Impact of High Photo-Voltaic Penetration on Distribution Systems

Project plan

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1 Introduction

1.1 PROJECT STATEMENT

Our senior design project is about observing and analyzing new trends in distributions systems as solar Photo-Voltaic generation is increasing in Washington, Iowa. We will collaborate to develop a solution that can handle extreme instability trends such as over-voltage, reverse power, and etc.

1.2 PURPOSE

Our team is focused on making sure that Alliant Energy's distribution system will have the capabilities of handling an increasing PV generation. These tests will help develop a steady system that will keep their distribution system running in a stable fashion. Stability will be able to keep Alliant Energy's solar Photo-Voltaic generation attractive to their customers. Alliant Energy and our team are looking forward to helping the energy grid become more eco-friendly.

1.3 GOALS

Our team will familiarize ourselves with OpenDSS to achieve these goals. Our group's goals consist of:

- Simulating a real world distribution feeder owned by Alliant Energy with high solar PV penetration.
- Assessing the impact of high PV penetration on voltage profile of the feeder for the worst case scenarios such as high generation, low demand etc.
- Analyzing and comparing the impact of residential PV and community solar PV generation.
- Developing some solutions or guidelines that would benefit Alliant Energy to prevent future problems associated with high solar PV penetration.

2 Deliverables

Our deliverables will be better achieved by partnering with Alliant Energy. They own the distribution feeder that allows us to simulate high solar PV penetration. This feeder will be the key to our analysis.

One of our project deliverables is to perform a simulation of a real world distribution feeder with high solar PV penetration that will be finished by the end of the project design. Additionally, our team will conduct an evaluation and assessment for the worst case scenario. Finally, the output of the project will consist of concrete solutions and guidelines for the previously stated previsioned problems.

3 Design

To achieve the most practicable solutions for a stable distribution system with high PV penetration. We will follow these pre-determined phases:

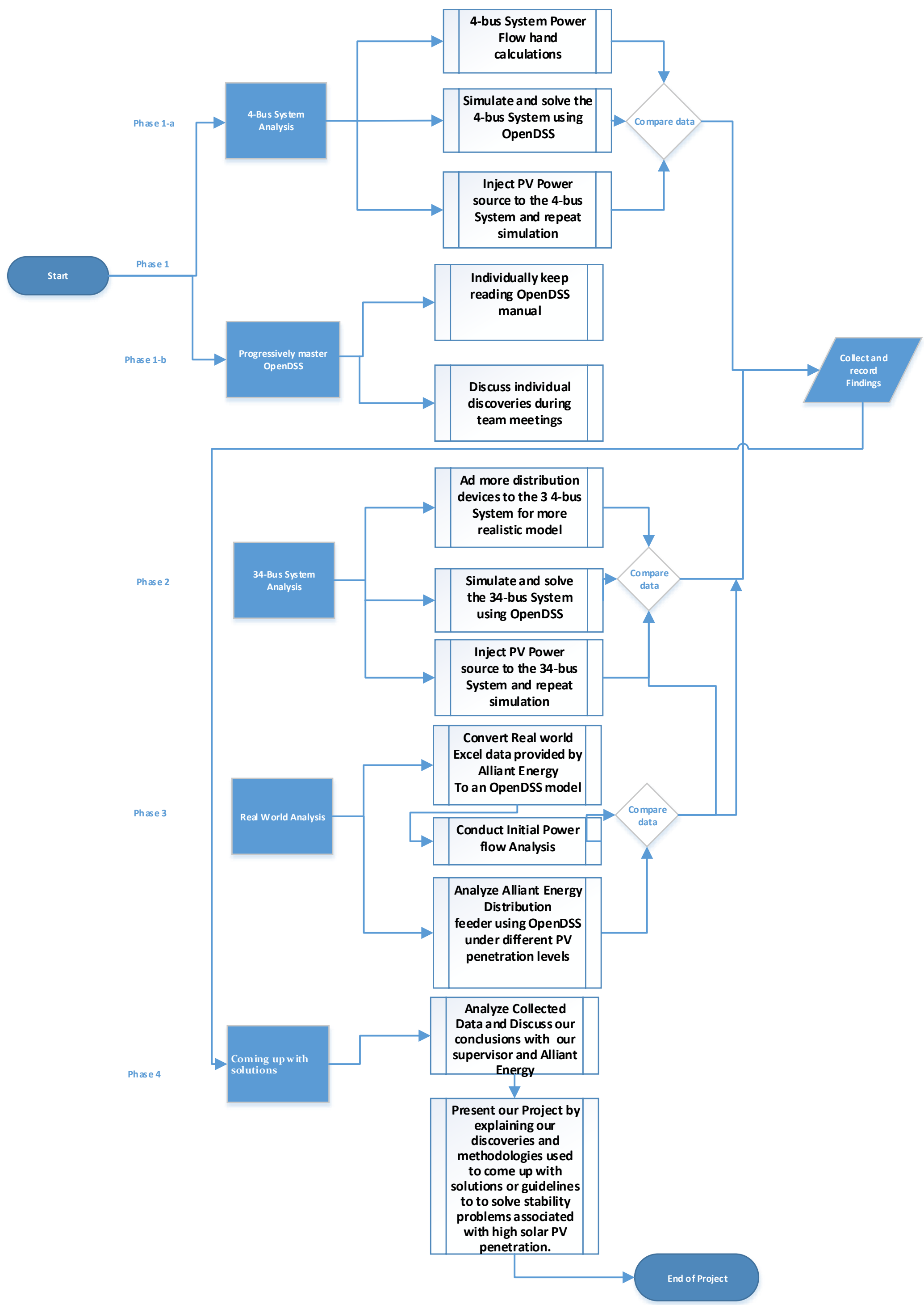


Figure 1 Project Roadmap

3.1 PREVIOUS WORK/LITERATURE

In the previous year, a group of students (Group 1520) attempted to analyze a similar distribution system. Due to some administrative delays their project ended without a concrete and realistic solutions that was based on real data. To resolve issues such as In-Rush Current and Voltage violations, they decided to focus on two major points:

I) Distribution Feeder Level: Group 1520 decided that in order to increase rated capacity and limit damages, current lines has to be upgraded from 13.2 kV to 24.9 kV.

II) PV Generation Level: at this level, Group 1520 decided to use smart inverter with add-ons features to automatically adjust to system changes. Finally they decided to use advanced batteries for storage.

More detail about the previous work performed by last year's group can be found at:

"dec1520.sd.ece.iastate.edu/uploads/4/7/7/3/47738801/_copy___current_fall_semester_dec15-20_final_presentation_template.pptx"

Our group appreciates the work achieved by Group 1520, but the group believes that the solutions were more generic and didn't take in consideration the specificity of Alliant Energy System. Our group will change that by working closely with Alliant Energy using their real data. We are also opening up more communication channels with Alliant Energy to that any solutions that we might suggest is adapted to the company's standards and philosophy.

3.2 PROPOSED SYSTEM BLOCK DIAGRAM

Our team will be processing the project by dividing it into 3 main stages as follow:

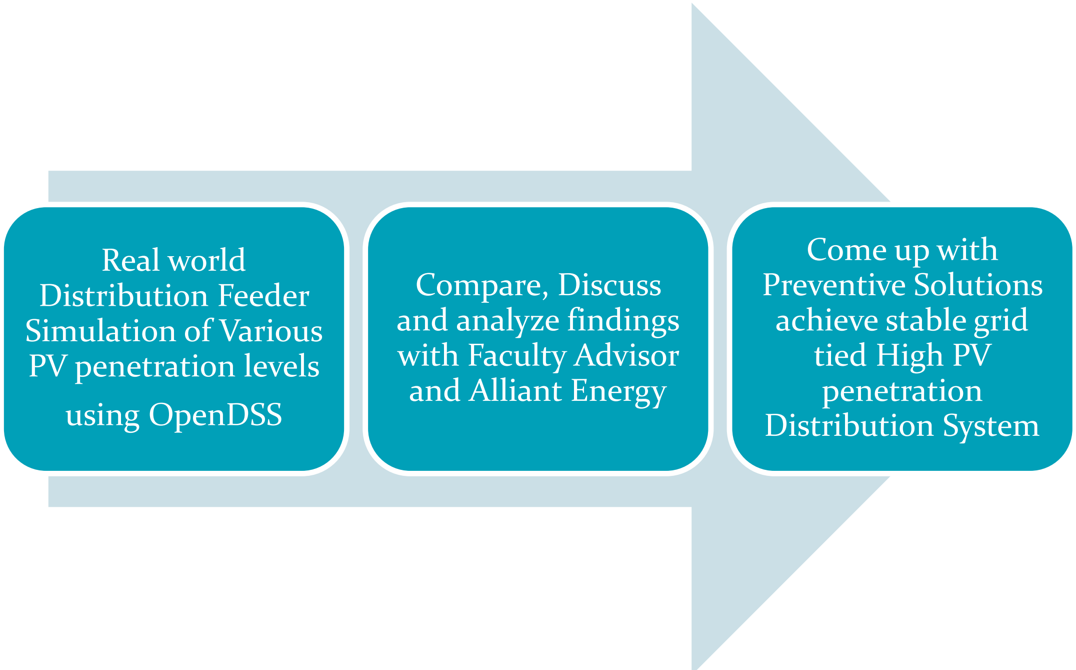


Figure 2 Project Main Stages

3.3 ASSESSMENT OF PROPOSED METHODS

Through OpenDSS we will be able to inject PV generation to various buses varying the level of PV penetration. During each case we will observe and compare how the distribution feeder respond to each scenario. Data will be collected in the form of voltages, currents, and power values at all buses. By analyzing each case, our team will define the proportion to where such PV integration starts causing problems to Alliant Energy's distribution system. Knowing the exact percentage will allow us to conduct a more realistic simulations which would be more applicable to our client. Finally, we have to come with preventive plan to solve problems such as voltage level variations due the cycle nature of solar energy (day versus night), and reverse power flow.

3.4 VALIDATION

With the help of OpenDSS, a real data analysis software, an experienced faculty advisor like Dr. Ajjarapu, and Alliant Energy as our client, we will be able to get an ongoing feedback to help us certify each phase of the project.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

Project functional requirements:

Generally, there are three fundamental functional requirements for our project:

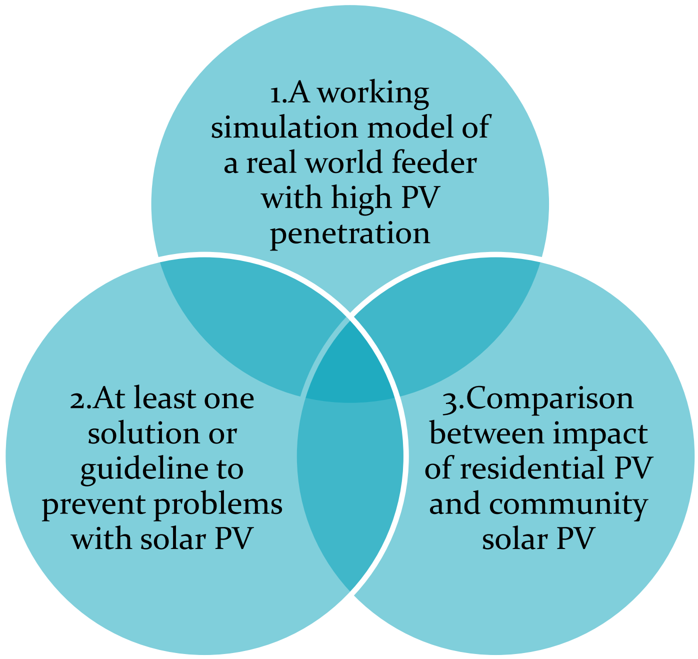


Figure 3 Fundamental Functional Requirements

In order to deal with the requirements more specifically, we did some research and we found four possible specific requirements (potential solutions) that we would potentially need to solve in our project:

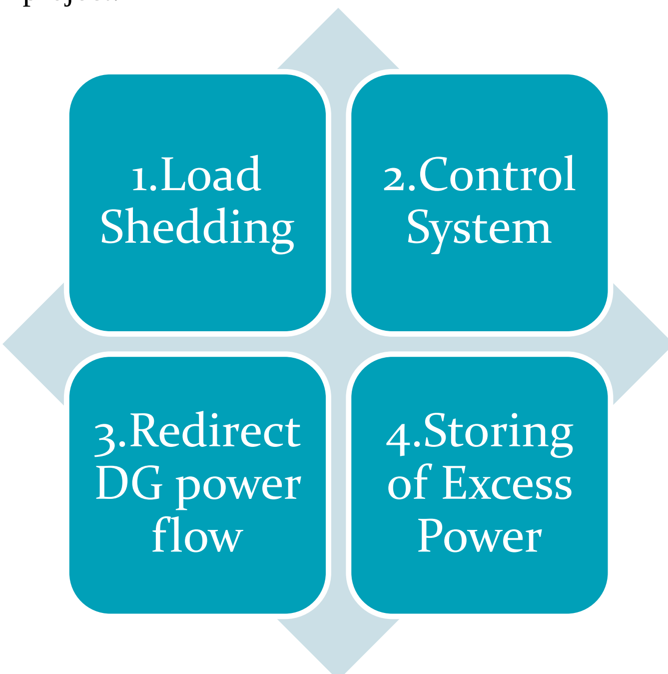


Figure 4 Project's Potential Solutions

1. **Distribution Load Shedding**
   Load shedding is a controlled way to prevent the unplanned events to the electricity power system from blackout. In other words, based on our project—in the Washington Area Iowa, consumers could use their own green generation power (solar PV) to feed themselves while the energy they are generating is sufficient and that would lead them to be disengaged from the grid temporarily. Once the power that they are generating is not sufficient, the system could draw them back to the grid by a sensor. Load shedding can dramatically increase the efficiency of the power usage of the grid in Washington area and it would effectively lead the power not excess the maximum limit of the entire system.

2. **Control System**
   The control system would possibly introduce a sensing mechanism that will detect the feedback power and voltages into the distribution loads/feeders and reroute the energy into a capacitor bank. The system can operate reversely to allow the energy back to the grid when the system is at a lower stage of usage.

3. **Redirect DG Power Flow**
   Modify the connection lines to the home—allow the excess of the power that generated by each individual home to transfer to the nearest substation and have it redistributed to the entire grid of the power system.

4. **Storing of Excess Power**
   Each individual customer may generate additional DC power by the solar PV and it will be stored in their own batteries. Once the demand of a load is in some specific scenario it could convert the excess power to an AC form and be transferred to the distribution grid in case to compensate the additional demand on utility lines especially in some high peak periods (hot summer & cold winter).

4.2 NON-FUNCTIONAL

Project Non-functional requirements:

There are four non-functional requirements/deliverable for our project:

Deliverable:

- Simulate a real world distribution feeder owned by Alliant Energy with high solar PV penetration
- Access the impact of high PV penetration on voltage profile of the case scenarios such as high generation, low demand etc.
- Analyze and compare the impact of residential PV and community solar PV generation
- Find some solutions or guidelines that would benefit Alliant Energy to prevent future problems associated with high solar PV penetration

Additionally, our client assigned several specific desired deliverables:

1. How much solar can the system handle, percent based on peak, before problems become apparent
2. What are the problems that exist at a high level of solar penetration
3. What solutions can you come up with to fix the problems

5 Challenges

Our group has encountered several obstacles during the process:

The reasons are explained in details as below:

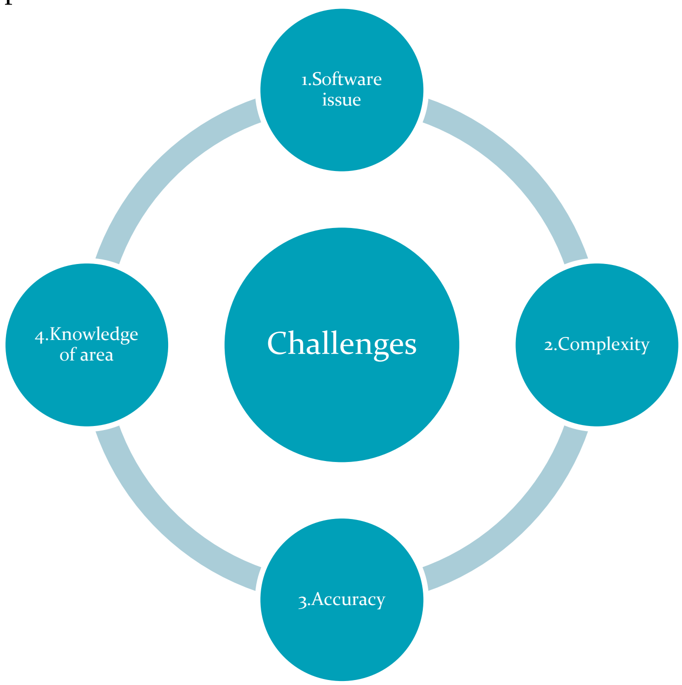


Figure 5 Project Challenges

Challenges:

1. Software issue—OpenDSS is a free software to simulate the distribution power grid but this software is not powerful enough and some of its functions aren't user friendly and difficult to operate, since it's a free software.

