New Design Concept for Residential Electric Meter Adapter

DESIGN DOCUMENT

sdMay20-28

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Alliant Energy

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Executive Summary

Engineering Standards and Design Practices

- NEC 2017
  - section 110.28: Outdoor Electrical Enclosures
- NFPA Code
- City codes under Alliant Energy jurisdiction

Summary of Requirements

- Provide a new adapter prototype to Alliant for the project
- Abide by Iowa electric code, NEC, and any other applicable codes
- Effectively connect to existing meter socket without altering the meter/socket
- Create a product that reduces cost for clients and Alliant
- Create a more aesthetically pleasing / smaller design

Applicable Courses from Iowa State University Curriculum

- EE 303
- EE 456
- EE 457
- EE 458
- IE 305

New Skills/Knowledge acquired that was not taught in courses

- Knowledge of NEC code and local electrical codes
- Electrical contractor experience
- CAD 3D modeling software
- Control panel manufacturing experience
- Sheet metal fabrication

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1 Introduction

1.1 Acknowledgement

We would like to thank Alliant Energy and specifically Joel Peyton and Nick Peterson for providing valuable resources and support throughout the project. We would also like to thank Professor Zhaoyu Wang for his advice and support and ability to provide us greatly appreciated perspective and support within the professional and academic communities in the university.

1.2 Problem and Project Statement

Problem Statement

Our client is in the process of converting all their overhead connections to meters into underground connections in order to avoid power outages during heavy storms. This process is costly and if done wrong will result in homeowners being required by law to bring their entire home up to code. Our task is to devise a way to bring this new connection into consumers' homes in a cost-effective manner that does not result in costly updates to the entire home by altering the meter socket.

Solution

We are going to approach this problem with three goals in mind: cutting down on Alliant Energy labor, cutting down on contractor labor, and cutting down on material costs. We are coming up with multiple solutions that incorporate these ideas, but cutting down on one usually adds costs elsewhere. We will be constantly refining our ideas to optimize the solution.

Driving Factors

The main driving factor of this project is that many of the Alliant Energy supplied houses in Cedar Rapids are very prone to power outages, since they have overhead electrical input to the house. We seek to remedy this by creating a system where the electrical input to the meter on the house can be relatively easily converted to a connection to an underground electrical cable. This will cause there to be virtually no power outages on the Alliant Energy customers' side, and will also make for a safer work environment for Alliant Energy employees, who will then not have to perform frequent maintenance on downed power lines.

1.3 Operational Environment

This final project will be required to operate on the exterior of residential homes. It must be able to withstand the temperature swings of Iowa homes as well as ice storms and severe thunderstorms. It must be able to withstand these conditions while maintaining delivery to the homes without being the cause of additional service interruptions once the conversion is made.

1.4 Requirements

- We have to successfully connect underground utility lines to the meter without violating NEC Code.
- We need to make it as cost-effective as possible. Current process is too expensive for customers.
- The solution has to be relatively low profile and be able to fit on every house, each with a unique layout.
- Must be weather-resistant. Our product will be outfitted on the outside of a house, so it will be outdoors at all times.
- Must be possible to install without extensive tampering of the electrical meter itself.

1.5 Intended Users and Uses

Intended users are homeowners that currently have overhead power connected to their house who would want to convert to underground feeds. This technology is already available but is not cost-effective, so our project aims to lower homeowner expense.

1.6 Assumptions and Limitations

Assumptions:

- Flexible installation options.
- As aesthetically pleasing as possible.
- End product will be used for Alliant Energy customers.
- Upgrade will be available to all customers who are interested in underground electrical feed.

Limitations:

- Installation should not exceed the existing price point.
- Cannot violate NEC 2017 codebook.
- Cannot violate NFPA regulations.
- Unable to test our product on high-voltage application, since we do not have access to something in which we could perform this test

1.7 Expected End Product and Deliverables

For our project, we need to create a design schematic and model of the adapter enclosure and the connection to electric underground feeds. Our design is an electrical meter socket adapter enclosure. The goal is going to be taking Alliant Energy's current solution and streamlining it by taking out wire bends and making it a true adapter. Our enclosure will connect to the top of the meter socket by conduit, run parallel across the top of the meter socket, and then protrude beyond the side of the socket and come down out of a conduit knockout. Alliant will be able to connect the underground to the bottom of our enclosure where we will provide a conduit knockout of differing sizes. We will also provide a knockout where the conduit will connect our adapter to the meter socket. Inside the enclosure, we are designing 3 raceways at the top of the enclosure that will carry power across the enclosure. The underground feeders will connect with lug nuts to the raceway on the underground side, and we will provide wire tails that will connect to lug nuts on the meter socket side of the enclosure. This eliminates the need for the wire bend in their existing solution, which forces the box to be much larger than our current design.

We will also create a CAD model of our design to further visualize our design beyond the schematic. This model will include all aspects of the design, including accurate dimensions, materials, and interior hardware.

*We also plan on creating a prototype of our project to showcase at the end of the school year when we present our final project.

Our planned date of completion for these deliverables are as follows:

