Resilient-Redundant Control Systems Bridging Multiple Plants

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Problem:

Process Control and SCADA/HMI systems are often not considered when developing resilient-redundant district energy plants. Often control systems become the weak link of systems.

CU Boulder WDEP and EDEP

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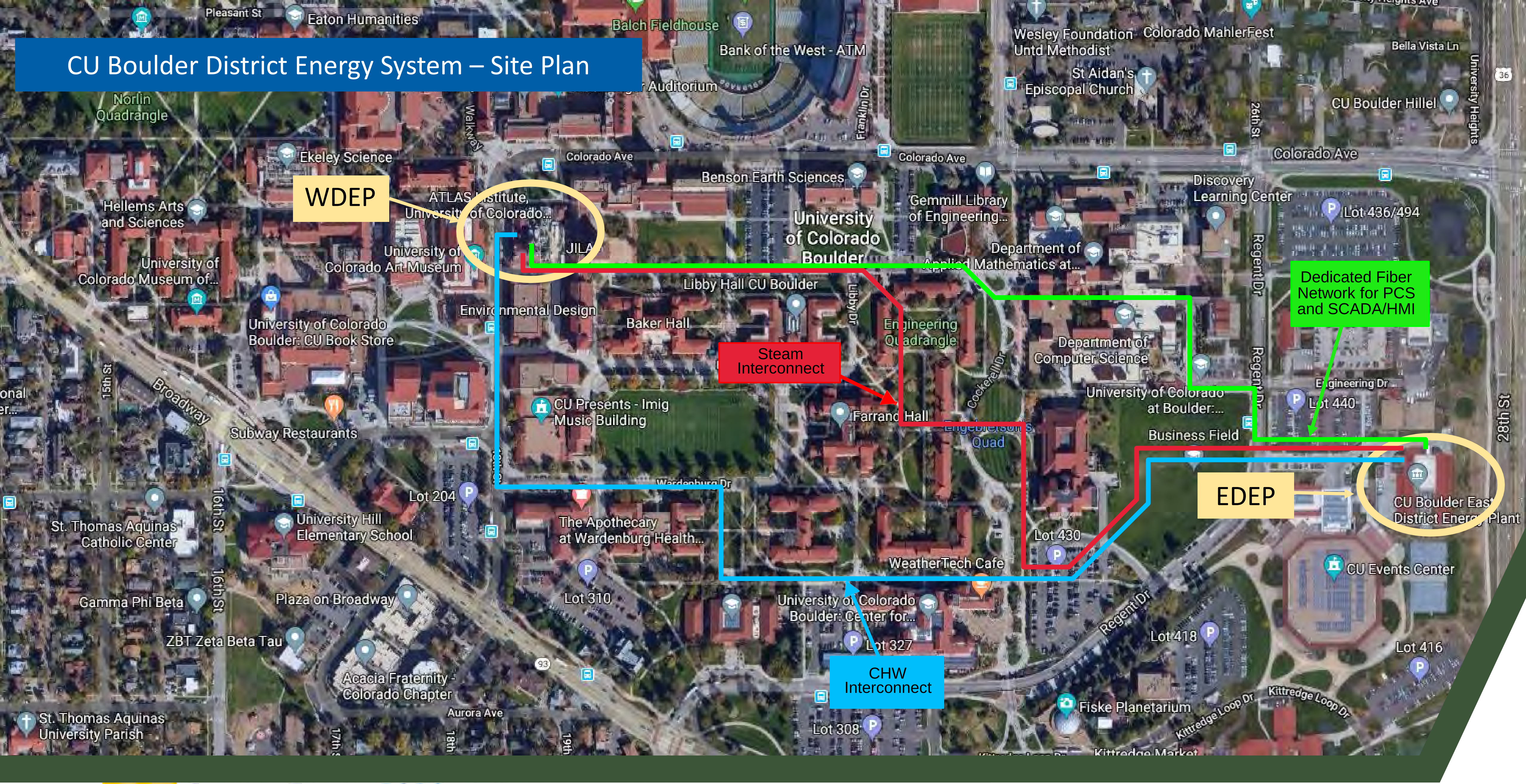
Campus Utility Services Overview

- CU Boulder owns and operates two district energy plants on their main campus.
  - West District Energy Plant (WDEP): 30MW combined heat and power (CHP), conventional steam boilers, and chilled water (CHW) plant.
  - East District Energy Plant (EDEP): conventional steam and CHW plant.
- District energy system was expanded in 2015.
- Process control systems were integrated between plants under one control system hierarchy.
- Dedicated redundant fiberoptic network.

CU Boulder District Energy System – Site Plan



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Plant Assets and Campus Demand

WDEP	EDEP	DEMAND
2 – 1,625 Ton Variable Flow Chillers	2 – 1,650 Ton Variable Flow Chillers	160,000 lbs/hr
130,000 lbs/hr Dual Fuel Boiler	100,000 lbs/hr Boiler	5,000 tons
105,000 lbs/hr Dual Fuel Boiler	50,000 lbs/hr Boiler	20 MW
2 – 50,000 lbs/hr Heat Recovery Steam Generators (HRSG)	2 – 1,225 Ton Economizer [Free-Cooling] Heat Exchangers	
2 – 30,000 lbs/hr HRSG Gas Fired Duct Burners (Supplemental)	1,200 Ton Satellite CHW Plant	
2 – 15 MW Dual Fuel Combustion Turbines	1 – 1,650 Ton Variable Flow Chiller (Under Construction)	
1 – 2.75 MW Extraction-Condensing Turbine	n+1 Heating & Cooling System Pump Capacity	
n+1 Heating & Cooling System Pump Capacity		

Infrastructure Upgrade Projects: Perfect Time to Address Process Controls and SCADA/HMI

- CU Boulder Goals
  - Design control and SCADA systems to match system redundancy requirements of n+1.
  - Design a hierarchical Process Control and SCADA/HMI. Address resiliency and redundancy.
  - Redundant network reliability.
  - Visualization and alarming standards.
  - Ability to layer on optimization.
  - Address legacy control systems.

