Power Plant Relay Replacement Project

ISU Senior Design Group: DEC15-22

By Dan Dye

Project Sponsor: CIPCO

Project Advisor: Professor Mani Mina

Website: http://dec1522.sd.ece.iastate.edu/

Team and Client Information

- Designer: Dan Dye
- Project Sponsor: Terry Fett, Manager of Engineering
- Advisor: Mani Mina
- Client: CIPCO (Central Iowa Power Cooperative)
  - Generation and Transmission Company
  - Provide power to 13 rural electric cooperatives and associations
  - Spanning 58 counties across Iowa's 99 counties
  - Locations in Cedar Rapids, Creston, Des Monies and Wilton

Agenda

- Project Overview
- Definitions
- Current Design
- Design Process
- Challenges
- Demo

Project Overview

Problem Statement

Due to age, condition, and safety concerns:

- Relay replacement
- Arc flash calculations
- Two engineering solutions to operate metal clad switchgear safely

Project Goals

- Produce for-construction design drawings to complete the replacement of four power plant relays
- Produce arc flash calculations and analysis for the existing metal clad switchgear.
- Identify two engineering solutions to operate the switchgear safely.

Functional Requirements

- There will be no physical deliverables to test the functionality of the design
- The project will be designed to meet the following:
  - Industry standards
  - CIPCO CAD and design standards
  - Regulatory and compliance standards
- Formal review completed by the Project Sponsor and Health and Safety Manager:
  - The design meets all requirements and regulations
  - Will function as needed after implementation

Deliverables

- Relay Replacement
  - For construction package
    - Project paper work
    - Bill of material
    - Construction drawings
  - Cost estimates
  - Relay functions

Deliverables

- Arc Flash
  - Calculation per OSHA standard
  - Calculation analysis
- Safe Operation of Metal Clad Switchgear
  - Identified two possible engineering solutions
  - Bill of material
  - Cost estimates
  - Operation guides
  - Evaluation of solutions

Excluded From the Project

- Design simulation and testing
- Relay settings and testing

Definition

Metal Clad Switchgear

Is a combination of electrical disconnect switches and circuit breakers enclosed in a grounded metal compartment. These are used in power system to control, protect and isolate electrical equipment. These are used to both de-energize equipment to allow work to be completed and to clear faults downstream.

CIPEC

Definition

Protective Relay

A protective relay is a device designed to trip a circuit breaker when a fault or other undesirable operation conditions are detected. The original protective relays were electromechanical devices that relied on coils and moving parts to provide detection of abnormal operation conditions. Microprocessor-based protective relays use software base protection algorithms for detection of electrical faults.


2


SEL-351A
DISTRIBUTION PROTECTION SYSTEM
SEL
SCHWEITZER ENGINEERING LABORATORIES
4

Definition

Arc Flash

Is a flashover of electric current where it leaves its intended path and travels through the air from one conductor to another, or to ground.

Causes, Results, Injury factors

Arc Flash Video

Definition

OSHA (Occupational Safety & Health Administration)

OSHA was created in 1970 by Congress to assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance. There web site can be found at: www.osha.gov

Definition

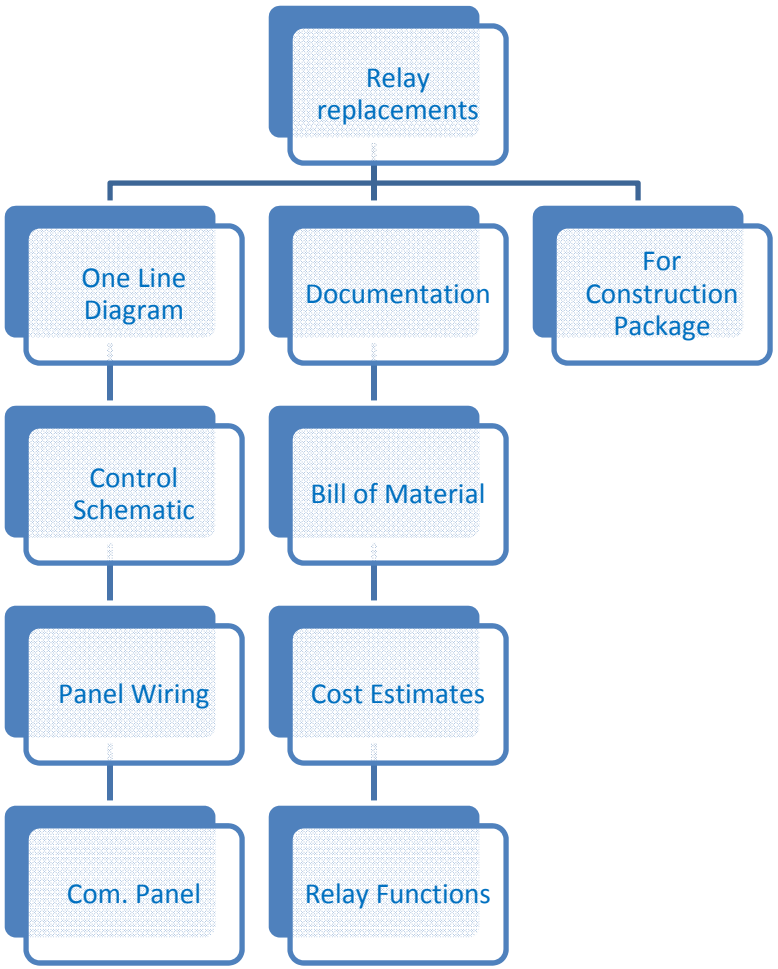
MAD (minimum approach distance)

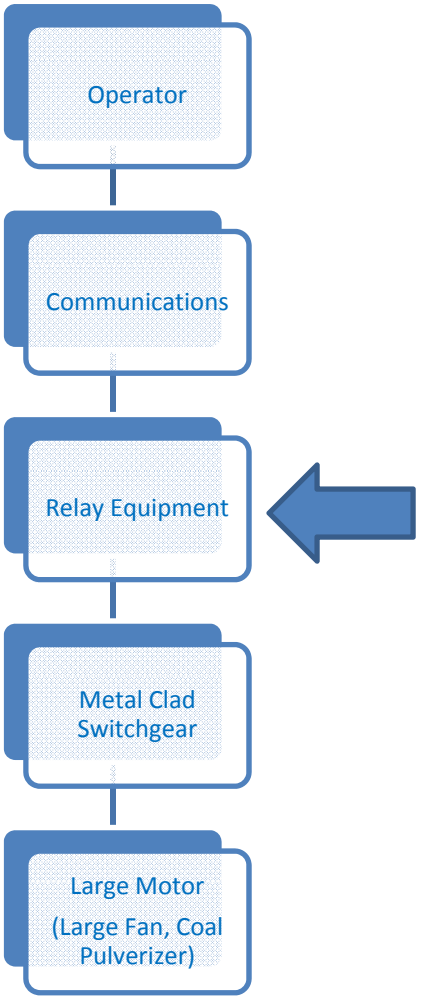
OSHA defines MAD in standard table R-6 1910.268 as the minimum approach distance that must be maintained, based on voltage involved, for unprotected qualified employees when exposed to energized equipment.