-Schematic : January 24th, 2020

-Model : January 31st, 2020

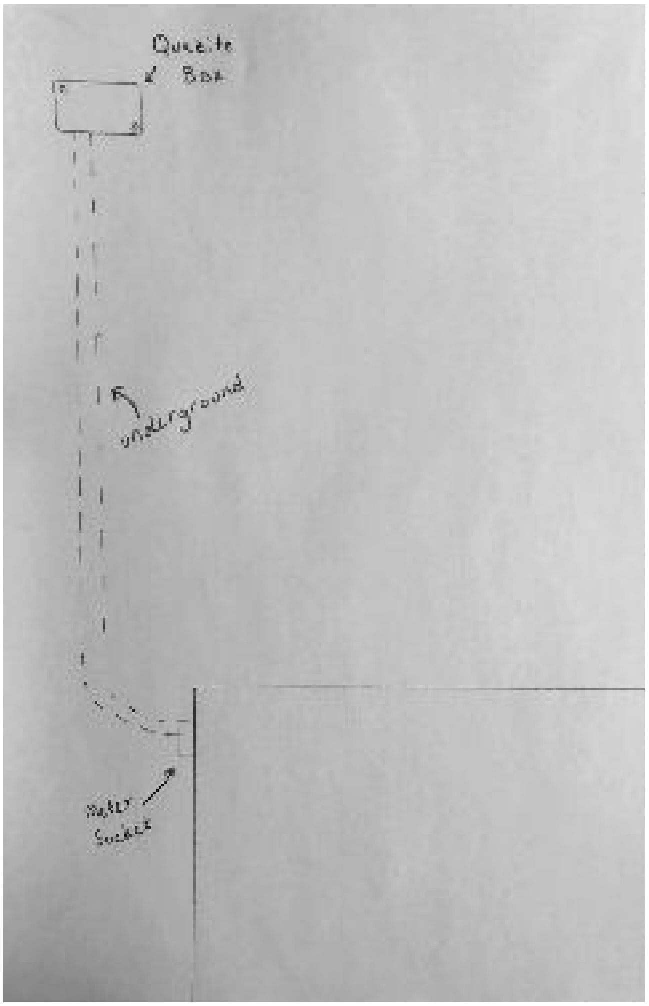
*-Prototype : April 24th, 2020

* unable to complete due to COVID-19 outbreak

2. Specifications and Analysis

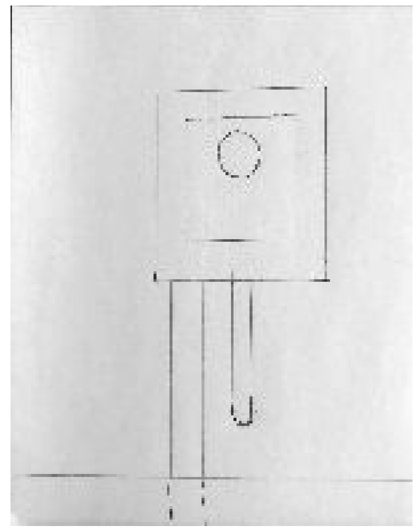
2.1 Proposed Design

Quazite Box Idea



Outer Shell Idea

V1



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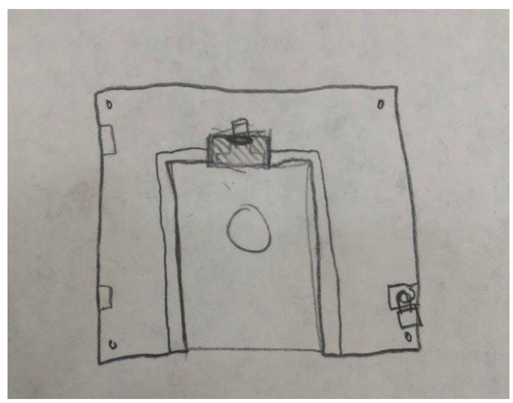
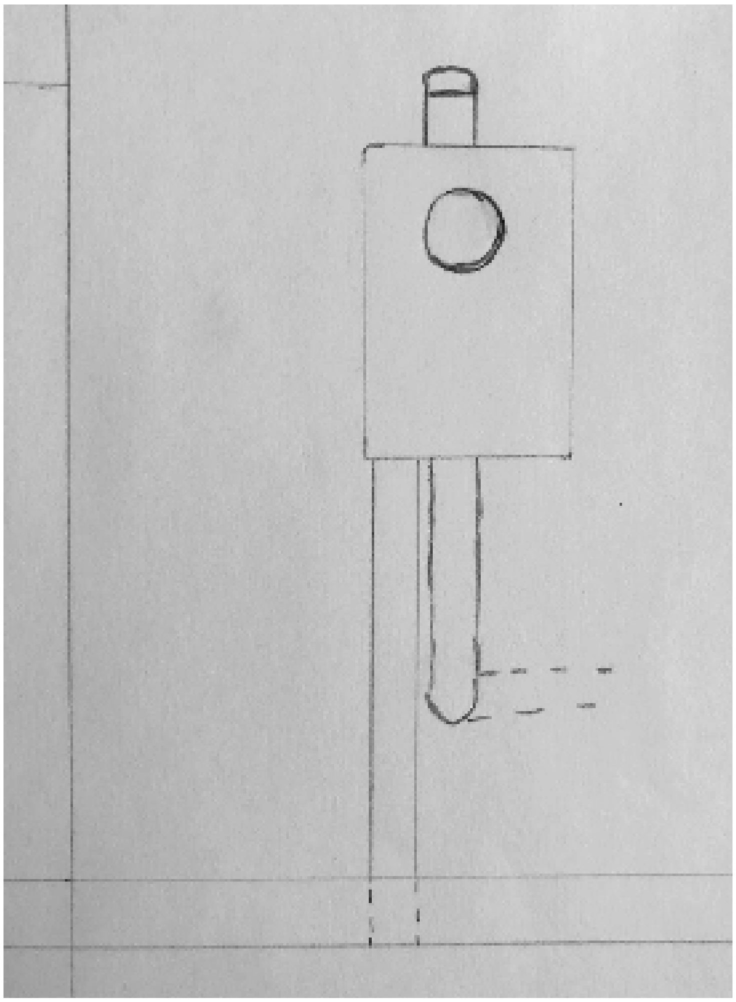
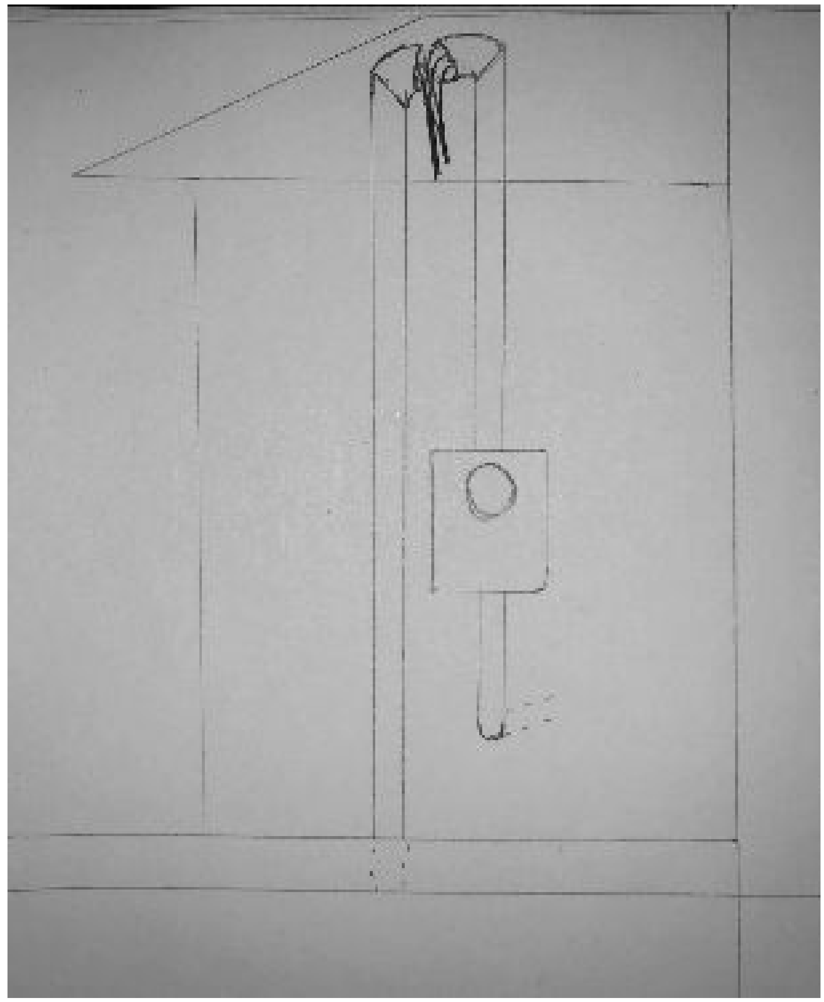


