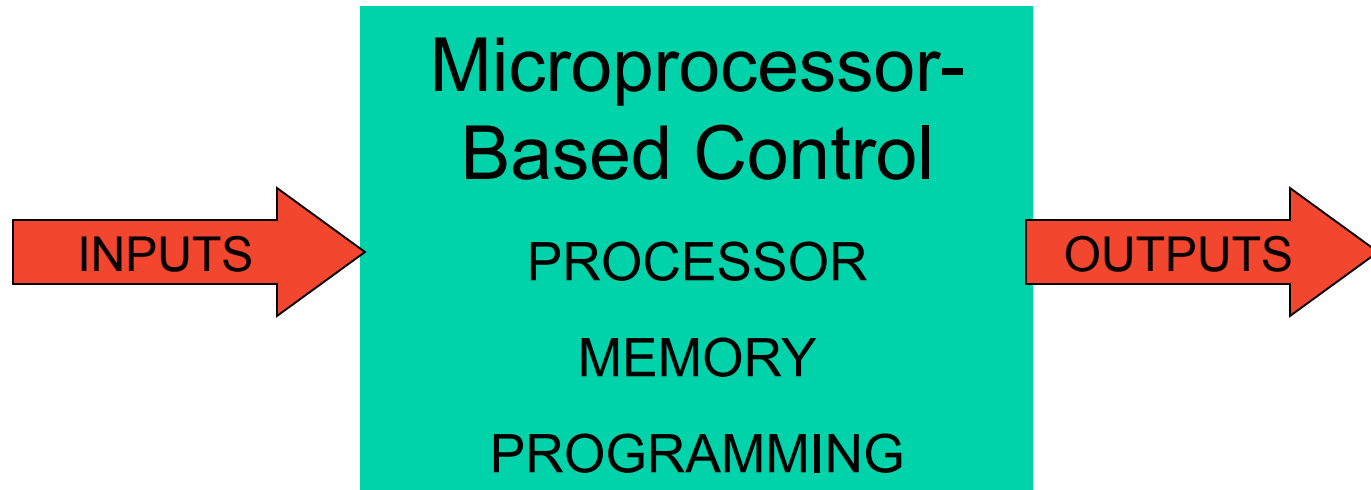
# Traditional Controls

- Component Based Paralleling
  - Transformers
  - Load Sharing/Governing Module
  - Synchronizer/Sync check
  - Protection Relays
  - Control/Logic Relays
  - Metering/Manual Controls

# Traditional Design



# The Digital World

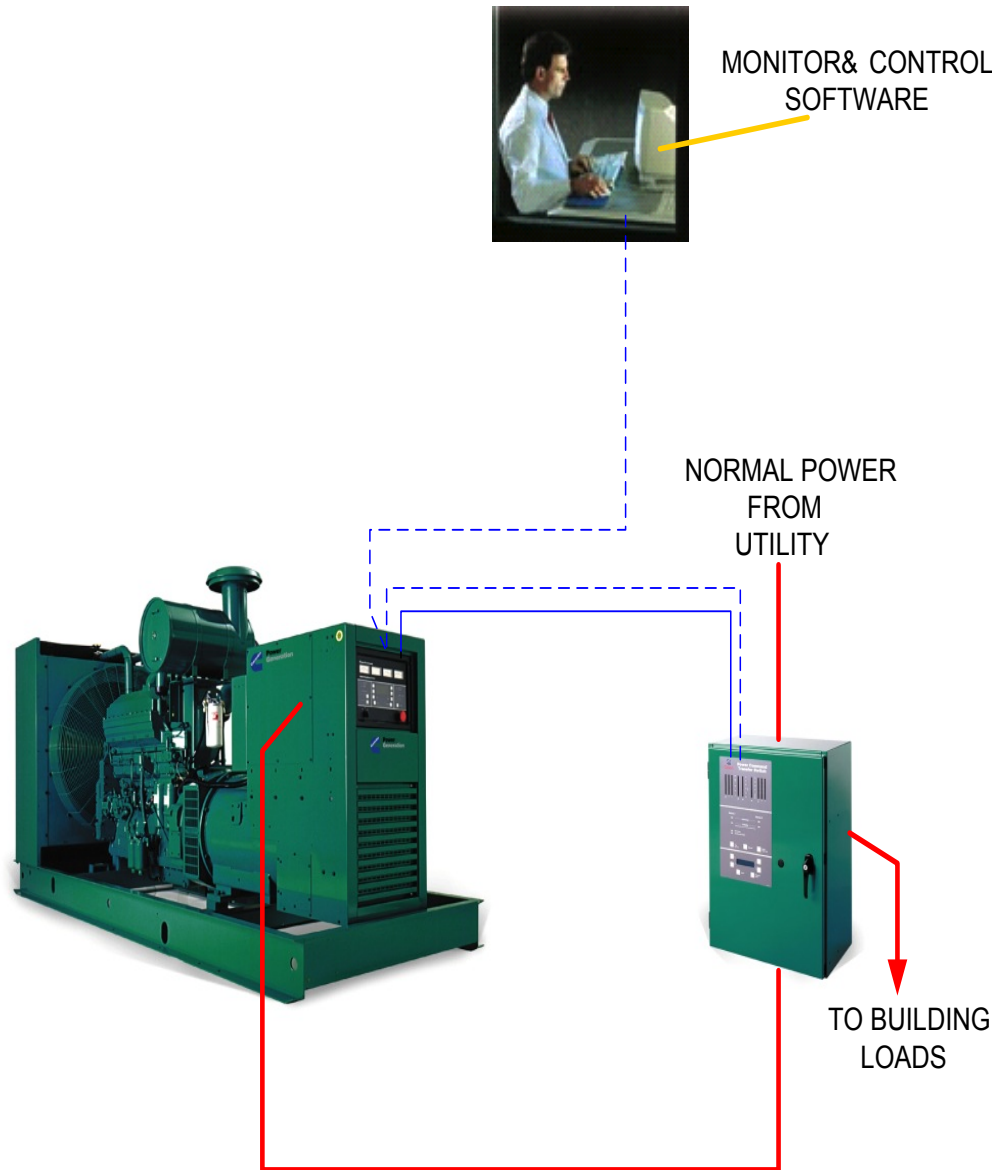


- Processor & Memory are Cheap
- Most of Cost is in the I/O
- Limited Mostly by Creativity of the Designer
- Minimize I/O to minimize cost and improve reliability

