Design of Vehicle to Home and Vehicle to Grid Energy System for Newfoundland Conditions

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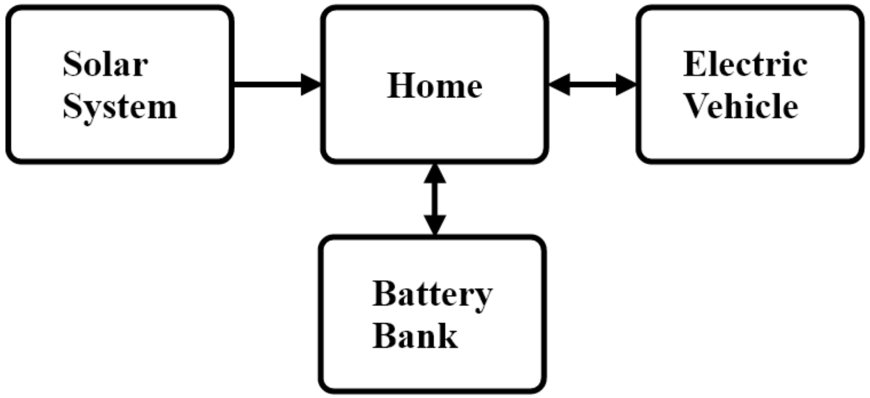
Outline

Introduction

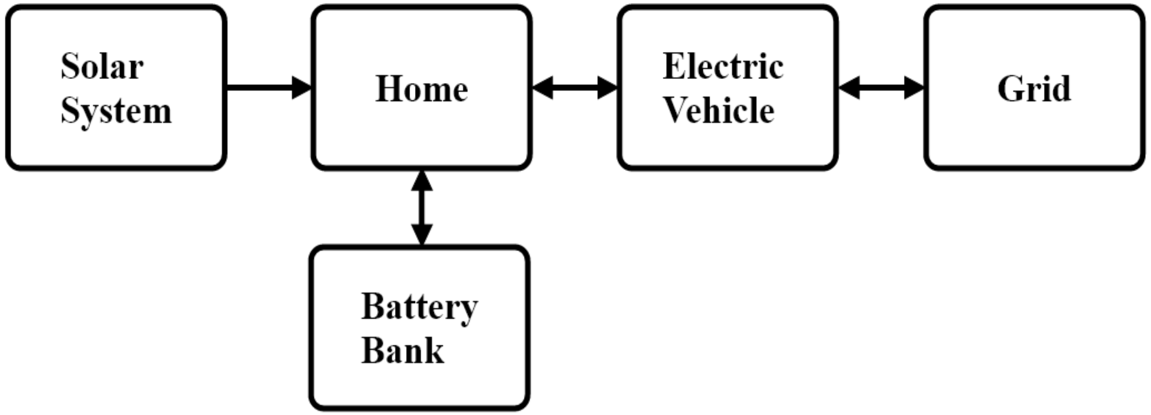
- We are now seeing a rise in interest and development of electric vehicles (EVs) and renewable energy as people become more conscious of the impact that fossil fuels and rising CO2 output have on our environment.
- Furthermore, with the recent drive for a better environment, renewable energy is increasingly being used for power generation.
- Since 2016, an increasing number of nations throughout the world have pledged to uphold the Paris Agreement, whose principal objective is to reduce greenhouse gas emissions.
- Power plants powered by renewable sources such as solar, wind, hydro, and others are projected to surpass conventional power plants powered by fossil fuels, since renewable energy is a major element in achieving the following goal.
- Electric vehicles (EVs) will eventually replace fuel and hybrid-powered cars, resulting in a completely electrified ground transportation system.
- The major benefits of electric vehicles are that they produce zero emissions when powered by renewable energy, are more powerful, quiet, and can function as mobile power banks

Introduction

- Vehicle to Home and Vehicle to Grid



Vehicle to Home (V2H)



Vehicle to Grid (V2G)

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Literature Review

Design of solar PV system for a home with V2H and V2G option

S.No	Author	Research Article	Comments
1	G. M. De Lazari	Vehicle to a Home evaluation in Brazil	Discussed the use of EV to power a residence, it also explained how implementing V2H system reduces the tariffs.
2	M. S. Shemami	Reliable and economy modes of operation for an electric Vehicle to Home (V2H) System	Discussed the two different modes of operation of V2H system, under reliability mode the system works towards maximum reliability of the standard power source. In economy mode, it focuses on maximizing the production and powering the loads.
3	M. Longo	Electric Vehicle Charged with residential's roof solar photovoltaic system : A case study in Ottawa.	Discussed about using renewable energy – PV to charge the electric vehicle to eliminate emissions
4	R. Hemmati	Mutual Vehicle-to-Home and Vehicle-to-Grid Operation Considering Solar-Load Uncertainty	Discussed the various modes of using EV to power the building and grid at the same time in V2H, V2G modes. Further, this was executed to reel power from the EV when the demand is high to cut down on the daily energy cost.
5	F.M. Shakeel	Vehicle-To-Grid Technology in a Micro-grid Using DC Fast Charging Architecture	Discussed Architecture for implementing a V2G-G2V system in a micro-grid using level-3 fast charging of Evs. . A dc fast charging station with off-board chargers and a grid connected inverter is designed to interface EVs to the microgrid.
6	N. Z. Xu	Reliability Evaluation of Distribution Systems Including Vehicle-to-Home and Vehicle-to-Grid	Discussed V2H and V2G as leverage for the improvement of distribution system reliability. Two topologies – centralized and dispersed EV charging were considered.

