Sdmay 18-06
Black & Veatch
Advisors: Dr. Ajjarapu, Cole Beaulieu, Adam Literski
Andrew Brown
Gavin Christenson
Eric Fritzy
Brent Hines
Weng Hoong Loo
sdmay18-06@iastate.edu
http://sdmay18-06.sd.ece.iastate.edu/

Revised: 10-15-17/v1

138kV/ 13.8kV Substation

Design Document

Table of Contents

1 Introduction

1.1 Acknowledgement

Black & Veatch will be providing a wide range of documents for designing a 138kV / 13.8k. Black & Veatch have provided us template diagrams where which we will fix the mistakes and add appropriate information.
Professor Venkataramana Ajjarapu will also assist us in resources on substation as he is an experienced professor on power systems as well as being technical advisors for various senior design group.

1.2 Problem and Project Statement

The purpose of this project is to design a 138kV / 13.8kV distribution substation that safely steps down voltage for distribution lines. Through the design process, our senior design team will create several design documents needed to construct a distribution substation. The most important document will be the one-line Diagram. All diagrams including the key protection diagram, three-line diagram, and wiring diagrams will be based off of the one-line diagram. To build these documents, we will use a wide range of resources available to us. The resources include System Protection Requirements, which Black & Veatch provided, and previous senior design projects and a powerpoint presentation of High Voltage Substation Process, which our faculty advisor provided.

A 138kV transmission line will connect to the distribution substation primary bus, where the power will go through several step-down transformers, until reaching three feeders where the power will then be distributed to the general population. All components involved in the distribution substation will be interconnected, as well as having a protection plan design for each component. Once the design documents are completed, a final presentation will be created to present to Black & Veatch headquarters in Kansas City.

1.3 operational Environment

The operational environment will be a non-factor when designing the various documents required to build a 138kV/13.8kV substation. The substation however, will outdoors, so outside factors will be required. Included in the key protection plan, lighting arresters as well as a control house will be used to ensure the working capability of the substation.

1.4 Intended Users and uses

The intended user of these substation design documents will be Black & Veatch. Black & Veatch will then use these documents to build the substation in order to provide electricity for commercial uses or as a distribution line which later could be stepped down for the use of general residence.

1.5 Assumptions and Limitations

Assumptions: -

- Must be used within United States or Countries with AC Electrical Frequency of 60Hz as the usage with different frequency could damage the load or electrical components.
- Capacitor bank has to be present to control the reactive power as stated in the NEC standards.

- Protection and relays are compatible with the NEC code [1] to protect both the substation and the Transmission Grid.
- A generic location in United States will be used as our control location for simulation purposes.

Limitations: -

- The load of the substation must be able to take in 13.8kV as the output would be a stepped down voltage of 13.8kV.
- The tapping of the substation from the transmission lines has to be 138kV at all running times.
- No prototyping will carried out due to the feasibility.
- The end product will only go through simulations for testing purposes.
- The design of the substation is based on the one-line diagram of the substation which includes most specification requirements.

1.6 Expected End Product and Deliverables

Deliverables

1.6.1 Development of an engineering man-hour budget and schedule for the project with tracking of hours spent on each task for comparison to actual budgeted engineering man-hours, presented at each design review.

1.6.2 Development of panel arrangements (panel layouts), one-line diagrams, three-line diagrams, protection and control AC and DC schematics and wiring diagrams based upon the protective relay scheme identified by B&V and the provided equipment (circuit breaker, disconnect switches, Coupling Capacitor Voltage Transformers (CCVTs), Current Transformers (CTs), station service transformer, etc).

1.6.3 Development of a Materials List for the project which includes equipments needed for the specifications of the Substation as it is tailored made for it.

1.6.4 Weekly teleconference, via Google Hangout, with B&V and weekly progress reports in email format to Black & Veatch.

1.6.5 Project design reviews, to constantly improve the drawings up till the best of quality.

1.6.6 Final report and presentation to Black & Veatch. The final report should include a section listing any lessons learned during the design process. This should take place in Spring 2018.

Deliverables Timeline

Task	Deliverable Date
Man-Hour Budget	21-Sep
Key Protection Plan	27-Oct
Final One-Line Diagram	27-Oct
Initial Three-Line Diagram	30-Nov
Protection & Control Schematics	15-Dec

Final Three-Line Diagram	28-Dec
Materials List	15-Feb
Project Design Review	15-Mar
Final Report to Black & Veatch	15-Apr

2 Specifications and Analysis

Designing a substation is totally new to us. Hence, we will need to put in as much effort we can especially in finding ways to ensure that this project meets the highest standards. Up to today, we have been meeting weekly with Black & Veatch to discuss our findings and our work progress over the week. During the meetings, we reviewed what we've done for validity and consider how best to proceed with the project.

