# DYNAMIC MODELING AND SIMULATION OF AN ISOLATED HYBRID RENEWABLE POWER SYSTEM FOR PARADISE RIVER, LABRADOR

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# Outline

- Introduction
- Literature Review
- Research Objectives
- Site Selection and Sizing
- Hybrid renewable power system (HRPS) Dynamic Modeling and Simulation
- PV-Battery Bond Graph Modeling
- Cuk-Boost converter and Controller Design and Modeling
- SCADA System Design and Implementation
- Conclusion
- Future Works
- Acknowledgment
- Publications

# Introduction

Motivations:

- Providing low-cost and reliable electricity for a remote area
- Reducing greenhouse gas emission
- In-depth modeling of HRPS components, to study their behavior at different environmental situations
- Design an efficient converter, as a main part of a HRPS, to reduce the system overall power loss
- Design and implantation a SCADA system, to monitor the system, to address any possible fault faster, and to improve the system performance by controlling it.

# Introduction

- Newfoundland and Labrador average solar energy production is 949 kWh per year
- Paradise River average solar energy production is 977 kWh per year

| Months | kWh/kW |
|---|---|
| January | 51 |
| February | 75 |
| March | 95 |
| April | 96 |
| May | 98 |
| June | 100 |
| July | 103 |
| August | 99 |
| September | 85 |
| October | 63 |
| November | 44 |
| December | 38 |
| Annual Total | 949 |

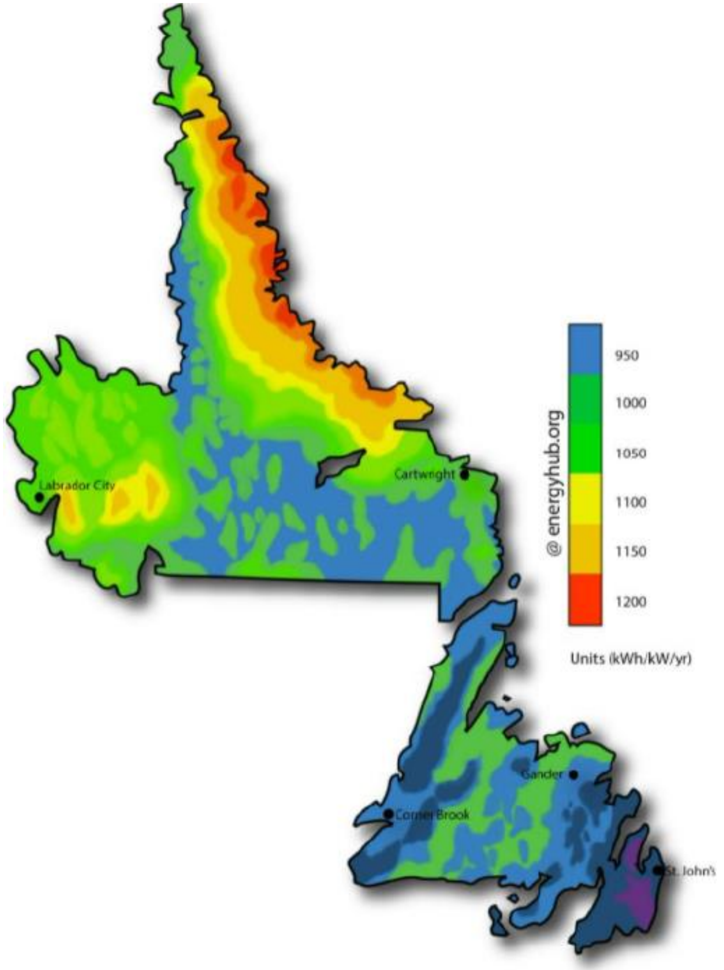


Figure 1. Newfoundland and Labrador Solar Irradiation

# Literature Review

| Reference No. | Hybrid System | Software | Site | Strategy | Approach |
|---|---|---|---|---|---|
| [1] | PV-Wind-Diesel-Battery | HOMER Pro | South of Iran | Cost of Energy | Optimizing the configuration of components |
| [2] | PV-Diesel-Battery | HOMER Pro | Bangladesh | Cost of Energy | Reducing CO2 emission for load following strategy with cyclic charging and combined dispatch |
| [3] | PV-Diesel-Battery | HOMER Pro | Sabah, Malaysia | Levelization the Cost of Energy | Increasing sustainability by utilizing Hybrid System |
| [4] | PV-Wind-Diesel-Battery | HOMER Pro | Twelve islands surrounding Tiomans islands, South China sea, Malaysia | Cost of Energy | Illustrating that total cost for hybrid system is less that diesel system |

# Research Objectives

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- To investigate Paradise River annual power consumption
- To design, size, and simulate an optimized HRPS with Homer pro
- To model the sized HRPS in MATLAB/Simulink to analyze the system's dynamic behavior
- To model essential parts the system using bond graph technique
- To design, simulate, model, and control a novel efficient DC-DC converter
- To design and implement a low cost open source SCADA system

# SITE SELECTION AND SIZING

# Site Selection and Sizing

## PARADISE RIVER COMMUNITY

- A community on the southwestern coastline of Sandwich Bay in southeastern Labrador, Canada.
- Current population is 14.

## DIESEL GENERATOR DISADVANTAGES

- Not environmentally friendly
- It is difficult to provide fuel in harsh climate
- Risking residents' lives and properties

Figure 3. Satellite Image of Paradise River Community


Figure 2. Satellite Image of Newfoundland and Labrador

## ISOLATED HYBRID RENEWABLE POWER SYSTEM

- Reduction in fuel consumption and pollution due to decrease in Diesel Generator size and Energy Storage System
- Lower electricity price as a high-available renewable power system

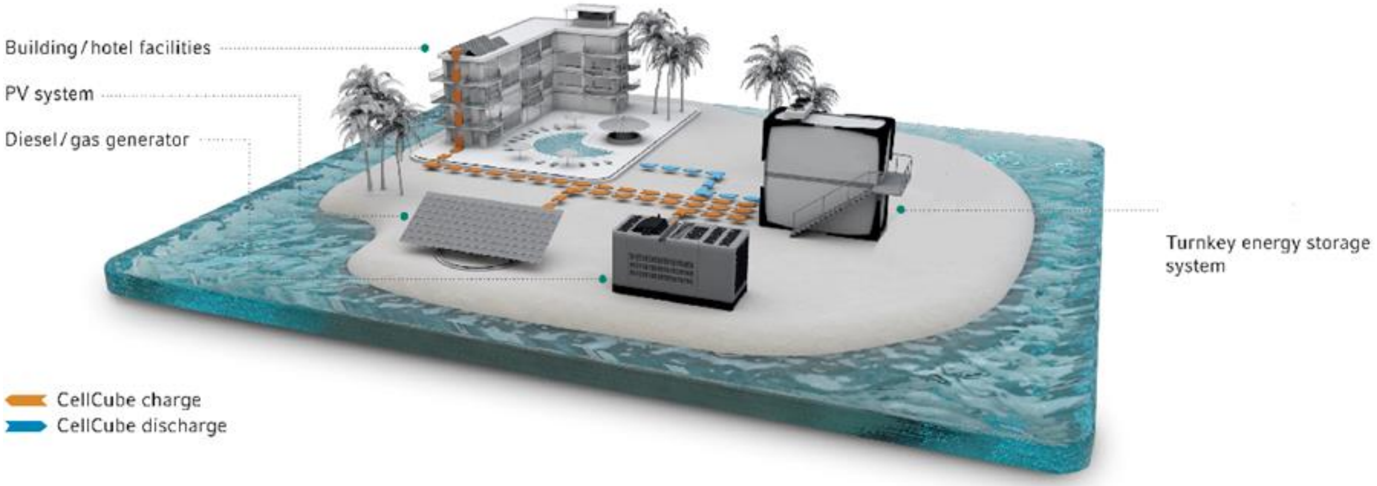


Figure 4. A Graphic of an Isolated Hybrid Power System

# Site Selection and Sizing

## POWER CONSUMPTION DATA AND WEATHER CONDITION

- The annual power consumption data(every fifteen minutes) has been obtained from Newfoundland and Labrador Hydro(Electricity Generation Company)
- Annual weather condition is achieved from Nasa Prediction of Worldwide Energy Resources.

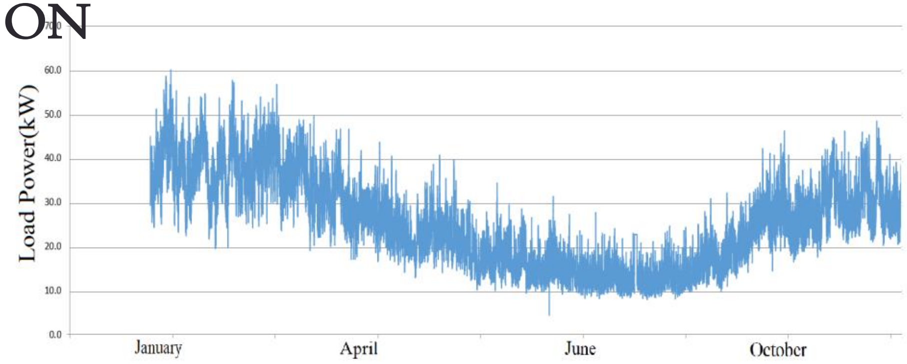


Figure 5. Paradise River Annual Power Consumption

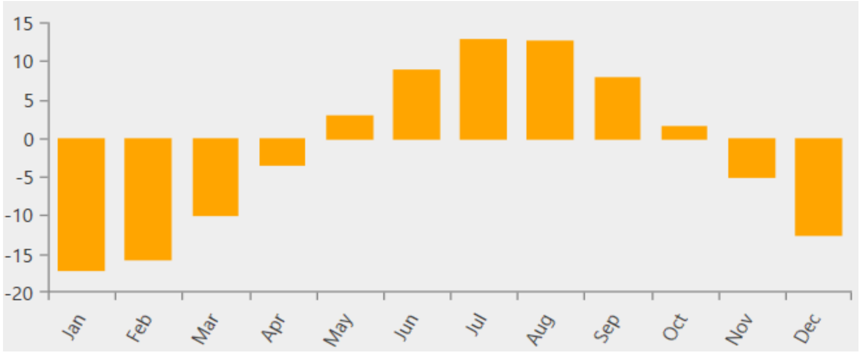


Figure 7. Monthly Average Air Temperature for Paradise River


Figure 6. Monthly Average Solar GHI for Paradise River

# Site Selection and Sizing

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## SIZING THE SYSTEM USING HOMER PRO

Based on the optimization results:

- 186kW capacity PV array
- 780 number of battery which means 13 strings with size of 60
- one diesel generator Cat 45
- one IM 66kVA TR UL inverter
- Renewable fraction is 77.6%
- Excess electricity is 32.1%

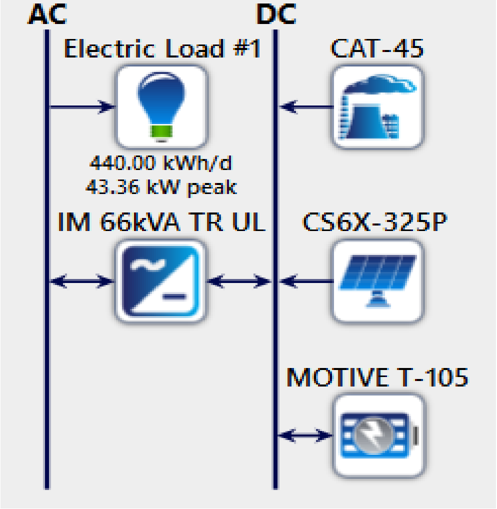


Figure 8. Schematic diagram of the system

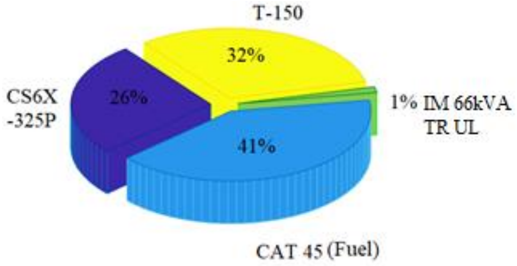


Figure 9. Cost Summary

| Architecture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CS6X-325P (kW) | CAT-45 (kW) | MOTIVE T-105 | IM 66kVA TR UL (kW) | NPC ($) | COE ($) |
| | | | | 186 | 45.0 | 780 | 27.5 | $753,420 | $0.380 |

Figure 10. Optimization results

# HRPS DYNAMIC MODELING AND SIMULATION

# HRPS Dynamic Modeling and Simulation

## DYNAMIC MODEL IN MATLAB/SIMULINK

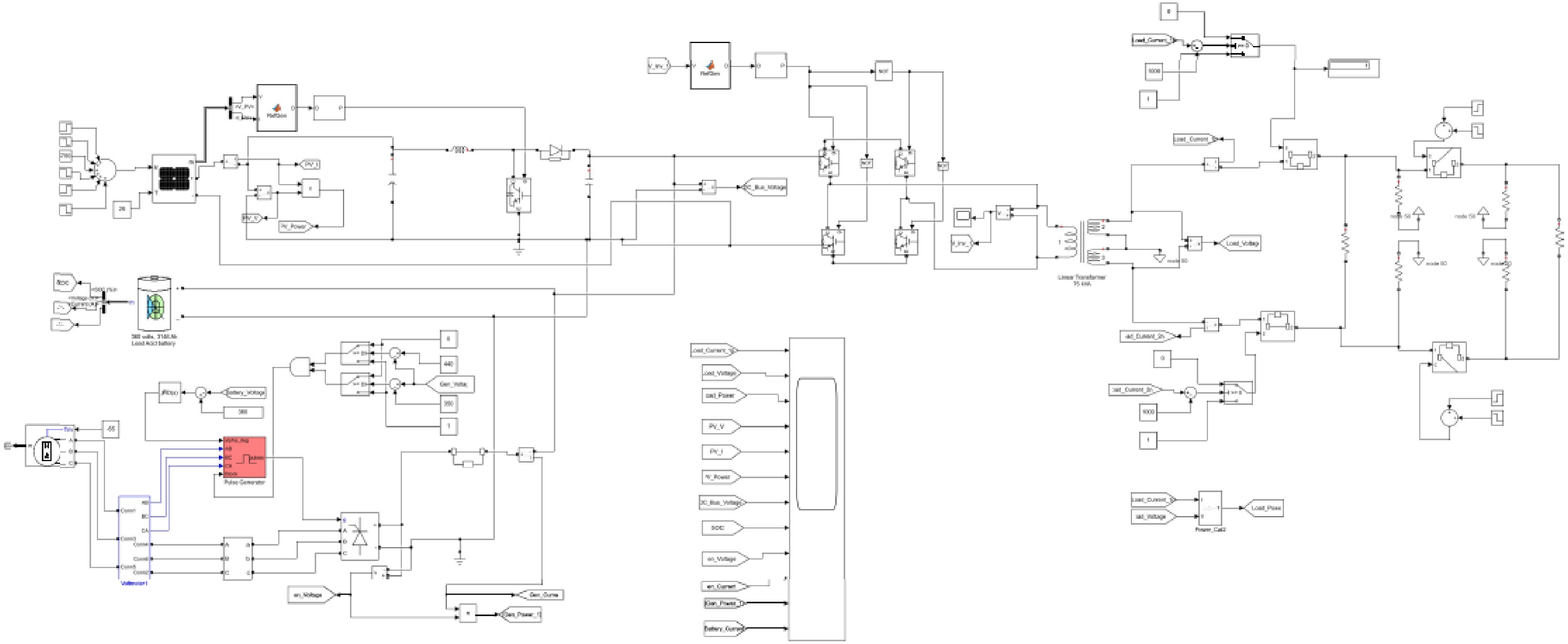

Figure 11. Dynamic Simulation Hybrid Power System in MATLAB/Simulink software

# HRPS Dynamic Modeling and Simulation

Simulation has been done under different conditions and in different scenarios. The 7 different Scenarios have been defined in 9 intervals, as follows:

Interval 1(0s – 2s): During this interval:
Solar irradiation = 700 $\frac{W}{m^2}$
PV output power = 135 kW
Load Power = 40 kW
DG Power = 0 kW

Interval 2 (2s – 4s): At this interval:
Solar irradiation = 700 $\frac{W}{m^2}$
PV output power = 135 kW
Load Power = 40 kW
DG Power = 45 kW

Interval 3 (4s -5s): During this interval:
Solar irradiation = 400 $\frac{W}{m^2}$
PV output power = 80 kW
Load Power = 40 kW
DG Power = 45 kW

- Interval 4 (5s -6s): During this interval:
- Solar irradiation = 400 $\frac{W}{m^2}$
- PV output power = 80 kW
- Load Power = 62 kW
- DG Power = 45 kW
- Interval 5 (6s -7s): At this interval:
- Solar irradiation = 100 $\frac{W}{m^2}$
- PV output power = 20 kW
- Load Power = 62 kW
- DG Power = 45 kW
- Interval 6 (7s -8s): At this interval:
- Solar irradiation = 100 $\frac{W}{m^2}$
- PV output power = 20 kW
- Load Power = 40 kW
- DG Power = 45 kW
- Interval 7 (8s -10s): Same as Interval 3.
- Interval 8 (10s -16s): Same as Interval 2.
- Interval 9 (16s -20s): During this interval:
- Solar irradiation = 0 $\frac{W}{m^2}$
- PV output power = 0 kW
- Load Power = 40 kW
- DG Power = 0 kW

# HRPS Dynamic Modeling and Simulation

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## DYNAMIC SIMULATION RESULTS

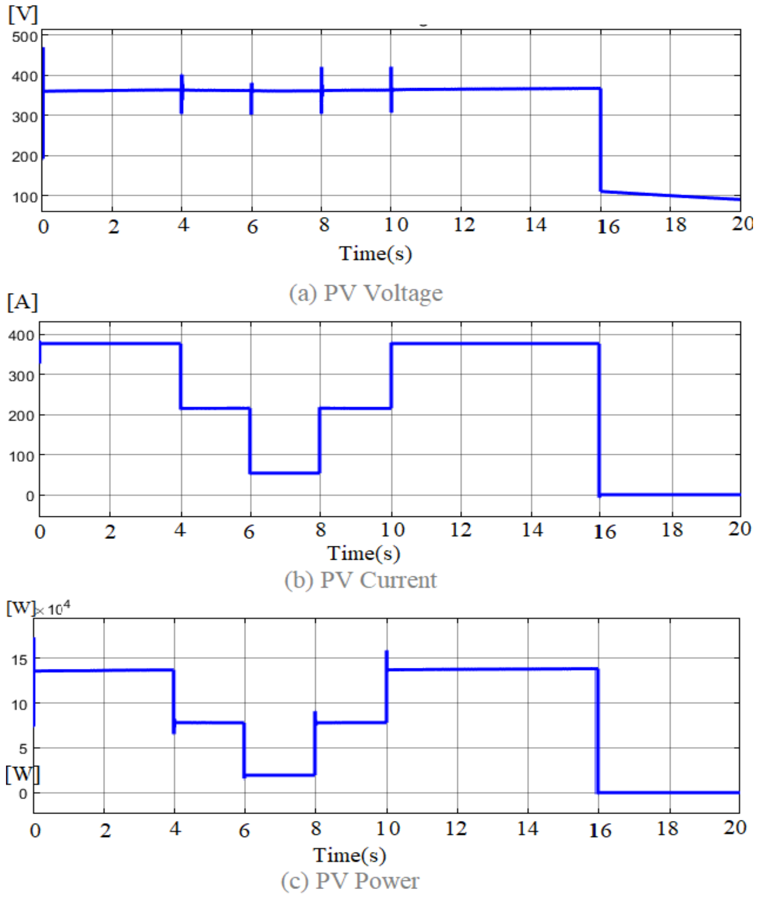



Figure 13. PV (a) Voltage, (b) Current, and (c) Power

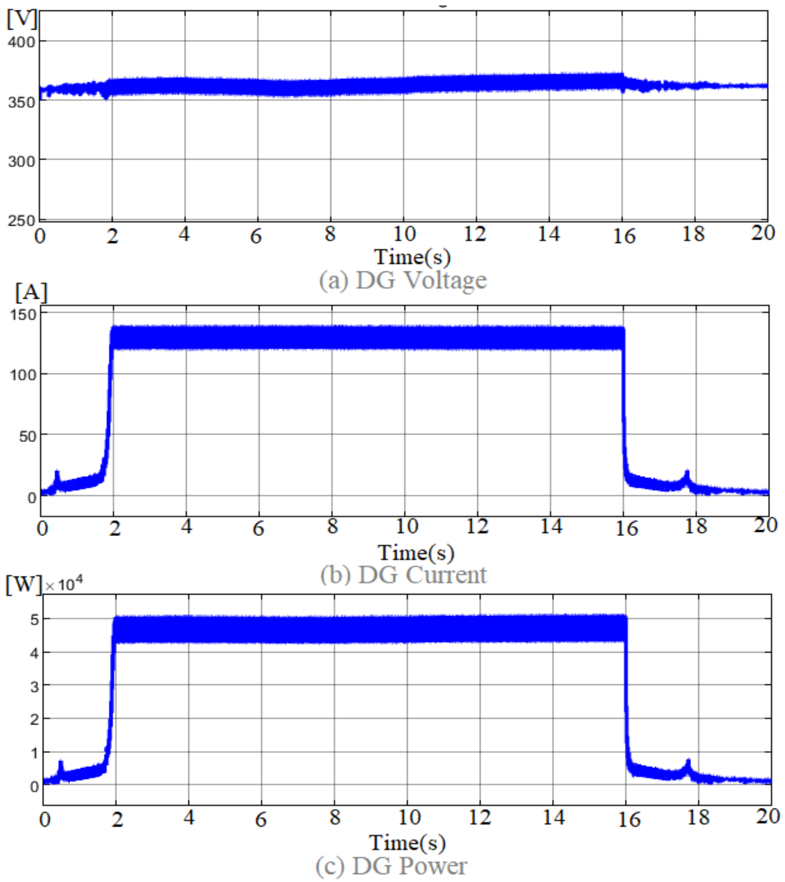



Figure 12. Diesel Generator (a) Output voltage, (b) Output current, and (c) Output power

# HRPS Dynamic Modeling and Simulation

## DYNAMIC SIMULATION RESULTS

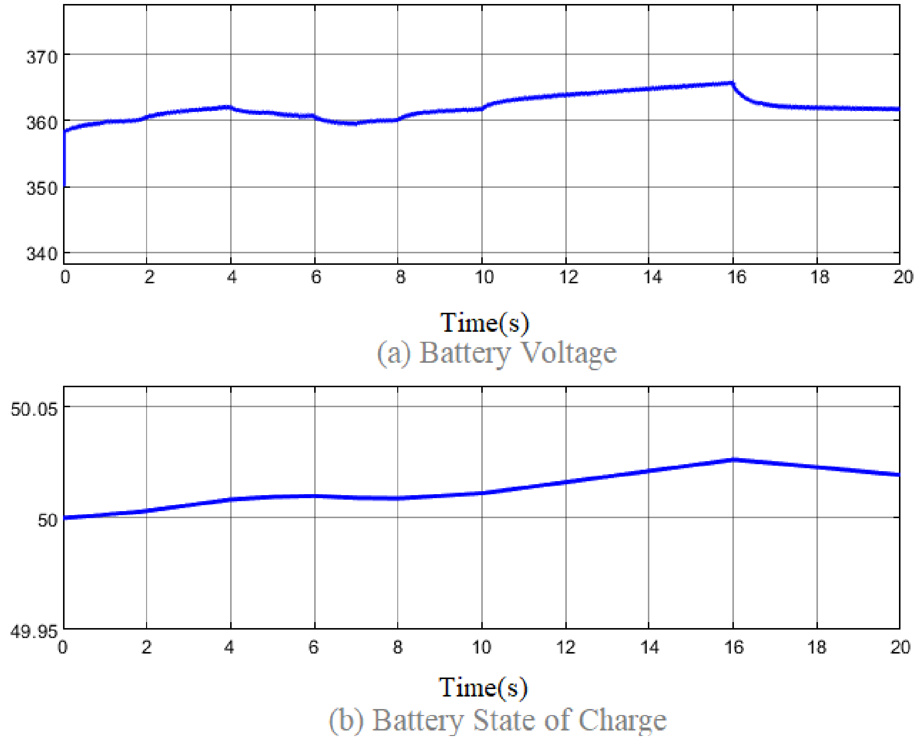



Figure 15. Battery (a) Voltage and (b) State of Charge

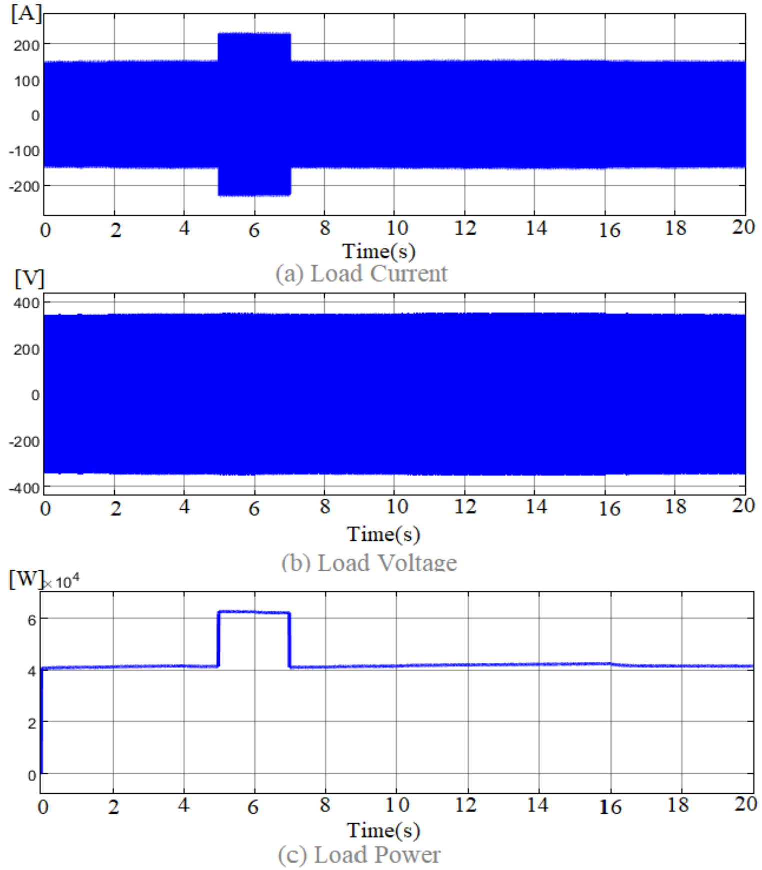



Figure 14. Load (a) Current, (b) Voltage, and (c) Power

# PV-BATTERY BOND GRAPH MODELING

# PV-Battery Bond Graph Modeling

## PV-BATTERY SYSTEM FOUR MAIN PARTS

- PV Cell
- DC-DC Converter
- Energy Storage System
- Three-Phase Inverter

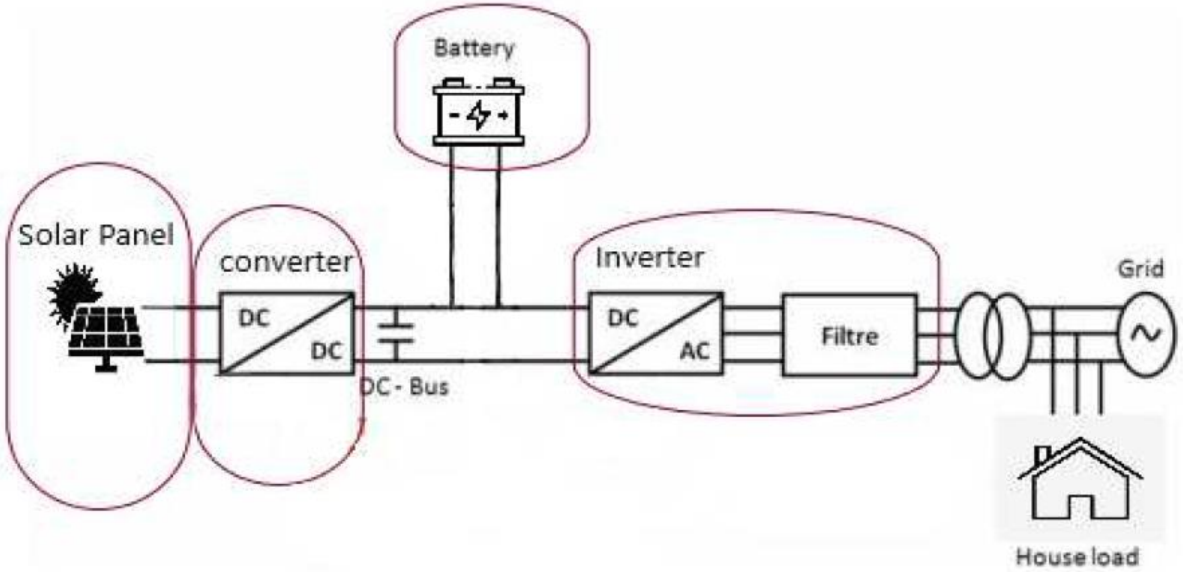



Figure 16. A PV-Battery four main parts

## BOND GRAPH MODELING

Advantages of Bond Graph Modeling.