Literature Review

Dynamic modelling and hardware implementation of solar PV system for a home with V2H and V2G option

S.No	Author	Research Article	Comments
1	J. Gupta	A Bidirectional Home Charging Solution for an Electric Vehicle	Discussed the working of the proposed charger in V2G and G2V mode.
2	X. Wu	Stochastic Optimal Energy Management of Smart Home With PEV Energy Storage	Discussed the mode of operation of EV in V2H, V2G and G2V mode. Further, equivalent PEV battery models and trip time were used to calculate the amount of power that the EV could reel to home or grid.
3	D.C. Urcan	Integrating and modeling the Vehicle to Grid concept in Micro-Grids	Discussed a model for implementing V2G concept in a microsystem that aims to charge the electric vehicle battery based on renewable energy.
4	A. k. Verma	Grid to vehicle and vehicle to grid energy transfer using single-phase bidirectional AC-DC converter and bidirectional DC-DC converter	Discussed a configuration of a single-phase bidirectional AC-DC converter and bidirectional DC-DC converter is proposed to transfer electrical power from the grid to an electrical vehicle (EV) and from an EV to the grid while keeping improved power factor of the grid.
5	E. Stark	Adapter Implementation into Mozilla WebTThings IoT platform using JavaScript	Discussed the Web of Things standard and also explained how to create an adapter for a new device using the Things Framework, that runs on the Raspberry Pi computer.
6	T. Tavade	Raspberry Pi: Data logging IOT device	Discussed the implementation of a data logger system which will act like a fault diagnostic system for mechanical engine and log the data on the web server for remote access

Research Objective

Objective 1

- To design a PV power system for a selected house in Newfoundland, estimate load data, PV sizing, battery calculation, and size the designed system for the most optimum design.

Objective 2

- To build a dynamic model of the solar energy system for a house with V2H option in MATLAB/ Simulink and develop a control system to keep the system mode operating on different modes.

Objective 3

- To build a dynamic model of the solar energy system for a house with V2H and V2G option in MATLAB / Simulink and develop a control system to keep the system operating on different modes.

Objective 4

- To design an IoT interface for a solar energy system with a Vehicle to Home option for Newfoundland conditions.

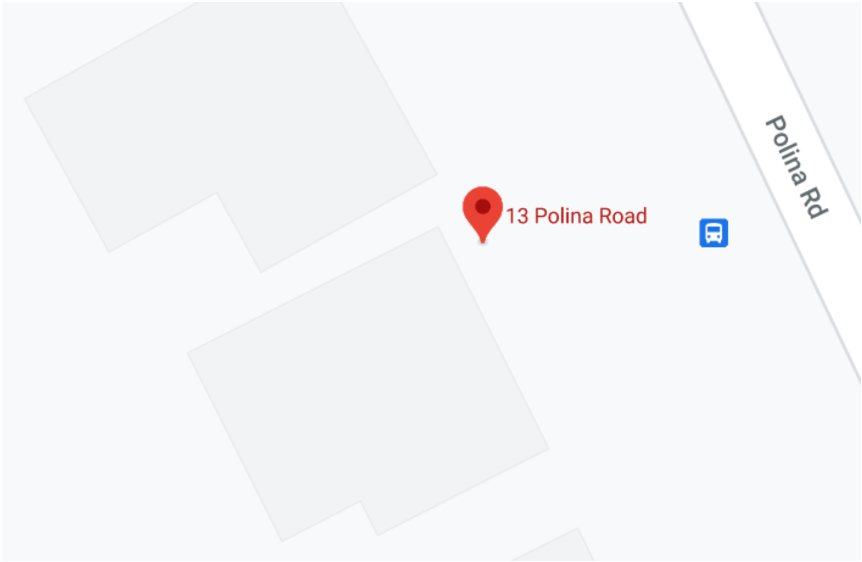
Objective 5

- To design a hardware model for solar energy system for a house in Newfoundland with V2H and V2G option using Mozilla IoT to remotely monitor and control the execution through various modes.

