115 kV / 34.5 kV Solar Power Plant / Substation

Project Plan

MAY1602

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PROJECT SCOPE

Due to increasing renewable energy standards set by RES, Black & Veatch is sponsoring a senior design project to design a 60 MW grid tied solar power plant with an attached 115/34.5 kV substation. The senior design team will design both parts of the project including the solar layout, substation component, and associated deliverables. Deliverables consist of equipment sizing calculations, solar layout drawings, solar panel sizing, protection, control schematics, and project schedules.

The first semester of the design project will consist mainly of solar plant sizing, layout, substation layout, material sizing and budget. The second semester will consist of final design, optimization and presentation. Black & Veatch, our client, will also provide conceptual engineering support to manage the large scale of this design.

GOALS

The goals of this project are:

- Efficiently manage the scope of the project.
- Produce proper documentation for all design aspects.
- 100% NEC compliance for all components and layouts.
- Complete and present design to client and advisors.

PROJECT DESCRIPTION

Solar Plant

The solar power plant will consist of about 100 acres of solar arrays. Each solar array will be a unit containing all solar modules, combiner boxes, re-combiner boxes, inverter, and step-up transformer and associated conductors. The components used are listed below.

- Hanwha QCELLS 325 W solar modules, 6608 total.
- Eaton 1666 kW inverter and 357/34.5kV transformer, 36 total
- DC combiner box, SolarBos 1500 VDC, 396 total.
- Variety of conductors, sizes ranging from 12 – 700 AWG.

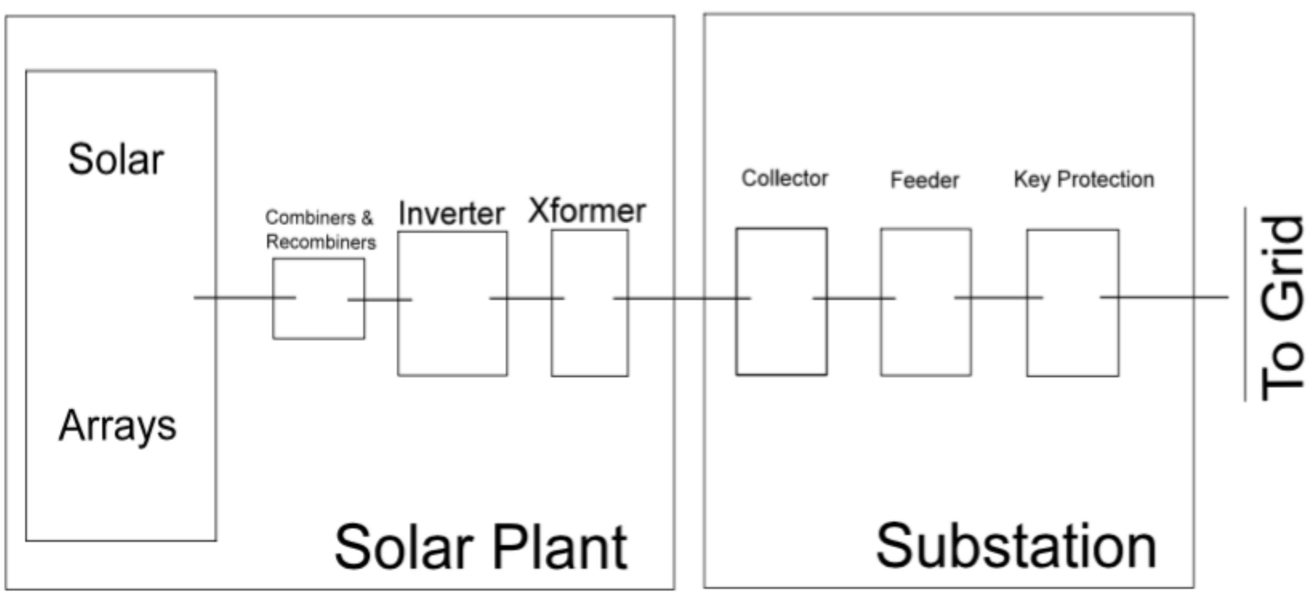
Substation

This design project consists of a solar plant producing 60 MW that will be injected into the distribution system through a substation. Thus a new substation is required. The PV output circuit will be looped through this substation to feed a new bank. An air break switch will be located on the high side of the bank. The substation layout will closely match a retail 85 MVA substation. The three major components of the substation are the collector, the feeder, and the key protection. The PV output will be sent to the collector where we step up the voltage to a transmission level voltage (34.5kV). From there the feeder bay routes power from the substation to the distribution primary feeder circuits. The key protection is made up of a variety of circuit breakers and relays that are devised to interrupt fault current and to switch loads on and off. Most of the relays will be replaced with their Ethernet version and the communication processor will be an Orion LX. The following is a list of relays needed in the control building.

