Power System Control

Shipboard Power System Fundamentals

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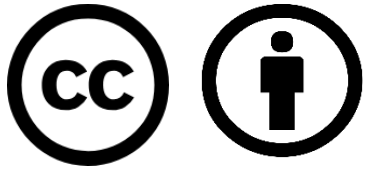


http://doerry.org/norbert/MarineElectricalPowerSystems/index.htm

Essential Questions

What power system control architectures are used on ships and why?	Understand
What is time scale separation in relationship to controls?	Understand
What are the layers of control as defined in IEEE Std. 1676?	Remember
What are the typical power system control functions?	Understand

Introduction:
Objectives of power system design

"The primary aim of the design of a shipboard electric power system has traditionally been survivability and continuity of the electrical power supply. Survivability relates to the ability of the power system, when damaged by a threat, to support the ship's ability to continue its missions. Power continuity relates to the ability of the power system to reliably provide power to ship systems under normal operations."

USS Forrest Sherman (DDG 98) Electric Plant Control Console

Doerry, Norbert, "Designing Electrical Power Systems for Survivability and Quality of Service", presented at ASNE DAY 2007, Arlington, VA, June 25-26, 2007. Also published in ASNE Naval Engineers Journal, 2007, Vol. 119 No 2, pp 25-34.

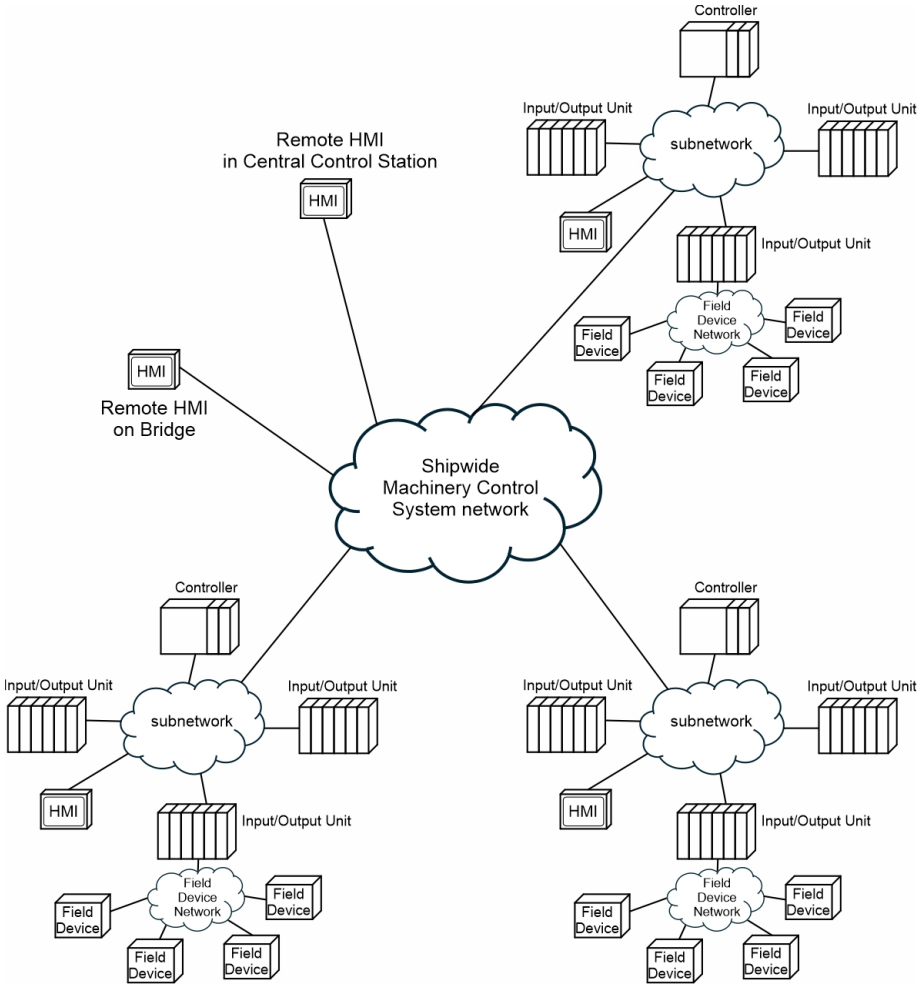
Electrical Power System control functions