Current Design

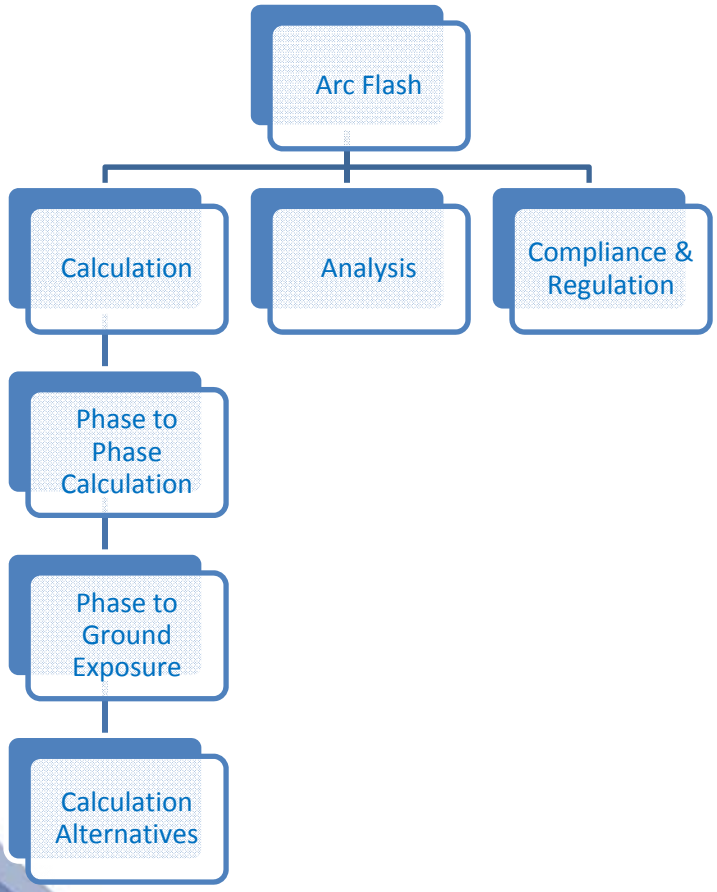
CIPCO employees Dan Dye and Craig Timson checking substation equipment ratings at Bertram substation.

Current Design – Relay Replacement





Current Design – Arc Flash



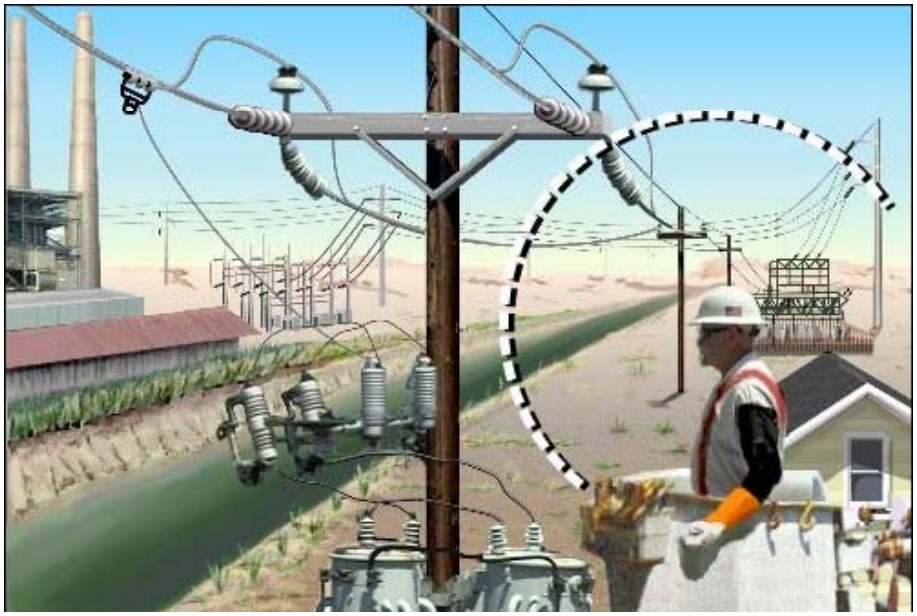
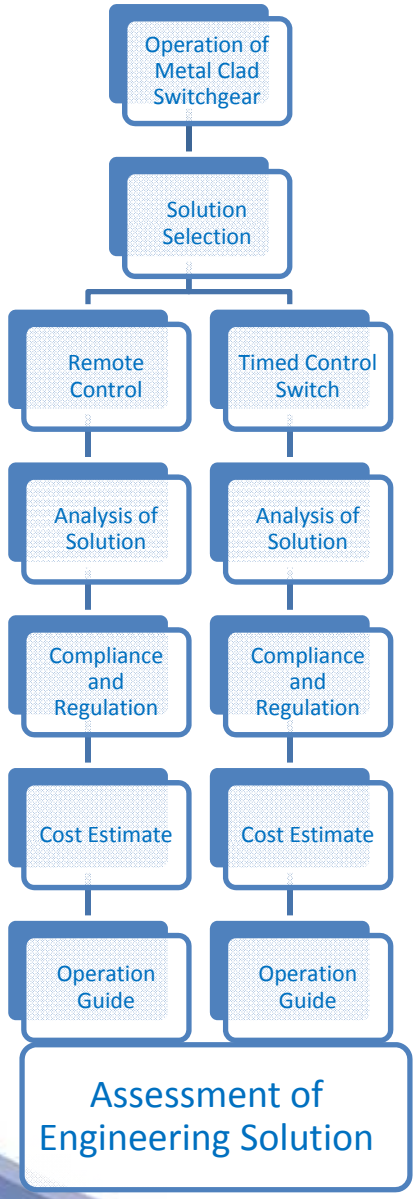