# Rule #1

**Every** paralleling/power system is  
made of  
a small group of functions  
that are common  
to all systems.

# ■ System Control Functions



## ■ Power transfer control

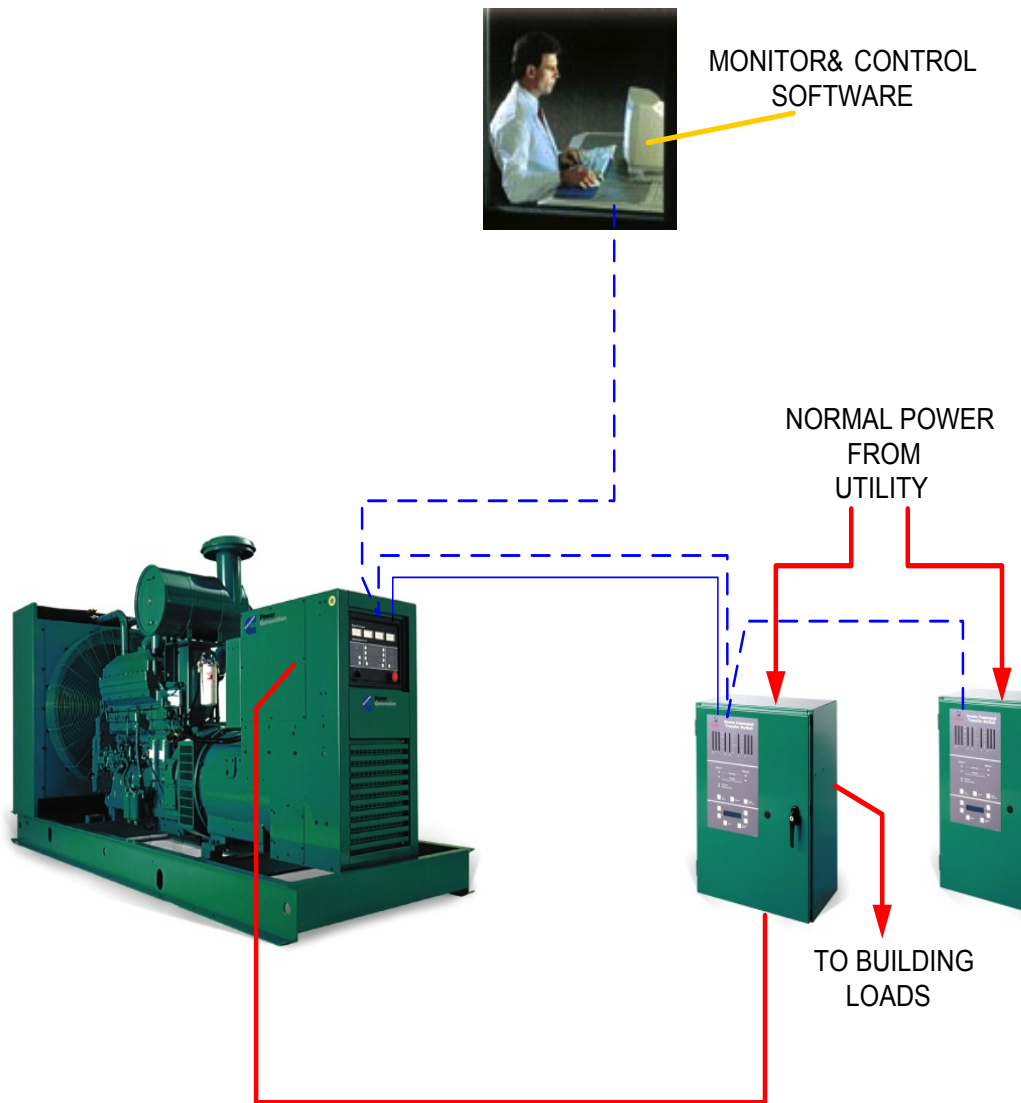
- Source Availability
- Timers/Logic
- Operator Panel
  - AC Metering

