



## POWER PLANT – RELAY REPLACEMENT



ISU Senior Design Group: Dec15-22

Dan Dye

Project Web Site:

<http://dec1522.sd.ece.iastate.edu/>

Project Sponsor: CIPCO

Project Advisor: Professor Mani Mina

## Table of Contents

1.	PROBLEM STATEMENT .....	4
2.	GOALS .....	4
3.	PROJECT SCOPE .....	4
3.1.	RELAY REPLACEMENT .....	4
3.2.	ARC FLASH CALCULATIONS AND ANALYSIS .....	4
3.3.	SAFE OPERATION OF METAL CLAD SWITCH GEAR .....	5
4.	EXCLUDED FROM PROJECT .....	5
4.1.	DESIGN SIMULATION AND TESTING.....	5
4.2.	RELAY SETTINGS .....	5
4.3.	RELAY TESTING.....	5
5.	PROJECT REQUIREMENTS .....	5
5.1.	SPRING SEMESTER 2015 DELIVERABLES .....	5
5.1.1.	RELAY REPLACEMENT DESIGN .....	5
5.1.2.	ARC FLASH CALCULATION.....	5
5.1.3.	SAFE OPERATION OF METAL CLAD SWITCH GEAR .....	6
5.2.	FALL SEMESTER 2015 DELIVERABLES.....	6
5.2.1.	RELAY REPLACEMENT DESIGN.....	6
5.2.2.	ARC FLASH ANALYSIS .....	6
5.2.3.	SAFETY OPERATION SOLUTIONS.....	6
5.3.	Function Requirements .....	6
5.4.	Non-Functional Requirements .....	7
6.	ASSESSMENT OF PROPOSED SOLUTION.....	7
6.1.	Relay Replacement .....	7
6.2.	Arc Flash.....	7
6.3.	Safety Operation .....	7
7.	VALIDATION & ACCEPTANCE TEST .....	7
8.	TECHNICAL APPROACH.....	8
8.1.	Design Specifications.....	8
8.1.1.	Operating Environment.....	8
8.1.2.	Compliance Standards.....	8
8.1.3.	Standards.....	8
9.	PROCESS DETAILS.....	9

9.1.	System input/output Analysis .....	9
9.1.1.	System Inputs.....	9
9.1.2.	System Outputs .....	9
9.2.	User Interface Specifications .....	9
9.3.	Hardware/software Specifications .....	9
9.4.	Simulations and Modeling .....	9
9.5.	Implementation Issues Challenges.....	10
9.6.	Testing, Procedures and Specifications .....	10
10.	TEST PLAN.....	10
11.	PROJECT SCHEDULE.....	12
12.	RISK / FEASIBILITY ASSESSMENT.....	12
12.1.	RISK ITEMS .....	12
12.2.	FEASIBILITY ASSESSMENT .....	13
13.	COST CONSIDERATION.....	13
14.	MARKET/LITERATURE SURVEY .....	13
15.	CONCLUSION.....	13

### Figures and Diagrams:

Figure 1: REVIEW PROCESS BLOCK DIAGRAM.....	11
---	----

### Tables:

Table 1: PROJECT SCHEDULE GANTT CHART.....	12
--	----

## 1. PROBLEM STATEMENT

There are three main parts to this project. First, due to age and condition the existing power plant electro-mechanical relay equipment will be retired and new microprocessor based relaying equipment will be installed. The senior design project will be responsible for the complete design of the relay replacement which includes all required schematics and wiring diagrams.

Second, the senior design project will complete arc flash calculations and analysis for the existing metal clad switch gear. Metal clad switch gear has been known in the industry to have a high potential for arc flash issues. Determining the potential of these issues allows the operator to be aware of the proper amount of precaution and personal protective equipment.

Third, the senior design project will provide engineering solutions to operate the switch gear safely. By researching alternative and analysis of the potential of arc flash, engineering solutions shall be provided to advise in choosing the proper safety precautions during operations.

## 2. GOALS

The goal of this project is to produce a 100% complete:

- For-construction drawing set to complete the replacement of four power plant electromechanical relays with microprocessor based SEL relays.
- Arc flash calculations and analysis for the existing metal clad switch gear.
- Two engineering solutions to operate the switch gear safely.

All goals are to be completed on time, under budget, and with emphasis on CIPCO cultural priorities of safety, reliability, and compliance.

## 3. PROJECT SCOPE

### 3.1. RELAY REPLACEMENT

The primary goal of this project is to replace four power plant electromechanical relays with microprocessor based SEL relays. A full set of for-construction drawings will be completed showing the remove and addition of equipment and wiring, including communication equipment. The drawings will be completed using existing drawings while following CIPCO drafting standards and design templates. Relay functions for this situation will be identified and described.