Weatherproof Plug Idea



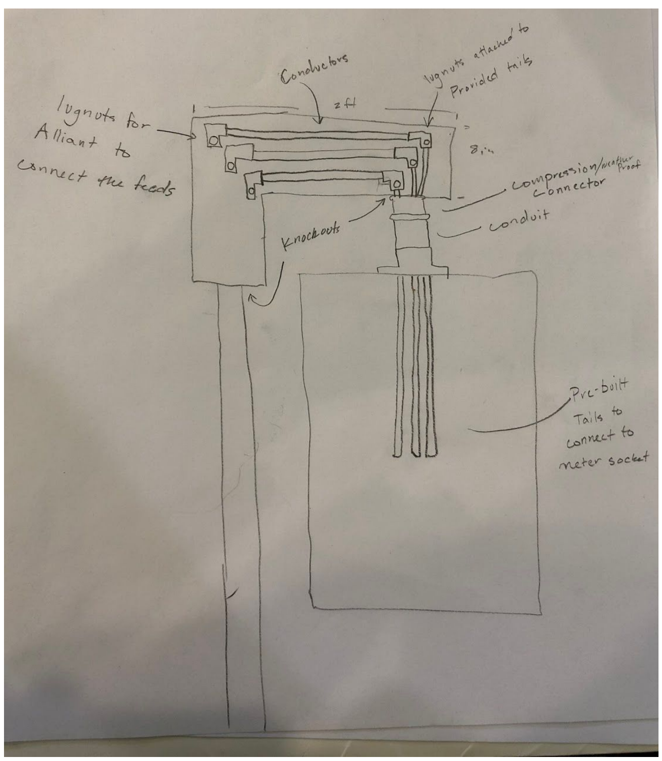
Weatherhead Idea



We had an original four potential solutions: Quazite Box, Outer Shell, Weatherproof Plug, and Weatherhead. Refer to the figures above. For the Quazite Box, we are cutting down on Alliant Energy labor, but adding to electrical contractor labor. The idea behind this is that electrical contractors work for less money than electrical utility companies. The Outer Shell is going to add to material costs, but will shorten electrical contractor labor and be more aesthetically pleasing. The utility labor will remain the same. The Weatherproof Plug has potential to run into code issues, but it will be the most aesthetically pleasing and will cut down on both material and labor costs. The weatherhead solution cuts out the electrical contractor completely, potentially saving labor. The downside is going from underground all the way to the top of the weatherhead will look terrible.

We originally went with the outer shell idea after having a meeting with Alliant energy. They were enthusiastic about that option and asked if we could make it universal for the two seperate sizes of meter sockets that they offer. We pursued this option for several weeks and pitched the updated outer shell option and asked for the dimensions of those different meter sockets. Alliant then gave us the information that there were actually over 20 different sizes of meter sockets being used out in the field of varying dimensions and shapes. We then scrapped that idea and started from scratch.

Raceway Adapter Design



We eventually decided on our Raceway Adaptor Design. This design was sent as an idea by our contact in Alliant as a solution to the issues we had with our outer shell idea. The idea is that we can connect to any size or shape of meter socket, as long as we design it wide enough to clear the largest meter socket in the market. This design will still be much smaller than the existing solution in use by Alliant Energy. The shrinking of the box is going to reduce material cost, and become more aesthetically pleasing.

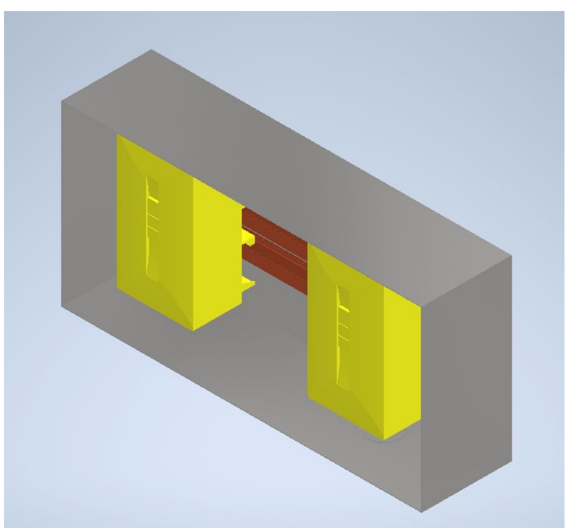
2.2 Design Analysis

We originally pitched four different ideas to Alliant Energy. The Quazite Box idea was discarded because Alliant Energy was worried about who would have ownership of the wire between the house box and the meter socket, and they didn't want to sort through the liability. The Waterproof Plug idea failed because after calling a state inspector, they stated that if a new hole was punched into the meter socket, then the entire house required an electrical inspection and must be up to code. That was one of the original problems Alliant was hoping to avoid. The Weatherhead option was originally proposed as an option of saving money, but was understandably scrapped because it is going to look terrible.

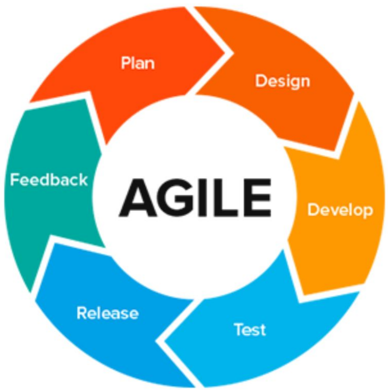
We had a meeting with our contact from Alliant Energy, and he encouraged us to follow up on the outer shell idea and make it a universal fit for the two different size meter sockets. After several rounds of preliminary design and research, we came up with the outer shell version two. We pitched the new design to Alliant and asked for the different dimensions of the two meter sockets. They responded and informed us that there were actually over twenty different meter sockets being used, so this option was actually not going to work at all.

We designed and researched the new Raceway Adaptor option as our most recent design This design was built without the need for opening the meter socket while still being aesthetically pleasing. We are designing this option to be an enclosure that Alliant is going to connect their underground conduit to from the bottom. This enclosure is also going to connect to the top of the meter socket. We are able to justify the smaller size by using raceway connections to the wires that do not require the wires to be bent at all, let alone to their maximum compliance rating.

After getting feedback from industry professionals we decided to change the shape of our design from an "Ell" to a rectangle. The rectangular shape allows for an off the shelf enclosure instead of a custom build. This is a much more cost effective option, and reduces the footprint on the house.



2.3 Development Process



We're following the Agile development process because we think it fits best with the nature of our project.

Plan: First, we met as a team with the proposed project description and decided what direction we wanted to go with the project. We researched relevant information about the project, such as electrical safety codes and standards for this industry. In this stage, we also met with our faculty advisor, Dr. Wang, and also met with our contacts Joel Peyton and Nick Peterson from Alliant Energy to get familiar with the scope of the project.

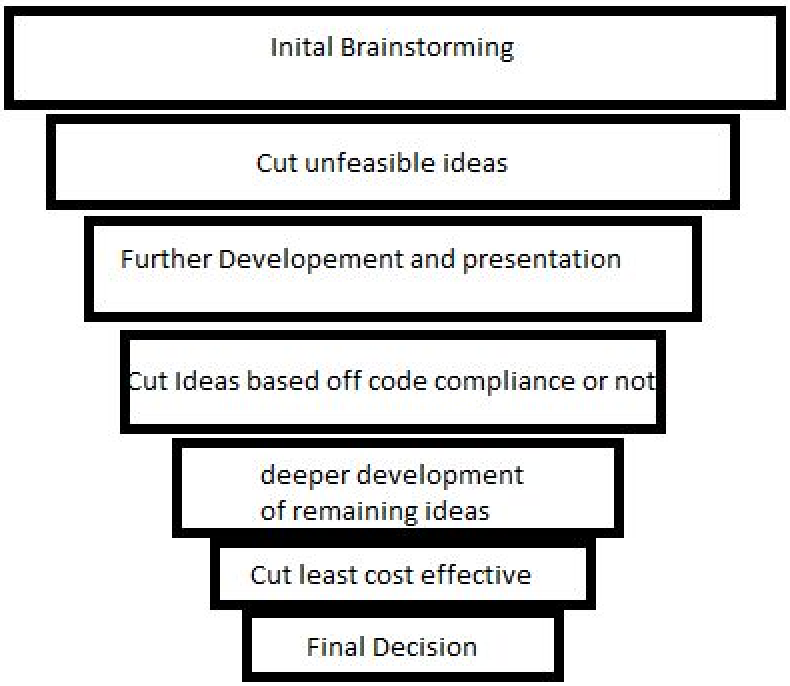
Design: Once we felt that we had a grasp on the scope of the project, we began the designing phase. In this stage, we came up with a number of different possible designs for our project.

