138kV / 13.8kV Substation Protection Design Project

Project Plan

Team	: sdmay18-06
Client	: Black & Veatch
Team Advisor	:Dr. Ajjarapu
Team Members	: Andrew Brown Gavin Christenson Eric Fritz Brent Hines Weng Hoong Loo (Terry)
Team Email	: sdmay18-06@iastate.edu
Team Website	: http://sdmay18-06.sd.ece.iastate.edu/
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1.Introduction

1.1 PROJECT STATEMENT

The purpose of this project is to design a the protection systems of a 138kV / 13.8kV distribution substation that safely steps down voltage. A 138kV transmission line will connect to the distribution substation primary bus, where the power will go through a step-down transformer, until reaching three feeders where the power will then be distributed to the general population. The protection system for the substation consists of various current transformers connected to relays that are designed to prevent overcurrent, as well as a relay for the voltage transformer with a number of grounding contacts. All components involved in the distribution substation will be interconnected, as well as having a protection plan design for each component, as well as wiring diagrams of all the various electrical contacts. Once the design documents are completed, a final presentation will be created to present to Black & Veatch headquarters in Kansas City.

1.2 PURPOSE

The purpose of this project is to create a protection scheme for a 138kV / 13.8kV distribution substation. Our client, Black & Veatch, has provided us with a list of relays they would like to use for the project, and we are tasked with connecting these relays to the substation via current transformers to protect against overcurrent. Throughout this project, we will create a database of drawings detailing the protection system, including the relay connections, control house layout, panel layouts and diagrams, and so forth.

1.3 GOALS

The goals for this senior design project are as follows:

- Design and refine a 138kV / 13.8kV substation one-line and three-line diagram
- Create a protection plan for the substation
- Plan the layout for the substation control house
    - Panel Layouts
    - Wiring Diagrams
- Create a final presentation of the design to be presented to Black & Veatch

2 Deliverables

To meet our goals for this project, we have the following list of deliverables:

- Based on the protective relay scheme identified by Black & Veatch:
    - System one-line diagram
    - System three-line diagram
    - Protection and control schematics
    - Wiring diagram and panel layouts
- Materials List
- Weekly teleconference with Black & Veatch
    - Weekly progress report & meeting minutes
    - Weekly meeting agenda in advance of meeting
- Project Design Review
- Final Presentation to Black & Veatch

3 Design

To design this substation, we are taking a preliminary one-line diagram provided by Black & Veatch and creating a more detail lower level design to suit the design requirements, standards and guidelines such as those mentioned in 8.references . We will also create a three-line diagram from our final version of the one-line diagram, as well as a wiring diagram for the system protection and controls. Substation design is more than a simple transformer stepping down high voltages to low voltages. It has be designed with protective equipments to ensure faults can be cleared safely to protect the transmission lines and the consumer end.

3.1 Previous Work/ Literature

As common as distribution substations are in the world today, we have a lot of information at our disposal for this project. Black & Veatch is our primary source of information, and they have provided us with many preliminary drawings, as well as a PowerPoint explaining various concepts we can use for the one-line and three-line diagrams. Various documents have been provided from Black & Veatch which will help with the design process. These documents include templates of the key protection diagram, one-line diagram, three-line diagrams, AC-DC protection documents and relay diagrams. A powerpoint on high voltage substations and previous senior design projects were given to us from our faculty advisor, which will also help the design process.

These works from previous groups have a persistent pattern of time-management issues. To overcome this problem, we will be implementing strict deadlines which we will stick to throughout the semester. Besides that, often these equipment could be outdated and it will be our job to update the equipments to use the latest technology for the optimal utilization of the equipment.

One challenge previous senior design teams have had was finishing all of the drawings entailed in the scope of work. In order to prevent this, we will be enforcing strict deadlines for every drawing to ensure all works will be completed. We are also going above and beyond other projects, for we will be doing various power calculations to ensure the equipment can handle the current at which it is regulated for.