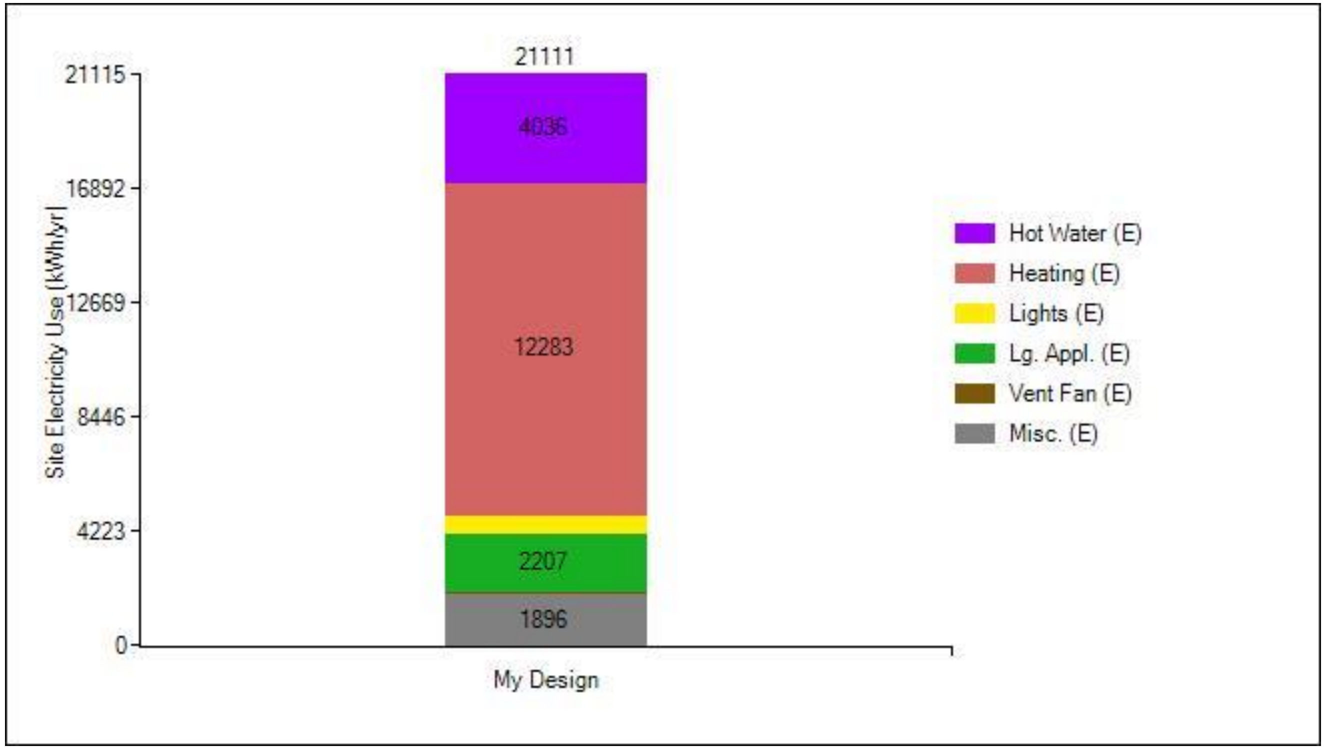
Design of PV system with V2H and V2G option

Selected Site

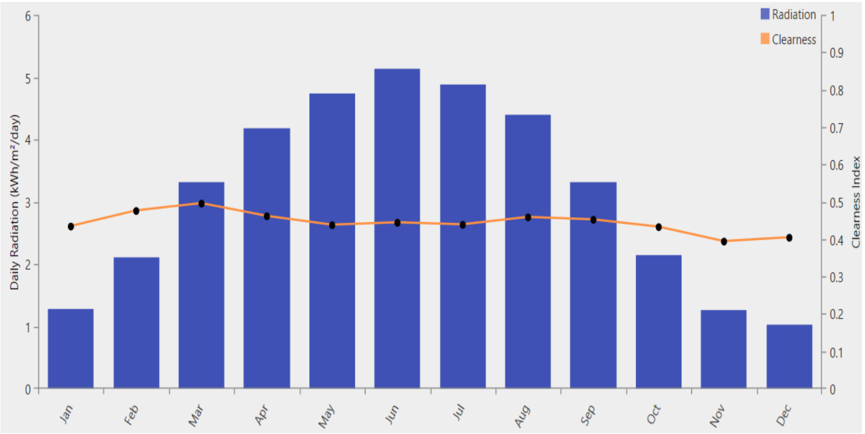
The site selected for this research was 13 Polina Road, St. John's, Newfoundland, Canada. It spans around an area of 185.89 m^2

