Portfolio
Hardware In-The-Loop Simulation

Lance Carr
David Bowman
David Lowe

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Team Mission

Develop model of distribution system with multiple photovoltaic inverters and implement external controller to coordinate real and reactive power output from inverters

Objectives

1) Select hardware in the loop application
2) Design, develop, and implement several use cases for the
3) Build models in the RTDS utilizing existing models available in the program or through industry advisors for the project.
4) Validate models using analytical approaches or conventional simulation tools such as Power world.
5) Develop and implement external interfaces to external control hardware.
6) Design, implement and test control schemes in the hardware
7) Write up the scheme in a laboratory exercise format.

1st Meeting 08-Sep-2020

Tuesday, September 08, 2020
3:42 PM

Team Meetings
1530 Thursdays Standard Time

Schedule Conflicts and Contact Info

David Lowe
-Normal Class time
-Work: M 12-15; W & F
-Class Tues-Thur
-No Sun
> dalowe48@gmail.com
> lowe8625@vandals.uidaho.edu

David Bowman
-Work: T & Thur before class
M,W, or F (one of) In afternoon
-Good Sat
> bowmandm1@gmail.com
> bowm3340@vandals.uidaho.edu

Lance Carr
Work: Wed& Friday
>lance.c.carr@gmail.com
>carr9733@vandals.uidaho.edu

Abdallah
Tues-Thurs
MWF more flexible
-Send HW assignments
Team Contract & email Dr. Li

Lab hours (open during weekends)
-need Keys
-Schedule time thorough google calendar
>use Gmail
-Can be used remotely
>need UofI IT to install remotely
-Power Engineers uses is occasionally during business hours

Choosing Direction of Project

- (3) Develop Distribution system with multiple photovoltaic inverters
    - --Automation controls in RTDS (switching /non-switching models)
    - --switching needs to be under human audible range
    - --Relays for meeting (allow utility oversight)
    - --Budget enough for a poster, and what set up cost would be
        - $100-$150
        - Most ordered through copy center in

Team Name Simulation Sages

i. we are all old

ii. we all have previous degrees

Team Members Jobs
Lead David Bowman
Scribe Lance Carr

14-Sep 2020

Monday, September 14, 2020
4:29 PM

Next Team Meeting:

17-Sep 2020 at 1530-1700 at ECE office

For Lab intro and key issue

14-Day out Plan of Action and Milestones (POA&M)

i. Team learns basic RTDS operations and progresses through tutorials in order to build foundation and questions before meeting with Assad.
ii. Team Member gets issues a Lab Key (From ECE front office Admin)
iii. Team Members receive access to download RS CAD (via U of I IT-dept)
iv. Team Members receive VPN access to RTSD
v. Reserve RTDS lab for 17-Sep2020 at 1530-1700
vi. Reserve RTDS lab for 24-Sep2020 at 1730 for **Meeting with Asad (SEL)**

Members Present:

Davids Lowe and Bowman
Lance
Abdallah (Grad-Mentor)

Dr. Johnson
Asad Mohammad (SEL)

Project:

Develop model of distribution system with multiple photovoltaic inverters and implement external controller to coordinate real and reactive power output from inverters

Dr. Johnson has had multiple M. Deg Students
model systems
-We will have access to some of their material
-He will email copy of thesis(s)
-Some tried a non-switching model
-Some used an inverter modeled in RTDS
>Recommends non-switching Model
BUT, learning about switching model is good as well
*Recommend us go through tutorial systems

Best Options:

1. use RS CAD Bucannon G11
2. Dr. J is submitting a request for RTDS remote access and install RSCAD on our PCs

RS CAD also installs tutorial software

Bucannon Engineering Lab Basement
One of use needs keys, get them through
*Meet up Thursday 3:30-4:45 for keys and lab into

Agenda: Simulation Sages Meeting 1 14 September 2020

Team Introductions

- Introduce members present briefly
- Introduce the specific project that we chose out of the options for hardware-in-the-loop

Scheduling Needs

- Discuss with Asad the best scheduled time to meet with him to learn about the RTDS
- Discuss with Dr. Johnson the best times to meet in the lab

Budget Needs

- Discuss any budgetary needs that the project requires at this time

Screen clipping taken: 14-Sep-20 4:31 PM

Asad:
Asad experience Modeling PV
-Minor experience
-Use Generic model (not much switching)
-hoping to get a much better understanding of modeling systems …learn with us

we are limited to one rack, and switching models requires a lot of bandwidth.
Two Tasks:

1. understand model itself
    a. how to use racks and software
    b. look over simple examples
    c. RTDS has a whole library of functions to do
2. Create Single Line Diagram of task