3.2 Proposed Block Diagram System

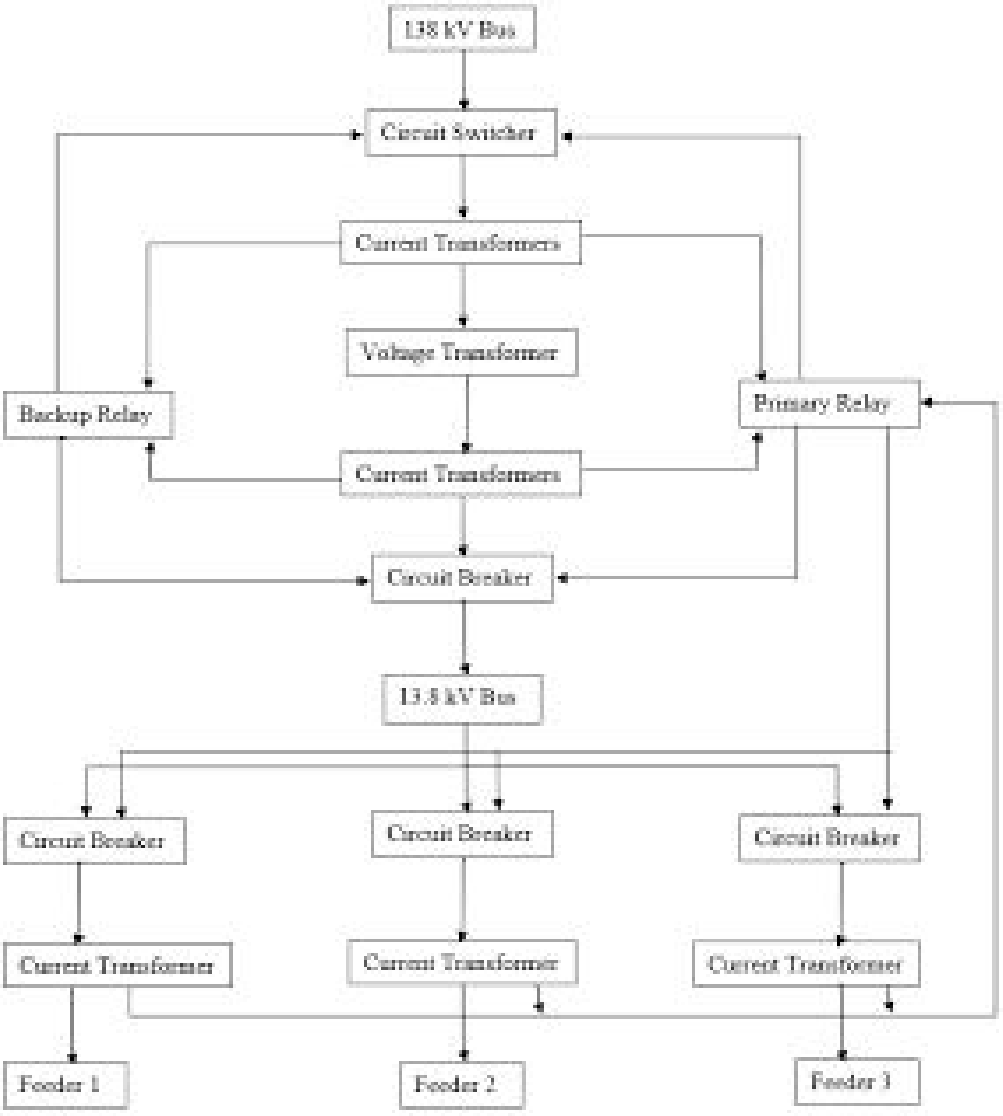


Figure 1. Block diagram of the protection system for the substation.

The substation will transform 138kV down to 13.8 kV, and will be protected by a SEL-487E transformer relay as well as multiple SEL-351S overcurrent protection relays. The relays are attached to the main line via a number of current transformers. There are circuit breakers designed to trip in case of overcurrent on the main line and each of the feeder lines, as well as a circuit switcher on the main line capable of handling up to 25kA of fault current. The main purpose is to design and understand what type of electrical contacts will be made throughout the various relays and why we are making them.

3.3 Assessment of Proposed Methods

We are taking an approach to our design project that involves laying out our schedule first with a Gantt chart and man-hour budget, and then creating one-line and three-line diagrams, wiring diagrams, panel layouts, and control schematics in AutoCAD. Since we are working with Black & Veatch, we are using an approach very similar to their own. However, technical manuals, requirements and standards have to be met. We have finished our Key Protection Diagram, the document in which all other documents will be based off of. In this document, we specify the relays in which fault currents will travel.

Specifically, we will be designing the electrical contacts within the substation including the SEL-487E relay and the multiple SEL-351S relays. We will designing the wiring diagrams of each relay and circuit breaker, as well as the different disconnecting switches will be switched depending on the type of fault that is detected. For example, if a fault is detected in phase A, but phase B and phase C are working properly, phase A will trip independently from the other phases.

3.4 Validation

Since we will only be designing a substation, and not building it, we will be using our weekly teleconferences and final presentation with Black & Veatch to validate our design. Black & Veatch has a wealth of experience with distribution substations that we will be using not only for guidance, but also for confirmation that our design project is successful. A deadline for each rough draft of every document will be set in order to receive proper feedback and validation in a timely fashion. We might potentially do simulations for example testing for the 25kA of fault current that the substation can withhold if time allows.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

The technical requirements for this project include designing a distribution substation to convert 138kV to 13.8kV using a radial bus system, and the panel layout, protection and control schematics, and wiring diagrams that go along with it. All of the functional components for this project will be designed in AutoCAD.

