Contents

Appendix A

Appendix A

Part 1

Part 1

A.1 Internal Designs:

A.1.1 Grid:

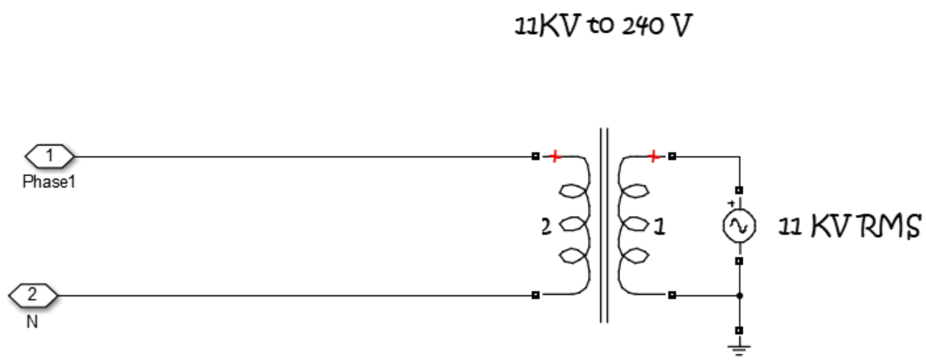

Figure A-1: Internal design of grid in SIMULINK.

A.1.2 Boost Converter:

Both boosts have the same internal design which is:

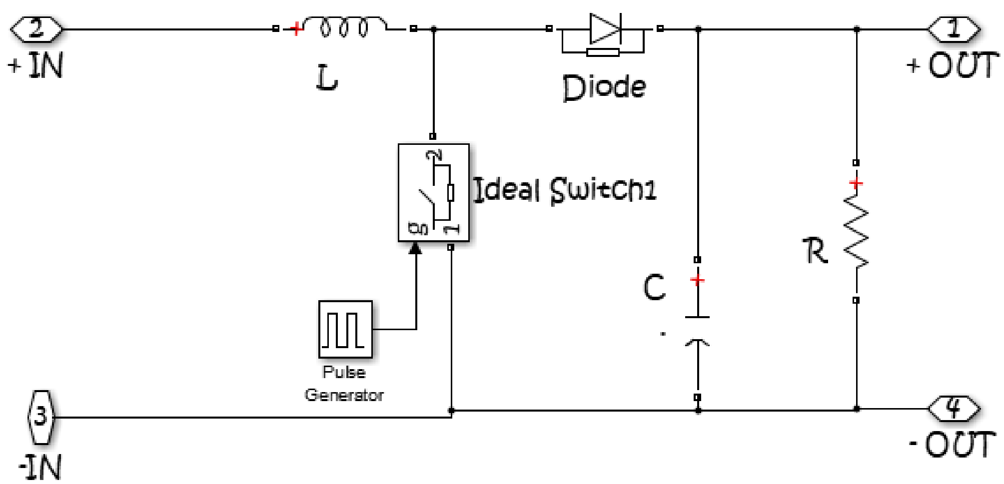

Figure A-2: Internal design of boost converter in SIMULINK.

A.1.3 Inverter:

This inverter using PWM control with phase (time) shift between the four internal switches depending on the equation:

$$Time\ Shift = \frac{\pi * \ \theta}{180 * 2 * \ \pi * freq}$$

Or simply used (Not) logical operator as shown:

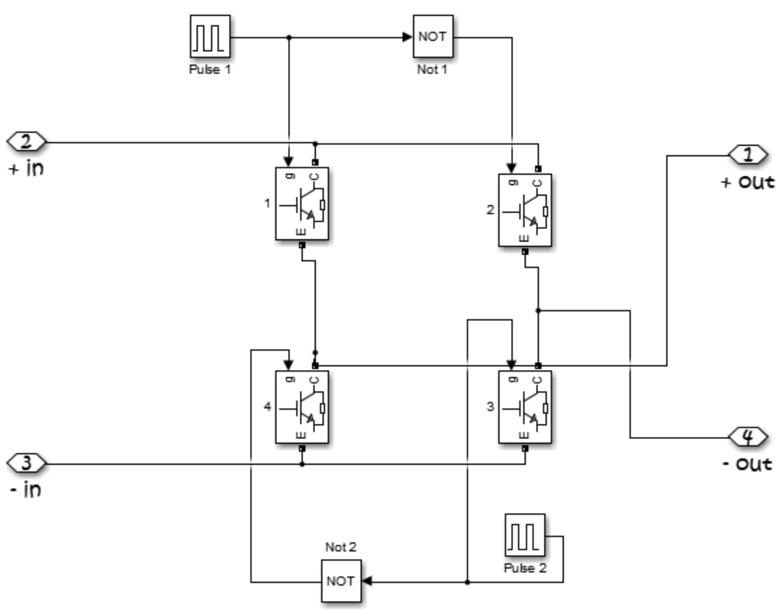

Figure A-3: Internal design of inverter in SIMULINK.

A.1.4 Filter:

It contains a resistor, inductor, and a capacitor their selection is included in the next part of Appendix A.

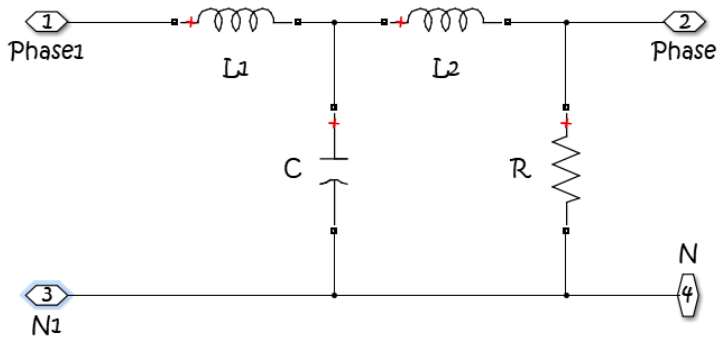

Figure A-4: Internal design of filter in SIMULINK.

A.2 Calculations:

A.2.1 DC Bus Capacitor:

The input voltage of the inverter comes from a DC source. However, even the most accurate source produces some noise that distorts the original waveform, for this reason, it is normal to include a capacitor on the DC bus of the inverter, in order to stabilize voltage, it can be calculated by:

$$C > \frac{Pnom}{\Delta VDC * VDC * \omega}$$

Since:

-P nom is nominal power.

- ΔV_{DC} is the maximum ripple voltage desired in the capacitor.

- ω is the output frequency × π × 2.

- V_{DC} is the voltage in the DC side.

- Out frequency is 50 HZ.

For the mentioned experiments in chapter 4, PV power is 2250 W; DC volt is 110 V; take the voltage ripple of 1%, and applying the previous equation, DC bus capacitor is **0.06 F**.

A.2.2 Boost Converter:

For boost calculations, these equations are used:

$$D = 1 - \frac{Vin}{V\ out}$$

$$L = \frac{D(1-D^2)R}{2f}$$

$$C > \frac{D}{R\left(\frac{\Delta Vout}{Vout}\right)f}$$

Since:

- D is duty cycle.
- Vin is the input DC voltage.
- Vout is the output DC voltage.
- L is inductor of boost.
- C is capacitor.
- R is resistor.

- ΔV_{out} is the maximum ripple voltage desired.
- F is the switching frequency which used (25 KHZ).

Batteries give 55 V_{DC}, this voltage should be boosted to get 110 V_{DC} to be as same as PV station output voltage.

For **boost 2**, suppose that R =100 **Ω**, and the voltage ripple in the capacitor is 1%, applying these equations to get:

- D= 0.5.
- L = 7.5 $\times 10^{-4}$ H.
- C = 2 $\times 10^{-5}$ F.

For **boost (both PV and batteries):**

The input voltage is 110 V, the output is 340 V that will be the inverter input voltage.

Assume R is 10 **Ω**, and the voltage ripple is also 1%, apply equations to get:

- D= 0.68.
- L = 7 $\times 10^{-5}$ H.
- C = 3 $\times 10^{-4}$ F.

A.2.3 Filter Calculations:

Filter of inverter contains inductance, capacitance, and a small resistor, L can be calculated using equation of:

$$L > \frac{Vin}{8 * \Delta i * f\ switch}$$

Since:

- L is minimum inductance of the filter.
- Δi is the maximum load current × current ripple.

- F switching = 2× switching frequency.

For Vin = 340 V, current ripple of 1%, f switching = 50 KHZ, and load current of:

$$I = \frac{750\ W}{250\ \Omega} = 3.125 \text{ A rms} = 4.5 \text{ A peak.}$$

$\Delta i = 4.5 * 0.01 = 0.045\ A.$

So, apply the equation, L =19 mH.

As the values of the capacitors are standard, the procedure chosen will be that of selecting a capacitor which assures a satisfactory output waveform. This way, on a rough range between 50 and 500µF, it will be chosen a capacitance of 280µF.
Also, a small resistor is chosen to avoid open circuit and increasing of voltages, R=20.

Table A-1: Table of used values for each component:

Items / Component	Item	Values	Unit
Boost2	R	100	Ω
	L	$10*10^{-4}$	H
	C	$5*10^{-5}$	F
Boost	R	10	Ω
	L	$10*10^{-5}$	H
	C	$5*10^{-4}$	F
Filter	R	20	Ω
	L	$30*10^{-3}$	H
	C	$280*10^{-6}$	F

Part 2

Part 2

This part is to highlight smart grid university lab model, and to look inside each block at it.

A.1 Induction Generator:

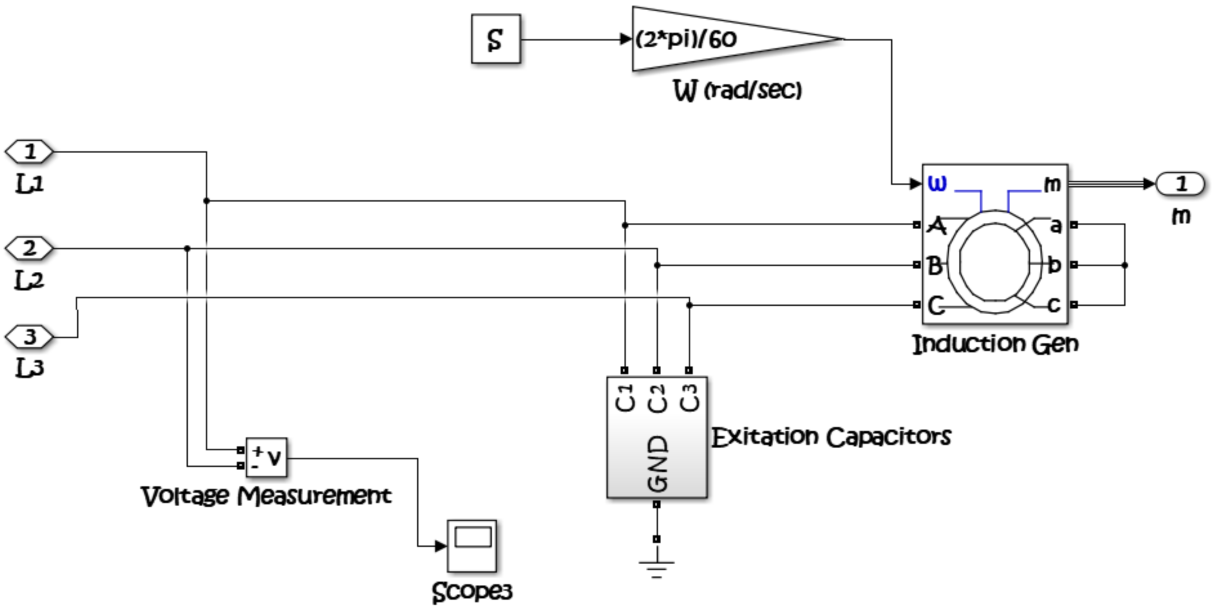

Figure A-5: Internal design of induction generator by SIMULINK.

