DEC13_03 Project Plan:

Iowa State 115kV Substation

Jane Peters

Jared Jasper

Matt Murphy

Muzi Li

Riley Groves

Project Sponsor: Burns and McDonnell

Project Adviser: Venkataramana Ajjarapu

Contents

1 Project Overview

1.1 Project Description

Electrical substations serve as an integral part of the power network, serving as a conduit between the different components of the network: transmission, distribution and generation of power [1]. The primary tasks of substations include:

- Transformation of voltage to different levels via transformers
- Communication with other substations and the regional control center
- Connection of various transmission lines across a region
- Monitoring of system health via the control center
- System protection

These tasks are crucial to continued power grid reliability and are addressed via sound substation design and maintenance [2]. The focus of this senior capstone project is to serve as a contracting team responsible for the design of a new 115-kV distribution substation for Burns and McDonnell Engineering to serve the Ames area, specifically, the Iowa State University Campus [3]. This new substation is required to be designed and built on the Iowa State University Campus to allow for the expansion of the local power grid to include a new wind farm located in the surrounding Ames region.

1.2 Project Scope

The scope has been pre-defined and provided by the client, Burns and McDonnell Engineering in a "Scope of Services" document [4]. The contents of this document are outlined below.

Burns and McDonnell Engineering has requested a comprehensive design plan for a new 115kV distribution substation. The design is intended to account not only for the physical design of the substation, but also the protective relaying and communication components [3]. Following are the components that are to be addressed in the substation design.

NOTE: This project is purely for academic and learning purposes. The scenarios described and addresses may be fictitious and have been defined by Burns and McDonnell for the purpose of this project.

1.2.1 Included Within the Scope

Substation Specification Materials Package

Burns and McDonnell is expecting an inclusive set of specifications and drawings, following Burns and McDonnell, IEEE and acknowledged industry standards. These documents are intended to be used to solicit bids from pre-qualified substation packagers. The specifications included in this package should address such areas as the substation structural steel as well as all electrical equipment and materials required for the project.

Site Design

Burns and McDonnell will provide a location for the new substation site. The team will be responsible for determining the layout of the new site. Considerations shall include details such as site access, construction access and fencing details. The design will be completed utilizing AutoCAD.

Substation Foundation Design

Burns and McDonnell is expecting a full foundation layout and design. As no member of the team has an civil engineering or construction engineering experience, Burns and McDonnell has agreed to cover a majority of this responsibility. The expectation from the Iowa State University design team will be to provide the location of the required foundation for each component of the substation. In addition to the location, the team will be required to supply the weight that the foundation will be expected to support.

Physical Substation Campus Layout

In addition to the site design, the team will be responsible for determining the layout of the components that comprise the substation. The substation layout is expected to be conservative space-wise to allow for future expansion of the site to allow for additional load requirements. The substation layout will be primarily presented via a one-line diagram, which will illustrate the location of substation components as well as their connections. In addition to a top-down view, the team is expected to provide several cross sectional views with elevation indicators.

Bus and Insulator Design

The senior design team will be responsible for defining the bus and insulator design for the substation. The design will be based upon calculations including weather conditions and expected fault levels. The weather conditions to be used in the consideration of the design will be average weather conditions experienced in Iowa. The fault levels to be used in these calculations will be provided by Burns and McDonnell.

Ground Grid Design

A key expectation for this project is the design and layout of the grounding grid for the substation. The design is to be completed utilizing the WinIGS grounding software. The design of the grounding grid will be based upon standards set defined by IEEE 80 techniques. This also includes sizing the grounding conductors to handle the expected fault current.

Control Station Service Voltage Transformer (SSVT)

The service transformer for the control station will need to be selected by the design group. The transformer will be selected based upon the requirements of the equipment powered by the station service transformer. After selecting the transformer, sizing will be determined for the distribution panel and the incoming conductors. A factor to be considered when selecting the transformer will be needs of not only the current equipment, but also future equipment required to accommodate future loads.

Substation Raceway Design

The senior design team is expected to develop a conduit plan, including a raceway sized to accommodate each specific component of the substation. These raceways will be implemented utilizing a combination of techniques including surface trenches, underground conduits and equipment riser conduits.