Control System Planning

- CU Boulder’s master plan based on detailed system architecture.
- Simple or very involved process to determine a path forward.
- Utilize tools such as evaluation matrixes.
- Address resiliency, redundancy, networking, packaged controls, instrumentation, and tagging.
- Develop failure scenarios.
- Consider graphics and programming standards.

Evaluation Matrix Tool

SCADA COMPARISON

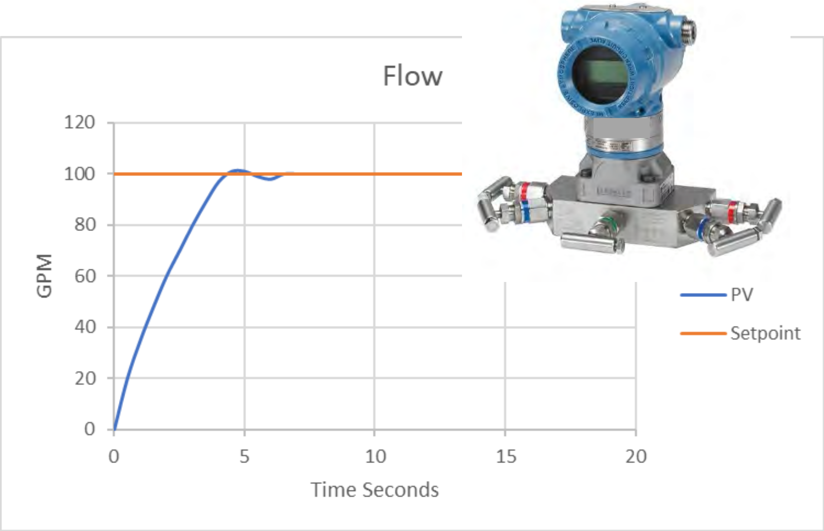
COLOR LEGEND →	UNACCEPTABLE	ACCEPTABLE	PREFERRED		

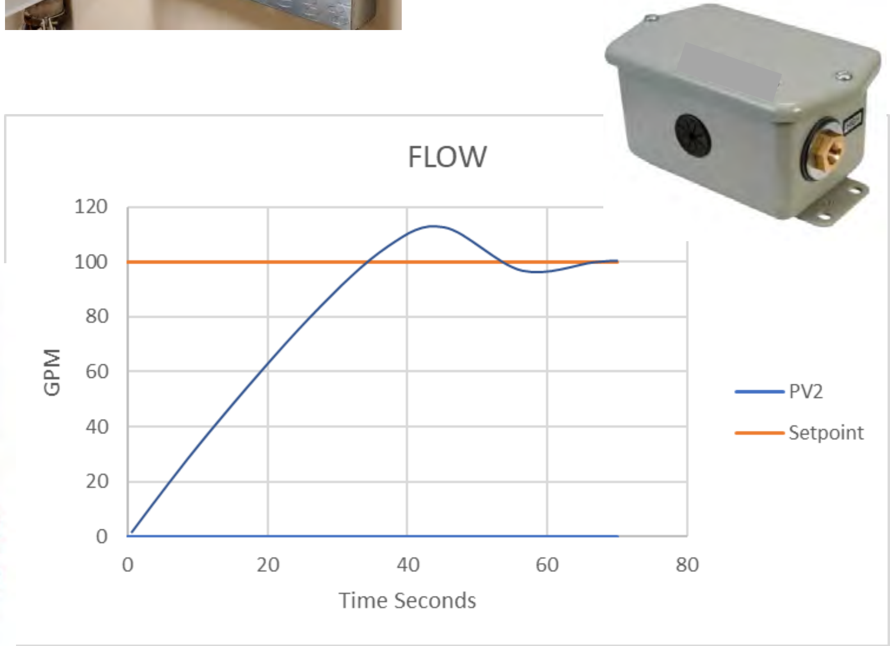
SCADA COMPARISON MATRIX

	Vendor A	Vendor B	Vendor C	Vendor D	Vendor E
Multiple sources available to provide solutions	No	Yes	Yes	No	No
Company Age	170	32	116	31	4
Company Size	Large	Large	Large	Large	Small subsidiary of a larger company
E&U Experience	Yes, major focus	Yes, but dependent on integrator selected	Yes, but dependent on integrator selected	Yes, major focus	Yes, major focus
Opportunity to Minimize Vendors	Yes	Yes	Yes	Yes	Yes
Operating Systems Supported	Windows	Windows	Windows	Windows	Windows
Redundancy Available	Yes	Yes	Yes	No	Yes
Database Type	SQL	SQL	OSI PI	Vendor Developed	OSI PI
Simulation	Yes	Yes	Yes	Yes	Yes
Availability of training	Yes	Yes	Yes	Yes	Yes
Scalability (Need small scale and large scale installations)	Yes	Yes	Yes	Yes	Yes
Licensing Sturcture/Cost	Per Tag. One time cost but charged for new software releases.	Per Tag. One time cost but charged for new software releases.	Per Display. One time cost but charged for new software releases.	Based on control points, monitoring points, and options. One time cost but charged for new software releases.	Based on Project Resources. One time cost but charged for new software releases.
Service Agreement	Yes	Yes, through integrator or vendor.	Yes, through integrator or Vendor.	Yes	Yes
Remote management of applications	Yes	Yes	Yes	Yes	Yes
Proven Software technology	Yes	Yes	Yes	Yes	No
Backward compatibility	Yes, but may require application to be run through each version	Yes, but may require application to be run through each version	Yes, but may require application to be run through each version	Yes, but may require application to be run through each version	New Product
High Performance Graphics	Yes	Yes	Yes	Yes	No
Mobile device compatibility	Yes	Yes	Yes	Yes	Yes
Security	IT, Firewalls, Login, etc.	IT, Firewalls, Login, etc.	IT, Firewalls, Login, etc.	IT, Firewalls, Login, etc.	IT, Firewalls, Login, etc.

Industrial/Process Grade Instrumentation Vs. Commercial Grade

Vs.