- Remote monitoring and control of electrical power system equipment
- Resource planning and system configuration to support the EPS-CONOPS
- Mission priority load shedding
- Coordination of fault detection, fault isolation, and reconfiguration
- Optimization of QoS and QoS load shedding
- Interfacing with the overall machinery control system
- Performance analysis, parameter trending, and logging
- Maintenance support
- Training

Control System Hardware

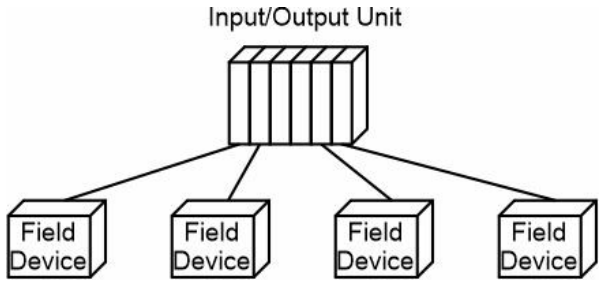
- Field Device
  - Converts digital commands to physical actuation.
  - Converts measurements to digital data.
- Input / Output unit
  - Perform data translation, signal conditioning, and basic signal processing.
  - Not intended to implement control algorithms.
- Controller
  - Typically, a Programmable Logic Controller (PLC).
  - Implements control algorithms.
- Network
  - Multi-level to enable communications among control system hardware elements.
- Human-Machine Interface (HMI)
  - Provides operators with situational awareness.
  - Enables operators to configure or provide control set points for the electrical power system.

Control System Networks



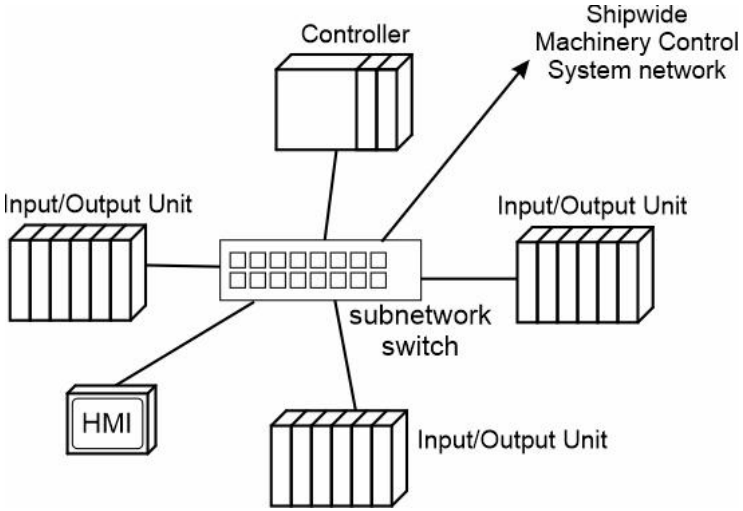
- Field devices
- Input/Output unit
- Controller
- Network
- Human Machine Interface (HMI)