## ■ Genset control

- Engine Control
- Governor
- AVR
- Protection
- Operator Panel
  - AC Metering

## ■ Remote Monitoring

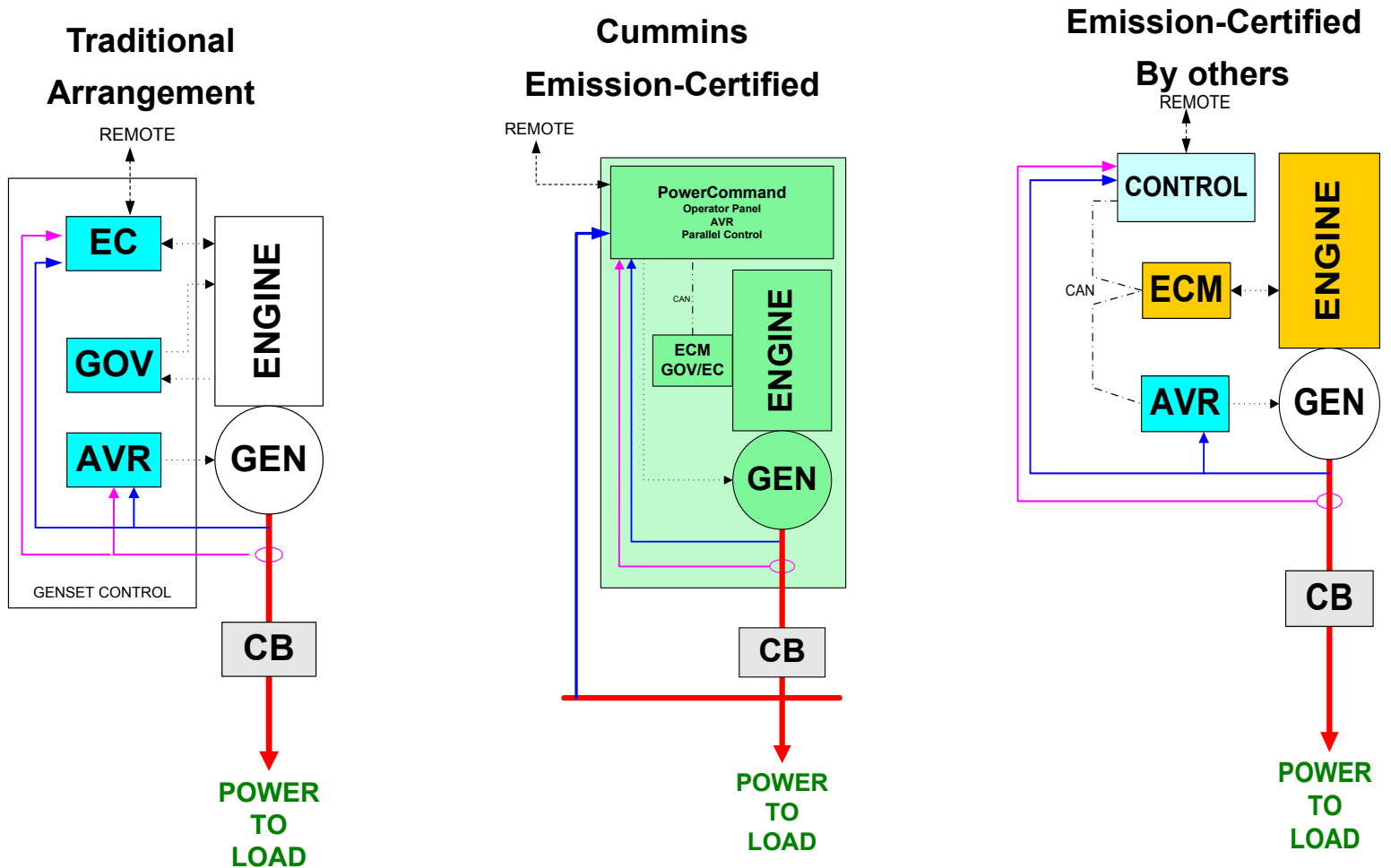
- Annunciator
- Network/etc.



- **System Control Functions**

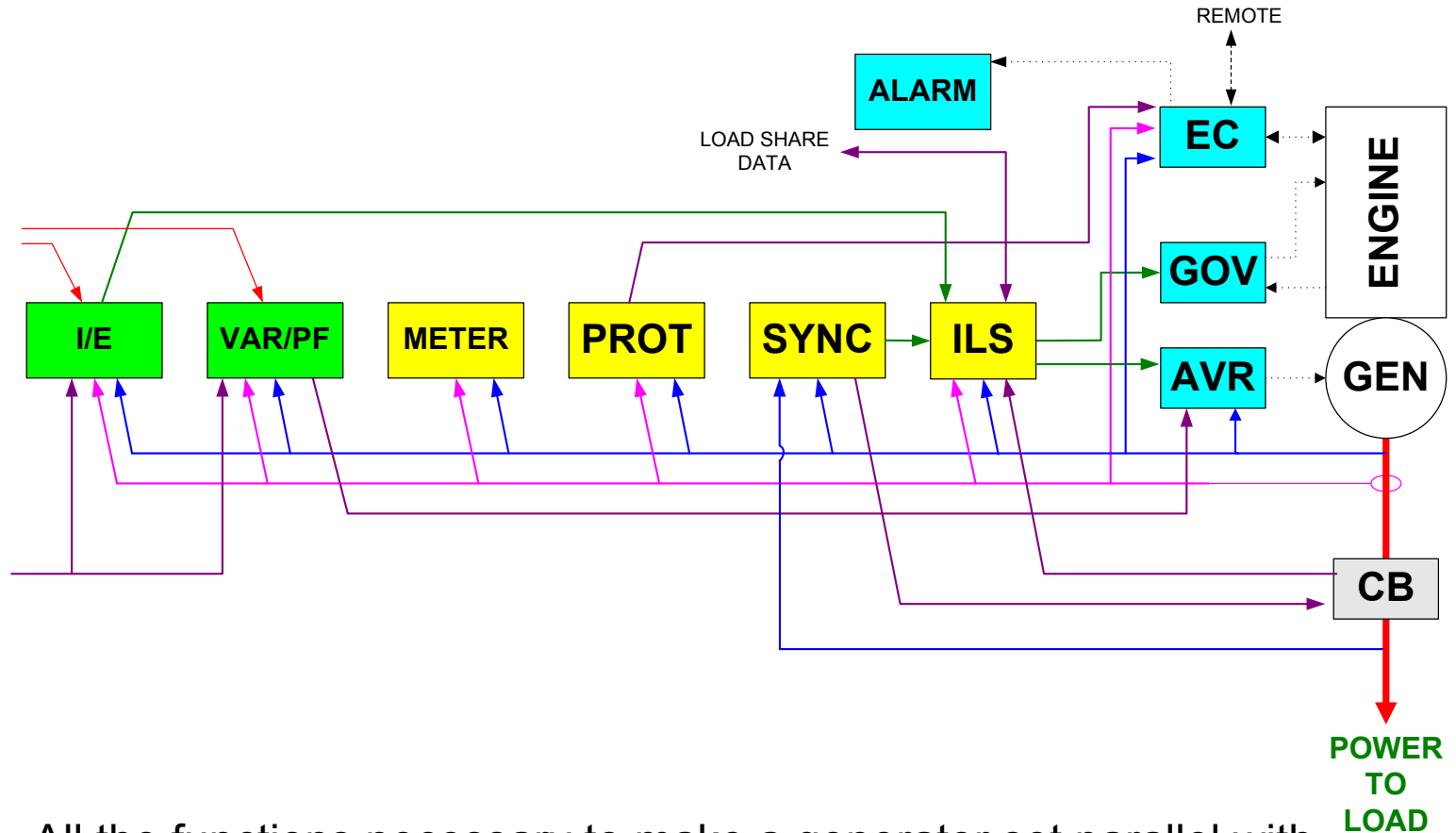
- **(2) Power transfer controls**
  - Source Availability
    - Timers/Logic
    - Operator Panel
      - AC Metering
- **Genset control**
  - Engine Control
    - Governor
    - AVR
    - Protection
  - Operator Panel
    - AC Metering
- **Remote Monitoring**
  - Annunciator
  - Network/etc.