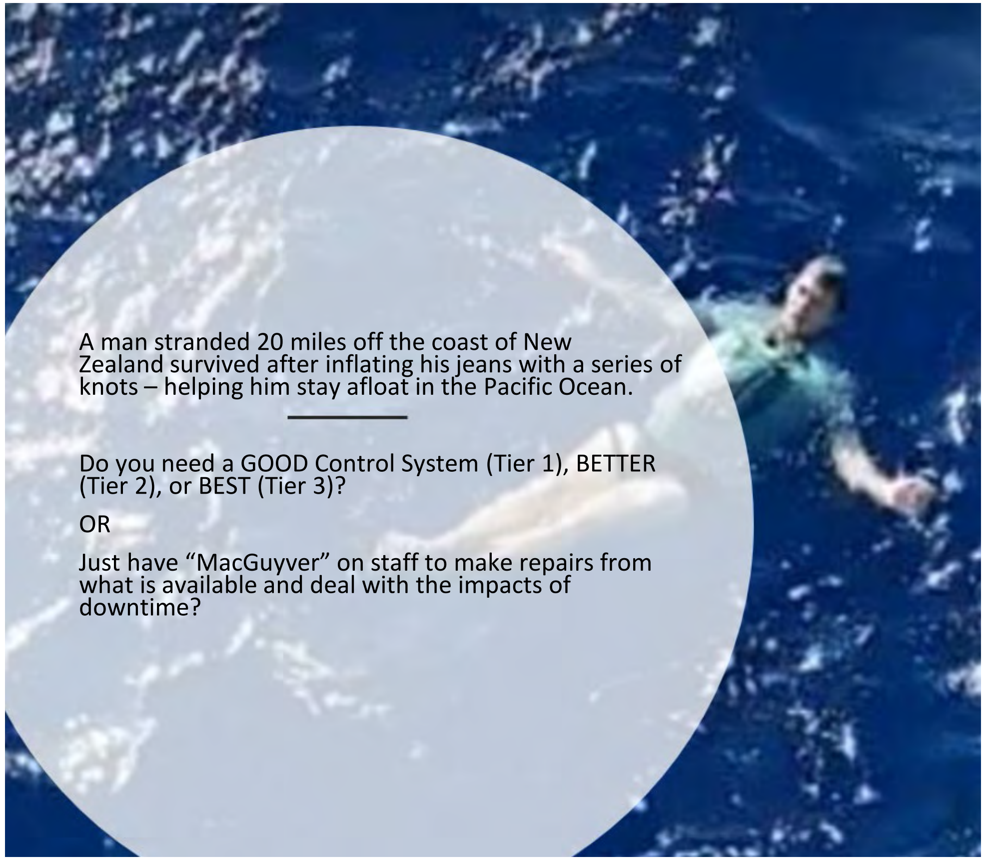
Campus Risk Tolerance to Service Impacts – Justification for System Resiliency

Tier 3

Tier 2

Tier 1

or



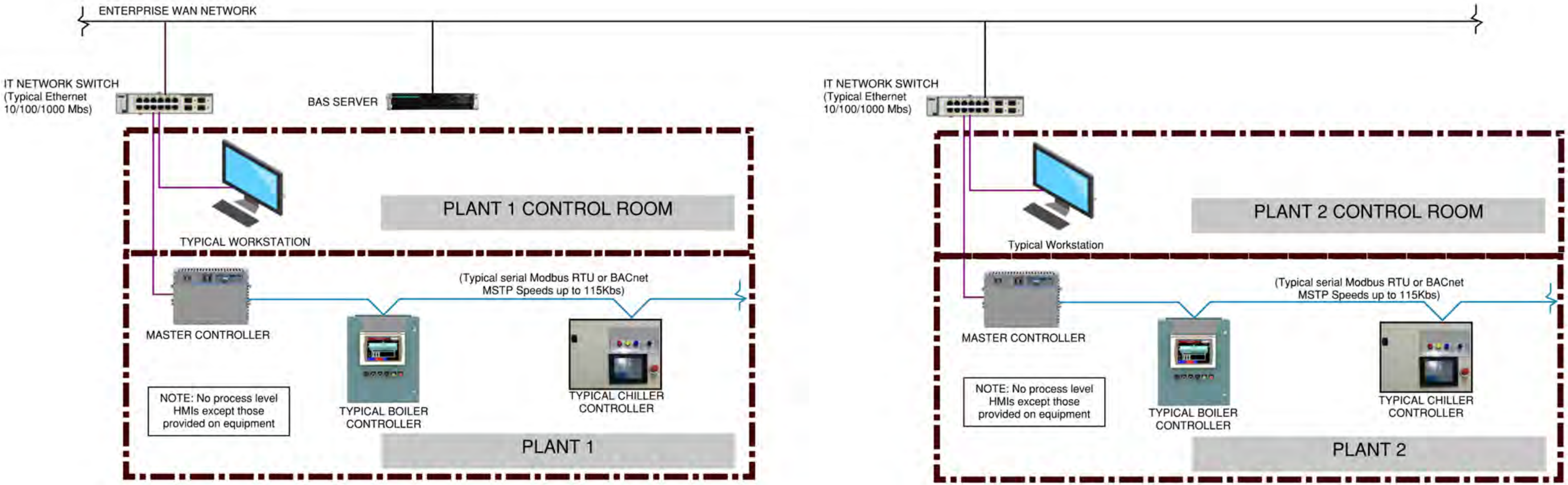
A man stranded 20 miles off the coast of New Zealand survived after inflating his jeans with a series of knots – helping him stay afloat in the Pacific Ocean.

Do you need a GOOD Control System (Tier 1), BETTER (Tier 2), or BEST (Tier 3)?