Nothing is online
>He can come in after 1700 weekdays and some weekends
Meet up with Asad 1730 09/24
-->Team "Scribe" sent google calendar even to all participants for meeting with Asad

17-Sep 2020

Thursday, September 17, 2020
3:41 PM

Face-to-Face meeting canceled due to Unhealthy Air pollution levels and HVAC shutdown of Bldg.
Dr. Johnson instead gave a virtual tutorial of the software we will use.
Participants:
David Bowman
David Lowe
Lance Carr
Dr. Johnson

Dr. Johnson
Submitted RSCAD request to IT-dept
Showing us how to use RSCAD
Tutorial
Draft
- R-R "resistors in series"
- R//R "resistors in parallel"

29-Sep 2020

Tuesday, September 29, 2020
4:17 PM

Attendees:
David Lowe
David Bowman
Lance Carr

Goals:
(1) Goal Through Tutorials on RSCad to learn how to operate the system.
(2) Finish Product Requirements Document
(3) Get access to RTDS via VPN

Next Meeting 01 Oct at 330 for Team meeting with advisor.
Order of Business (3)
As of this Date the Team had not gained VPN permissions from the U of Idaho IT dept.

- All team members email IT support requesting access.
- It was discovered last meeting that VPN is required, even in the lab, to run simulations.

vpn.uidaho.edu/ece-rtds

It will ask for your UI password and send you a DUO approval.

For your config file

Rack 1 is now 172.30.192.60

Rack 2 is now 172.30.192.59

Rack 3 (the new NovaCor) is now 172.30.192.62

GTNet on Rack 1 is 172.30.192.58

Subnet is 255.255.255.192

Gateway is 172.30.192.1

-

01-Oct 2020

Thursday, October 1, 2020
3:31 PM

We will use the IEEE 13-buss RSCAD model (agreed by all)
We need to figure out how many PVs and where
--> suggested by Smadi that we place buses at weakest bus
->Lowe suggests we use 3PVs (all agree)
All thee on same bus or separate bus?
--> Samdi: we could split PVs to support busses with low voltage.
I suggest we build our model (without PV) then experiment with PV placement.

Bowman ask we research IEEE model and what the sources are and begin to develop our one line diagram with loads.

Bowman will work on the next deliverable this weekend for completion by next meeting.
Attendees:
David Lowe
David Bowman
Lance Carr
Abdalla Smadi

Next meeting at 330 Tuesday
Lowe with request labs rack for that time

08-Oct-2020

Thursday, October 8, 2020
3:36 PM

Attendees:
David Lowe
Lance Carr
Dr. Johnson

>David could not make it

Snapshot day:
Use RTDS live simulation
Have one person manage RSCad dynamically with the Lab computer, while another team member gives the presentation
General Outline:

i. Go over project mission and goals
ii. Give orientation on RSCad and RTDS
    a. In project and industry
iii. Show case bases model we are using
    a. At least one PV-array on grid
iv. Discuss learning and fiction points

Lance will run the dynamic simulation
David & David will create the presentation scrip this weekend for the narration
Abdulla will
We will meet up Monday and 1645 to due a walk through on our presentation.

Project Portfolio:
Deadline Extended to Sunday night
Lance Will turn in

Need to clean up
Add Cover Page
Add Table of contents

13-Oct Snapshot Day

Thursday, October 8, 2020
4:01 PM

David Lowe (Power Point) and Lance Carr (RSCad sim)
Presented first to Abdalla Smadi
Presented to Alex Olson and Andrew Eberhardt
Recommended dynamic loads
Presented to Dr. Johnson
>using a slider to change the load is good for this project.
After Presentation David Lowe Checked out Project '10' Tesla Coil Based Security System
Attendees:
David Bowman
David Lowe
Lance Carr

27 Oct 2020

Tuesday, October 27, 2020
4:06 PM

Checking over the RMS values at each buss, the nodes off 671 has the weakest buss values These are prime candidates to add the PV array elements.

When I moved the PV array, I kept getting compile errors. I reached out to Dr. Johnson to see if he can help next Thursday.

29-Oct 2020

Tuesday, November 3, 2020
4:00 PM

Attendees: David Lowe, Lance Carr and David Bowman

Group continued working on the model but ran into issues trying to measure the voltage supplied by the PV array.

With the PV array attached to the bus system, there was not a measurable change to the power factor on the bus's node.

Lance started to try and build up from scratch the PV system to better understand what was imported from the microgrid template.

03 Nov 2020

Tuesday, November 3, 2020
4:04 PM

Lance Reached out to Dr. Johnson to see if he can help trouble shoot with the PV system.
Present: Lance Carr and David Lowe.

David is working on updating the group Wiki page as the site master.
Lance is continuing working on the PV integration.