- Faster and easier than other methods to simulate different types of dynamic systems.
- Versatile and reliable for modeling complicated dynamic systems.
- The best tool to model systems which are a mixture of differen types pf systems, such as wind turbines(One part is Mechanical system, the other part is Electrical System)

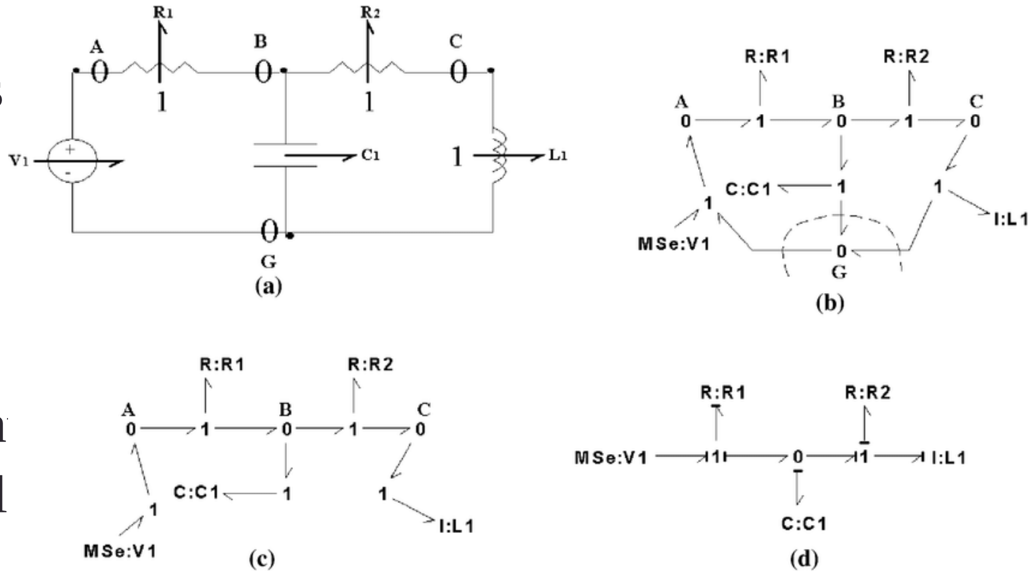



Figure 17. An RLC circuit three different bond graph models

# PV-Battery Bond Graph Modeling

## PV GENERATOR FIVE-PARAMETER MODEL

Advantages

- ❖ The effects of temperature is accurately illustrated.
- ❖ Results are similar to reality in different solar irradiations.

$$I_{ph} = n_p(I_{sc} + K_i(T - T_r))(S_i/100) \qquad I_d = n_p I_{sat}\left(\exp\left(\frac{qV}{AKTn_s}\right)\right)$$

$$V_t = K_v(T - T_r) \qquad V = Vp - V_t$$

$$I(1 + R_s/\,R_p) = -n_p I_{sat}\left\{\exp\left((\frac{q}{AKTn_s})(\frac{V}{n_s} + IR_s)\right) - 1\right\} + n_p I_{ph} - \frac{V - n_s}{R_p}))$$

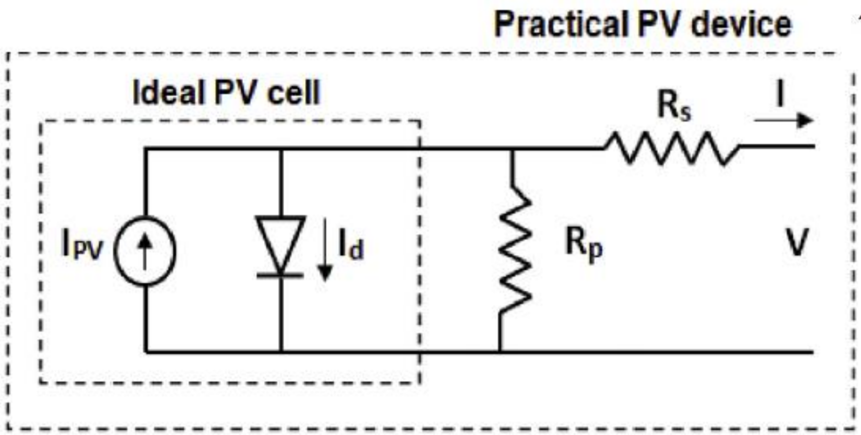



Figure 18. A PV cell five-parameter circuit model

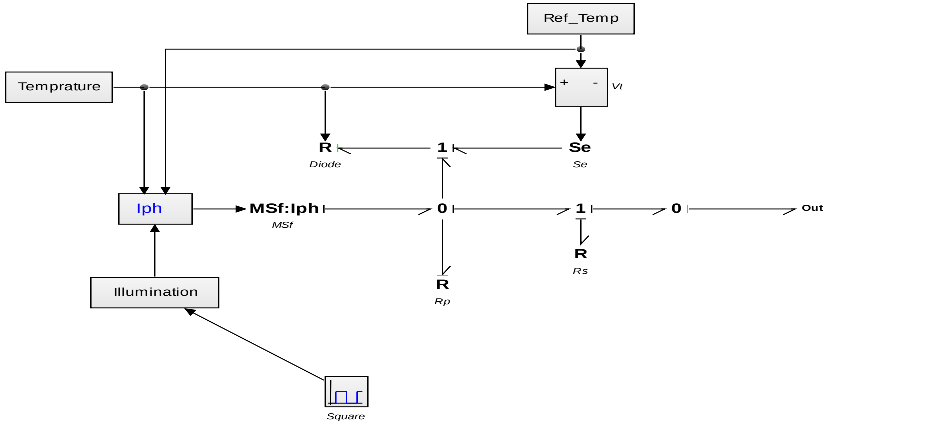
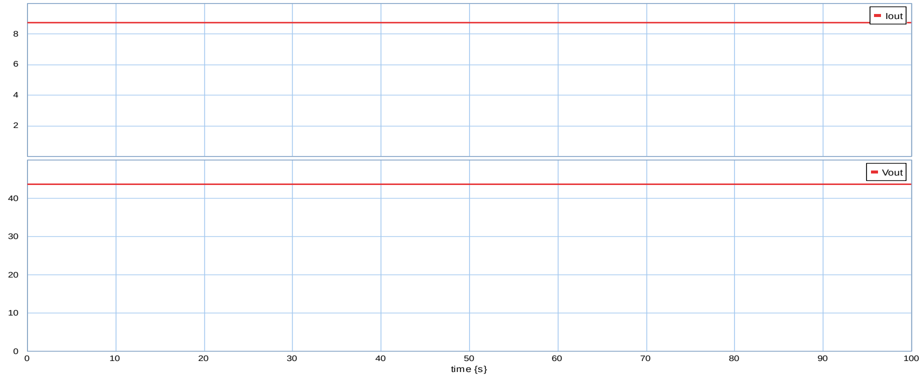



Figure 19. A PV cell five-parameter bond graph model

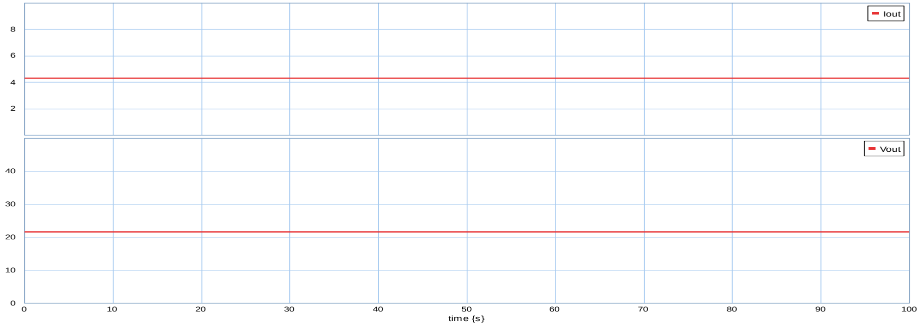
## PV GENERATION SIMULATION RESULTS

Based on CS1U-Canadian Solar Module specifications.

- ❖ Higher temperature, lower efficiency.
- ❖ Lower irradiation, lower efficiency.




(a) Nominal Irradiation, at 25°




(b) 45% of nominal Irradiation, at 60°

Figure 20. PV cell bond graph model simulation results

# PV-Battery Bond Graph Modeling

## DC-DC CONVERTER – SYNCHRONOUS BOOST CONVERTER

- Each switch has been modeled by two resistors and one capacitor, as the drain-source resistor, the parasitic resistor, and the drain-source capacitor, respectively.
- IRF150 specifications are used as the Power Switch.

$$\frac{V_{out}}{V_{in}} = \frac{1}{1-D} \qquad \frac{I_{out}}{I_{in}} = 1 - D$$

$$L = \frac{V_{out}D}{\Delta i_L f} \qquad C_o = \frac{D}{R(\Delta V_{out}/V_{in})f}$$

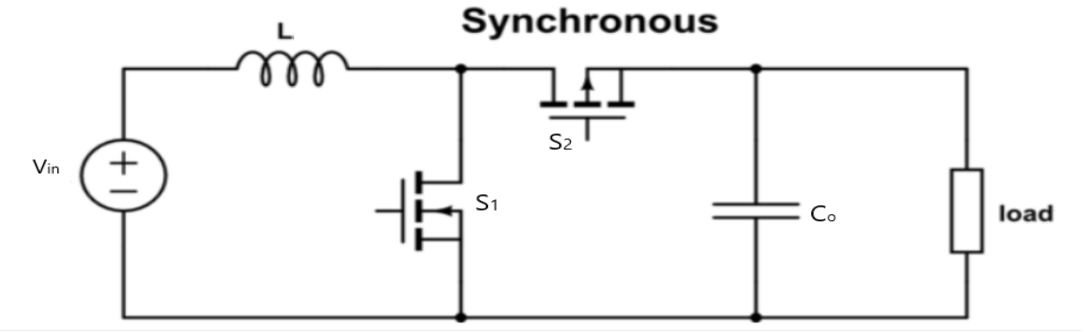



Figure 21.Boost converter circuit topology

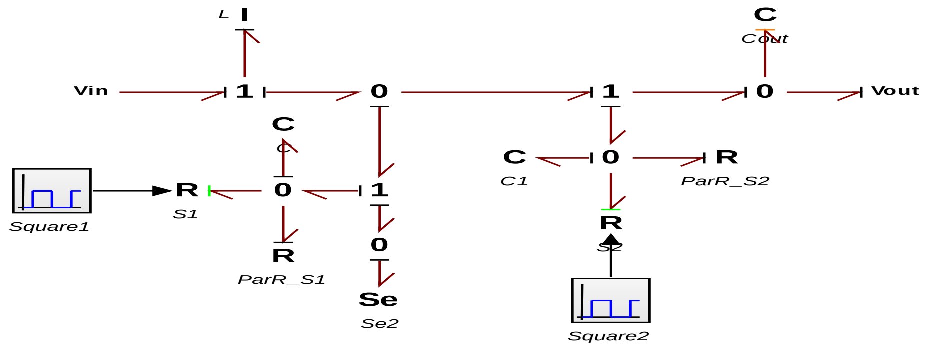



Figure 22. Boost converter bond graph model

# PV-Battery Bond Graph Modeling

## SYNCHRONOUS BOOST CONVERTER-SIMULATION RESULTS

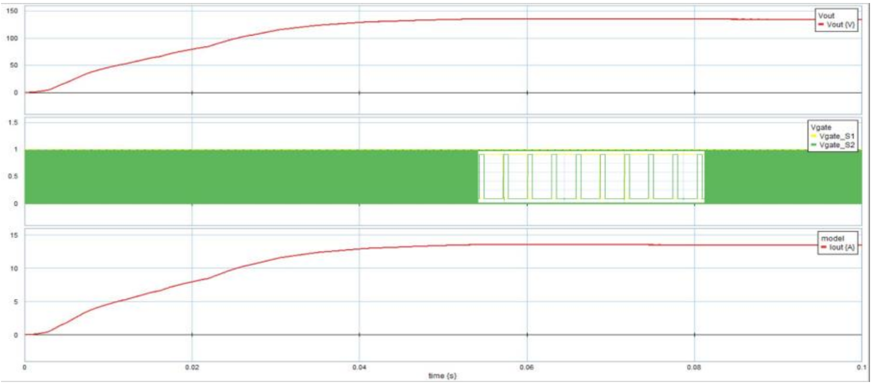
- Operating at 50 kHz, up to 2 kW.

Input Voltage=45 V.
At D 0.75:
Output Voltage = 140.

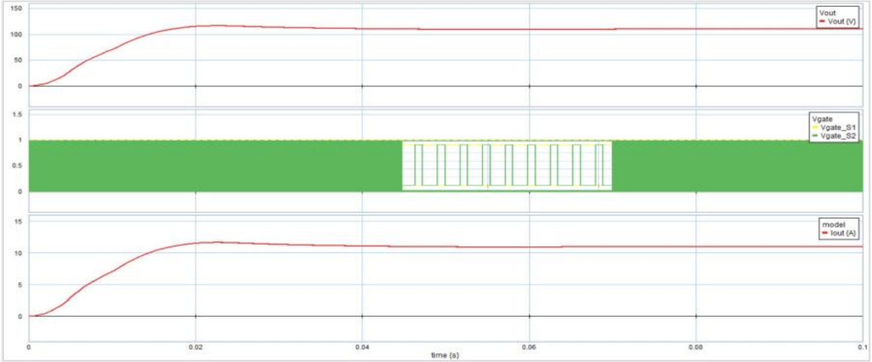
At D 0.65:
Output Voltage = 110

**Product Summary**

| Part Number | $BV_{DSS}$ | $R_{DS(on)}$ | $I_D$ |
|---|---|---|---|
| IRF150 | 100V | 0.055Ω | 38A |



(a) Duty cycle 0.75



(b) Duty Cycle 0.65

Figure 23. Boost converter bond graph simulation results

# PV-Battery Bond Graph Modeling

## DC-DC CONVERTER – SYNCHRONOUS CUK CONVERTER

- ❖ IRF150 specifications are used as the Power Switch.

$$\frac{V_{out}}{V_{in}} = -\frac{D}{1-D} \qquad \frac{I_{out}}{I_{in}} = -\frac{1-D}{D}$$

$$L_1 = \frac{V_{out}D}{\Delta i_{L1} f} \qquad L_2 = \frac{V_{out}D}{\Delta i_{L2} f}$$

$$C_o = \frac{D}{R(\Delta V_{out}/V_{in})f} \qquad C_1 = \frac{D}{R(\Delta V_{C1}/V_{out})f}$$