# Control Blocks (Non-Parallel) Emission-certified



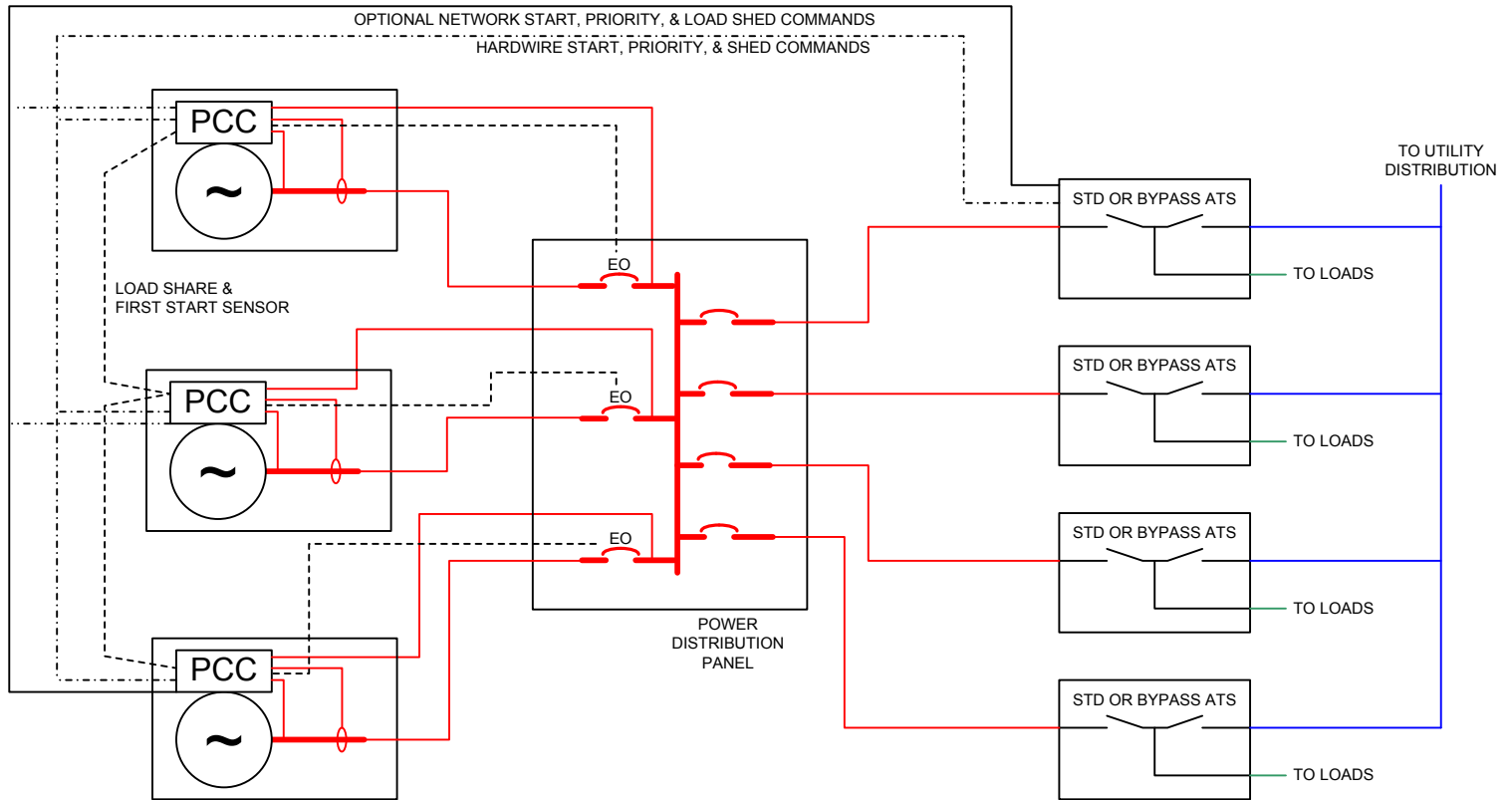
- Control blocks are groups of functions
- Different Manufacturers group differently