Develop: Once we settled on one of our original designs, we began further developing the idea. Once example was the "Shell" idea.

Test/Release/Feedback: After we had developed our initial plan, we met with our Alliant Energy contacts again, where we found that our design would not work since there are several different electrical meter sizes. After this realization, our team had to revert back to the "Plan" phase and continue on to eventually arrive at the "Raceway" solution.

2.4 Design Plan

Our team's design plan was to start with brainstorming as many ideas as we can. We then began to narrow them down based on feasibility and code compliance. As we got to frontrunning ideas we then made cuts based on cost and aesthetics and made our final choices and see if there is a clear option at the end of the process. Once this was done we presented the idea to Alliant and a state inspector for approval of the concept and any advice they may have as we began the process of modeling and making more in-depth design decisions. Once we finished we evaluated how much time and money we had left as we wanted to make a working prototype but it is not a required deliverable and we simply have to make sure we had a well thought out CAD model ready to submit to alliant. The prototype would have allowed us to better test the installation and performance of the design but we were unable to complete this step due to the COVID-19 outbreak.



3. Statement of Work

3.1 Previous Work And Literature

Currently, overhead to underground conversions are made by completely replacing the meter socket, installing an adapter to go around the existing meter socket, or modifying the meter socket with knockouts.

As of now, the current "Ell" solution, developed by Alliant Energy, is very bulky, and our solution seeks to cut down on size by eliminating the need for wire bends within the enclosure by using raceways instead of wires.

3.2 Technology Considerations

The current and best solution to this current problem is replacing the meter socket or running the underground into the bottom of the existing meter socket and then putting a cap on the top conduit. There are several issues with these solutions. Replacing the entire meter socket is not very cost-effective to begin with, but both solutions have a code requirement that forces the price to skyrocket. These solutions mandate that a state inspector must inspect the entire house and electric panel to make sure the house is up to code. If the house is not up to code, they must update everything before the inspector will sign off on the renovation. This becomes very costly, and Alliant Energy wants to avoid running into these costs.

These are the current solutions that are being pursued by Alliant Energy. The junction box is a practical solution but it is the worst looking option available. This is also an expensive option. The Ell Adaptor is the current adaptor that Alliant is trying to push, but they also do not like a large, bulky look.

The other issues are that it requires a lot of wall space and has the highest cost of all the issues. The third option has several different code violations that Alliant is internally trying to pursue. It is the same issue with using a seperate knockout, where the entire home must be code compliant.

Our design solution aims to avoid opening up the meter socket, to avoid the mandated state inspection. We are also trying to limit unnecessary costs and make this box as unobtrusive as possible. We have presented several different options to bypass these issues, but each had their own different setbacks. We pursued what we believed to be the best option, and we attempted to mitigate each individual setback during the design process.

3.3 Task Decomposition

Task 1: Create a list of constraints and understand client's requests

Task 2: Look into existing ell solution and diagnose issues

Task 3: Research potential NEC code violations and current standards

Task 4: Develop potential solutions and evaluate the pros and cons

Task 5: Decide on most practical solution

Task 6: Develop preliminary designs for chosen solution

Task 7: Present designs to Alliant Energy and receive feedback, look into any potential flaws

Task 8: Develop final design with feedback and personal research

Task 9: Develop a model

Task 10: Prepare prototype build

*Task 10: Build the prototype

*cancelled due to COVID-19

3.4 Possible Risks And Risk Management

Knowledge of the code could potentially derail the project if we decide on an idea that violates the National Electrical Code and we don't realize until the end. Also, any idea we come up with will be difficult to use as a universal solution with every house having a slightly different meter location and many different types of meters that could be on it.

More specifically with our design, there is the risk that once we calculate the cost of the process that it will not be more cost-effective than the existing process.

We will also have to be careful not to be too deep into final designs and component choices as the NEC will update in 2020, bringing new lists of approved components and new rules. We can avoid this issue by making final component selections and enclosure properties when the new code updates.

We also faced the risk of creating a design that cannot be implemented in the real world, which we can mitigate by thorough design testing of our project and collecting feedback and opinions from our client and industry professionals.

3.5 Project Proposed Milestones and Evaluation Criteria

Milestone 1: Final decision on a design concept to run with.

Success: Design concept is approved by Alliant and a state inspector.

Milestone 2: Create initial model and precise concepts.

Success: Design can be reviewed for any smaller code violations internal to it and not the overall system as a whole.

Milestone 3: Compare model/concepts to available parts from Alliant.

Success: parts have been evaluated and any existing technology is incorporated.

Milestone 4: Final model complete.

Success: Alliant reviews the final design and approves.

*Optional Milestone: Prototype is complete to exemplify effectiveness and provide more insight to flaws.

*Process: Install design in a low risk situation to discover any unanticipated problems and confirm effectiveness in criteria.

*cancelled due to COVID-19

3.6 Project Tracking Procedures

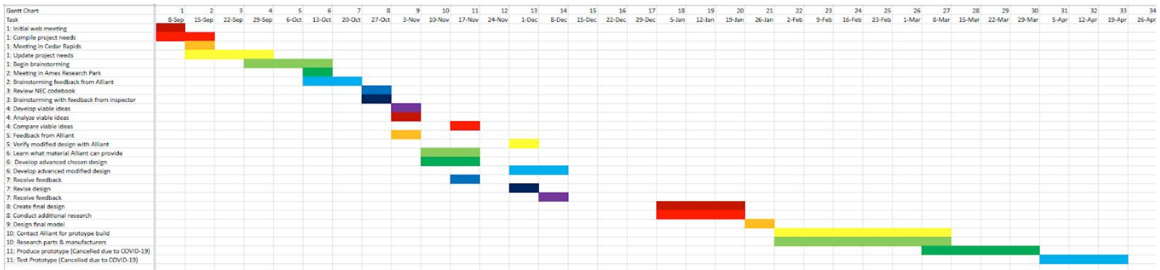
Tracking this project was simple, as this will be an adapter to make physical wiring connections that we modeled. Tracking this project was much easier than anything software based because we had very obvious progress in each step. Since we hit milestones in line with our schedule this project was successfully completed on time.

3.7 Expected Results and Validation

The required outcome is a 3D model submitted to Alliant in order to provide an illustration of how this design will function and solve their problems. We also wanted to take part of the project budget to develop a functioning prototype to show our client how the idea would function and be installed. That high level of making connections and delivering reliable power will be hard to prove in a CAD model so that is why we are striving to develop a working unit to exemplify the function of the adapter. However, Covid-19 derailed our attempts at a prototype.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline



Task	Start Date	End Date
Task 1: Create a list of constraints and understand client's requests		
Initial web meeting with Alliant Energy	9/12/2019	9/12/2019
Compile initial list of needs for the project	9/13/2019	9/19/2019
Trip to Cedar Rapids to meet with Alliant Energy contacts, and look at project scope in the field	9/20/2019	9/20/2019
Refine list of project needs	9/21/2019	10/1/2019
Begin brainstorming ideas	10/1/2019	10/17/2019
Task 2: Look into existing ell solution and diagnose issues		
Meet at Alliant Energy workspace in Ames to review existing solution	10/18/2019	10/18/2019
Cross check existing issues with our new designs	10/19/2019	10/26/2019