Deliverables that we have achieved so far have been on a man hour budget, Gantt chart and the Key Protection Plan (KPP). We've been able to split the work among us but usually find ourselves meeting as a group to tackle some of these items. The KPP is our first major piece of work as everything we do from now is based on the KPP. We modified an existing KPP template to suit specifics of our substation. We have a number of resources available to do this outside of those weekly meetings talked about earlier. Mainly, we're following the single-line diagram given to us by Black & Veatch for this project and translating it into the KPP. We also received a document describing the scope of the project which included more specific information on what's needed to go into our substation and what the inputs and outputs to relevant banks should be.

Questions regarding the elements for the KPP can be answered through the scope document, asking Black & Veatch during a weekly meeting, asking Dr. Ajjarapu during one of our weekly meetings with him or through independent research online. If the question is regarding its use in the substation, Black & Veatch is a good source of information. If the question is regarding its general function, information on the element is best found through Dr. Ajjarapu or independent research. We've made a document for each device with an ANSI number that includes a picture and description of what the device does.

2.1 Proposed Design

As discussed earlier, our team has a number of items we wish to complete. Some of these will be delivered to our clients at Black & Veatch and some of them will be used solely for our benefit. These deliverables can be found in section 1.6. They include a man hour budget which was compiled with the help of Black & Veatch during an in person meeting, a key protection plan based on the single-line diagram which we were given along with a document describing the scope of the project, a three-line and wiring diagram (if time permits) which expand upon the other design documents for our substation and a final presentation of our work which will be given in Kansas City. Each of these parts build off of the last and will be completed sequentially with weekly (or more) reviews from Black & Veatch for our work and from Dr. Ajjarapu for our understanding and participation.

We have worked on several documents for our own reference already and it is likely that more will come up as we proceed with the project. These describe how parts of the substation or how the substation as a whole may work and are not delivered to our client but used by us during the design process.

2.2 Design Analysis

So far we have nearly completed our work on the KPP and have created a number of documents which we can use to reference how parts of the substation work. We've meet with both our advisor and our client each week consistently and are continuing to bounce ideas off of them to further our progress. Our first main review of our work is forthcoming early this week and will give us a better idea of how to improve what we have done.

Understanding the existing work and documents which we have been given has been step 1. Following that we have been able to make adjustments to the KPP and think about future steps in the process of designing a substation. So far we have done most of the work individually or in smaller groups but there been talk of getting all of us together to make adjustments as a full group to keep everyone participating, up to date and to ensure the best use of our combined talents.

3 Testing and Implementation

We will be testing the panel arrangement, one-line diagram, three-line diagrams, protection and control AC and DC schematics, and wiring diagrams.

Our testing process will be to use the given documents as resources to create the next diagram. As a team we will look over the document to make sure we have done it to the best of our ability. The software such as PSS/E will be used to assist in testing. Then the document will be sent off to Black & Veatch and our contact will analyze it and give us feedback. Our team will review the comments and fix the highlighted problems. To document changes made we have created a spreadsheet and whenever someone alters a drawing or other asset that change is added to the spreadsheet.

Interface Specifications

This project focuses on the design of the functional components of a 138 kV substation. We will be concerned with providing power to the control house but the interface of that house, or any other interface, is beyond the scope of this project.

3.1 Hardware and software

For testing AutoDesk's AutoCAD will be used to view and make changes of the designs as we perform tests. PSS/E will also be used in a much smaller capacity.