# Paralleling control functions



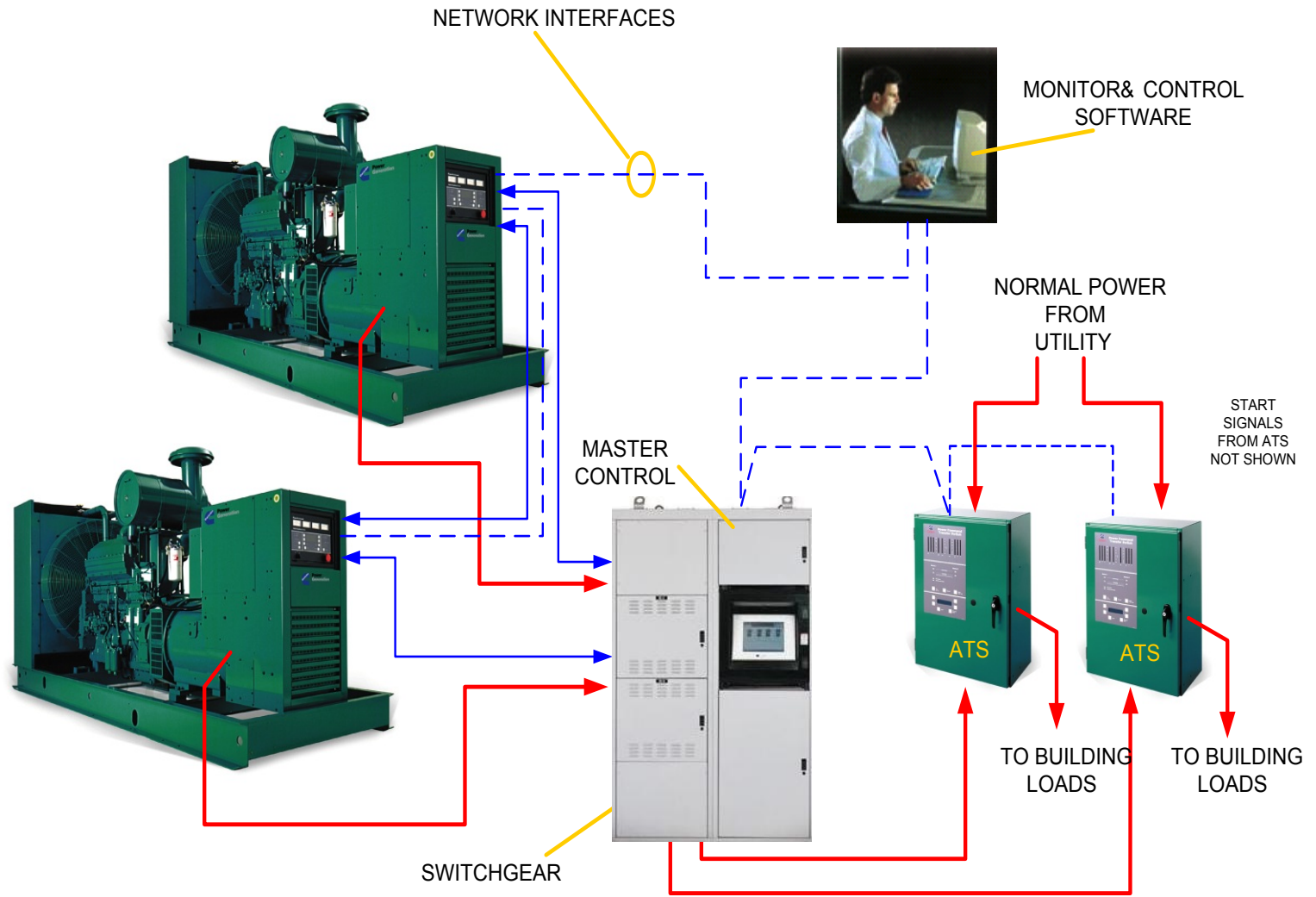
- All the functions necessary to make a generator set parallel with other generator sets, or with an infinite source (i.e., the utility service)
- Traditional equipment designs use one component for each function

# Simply Paralleling



# Remember

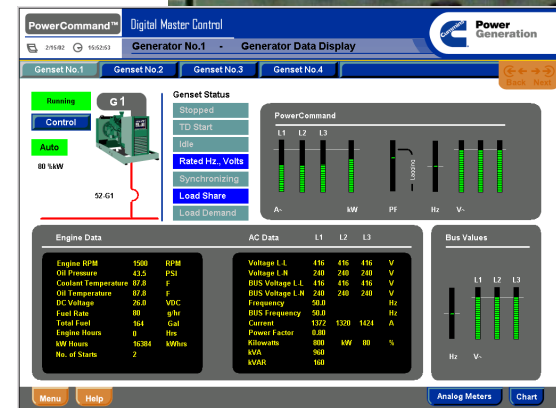
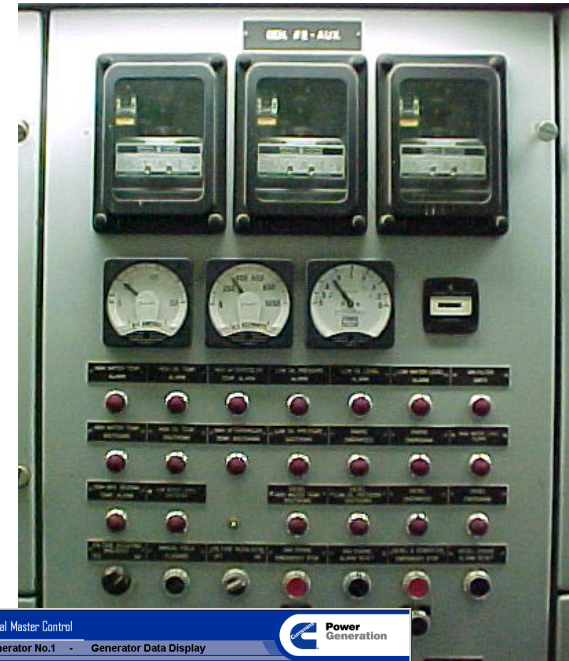
- Each GenSet in a paralleling system needs a **paralleling control**.
  - Synchronizer
  - Load Sharing
  - Protection
  - Metering/Manual Controls
  - Var/PF Controls
  - Import/Export Controls



- What do master controls do?