The subsystem design contains an induction machine block from SIMULINK library, it is designed to be even motor or generator. The capacitors are used to make excitation for the generator to allow it to work island from grid, there value can change the out voltage too, so they can be changed until having the desired voltage.

The input of induction machine may be **torque (N.m), speed (ω), or mechanical rotational port**.

A.1.1 RPM (Revelation Per Minuit) is The Input:

If the used machine, had input of speed (ω) in rad/s, which has a relation with RPM (Revelation Per Minuit), **rad/s = RPM*2*π / 60**, then the RPM will be the user input converted to rad/s, its modeling shown in figure (A-5), and the testing is below.

Changing the RPM will change the voltage out from generator as shown below:

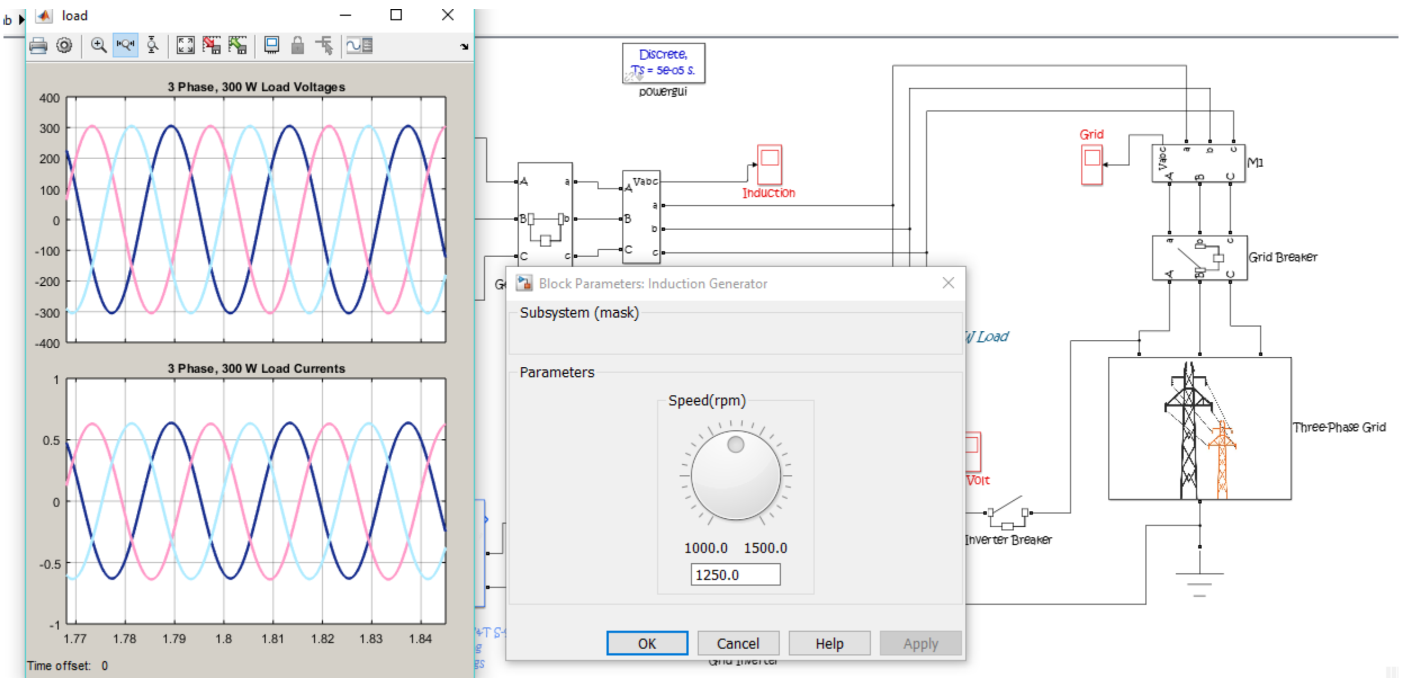

Figure A-6: RPM and voltage out from induction generator by SIMULINK.

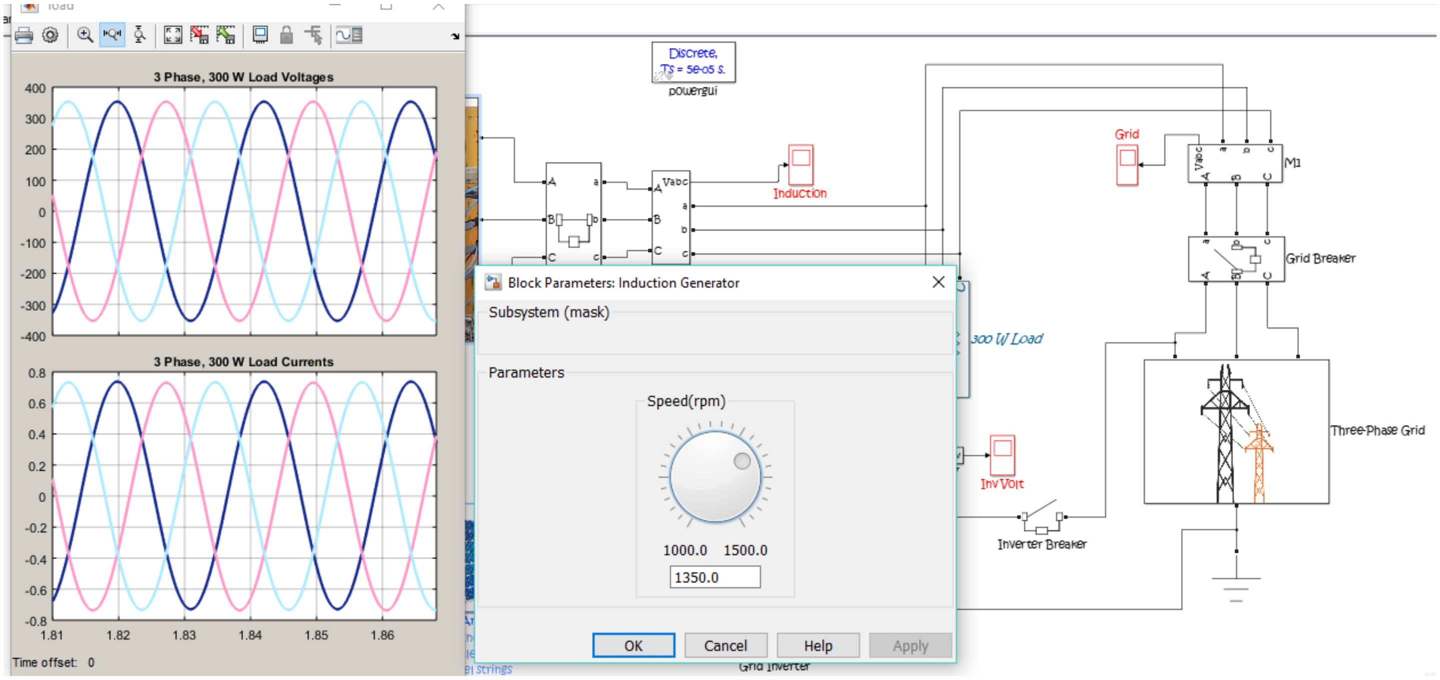

Figure A-7: RPM and voltage out from induction generator by SIMULINK.

A.1.2 Torque is The Input:

The torque of the induction generator can be calculated as same as the torque of induction motor, except that it is a negative torque, it can be calculated using equation of:

$$T\ (N.m) = \frac{P\ out\ in\ Watt}{RPM\ (\frac{Revelutions}{minuit}) * 2 * \pi\ (\frac{rad}{sec}) * \frac{1\ minuit}{60\ sec}}$$

Applying this equation for the 1500 W, 1650 RPM induction generator, getting that **T= 8.7 N.m**.

The following figures show the out voltage of the induction generator.

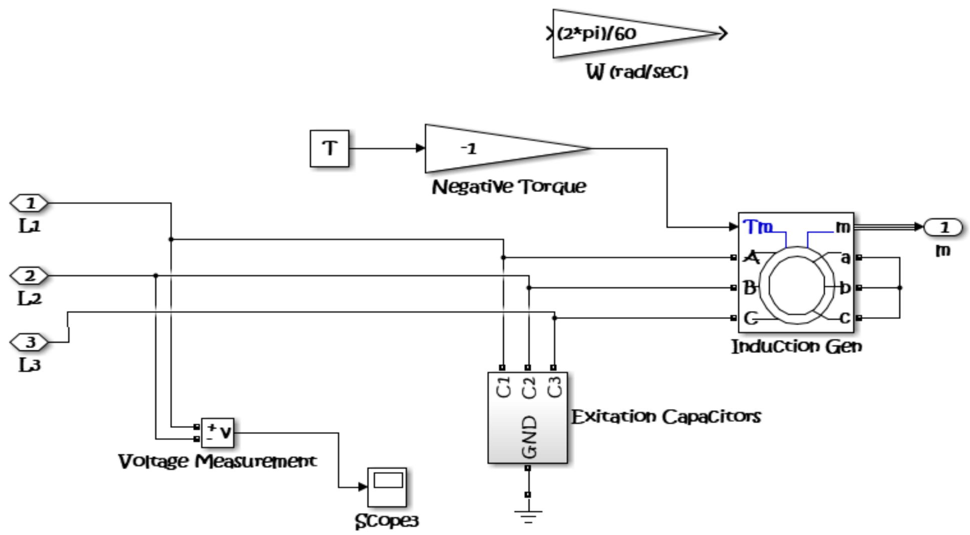

Figure A-8: Internal design of induction generator with torque by SIMULINK.

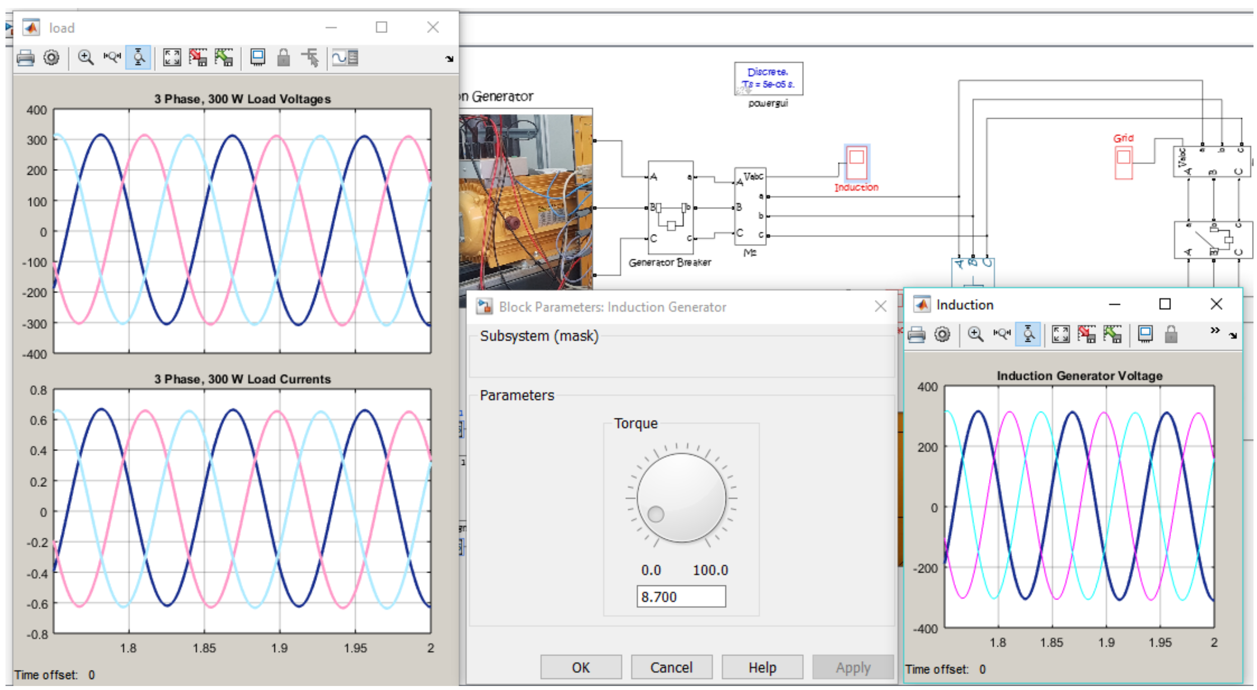

Figure A-9: Torque and voltage out from induction generator by SIMULINK.