Figure 1
www.osha/sltc/etools/electricpower

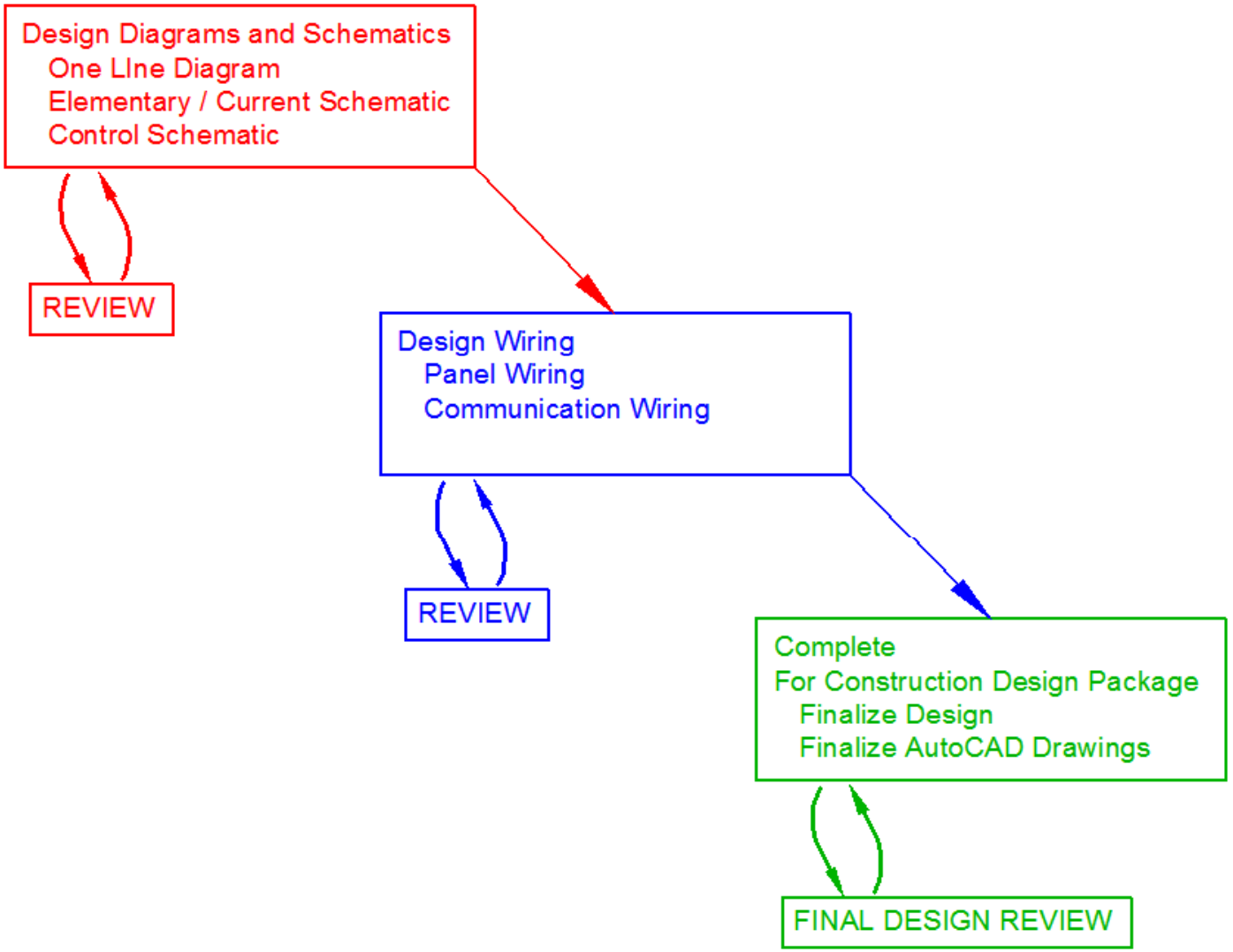
Current Design – Safe Operation



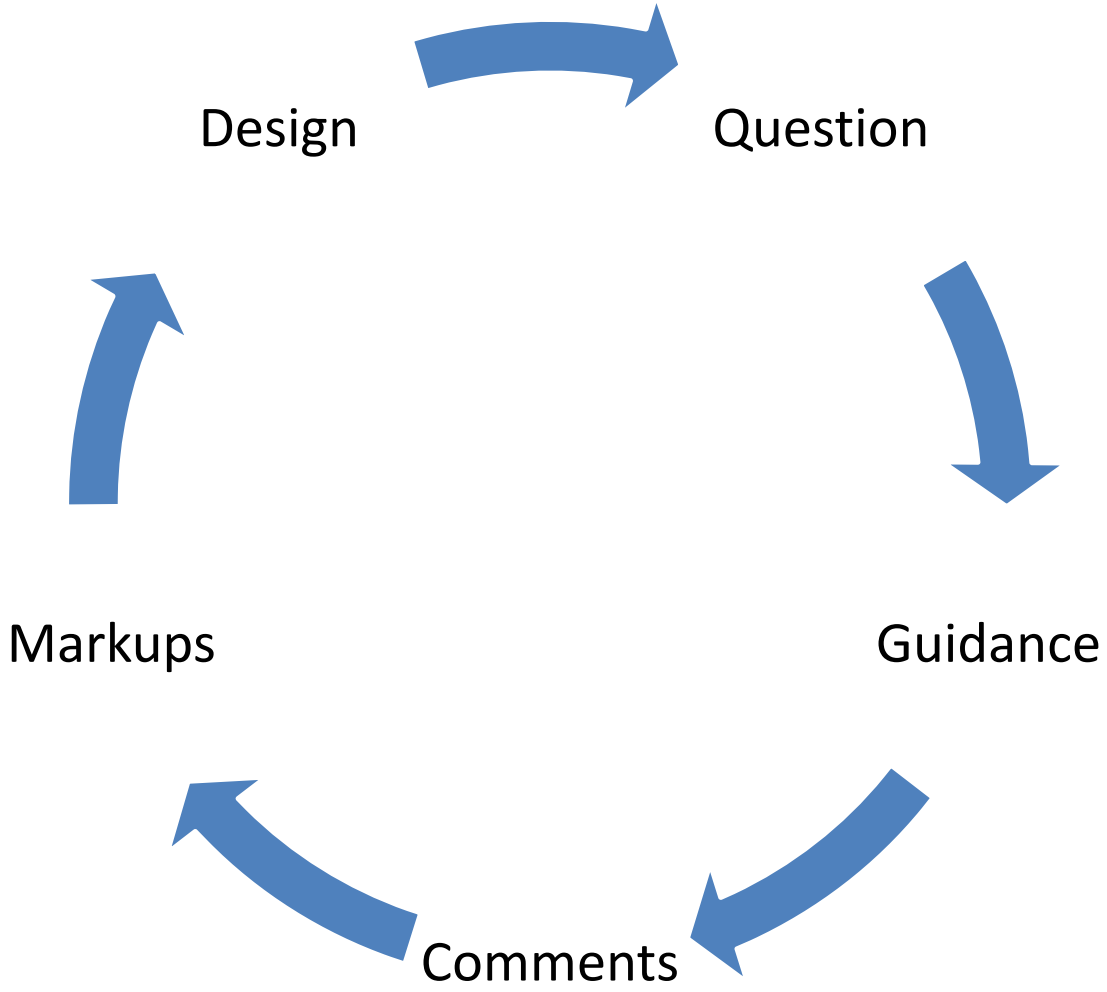
Electroswitch (TD-CSR)

SEL-351

Design Process



Design Process



System Design & Functional Decomposition

CIPCO

System Level Design – Relay Replacement

- Relay replacements on 4 sets of metal clad switchgear on panel units 6,7,8, and 9.
- Relays will be replaced with SEL 351 relays.

- Design Challenges

System Level Design – Arc Flash Calculations

- Arc Fault calculations will follow
  - OSHA 29 CFR 1910.269 standard
- CIPCO standards

- Design Challenges

System Level Design – Safe Operation

- Two engineered safety solutions to operate existing switchgear
- Follow compliance and CIPCO standards