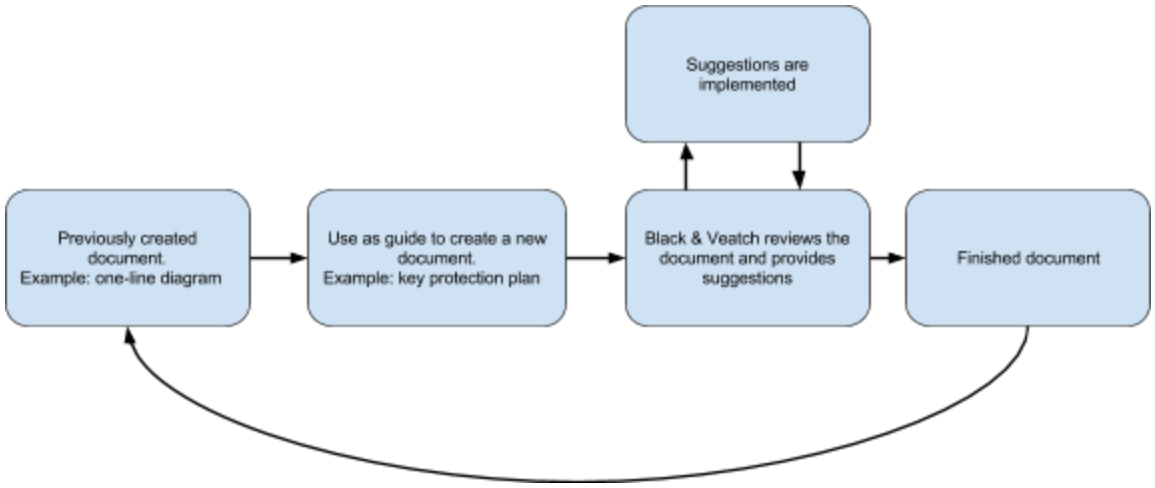
AutoCAD excels at editing the drawing the files we will be creating. It will allow our team to quickly view and analyze the diagrams and any changes changes in a fast efficient manner.

3.2 Process

Section 2 discussed the creation of the man hour budget, Gantt chart, key protection plan, and ANSI key. The man hour budget and gantt chart are for the benefit of our team to gauge the project

and will be tested and altered as the project progresses. As time passes we will have a more accurate document to follow.

The key protection plan in the same process as shown in the flowchart below. The testing was performed in a back and forth between Black & Veatch and our team. To this point we have much to learn before we are able know how well our designs will perform.



3.3 Results

The design to this point has been the creating of the key protection plan. We have not tested the validity of the one-line diagram and have not completed the key protection plan, and consequently have not performed any testing.

4 Closing Material

4.1 Conclusion

Up to now, we have completed the man-hour budget and almost completed the Key Protection Plan. The KPP will be our first major stepping stone as everything after the KPP is all based off from KPP. As long as we follow the requirements based off of the one-line diagram provided by the client, we will be on the right track towards the completion of this design project. Of course, we will still refer to standard documents, professionals from B&V and professor Ajjarapu as resources to expand our knowledge and to ensure our design is the best of quality.

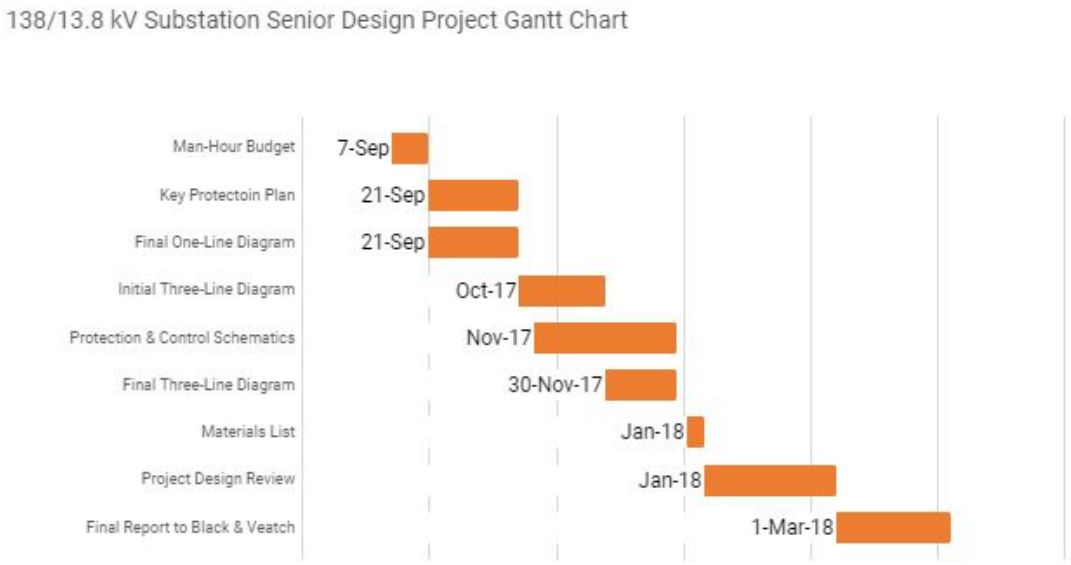
4.2 References

Our references for this project were provided by Black & Veatch and include a reference powerpoint with details on electrical and safety components of the substation, a preliminary one-line diagram for the substation, and the 2014 NFPA National Electrical Code. Our final design will be built on the skeleton that is the initial one-line diagram and will meet the standards outlined in the National Electrical Code.