Substation Control Building Design

The team will be required to develop layout plans for the control house, including wiring plans. The control house will be required to house protective relay panels, the 125V battery and charger, the AC and DC panels and the Scada RTU.

125V DC Station Battery Design

Prior to the development of the control house, the team is expected to design the 125V battery. The sizing of the batteries, battery chargers and panels utilized by the 125V system will be calculated based upon the expected load on the system. Burns and McDonnell has requested that the team take into account the time period for a service station outing when determining the battery size.

Substation Relay Design and Control System

The team is expected to generate one-line and/or three-line diagrams as well as mechanical drawings for the 115kV circuit breakers required. The model number for the relays to be used will be provided by Burns and McDonnell.

1.2.2 Excluded From the Scope

System Simulation and Testing

The team is not expected to run simulations on the design nor do any formal testing. Verification of the design will be completed via review from external experts and design review meetings with the sponsor, Burns and McDonnell. Though a system-wide simulation will not be run, the team will be using the grounding software, WinIGS to simulate various grounding scenarios.

Substation Transformer

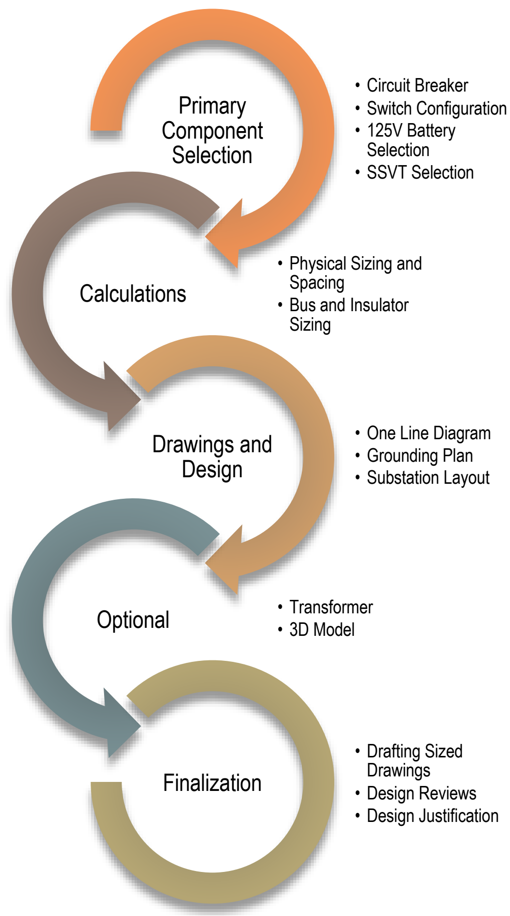
At this point in time, the team is not expected to incorporate a substation transformer into the substation design. This may change at a later date, however.

Substation Panel Diagrams – REMOVED FROM SCOPE 10/2013

The senior design team will be required to create a panel layout and schematic diagram to be furnished to a panel vendor. The vendor will use these materials to generate a wiring diagram. The team will also be responsible for generating wiring diagrams for the yard equipment. **THIS WAS REMOVED FROM OUR SCOPE BY BURNS AND MCDONNELL .

2 Requirements Specification

2.1 System Development Diagram



2.2 Requirements

Due to the theoretical nature of this project (no physical items are expected as deliverables), the requirements given are all necessary to the proper design of a functional substation. Therefore, all requirements are considered to be **functional**.

- Design services
  - Layout will allow for future expansion
  - 125 Volt Station Battery supply for station service outage
  - Fiber-Optics communication between substations
  - The substation be designed with Iowa weather in mind
- Safety
  - Clearance for emergency vehicles
  - Clearance for removal of defective parts
  - Ground grid capable of handling a fault
  - Follow industry and company standards

2.3 Expected Deliverables

Following is the list of expected deliverables as set forth by Burns and McDonnell.