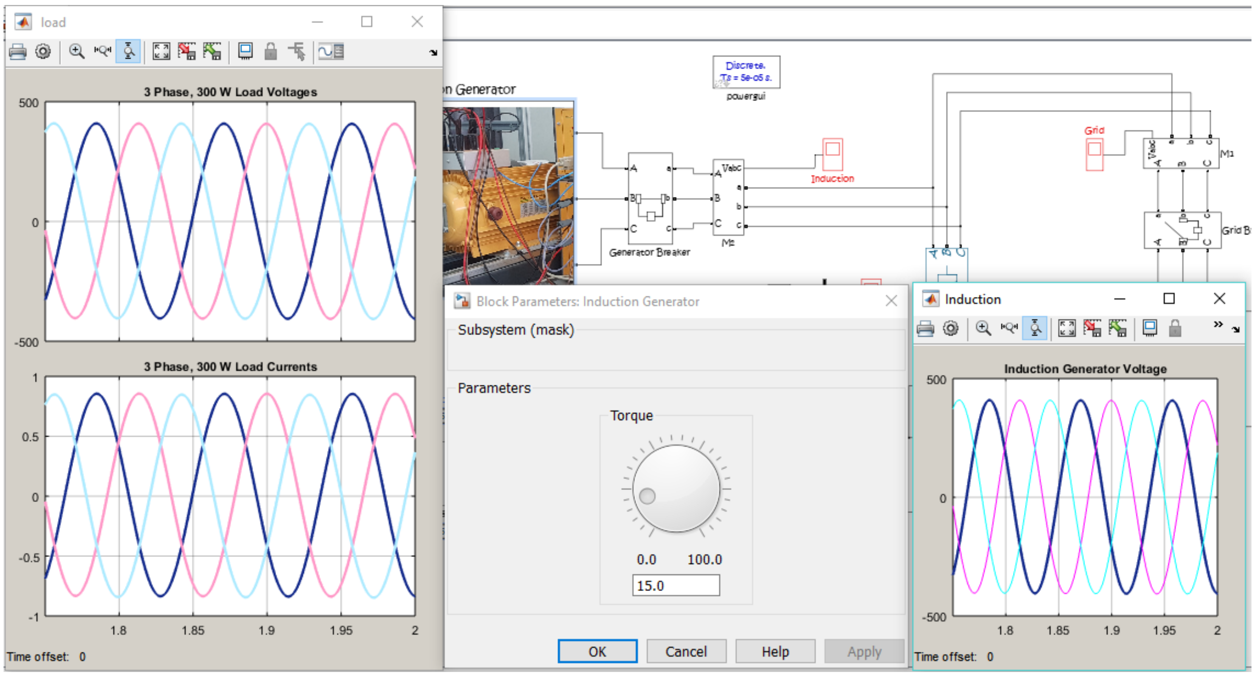

Figure A-10: Torque and voltage out from induction generator by SIMULINK.

A.2 PV Block:

90 W, 12 V, small PV string designed for domestic use, at the day when the experiments were finished, the irradiance is not an important issue, because the string used a light instead of sun shines.

The designed model is close type to the real one, and give 18 V at MPPT, 22 V at open circuit.

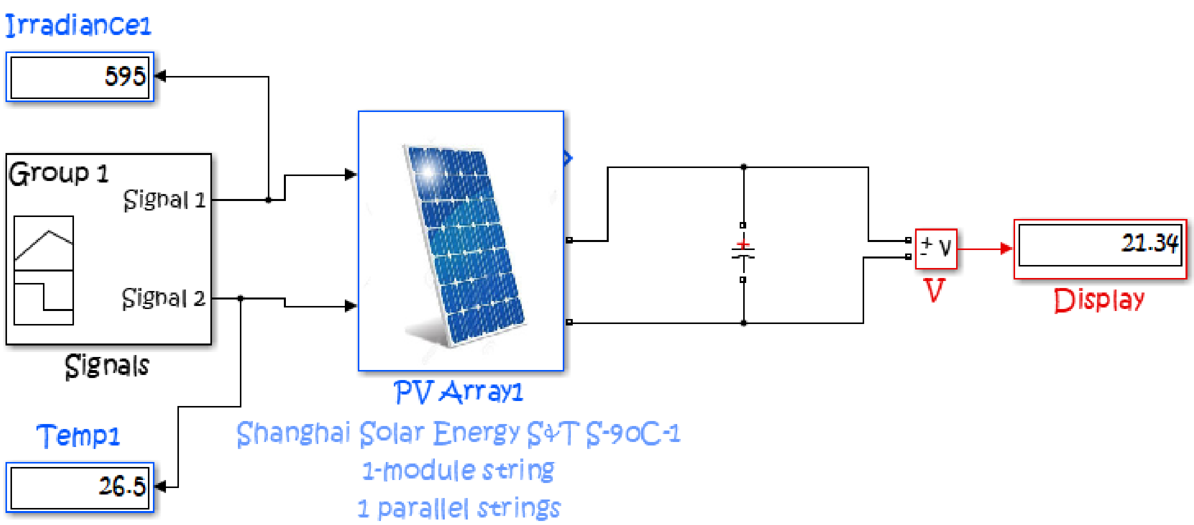

Figure A-7: PV string design, SIMULINK.

A.3 Grid Inverter:

This design is similar to the one n JDECo. model, with different values.

Since the PV string is only 90 W, 12 V cannot be boosted up using only power electronics, so in this design, 18 V ac from inverter will be transformed to 240 V using single phase transformer and then connected to line 1 of grid.

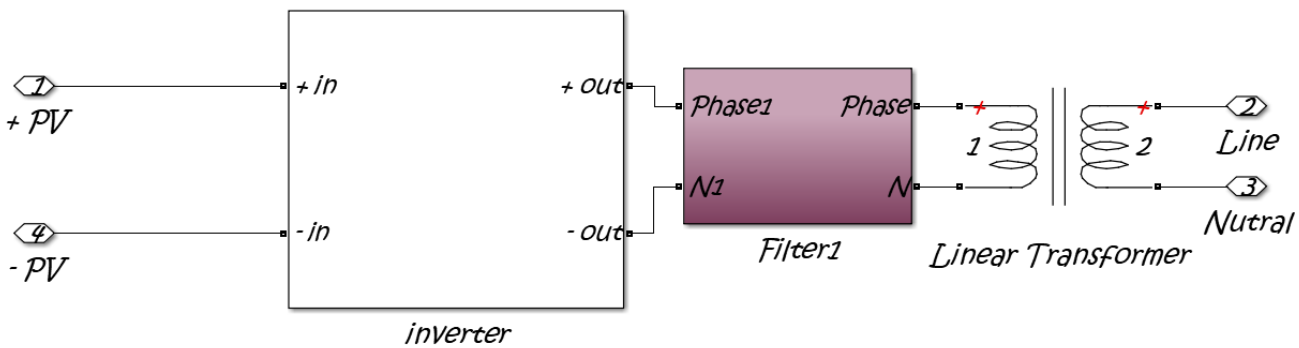

Figure A-8: Grid inverter internal block, SIMULINK.

Appendix B

Appendix B

Part 1

Part 1

B.1 Overview:

In this section, location of the determined site which is Beit Sahour village, and analysis of grid will be presented, including power flow and losses. These losses will be compared with the reality in order to prove the features of smart meters, also an increasing of load on transformer will be mentioned to run the transformer at full capacity to calculate the losses at it.

B.2 Highlights:

1) Three feeders are connected to the transformer, one is the main from the electrical grid, and the other two feeders are CR3, and CR6 is for the same consumer that has PV station, and CR3 is for other consumers, a load profile was generated by smart meters in 2-5 days with time interval of 0:30 hrs. is included in the tables below:

i. Feeder CR3:

Table B-1: CR3 feeder**.**

Date	Maximum Demand(KW)
11/14/2017 12:00 PM	32
11/14/2017 2:30 PM	29.4
11/14/2017 3:30 PM	27.8
11/14/2017 6:00 PM	34
11/14/2017 7:30 PM	32.6
11/14/2017 9:00 PM	32.2
11/14/2017 9:30 PM	32
11/14/2017 10:00 PM	30.2
11/14/2017 10:30 PM	28.7
11/14/2017 11:00 PM	28.3
11/14/2017 11:30 PM	27.6
11/15/2017 12:30 AM	24
11/15/2017 1:30 AM	25.7

11/15/2017 2:30 AM	18.8
11/15/2017 3:00 AM	18
11/15/2017 3:30 AM	18.2
11/15/2017 4:00 AM	18
11/15/2017 4:30 AM	17.3
11/15/2017 5:00 AM	17.6
11/15/2017 5:30 AM	15
11/15/2017 6:30 AM	13.2
11/15/2017 7:00 AM	14.6
11/15/2017 7:30 AM	14.4
11/15/2017 8:00 AM	16.9
11/15/2017 8:30 AM	19.8
11/15/2017 9:30 AM	26.3
11/15/2017 10:00 AM	21.9
11/15/2017 11:00 AM	34.9
11/15/2017 11:30 AM	27.6
11/15/2017 12:30 PM	27.8
11/15/2017 1:00 PM	31.4
11/15/2017 2:00 PM	31.3
11/15/2017 2:30 PM	32.8
11/15/2017 3:30 PM	29.6
11/15/2017 4:30 PM	30.7
11/15/2017 5:00 PM	29.8
11/15/2017 5:30 PM	36.9
11/15/2017 6:30 PM	40.2
11/15/2017 7:00 PM	44.9
11/15/2017 7:30 PM	41.2
11/15/2017 9:00 PM	42.4
11/15/2017 9:30 PM	36
11/15/2017 10:00 PM	32.6
11/15/2017 10:30 PM	31.6
11/15/2017 11:00 PM	30.9
11/15/2017 11:30 PM	28.4
11/16/2017 12:00 AM	25.2
11/16/2017 12:30 AM	21.2
11/16/2017 1:00 AM	19.5
11/16/2017 1:30 AM	19.5
11/16/2017 2:00 AM	17.2
11/16/2017 2:30 AM	16.6
11/16/2017 3:00 AM	16.2
11/16/2017 3:30 AM	20

11/16/2017 4:00 AM	20.4
11/16/2017 4:30 AM	16.4
11/16/2017 5:00 AM	16.4
11/16/2017 5:30 AM	15.2
11/16/2017 6:00 AM	16.7
11/16/2017 6:30 AM	19.2
11/16/2017 7:30 AM	17.5
11/16/2017 8:00 AM	18.9
11/16/2017 8:30 AM	20.9
11/16/2017 9:30 AM	26.8
11/16/2017 10:00 AM	21.6
11/16/2017 10:30 AM	20.1
11/16/2017 11:30 AM	24
11/16/2017 12:00 PM	22.8
11/16/2017 12:30 PM	27.2
11/16/2017 1:00 PM	30.1
11/16/2017 1:30 PM	27.9
11/16/2017 2:00 PM	25.1
11/16/2017 2:30 PM	21.4
11/16/2017 3:00 PM	25.5
11/16/2017 3:30 PM	29.5
11/16/2017 5:00 PM	30.2
11/16/2017 5:30 PM	31.6
11/16/2017 7:30 PM	31.7
11/16/2017 9:00 PM	34.9
11/16/2017 9:30 PM	32.5
11/16/2017 10:30 PM	34.2
11/16/2017 11:00 PM	25.7
11/17/2017 12:00 AM	22.6
11/17/2017 12:30 AM	19.9
11/17/2017 1:00 AM	19.3
11/17/2017 1:30 AM	19.3
11/17/2017 2:00 AM	18.3
11/17/2017 2:30 AM	17
11/17/2017 3:00 AM	17.5
11/17/2017 3:30 AM	18.2
11/17/2017 4:00 AM	19.7
11/17/2017 6:00 AM	15.2
11/17/2017 6:30 AM	15.6
11/17/2017 7:30 AM	19.5
11/17/2017 9:00 AM	25.3