We will testing the protection status of the substation by doing several power calculations testing the amount of current going through the SEL-487E and the multiple SEL-351S relays. We will be designing the electrical contacts within the substation including the SEL-487E relay and the multiple SEL-351S relay as well as designing the wiring diagrams of each relay and circuit breaker. Programing the disconnecting switches will be switched depending on the type of fault that is detected. For example, if a fault is detected in phase A, but phase B and phase C are working properly, phase A will trip independently from the other phases.

4.2 NON-FUNCTIONAL TESTING

The biggest non-functional component of this project is weekly meetings with Black & Veatch via Google Hangout to provide updates on our progress, with meeting agendas beforehand and meeting minutes after. The other non-technical deliverables include a Gantt chart, man-hour budget, materials list, and final presentation to Black & Veatch.

4.3 STANDARDS

The standards for our design project are based on the 2014 NFPA National Electrical Code which will play a huge role in governing the design process and will serve as rigid design constraints. However, it should be noted that this project will be drawing upon guidelines set forth by industry, local, environmental and component-specific standards that can be found in the reference section 8. We will be using the SEL-487E relay for the primary protection of Bank 1. We will also be using the SEL-351S for the back-up relays, lt relay, as well as the relays which will be used to protect the feeders. The types of disconnect switches and circuit switches we will use will be determined once we create the materials list, a deliverable which we will complete next semester. [1]

5 Challenges

The main challenge we are facing as a group is understanding the project material such as the key protection plan, one line diagram,and the protection schematics. The major reason for us facing this challenge is the project being complicated and bulky as it is a real world designing problem, as well as us having minimal knowledge about the material. Even if we manage to pull off the project it wouldn’t mean anything to us if we don’t understand the reasoning behind the decisions made while revising the drawings. For example

Hence, at times when we are could not figure out the materials at hand, we plan to consult multiple experts and resources in the field which includes our Senior Design Advisor Professor Ajjarapu, Black & Veatch Experts, National Electrical Code and of course researching through the internet.

Another challenge we will face is designing the lower level documents in the future as the drawings requires more and more detail as we proceed with the project. These documents will be based off of the key protection diagram, as well as the project scope document which was provided by Black & Veatch. There will be a lot of cross referencing of these documents, for this will be key to completing our project in an efficient manner.

The next challenge we will face will be ensuring that the specified amount of fault current will safely pass through the substation and be dispersed in a safe manor without affecting the substation equipment. In order to do these calculations, we will rate the current transformers 25% greater than listed to ensure the substation is working correctly and safely.

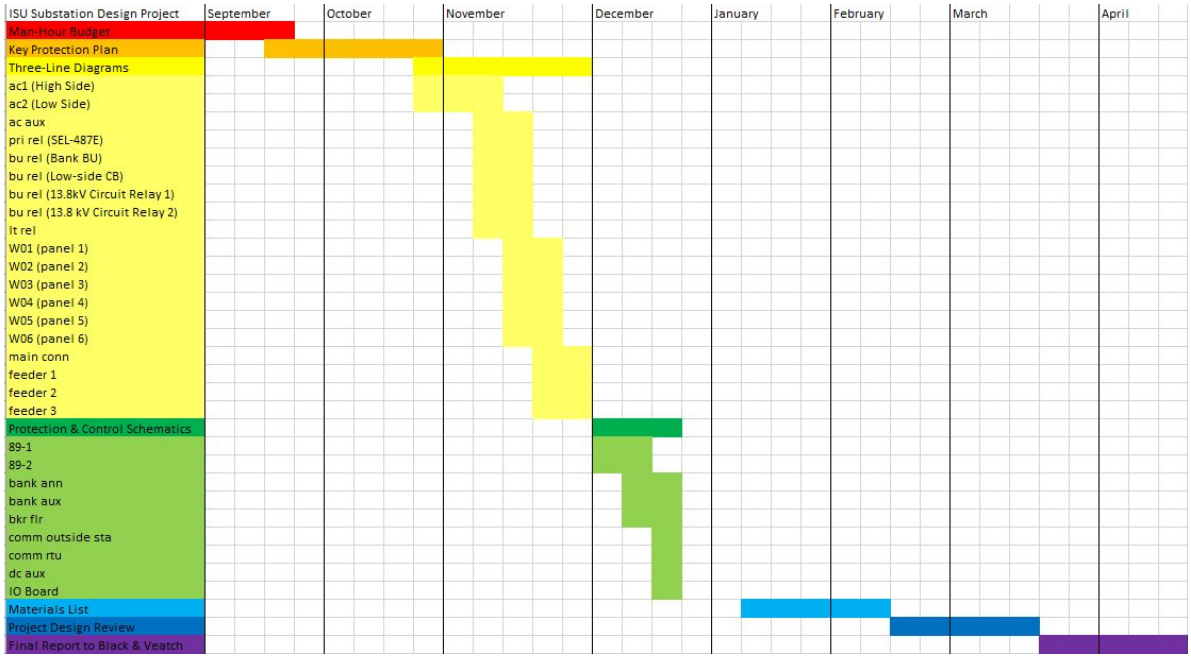
Besides that, another challenge that our group was facing is using AutoCAD to complete our designs. We are mostly new to AutoCAD, so we have a lot to learn for that portion of our project. However as time goes by, we get more and more familiar with the different functionality of autoCAD and the challenge is no longer a big threat anymore.