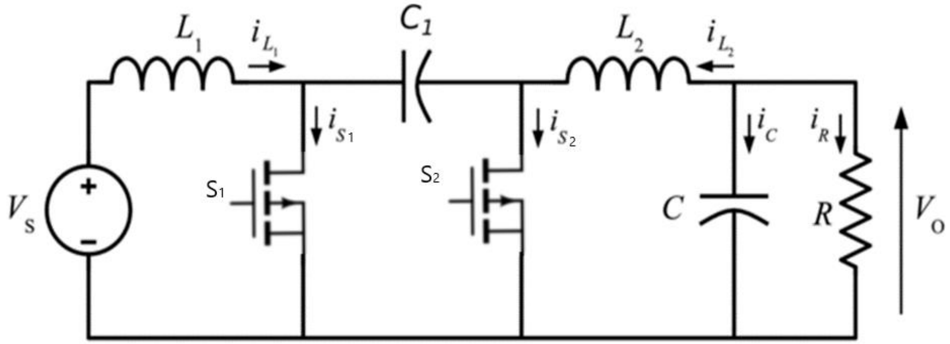



Figure 24.Cuk converter circuit topology

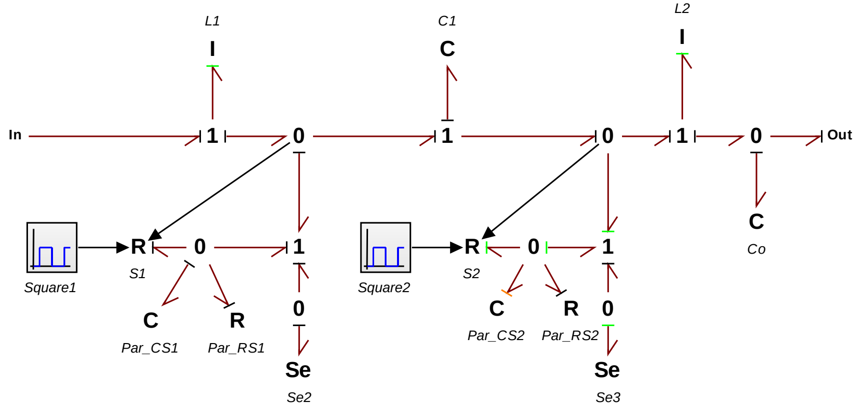



Figure 25. Cuk converter bond graph model

# PV-Battery Bond Graph Modeling

## SYNCHRONOUS CUK CONVERTER SIMULATION RESULTS

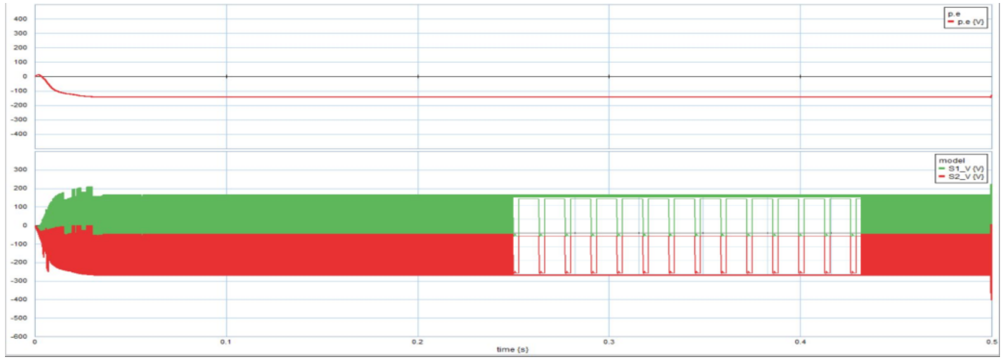
- Operating at 50 kHz, up to 2 kW.

Input Voltage=45 V.
At D 0.7:
Output Voltage = 140.

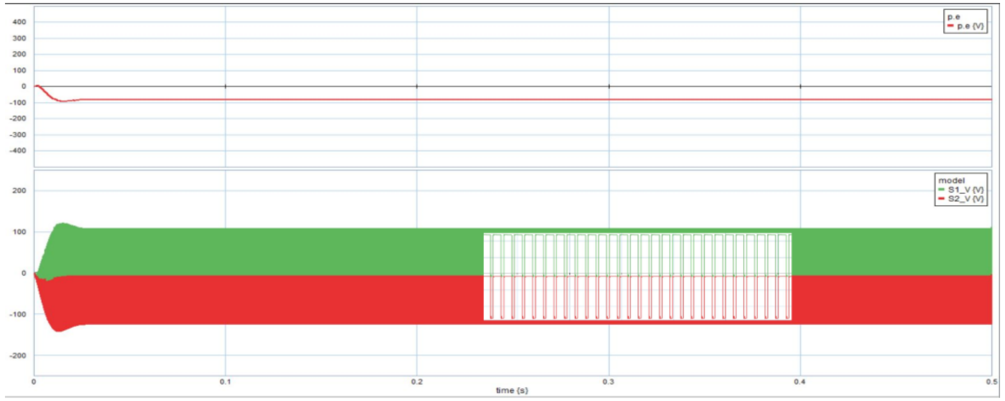
At D 0.6:
Output Voltage = 110

**Product Summary**

| Part Number | $BV_{DSS}$ | $R_{DS(on)}$ | $I_D$ |
|---|---|---|---|
| IRF150 | 100V | 0.055Ω | 38A |



(a) Duty cycle is 0.8



(b) Duty Cycle is 0.7

Figure 26. Cuk converter bond graph simulation results(Output Voltage and DS Voltage)

# PV-Battery Bond Graph Modeling

## ENERGY STORAGE SYSTEM (LEAD ACID BATTERY)

❖Lead Acid battery model with different charging and discharging series resistors as functions of State of Charge.

❖Considering temperature effects on capacity and series resistor.

$R_S = R_{S0} - K_S(T - 25)$

$R_{DisCharge} = -R_{D0} * \ln(SOC)$ $R_{Charge} = -R_{C0} * \ln(1 - SOC)$

$$SOC = \frac{Capacity\ remaining\ in\ Battery(state)}{Rated\ Capacity}$$

$$Capacity_0[F] = \frac{Capacity[A.H]\times 3600}{Voltage}$$

$$Capacity(T) = Capacity_0 * (d_0 + d_1T + d_2T^2)$$

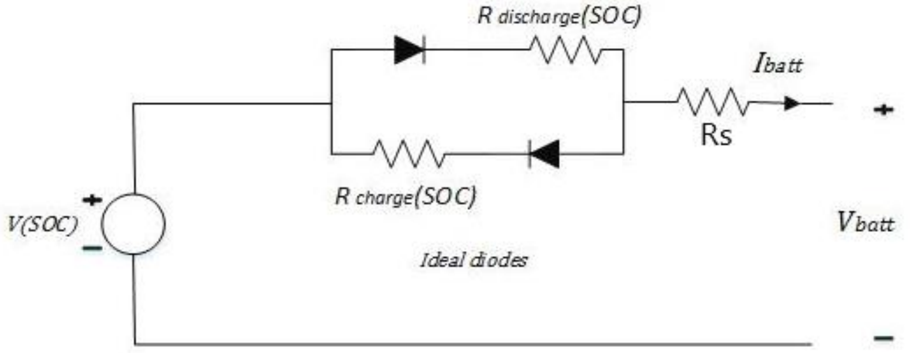



Figure 27.Lead Acid Battery circuit Model

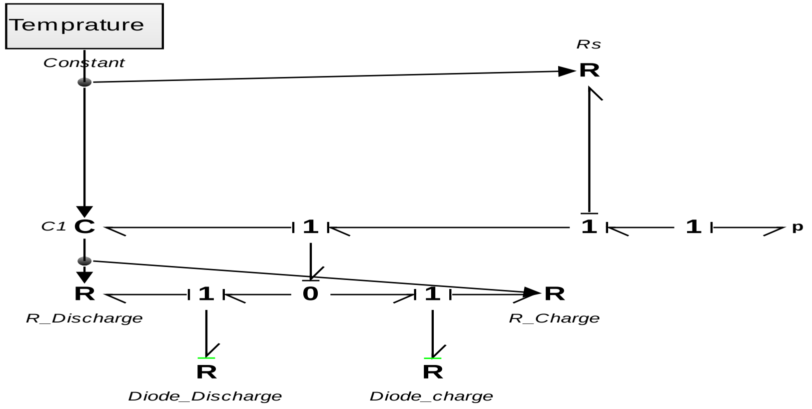
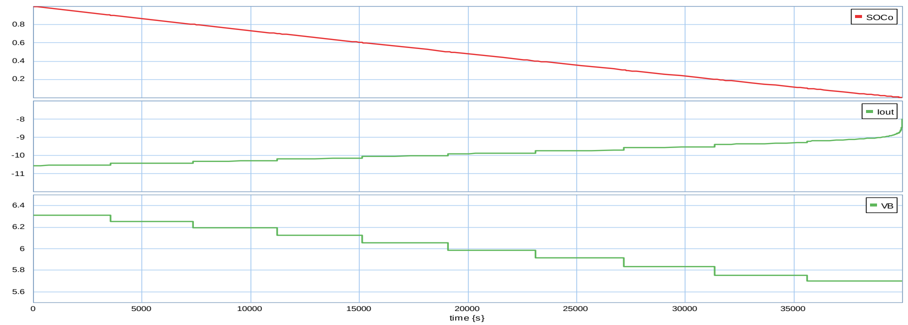
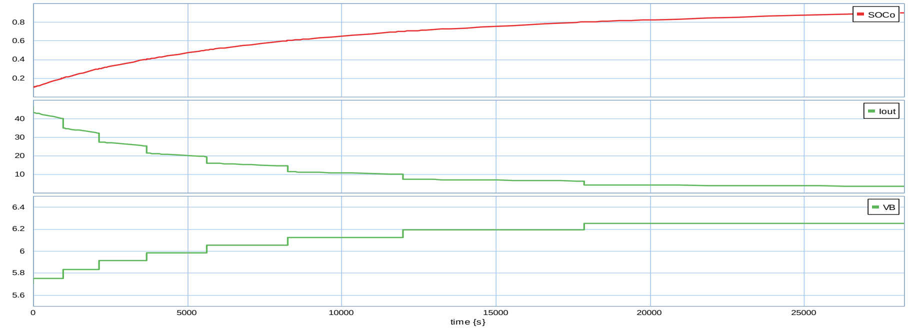



Figure 28. Lead Acid Battery bond graph model

## ENERGY STORAGE SYSTEM SIMULATION RESULTS

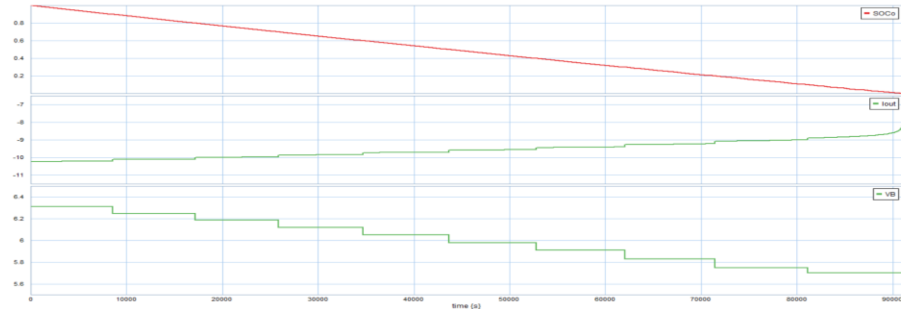



(a) Discharging by 10A




(b) Charging by 30A

Figure 30. Lead Acid Battery bond graph simulation results (Output Voltage and State of Charge) at -10 degrees




(c) Discharging by 10A


(d) Charging by 30A

Figure 29. Lead Acid Battery bond graph simulation results (Output Voltage and State of Charge) at 25 degrees

## THREE-PHASE INVERTER

The output phase voltage of the inverter can be calculated by following equation:

$$V_{out\_n} = \left|\frac{2Vdc}{3n\pi}\left[2 + cos\left(n\frac{\pi}{3}\right) - cos\left(n\frac{2\pi}{3}\right)\right]\right|$$

n= 1, 3, 5, 7, 11, 13, …

After output filter:

$$V_{o\_n} = \left|\frac{2V_{dc}}{\pi}\right|$$

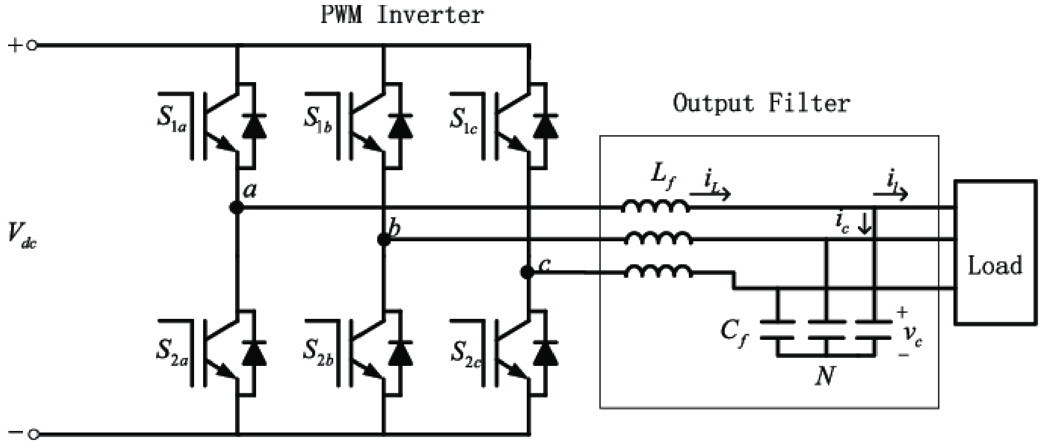



Figure 31.Three-Phase Inverter circuit model

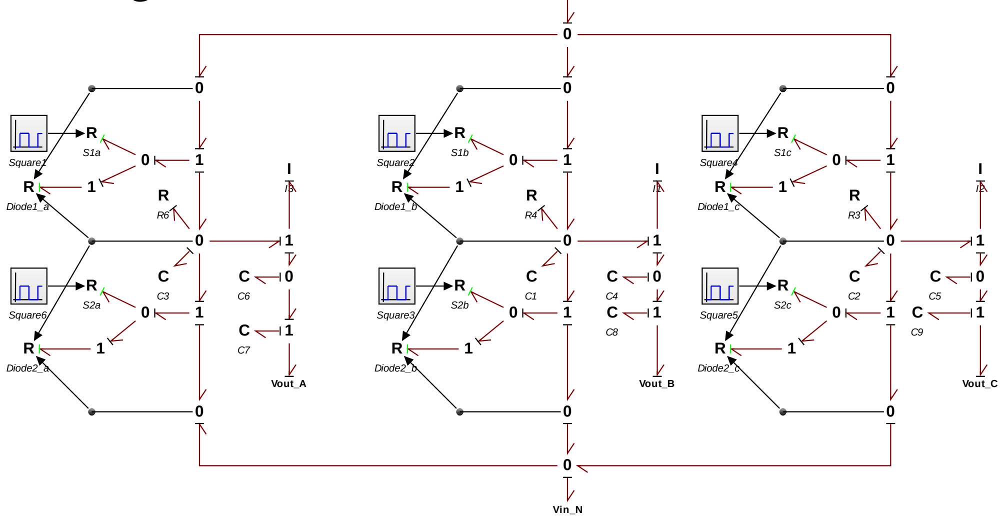



Figure 32. Three-Phase Inverter bond graph model

# PV-Battery Bond Graph Modeling

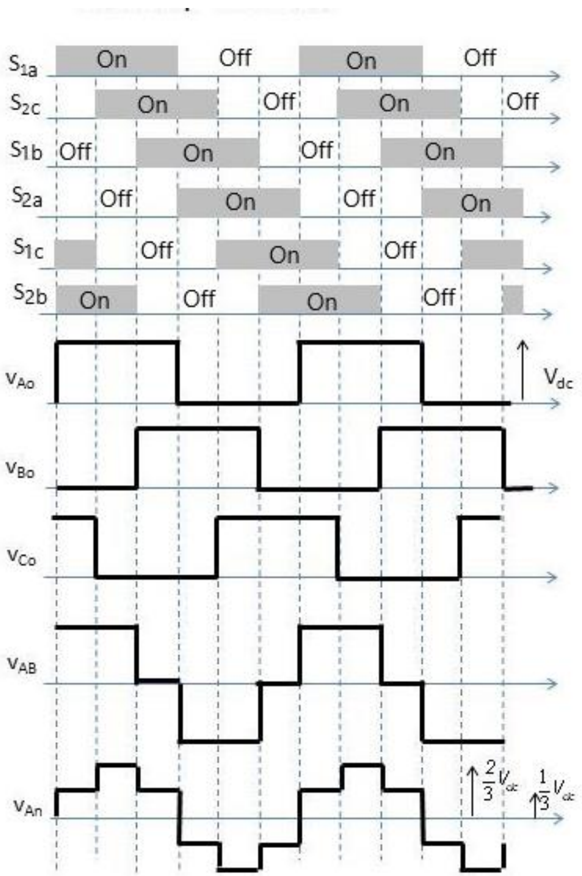
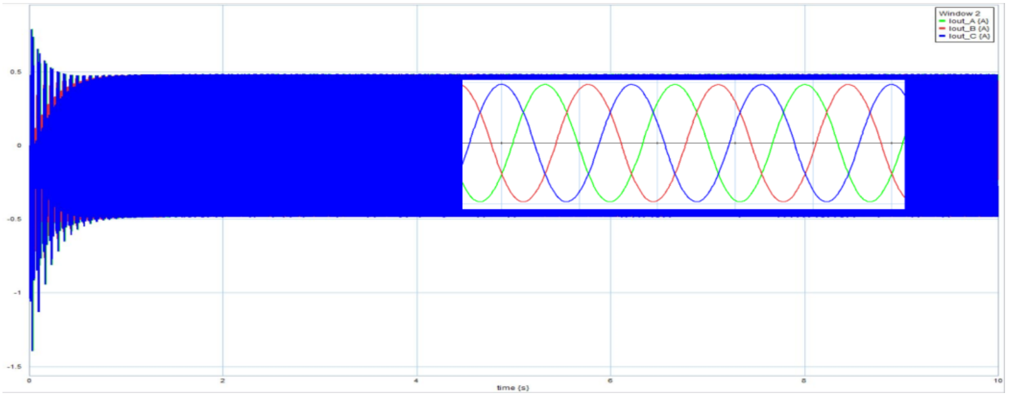
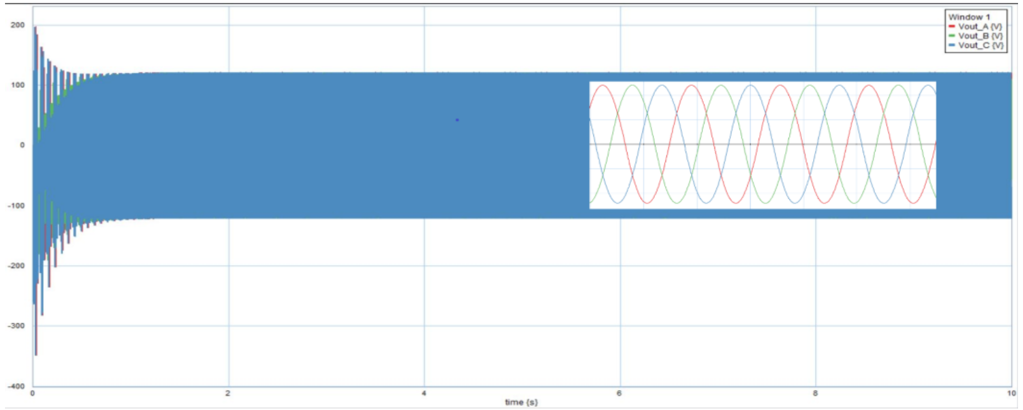



Figure 34. Three-Phase Inverter Waveform



(a) Output Current



(B) Output Voltage

Figure 33. Three-Phase Inverter bond graph model simulation results (outputs Current and Voltage)

# CUK-BOOST CONVERTER AND CONTROLLER DESIGN AND MODELING

# Cuk-Boost converter with Controller Design and Modeling

## PROPOSED CUK-BOOST CONVERTER

- Combination of Cuk converter and Boost converter using shared component technique.
- Advantages:
- High conversion ratio, for High step-up applications, e.g. PV systems.
- High efficiency and no switching loss.
- Reliable and compact

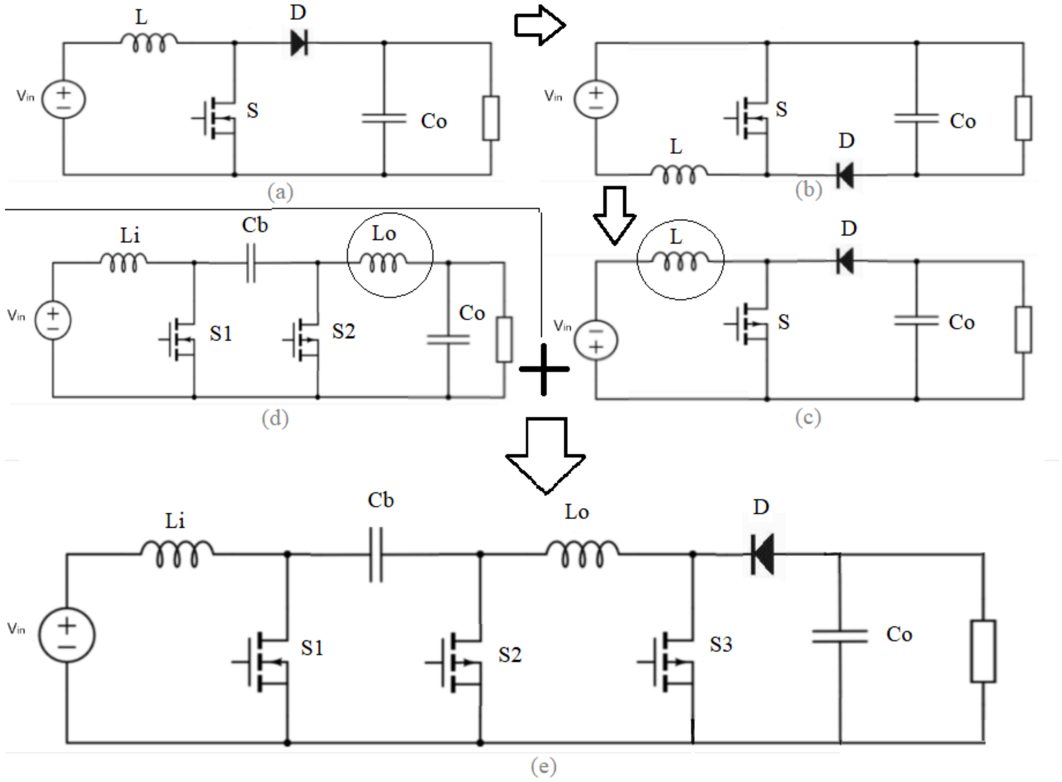



Figure 35. The proposed Cuk-Boost converter topology

## OPERATION MODES

- This converter operates at 6 operation modes.
- 3 Switches
- 1 Diode
- 2 main capacitors
- 3 snubber capacitors
- 2 inductors

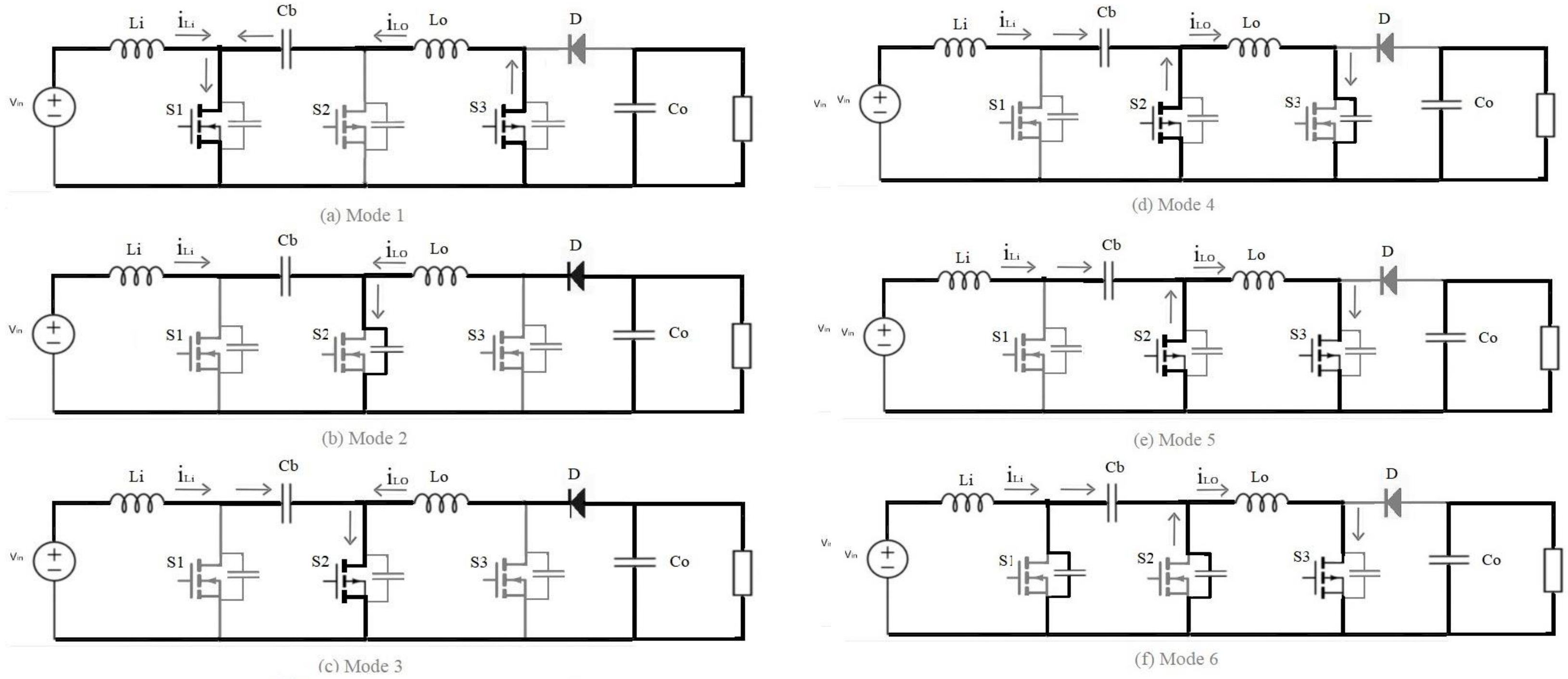



Figure 36. Mode operations of proposed Cuk-Boost converter. (a) Mode 1, (b) Mode 2, (c) Mode 3, (d) Mode 4, (e) Mode 5, and (f) Mode 6

# Cuk-Boost converter with Controller Design and Modeling

## EQUATIONS

- Conversion ratio:

$$\frac{V_{out}}{V_{in}} = -\frac{D}{(1-D)(1-D-D')}$$

- Voltage stress across Switches and diodes:

$$V_{s1} = \frac{V_i}{1-D}$$

$$V_{s2} = \frac{V_i}{1-D}$$

$$V_{s3} = \frac{DV_i}{(1-D)(1-D-D')}$$

$$V_D = \frac{DV_i}{(1-D)(1-D-D')}$$

- Components design:

$$L_1 = \frac{V_{in}D}{\Delta i_{Li}f}$$

$$C_o = \frac{D+D'}{R(\Delta V_{out}/V_{out})f}$$

$$L_o \leq \frac{\left(\sqrt{\frac{C_{S3}}{2}}V_{DS3}-\sqrt{2C_e}V_{DS2}\right)^2}{i_{L1}^2} * Coeff$$

## SIMULATION RESULTS

- C3M0015065D as the switch, and 80EBU02 as the diode.
- 225 w output power.
- 24 V Input voltage
- -150 output voltage
- 100 kHz Switching Frequency