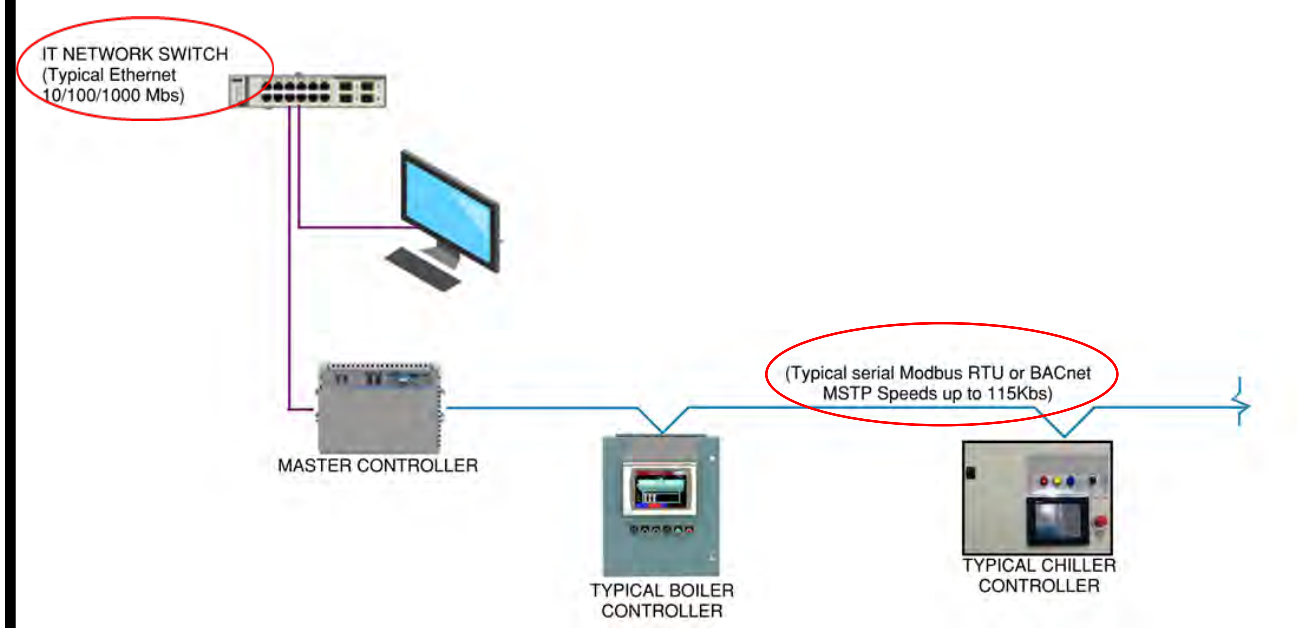
OR

Just have "MacGuyver" on staff to make repairs from what is available and deal with the impacts of downtime?

Tier 1 (Base) For a District Energy Plant Configuration



Tier 1 (Base) For a District Energy Plant Configuration



- Network based on typical building controls. Leverage IT network and serial communication (Modbus RTU and BACnet MSTP communications).

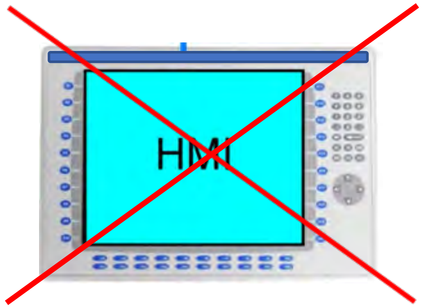
Tier 1 (Base) For a District Energy Plant Configuration

- IT protects SCADA and controls with firewall.
- Additional security through control system logins and user privileges.

Tier 1 (Base) For a District Energy Plant Configuration

- Typically no balance of plant HMIs.

NOTE: No process level HMIs except those provided on equipment



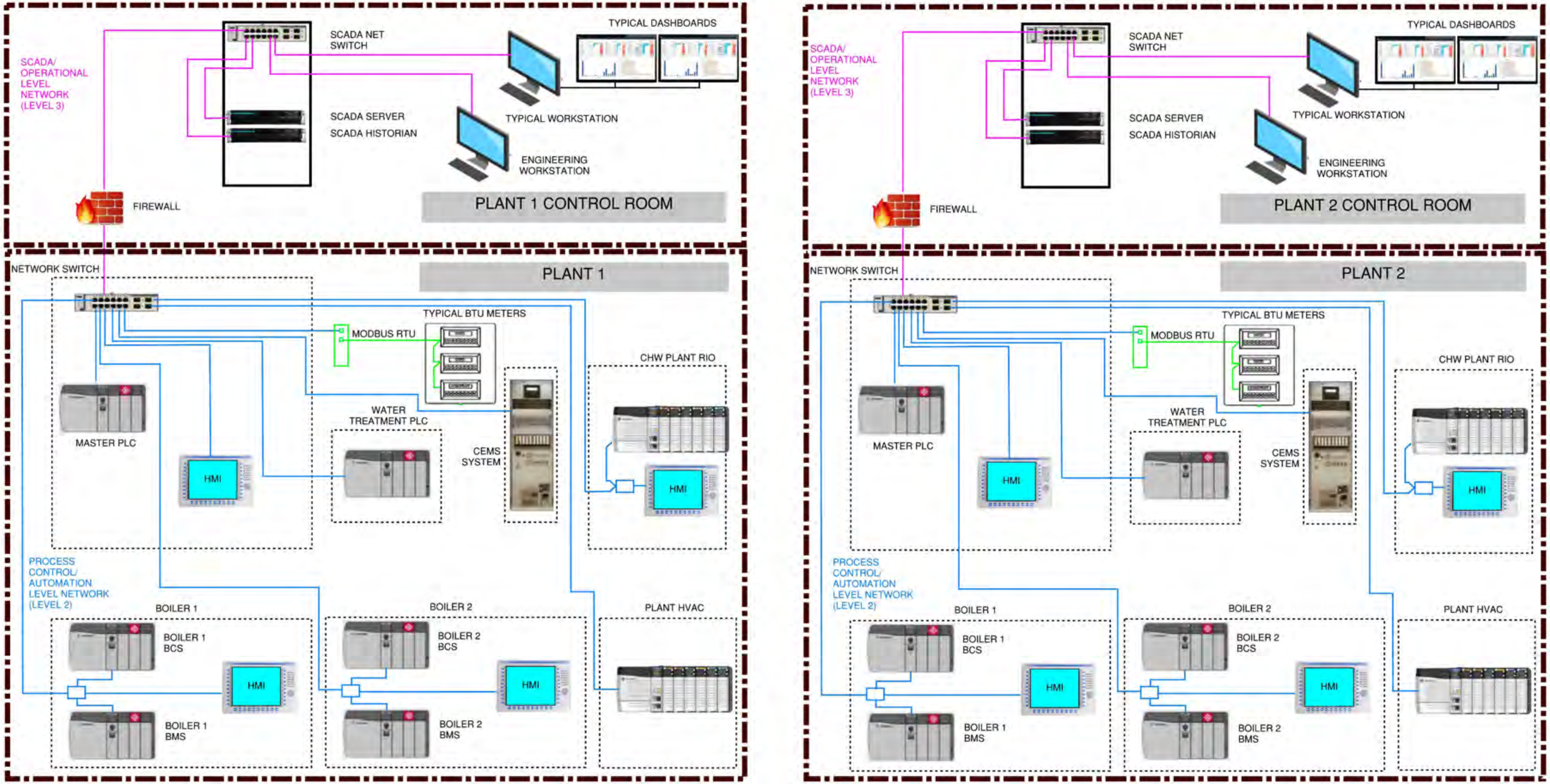
Tier 1 (Base) For a District Energy Plant Configuration