The PV array was moved to node 675, since it already has a circuit breaker built. This seemed to be an easy way to test an isolated bus if it was received power.

Simulator not showing much. With Circuit breaker open, and PV breaker close Node 675 reads Bus A RMS of 6.9e-8, PV breaker open no change. This very tiny voltage could be due to coupling from node 671.

PV Breaker	Bus 675 Breaker	Bus A_RMS
Open	Open	6.9e-8
Closed	Open	No change
Open	Closed	0.99
Closed	Closed	0.99

Next Meetings

Thursday 1530

05 Nov 2020

Thursday, November 5, 2020
3:25 PM

Attendees: Lance Carr and David Bowman, David Lowe, and Abdallah Smadi
David Bowman is running the meeting remotely (since he is sick)
Lance Carr is in the Lab working
Abdallah Smadi also joined the meeting remotely.
RFI:
Will the Lab still be accessible during the break, and beyond for the semester
What all do we need to prepare for design review.

I. 20-30 minutes
II. Like snapshot day, but more of what we have accomplished
    a. Circuit Designs, Diagrams,
    b. Issues, and roadblocks
    c. Delve into the buss
    d. Assume audience is non-electrical engineer
III. Use PowerPoint Slides to cover material

I. David Bowman to showcase the Microgrid Simulator we are pulling the PV array from
II. David Lowe working on wiki showcase.

Next Meeting:

- Tuesday 1600 in the lab
    - Design Review Dress Rehearsal

- Design Review Thursday 12-November at 1630

Upcoming Deadlines

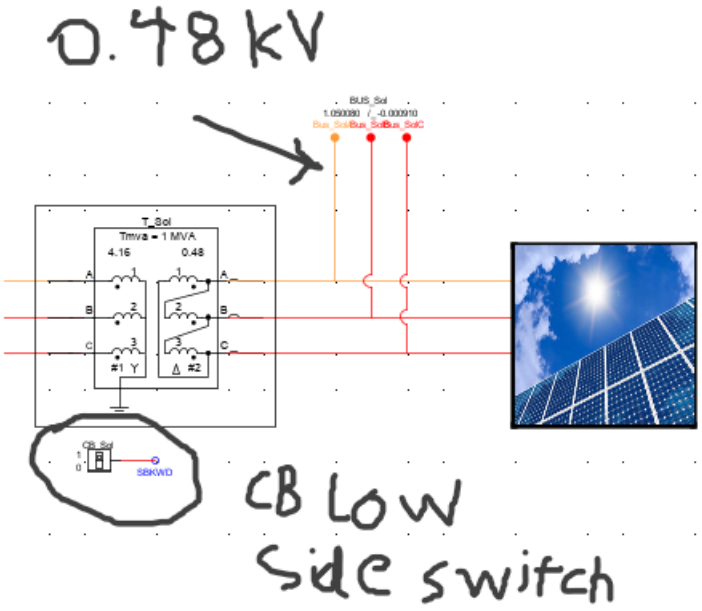
- Logbook and Portfolio due on the 12th Nov.
    - Portfolio (Lance)
- 13 Nov design reviews
- 20 Nov Citizenship