11/17/2017 9:30 AM	26.3
11/17/2017 10:30 AM	30.1
11/17/2017 11:00 AM	31.3
11/17/2017 2:30 PM	32.4
11/17/2017 3:30 PM	30.2
11/17/2017 4:30 PM	30.8
11/17/2017 5:30 PM	31.8
11/17/2017 6:00 PM	32.8
11/17/2017 6:30 PM	32.8
11/17/2017 7:00 PM	35.8
11/17/2017 9:00 PM	33.8
11/17/2017 9:30 PM	33
11/17/2017 10:00 PM	31.6
11/17/2017 10:30 PM	39.5
11/17/2017 11:00 PM	36.4
11/17/2017 11:30 PM	29.6
11/18/2017 12:30 AM	25.2
11/18/2017 1:00 AM	19.8
11/18/2017 1:30 AM	19.8
11/18/2017 2:00 AM	18.1
11/18/2017 2:30 AM	17.5
11/18/2017 3:00 AM	18.8
11/18/2017 3:30 AM	17.8
11/18/2017 4:00 AM	17.8
11/18/2017 4:30 AM	16.6
11/18/2017 5:30 AM	14.5
11/18/2017 6:30 AM	21.3
11/18/2017 7:30 AM	23.9
11/18/2017 8:00 AM	31.3

ii. Feeder CX6:

Table B-2: CR6 feeder

Date	Maximum Demand(KW)
11/14/2017 12:00 PM	5.4
11/14/2017 2:30 PM	3
11/14/2017 3:30 PM	11
11/14/2017 4:00 PM	10.4
11/14/2017 4:30 PM	3

11/14/2017 5:30 PM	3.6
11/14/2017 6:00 PM	3.6
11/14/2017 6:30 PM	3.5
11/14/2017 9:00 PM	1.9
11/14/2017 9:30 PM	2.1
11/14/2017 10:00 PM	2.5
11/14/2017 10:30 PM	1.7
11/14/2017 11:00 PM	1.7
11/15/2017 12:30 AM	1.8
11/15/2017 1:30 AM	1.7
11/15/2017 2:00 AM	1.7
11/15/2017 2:30 AM	1.7
11/15/2017 3:00 AM	1.6
11/15/2017 3:30 AM	1.6
11/15/2017 4:00 AM	2
11/15/2017 4:30 AM	1.7
11/15/2017 5:30 AM	2.2
11/15/2017 6:30 AM	2.3
11/15/2017 7:00 AM	5.4
11/15/2017 7:30 AM	4.4
11/15/2017 8:30 AM	3.4
11/15/2017 9:00 AM	1.2
11/15/2017 9:30 AM	1.5
11/15/2017 10:30 AM	6.2
11/15/2017 11:30 AM	6.8
11/15/2017 12:00 PM	7.3
11/15/2017 12:30 PM	6.1
11/15/2017 1:00 PM	8.4
11/15/2017 2:00 PM	2.2
11/15/2017 3:30 PM	7.2
11/15/2017 4:00 PM	9.5
11/15/2017 4:30 PM	6.7
11/15/2017 5:00 PM	7.5
11/15/2017 5:30 PM	7.2
11/15/2017 6:30 PM	6.8
11/15/2017 7:30 PM	2.1
11/15/2017 9:00 PM	1.9
11/15/2017 9:30 PM	1.8
11/15/2017 10:00 PM	1.7
11/15/2017 10:30 PM	1.6
11/15/2017 11:30 PM	1.7

11/16/2017 12:00 AM	1.5
11/16/2017 12:30 AM	1.6
11/16/2017 1:00 AM	1.6
11/16/2017 1:30 AM	1.6
11/16/2017 2:00 AM	1.5
11/16/2017 2:30 AM	1.6
11/16/2017 3:00 AM	1.6
11/16/2017 3:30 AM	1.6
11/16/2017 4:00 AM	1.6
11/16/2017 4:30 AM	1.6
11/16/2017 5:00 AM	1.6
11/16/2017 5:30 AM	1.7
11/16/2017 6:00 AM	1.8
11/16/2017 6:30 AM	2
11/16/2017 7:30 AM	3.5
11/16/2017 8:00 AM	7.4
11/16/2017 8:30 AM	6.2
11/16/2017 9:30 AM	0.7
11/16/2017 10:00 AM	3.2
11/16/2017 10:30 AM	5.8
11/16/2017 11:30 AM	5.6
11/16/2017 12:00 PM	6.3
11/16/2017 1:00 PM	6.9
11/16/2017 1:30 PM	4
11/16/2017 2:00 PM	3.2
11/16/2017 2:30 PM	4.8
11/16/2017 3:00 PM	7.3
11/16/2017 3:30 PM	3.8
11/16/2017 4:30 PM	2.8
11/16/2017 5:00 PM	3.5
11/16/2017 5:30 PM	3.5
11/16/2017 7:00 PM	3.8
11/16/2017 7:30 PM	3.4
11/16/2017 9:30 PM	2.4
11/16/2017 10:30 PM	2.4
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11/17/2017 12:30 AM	2.2
11/17/2017 1:00 AM	2.4
11/17/2017 1:30 AM	2.4
11/17/2017 2:00 AM	2.4

11/17/2017 2:30 AM	2.4
11/17/2017 3:00 AM	2.4
11/17/2017 3:30 AM	2.3
11/17/2017 4:00 AM	2.3
11/17/2017 5:00 AM	2.4
11/17/2017 6:30 AM	2.2
11/17/2017 7:30 AM	1.7
11/17/2017 8:00 AM	5.3
11/17/2017 9:00 AM	8.8
11/17/2017 9:30 AM	11.4
11/17/2017 10:30 AM	16
11/17/2017 11:00 AM	17.1
11/17/2017 12:00 PM	17.1
11/17/2017 12:30 PM	16.6
11/17/2017 2:30 PM	10.5
11/17/2017 3:30 PM	4.3
11/17/2017 4:00 PM	1.4
11/17/2017 4:30 PM	2.1
11/17/2017 5:30 PM	3.3
11/17/2017 6:00 PM	3.3
11/17/2017 6:30 PM	3.3
11/17/2017 7:00 PM	3.4
11/17/2017 7:30 PM	3.6
11/17/2017 9:00 PM	2.6
11/17/2017 9:30 PM	2.4
11/17/2017 10:30 PM	2.4
11/17/2017 11:00 PM	2.3
11/17/2017 11:30 PM	2.3
11/18/2017 12:30 AM	2.3
11/18/2017 1:00 AM	2.2
11/18/2017 1:30 AM	2.2
11/18/2017 2:00 AM	2.5
11/18/2017 2:30 AM	2.2
11/18/2017 3:00 AM	2.4
11/18/2017 3:30 AM	2.4
11/18/2017 4:00 AM	2.2
11/18/2017 4:30 AM	2.4
11/18/2017 5:00 AM	2.4
11/18/2017 5:30 AM	2.3
11/18/2017 6:00 AM	2.5
11/18/2017 6:30 AM	2.5

11/18/2017 7:00 AM	5.2
11/18/2017 7:30 AM	6.9
11/18/2017 8:00 AM	6.9
11/18/2017 9:00 AM	3.2

iii. Load of PV station (Bidirectional meter):

Table B-3: Load of PV station.

Date	Maximum Demand(KW)
11/14/2017 2:30 PM	3.04
11/14/2017 3:00 PM	5.77
11/14/2017 3:30 PM	10.95
11/14/2017 6:00 PM	3.59
11/14/2017 7:30 PM	2.12
11/14/2017 9:00 PM	1.91
11/14/2017 9:30 PM	2.145
11/14/2017 10:00 PM	2.51
11/14/2017 10:30 PM	1.735
11/14/2017 11:00 PM	1.745
11/14/2017 11:30 PM	1.68
11/15/2017 12:00 AM	1.545
11/15/2017 12:30 AM	1.845
11/15/2017 1:30 AM	1.275
11/15/2017 2:30 AM	1.68
11/15/2017 3:00 AM	1.605
11/15/2017 3:30 AM	1.63
11/15/2017 4:00 AM	1.965
11/15/2017 4:30 AM	1.685
11/15/2017 5:00 AM	1.665
11/15/2017 5:30 AM	2.24
11/15/2017 6:00 AM	1.805
11/15/2017 6:30 AM	2.29
11/15/2017 7:00 AM	5.36
11/15/2017 8:00 AM	5.765
11/15/2017 8:30 AM	3.305
11/15/2017 10:00 AM	4.345

11/15/2017 11:00 AM	6.21
11/15/2017 11:30 AM	6.895
11/15/2017 12:30 PM	6.13
11/15/2017 1:00 PM	8.495
11/15/2017 2:00 PM	2.285
11/15/2017 2:30 PM	0.79
11/15/2017 3:30 PM	7.095
11/15/2017 4:30 PM	6.685
11/15/2017 5:00 PM	7.48
11/15/2017 6:00 PM	6.82
11/15/2017 7:00 PM	6.57
11/15/2017 7:30 PM	2.15
11/15/2017 9:00 PM	1.885
11/15/2017 9:30 PM	1.86
11/15/2017 10:00 PM	1.755
11/15/2017 10:30 PM	1.565
11/15/2017 11:00 PM	1.505
11/15/2017 11:30 PM	1.75
11/16/2017 12:00 AM	1.485
11/16/2017 12:30 AM	1.555
11/16/2017 1:00 AM	1.685
11/16/2017 2:00 AM	1.52
11/16/2017 2:30 AM	1.665
11/16/2017 3:00 AM	1.57
11/16/2017 3:30 AM	1.595
11/16/2017 4:00 AM	1.58
11/16/2017 4:30 AM	1.61
11/16/2017 5:00 AM	1.58
11/16/2017 5:30 AM	1.715
11/16/2017 6:00 AM	1.765
11/16/2017 6:30 AM	2.04
11/16/2017 7:30 AM	3.43
11/16/2017 8:00 AM	7.325
11/16/2017 9:00 AM	3.72
11/16/2017 9:30 AM	1.165
11/16/2017 10:00 AM	3.285
11/16/2017 10:30 AM	5.83
11/16/2017 11:30 AM	5.64
11/16/2017 12:00 PM	6.4
11/16/2017 1:30 PM	4.035
11/16/2017 2:00 PM	3.29

11/16/2017 2:30 PM	4.89
11/16/2017 3:00 PM	7.345
11/16/2017 3:30 PM	3.88
11/16/2017 5:00 PM	3.495
11/16/2017 5:30 PM	3.55
11/16/2017 7:30 PM	3.47
11/16/2017 9:00 PM	2.505
11/16/2017 9:30 PM	2.37
11/16/2017 10:00 PM	2.335
11/16/2017 10:30 PM	2.34
11/16/2017 11:00 PM	2.2
11/17/2017 12:00 AM	2.605
11/17/2017 12:30 AM	2.24
11/17/2017 1:00 AM	2.4
11/17/2017 1:30 AM	2.035
11/17/2017 2:00 AM	2.435
11/17/2017 2:30 AM	2.38
11/17/2017 3:00 AM	2.44
11/17/2017 3:30 AM	2.295
11/17/2017 4:00 AM	2.345
11/17/2017 4:30 AM	2.67
11/17/2017 6:00 AM	2.45
11/17/2017 6:30 AM	2.2
11/17/2017 7:30 AM	1.79
11/17/2017 9:00 AM	8.865
11/17/2017 9:30 AM	11.445
11/17/2017 10:30 AM	16.085
11/17/2017 11:00 AM	17.145
11/17/2017 2:30 PM	10.5
11/17/2017 3:30 PM	4.34
11/17/2017 5:00 PM	3.2
11/17/2017 6:00 PM	3.285
11/17/2017 6:30 PM	3.32
11/17/2017 7:00 PM	3.37
11/17/2017 7:30 PM	3.625
11/17/2017 9:00 PM	2.59
11/17/2017 9:30 PM	2.47
11/17/2017 10:00 PM	2.515
11/17/2017 10:30 PM	2.425
11/17/2017 11:00 PM	2.295
11/17/2017 11:30 PM	2.315

11/18/2017 12:30 AM	2.29
11/18/2017 1:00 AM	2.25
11/18/2017 1:30 AM	1.975
11/18/2017 2:00 AM	2.51
11/18/2017 2:30 AM	2.26
11/18/2017 3:00 AM	2.45
11/18/2017 3:30 AM	2.355
11/18/2017 4:00 AM	2.235
11/18/2017 4:30 AM	2.455
11/18/2017 5:00 AM	2.335
11/18/2017 6:00 AM	2.52
11/18/2017 6:30 AM	2.48
11/18/2017 7:30 AM	6.91
11/18/2017 8:00 AM	6.87
11/18/2017 9:00 AM	3.195

iv. PV station generation meter:

Table B-4: PV generation meter.