2. Complexity of the real world distribution system in Washington area:
    - There are 123 buses/feeders in the real system
    - Even more complex when the solar PV introduced into the grid
    - Need to find a way to balance the benefit for Alliant Energy Company and functionality for the entire system

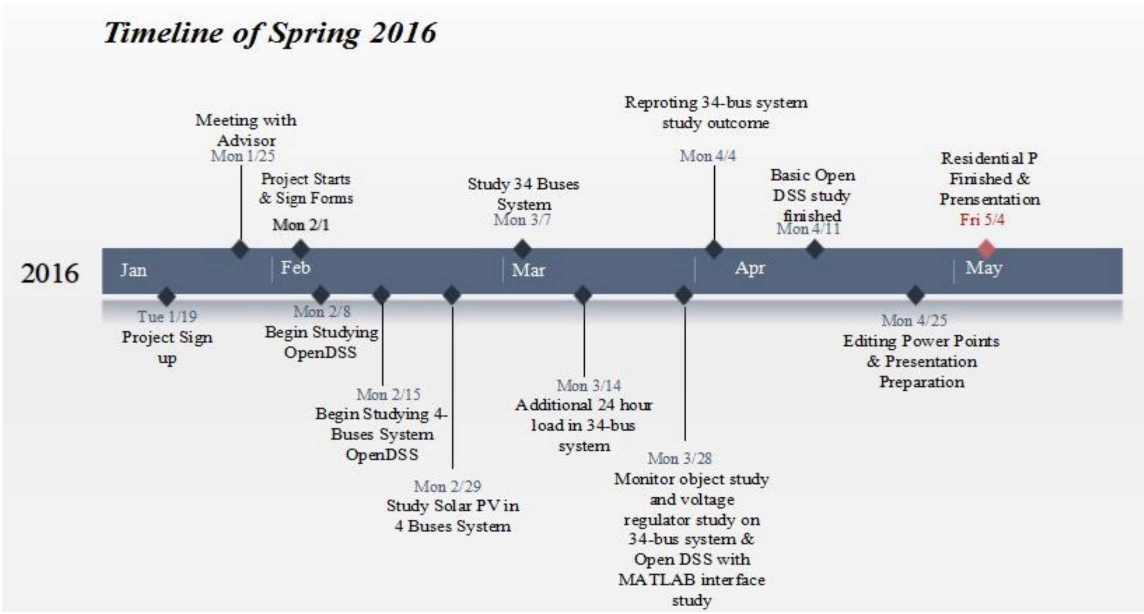
3. Data may not be accurate—the data we are dealing with is the data from the previous years. The accuracy may vary since there could be more potential solar PV introduced to the grid in the real world.

4. Enormous extending reading materials—what we learned from EE303 is not enough understanding for this project. We need to frequently reference the manual for OpenDSS, a whole textbook of power distribution system and other related materials