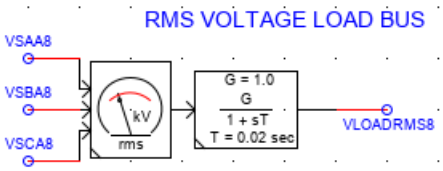
05 Nov |Dr. Johnson Help|

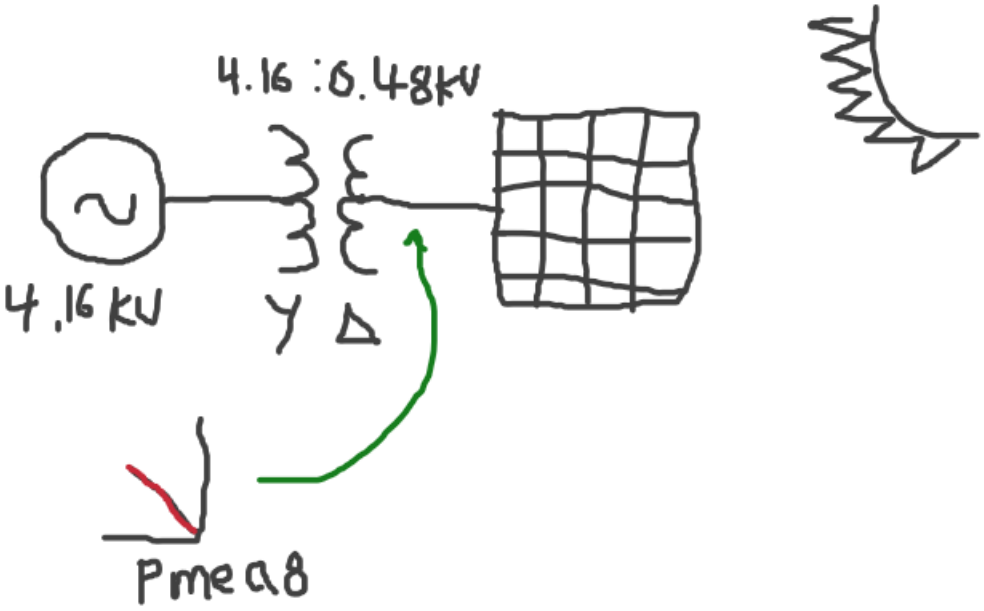
Thursday, November 5, 2020
4:57 PM

1. Reviewing the model Dr. Johnson confirmed that the PV array was not providing power to the system.
    a. The Microgrid PV model was designed to output 480 Volts, while the 13 Bus Model operates at 4.16 kV.
    b. He recommended installing a step-up transformer to the system, and he assisted integrating it into the network.
2. The Step-up Transformer is T_Sol. For simplicity, the Circuit Breaker on the high side is turned off. A switch CB_Sol controls the low side CB of the transformer.
    a. It was recommended to go with a Delta (low) | Y (high side transformer)
    b. This allows the Y to be grounded.
3. Digging into the PV model > PV Controls > Power & Voltage Measurement is we found the data points to create meters of the PV's power and voltage output from on the AC side.
    a. VLOADRMS8 compiles the three node voltages pushed to the bus.
    b. The Three Phase P (Watt) and Q (VARs) are in the same control window
        a. Pmea8 and Qmea8 respectively
4. We recompiled the draft and measured the power. Zero power was pushed by the PV

It is recommended that we create a new test. dft to identify the problem using the 4.16 kV ideal source connected to the PV and step up transformer.
NOTE: The PV must be connected to a source, since it is grid following, to work properly


0.48 kV
BUS_Sol
T_Sol
Tmva = 1 MVA
4.16
0.48
#1 Y
Δ #2
CB_Sol
SBKWD
CB low side switch


RMS VOLTAGE LOAD BUS
VSAA8
VSBA8
VSCA8
kV
rms
G = 1.0
G
1 + sT
T = 0.02 sec
VLOADRMS8


4.16 :0.48kV
4.16 kV
Y Δ
Pmeas

10 Nov 2020

Tuesday, November 10, 2020
4:08 PM

A separate Zoom Meeting with Asad is scheduled for 1700 today.
Team members present:
David Lowe, David Bowman, Lance Carr

David and David are continuing building slides for our presentation Thursday 12 Nov and 1630.

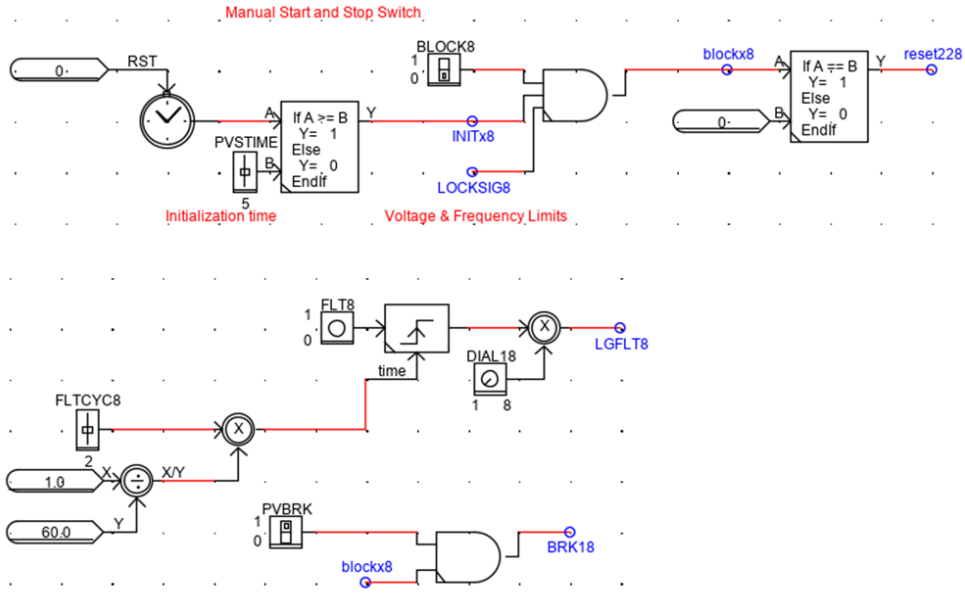
Lance is working the trouble shooting with the PV array based off Dr. Johnson's guidance.