- Controls and SCADA powered from UPS (Distributed or Central).
- Wiring of systems is based on typical configuration.
- Resiliency is achieved by SOPs and manual operation of plant.
- Critical spare components kept in inventory.
- Proven operational sequences that have been commissioned.

Tier 2 (Better) For a District Energy Plant Configuration

SCADA/HMI SYSTEM

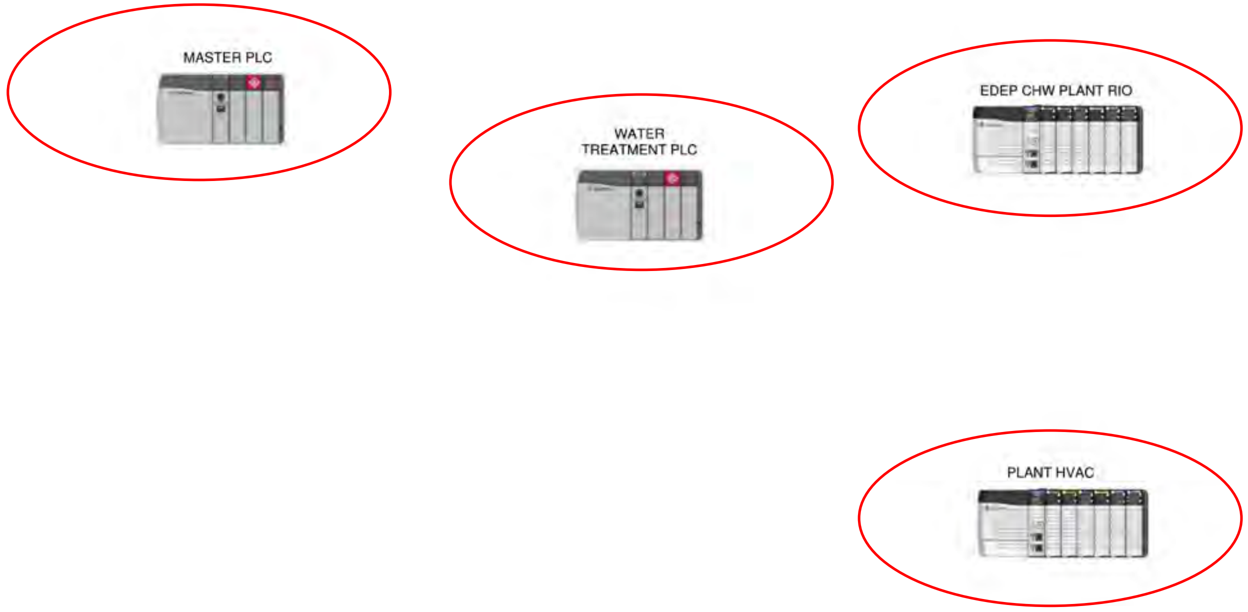
Process Control System (PCS)