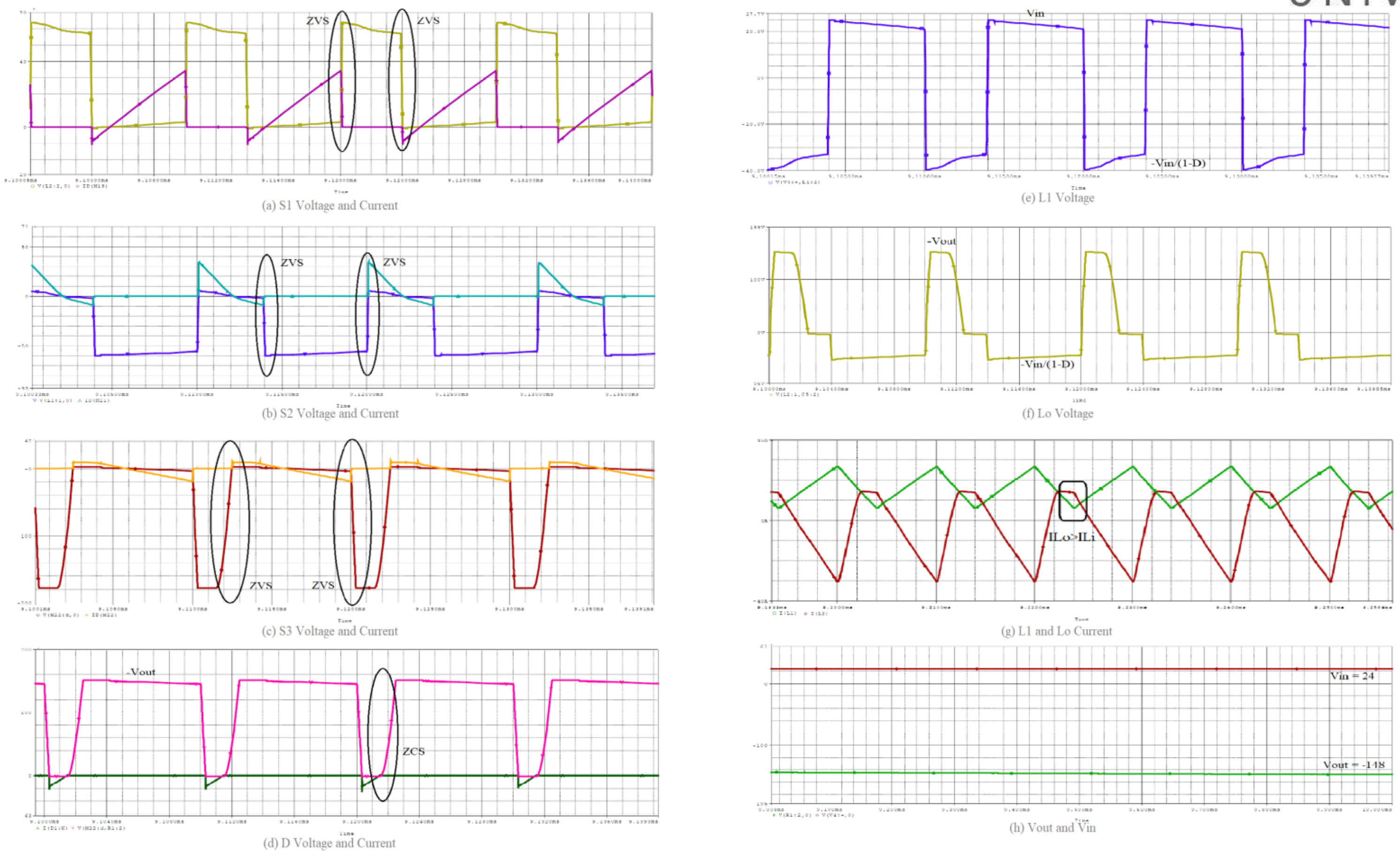



Figure 37. Simulation results (a) S1 Voltage and Current (b) S2 Voltage and Current (c) S3 Voltage and Current (d) D voltage and Current (e) L1 Voltage (f) Lo Voltage (g) L1 and Lo Current (h) Vout and Vin

# Cuk-Boost converter with Controller Design and Modeling

## EFFICIENCY ANALYSIS

- Semiconductors conduction loss
- Inductors conduction loss caused by ESR.
- Capacitors conduction loss caused by ESR

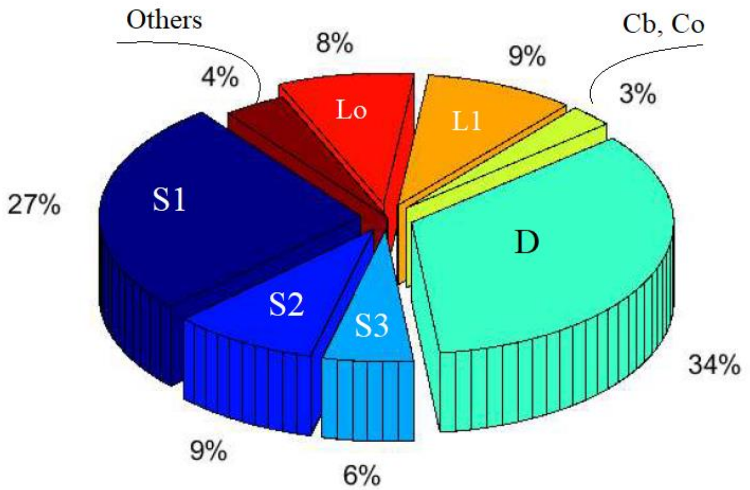



Figure 38.Components power loss precentage

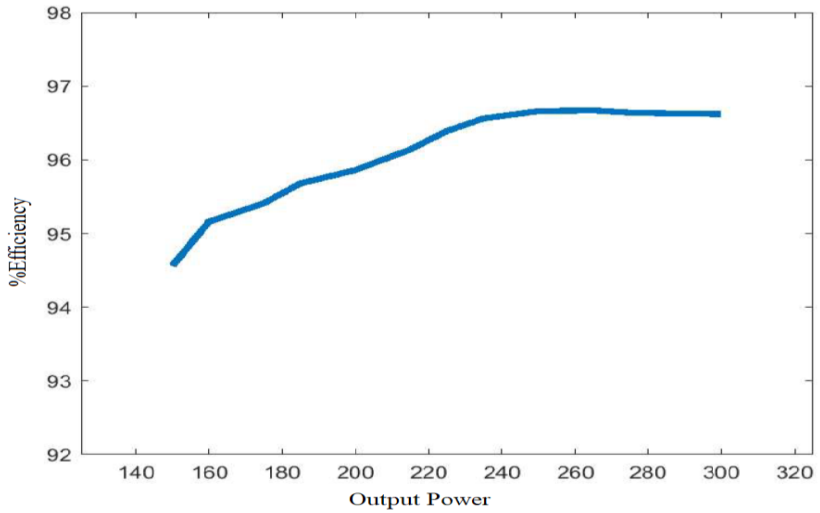



Figure 39. Proposed converter efficiency in different output power

# Cuk-Boost converter with Controller Design and Modeling

## BOND GRAPH MODEL

- Purpose is studying dynamic behavior of proposed converter.
- To derive all semiconductors' parameters, datasheet documents have been used.

Table 1. components values

| Parameters | Values |
|---|---|
| Gate C_S1, S2, S3 | 5.011 nF |
| Drain C_S1, S2, S3 | 289 pF |
| Parasitic Series Gate R_S1, S2, S3 | 0.25 Ohm |
| Parasitic Parallel Drain R_S1, S2, S3 | 13e6 |
| Drain-Source on R_S1, S2, S3 | 15 mOhm |
| Parasitic Parallel R_Diode | 4e6 Ohm |
| Parasitic Parallel C_Diode | 92 pF |

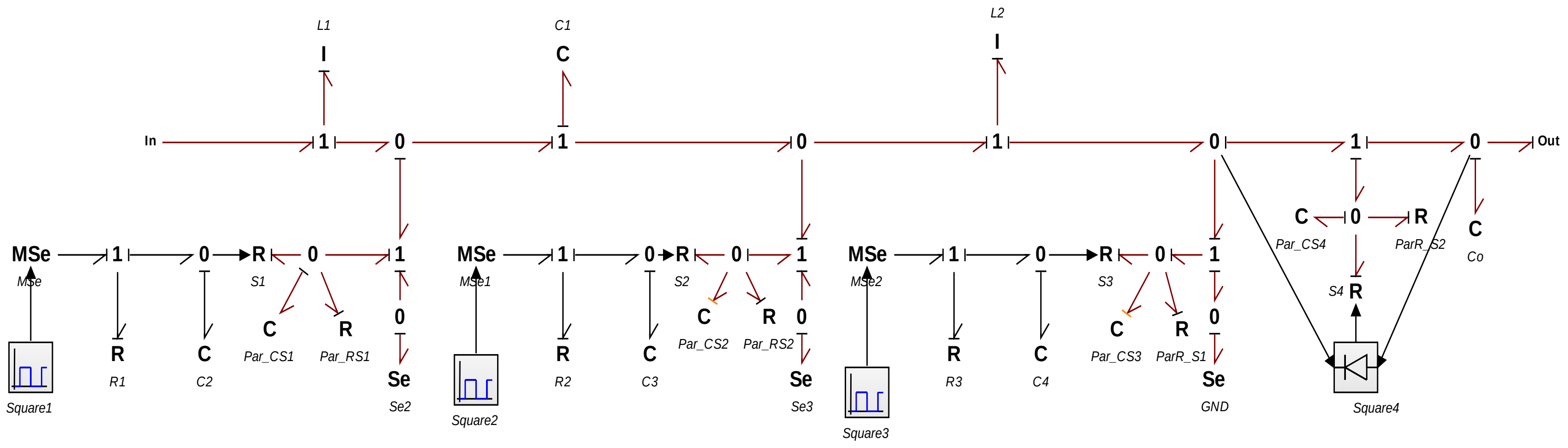
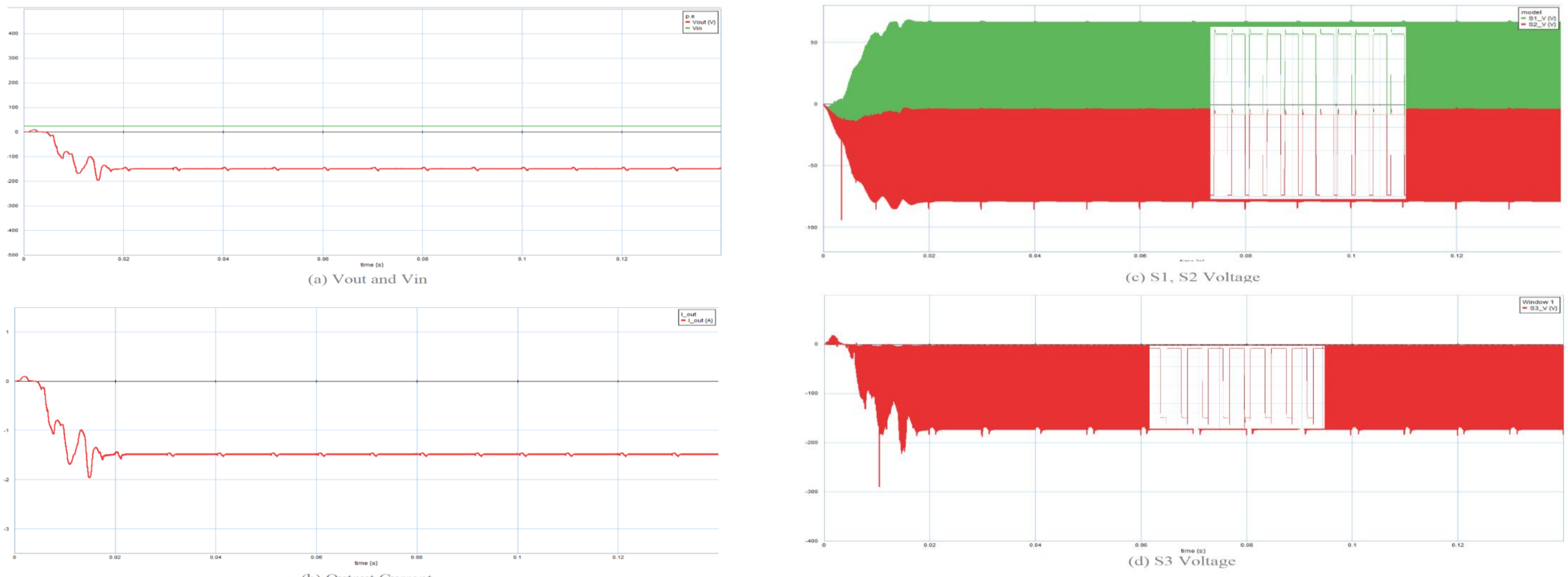



Figure 40. Proposed converter bond graph model

# Cuk-Boost converter with Controller Design and Modeling

## SIMULATION RESULTS




(a) Vout and Vin
(b) Output Current
(c) S1, S2 Voltage
(d) S3 Voltage

Figure 41. Bond Graph Simulation results.(a) Output and Input Voltage. (b) output Current. (c) S1, S2 Voltage. (d) S3 voltage

# Cuk-Boost converter with Controller Design and Modeling

## STATE SPACE AVERAGING TECHNIQUE AND PID CONTROLLER

- By applying state space averaging technique on small signal analysis:

$$A = \begin{bmatrix} 0 & 0 & -\frac{1-D}{L_1} & 0 \\ 0 & 0 & \frac{D}{L_o} & \frac{1-D-D\prime}{L_o} \\ \frac{1-D}{C_b} & -\frac{D}{C_b} & 0 & 0 \\ 0 & \frac{1-D-D\prime}{C_o} & 0 & -\frac{1}{RC_o} \end{bmatrix}$$

$$B = \begin{bmatrix} -\frac{V_{Cb}}{L_1} \\ \frac{V_{Cb}}{L_o} - \frac{V_{Co}}{L_o} \\ \frac{I_{Lo}}{C_b} - \frac{I_{L1}}{C_b} \\ -\frac{I_{Lo}}{C_o} \end{bmatrix}$$

$$C = [0 \quad 0 \quad 0 \quad 1]$$

- Using following formula to calculate transfer function:

$$\frac{V_O(s)}{d(s)} = C\,[SI - A]^{-1}\,B$$

- Considering values which have been used in simulation, transfer function is derived as:

$$G(s) = \frac{V_{out}}{d\prime} = \frac{333.3S^3+4e6S^2+3.704e6S+2.222e10}{S^4+1.667S^3+7.556S^2-1.48e5S+5.926e7}$$

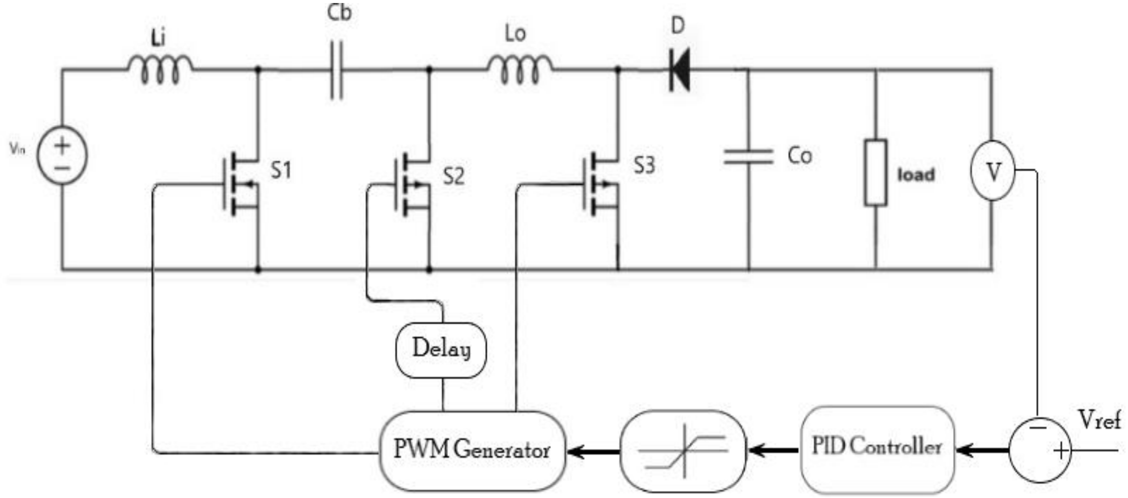



Figure 42. Proposed converter schematic with PID controller for Vout

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## PID CONTROLLER DESIGN USING SISOTOOL