The VSA buss is outputting zero Volts
Blockx8 is forcing Brk18 to open automatically
We may need to remove the fault block.

PV transformer needs to have control bits from switch all be 1.

PV array's max rated voltage

In meeting with Asad we determined that the PV's breaker was tripping due to 'blockx8' being triggered. Digging through the logic we did not find the route cause. We developed a workaround by removing 'blockx8' from the breaker's controls



12- Nov Project Design Review

Thursday, November 12, 2020
5:40 PM

Follow up Comments
(1) Recommend we look at IEEE std 1547 for inverter controls as a guide for our system
(2) Use Cat 5 connectors to link RTAC into RTDS I/O cube.
(3) Use HMI to control/ monitor RTAC
(4) DC voltage is incorrect 25kV is too high.
(5) This lab would be tied into an existing 400 level class. So Prerequires would be completion of ECE 320.

19-November

Thursday, November 19, 2020
3:31 PM

Lance is under quarantine until after the break.
David Lowe has started the paperwork process to get a lab key

Break Plans:
Bowman working on Simulation
Lance Working on Inverter controls and layout

RTAC at the bottom of the cabinet
Over Ethernet need to create a block in RSCad for goose messages
>Asad has offered to help with the physical connection
>David Bowman will reach out to Asad to meet up after the break
Attendees:
David Lowe
David Bowman
Lance Carr
Dr. Johnson
Abdallah Smadi

Next Meeting Tuesday 01 December After the General Session

End of Semester on the 4th of Dec

03-Dec 2020 Snapshot prep

Thursday, December 3, 2020
3:34 PM

People Present:
David Lowe, David Bowman, Lance Carr, Abdallah Smadi, Dr. Johnson

Snapshot II will be a condensed repeat of Design Review II
Have each team member be prepared to give a whole presentation.