### 3.2. ARC FLASH CALCULATIONS AND ANALYSIS

The second part of this project is to complete arc flash calculations and analysis. These will be used to show the potential of an arc flash on metal clad switch gears which are controlled by the relay equipment that will be replaced.

### 3.3. SAFE OPERATION OF METAL CLAD SWITCH GEAR

Metal clad switch gear have an industry history of arc flash safety problems during operation. The third part of this project will be to identify two engineering solutions to operate the metal clad switch gear and relay equipment safely. Cost estimates and benefits of both solutions will be reviewed.

## 4. EXCLUDED FROM PROJECT

### 4.1. DESIGN SIMULATION AND TESTING

While all due diligence will be given during the design of this project, simulation and testing will not be completed as part of this project. Verification of design documentation will be completed during design review meetings with CIPCO.

### 4.2. RELAY SETTINGS

Relay settings will not be included as part of the relay replacement. Identification of suggested relay functions will be included.

### 4.3. RELAY TESTING

Microprocessor based relays require very precise testing due to the amount of features and internal programming. Relay tests or system check out procedure will not be provided as part of this senior design project.

## 5. PROJECT REQUIREMENTS

The following list of requirements was established with CIPCO and in accordance with CIPCO document "Project Scope" included under section design documents. The template for the CIPCO Project Scope was provided by CIPCO.

### 5.1. SPRING SEMESTER 2015 DELIVERABLES

#### 5.1.1. RELAY REPLACEMENT DESIGN

- Relay one line diagram
- Elementary diagram / current schematic
- Control schematic
- Panel wiring
- Communication processor wiring
- Drafting and review

#### 5.1.2. ARC FLASH CALCULATION

- Calculation per O.S.H.A. (Occupational Safety & Health Administration)

### 5.1.3. SAFE OPERATION OF METAL CLAD SWITCH GEAR

- Research and identify two possible engineering solutions
- Pros and Cons of both solutions

## 5.2. FALL SEMESTER 2015 DELIVERABLES

### 5.2.1. RELAY REPLACEMENT DESIGN

- For construction package
- Bill of material
- Cost estimates
- Relay functions

### 5.2.2. ARC FLASH ANALYSIS

- Calculation analysis
- Compliance regulations

### 5.2.3. SAFETY OPERATION SOLUTIONS

- Compliance regulation
- Cost estimates
- Operation guides

## 5.3. FUNCTIONAL REQUIREMENTS

Due to the inherent properties of this project, there will be no physical deliverables. The project requirements are for proper design of a relay replacement, calculation and analysis of arc flash potential, and two engineering solutions to operate the switchgear safely. With this being said the following are considered functional requirements of this design project:

- Development of engineering for construction drawing package in AutoCAD format for relay replacement including the following:
  - Relay one line diagram
  - Elementary diagram / current schematic
  - Control schematic
  - Panel wiring
  - Communication processor wiring
  - All required drafted
  - Proposed relay functions
- Arc flash calculations and analysis
  - Per OSHA standard 29 CFR 1910.269
  - Calculation analysis and safety recommendations
- Safe operation of metal clad switch gear
  - Two possible engineering solutions to safely operated switchgear

- Analysis of compliance regulation
- Cost estimates
- Operations guides for solutions

#### **5.4. NON-FUNCTIONAL REQUIREMENTS**

Due to this project being a design without implantation, there are no non-functional requirements. This is primarily due to the project exceptions of relay modeling and testing. The project will be designed to meet all standards to insure the equipment will function as required when installed and tested. The functionality and relay settings will be tested at installation and is out of scope for this project.

### **6. ASSESSMENT OF PROPOSED SOLUTION**

The solution to the proposed requirements will be a team effort between CIPCO and the design team. Strengths, weakness, and tradeoffs will be identified for each part of the project.

#### **6.1. RELAY REPLACEMENT**

The relay replacement must follow strict guild lines and compliance standards limiting the diversity of design solutions.

#### **6.2. ARC FLASH**

Similarly, the arc flash calculation and analysis must follow strict guidelines and compliance standards limiting the diversity of design solutions.

#### **6.3. SAFETY OPERATION**

The safety operation solutions allows for creativity while adhering to safety and compliance standards.

### **7. VALIDATION & ACCEPTANCE TEST**

During the design process all drawings, calculations, and solutions will be reviewed by CIPCO engineering for accuracy and correct implantation. Design documentation will be revised per CIPCO feedback and revised until the documentation is correct per CIPCO standards and expectations and ready for implementation.

## 8. TECHNICAL APPROACH

### 8.1. DESIGN SPECIFICATIONS

As stated, the existing electro-mechanical relays are being replaced due to age and condition. The new SEL 351 relays are microprocessor based and which has many benefits over electro-mechanical style relays, such as the following:

- Higher level of flexibility of protection schemes
- More inputs and outputs for greater control and room for expansion
- Faster and more precise relay testing
- Communication to monitor and gather data

The new SEL relays give overall flexibility and room to grow as protection needs and technology change.