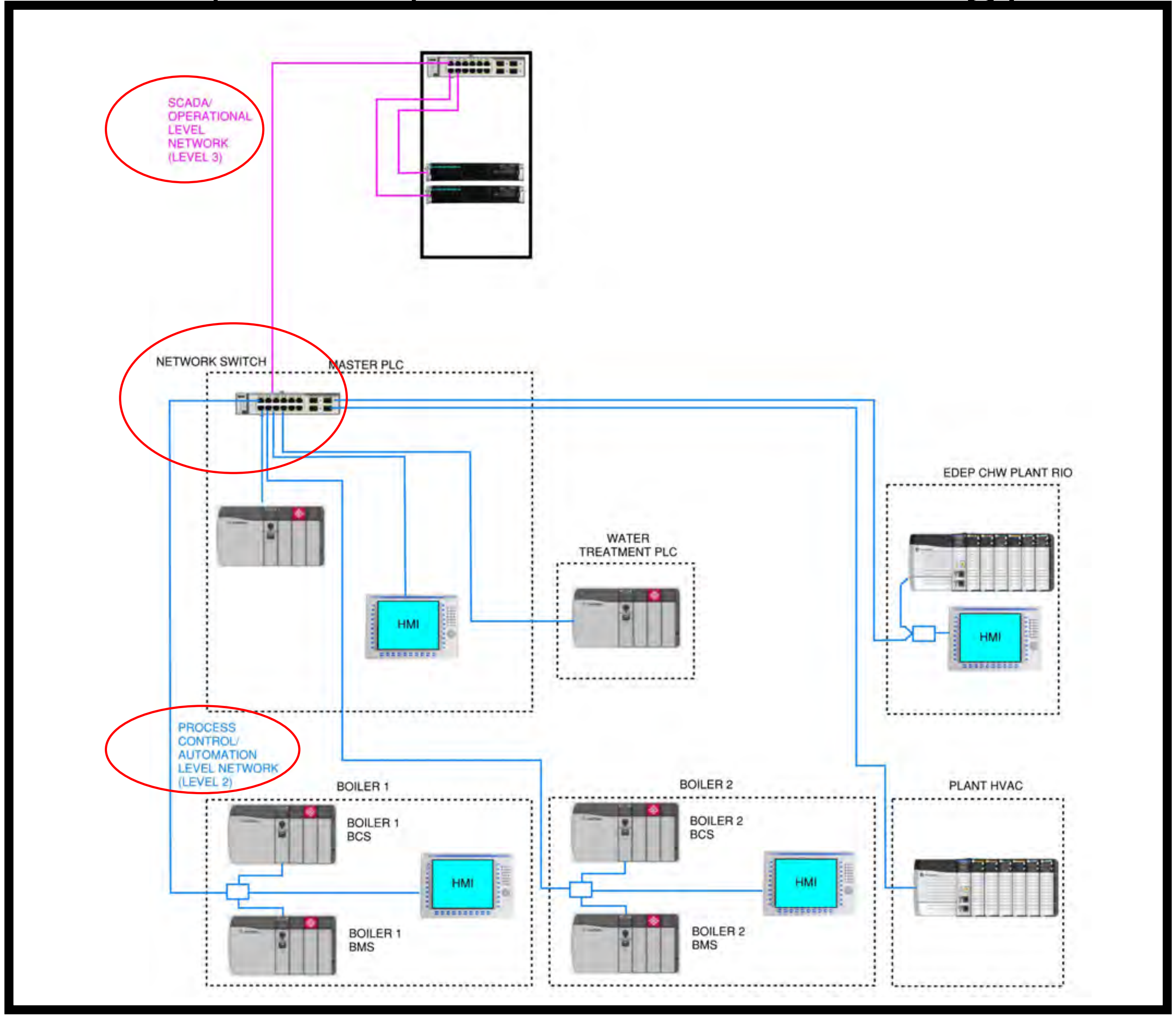
Tier 2 (Better) For a District Energy Plant Configuration

(Note: Many of the these items can be applied to BAS solutions also.)

- Industrial hardened controller (PLC or DCS based).



Tier 2 (Better) For a District Energy Plant Configuration



- Dedicated PCS and SCADA/HMI network that leverages Ethernet for higher communication speeds allowing for viewing data near real-time and trending data at higher speeds.

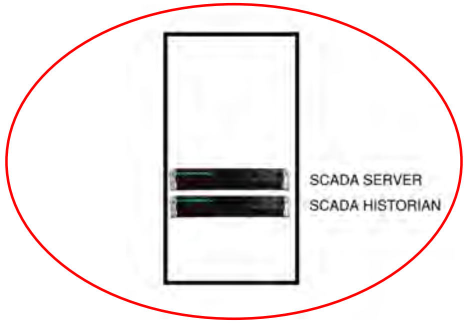
Tier 2 (Better) For a District Energy Plant Configuration

- IT protects SCADA and PCS through multiple firewalls.

Tier 2 (Better) For a District Energy Plant Configuration

- Distributed HMIs on the plant floor to run the plant in the event of a SCADA failure.