- One-line diagram
- Site layout drawing
- Foundation plan drawing
- Grounding plan drawing
- Substation layout (top-down view) drawing
- Substation Elevation section cut drawing
- Conduit plan drawing
- Control building equipment layout drawings
- Substation battery design drawing
- Design Justifications

2.4 Project Constraints

Although purely educational in nature, there are several constraints that limit the design and process used to complete this project.

2.4.1 Burns and McDonnell Expectations

As Burns and McDonnell developed this project, as the sponsor for the project, they are also responsible for defining the desired parameters. These parameters should be considered project constraints and taken into account during the design process. A notable project parameter defined by Burns and McDonnell is the substation configuration: a ring bus configuration was selected as the desired configuration for this design.

A ring bus design comes with the expected fusion of pros and cons [5]. Due to the simplified design, the ring bus is often a more cost effective option. Additionally, due to the configuration of a ring bus (each section is separated by a circuit breaker) the design is highly flexible and reliable. However, this arrangement of having each section separated by a breaker can also be problematic during a fault. However, this design was selected for the project due to its ability to expand into other configuration and its simplicity [6]. This constraint will affect the quantity of circuit breakers used, the layout and all dependent designs (grounding, raceway, etc.)

2.4.2 Operating environment

As this hypothetical substation is intended to be built on the Iowa State University campus, the Iowa environment will be a constraint for this project. Specifically, this will not directly affect any calculations; it will merely be a factor to take into account when considering soil type and humidity. Both of these parameters will affect design steps such as foundation planning and grounding.

2.4.3 Standards

Standards will play a huge role in governing the design process and will serve as rigid design constraints. Specific standards considered will be addressed later in this document and in other project documents, but it should be noted that this project will be drawing upon guidelines set forth by industry, local, environmental and component-specific standards.

3 Market Analysis

3.1 Current Industry Standards

The current industry standards are mandated through updated guides of national organizations such as the American National Standard Institute (ANSI), Institution of Electrical Engineers (IEEE), National Manufactures Association (NEMA), etc. The equipment and design practices are to be modeled and referenced from industry manuals depending on the nominal system voltages and power distributed. The design takes into account the geographical location while considering the climate and weather patterns the equipment will be exposed to over the planned lifetime of the substation. Operations and Maintenance (O&M) is the care for the equipment to make sure it is functional according to industry specification and rated performance.

3.2 Current Ames/Iowa Solutions

Iowa follows the current industry standards of the national organizations as mentioned in the Market Analysis section of the report. Design implementations consider Iowa's climate and plans for the weather patterns throughout the lifetime of the substation to make sure of the durability design. O&M provides the care needed to keep the substation at peak performance.

4 Design Strategy

4.1 Priority Ranking

Based upon our research into power system substation development, the team has developed the following series of tasks, listed in order of highest priority to least. The ranking was based upon the dependencies of certain tasks upon the completion of others.

1. Development of the one-line diagram
2. Development of the three-line diagram
3. Drawing of the substation component layout
4. Drawing of the site (whole campus) layout
5. Drawing detailing the foundation plan
6. Development of the grounding plan and design of the grounding grid
7. Drawing of the raceway, including individual conduits for each components
8. Development of the control house layout, including equipment arrangements
9. Development of circuit breakers and other safety equipment
10. Development of the substation 125V battery design

4.2 Risk Assessment/Technical Challenges

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 with completing this project that exist in the form of bottlenecks. Potential bottlenecks on this project include:

- Learning curve associated with learning the two software packages associated with this project: WinIGS and AutoCAD
- Learning and becoming familiar with Burns and McDonnell, as well as industry safety standards
- Learning Burns and McDonnell symbology
- The relay panel and protection equipment design

4.3 Verification/Review

As no formal testing is required for this project, the team will verify the design by conducting numerous design review meetings with experts in the field. Not only will the team advisor, Professor Ajjarapu, be supervising the design, the team will be consulting with engineers at the client company, Burns and McDonnell.

5 Work Plan

5.1 Scheduling: Jan 14, 2013 - Dec 3, 2013

Please see attached GANNT chart.