#### 8.1.1. OPERATING ENVIRONMENT

The operating environment will be considered for each part of the project due to the harsh power plant environment. The environment can have large temperature changes along with dust, vibration, audio and electrical noise. These, among other operating constraints, will be considered during the design of this project.

#### 8.1.2. COMPLIANCE STANDARDS

Compliance standards play a large part in all aspects of the electric utility business and operation. These compliance standards will be ever present in all aspects of this project

##### 8.1.2.1. OSHA

Occupational Safety and Health Administration (OSHA) standard 29 CFR Parts 1910 & 1920 Electric Power Generation, Transmission, and Distribution. This standard helps setup rules and standards to promote safety in the electric utility industry.

##### 8.1.2.2. NERC

North American Electric Reliability Corporation (NERC) standards are in place to help protect the reliability of the electric system. These standards are highly important and full compliance is required.

#### 8.1.3. STANDARDS

##### 8.1.3.1. DESIGN AND CAD STANDARDS

CIPCO design and CAD standards will be followed during the design of this project. These design standards are in place to insure the



equipment is designed properly, and to help prevent field installation problems, and ease of design and checkout.

## **9. PROCESS DETAILS**

The electromechanical relays to be replaced are on four different units, controlling four different switch gear, and powering different power plant equipment.

### **9.1. SYSTEM INPUT/OUTPUT ANALYSIS**

#### **9.1.1. SYSTEM INPUTS**

The inputs to the new relay equipment will be very similar to the existing relays. AC line currents, AC bus voltages, 125VDC to power the relay, alarms, and breaker status will be brought into the SEL relay. The relay will use its programming to determine multiple functions and actions including tripping or closing the switchgear.

#### **9.1.2. SYSTEM OUTPUTS**

The outputs are similar to the relay inputs in that they will remain similar to the existing relay equipment's outputs. The outputs will be switchgear trip and close, relay alarm, and communications.

### **9.2. USER INTERFACE SPECIFICATIONS**

The primary software used for this project is AutoCAD. The CAD files will work as specified in the CIPCO CAD standard. These will be saved as .dwg file types and printed to .pdf. Fonts, layering, colors, title blocks, and additional items are covered in the CAD standard. The design review will cover both the electrical design as well as the drafting details.

### **9.3. HARDWARE/SOFTWARE SPECIFICATIONS**

This project is software based, in that no physical product will be delivered. The project will be primarily designed in AutoCAD software. Other software used will be Microsoft products and Adobe Acrobat. No specialized software will be required and all CIPCO CAD standards will be followed.

### **9.4. SIMULATIONS AND MODELING**

All design drawings will be completed in AutoCAD and printed to pdf for review and for final construction drawings. These reviews will act as our testing grounds to produce a theoretical functioning design that meets industry standards. Arc flash calculations will be completed in Excel for ease of use and repeatability. Simulations and relay testing are out of scope for this project.

### **9.5. IMPLEMENTATIONS ISSUES CHALLENGES**

There are many challenges to this project. Some are based on lack of experience with this type of equipment and the environment that it is operated in. Other challenges can schedule conflicts and meeting required deadlines. Other challenges could be to balance cost versus benefit of the particular solution. All challenges will be met with a tenacious determination and a wiliness to learn.

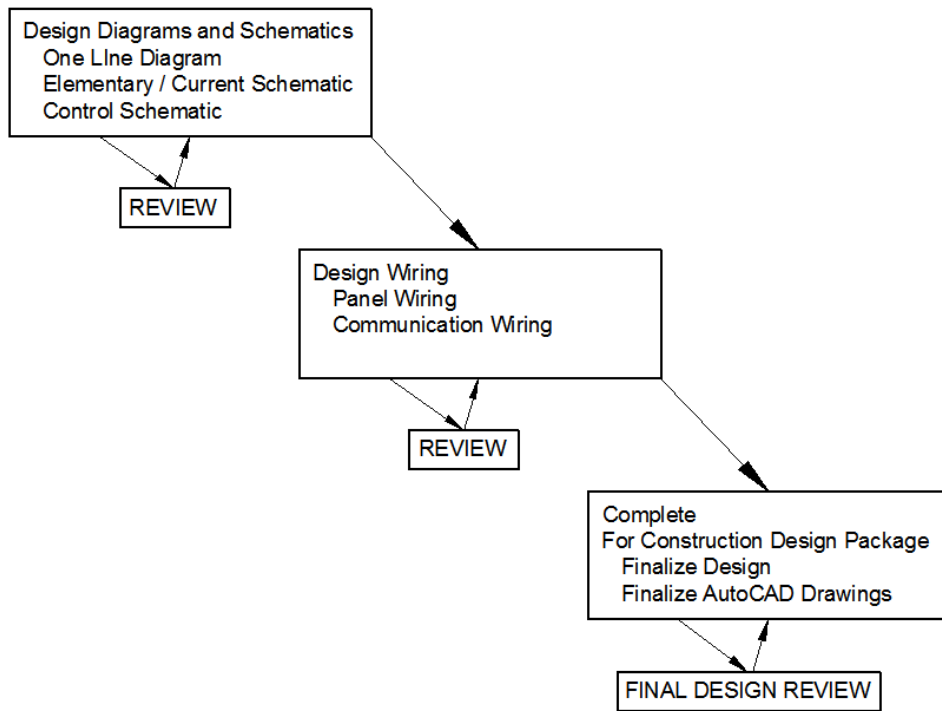
### **9.6. TESTING, PROCEDURES, AND SPECIFICATIONS**

