

## **EE 491 – sdmay19-26**

# **115kV / 34.5kV SOLAR POWER PLANT/SUBSTATION DESIGN PROJECT**

## **Week 9 Report**

*Monday (10/29/2018) – Sunday (11/4/2018)*

*Client: Black & Veatch*

*Advisor: Venkataramana Ajjarapu*

*Team Email: sdmay19-26@iastate.edu*

### **Team Members:**

Katayi Katanga – Communication Leader

Nur Shuazlan – Meeting Scribe

Yao Cheah – Website Manager #1

Ahmed Sobi – Team Leader/Layout Designer #1

Chufu Zhou – Website Manager #2/Layout Designer #2

Tam Nguyen – Report Manager

### **Weekly Summary:**

In this week, we had a meeting with the client, and we talked about array wiring diagram, conductor sizing and type, voltage drop calculations, collector AutoCAD and parameters calculation, and feeder drawing. Then, we started working on the key protection diagram, and concept presentation for our advisor.

### **Summary of Client/Advisor Meeting:**

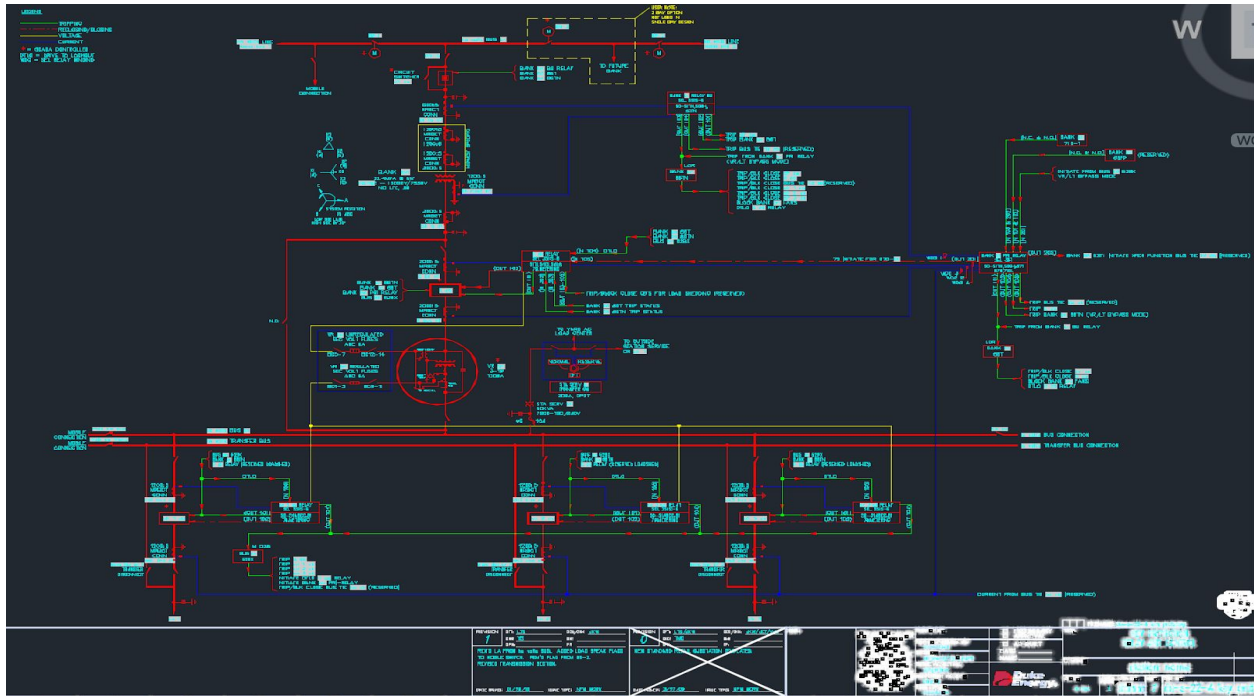
- Katayi did safety moment about how to safely reset a household circuit breaker.
- We talked about the Array/Solar Plant Wiring Diagram and Conductor Sizing. Katayi discussed our final array layout and how each component in the array is wired and connected. She also presented the average worst-case DCB voltage drop percentage and the wiring diagram of our entire solar power plant. Then, she explained how we did the conductor sizing for every cable that is used in the solar plant, including the IMP of each cable.
- Then, we talked about the collector. We presented the collector drawings based on calculations. The client wanted us to review the calculations and ensure that the inverter can handle that amount of current. The client also requested the students redo the AutoCAD drawings to make things more visible.
- Lastly, we talked about Collector & Feeder AutoCAD and Parameter Calculations. Ahmed presented calculations for the collector using equations found online. The single inverter skid output current is 30.64A. The output of the transformer will be collected with 8 AWG copper conductor and another collector with 1 AWG size will collect and combine all the current and deliver it to the feeder.