Date	Maximum Generation(KW)
11/14/2017 12:00 PM	19.81
11/14/2017 2:15 PM	11.69
11/14/2017 2:30 PM	11.7
11/14/2017 2:45 PM	10.76
11/14/2017 3:15 PM	3.59
11/14/2017 3:30 PM	2.3
11/14/2017 3:45 PM	2.3
11/14/2017 4:15 PM	0.78
11/14/2017 4:45 PM	0.28
11/14/2017 5:15 PM	0
11/14/2017 6:00 PM	0
11/14/2017 6:15 PM	0
11/14/2017 6:45 PM	0
11/14/2017 7:15 PM	0
11/14/2017 7:30 PM	0.01
11/14/2017 9:00 PM	0
11/14/2017 9:15 PM	0
11/14/2017 9:30 PM	0.01
11/15/2017 1:15 AM	0

11/15/2017 1:30 AM	0
11/15/2017 1:45 AM	0
11/15/2017 2:15 AM	0
11/15/2017 2:30 AM	0
11/15/2017 2:45 AM	0
11/15/2017 3:00 AM	0.01
11/15/2017 3:15 AM	0
11/15/2017 3:30 AM	0
11/15/2017 3:45 AM	0
11/15/2017 4:00 AM	0.01
11/15/2017 4:15 AM	0
11/15/2017 4:30 AM	0
11/15/2017 4:45 AM	0.01
11/15/2017 5:00 AM	0
11/15/2017 5:15 AM	0
11/15/2017 5:30 AM	0
11/15/2017 5:45 AM	0.01
11/15/2017 6:00 AM	0
11/15/2017 6:15 AM	0.01
11/15/2017 6:30 AM	0.27
11/15/2017 6:45 AM	0.97
11/15/2017 7:00 AM	1.99
11/15/2017 7:15 AM	3.59
11/15/2017 7:30 AM	5.22
11/15/2017 8:00 AM	8.25
11/15/2017 8:15 AM	9.58
11/15/2017 8:30 AM	10.64
11/15/2017 8:45 AM	11.65
11/15/2017 9:15 AM	14.14
11/15/2017 9:30 AM	15.04
11/15/2017 9:45 AM	16.37
11/15/2017 10:00 AM	18.18
11/15/2017 10:15 AM	19.34
11/15/2017 10:45 AM	19.98
11/15/2017 11:00 AM	20.19
11/15/2017 11:15 AM	20.34
11/15/2017 11:30 AM	20.59
11/15/2017 11:45 AM	21.04
11/15/2017 12:15 PM	20.81
11/15/2017 12:30 PM	20.49
11/15/2017 12:45 PM	19.97

11/15/2017 1:00 PM	19.33
11/15/2017 1:15 PM	18.73
11/15/2017 1:45 PM	17.13
11/15/2017 2:00 PM	15.87
11/15/2017 2:15 PM	14.49
11/15/2017 2:30 PM	13.17
11/15/2017 2:45 PM	11.49
11/15/2017 3:15 PM	7.36
11/15/2017 3:30 PM	5.88
11/15/2017 3:45 PM	4.39
11/15/2017 4:15 PM	1.42
11/15/2017 4:30 PM	0.34
11/15/2017 4:45 PM	0.28
11/15/2017 5:00 PM	0.3
11/15/2017 5:15 PM	0.03
11/15/2017 5:30 PM	0
11/15/2017 5:45 PM	0
11/15/2017 6:00 PM	0.01
11/15/2017 6:15 PM	0
11/15/2017 6:45 PM	0
11/15/2017 7:00 PM	0.01
11/15/2017 7:15 PM	0
11/15/2017 7:30 PM	0
11/15/2017 9:00 PM	0.01
11/15/2017 10:00 PM	0.01
11/15/2017 11:45 PM	0.01
11/16/2017 12:00 AM	0
11/16/2017 12:15 AM	0
11/16/2017 12:30 AM	0
11/16/2017 12:45 AM	0.01
11/16/2017 1:00 AM	0
11/16/2017 1:15 AM	0
11/16/2017 2:00 AM	0
11/16/2017 2:15 AM	0
11/16/2017 2:30 AM	0.01
11/16/2017 2:45 AM	0
11/16/2017 3:15 AM	0
11/16/2017 3:30 AM	0.01
11/16/2017 4:00 AM	0
11/16/2017 4:15 AM	0
11/16/2017 4:30 AM	0.01

11/16/2017 4:45 AM	0
11/16/2017 5:00 AM	0
11/16/2017 5:15 AM	0.01
11/16/2017 5:30 AM	0
11/16/2017 5:45 AM	0
11/16/2017 6:00 AM	0
11/16/2017 6:15 AM	0.04
11/16/2017 6:30 AM	0.22
11/16/2017 6:45 AM	1.2
11/16/2017 7:15 AM	4.13
11/16/2017 7:30 AM	6.2
11/16/2017 7:45 AM	5.46
11/16/2017 8:00 AM	7.41
11/16/2017 8:15 AM	8.47
11/16/2017 8:30 AM	10.27
11/16/2017 9:15 AM	13.66
11/16/2017 9:30 AM	14.55
11/16/2017 9:45 AM	16.78
11/16/2017 10:00 AM	18.1
11/16/2017 10:15 AM	19.22
11/16/2017 10:30 AM	19.81
11/16/2017 10:45 AM	19.99
11/16/2017 11:15 AM	20.56
11/16/2017 11:30 AM	20.54
11/16/2017 11:45 AM	20.66
11/16/2017 12:00 PM	21.1
11/16/2017 12:15 PM	20.47
11/16/2017 12:30 PM	13.34
11/16/2017 12:45 PM	18.46
11/16/2017 1:00 PM	18.63
11/16/2017 1:15 PM	17.29
11/16/2017 1:30 PM	18.35
11/16/2017 2:00 PM	12.23
11/16/2017 2:15 PM	15.09
11/16/2017 2:30 PM	14.02
11/16/2017 2:45 PM	11.93
11/16/2017 3:00 PM	9.58
11/16/2017 3:15 PM	8.07
11/16/2017 3:30 PM	6.46
11/16/2017 3:45 PM	4.99
11/16/2017 4:15 PM	1.52

11/16/2017 4:45 PM	0.25
11/16/2017 5:00 PM	0.26
11/16/2017 5:15 PM	0.04
11/16/2017 5:30 PM	0
11/16/2017 5:45 PM	0.01
11/16/2017 6:15 PM	0
11/16/2017 6:45 PM	0.01
11/16/2017 7:15 PM	0
11/16/2017 7:30 PM	0
11/16/2017 9:00 PM	0
11/16/2017 9:15 PM	0
11/16/2017 9:30 PM	0.01
11/16/2017 9:45 PM	0
11/16/2017 10:00 PM	0
11/16/2017 10:15 PM	0
11/16/2017 10:30 PM	0.01
11/16/2017 10:45 PM	0
11/16/2017 11:00 PM	0
11/16/2017 11:15 PM	0.01
11/17/2017 12:00 AM	0
11/17/2017 12:15 AM	0.01
11/17/2017 12:30 AM	0
11/17/2017 12:45 AM	0
11/17/2017 1:00 AM	0
11/17/2017 1:15 AM	0
11/17/2017 1:30 AM	0
11/17/2017 1:45 AM	0
11/17/2017 2:00 AM	0.01
11/17/2017 3:45 AM	0.01
11/17/2017 4:00 AM	0
11/17/2017 4:15 AM	0
11/17/2017 4:45 AM	0.01
11/17/2017 5:00 AM	0
11/17/2017 5:15 AM	0
11/17/2017 6:00 AM	0
11/17/2017 6:15 AM	0
11/17/2017 6:30 AM	0.15
11/17/2017 6:45 AM	0.53
11/17/2017 7:15 AM	2.39
11/17/2017 7:30 AM	5.23
11/17/2017 7:45 AM	6.91

11/17/2017 8:15 AM	9.97
11/17/2017 8:45 AM	11.94
11/17/2017 9:00 AM	13.11
11/17/2017 9:15 AM	13.87
11/17/2017 9:30 AM	14.89
11/17/2017 9:45 AM	17.02
11/17/2017 10:15 AM	19.22
11/17/2017 10:30 AM	19.4
11/17/2017 10:45 AM	20.07
11/17/2017 11:00 AM	20.19
11/17/2017 11:15 AM	20.45
11/17/2017 11:45 AM	20.51
11/17/2017 12:15 PM	19.57
11/17/2017 12:45 PM	19.42
11/17/2017 1:15 PM	18.02
11/17/2017 1:45 PM	16.44
11/17/2017 2:15 PM	14.31
11/17/2017 2:30 PM	12.91
11/17/2017 2:45 PM	10.97
11/17/2017 3:15 PM	7.37
11/17/2017 3:30 PM	6.1
11/17/2017 3:45 PM	4.56
11/17/2017 4:15 PM	1.37
11/17/2017 4:45 PM	0.27
11/17/2017 5:00 PM	0.23
11/17/2017 5:30 PM	0.01
11/17/2017 5:45 PM	0
11/17/2017 6:00 PM	0
11/17/2017 6:15 PM	0
11/17/2017 6:30 PM	0.01
11/17/2017 6:45 PM	0
11/17/2017 7:00 PM	0
11/17/2017 7:15 PM	0
11/17/2017 9:00 PM	0
11/17/2017 9:15 PM	0.01
11/17/2017 9:30 PM	0
11/17/2017 9:45 PM	0
11/17/2017 10:00 PM	0
11/17/2017 10:15 PM	0.01
11/17/2017 10:30 PM	0
11/17/2017 11:00 PM	0.01

11/17/2017 11:15 PM	0
11/17/2017 11:30 PM	0
11/17/2017 11:45 PM	0
11/18/2017 12:15 AM	0
11/18/2017 12:30 AM	0
11/18/2017 12:45 AM	0
11/18/2017 1:00 AM	0.01
11/18/2017 1:15 AM	0
11/18/2017 1:30 AM	0
11/18/2017 1:45 AM	0.01
11/18/2017 2:00 AM	0
11/18/2017 2:15 AM	0
11/18/2017 2:30 AM	0
11/18/2017 2:45 AM	0.01
11/18/2017 3:00 AM	0
11/18/2017 3:15 AM	0
11/18/2017 3:30 AM	0.01
11/18/2017 3:45 AM	0
11/18/2017 4:00 AM	0
11/18/2017 4:15 AM	0
11/18/2017 4:30 AM	0.01
11/18/2017 6:30 AM	0.33
11/18/2017 6:45 AM	1.26
11/18/2017 7:15 AM	1.96
11/18/2017 7:30 AM	2.47
11/18/2017 7:45 AM	5.51
11/18/2017 8:00 AM	6.79
11/18/2017 8:15 AM	7.26
11/18/2017 8:45 AM	10.97
11/18/2017 9:00 AM	11.14

To calculate the maximum value of each table even demand or generation, use MATLAB, Math code, answers are:

```
Command Window

CR3 =

   44.9000


CR6 =

   17.1000


PV_Load =

   17.1450


PV_Generation =

   21.1000


Transformer_Load =

    62


Total_Load =

   83.1000

fx >>
```

Figure B-1: Maximum load and generation of feeders, MATLAB.