No formal testing or simulations will be completed during this project and are considered out of scope. This design will be heavily reviewed to insure all industry standards, and regulations will be met and followed.

## **10. TEST PLAN**

As stated previously, no formal testing or simulations will be completed during this project and are considered out of scope. This design will be heavily reviewed to insure all industry standards, and regulations will be met and followed.

Each step has a review process with the Terry Fett, the Project Sponsor from CIPCO and the Supervisor of the Engineering Department, to insure the right approach has been taken with the design. During the review process, drawings will be delivered to Terry Fett. He will review and comment on the drawings. The drawings will then be delivered back to the designer for corrections. This process continues until Terry has deemed the design correct and then the designer can move on to the next step. This early and often approach prevents mistakes from being carried throughout the project making corrections far more complicated, time consuming, and costly. This review process follows closely how CIPCO operates with internal and external design consultants.



**Figure 1: REVIEW PROCESS BLOCK DIAGRAM**

## 11. PROJECT SCHEDULE

### Power Plant - Relay Replacement

Iowa State EE Senior Design - December 2015

Group : Dec15-22

Dan Dye

Key Activities	Weeks - Spring 2015														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spring															
Develop Project Scope	█	█	█	█											
Develop Project Plan				█	█	█									
Develop Man-hour Budget						█									
Gantt Chart															
Design Relay One Line Diagram							█								
Design Elementary Diagram / Current Schematic								█	█	█					
Design Control Schematic									█	█	█				
Design Panel Wiring										█	█	█			
Design Communication processor Wiring											█	█			
Design Review												█	█		
Arc Flash Calculation													█	█	
Arc Flash Design Review														█	█
Safe Operation Engineering Solutions															█
Safe Operation Engineering Solutions Design Review															█
Completion of Project Report															█
Presentation Practice / Presentation															█

Key Activities	Weeks - Spring 2015														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fall															
Relay Replacement Design Construction Package	█	█													
Relay Replacement Design Function	█	█	█												
Arc Flash Calculation Analysis			█	█	█										
Arc Flash Calculation Compliance Regulations					█	█									
Arc Flash Analysis Review							█								
Safety Operation Solutions Compliance Regulations								█	█	█					
Safety Operation Solutions Cost Estimates									█	█					
Safety Operation Solutions Operation Guild										█	█				
Safety Operation Review												█	█		
Completion of Final Project Report														█	█
Design of Project Poster															█
Presentation Practice															█
Presentation															█

Table 1: PROJECT SCHEDULE GANTT CHART

## 12. RISK / FEASIBILITY ASSESSMENT

### 12.1. RISK ITEMS

This project involves many areas of risk. While designing this project the designer will have to take into account these risks and design around them. Some of these areas of risk are operating environment, complying with compliance standards, budgetary

constraints, and meeting project deadlines. During the design, the designer will need to build in protection from these risks.

## **12.2. FEASIBILITY ASSESSMENT**

A feasibility study will not be completed at part of this project. The technical feasibility of the project is high. This high assessment is due to the experience and knowledge of Terry Fett the project sponsor. His guidance and coaching will most likely lead to positive results.

## **13. COST CONSIDERATION**

The cost considerations are limited due to material and equipment acquisition will be completed at a later date. The main cost of this project will be labor associated with research, design, and design review. Additionally computer resources and a full seat of AutoCAD will be required.

## **14. MARKET/LITERATURE SURVEY**

This project will require research to gain background knowledge on equipment, compliance standards, and current practices and technology. This research will help determine the best approach for design and equipment specification.

## **15. CONCLUSION**

This senior design project has helped me improve my knowledge significantly while working on the relay replacement, arc flash calculation and analysis, and safe solutions for operating switchgear. I have a far better understanding of relay protection, power equipment, and the detail involved in the engineering and design process.