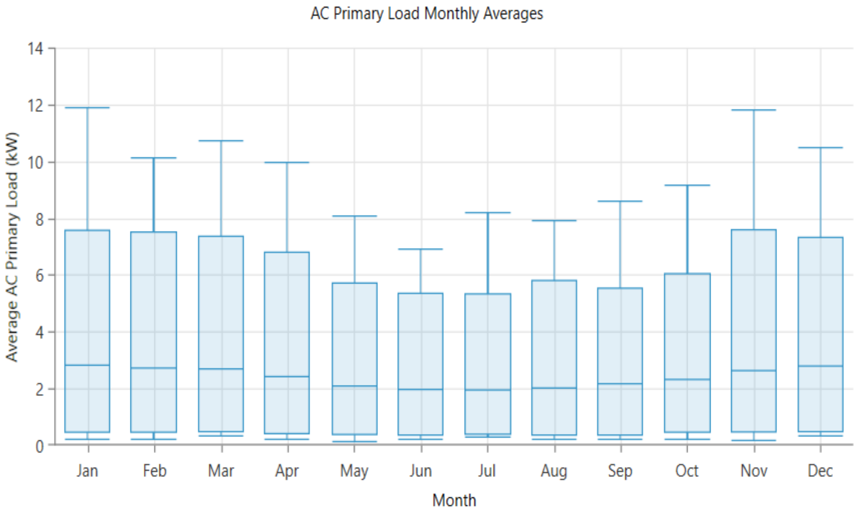


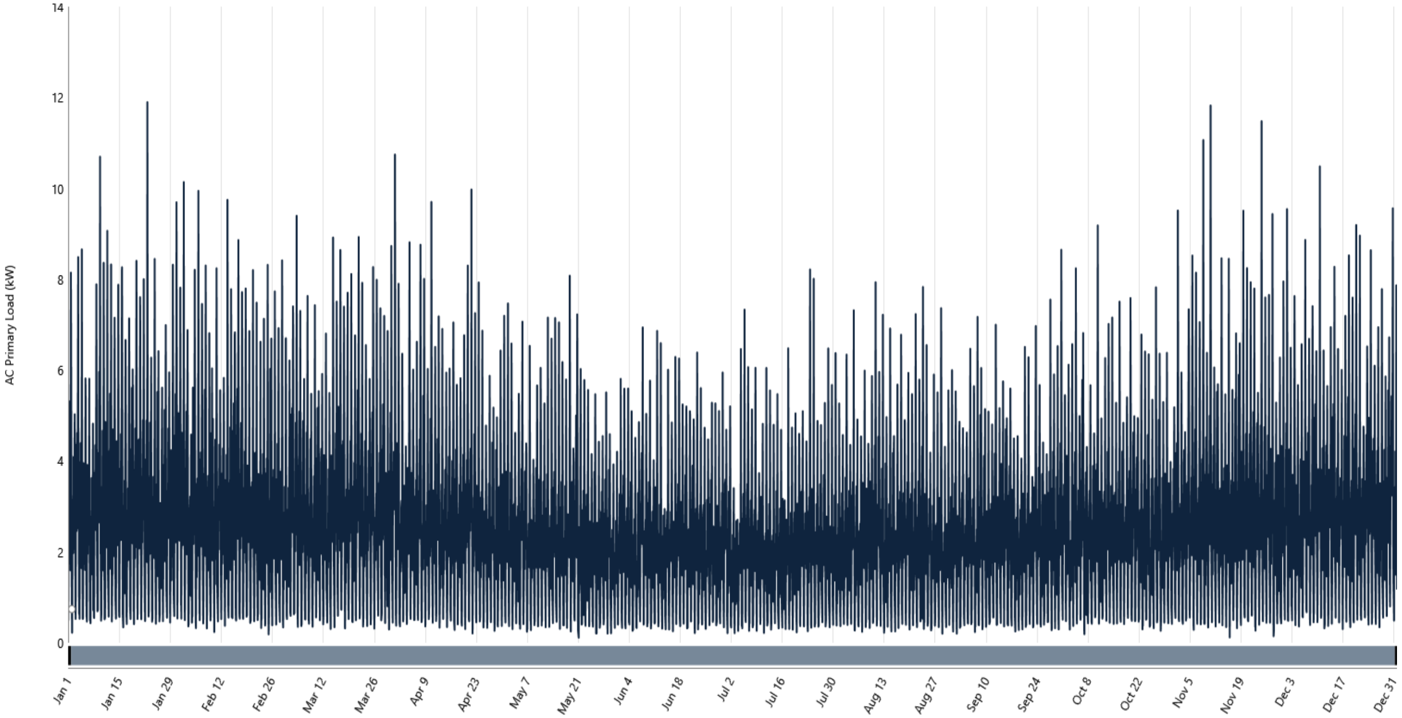
Site's Load Requirement



Solar Insolation, Annual load chart and daily load chart of the selected site







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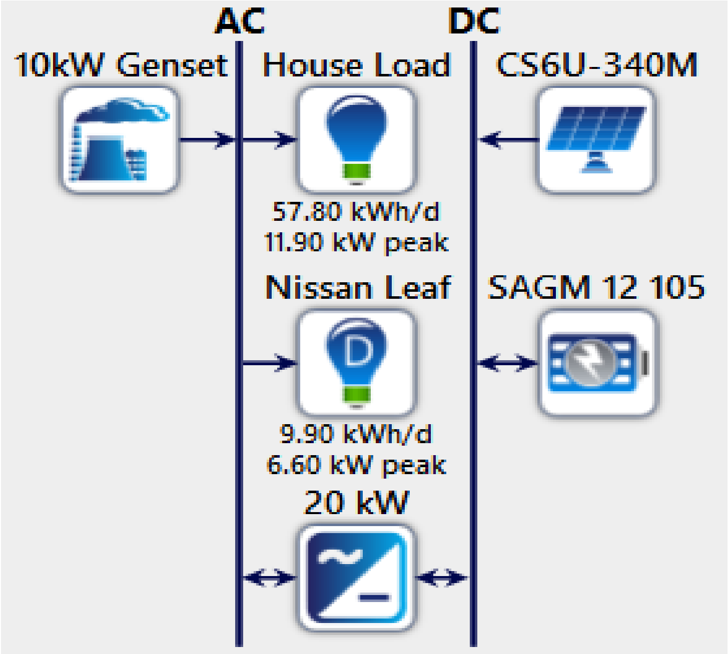
HOMER Schematic

The PV panel used is a Canadian Solar CS6U- 340M, the battery is a Trojan SAGM 12 105, the inverter is a 20 kW, 10kW genset which serves only as a backup and has no dynamic implications on the system, Nissan Leaf is added as deferrable load with 9.90 kWh/d with 6.60 kW peak and the home load profile is 57.80 kWh/d with a peak of 11.90 kW.