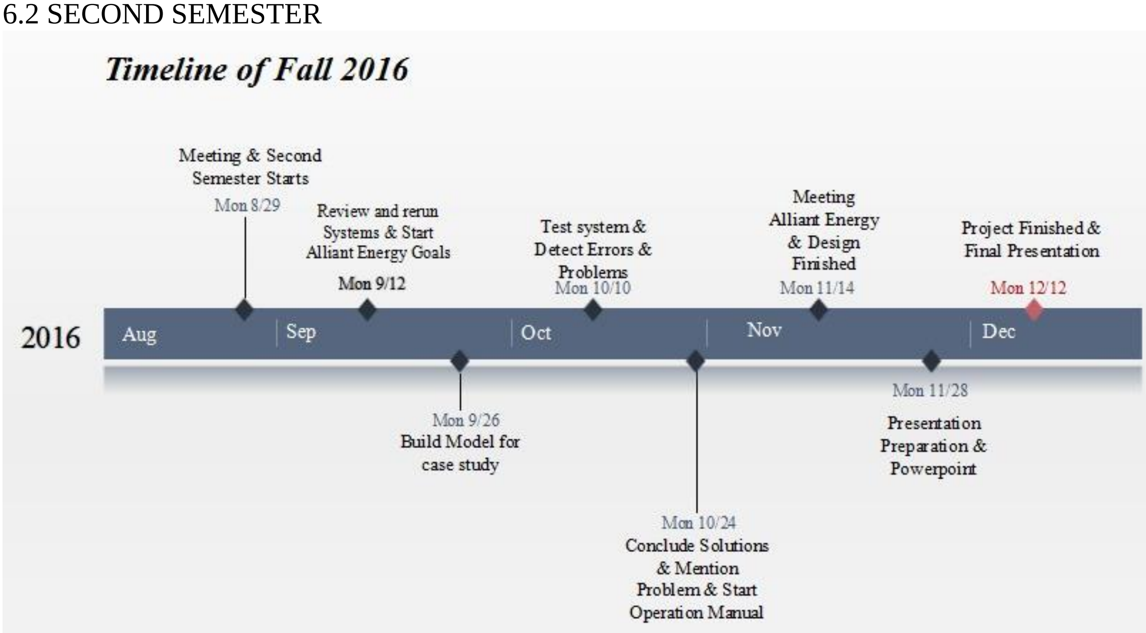
6 Timeline

According to the real working process and future schedule, we managed two separate timelines for spring semester and fall semester. So that project process can easier to understand.

6.1 FIRST SEMESTER



6.2 SECOND SEMESTER



7 Conclusions

After analyzing all of the project goals and challenges, we are thrilled to be working the Dr. Ajjarapu and Alliant Energy to help this distribution system become one step closer to a smart grid. Our goals for this senior design project are as following: to simulate a real world distribution feeder owned by Alliant energy with high solar PV penetration, assess its impact for different cases, analyze and compare the impact of residential and community solar PV generation, and find solution or guideline to their existing problems.

Besides, we will also focus on specific goals and requirements from Alliant Energy. And they are how much solar can the system handle, percent based on peak, before problems become apparent (excessive voltage rise, etc.); what the problems are existing at a high level of solar penetration; what solutions we can come up with to fix the problems.

Our team will be able to achieve all the goals and deliver all the results to Dr. Ajjarapu and Alliant Energy by the end 2016 fall semester. For the first semester of project, residential solar PV generation effects will be fully understood and simulated via OpenDSS. The fall semester will be spent on understanding these effects and forming a solution. A formal SOP will be edited as a part of expected deliverable as well. At the end of each semester, our team will conduct presentations to show our progress and end results.

8 References

"Project Abstract"
by Department of Electrical and Computer Engineering

"High Penetration PV Handbook"
by Rich Seguin, Jeremy Woyak, David Costyk, Josh Hambrick, Barry Mather

"High Penetration Photo-voltaic Case Study Report"
by J. Bank, B. Mather, J. Keller, M. Coddington

"Distribution System Modeling and Analysis"
by William H. Kersting

"Reference Guide The Open Distribution System Simulator"
by Roger C. Dugan

9 Appendices

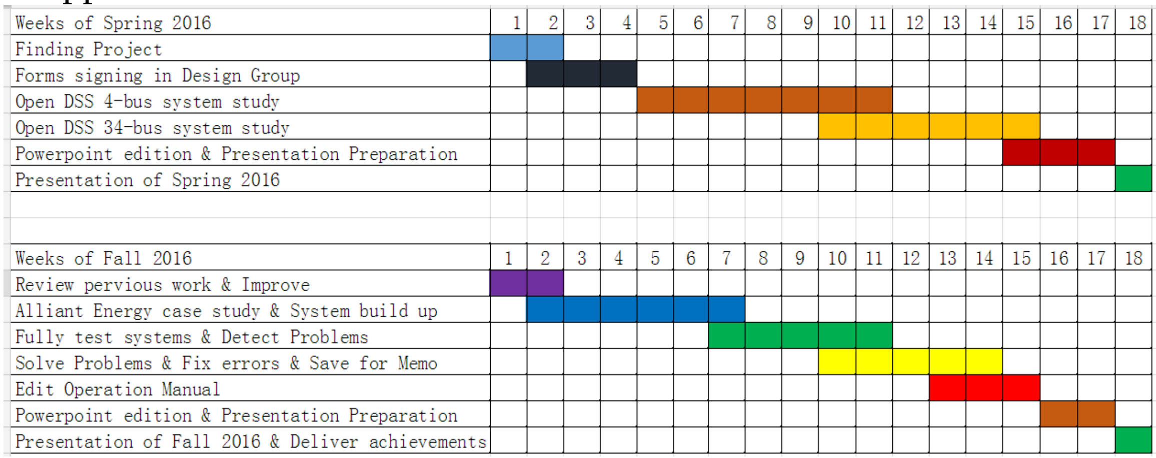


Figure 6 Weekly Breakdown