### **Past Week Accomplishments:**

In this week, we did two things, starting working on key protection diagram and preparing the concept presentation for our advisor.

- **Key Protection Diagram:**

We looked at the key protection diagram and come up with the questions about feeder, transformer in a circle, and capacitor bank.

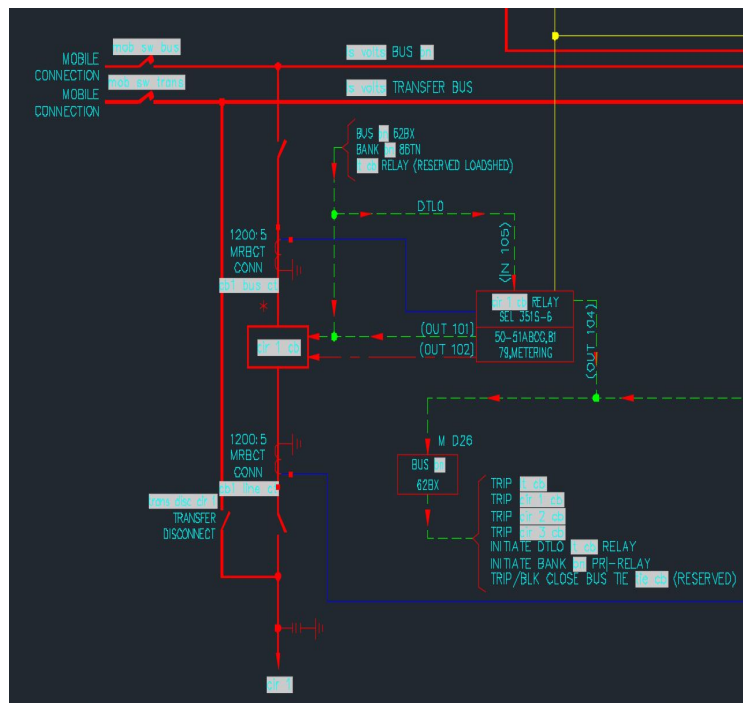


**Single feeder components:**

- Transfer disconnect switch
- Circuit breakers
- Protection relays

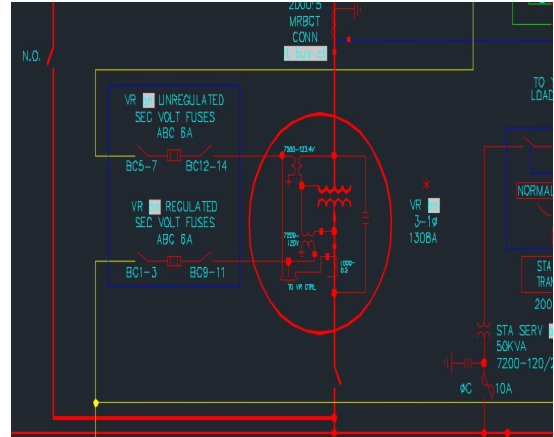
**Questions:**

- How does the transfer disconnect bus work? Is it at the same voltage level as the 34.5 kV bus?
- What is the mobile connection? How does it work?
- Why some relays have metering and other don't?



**The transformer in the circle:**

What is happening in the circle? What does the transformer represent?