David Lowe and Lance Carr will build the PowerPoint slide and script

Default RTAC front port
172.29.131.1

08 Dec 2020

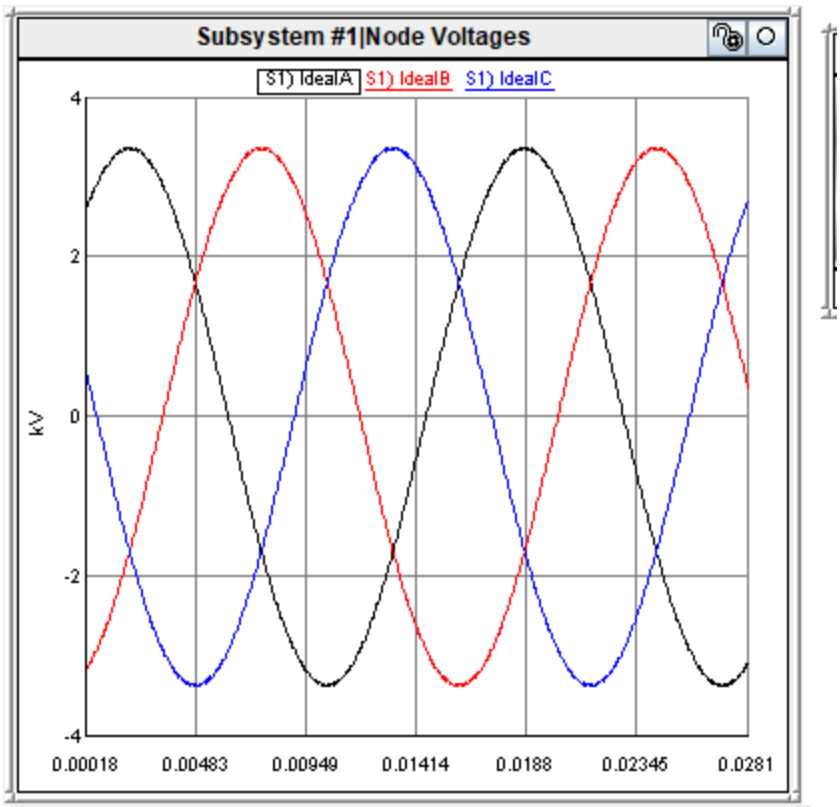
Tuesday, December 8, 2020
5:03 PM

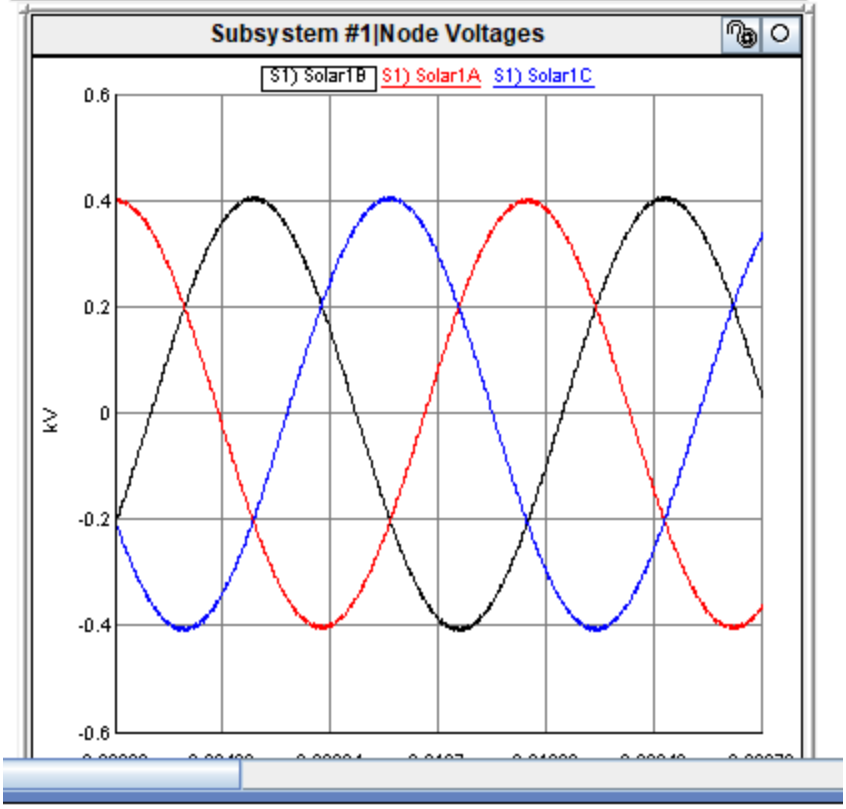
Meeting in lab with David Lowe and Lance Carr
Still having trouble connecting with the SEL

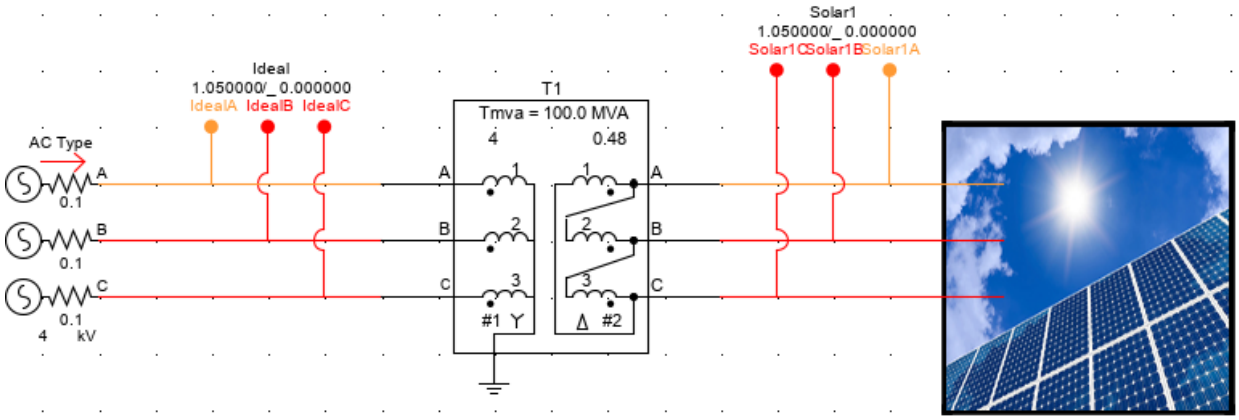
Reached out to Asad to meet up with us this next Thursday evening to help out

Working with the PV and Ideal Source only model I adjusted the Rated line to line voltage on the nodes to be above 0.48kV and this fixed my problems. The graph did have a thick transient in the 3 phases plot with the insol was about 1000W/M2.

I added a Y -- Delta transformer and this greatly reduced the noise on the node voltages.


Subsystem #1|Node Voltages
S1) IdealA
S1) IdealB
S1) IdealC
4
2
0
-2
-4
kV
0.00018
0.00483
0.00949
0.01414
0.0188
0.02345
0.0281


Subsystem #1|Node Voltages
S1) Solar1B
S1) Solar1A
S1) Solar1C
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
kV