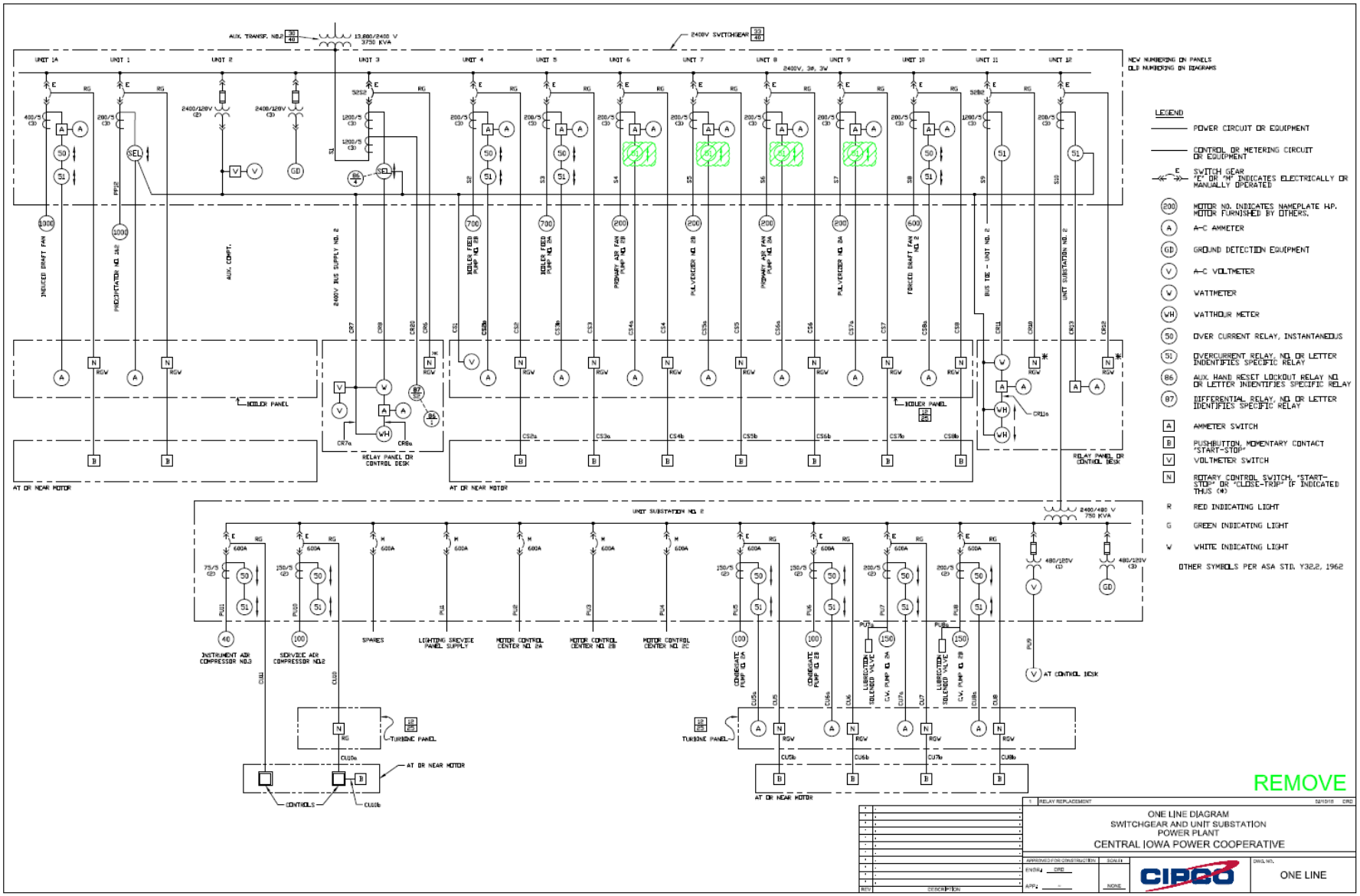
- Design Challenges

Detail Design

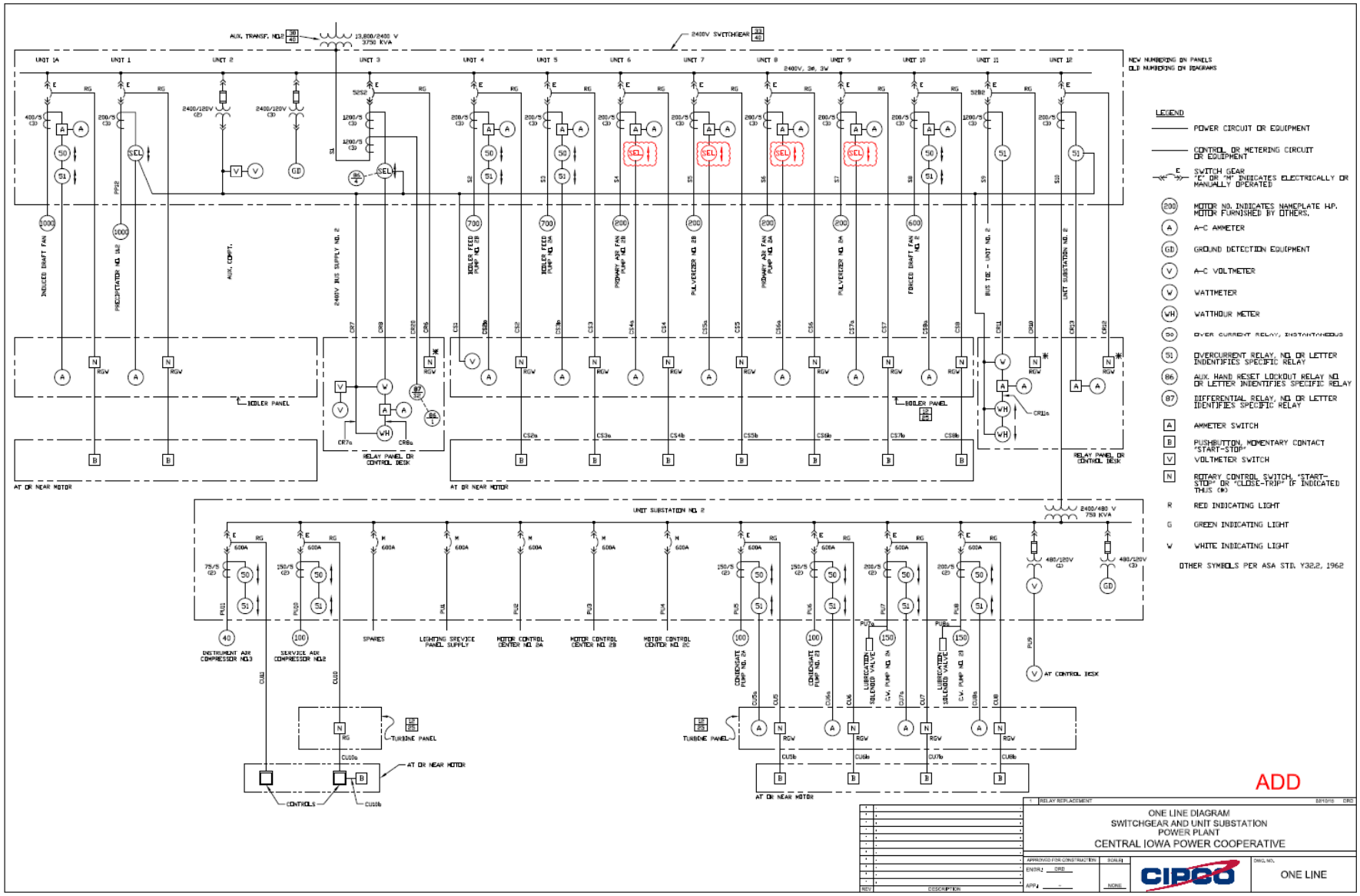
- System Inputs
  - AC line currents and bus voltages
  - 125 VDC to power relay, alarms, and switchgear status
- System Outputs
  - Switchgear trip and close, relay alarm, and communications
- Testing and Procedures
  - No equipment testing or simulations
  - Engineering drawings are heavily reviewed