Task 3: Research potential NEC code violations and current standards		
Review NEC codebook to identify potential problems our design could encounter	10/27/2019	11/1/2019
Contacted local electrical inspector to get professional input	10/31/2019	10/31/2019
Task 4: Develop potential solutions and evaluate the pros and cons		
Create design concepts of brainstormed ideas	11/4/2019	11/7/2019
Identify advantages and disadvantages of concepts.	11/4/2019	11/7/2019
*Re-evaluate design options	11/19/2019	11/19/2019
Task 5: Decide on most practical solution		
Video conference with Alliant Energy contacts to decide on an idea and receive feedback	11/8/2019	11/8/2019
*Verify modified design with Alliant Energy	12/2/2019	12/2/2019
Task 6: Develop preliminary designs for chosen solution		
Collect relevant parts list of what Alliant Energy can provide to us vs. what we will have to provide ourselves	11/11/2019	11/18/2019
Begin developing advanced concept of chosen design	11/11/2019	11/22/2019
*Begin developing advanced concept of new design	12/2/2019	12/13/2019
Task 7: Present designs to Alliant Energy, receive feedback, look into any potential flaws		
Receive feedback on design	11/18/2019	11/22/2019

Revise design with feedback	12/2/2019	12/6/2019
Receive additional feedback	12/9/2019	12/13/2019
Task 8: Develop final design & schematic with feedback/personal research		
Create finalized design schematic with all feedback	1/6/2019	1/24/2019
Conduct any additional research for the design	1/6/2019	1/24/2019
Task 9: Develop a model		
Develop finalized model with finalized design and all gathered information	1/27/2019	1/31/2019
Task 10: Prepare Prototype Build		
Contact Alliant Energy todiscuss prototype build	2/2/2020	3/9/2020
Research parts/manufacturers	2/2/2020	3/9/2020
Task 11: Build the prototype (Unable to complete due to COVID-19)		
Contact additional outside sources/Alliant Energy to help build prototype structure	3/10/2020	3/29/2020
Produce prototype based off of model and design	4/5/2020	4/19/2020

This proposed schedule covered both semesters. We gave ourselves most of the first semester to plan and research, then start our design. We then picked up right at the beginning of the second semester to continue developing our prototype.

4.2 Feasibility Assessment

We finally decided to design a smaller box on the side of the existing meter socket, and a process for installing that cuts down the utility company labor. The biggest challenge we anticipated was being code compliant and wrestling with new code updates that took effect in January. This means some of the rules for our project may change at the turn of the calendar. We worked on the initial model for our idea during the first semester and made sure to review all of our components for code compliance once the new code is released before we present the idea to Alliant. Once that was complete and we felt we were code compliant we moved forward with the project.

4.3 Personnel Effort Requirements

Task	Personnel Effort
Create a list of constraints and understand client's requests	Team visits Alliant Energy in Cedar Rapids to better understand the project and look at meter sockets in the field.
Look into existing ell solution and diagnose issues	Team discussion session to identify necessary criteria for new design.
Research potential NEC code violations and current standards	Review relevant NEC sections as a team and take note of what we need to watch out for.
Develop potential solutions and evaluate the pros and cons	Team will brainstorm solutions and get feedback from each other. The best designs will be presented to Alliant and get more feedback.w
Decide on most practical solution	Team decides on the solution that is most well-fitted for the project requirements.
Develop preliminary designs for chosen solution	Team discusses technical details of the chosen design.
Present designs to Alliant Energy and receive feedback, look into any potential flaws	Full team for WebX meeting with Alliant Energy to obtain feedback on design ideas.
Develop final design with feedback and personal research	Team members will be divided to do individual research and come back together with feedback from Alliant Energy to finalize design.
Develop a model	Team will work with AutoDesk Inventor to develop a detailed model of the project design.
Build the prototype: unable to complete due to COVID-19	Team will work with Alliant Energy to construct a prototype.

4.4 Other Resource Requirements

As far as materials to meet the minimum requirements of the project we had everything we needed with the software the university provides us. Once we moved into the optional side of the project we were looking into ways to get the prototype manufactured for us using our project budget. We had reviewed the NEC 2020 update on the turn of the calendar and had selected new parts to make the electrical connection and we were moving forward with manufacturers. We would have needed space and tools to make the final assembly ourselves but COVID-19 intervened and caused these plans to be cancelled.

4.5 Financial Requirements

We do not need financial resources beyond our included budget given by Alliant Energy to complete the requirements of the project.

5. Testing and Implementation

5.1 Interface Specifications

We only have hardware interaction between the adapter and existing meter socket. There is no software present in this project. The only software used was CAD software to create our 3D model of the solution.

5.2 Hardware and software

*Multimeter: Tests continuity to check for good connections and electrical isolation of the unit.

*unnecessary due to lack of ability to test due to COVID-19

5.3 Functional Testing

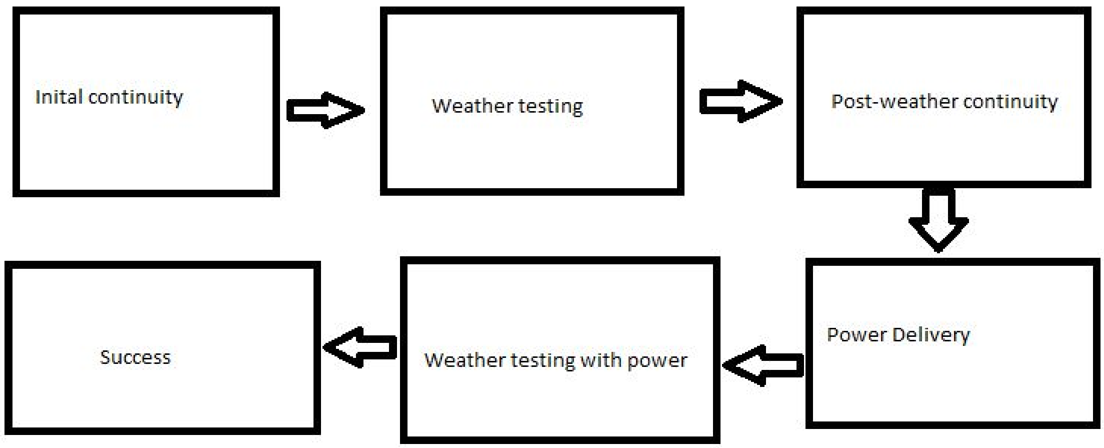
We will begin by checking the continuity of the installed system. It will then be subjected to weather testing to prove its abilities to survive Iowa's massive weather swings. We will then check the continuity to make sure no connections have been disrupted. Once we have tested that we will move onto the performance tests.

5.4 Non-Functional Testing

We will test for performance by installing the prototype and subjecting it to weather while it is providing power and making sure that service is uninterrupted. We would have tested for usability by having a contractor estimate the total cost to install the adapter and how easily it is installed by others. We were unable to complete these estimates because we were never able to have the labor force evaluate install times in order to give proper estimates on the job.