Cost and materials will not be a problem for us as this project is just a conceptual design together with our stakeholder, Black & Veatch. No cost implication as our main outcome of this project is to understand the basics on substations and the protection scheme as it is not as simple as just a stepping down transformer. Therefore,free CAD software available to us through Iowa State to omit the cost portion, and there will be no physical materials involved in the project.

There are no true risks associated with this project. This is due to the fact that the project is intended for educational purposes only. However, there are possible risks associated completing this project that exist in the form of bottlenecks. Potential bottlenecks on this project include AutoCAD and becoming familiar with the industry safety standards.

6 Timeline

The timeline for our project is outlined in the following Gantt chart:



6.1 FIRST SEMESTER

For the first semester of our senior design project, we are developing a Gantt chart and man-hour budget for the project. We are also finalizing the one-line diagram of the substation, as well as our key protection plan for the substation. Lastly, we will be starting the three-line diagram of the substation and the schematics for protection and control.

6.2 SECOND SEMESTER

During the second semester of our design project we will be finalizing the three-line diagram of the substation, as well as the protection and control schematics. We will be creating a database to convey all of the drawings we have completed during our senior design project. We will be developing a materials list for the project, and send our design to Black & Veatch for review. With feedback from Black & Veatch, we will make any necessary changes to our design and create a presentation for Black & Veatch of our final design.

7 Conclusion

In conclusion, this substation design will bring us a lot of industrial experiences that will help us have a taste of the things we do out in the job market. As we learn various method solve a problem as well as the standards and requirement.
Project wise, we are responsible for designing a substation and all the protection schemes, controls, wiring as whole so that we can truly understand the in depth details of designing a substation. The designing process includes us brainstorming and working together in a team to ensure fairness and the healthy balance of workload in the team. The design documents, which will be reviewed according to our standard reviewing procedure as mentioned before, will be used to ensure our design is of the best quality before finalizing it. At the very end of the project, we will showcase our final substation design to Black & Veatch and demonstrate our skills and knowledge along the way on working on this project.