Demo

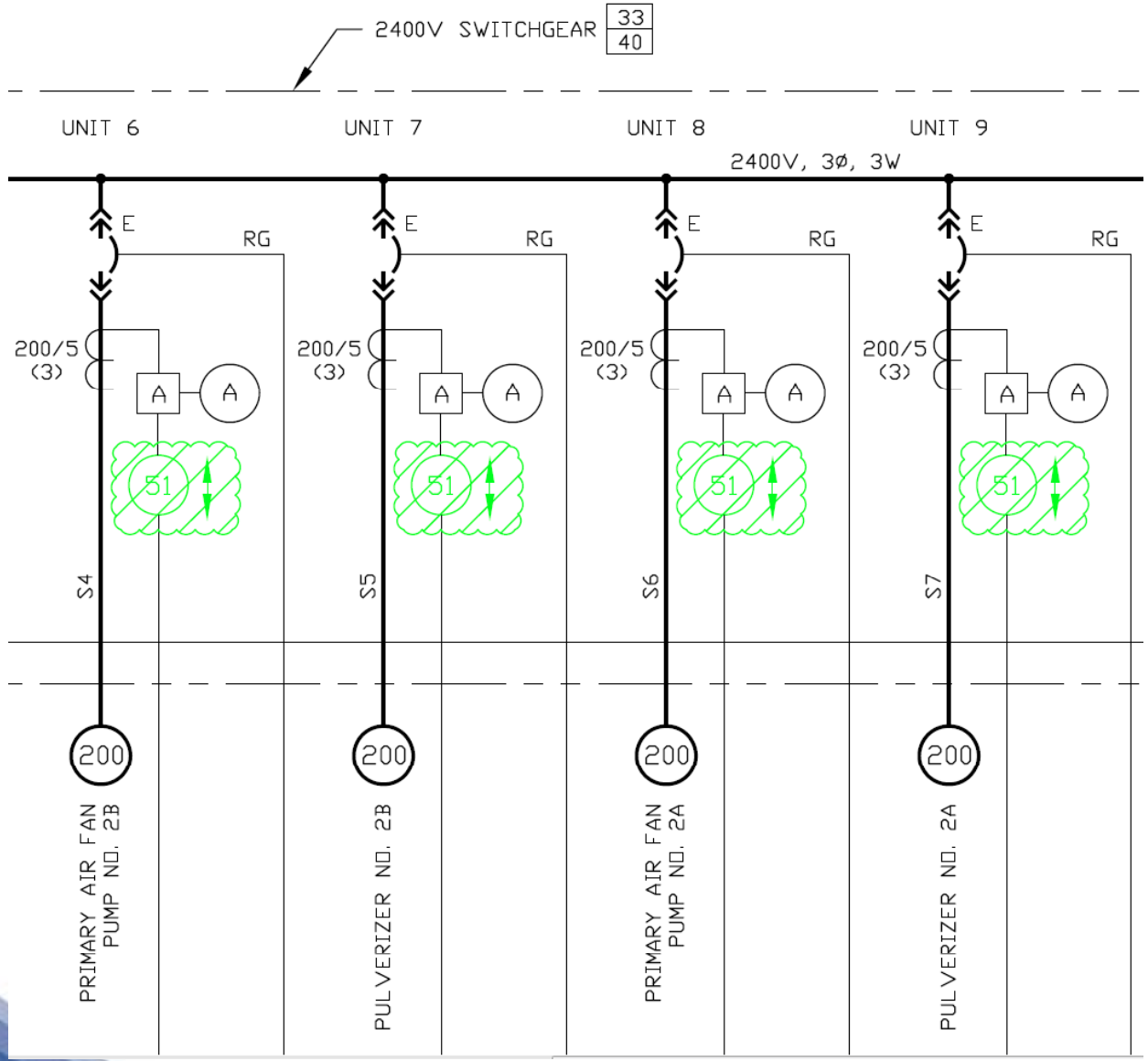
Demo – One Line



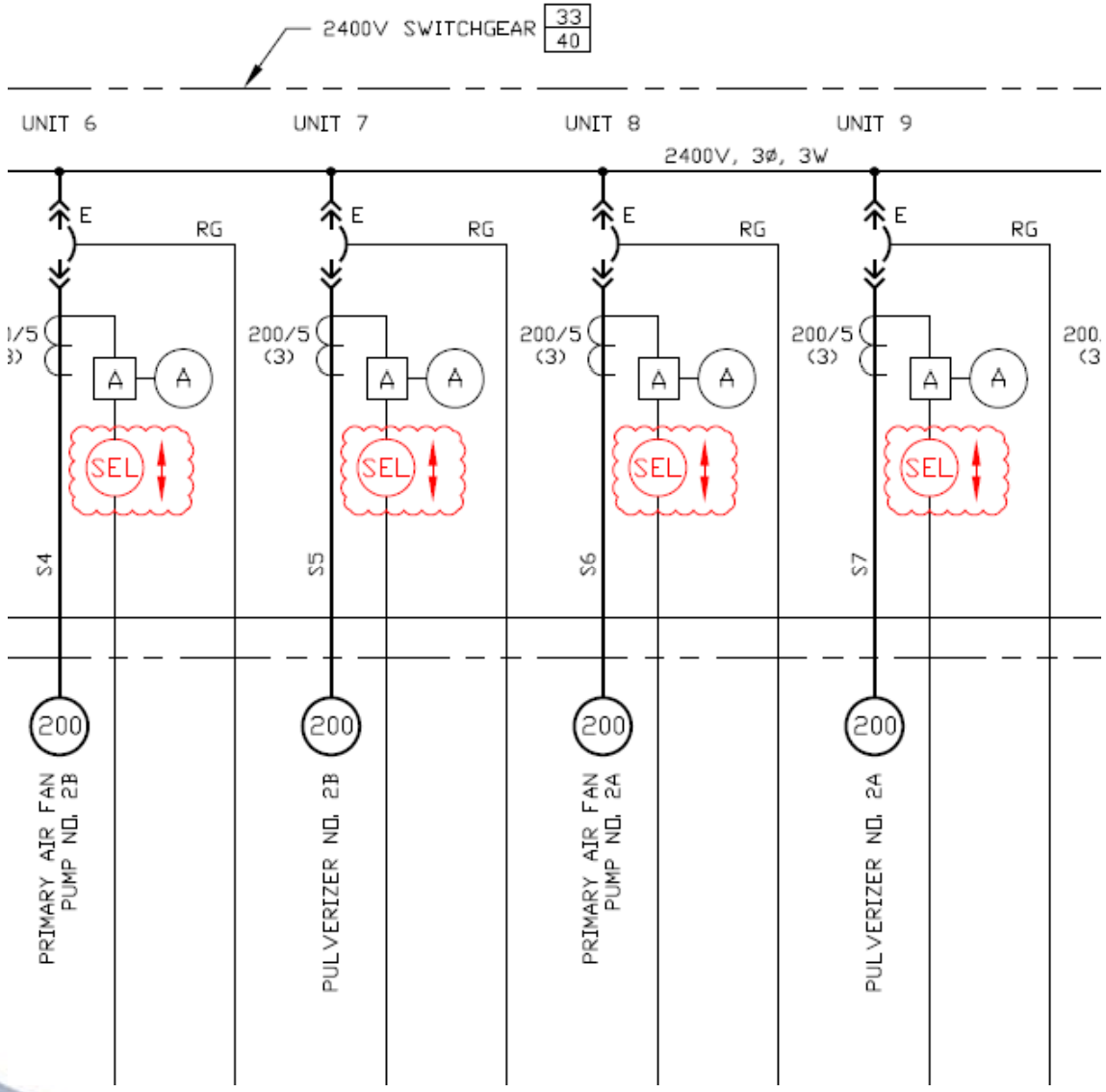
Demo – One Line



Demo – One Line

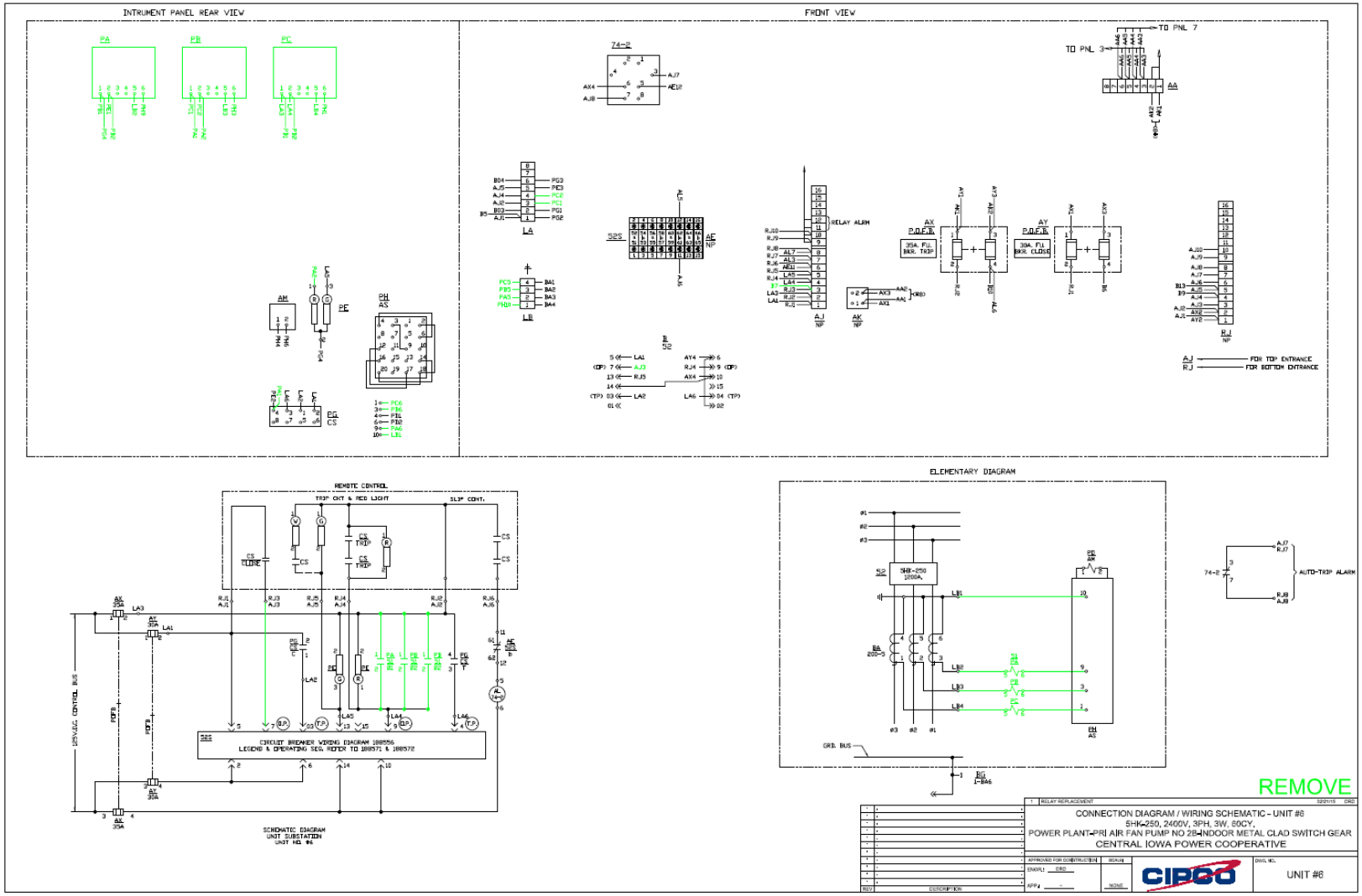