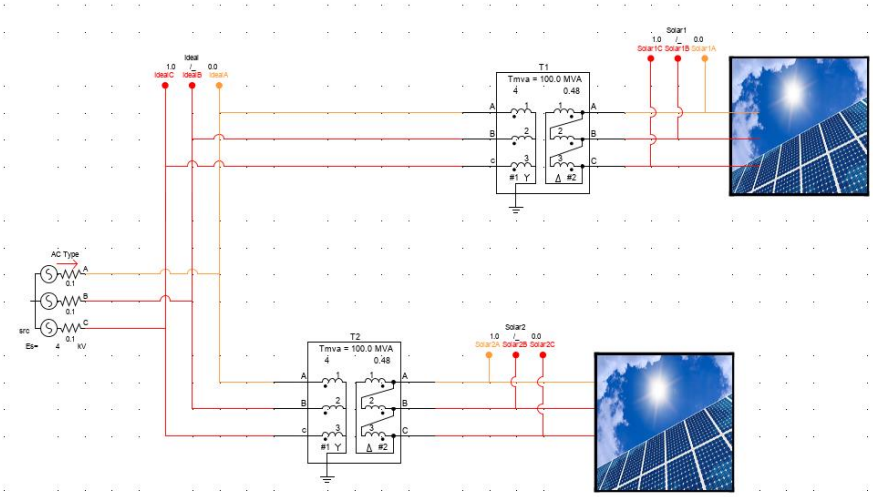
10-Dec-2020

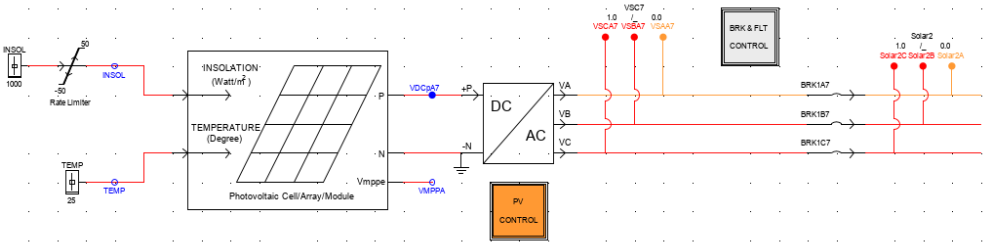
Thursday, December 10, 2020
3:45 PM

Team Meets up in the Lab
David Lowe, David Bowman, Lance Carr, Dr. Johnson

Actions:

I. Bowman worked on connected to the front port of the RTAC.
II. Simulation work
    a. With our simple PV, Transformer, and source model working we starting to make a second PV on our system. The second PV will require that all variables be converted to an independent name from the initial PV.
    b. Since the initial PV ends everything with 8, we will make PV (2) Variables end in 7. The first two layers of conversion have been completed to 7.
    c. The next steps are to be a two PV system to work (as shown below) then a (3) PV system. Once this is completed, we can attach the Transformer and PV to the 13 Buss IEEE model.





III. Next Meeting will be Friday 11-Dec-2020 at 5:30PM with Asad. He will come and help us trouble shoot our connection with the RTAC.

IV. The group is tentatively planning to work/meet up during the break. We all have finals that will take priority until next Wednesday.

11-Dec-2020

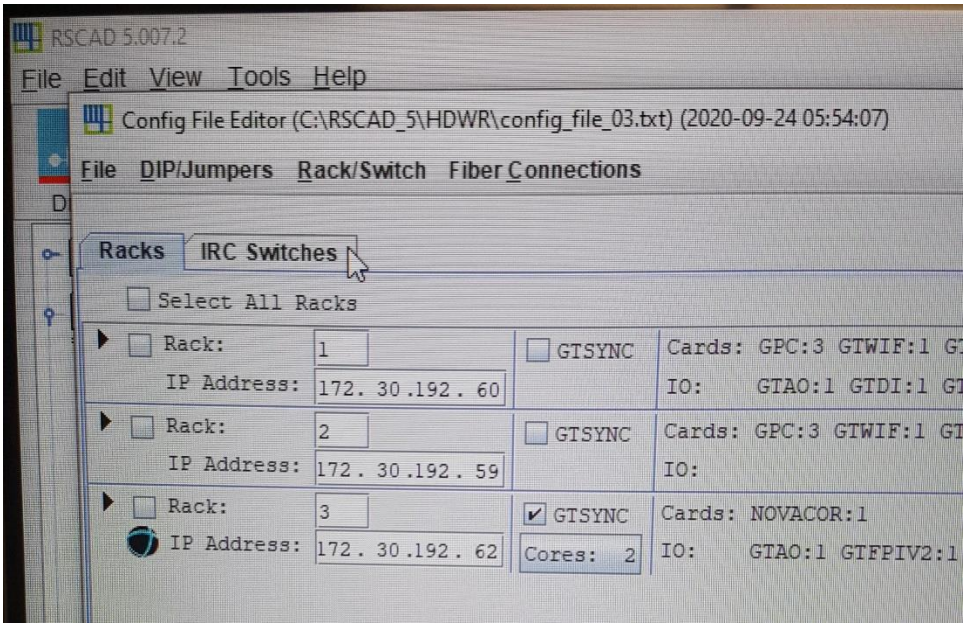
Friday, December 11, 2020
7:26 PM

Attendees: David Lowe, David Bowman, Lance Carr, Asad (SEL)