PV

Canadian Solar CS6U – 340M

PV array size = 48 Modules

Area needed = 90.24m^2

Area available = 185.89 m^2

Bus voltage = 48 V

Number of strings = 24 Strings

Panels per string = 2

Battery

Trojan SAGM 12 105

Wh/day= 57804 Wh/day

3 days = 57804 × 3 = 173413 Wh

40% DOD =173413/0.4 = 433532.5

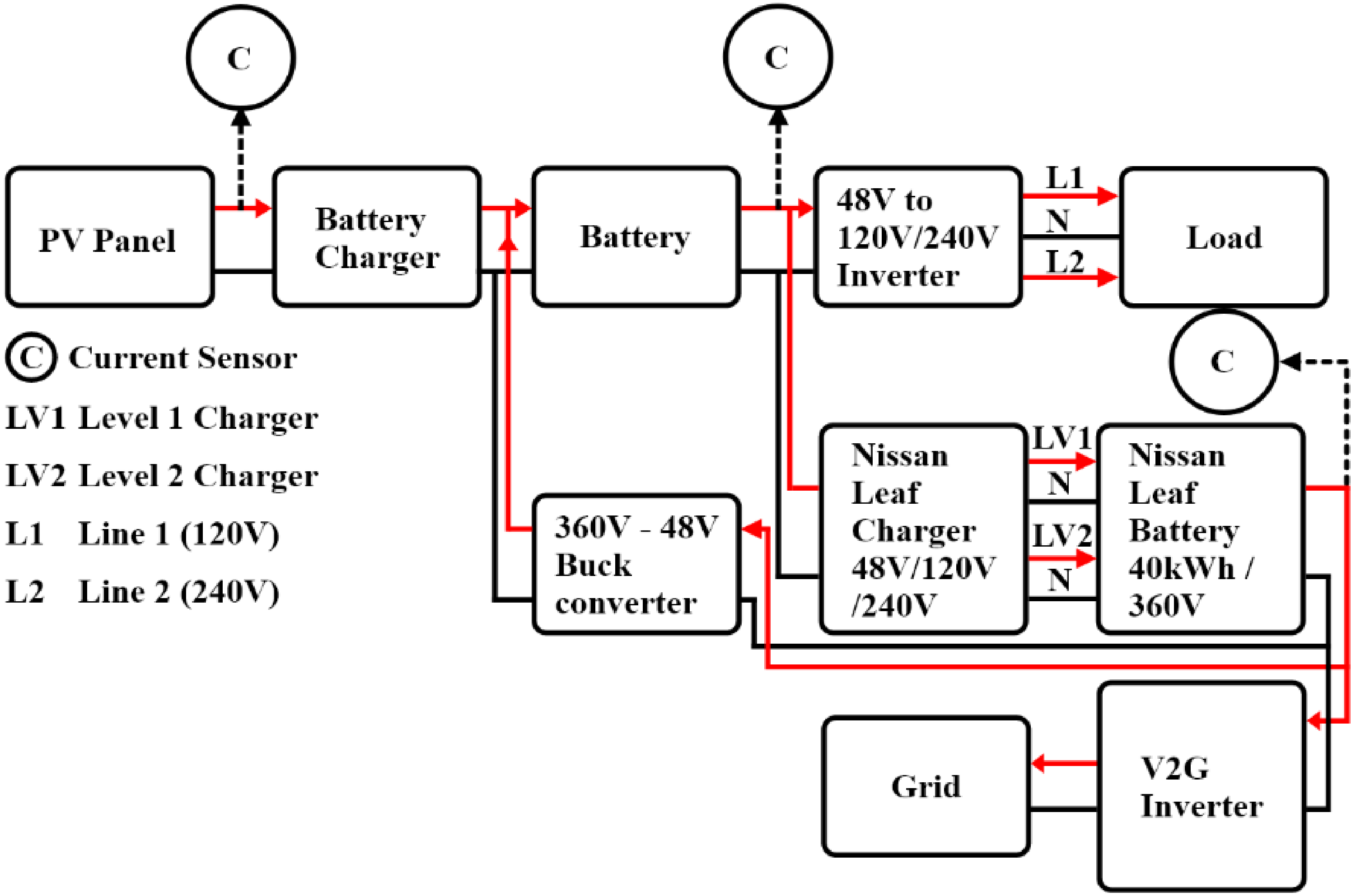
WhTemp Cons (> 80F) = 433532.5 × 1= 433532.5 Wh

Ah cap of Bt bank =433532.5/48 = 9031.92 Ah

Number of Batteries = (9031.92/100)×4=360 Nos.