Demo – One Line

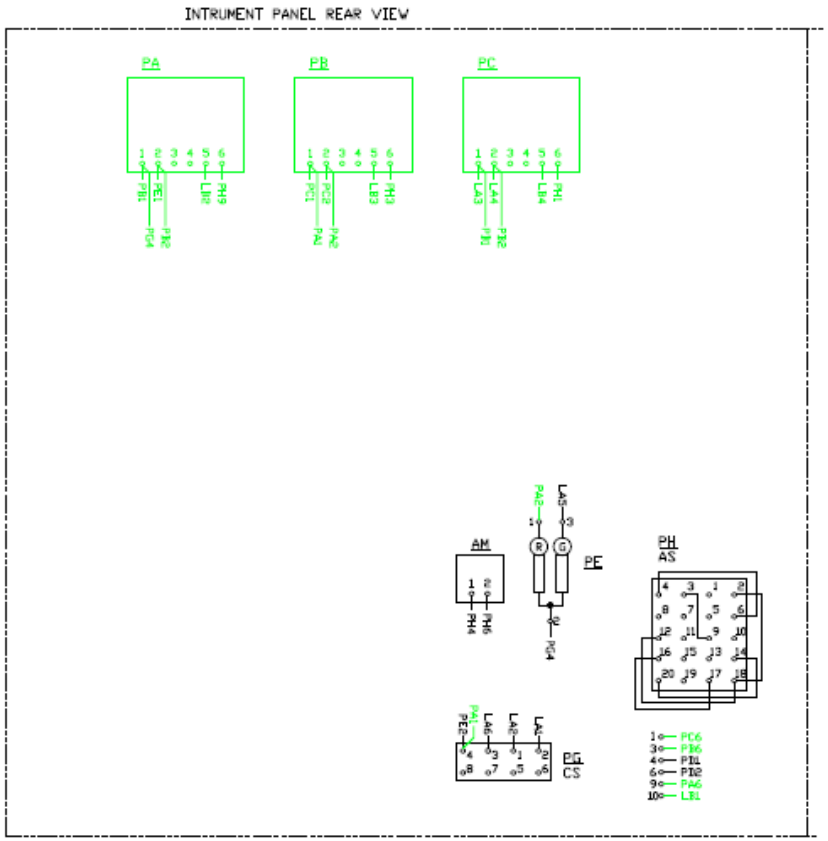


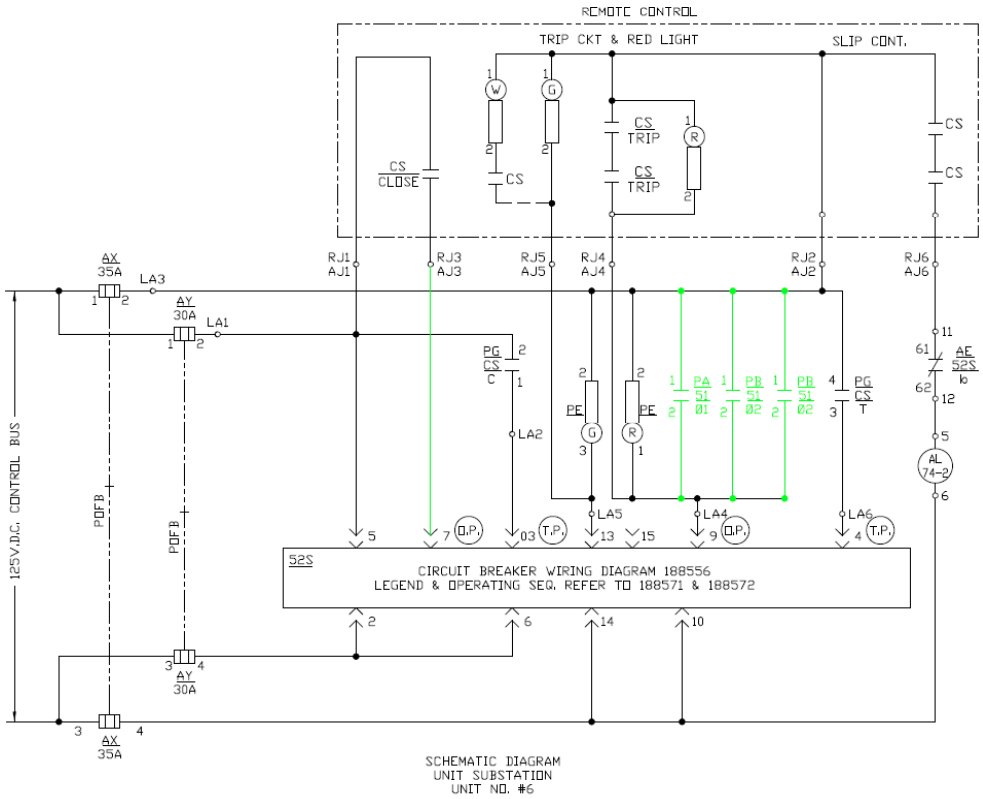
Demo – Connection Diagram / Wiring Schematic