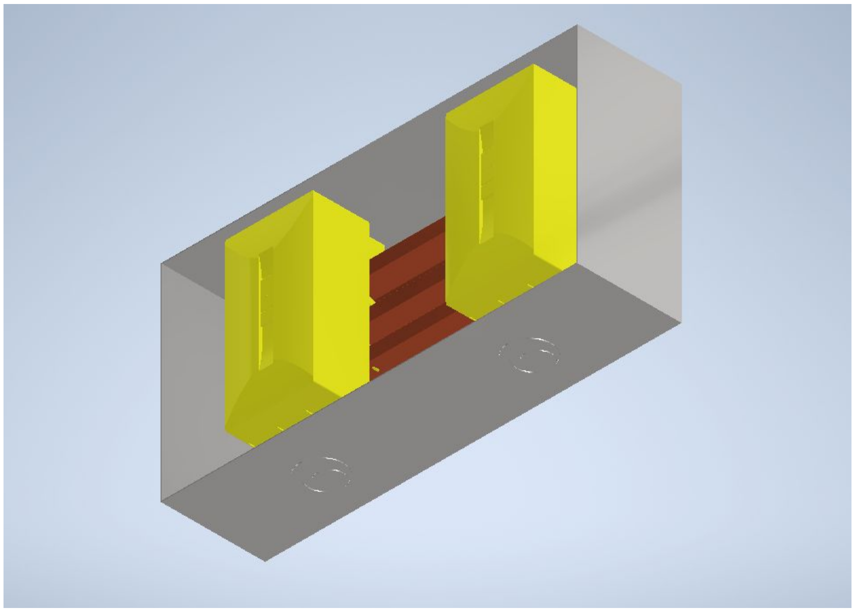
5.5 Process

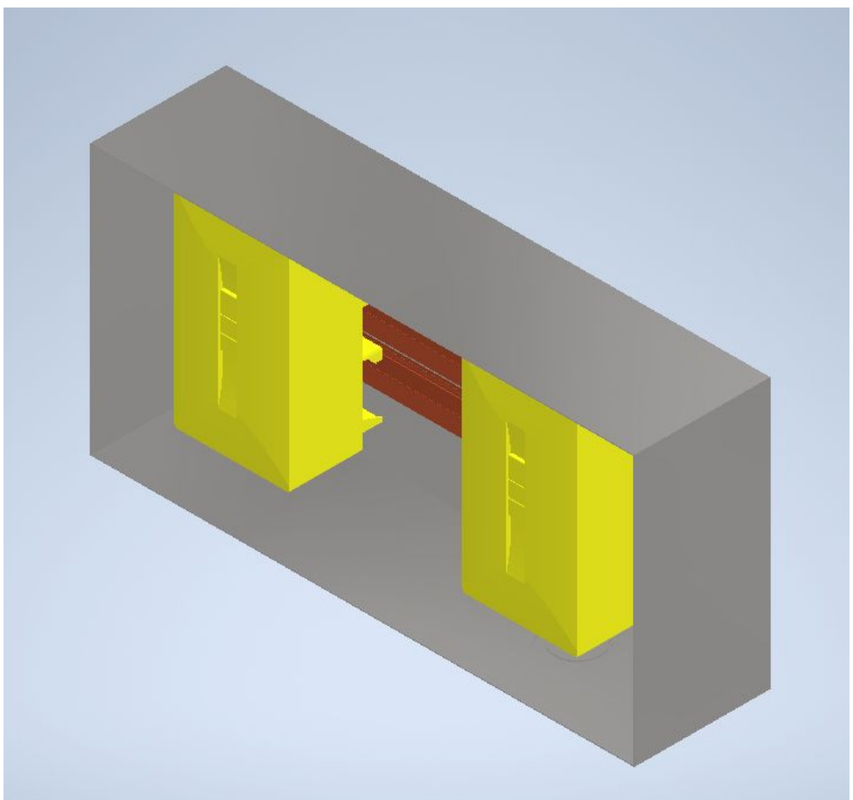
The testing we wanted to do was make sure the prototype could deliver stable service in various conditions and then also evaluate the cost effectiveness of the solution when we got to test installation time and evaluate the prices of bulk orders.