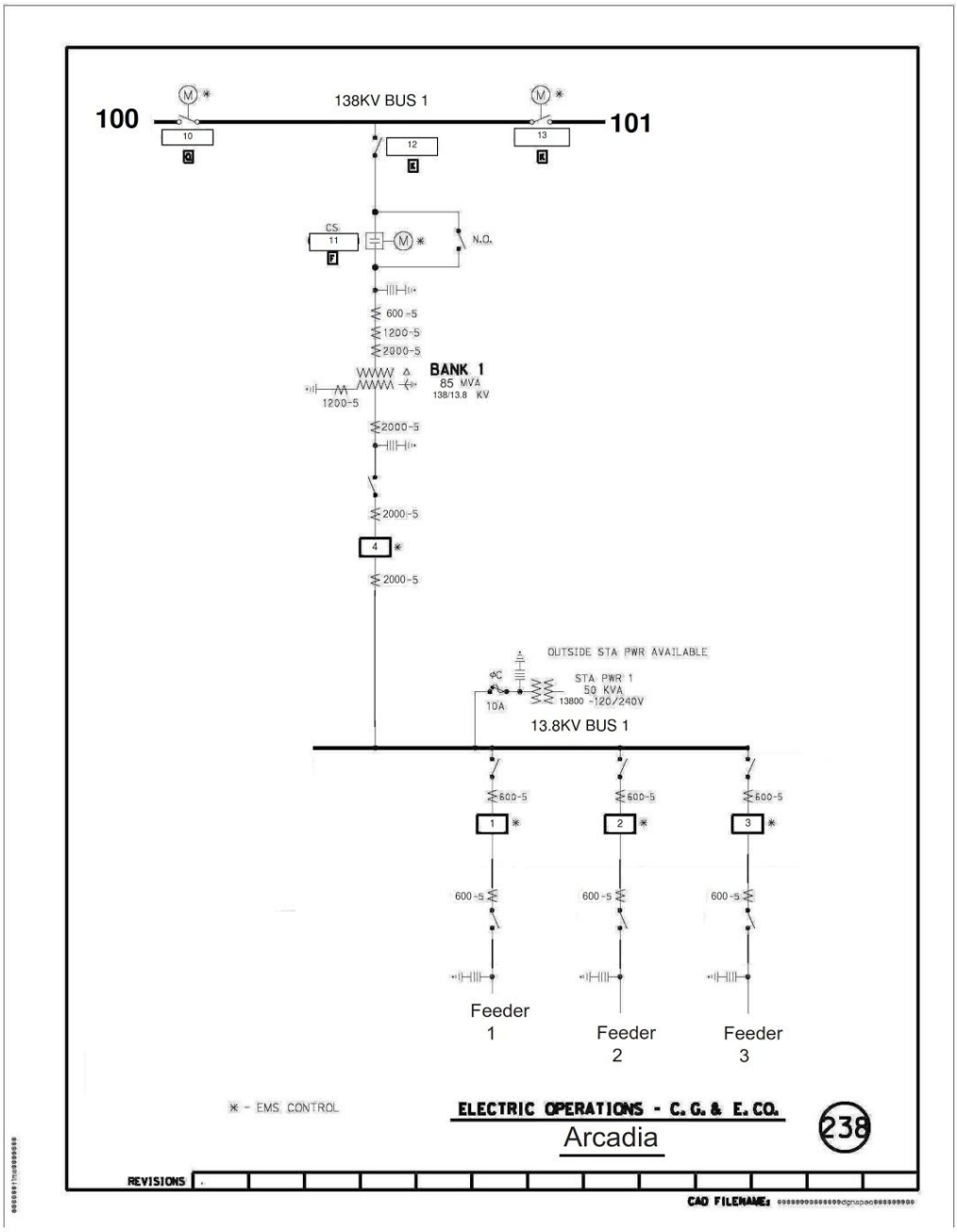
ANSI Standard Device Number

4.3 Appendices

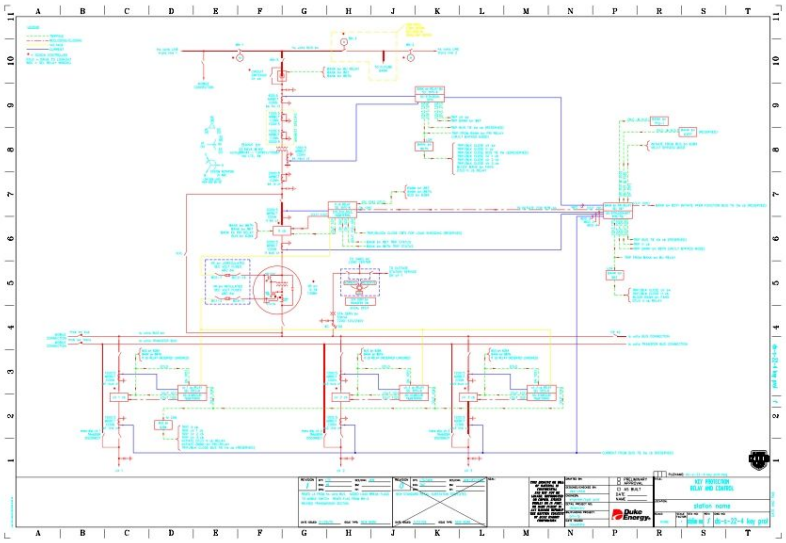
Gantt Chart on man-hour budgeting: -