POWER PLANT - RELAY REPLACEMENT

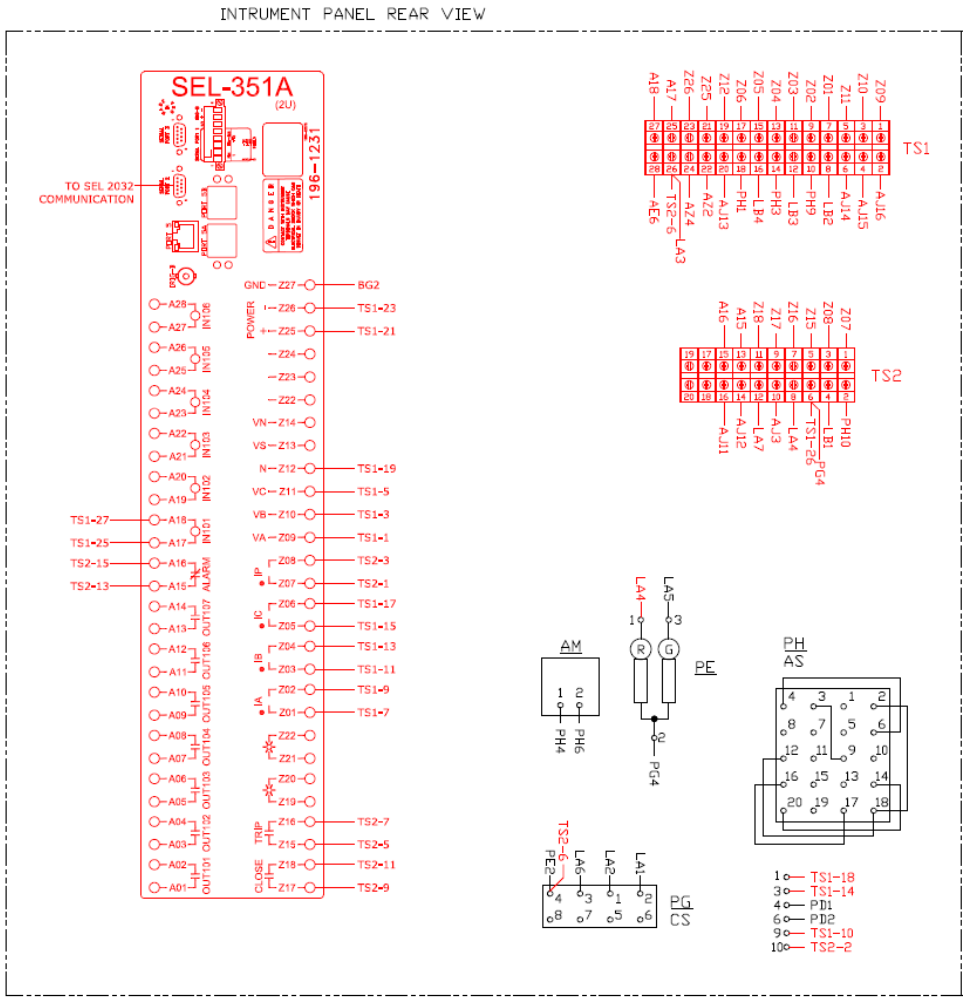


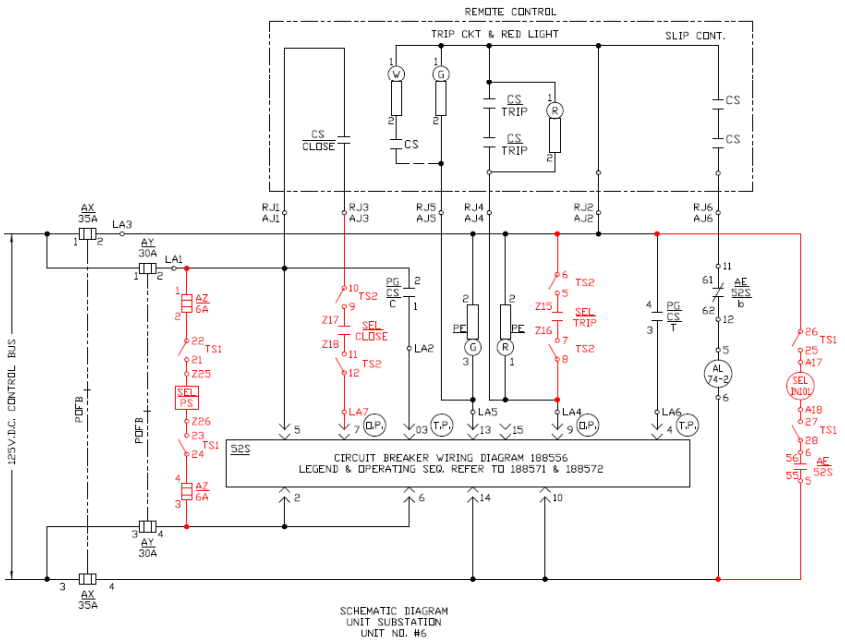
Demo – Connection Diagram / Wiring Schematic