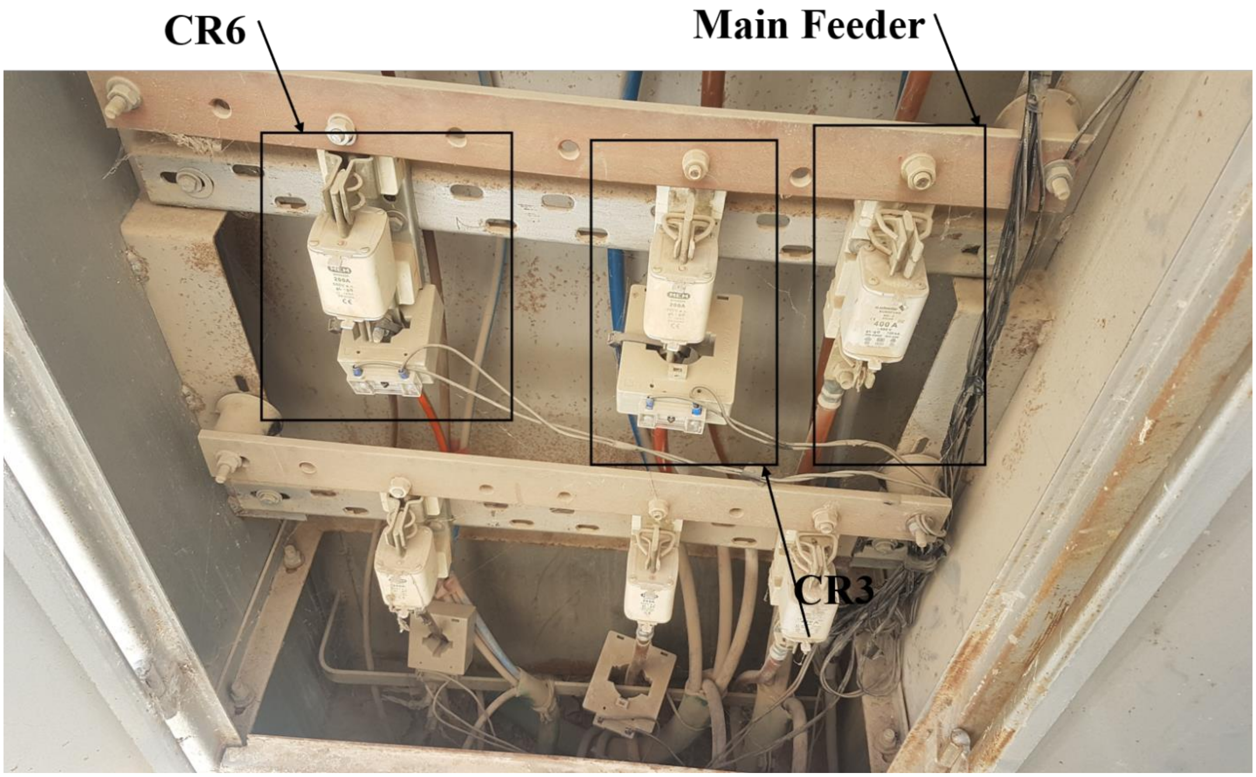

Figure B-3: Feeders of TR 3002 -13.

2) PV Station:

Configuration:

Four strings of 15 series cells are connected on the same inverter, at two different MPPT's, with rated of 20 KW, other 2 strings of 10 cells are connected in series then to one MPPT of a 13 KW inverter, the other MPPT is connected to a string that has 14 cells.

Nameplates of PV's and inverters are following:

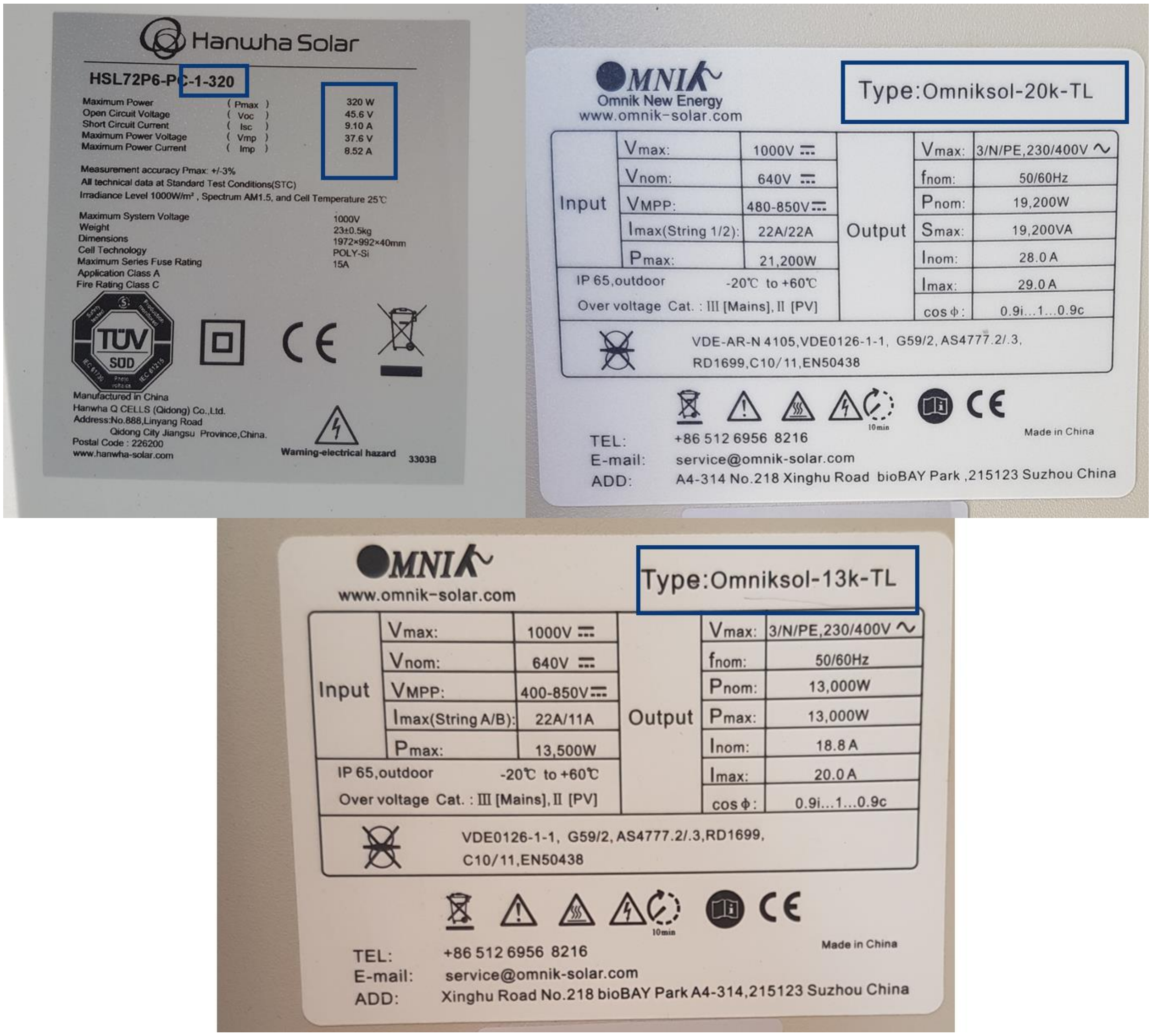

Figure B-4: Nameplates of PV and inverters.

Table B-5: PV and inverters nameplates.

Type:	Parameter
PV	Pm= 320 W, Vm= 37.6 V, Im= 8.5 A
Inverter 1	Pm = 13 KW, V =230 / 400 V with 50 HZ
Inverter2	Pm = 19.2 KW, V =230 / 400 V with 50 HZ

Figure B-5: 30 KW PV station.

B.3 Site:

AutoCAD maps are attached in the next A3 pages, they show the costumer nodes, and the pole nodes with cables and their lengths.

Cable impedances are appearing in the ETAP 16 utility, which follows the nodes pages.

Pole nodes

Costumer nodes

ETAP16 cables

B.4 Results:

Power flow: shows that, the transformer is loaded by 56.869 KW and the generation from PV station is 27.1 KW, the loads are at their maximum or rated values, sum of generation will be 84 KW which is close to the reality maximum loading, power flow network will be attached in the next A3 page.

Losses of actual load:

The reality losses are the losses of transformer and branches or cables between poles, it is in sum equals to 1630 KW which is considered as (1630/ 60 KW) * 100 = 2.71 %.

ETAP 16 simulation, gives losses in total (1.589 KW/ 56.869 KW) *100 % = 2.7 %.

Losses network is attached in the next A3 page.

ETAP16 power flow

ETAP16 losses actual load

There is a simulation results from GIS department in JDECo., results illustrate the losses during the simulation period, at this period, not all loads are at their rated, may be greater than or less than, load of transformer was 54.8 KW, and the losses were 1.58 %, as shown below:

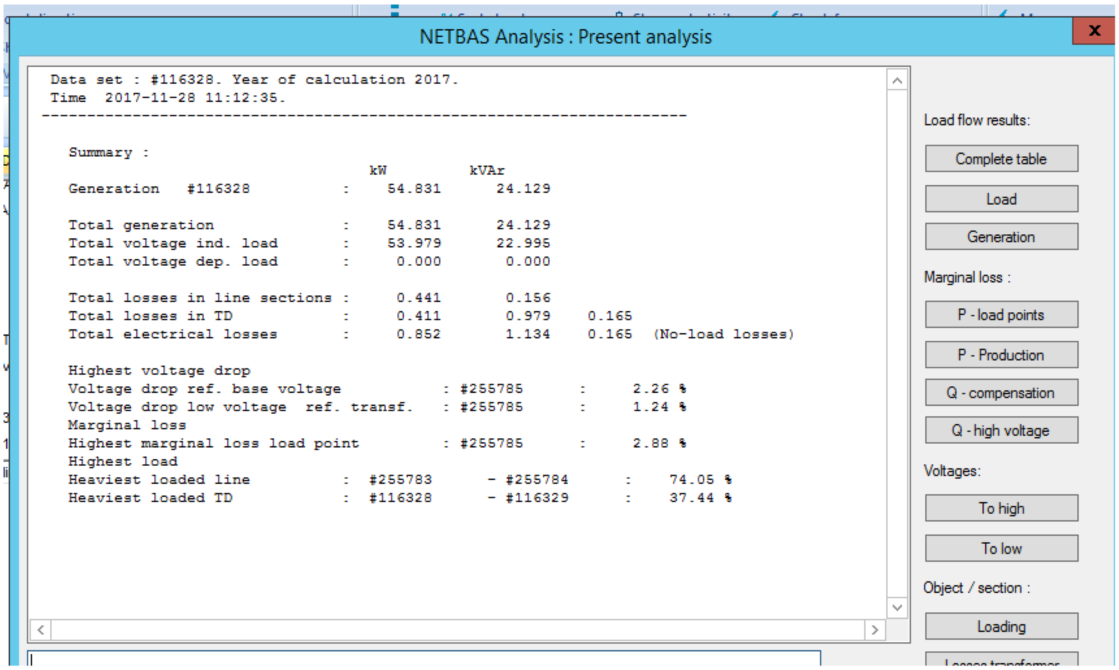

Figure B-6: Actual losses at transformer in a specific period.

Losses of scaled load:

Scaling the load in order to run the transformer at the full capacity (160 KVA) will give losses with higher value than the actual load. Load will be increased in approximately 270 % or almost 300 %, ETAP 16 flow results are:

Table B-6: ETAP 16 losses of scaled load.