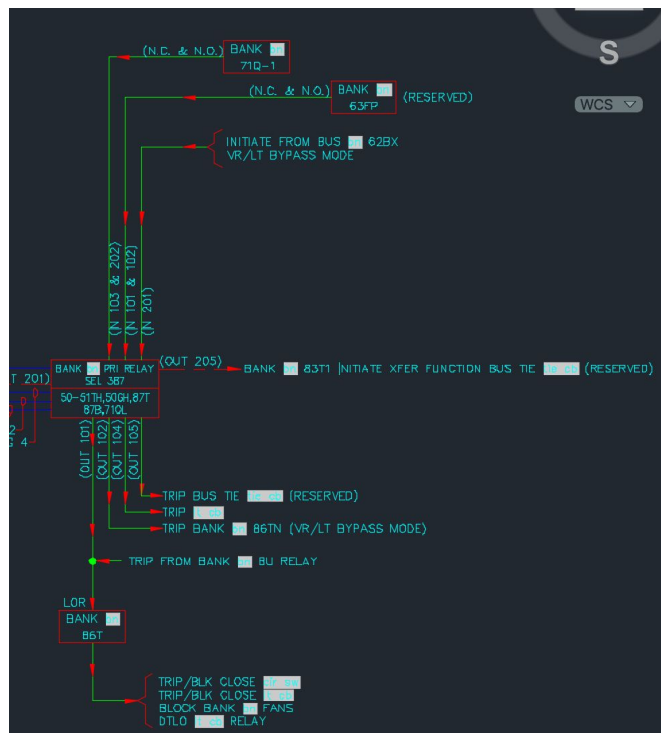


**Capacitor banks:**

- Set of many identical capacitors connected parallel
- Power factor correction and substation protection
- Reduction of the phase difference between voltage and current.

**Question:**

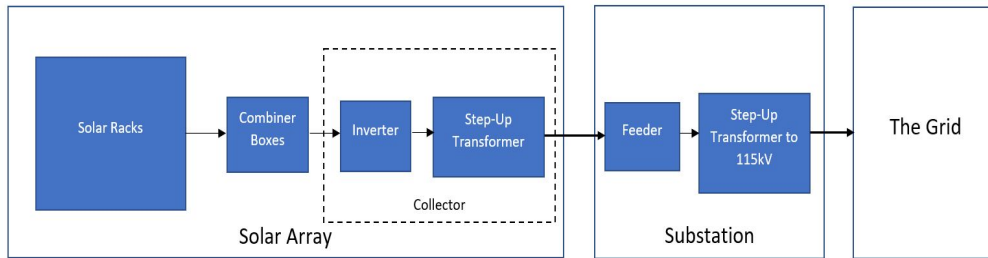
- What is a trip bank?



- **Concept Presentation:**

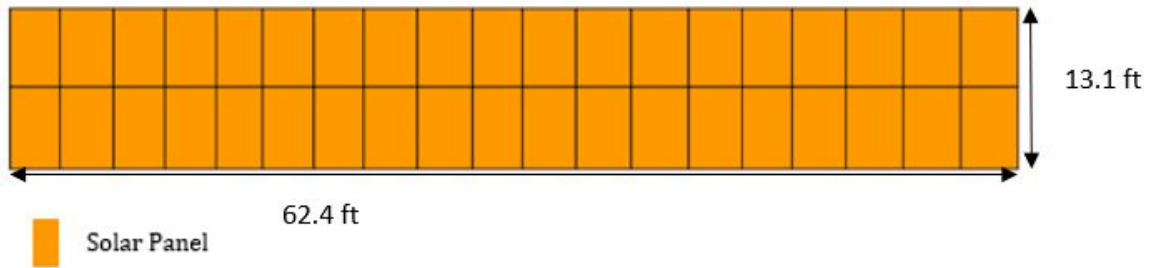
**Nur Shuazlan & Katayi Katanga**

- Power flow from generation to transmission:

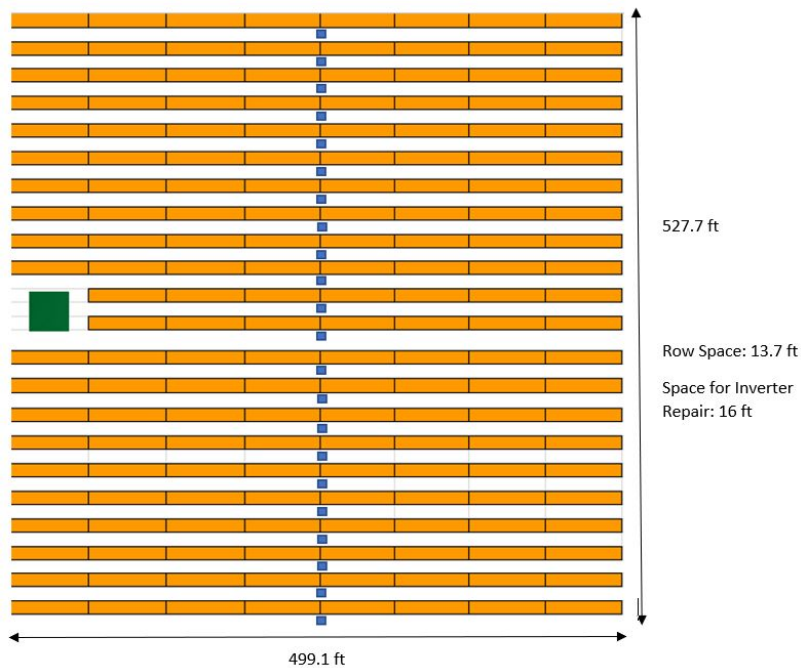


- Single Rack Layout (2x19 Panels)

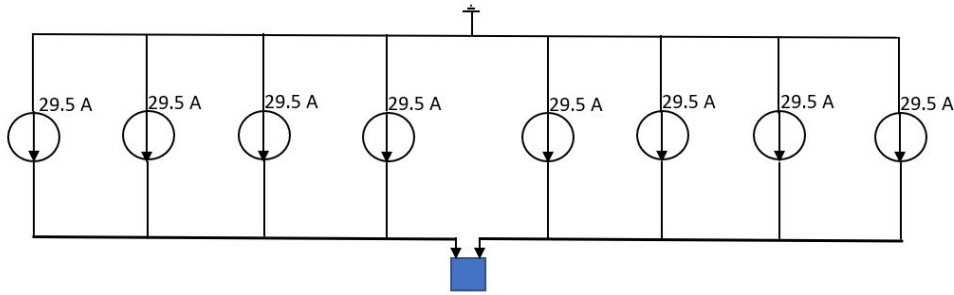
- Solar Rack:



- Single Array Layout (6x6 Arrays)



- Circuit model of a row of racks connected to a combiner box



- What's a combiner box? How many do we have? How many inputs does a combiner box have?

### Yao Cheah

- Solar Inverter Calculations: Did explanation about the relationship between real power, apparent power, and power factor ratio that are being mentioned on the solar inverter datasheet.

## Solar Inverter Calculations

$|S| = 1831KVA$   
 $P = 1666kW$   
 $pf = 0.91$   
 $\theta = \cos^{-1}(0.91)$   
 $Q = \sin(\theta) = 759VAR$   
 $|S| = \sqrt{P^2 + Q^2} = \sqrt{3}V_L I_L$   
 Proving:  
 $|S| = \sqrt{1666^2 + 759^2} \approx 1831KVA$

Description	Rating	
	1500 kW	1670 kW
<b>AC Output Specifications</b>		
Nominal apparent power AC at 50 °C	1650 kVA	1831 kVA
Rated output power AC at 50 °C	1500 kW	1666 kW
Nominal output current	2797 A	
Maximum continuous output current at 50 °C	3000 A	
Nominal operating voltage	370 Vac	357 Vac
Operating voltage range (withstand)	±10%	
Nominal operating frequency	60 Hz	
Operating frequency range	57-63 Hz	
Total harmonic distortion at rated power	Per IEC 1547	
Power factor at rated power	0.91 adjustable power factor	
AC configuration	Delta three wire or wye ungrounded	
<b>DC Input Specifications</b>		
Number of DC inputs	Customer-specified fuse arrangement (18-24 input pairs)	
Maximum input voltage open circuit, $V_{oc}$	1000 Vdc	
MPTT input DC voltage range (full power production)	500-1000 Vdc	550-1000 Vdc
MPTT DC voltage range for CFC weighted efficiency	500-800 Vdc	550-800 Vdc
Nominal DC operating current	3100 Adc	
PV array grounding	Negative and positive (optional)	
DC monitoring	Optional current sensors on each DC input	
Maximum DC short-circuit current	4480 Adc	
<b>Efficiency and Losses</b>		
CEC weighted efficiency	98.6%	98.5%
Maximum inverter efficiency	98.6%	98.7%
Nighttime power consumption	333 W	335 W
<b>Protection</b>		
AC disconnect	AC circuit breaker with LOTO	
AC surge suppression	Yes, monitored by inverter SCADA	
DC disconnect	Local break switch disconnect	
DC surge suppression	Yes, monitored by inverter SCADA	
Ground fault monitoring	Yes, monitored by inverter SCADA	
Insulation monitoring	Optional	