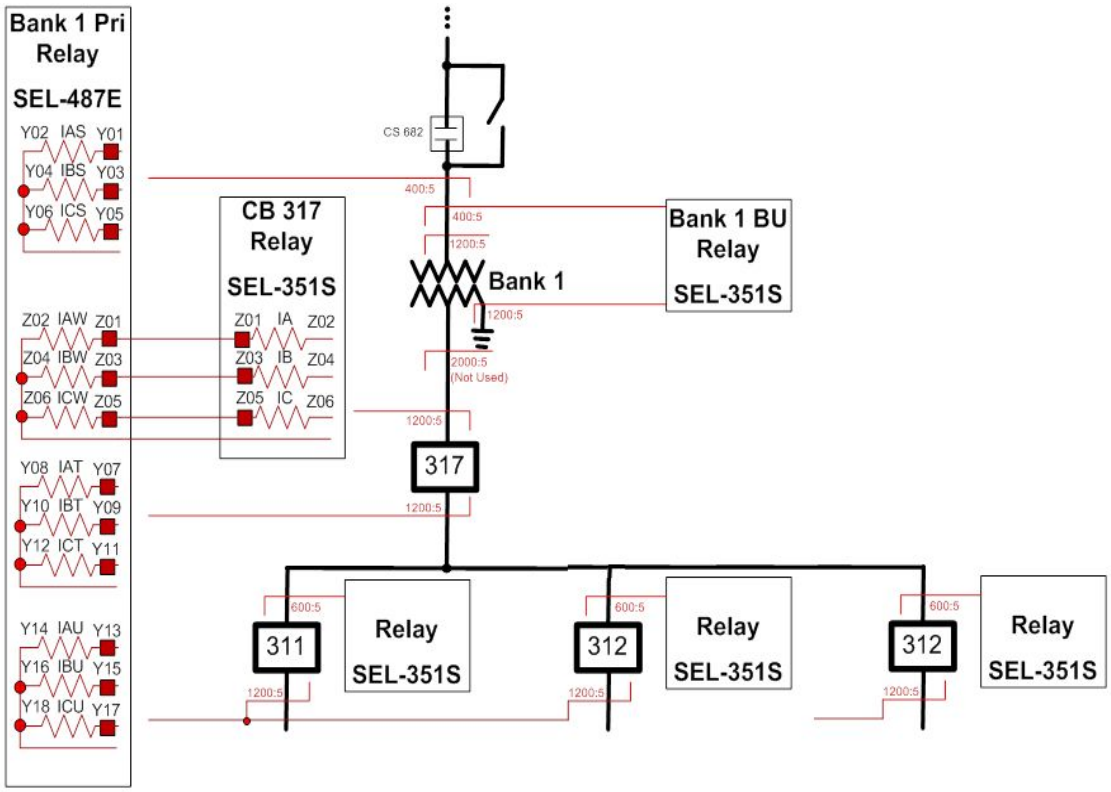
One-line Diagram: -



Key Protection Plan: -



Primary Protection Circuit Diagram: -



Communication Schematics: -