Losses / Branch	**Losses in KW**
Main Transformer	2.011
Under_G2	0.006
Under_G3	0.079
Under_G1	0.007
Over Head 1	2.373
Under_G4	0.121
Over Head 2	1.787
Bundel_3	0.126
Bundel_4	0.045
Bundel_5	0.045
Under_G8	0.027
Under_G9	0.074
Under_G7	0.006
Under_G18	0.004
Bundel_2	0.008
Under_G5	0.003
Bundel_6	0.616
Under_G10	0.005
Under_G11	0.018
Under_G12	0.008
Bundel_7	0.127
Bundel_8	0.478
Under_G13	0.299
Over Head 3	0.275
Under_G14	0.005
Over Head 4	0.35
Under_G15	0.352
Under_G16	0.145
Bundel_9	0.001
Under_G17	0
Sum	**9.4**

Scaling loads by 270 % as a middle value gave 183 KW which exceeds the full capacity of the transformer, losses at this case are (9.4 K/ 183 K) * 100 = 5%.

GIS department and after scaling the load, had these results:

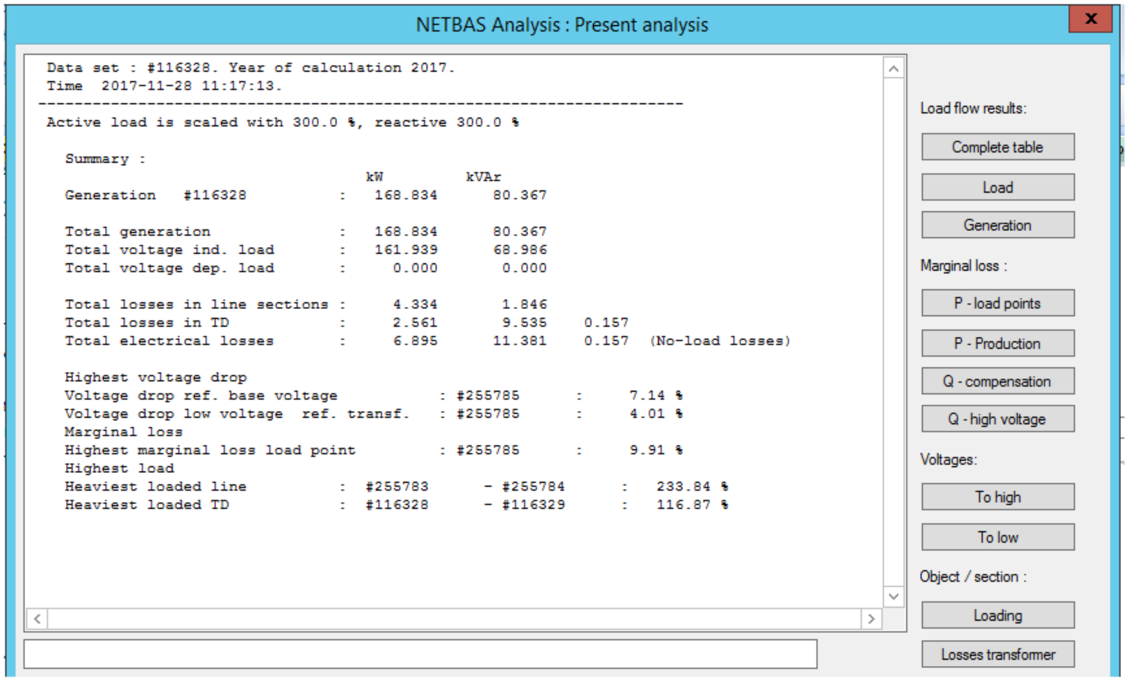

Figure B-6: Scaled load losses at transformer.

Power flow and losses of the scaled load case are following in the next A3 page.

ETAP16 power flow for scaled load

Part 2

Part 2

B.1 Monitoring system:

This model is a simple simulation for SCADA system that used to monitor and control grids remotely with a power flow by SIMULINK, MATLAB Ra2015.

B.1.1 Main parts of the grid in SIMULINK:

The grid is divided into 11 zones depending on their location, each zone is controlled by a circuit breaker, the whole system is:

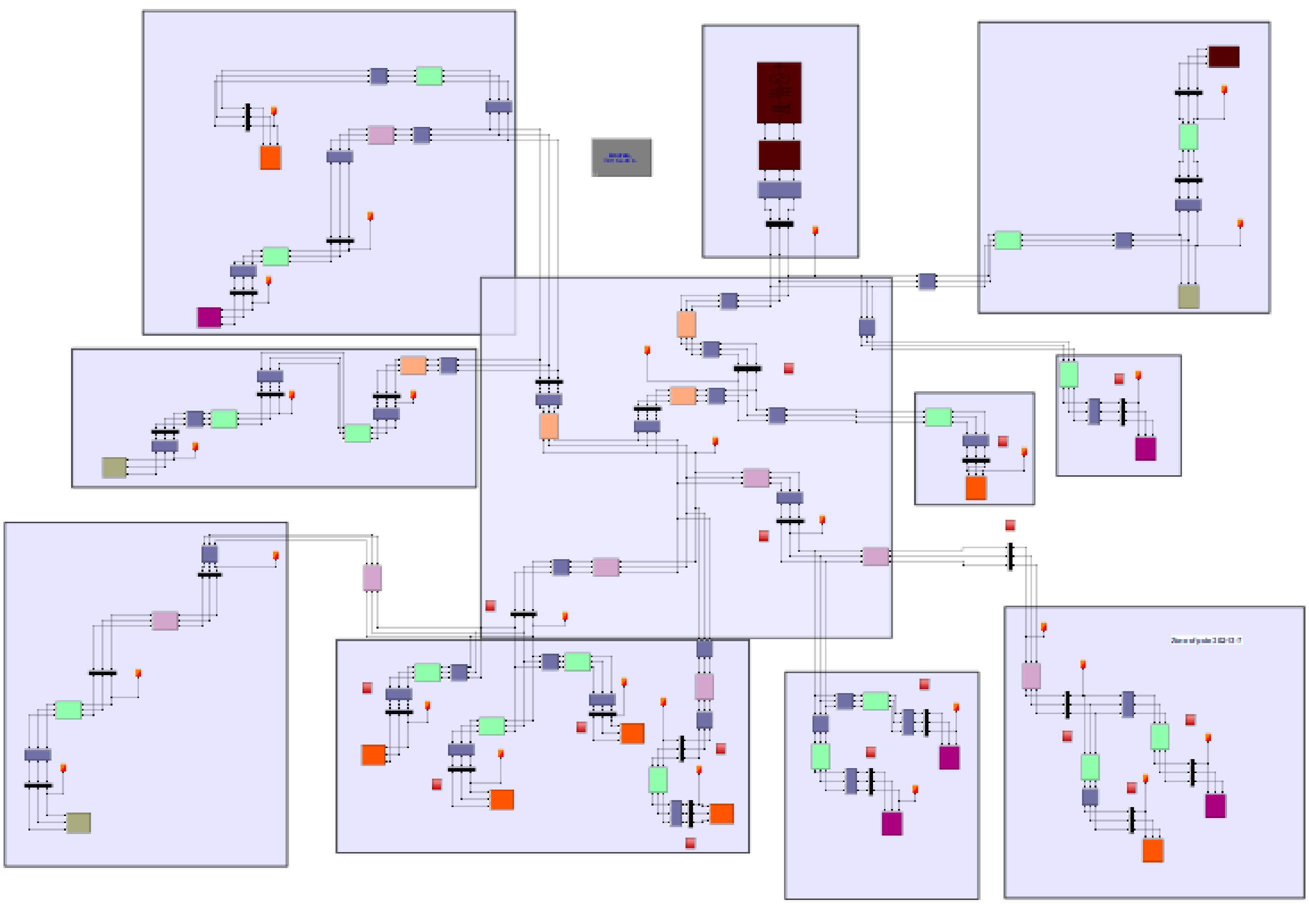

Figure B-7: Whole system design by SIMULINK.

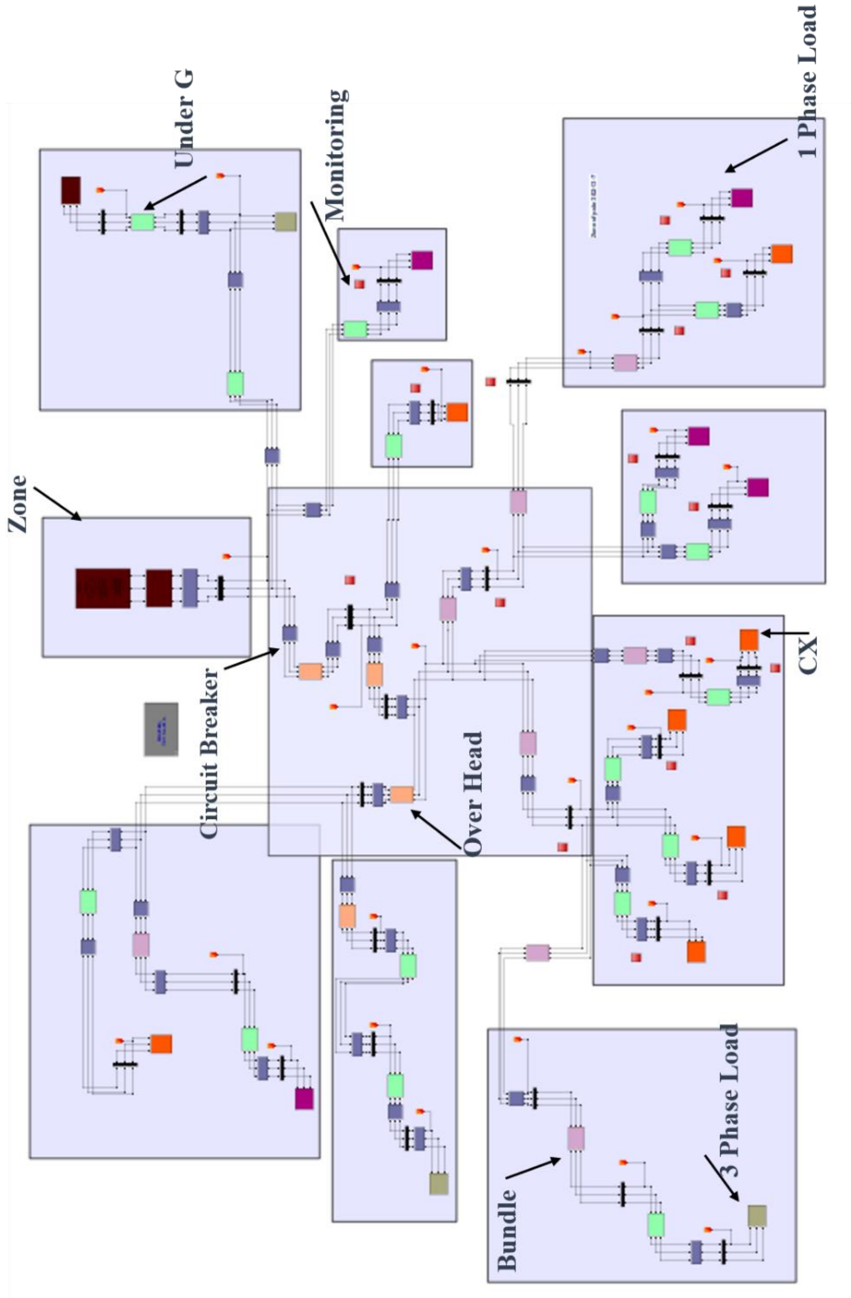

Figure B-8: System components by SIMULINK.

B.1.2 Monitoring block:

This block is designed and installed at each bus in the grid, it measures voltage of each phase, current, over voltage and under voltages percentage, real power, reactive power, apparent power, PF, THDv, THDi, and symmetrical components.