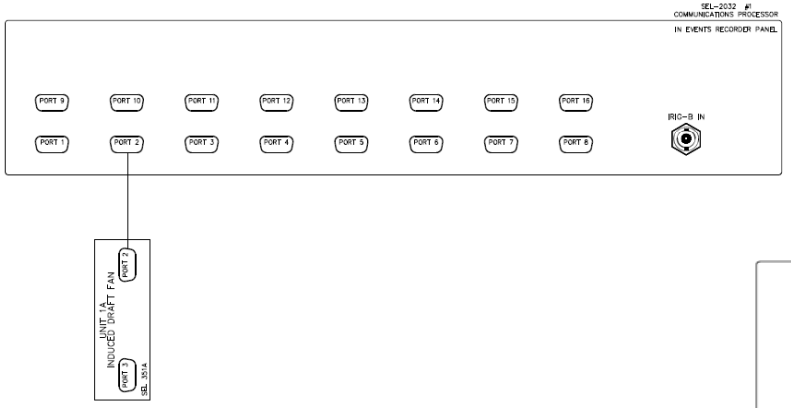


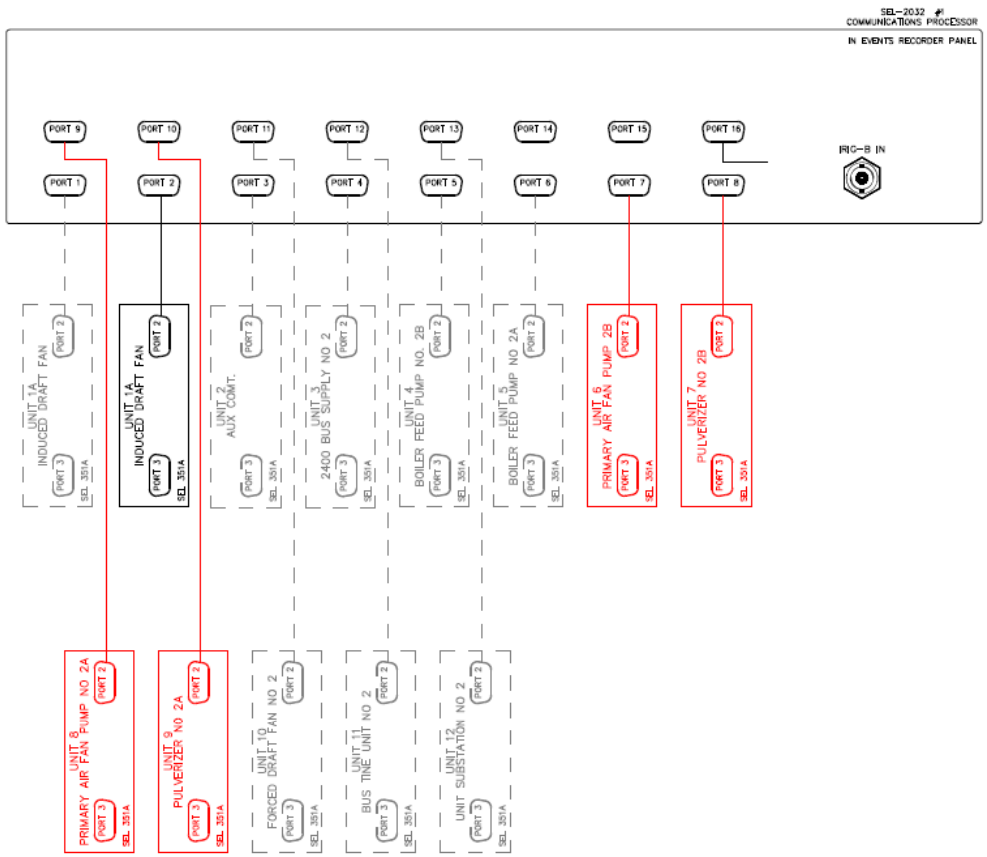
Demo – Connection Diagram / Wiring Schematic





Demo – Communication Schematic





CIPCO

Demo – Relay Functions

- Overcurrent protection
- Fault detection
- Ground time-overcurrent elements
- Over/under frequency elements
- Measure and record MW, MVAR, MWh, MVARh, Power Factor, instantaneous and/or peak demand

Demo – Arc Flash

- MAD – Minimum Approach Distance
  - Defined by OSHA and is a minimum approach distance that must be maintained while being exposed to energized parts.
  - Based on voltage
  - Sets the standard for working around energized equipment

Demo – Arc Flash

- Phase to Phase Calculation - OSHA Table R-3-AC Live-Line
  - For voltages under 72.5kV the minimum approach distance is) = M + D = 0.02 + 0.61 = 0.63 Meters (2.07 feet)

- Phase to Ground Calculation - OSHA Table R-6 Alternative Approach Distance
  - For voltage 750 – 5k VAC = 0.63 Meters (2.07 feet)

Demo – Arc Flash

- MAD is 2.07 feet
  - Minimum for being compliant
  - Most companies will be more conservative
    - CIPCO tries to complete all work on de-energized equipment
  - Work can be completed inside the MAD
    - They have to have the correct training
    - Level of FR and PPE

Demo – Safe Operation Solutions

- Two solutions were identified
  - Remote control using the new relay equipment
  - Timed control switch
- Each solution had pros and cons

Project Cost Estimate

PROJECT COST ESTIMATE
Power Plant - Relay Replacement

Required Material					
Material Description	**Manufacturer**	**Model**	**Qty**	**Unit Cost**	**Total**
Microprocessor relay	SEL	351A	4	$2,380.00	$9,520.00
Test switch 10 position	ABB	129A501G01	4	$56.00	$224.00
Test switch 14 position	ABB	129A514G01-6C	4	$64.00	$256.00
6 Amp fuse, 600V, medium time lag	Littelfuse	G-Class	8	$7.00	$56.00
Fuse holder - 2 pole - panel mount	Square D	9080FB2	4	$12.00	$48.00
Communication cable	MonoPrice	CAT6	4x500'	$0.094	$188.000
				sub total	$10,292.00

Optional Equipment					
Fiber-Optic transceiver/modem	SEL	2800	8	$102.00	$816.00
Fiber-Optic cable	SEL		4x500'	$1.98	$3,960.00
(for communication line interference)				**sub total**	$4,776.00
Control switch with time delay	Electroswitch	TD-CSR	4	$1,573.00	$6,292.00
(Arc flash safety switch option)				**sub total**	$6,292.00

Installation Cost				
Labor Description	Hours per Unit	Hours for 4 units	Cost per Hour	Total Cost
Relay installation	8	32	$160.00	$5,120.00
Checkout and testing	3	12	$160.00	$1,920.00
			sub total	$7,040.00

Optional Equipment Installation Cost				
Control Switch with time delay	1	4	$160.00	$640.00
(Arc flash safety switch option)			**sub total**	$640.00

TOTAL COST	
Standard Equipment option - Total	**$17,332.00**
Fiber-Optic Cable option - Total	**$21,920.00**
Arc Flash and Fiber-Optic Cable option - Total	**$28,852.00**

Demo – Safe Operation Solutions

- The assessment of the engineering solutions
  - Cost
  - Learning curve of equipment and training
  - How it would be operated (per basic operation guides)

Bring It Together

- The new relay equipment protects the heavy motors and fans by operating the switchgear under fault conditions
- The SEL relay will be used to remotely operate the switchgear keeping people out of harms way
- Arc Flash calculations help identify hazards and to help keep people out of the MAD.

SAFETY

Questions