Tier 2 (Better) For a District Energy Plant Configuration

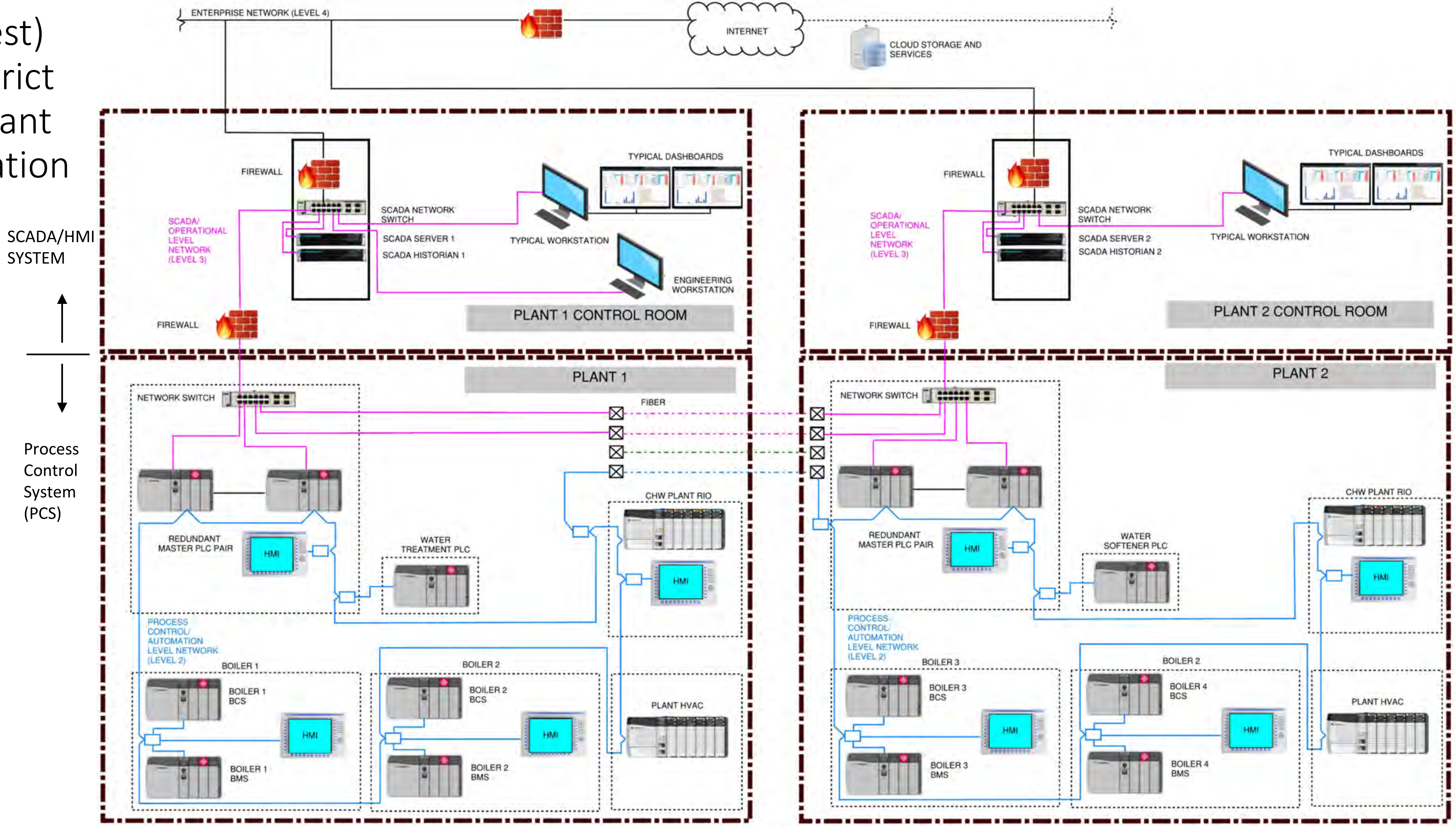


- Industrial grade SCADA/HMI system and historian integrates to standard industrial protocols (e.g. Ethernet IP, Profinet, Foundation Fieldbus, etc.).

Tier 2 (Better) For a District Energy Plant Configuration

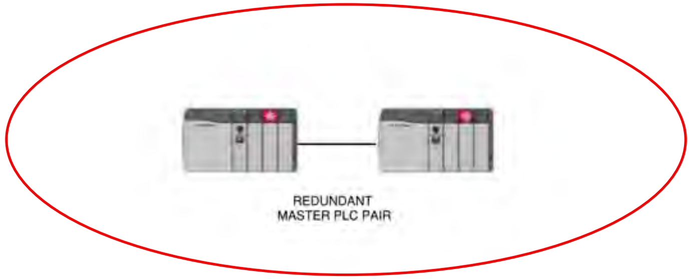
- Industrial grade instruments and devices for Process Control Systems (PCS). Redundant instruments on critical measurements, e.g. Boiler Header Pressure Control.
- Racks and I/O layout such that rack or I/O module does not shut down entire systems.
- Centralized UPS to power PCS and SCADA.
- Sequences that account for network or controller failures. All sequences commissioned.
- Manual operation of systems in the event of a major failure.
- Well documented systems utilizing industrial JIC wiring schematics and loop sheets.
- Single manufacturers platform for balance of plant controllers with large installation base.
- Critical spare components kept in inventory.
- Dedicated control room.
- SCADA system backed to a remote server for disaster recovery protocol.

Tier 3 (Best) For a District Energy Plant Configuration



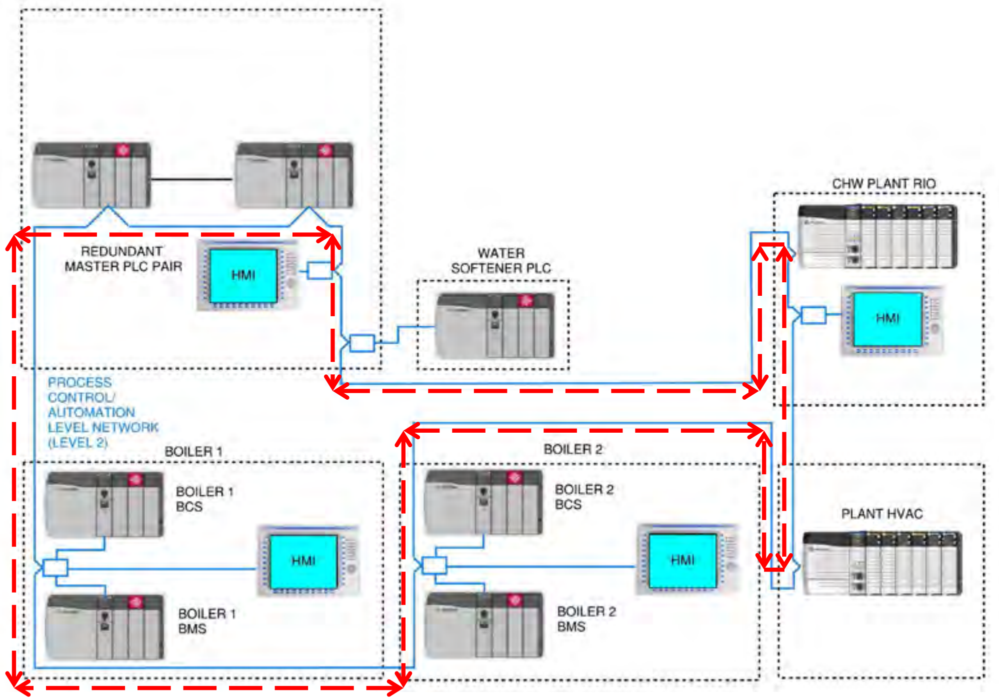
Tier 3 (Best) For a District Energy Plant Configuration

- Tier 2 plus the following:
- Redundant PLC or DCS Plant Master Controllers with redundant power supplies.



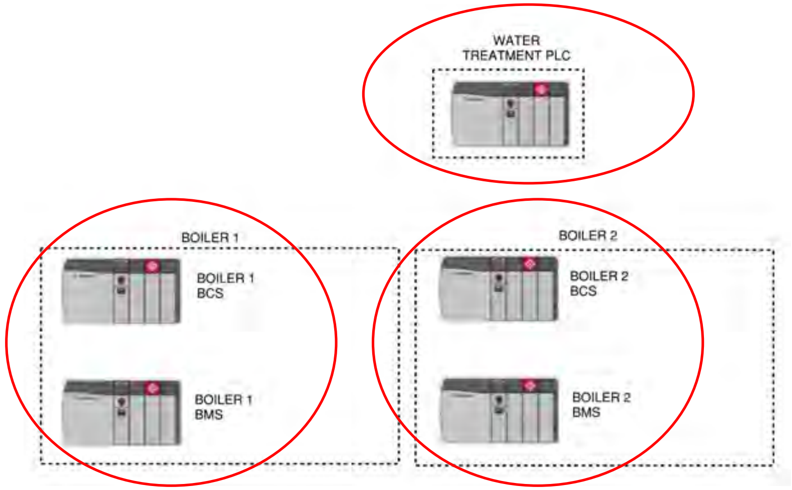
Tier 3 (Best) For a District Energy Plant Configuration

- Redundant ring PCS Ethernet Comm network for plant PCS PLCs.