The internal design is:

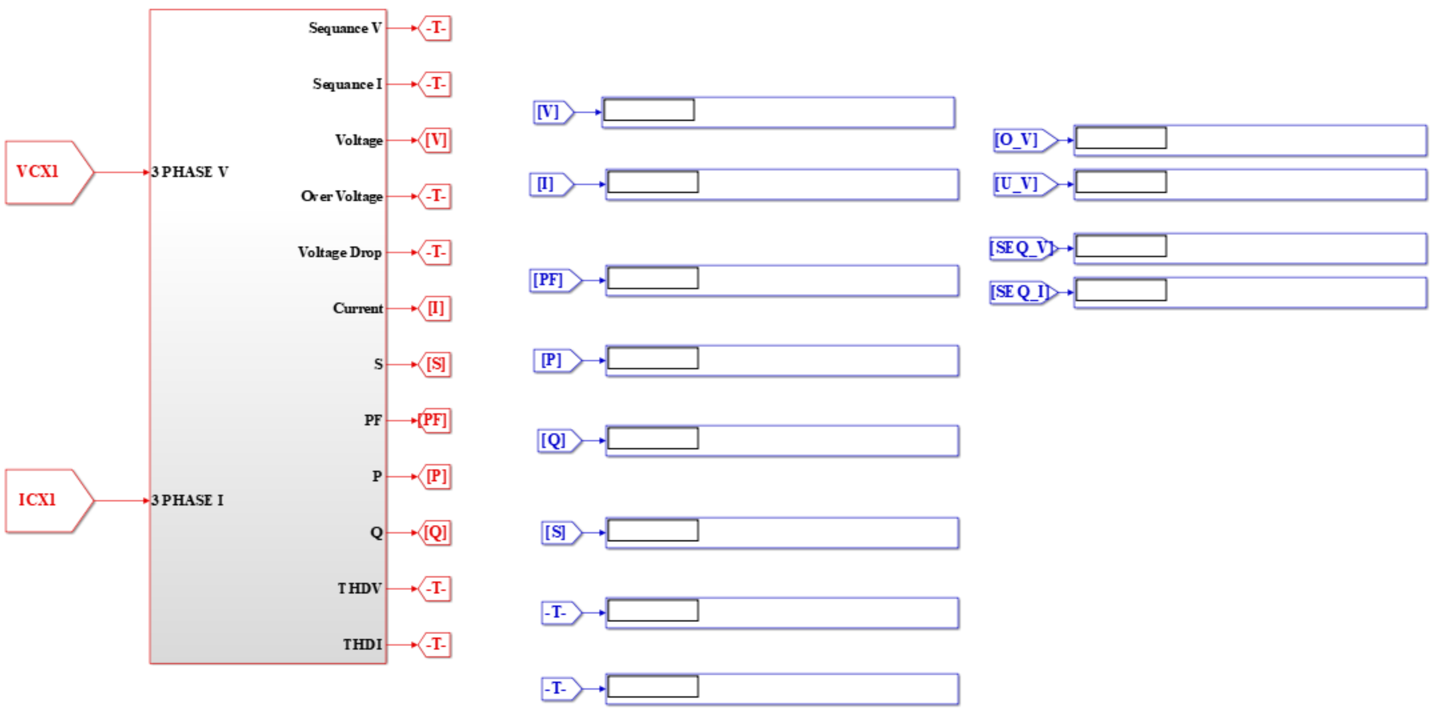

Figure B-9: Internal design of measuring block by SIMULINK.

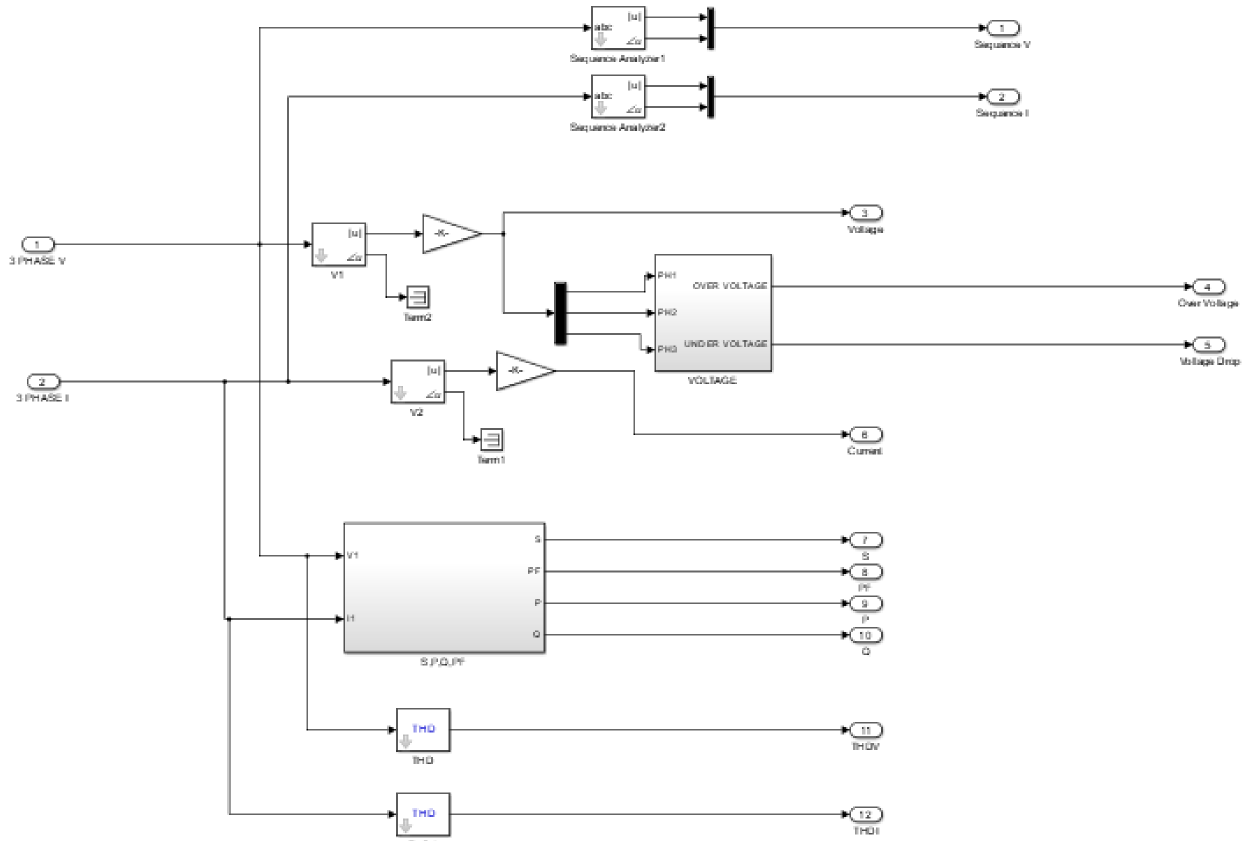

Figure B-10: Internal design of monitoring block by SIMULINK.

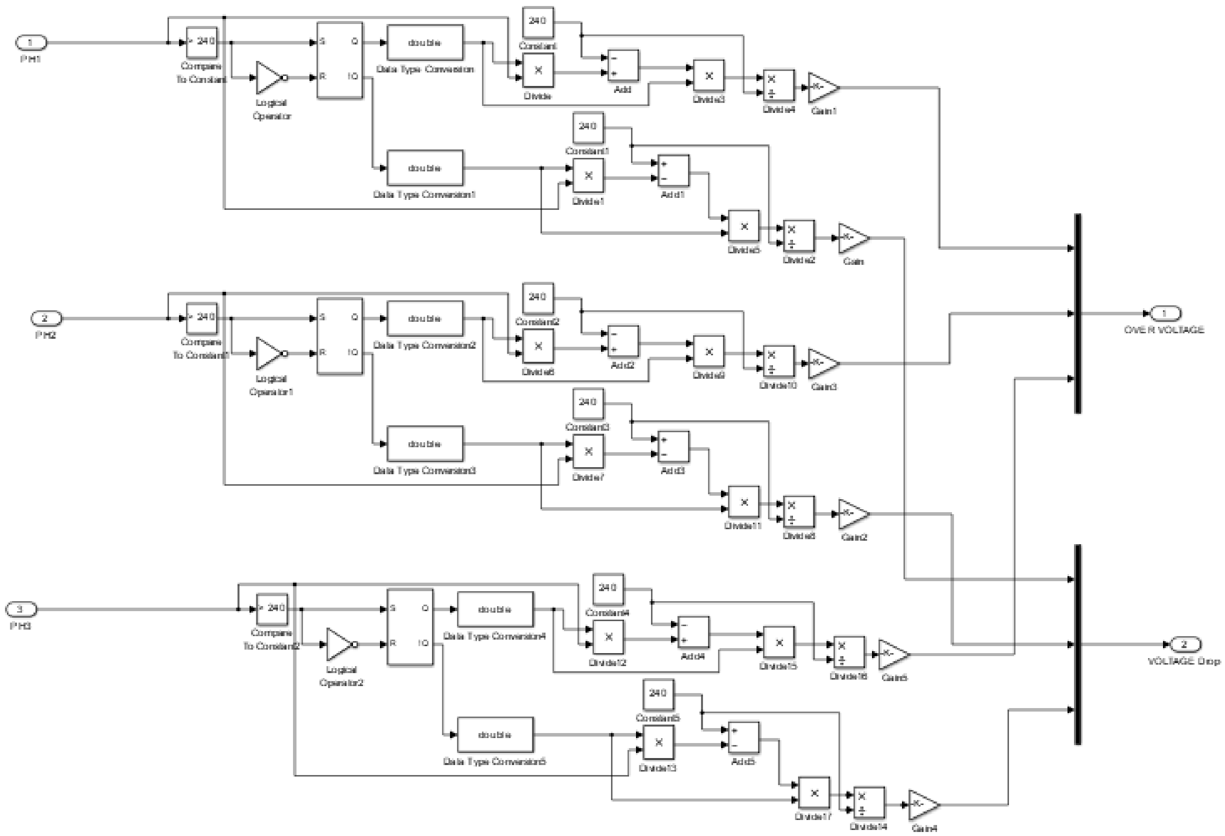

Figure B-11: Internal design of voltage block by SIMULINK.

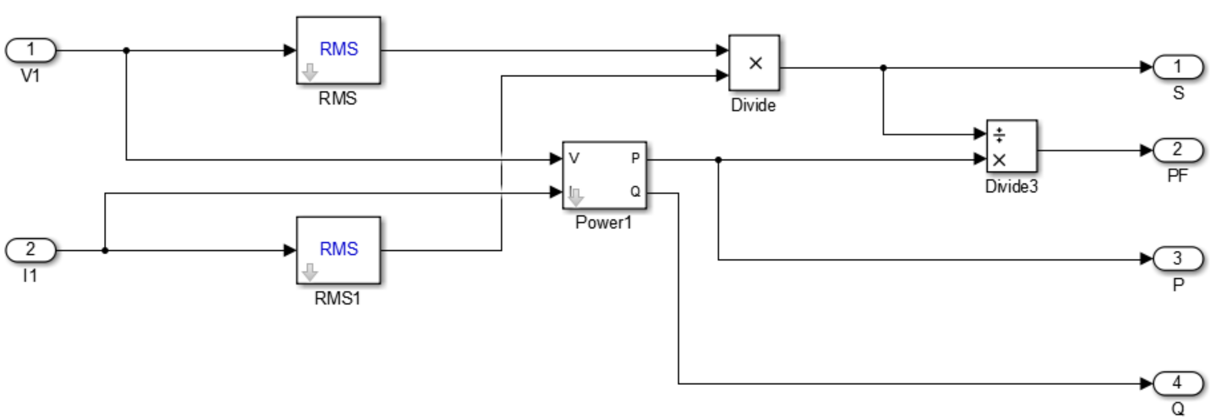

Figure B-12: Internal design of S,P,Q,PF block by SIMULINK.

End of Appendices