Topologies



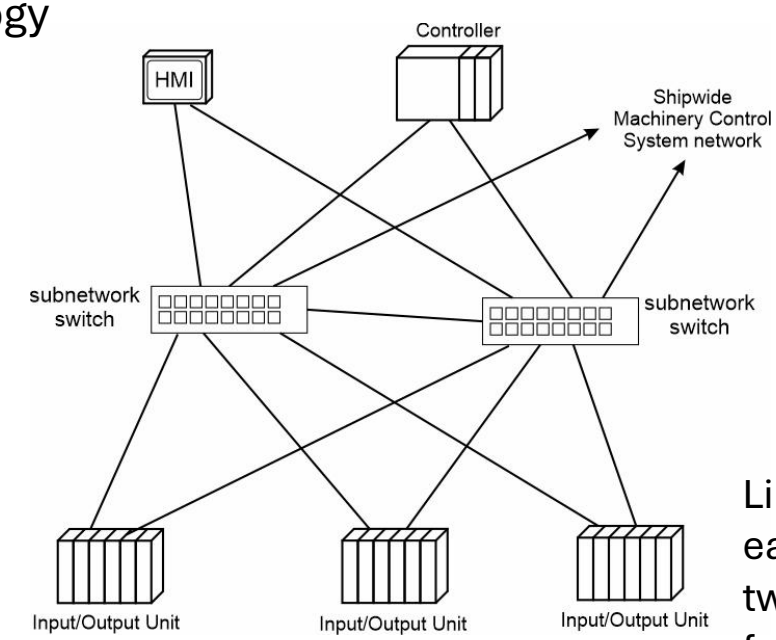
Point to point topology

Enables multiple interface types between Input/Output unit and Field Devices



Star topology

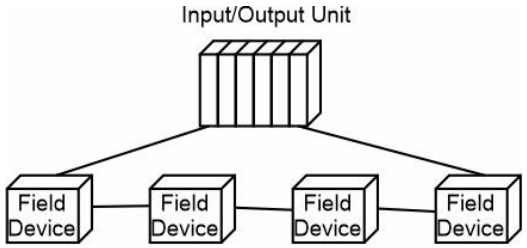
Devices connect to the same subnetwork switch using same interface type. Should be able to function without connection to ship wide machinery control system network.



Dual star topology

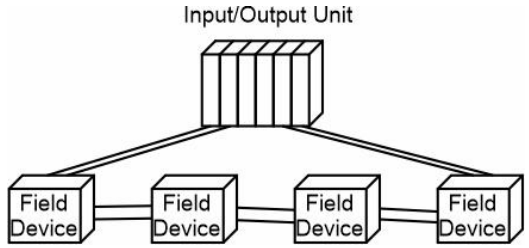
Like the star topology, but each device connects to two subnetwork switches for increased reliability and survivability

Topologies (continued)



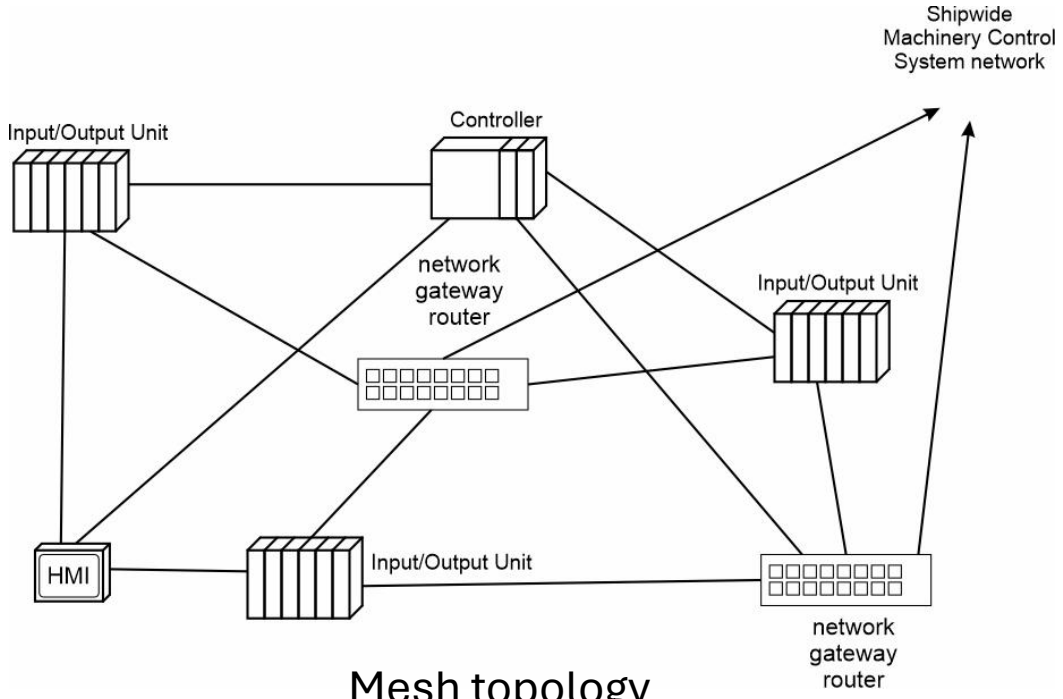
Ring bus topology

Can tolerate loss of a single connection.
Usually requires less cable than other topologies.
Does not require subnetwork switch.