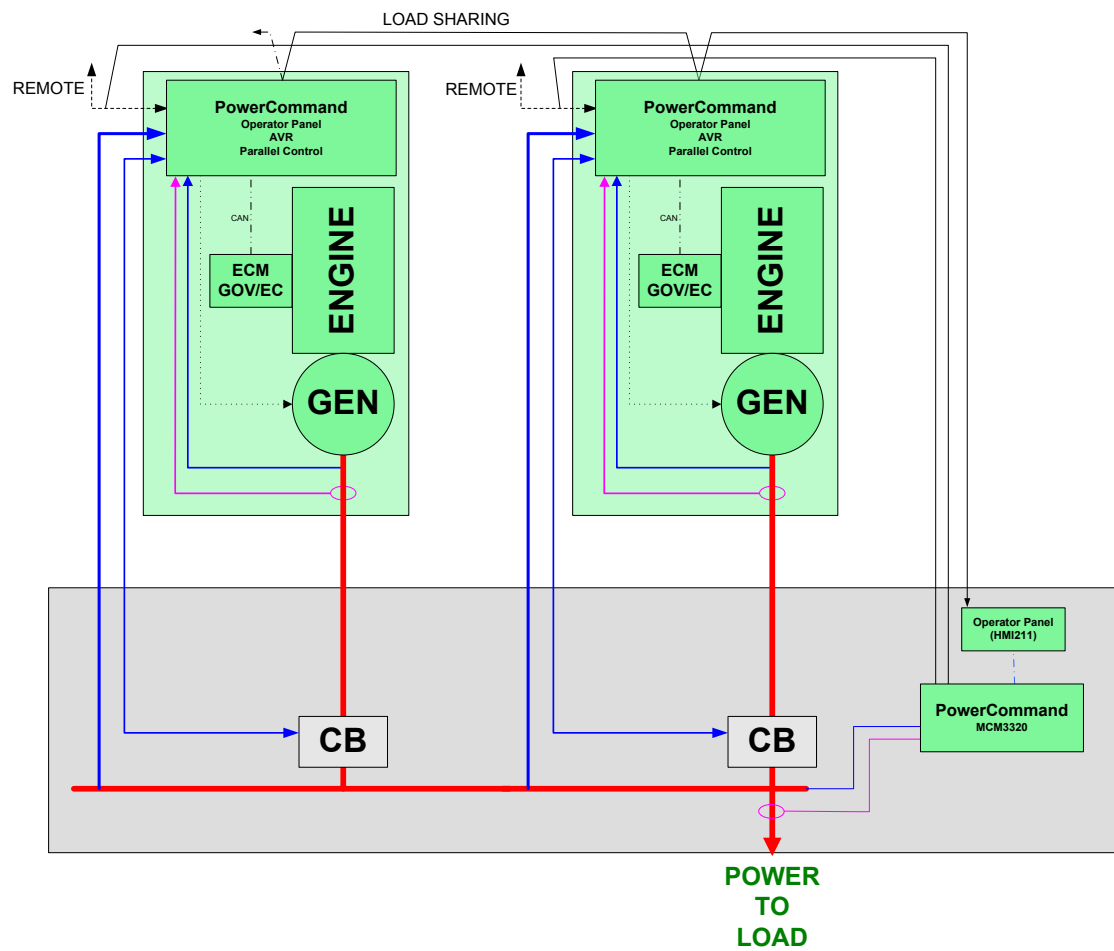
# Master Control Functions

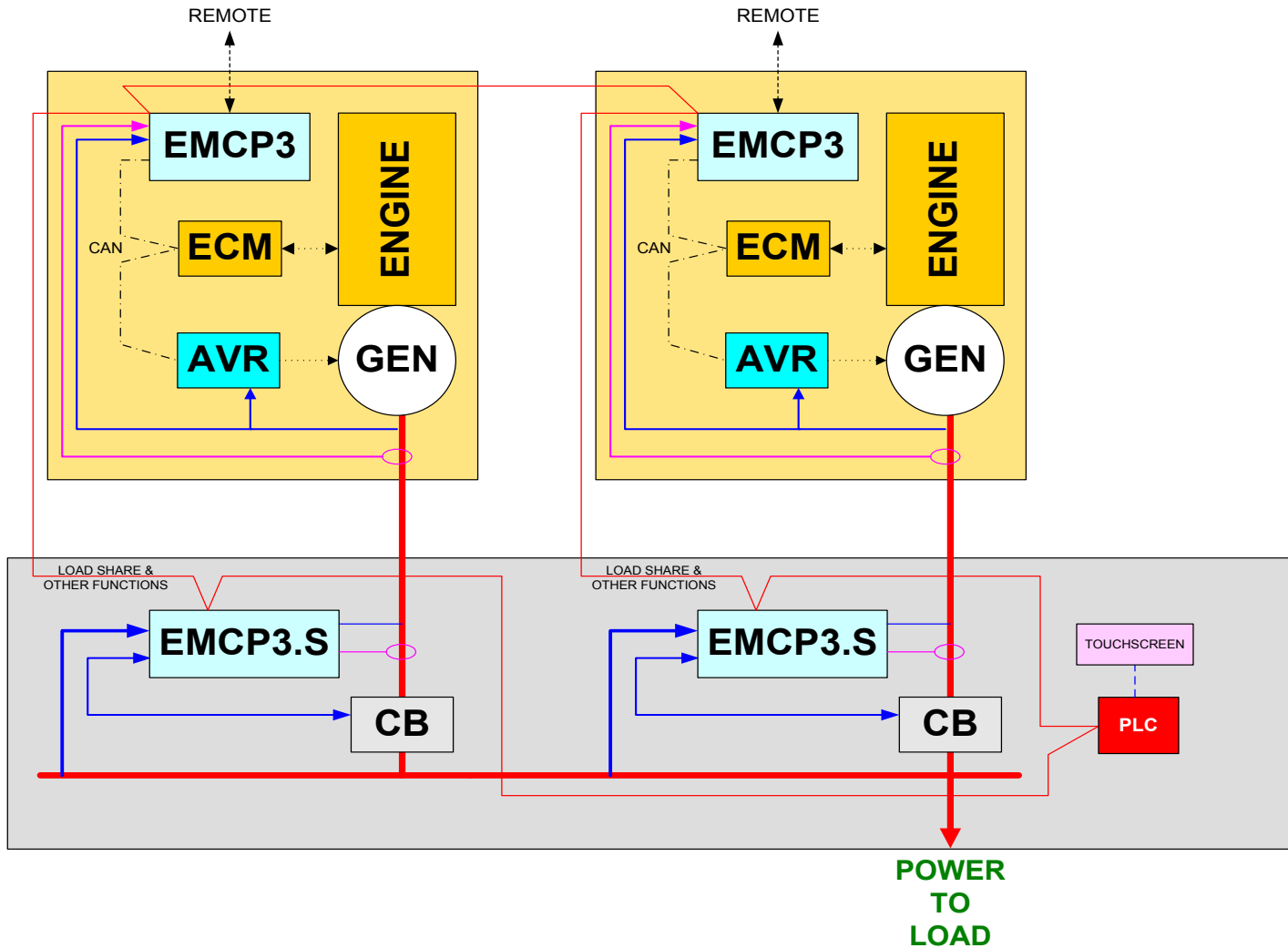
- Interfaces gensets to facility
- Functions include:
  - Load Add
  - Load Shed
  - Load Demand
  - Operator Monitoring Station
    - Total System AC Metering
      - Ammeter, Voltmeter, Frequency, KW
    - Status Display
      - Availability of Sources, Status of Load Service
      - Trending? Event Logging?
    - Manual Control Provisions
      - Auto Load Control Bypass
      - Manual Power Transfer
      - Test
    - Where do you want to see it?
  - Bus Protection