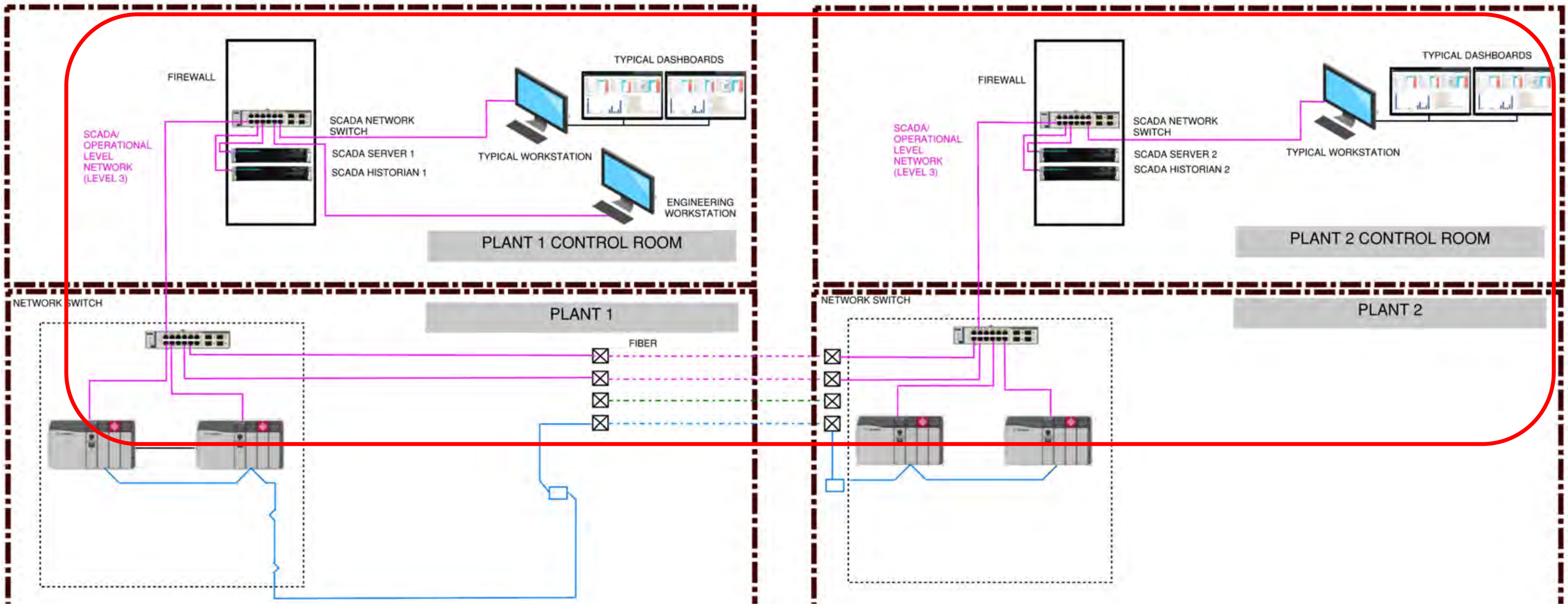


Tier 3 (Best) For a District Energy Plant Configuration

- All packaged equipment comes with industrial PLC controls with HMI (Boilers, chillers, fuel oil, etc.).



Tier 3 (Best) For a District Energy Plant Configuration



- Redundant SCADA network and SCADA Systems. Interconnect dedicated SCADA networks. Re-program for fail-over of SCADA/HMI. If Plant 1 SCADA fails, then automatically fail-over to Plant 2 SCADA (and vice versa).
- Redundant and dedicated fiber communications cable between plants for PCS and SCADA/HMI networks.

Tier 3 (Best) For a District Energy Plant Configuration

- SCADA system backed to cloud for analytics and disaster recovery.

Tier 3 (Best) For a District Energy Plant Configuration

- By interconnecting the systems you now make the infrastructure redundant.
- Dedicated control room with multiple monitors or video wall. Ability to control and monitor near real-time from any control room.
- All process control is managed by the PCS with local HMI. If SCADA/HMI system or network fails, then PCS can be operated from BOP at PCS level. Loss of SCADA/HMI is trending and historian only.

CU Boulder's Solution

CU Boulder's Solution

- Redundant balance of plant Allen Bradley PLCs.
- Equipment PLCs are ControlLogix PLCs networked together utilizing a dedicated fault tolerant Ethernet ring.
- SCADA system is on its own dedicated Ethernet redundant network protected by firewalls.
- Dedicated redundant fiber optic communication network that interconnects the plant process control systems to provide a hierarchical control scheme under normal conditions while providing reliable stand-alone operation whenever the network or master controller is unavailable.
- Interconnected SCADA/HMI system operating on local servers.
- Layers of operational redundancy were developed within the control system allowing the Master PLC to operate without the SCADA. e.g. distributed HMI at the PCS level, graphic standards identical for PCS HMI and SCADA/HMI, etc.
- Process/industrial instrumentation.
- Legacy System Integration.

Image of Redundant AB ControlLogix PLC

New Control Room

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Design Activities

- Detailed System Architecture and Network Design.
- P&ID Coordination.
- Tagging.
- Point List.
- Sequences.
- Specifications (Include Balance of Plant and Equipment).
- MEP Coordination.

Lessons Learned

- Contractors familiar with industrial/process controls.
- Contractors familiar with detailed tagging and labeling methods.
- Attention to detail in project execution.
- Documentation.

Questions

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