Dual ring bus topology

Can tolerate loss of multiple connections.
Requires twice as much cable as Ring Bus.
Does not require subnetwork switch.

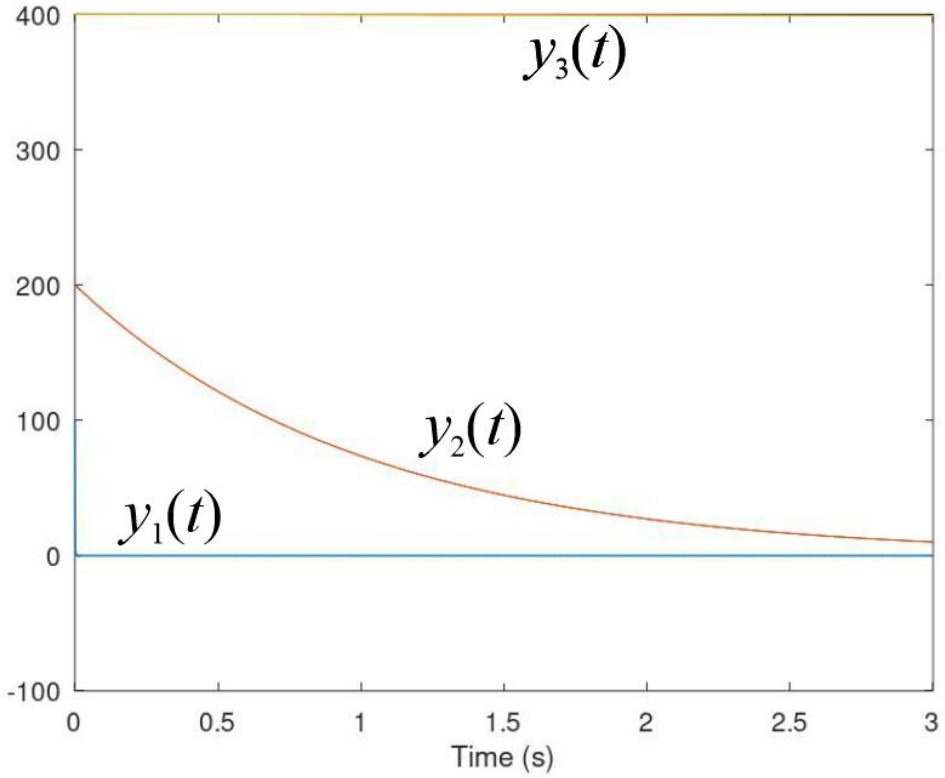


Mesh topology

Each device connects to multiple other devices.
Data may be routed through multiple paths between any two devices.
Can be very reliable and survivable.

Time scale separation

- Partitions the analysis and control of systems with dynamics that are of very different time scales.
  - Enables each partition to be treated separately from the other partitions.
- Each partition has a time scale of interest.
  - Dynamics that are much slower than the time scale of interest are assumed to be constant at their initial value.
  - Dynamics that are much faster than the time scale of interest are assumed to have happened instantaneously and have their “final” value.



$y_3(t)$ is much slower
$y_2(t)$ is in time scale of interest
$y_1(t)$ is much faster

IEEE Std. 1676 control layers

1. System control (characteristic time of 10 ms or greater)
   - Functions at total ship / zonal level.
   - Control of generator sets, converters, configuration of bus-tie breakers, commanding load shedding.
   - Zonal Ships: Multi-zone control, Zonal control, and In-zone control.
2. Application control (characteristic time of 1 ms to 1 s)
   - Functions at the power system component level.
   - Implements control objects provided b system control.
3. Converter control (characteristic time of 10 µs to 1 ms)
   - Translate objectives of application control to specific set-points and control schemes for implementation by the switching control.
4. Switching control (characteristic time of 1 to 10 µs)
   - Controls the switching logic to implement the control scheme of converter control.
5. Hardware control
   - Provides the direct interface with hardware to include snubbers, gate drives, sensors, A/D and D/A conversion, etc.