Using Sisotool to obtain PID controller:

$$K(s) = \frac{-1.9611e5}{s + 1.472e3} + \frac{0.05e5 + (0.017e5)i}{s + (00001e3 + (0.0773e3)i)} + \frac{0.05e5 - (0.017e5)i}{s + (00001e3 - (0.0773e3)i)} + \frac{0.0139e5}{s + 0.0143e3} + 112.57$$

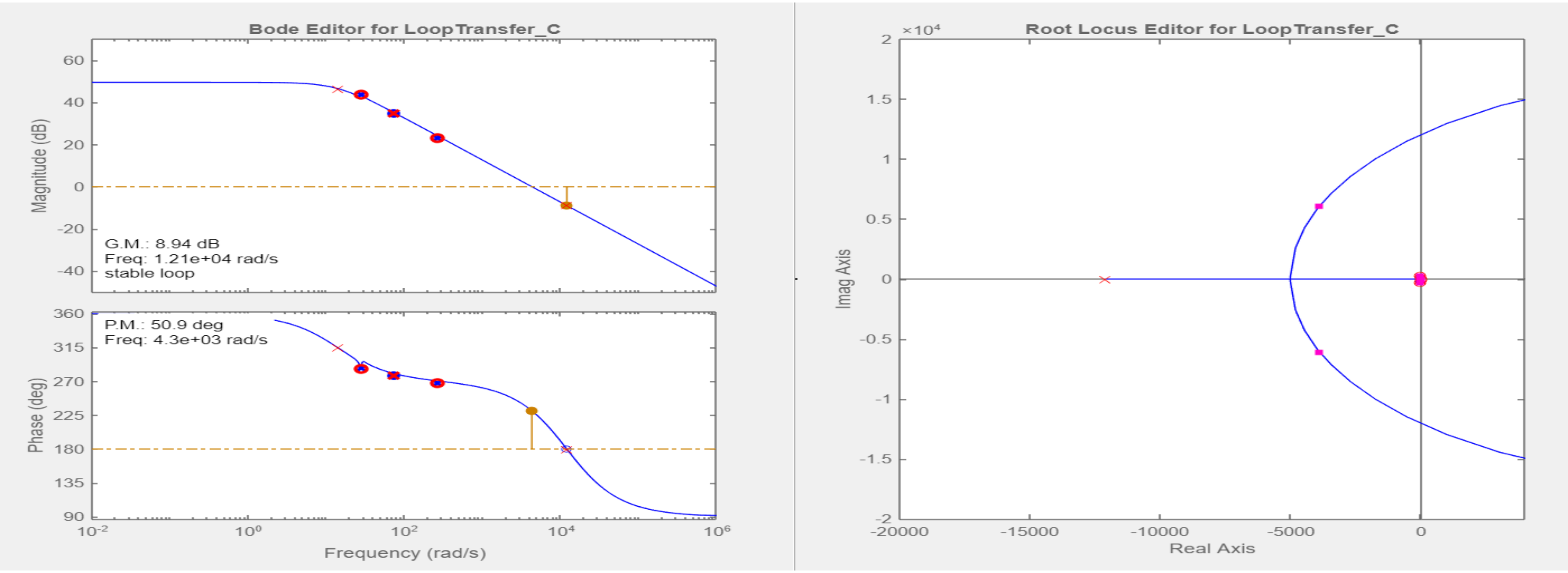


Figure 43. Root locus and bode plot of the closed loop circuit of the converter

# Cuk-Boost converter with Controller Design and Modeling

## SIMULINK SIMULATION RESULTS

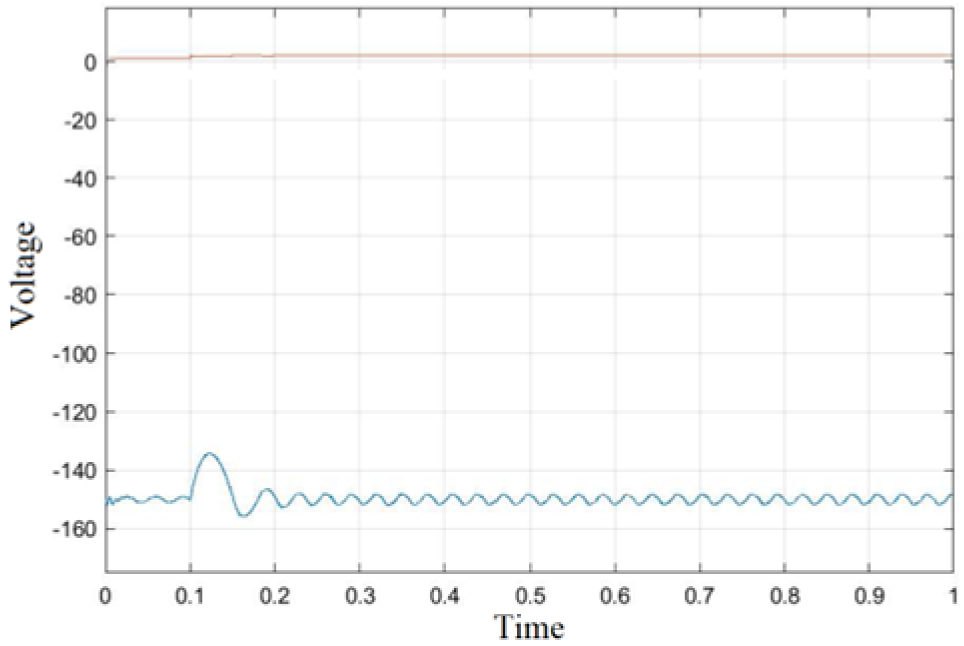


Figure 45. Closed loop output and input voltage

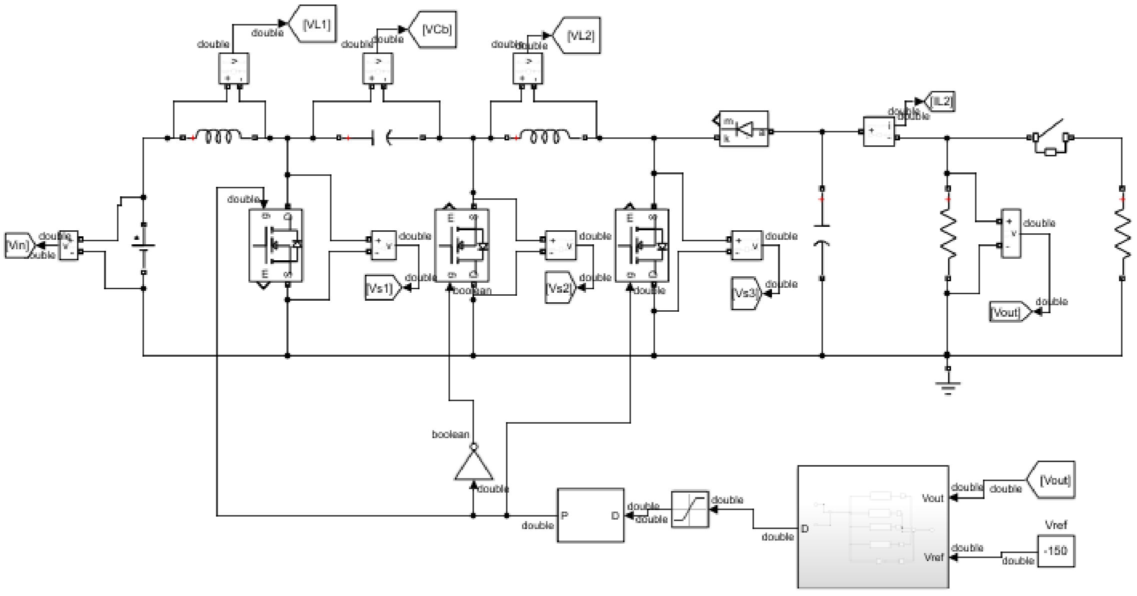


Figure 44. Closed-loop converter Simulink model

# SCADA SYSTEM DESIGN AND IMPLEMENTATION

## PROPOSED SCADA SYSTEM

Main purposes:

- **Monitoring** the system essential parameters real-time.
- Providing warning signals related to any **fault** in the system.
- Producing important **controlling** signals.
- **Saving** are received data for any future study.

Advantages:

- Low-cost
- Having remote access
- Wio terminal
- Open source

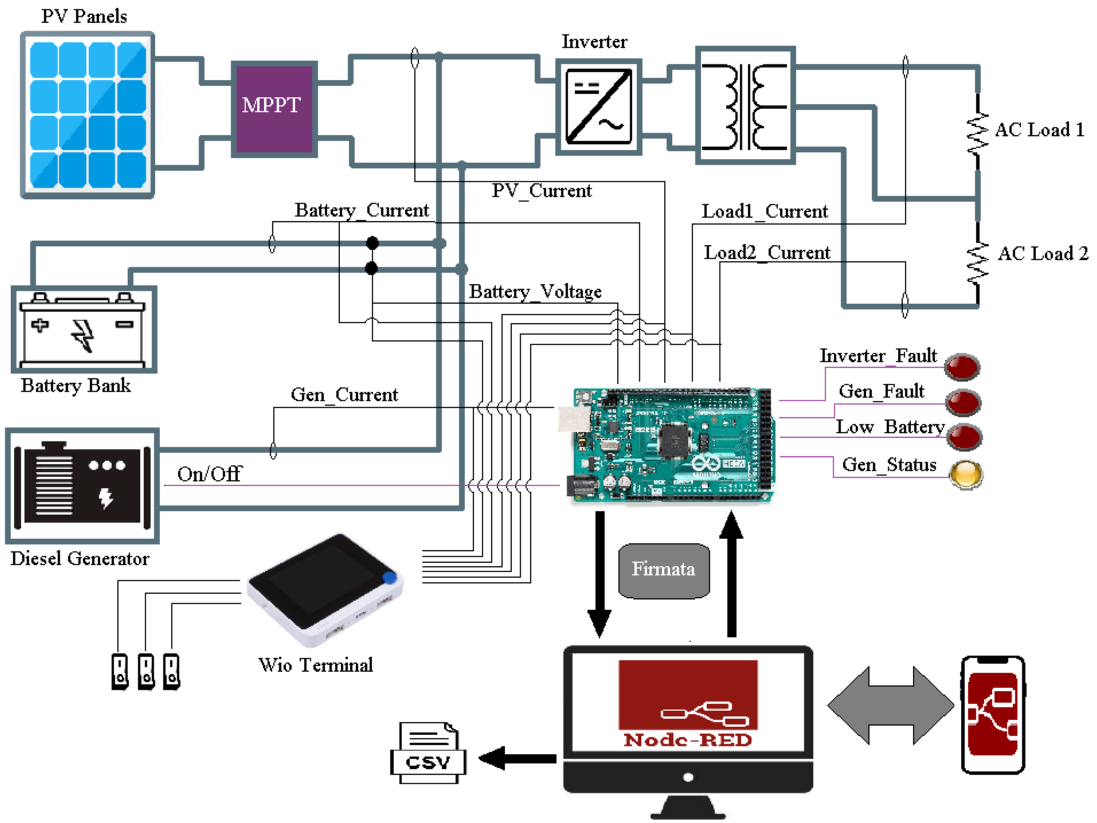


Figure 46. Designed SCADA system for a Hybrid Renewable Power System

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## COMPONENTS

- ❖ Arduino Mega2560(1st RTU)
- ❖ Wio terminal (2nd RTU)
- ❖ ACS712 Hall effect (current sensor)
- ❖ F031-06 (voltage sensor)

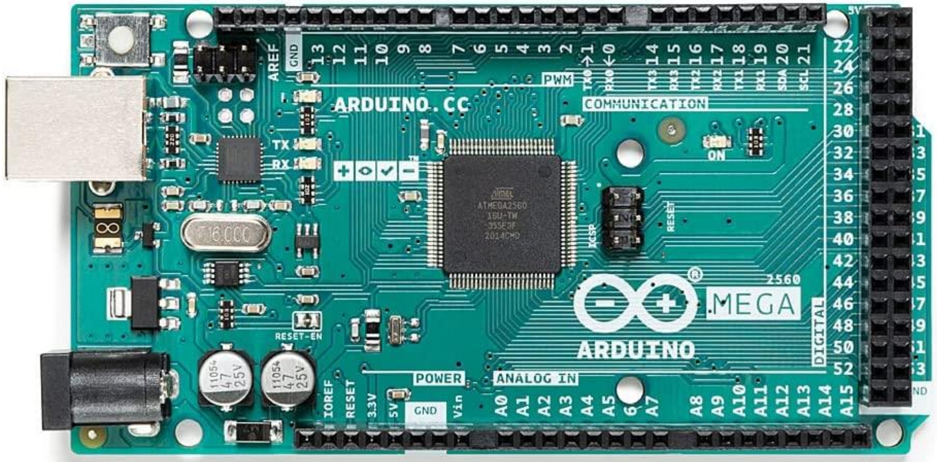


Figure 47. Arduino Mega 2560

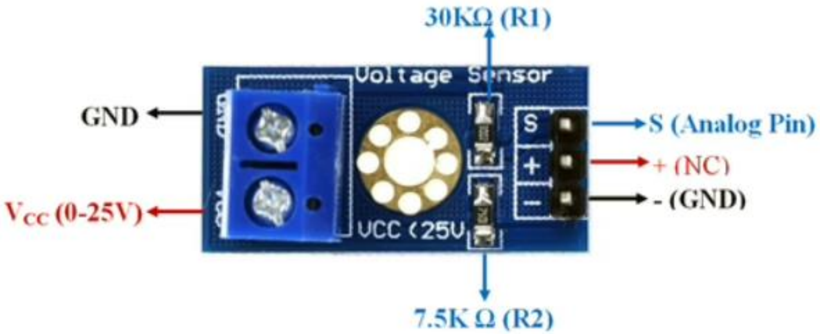


Figure 50. F031-06 (voltage sensor)

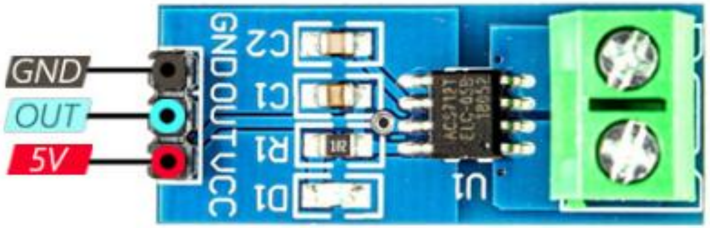


Figure 49. ACS712 Hall effect (current sensor)