- Calculation for the step-up transformer in the collector.

## Collector Transformer Calculations

Three phase transformer, let's consider in per-phase analysis:

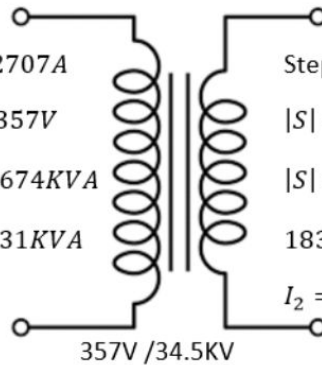
Operating voltage range:  $\pm 10\%$

Nominal Current (from inverter):  $I_1 = 2707A$

Nominal Voltage (from inverter):  $V_1 = 357V$

$|S| = \sqrt{3}V_1I_1 = \sqrt{3} \times 357 \times 2707 = 1674KVA$

Nominal apparent Power:  $|S| = 1831KVA$



Stepped up voltage:  $V_2 = 34.5KV$

$|S| = 1854KVA$

$|S| = \sqrt{3}V_2I_2$

$1831KVA = \sqrt{3} \times 34.5KV \times I_2$

$I_2 = 30.64A$

- Researched about the relationships between wire size and wire type on its resistance value.

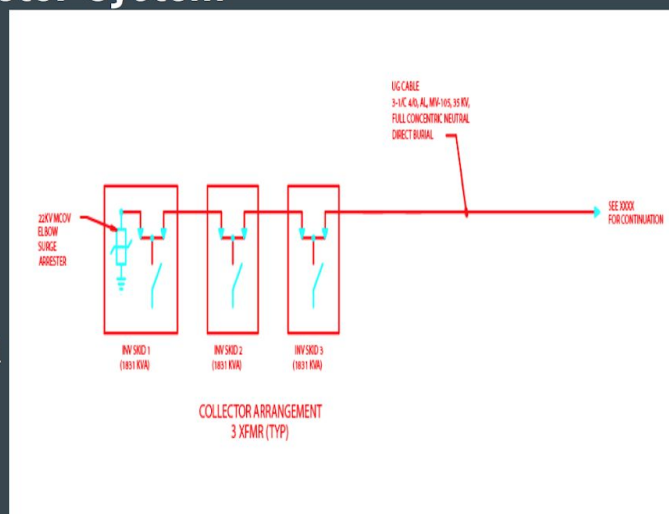
### Ahmed Sobi, Chufu Zhou

- Understanding the key protection diagram
- Recognize the key components of the key protection diagram
- AutoCAD modification to the key protection diagram
- We worked on the Advisor presentation to show our progress and understanding of the project so far
- Worked on the collector system concept

## Collector System

Skid arrangement:

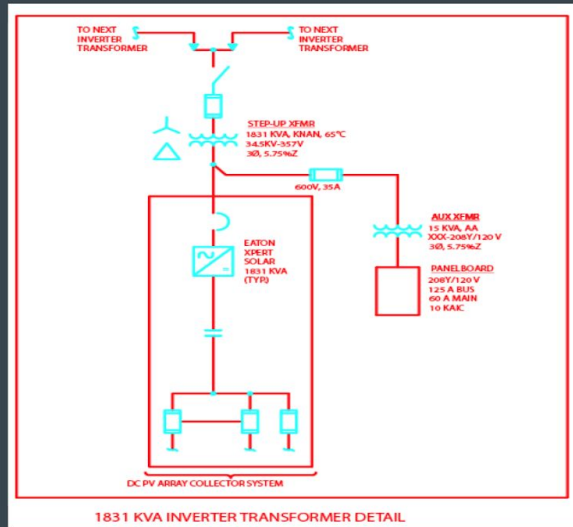
- Collect the output from the inverters and transformers (inverter skid)
- Each inverter has a step-up transformer attached to it.
- It sum up all the skids output and deliver it to the 3 bus feeder