Nissan Leaf

Overall Block diagram of PV system with V2H and V2G option



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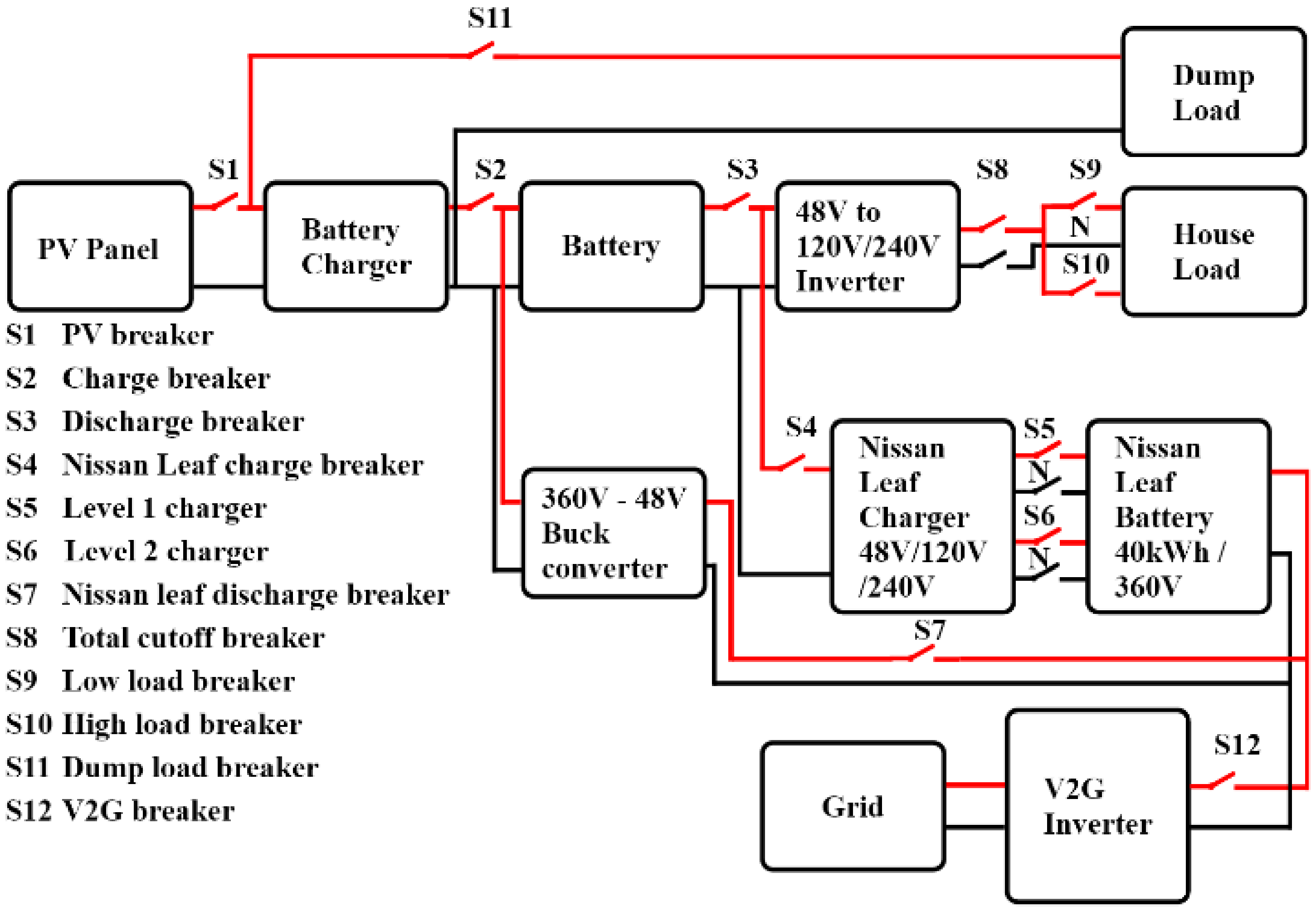
Switching control logic of PV system with V2H and V2G Option



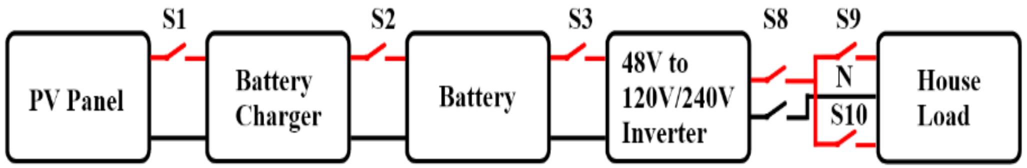
Control Logic of Simulated System

MODES	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Mode 1	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
Mode 2	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
Mode 3 (Level 1)	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
Mode 3 (Level 2)	ON	ON	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
Mode 4	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF
Mode 5	-	ON	ON	-	-	-	-	-	-	-	-	OFF
Mode 6	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	-	-	OFF	OFF
Mode 7	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
Mode 8 (Level 1)	OFF	OFF	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
Mode 8 (Level 2)	OFF	OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
Mode 9	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON

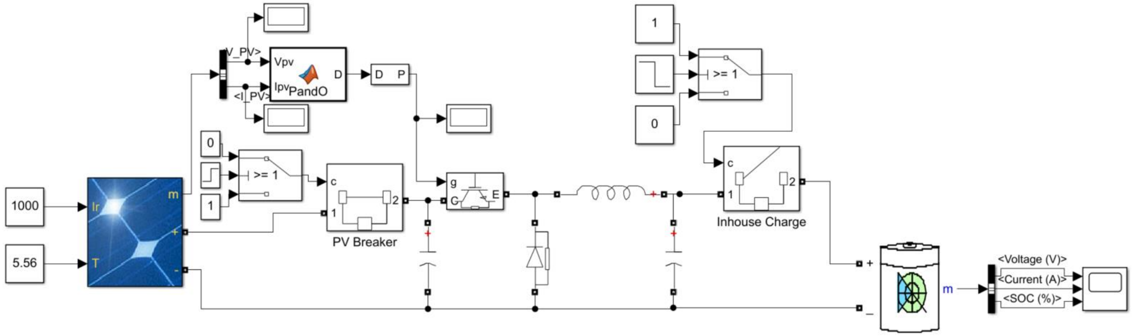
Mode 1 – Inhouse battery charge mode

In this mode the output from PV is used for charging the inhouse battery and for powering the loads. In this case the loads energy demand is low.

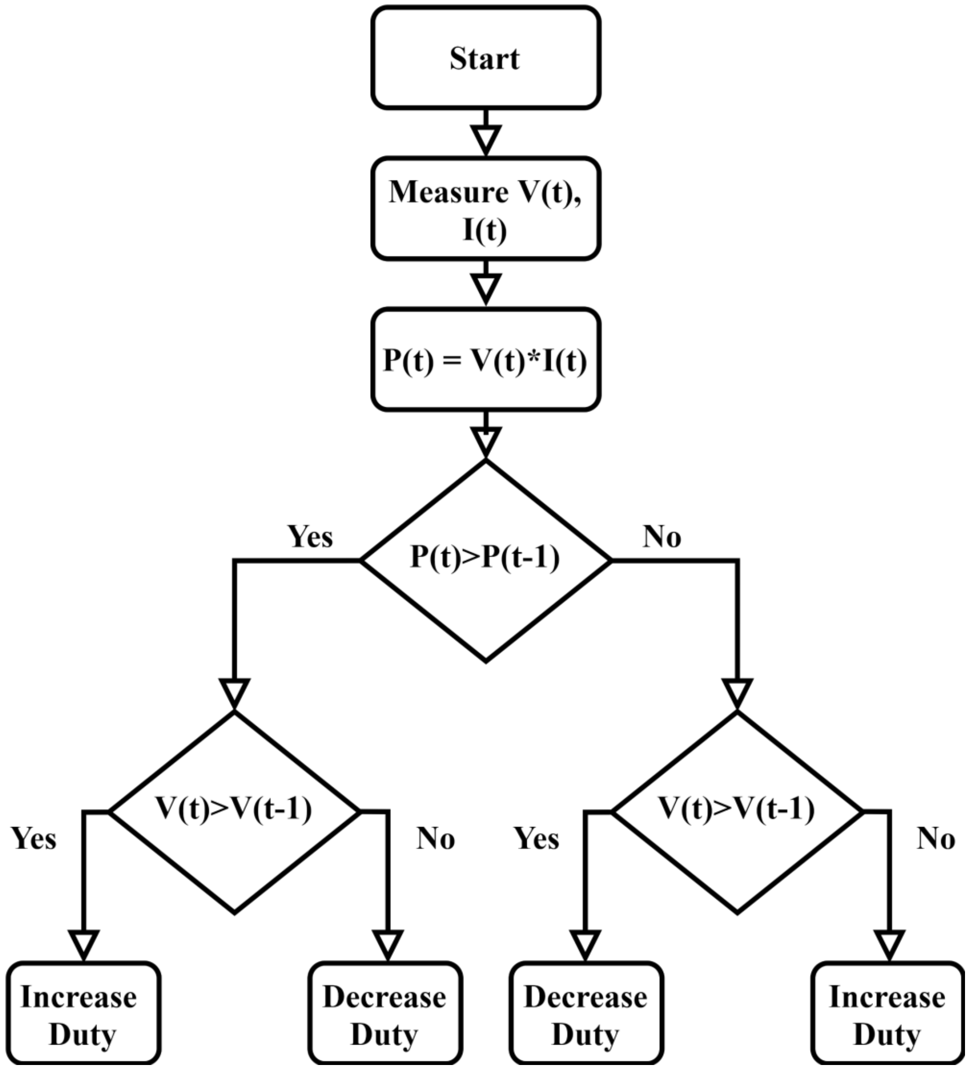
Switches	S1	S2	S3	S8	S9
Mode 1	ON	ON	ON	ON	ON