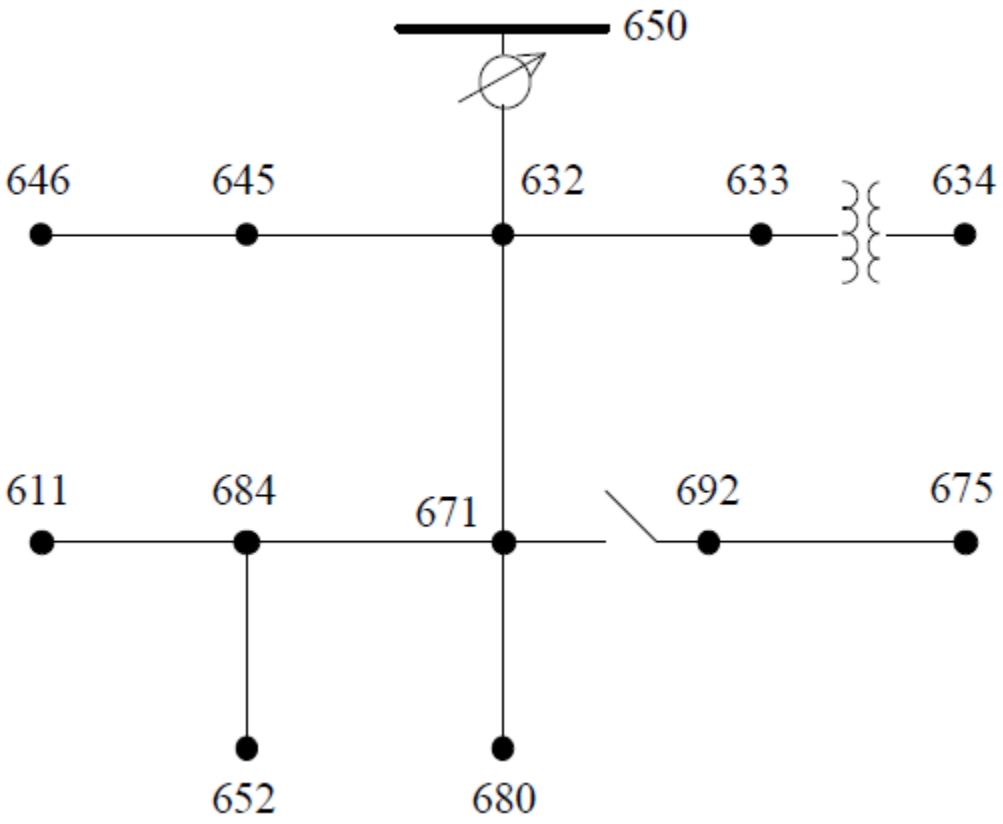
Team meet up in the lab to get Asad to help us establish communications with the RTAC.
The RTAC by default as the command prompt ping disabled.
We connected a VGH monitor to the RTAC to access the programs. Via USB we could connect a mouse and printer.
From the RTAC dashboard menu we changed the username a password to the SEL default for level two access. We also re-enabled the port ping.

Asad further helped us network the RTAC and RTDS (and its IO) with the network. We were not able to test out remote access from VPN to the RTAC. we will need to update the RTAC IP (ports) to fall under the RTDS IP octets.

The RTDS IPs are:



Appendix A –IEEE 13 Node Test Feeder One-Line Diagram



Appendix B -References

[1] X. Chen, "Protection Scheme of an Integrated Photovoltaic and Type 3 Wind Turbines System," *University of Idaho Graduate Studies,* December 2019.

[2] D. R. K. Varma, *Solar PV Applications of Power Electronics.*

[3] RDTS Technologies , "Real-Time Simulation Model of IEEE 13 Node Test Feeder," July 2018.

[4] Schweitzer Engineering Labs, "SEL - 3530 RTAC Manual".

Appendix C -- Wiki Site Link

Thursday, November 12, 2020
5:56 PM
http://mindworks.shoutwiki.com/wiki/RTDS_Simulation_of_PV_Inverters_in_a_Small_Power_System

References

[1] X. Chen, "Protection Scheme of an Integrated Photovoltaic and Type 3 Wind Turbines System," *University of Idaho Graduate Studies,* December 2019.

[2] D. R. K. Varma, *Solar PV Applications of Power Electronics.*

[3] RDTS Technologies , "Real-Time Simulation Model of IEEE 13 Node Test Feeder," July 2018.

[4] Schweitzer Engineering Labs, "SEL - 3530 RTAC Manual".