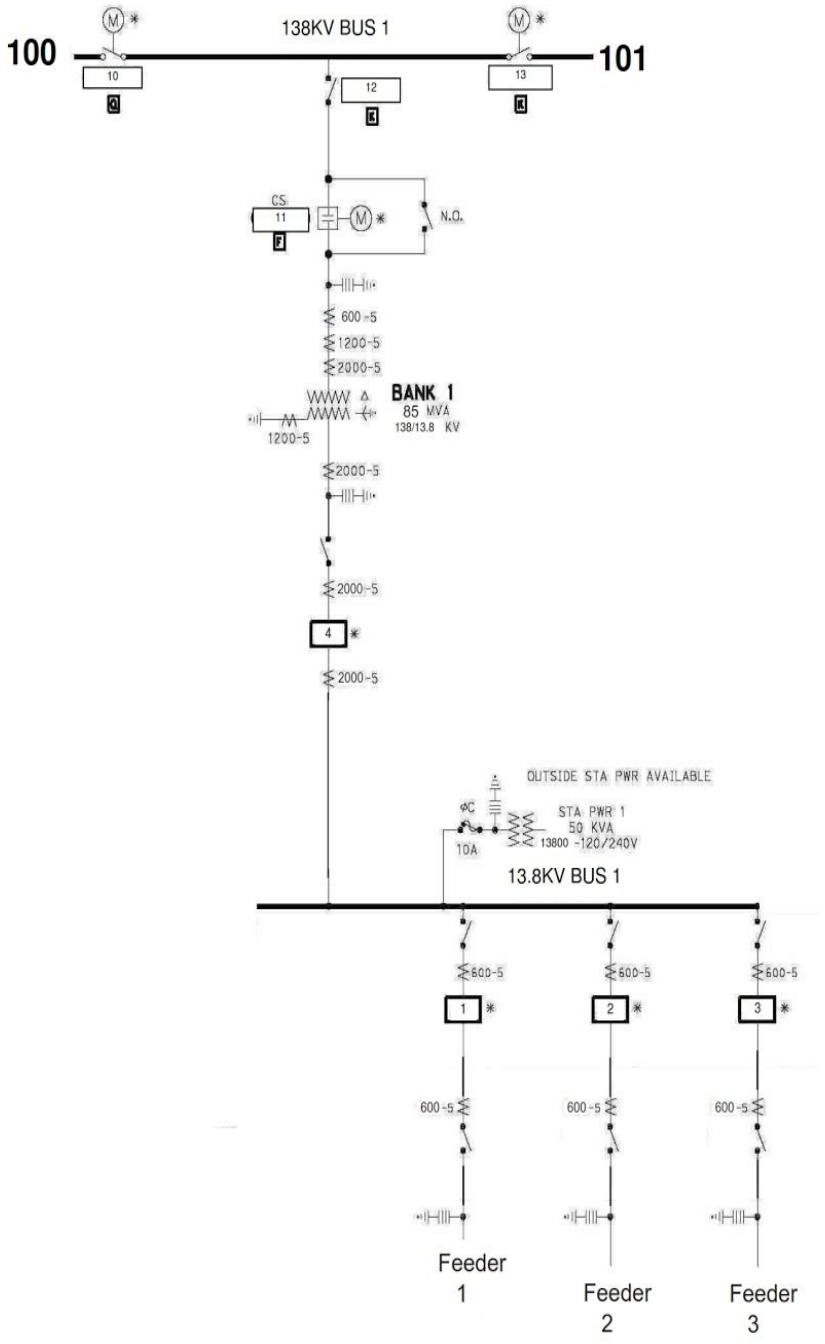
8 References

References for this project includes but not limited to:

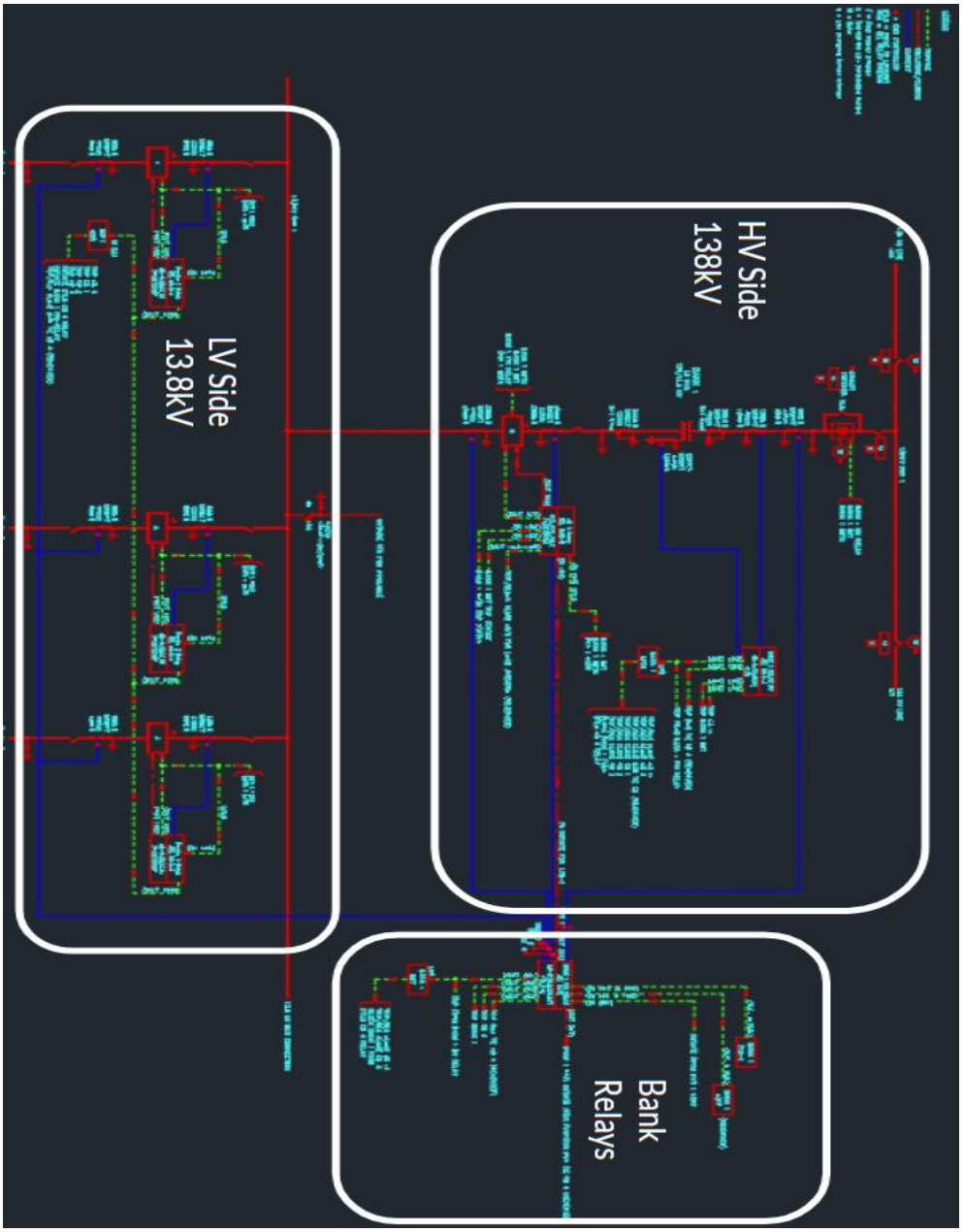
1. University of Iowa State Senior Design Substation: System Protection Requirements provided by Black & Veatch
2. HV Substation Design Notes by Professor Ajjarapu
3. ANSI Standard Device Number List
4. 2014 NFPA National Electrical Code
5. IEEE HV Substation Design Presentation Slides