Figure 48. Wio terminal

## SYSTEM SETUP

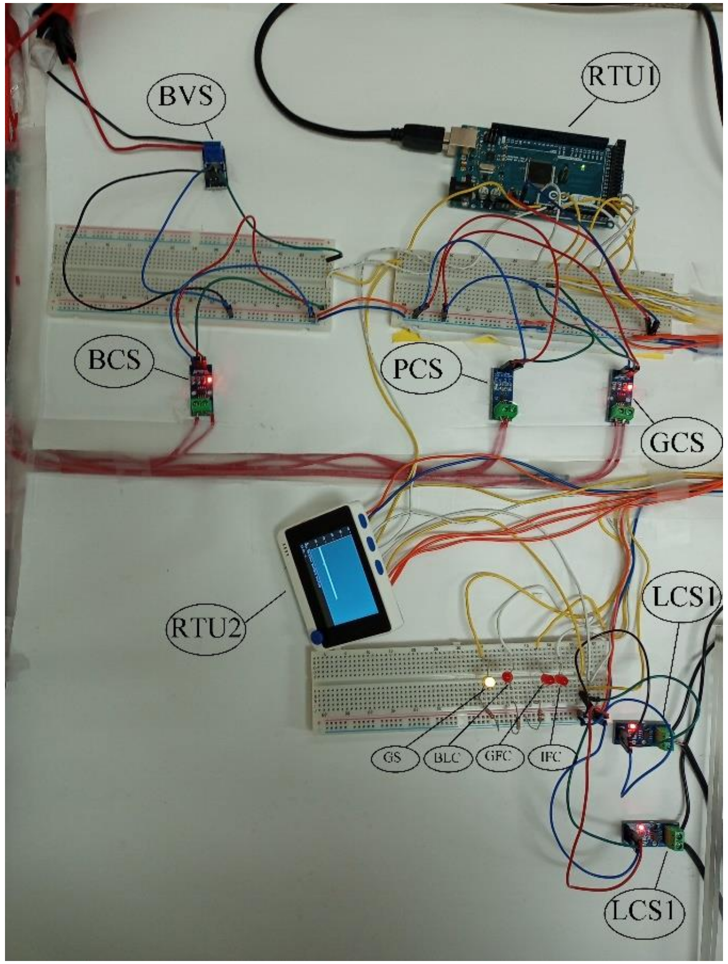


Figure 52. Hardware setup

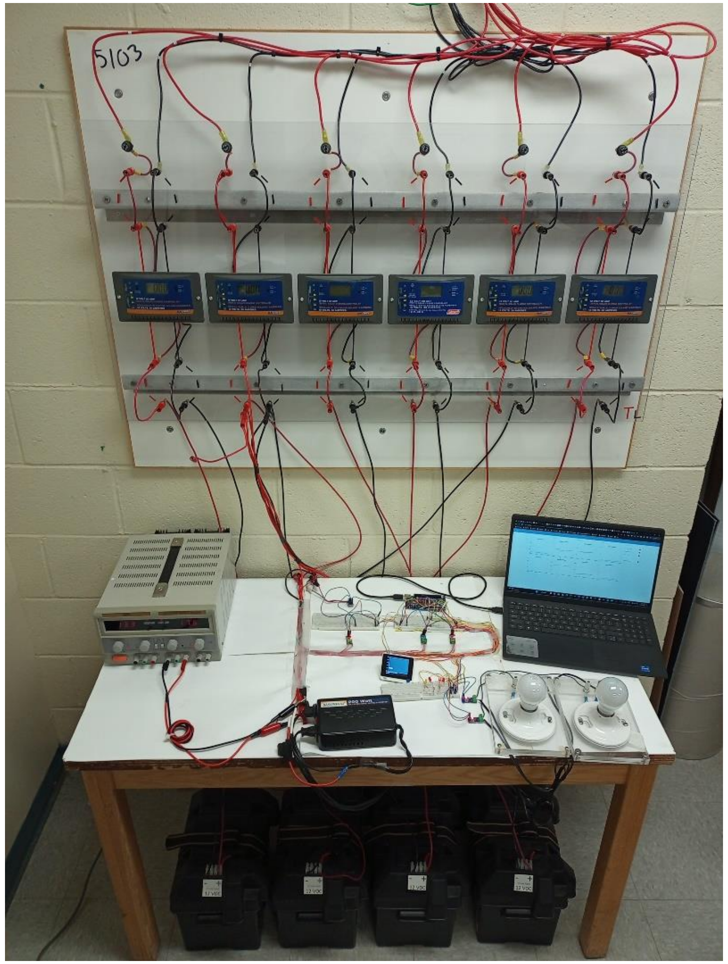

Figure 51. System setup

# SCADA System Design and Implementation

## WIO TERMINAL SETUP

1. If (D6, D7, D8) is equal to (0, 0, 0), target value is battery voltage.
2. If (D6, D7, D8) is equal to (0, 0, 1), target value is battery current.
3. If (D6, D7, D8) is equal to (0, 1, 0), target value is PV current.
4. If (D6, D7, D8) is equal to (0, 1, 1), target value is generator current.
5. If (D6, D7, D8) is equal to (1, 0, 0), target value is load current 1.
6. If (D6, D7, D8) is equal to (1, 0, 1), target value is load current 2.
7. If (D6, D7, D8) is equal to (1, 1, 0), target value is PV power.
8. If (D6, D7, D8) is equal to (1, 1, 1), target value is generator power.


Figure 49. Wio terminal

Figure 53. Node-Red flow

## SYSTEM SETUP


Figure 54. Battery bank

Figure 55. Roof top solar panel

# SCADA System Design and Implementation

## MAINTERMINAL UNIT (NODE_RED) - FLOW

- **Receives** data
- **Calculates** actual values
- **Calculates** generator power and PV power
- **Displays** all data
- **Save** all data in a CSV file
- **Analyze** data
- Produce **Warning** signals
- Produce **Control** signal

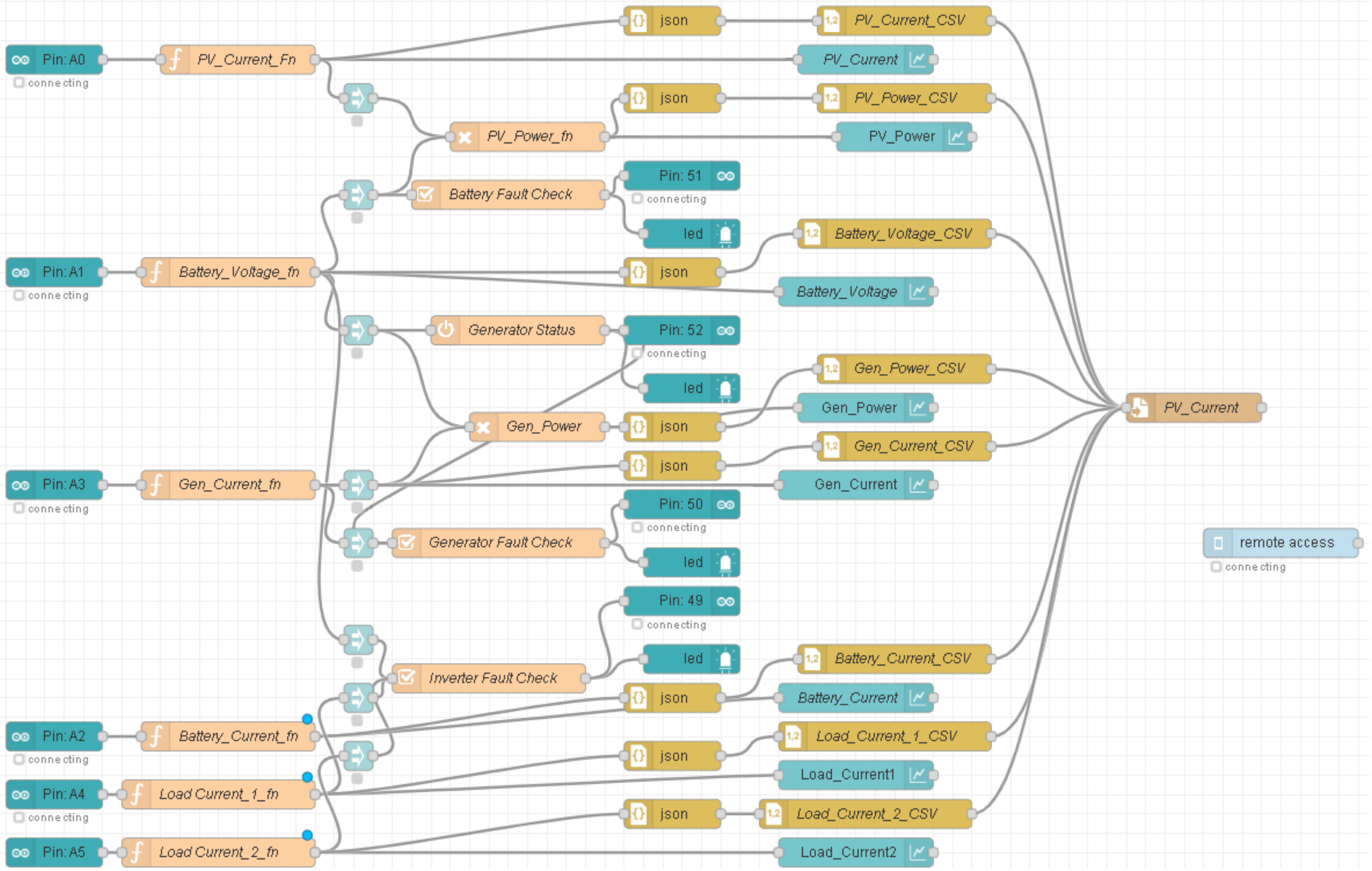


Figure 56. Node-Red flow

## MAINTERMINAL UNIT (NODE_RED) - DASHBOARD

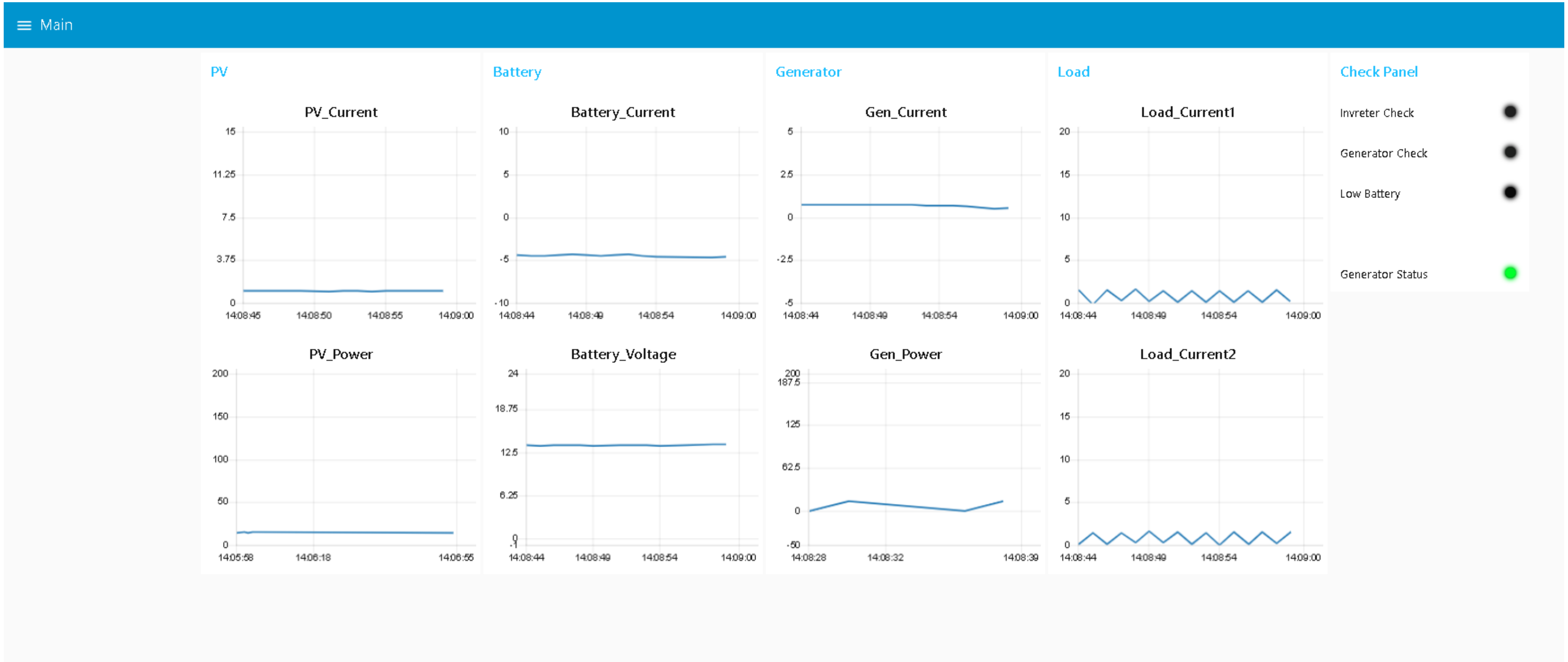


Figure 57. Node-Red dashboard

# CONCLUSION
# FUTURE WORKS
# ACKNOWLEDGMENT

# Conclusion

- Paradise River climate and environment has been studied and annual power consumption has been obtained
- An optimized low cost HRPS has been design and sized with Homer pro
- The system dynamic behavior has been studied and analyzed in MATLAB/Simulink
- Four main parts of a PV-Battery system have been modeled and simulated using bond graph technique
- A novel efficient high step-up DC-DC converter has been designed and simulated
- The bond graph model of the proposed converter has been studied
- A PID controller has been obtained to control the proposed converter using state space averaging technique with Sisotool and MATLAB/Simulink
- A SCADA system has been designed and implemented to monitor and control the HRPS

# Future works

- Bond graph model of all other components can been obtained using the manner and procedure provide in this thesis.
- The implementation challenges of the HRPS can be studied.
- The proposed DC-DC converter implementation can be tried.

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# Publications

- S. A. Omidi and M. T. Iqbal, "Sizing and dynamic modeling a Hybrid Renewable Power System for Paradise River, NL, Canada," 2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), 2022, pp. 0269-0276, doi: 10.1109/UEMCON54665.2022.9965652.
- Omidi, S. Arash, Geoff Rideout, and M. Tariq Iqbal. "Detailed Bond Graph Modeling of PV-Battery System." In 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), pp. 1-7. IEEE, 2022.
- Omidi, S. A., & Jamil, M. (2022, October). Design and Control of a Novel Cuk-Boost Converter Using State Space Averaging Technique with Dynamic Bond Graph Modeling. In 2022 IEEE 13th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON) (pp. 0573-0582). IEEE.
- Omidi, S. Arash, Mirza Jabbar Aziz Baig, and M. Tariq Iqbal. “Design and Implementation of Node-Red based Open-Source SCADA Architecture for a Hybrid Power System.” Energies journal, 2023.
- S. Arash Omidi, Zaid Saeed Patel, Karan Kumar Patel, Dr. M. Tariq Iqbal, “Design and Simulation of Isolated Hybrid Power System for Woody Island Resort.” Presented in International Conference on Persistent, Emerging, and Organic Pollution in the Environment (PEOPLE)2022