# Collector System

## Single Skid Parametres:

- 22 CB serve as input to 1666 KW Eaton Inverter
- Inverter output 1831 KVA will be matched with 1831 step-up transformer
- The output of transformer will be collected with 8 AWG copper conductor
- Another collector with 1 AWG size will collect and combine all the current and deliver it to the feeder.



## Tam Nguyen

- Feeder System Calculation:

Current go into the feeder:

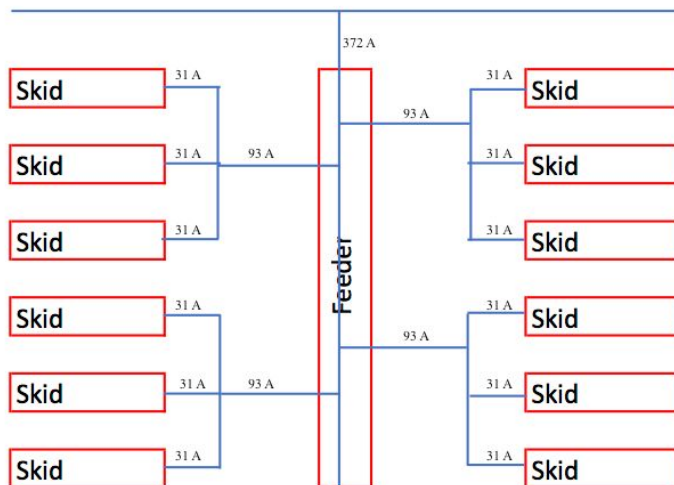
$$I_{\text{feeder}} = 93 \times 4 = 372 \text{ A}$$

Choosing conductor:

Add 10%

$$I_{\text{real feeder}} = 372 \times 1.1 = 409.2 \text{ A}$$

So we choose 800 Kcmil because it can handle 410 A.



## Pending Issues:

- N/A

## Plans For Next Week:

We will wait for the answers of the client about the key protection diagram, then we will divide tasks for everyone. However, next week, we will read the project scope and single line diagram to understand more about the key protection diagram, then we will make some changes.

## Individual Contributions

Team Member	Individual Contributions	Hours	Cumulative Hours
Katayi Katanga	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- Circuit model of our solar power plant</li> <li>- Key protection diagram</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- Concept presentation for the advisor</li> <li>- Key protection diagram</li> </ul>	15	117
Nur Shuazlan	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- Circuit model of our solar power plant</li> <li>- Key protection diagram</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- Concept presentation for the advisor</li> <li>- Key protection diagram</li> </ul>	15	119
Yao Cheah (YJ)	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- The relationship between conductor sizing and types towards its resistance value</li> <li>- Solar inverter calculation</li> <li>- Transformer calculation</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- Attended all meetings</li> <li>- Prepared presentation slides</li> </ul>	13	95
Ahmed Sobi	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- Capacitor bank</li> <li>- Circuits breakers</li> <li>- Disconnect switch</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- Prepared slide for key protection diagram</li> <li>- AutoCAD modification to the</li> </ul>	14	110



	<p>diagram</p> <ul style="list-style-type: none"> <li>- Attended all of the meetings</li> </ul>		
Tam Nguyen	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- Knowledge in EE 455 class for the concept presentation</li> <li>- Components in key protection diagram</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- Finalize feeder calculation</li> <li>- Attend all meetings</li> </ul>	14	88.5
Chufu Zhou	<p>Did research on:</p> <ul style="list-style-type: none"> <li>- Capacitor bank</li> <li>- Circuits breakers</li> <li>- Disconnect switch</li> </ul> <p>Created/Performed:</p> <ul style="list-style-type: none"> <li>- AutoCAD modification to the diagram</li> <li>- Attend all meetings</li> </ul>	13	84

Team Hours: 84

Cumulative Team Hours: 613.5