9 Appendices

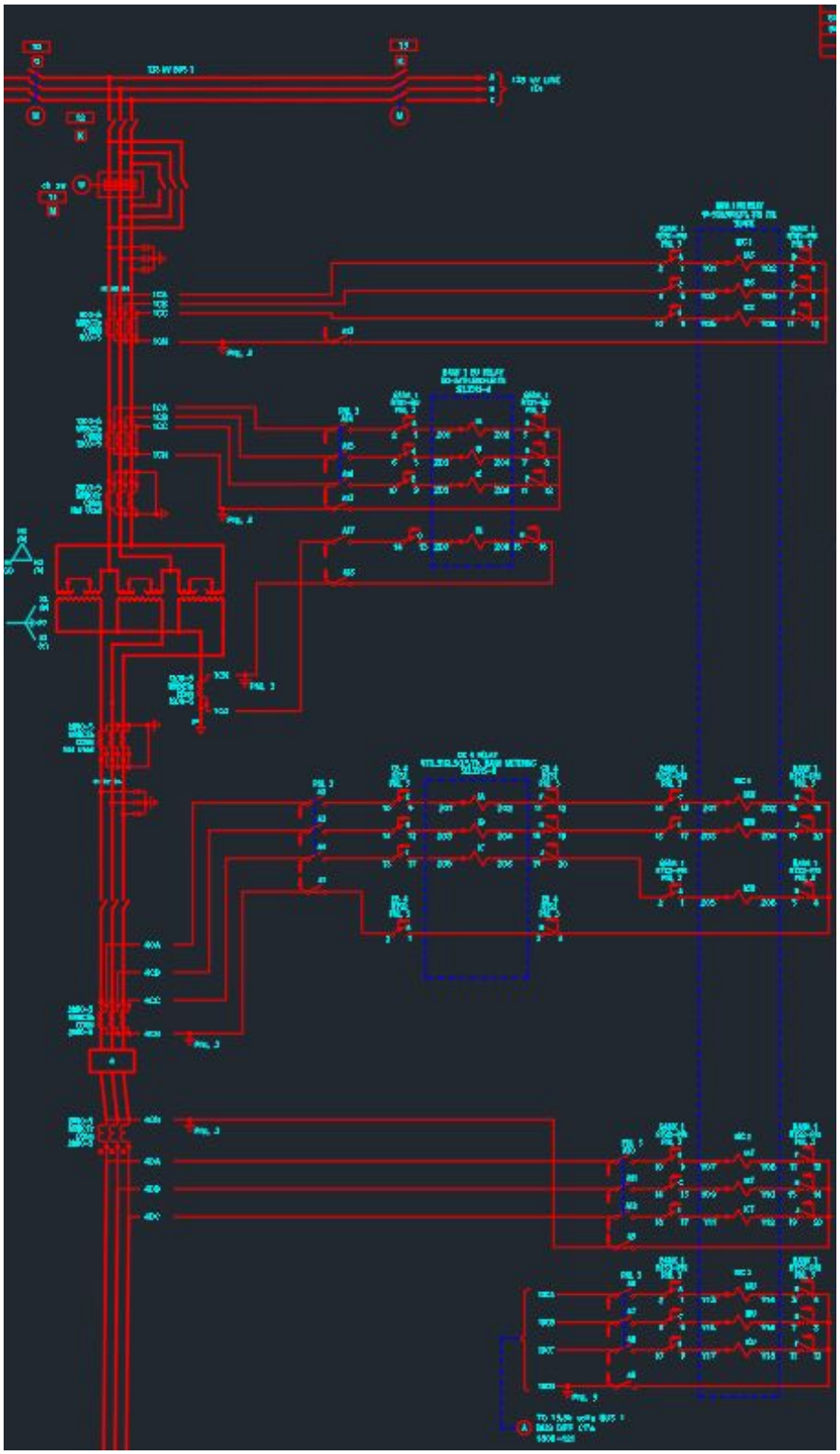
The figures and drawings below include the work that we have done and parts of references used or will be used in the future while designing.