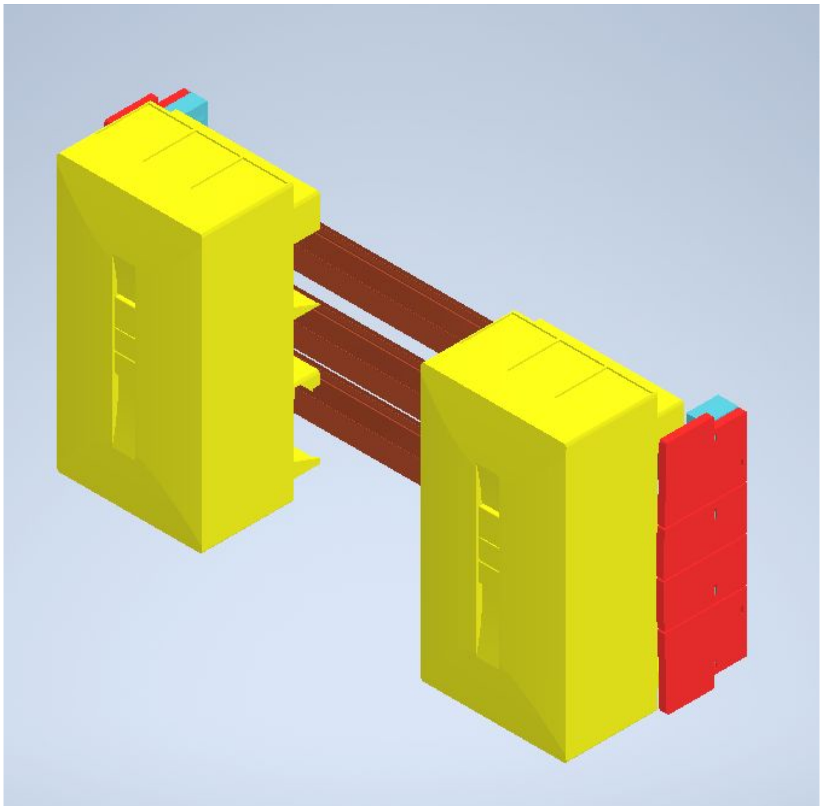


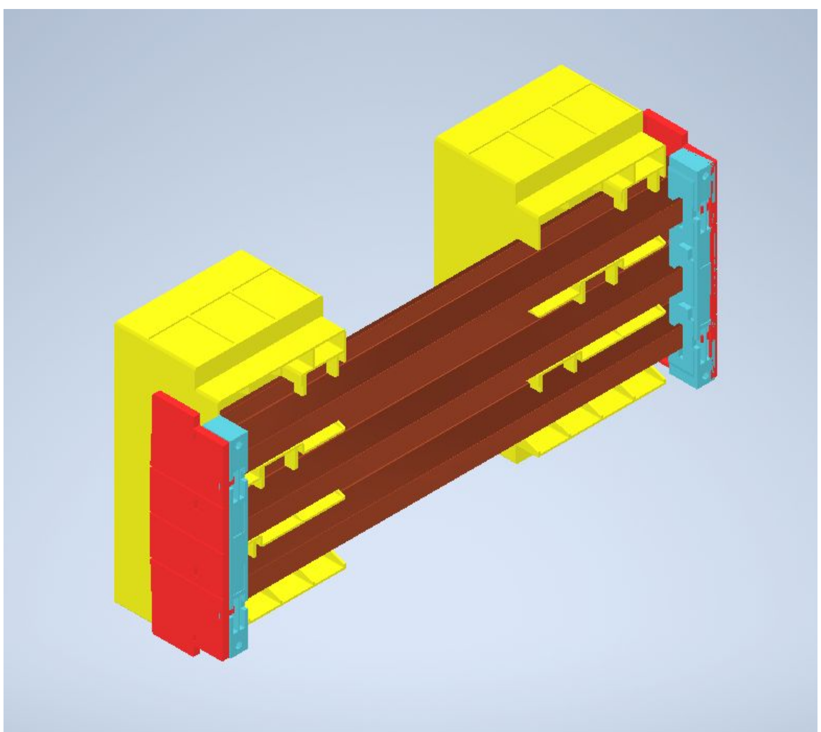
5.6 Results

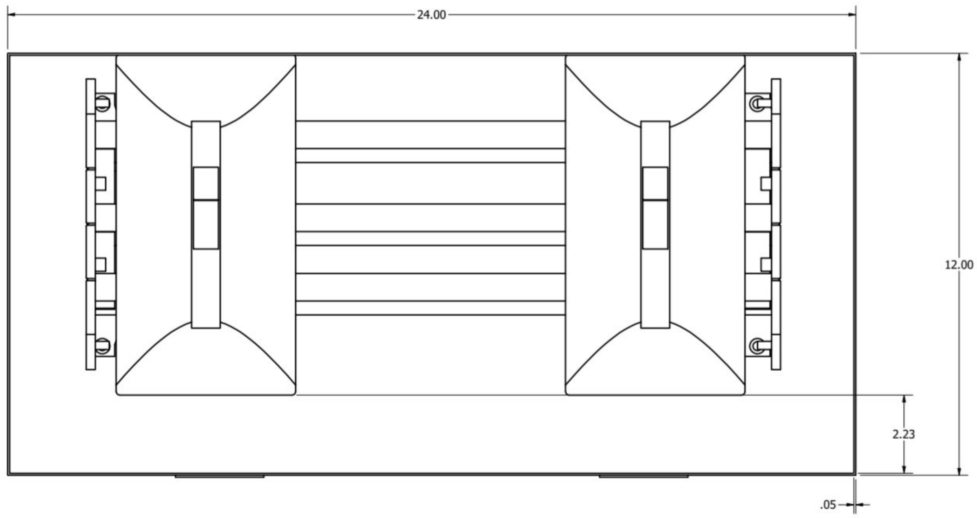
Due to the covid-19 outbreak we were unable to move forward with our testing plan. The farthest we got was receiving a manufacturing estimate for a single unit but then everything was shut down and we all went into quarantine. The resulting evaluation of success will be to revert back to the original deliverable on the project proposed by Alliant which called for a minimum of a 3D model to be delivered to Alliant. Our designs were approved and we provided the 3D model to alliant and the quotes that we received from the manufacturer. That was a manufacturing estimate of $1000, however, that estimate was for a single prototype unit and not one that was an estimate for bulk orders and we were unable to obtain one before the company was impacted by covid-19. We were also not able to conduct our in person installation and testing with a member of Alliant's labor force so we evaluated our success based on the 3D model delivery and the instructions that are included in Appendix 1 of this document along with very preliminary cost comparisons. Without the testing with labor and the estimates from manufacturers we were mostly unable to nail down exact estimates of total production or installation costs but we think they will be lower than existing based off the rather low quote on our single unit when compared to Alliant's existing costs for this process as it which we were told were $2500 for harder to install equipment that is available in bulk. Had we gotten a bulk estimate for this design we would have been able to get a closer comparison but we know that a single prototype unit was $1000 and that we believe it would have been a quick installation onto any house.







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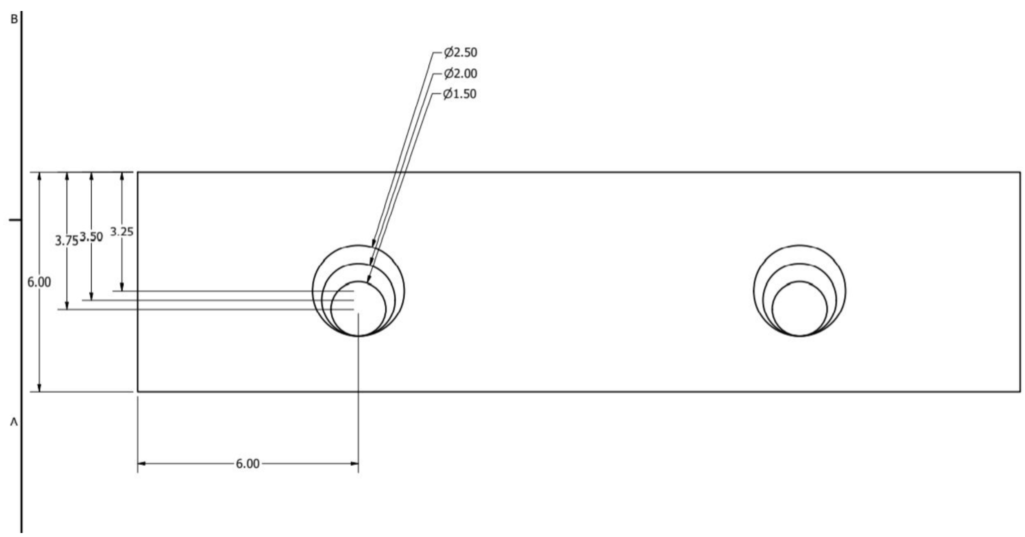
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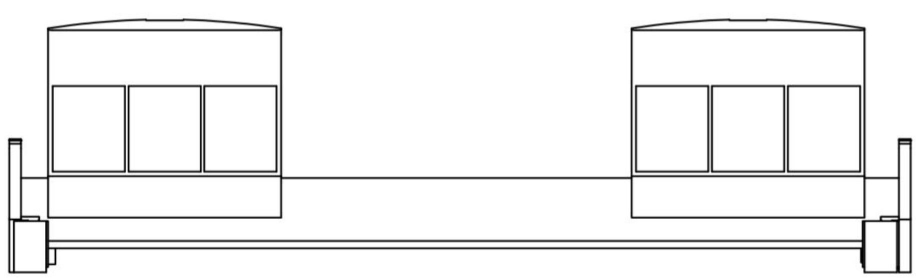
6.00



6. Closing Material

6.1 Conclusion

Our project was creating a new adapter to run from an existing meter socket to the new underground feeds. The most important aspects of this project were coming up with at least one cost effective and aesthetically pleasing alternative to the existing solution. We needed to make sure that these options abided by the NEC 2017 and different city codes that might conflict with our solutions. We were able to avoid unnecessary costs by limiting Alliant Energy labor, eliminating electrical contractor labor, and lowering material cost. Using these different options, we were able to test different solutions and receive feedback from Alliant and contractors to find the most practical option. Our "raceway" option was the best fit for this project, and we developed and finally submitted that idea to our client.

6.2 References

National Electrical Code Committee., & National Fire Protection Association. (2020). NFPA 70: National Electrical Code. Quincy, Ma: National Fire Protection Association.

Dominion Energy. (2019, April 1).Strategic Underground Program: EEI - Transmission Distribution Metering & Mutual Aid Conference.