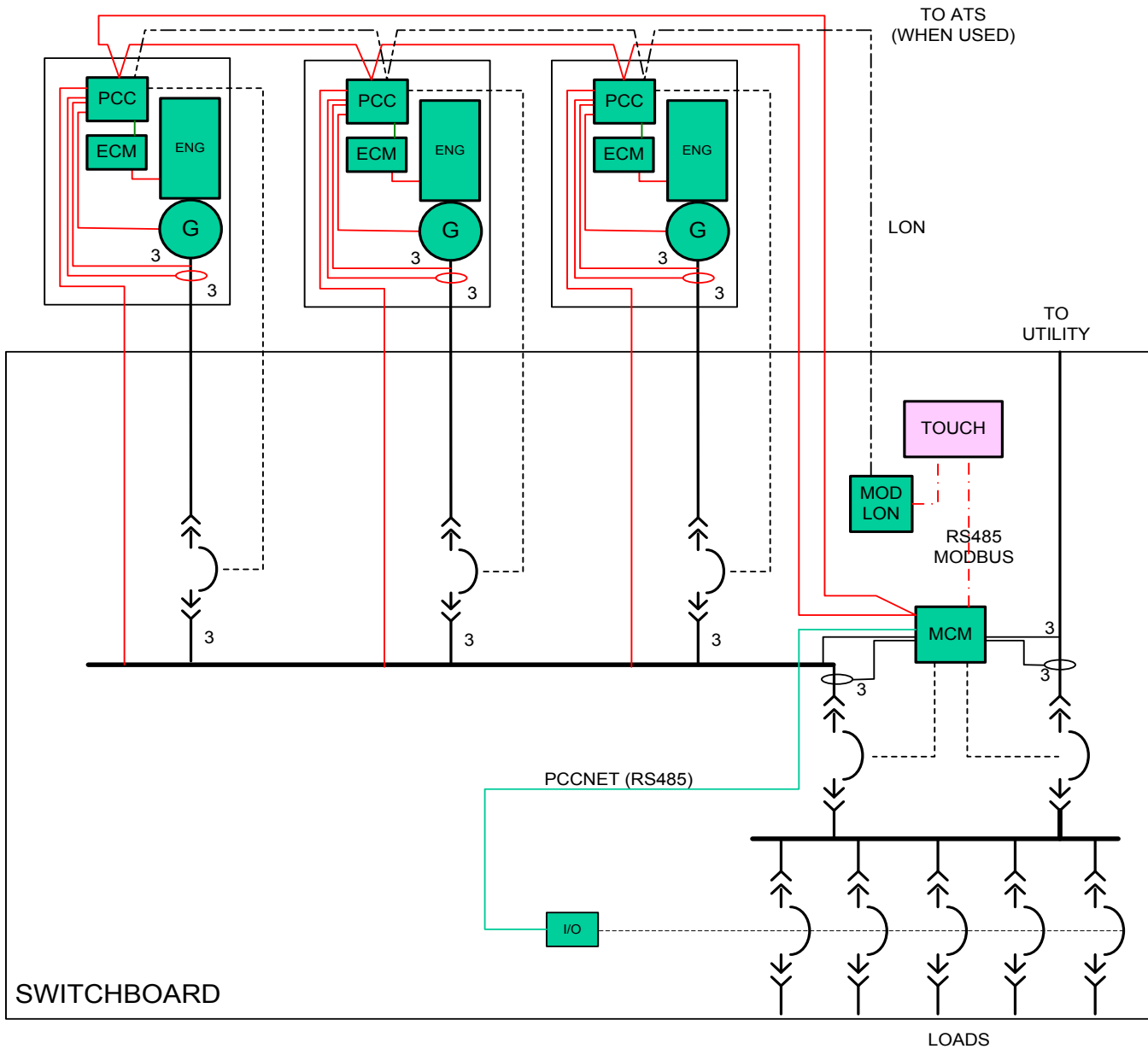
# Master Control Conclusions

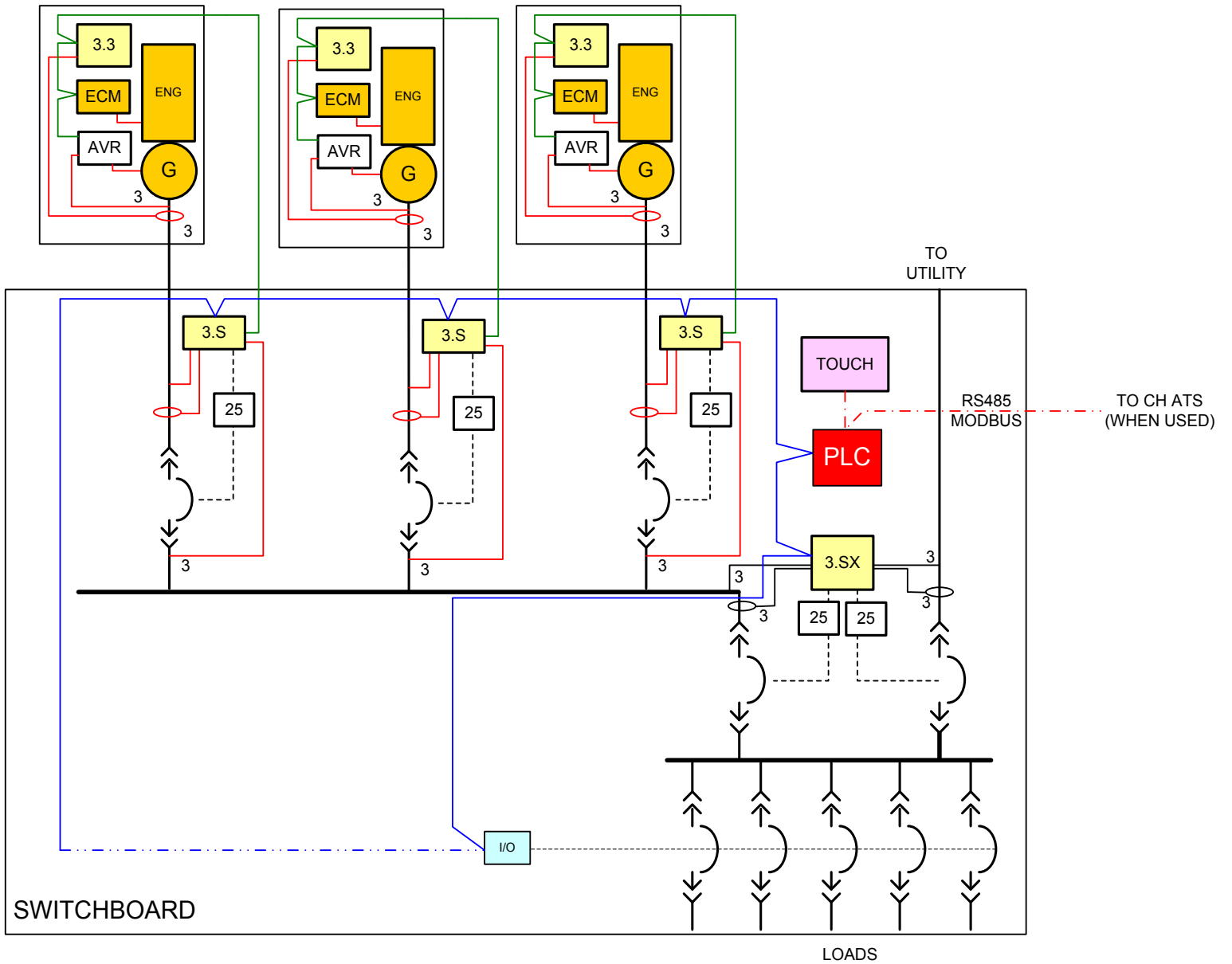
- Master Controls Have Common Core Functions
  - Load Add, Shed; Operator Panel, Load Demand, Power Transfer Controls
  - Different Combinations of Core Functions
  - Standard Controls can provide almost all functions
- Traditional Controls (since mid-80's) Use PLC for Master Functions
  - High Degree of Flexibility
    - High Degree of Customization
    - Need?
  - Reliability? Serviceability?





*Caterpillar shown, Asco, many others similar  
Generac is different...*





Caterpillar shown...Asco4000/7000, many European suppliers similar



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# System Design Conclusions

- All system designs are composed of paralleling controls, master controls, power transfer controls, and “remote” monitoring equipment
  - Not all are needed in every application—specify what is needed
- Provide a dedicated purpose, microprocessor-based control wherever available
  - One paralleling control for each generator set
  - One power transfer control for each utility
  - Master control with functions as needed (load control, load demand, etc)
  - Monitor functions where needed

# *The Primary Reason for Paralleling is to Achieve Added Reliability*

- KISS
- System Topology Selection
  - Simple is generally better
  - System Design with Load Add & Shed
- Reliable Components
- Manual Back-ups
- FMEA
  - Failure mode effects analysis