- 115 kV Bus 1 transmission line sectionalizer control. SEL-2411
- Bank 1 primary protection and 34.5 kV Bus 2 primary protection. SEL-487E
- Bank 1 back-up protection and CS 682 control. SEL-351S
- 34.5 kV Bus 1 back-up protection and CB 317 control. SEL-351S
- Feeder 1 protection and CB 311 control. SEL-351S
- Feeder 2 protection and CB 312 control. SEL-351S
- Feeder 3 protection and CB 312 control. SEL-351S

The simplified block diagram below illustrates the general layout. DC power will be produced in the solar plant, currents routed through combiners and re-combiner to an inverter. The inverter will output 3 phase AC current to a step up transformer. The transformer will send power to the substation, routed through a collector, feeder and protection circuitry. Finally, power will be injected to the grid at 115 kV.

Figure 1. System Block Diagram



REQUIRED COMPONENTS & PARAMETERS

The required components and parameters specifications provided by Black & Veatch are listed below. This list will be our starting point guidelines, the additional components will be determined in the design process.

Solar Plant:

- Location – Iowa.
- Inverter – Eaton 1670 kW.
- Solar Panel – Hanwha QCELLS 325 W.
- DC Voltage – 1500 V at each combiner box.
- Inverter Load Ratio – 1.30.

Substation:

- Project Scope document specifications.
- Arcadia single line diagram specifications.

PROJECT DELIVERABLES

Fall 2015 Deliverables:

- Engineering man hour budget, schedule, and cost estimates.
- Solar plant layout and conductor sizing.
- Substation single line diagram.
- Large scale AutoCAD drawings.
- Plant and substation component connections.

Spring 2016 Deliverables:

- Detailed substation AutoCAD drawings.
- Optimization revisions.
- Plant and substation protection
- Meet all NEC code.

VALIDATION & ACCEPTANCE

During the design process engineers from Black & Veatch will be probing the accuracy of our implementations while revising and providing feedback all while verifying NEC compliance. They will tentatively be changing the parameters to simulate a real world client and engineering team interactions.

DESIGN CONSTRAINTS

Operating Environment:

- Location compatibility depend on solar radiation concentration in Iowa.

Standards:

- The standards in the project will be based on guidelines given by Black & Veatch and dictated by the NFPA70 NEC Code Book.

SOFTWARE REQUIREMENTS

- AutoCAD for drafting detailed layouts and modifying existing drawings provided by Black & Veatch.
- Microsoft Office products for documentation, and data analysis.
- HelioScope PV production simulation software.

PROJECT SCHEDULE

FALL 2015															
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Assignment	■														
Team Roles/Advisor Meetings		■													
Discuss Project Scope with Client			■												
Research Project Components			■												
Solar Plant Area Calculation				■											
Project Plan				■	■										
Solar Panels Layout/Cables Sizing					■	■									
Design Solar Panel Schematics						■	■								
Discuss Design with Client								■							
Review Solar Panel Design								■	■						
Substation Single Line Diagram								■	■	■					
Substation Layout Design									■	■	■				
Plant and Substation Connection											■	■			
Review Project												■	■		
Complete Design Document													■	■	
Presentation 1														■	■

SPRING 2016															
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Group Review	■														
Meet with Client/Advisor		■													
Discuss Project Optimization			■	■											
In-depth Substation Design				■	■	■	■	■	■	■	■				
Optimization of Plant Layout				■	■	■									
Optimization of Substation Layout					■	■	■								
Review Project												■	■		
Complete Project Report													■	■	
Presentation 2														■	■

FEASIBILITY

The feasibility of obtaining funding for 60 MW scale solar generation in Iowa at present is unlikely due to the high cost, sub optimal yearly average sunlight, and the large amount of space needed. Unless large government subsidies are obtained. Large acreages are more economically suited for farmland in Iowa. Although the feasibility of successful design completion is highly likely, thus any design can be easily adapted to other environments. The modularity of our solar plant will alleviate uneven terrain and non-square plots.

COST CONSIDERATIONS

Cost will be a defining factor in this product due to the large scale of solar power generation. We will attempt to reduce the number of components by various tactics; such as placement, component selection, component minimization, and modularity of solar arrays to allow quick changes and serviceability. The substation component is a more standardized design, meaning we are limited to relay choice and placement for design optimization.

MARKET LITERATURE SOURCES

- NFPA 70 National Electrical Code (NEC) 2014 Edition.
- American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) data.
- Iowa Energy Center – Solar Calculator Tools.
- HelioScope simulations.
- PVWatts solar calculator tools.
- Various manufacturer specification documents.

REVISION HISTORY

Initial:	Project_Plan_may1602(V1)	*project_plan(v1).pdf*	*September 22, 2015*
Revision:	Project_Plan_may1602(V2)	*project_plan(v2).pdf*	*October 29, 2015*