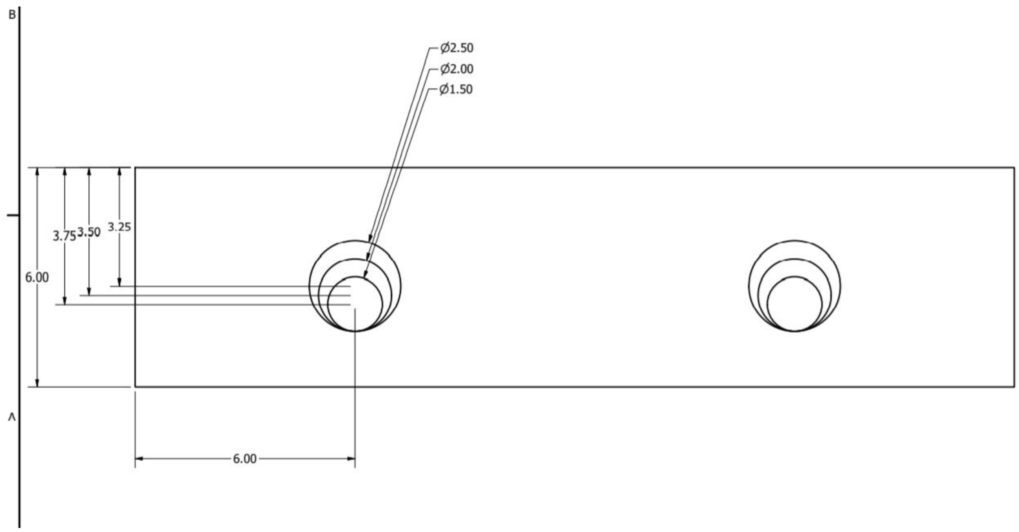
State Inspector Interview: Perry Johnson, Alliant Energy

Control panel manufacturing project managers

Appendix I: Operation Manual

Mount the box to the wall using appropriate anchors. This will vary based on siding of the house.

Knock out the appropriate sized knockouts to fit the correct conduit size. This will vary based on the type of wire used and the existing meter socket.



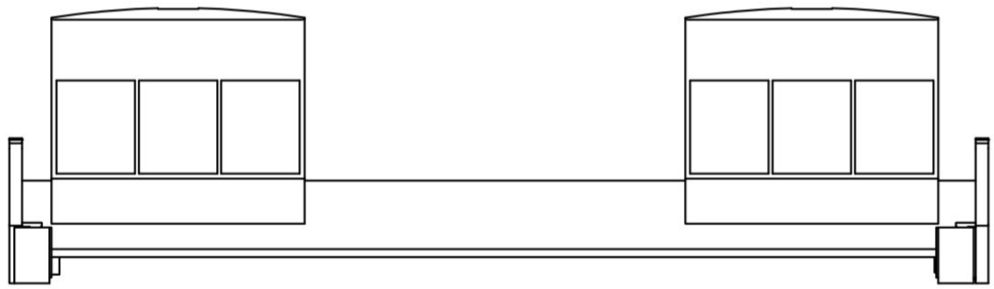
Land the wires from underground feed to connection ports of the adapter. Connect adapter to the busbar.

Wires will need to be stripped to fit correctly into the connection ports.

Loosen the screw terminals on the connector.

Insert wire into the connection port.

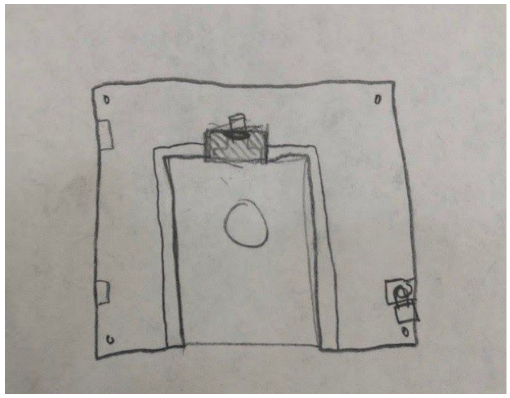
Re-tighten the screw to lock the wire into place and complete the electrical connection.



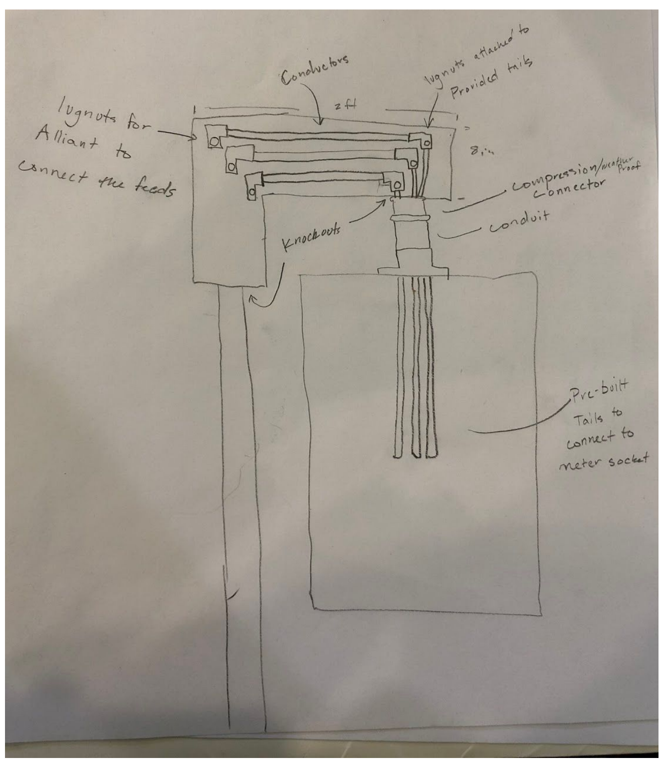
Repeat this step on the other side, connecting the meter socket to the adapter.

Close the enclosure and lock the door.

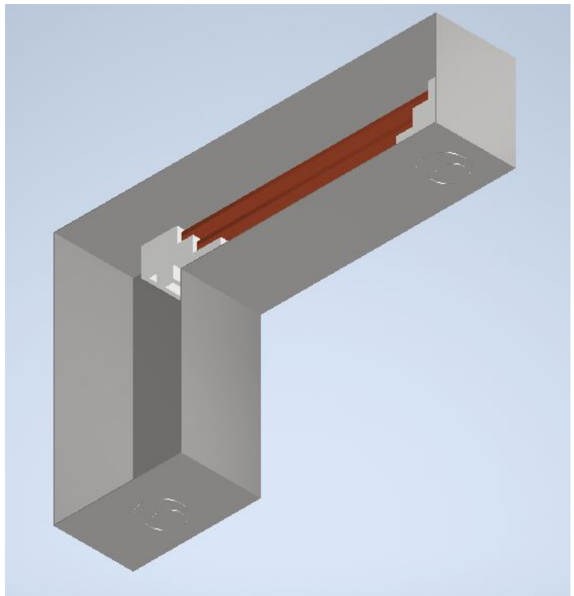
Appendix II: Old Versions

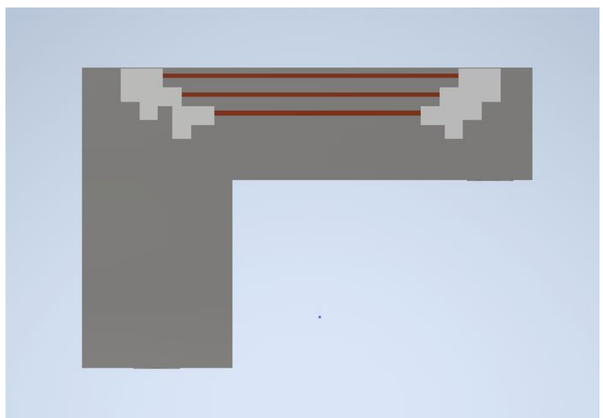


This is one of our first brainstorms, a “shell” around the existing meter socket, wrapping around the entire meter socket would blend in well.



“Ell” shaped adapter fits over one side of the meter socket and uses a raceway to connect the underground feed to the meter socket.





This is a 3D model of the “Ell” shape adapter. We eliminated the ‘Ell” shape in order to make the box a more standard size which changed our cost from $2500 to $1000 for a single prototype.This is one of the biggest cost reducers of our final design.