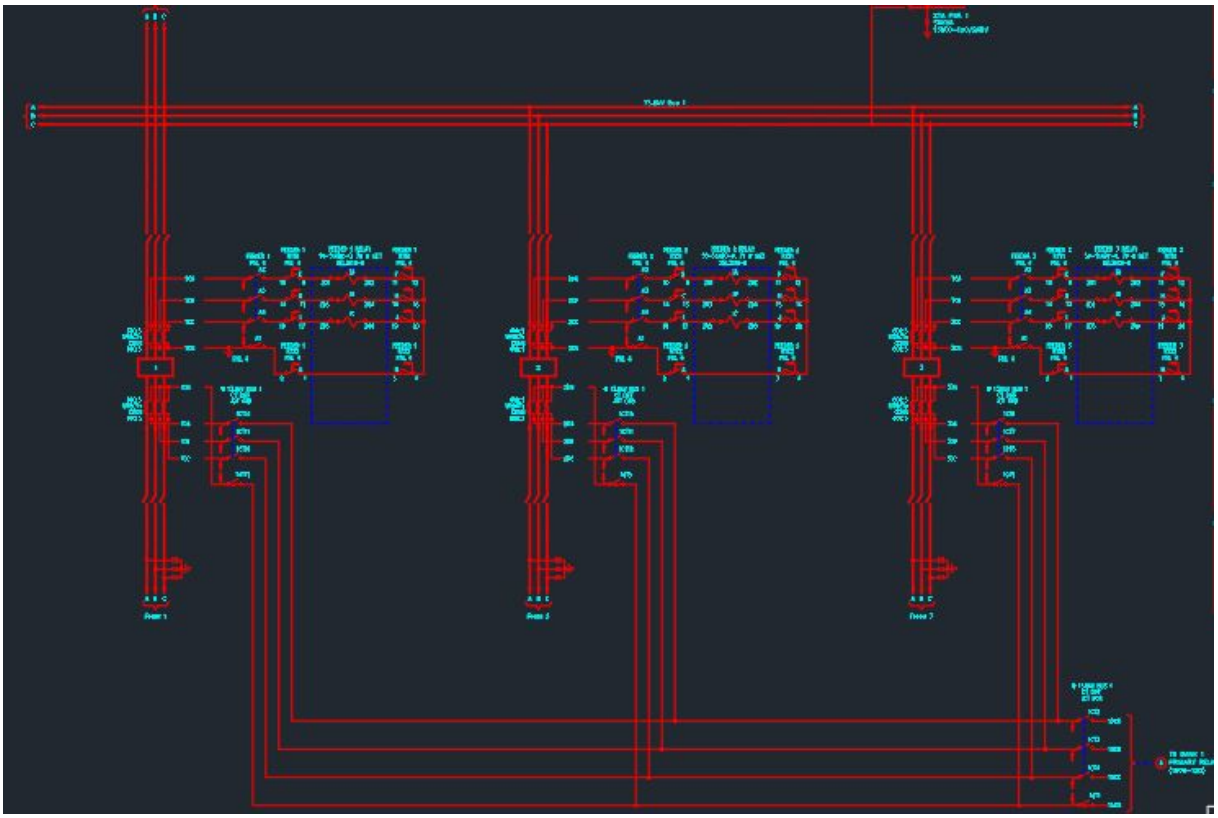
The drawing above is the one line diagram a higher level than the Key Protection Plan drawing below which is also the part of the specifications requested by the client, Black & Veatch.