5.2 Project Tracking

Deliverable Requirements	Start	End
One/Three Line Diagram	2/18/2013	
Foundation Design	4/1/2013	
Substation Layout	4/1/2013	
Bus and insulator sizing Design		
Ground Grid		
Station service transformer		
Raceway		
Control Building		
125V DC Station Battery Design		
Relaying and Controls		

Special Events	Date
Spring Break	03/18/2013---03/22/2013
Summer Break	05/11/2013---08/26/2013
Thanksgiving	11/25/2013---11/29/2013
Riley's Wedding	7/13/2013

5.3 Work Breakdown Structure

Review Materials	Responsible Party	Details
Understand Requirements and Specification	Entire Team	Substation Design Manual
	Entire Team	Scope Document
Project Documents	Jane Peters	Draft Project Plan
	Jane Peters, Jared Jasper	GANNT Chart
	Matt Murphy	Draft Design Document
	Jane Peters	Final Project Plan
	Jane Peters, Matt Murphy	Final Design Document
	Jared Jasper	Legend of Symbols
	Muzi Li	Bill of Materials
	Jane Peters, Matt Murphy, Jared Jasper	Project Poster
Calculations	Muzi Li	Bus calculation
	Jane Peters, Jared Jasper	Identify System Load
	Matt Murphy	Grounding Conductor Sizing
	Supplied	Fault Current Verification
Detailed Physical Design	Jared Jasper, Jane Peters	Site Design
	Muzi Li	Foundation Design
	Matt Murphy	Grounding Plan
	Muzi Li	Raceway
	Muzi Li	Bus and Insulator Sizing
	Matt Murphy	Service Station Transformer
	Jane Peters, Jared Jasper	Drawing for Circuit Breakers
Detailed Protection & Control Design	Matt Murphy	Relaying and Controls
	Riley Groves	125V DC Station Battery Design
	Jane Peters, Jared Jasper	Control Building Conduit Trench
Layout	Jane Peters, Riley Groves, Matt Murphy	One-line Diagram
	Jared Jasper, Jane Peters	Physical Layout (Substation)
	Jane Peters, Jared Jasper	Section Cut Drawing
	Muzi Li	Foundation Plan
	Matt Murphy	Grounding Layout
	Jane Peters, Jared Jasper	Control Building Sizing

5.4 Resource Allocation

Resource Allocation	
Software	AutoCAD, WinIGS T&D Toolkit
Hardware	ECpE Lab Resources
ECpE Faculty	Dr. Ajjarapu, Venkataramana

Burns &McDonnell Project Contacts	Brad Jensen Nathan G. Schares
Senior Design Funds	Diagram printing Travel cost to local substation

Personal Roles	
Groves, Riley	Communications Coordinator
Jasper, Jared	Webmaster
Peters, Jane	Project Leader
Li, Muzi	Layout (Site design)
Murphy, Matthew	Grounding expert and primary drafter

6 Works Cited

[1] "Design Guide for Rural Substations," *United States Department of Agriculture,* vol. 1724E, no. 300, pp. 38-39, 2001.

[2] L. Dam, M. Ghavami, C. Guo, Y. Guan, G. Karady and M. Kezunovic, "The 21st Century Substation Design; Final Project Report," PSERC, 2010.

[3] N. Schares, "Iowa State University Department of Electrical and Computer Engineering Senior Design Project Proposal Form," Burns & McDonnell Engineering, 2013.

[4] Burns & McDonnell Engineering, "Scope of Services," Burns & McDonnell Engineering, 2013.

[5] Consolidated Edison Company of New York, INC., "Standard Engineering Design Guidelines for Area Substations, Transmission Substations and Purs Facilities," New York, 2009.

[6] D. Nack, "Reliability of Substation Configurations," Iowa State University, Ames, 2005.

[7] B. Jensen, "ISU Senior Design Project: Protection and Measurement Equiptment Specifications," Burns & McDonnell Engineering, 2013.

7 Revision History

REVA: Draft of project reported completed 2/22/2013.
REVB: Update Project Plan 4/9/2013.
REVC: Update Final version of project plan for the first semester 4/27/2013.
REVD: Update Project Plan to reflect changes to scope. 10/15/2013.