- Avoiding Single Points of Failure
  - Three Steps:
    - Design it out
    - True Redundancy
    - Reliable components
  - Role of Distributed Logic
  - Careful Review of Design
- Service & Support

# Lessons Learned

- **COMPLEXITY!**
  - Drives high engineering cost
  - Hard to fix when it breaks
  - Long start up times
  - Hard to fully test
  - Obsolescence Issues
- **PLC-based Control**
  - Essentially a Master/Slave configuration
    - PLC Crash “kills” the system
  - Each System Runs “PROTOTYPE” software
    - Changes can be made at any time that can affect system reliability
  - High cost for tools, non-standard tools, few know how to use them
  - Hidden failure modes
  - Known weaknesses encourage band-aids
    - Redundant PLC’s (which drive additional complexity and slow down operation time)
  - Not well-suited to genset application
    - Ambient and control voltage limitations
- **Factory-based Service**
  - Local techs not normally not able to handle this

# Conclusions

- Next Generation Paralleling Systems Characteristics:
  - Major GenSet Manufacturers will Provide Integrated Paralleling Controls that will directly operate all paralleling breakers
  - Each Utility (or transfer pair) will be monitored by a dedicated controller, which will directly control the utility breaker and the genset main bus (if used)
    - PLC used for Coordination, Communication
    - Challenge: Making the PLC fail gracefully (when used)

**Questions?**