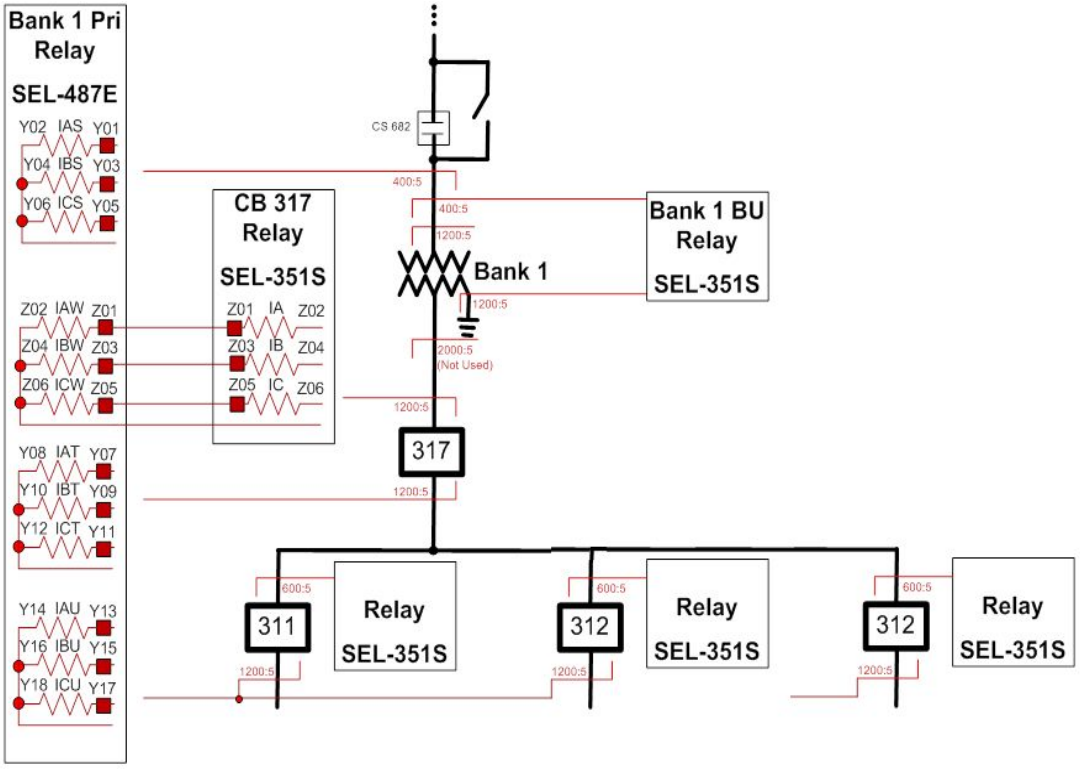
The drawing above shows the Key Protection Plan which is a lower level drawing than the one line diagram as this drawing shows the various components and connections in which this substation will be protected under. We created this document from the one-line diagram.



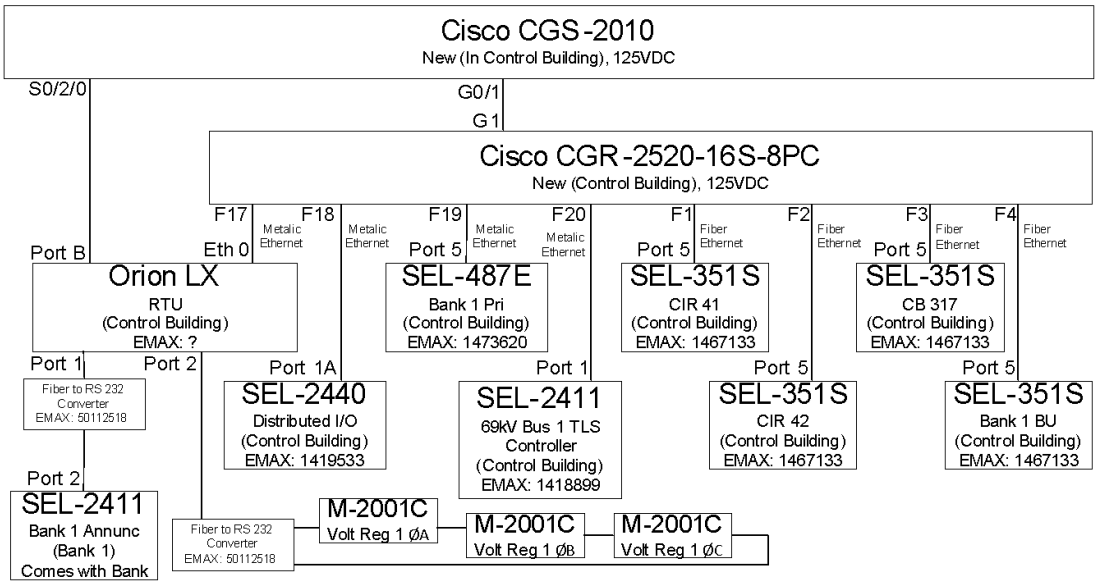
The three line drawing above is the AC Schematic 1 that shows the various switches to be tripped in the case of a fault in the substation. This drawing shows the in depth protection schemes used in the high voltage side (138kV). We used the Key Protection Plan to create this drawing.



The three line drawing above is the AC Schematic 2 shows the various switches to be tripped in the case of a fault in the substation. This drawing shows the in depth protection schemes used in the low voltage side (13.8kV). We used the Key Protection Plan to create this drawing as well.



The figure above shows a Primary Protection Circuit Diagram which describes the connection between relays and protective equipment in the substation. This is a part from a provided by Black & Veatch which is our primary document when designing the protection schematics of this substation. If you would like a copy of this document please let us know.



The figure above shows the Communication Schematics used in the control building that controls the protective equipment in the substation. This is from the same document mentioned above.