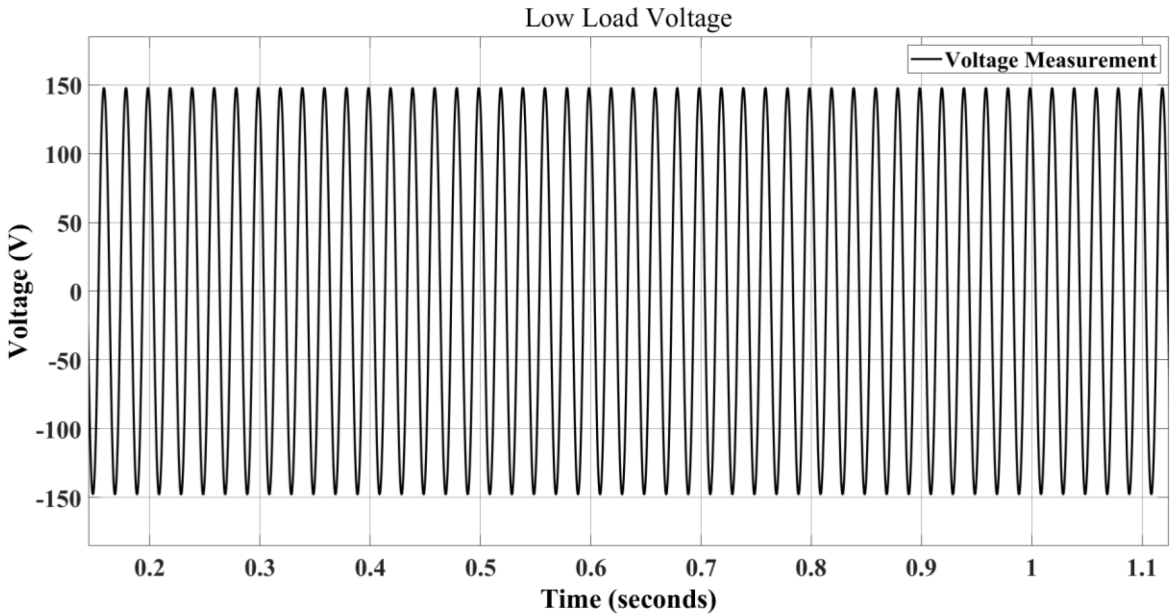
S1 PV breaker S2 Charge breaker S3 Discharge breaker S8 Total cutoff breaker
S9 Low load breaker

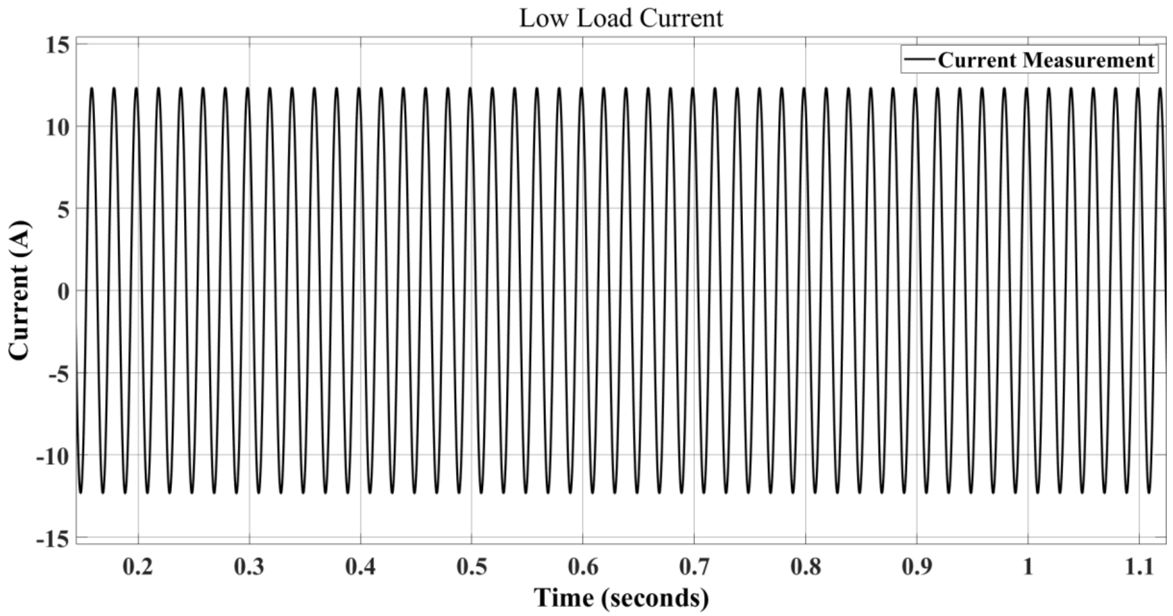


MPPT Algorithm



Mode 1 - Inhouse battery charge mode





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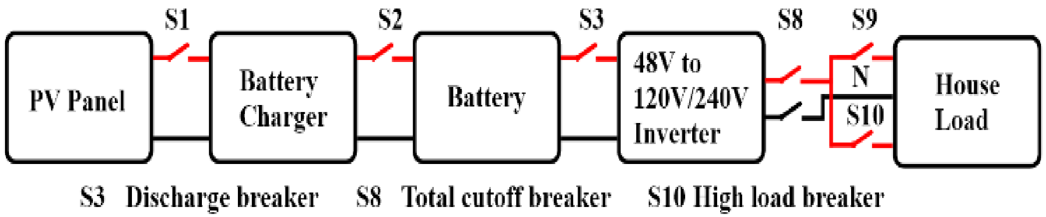
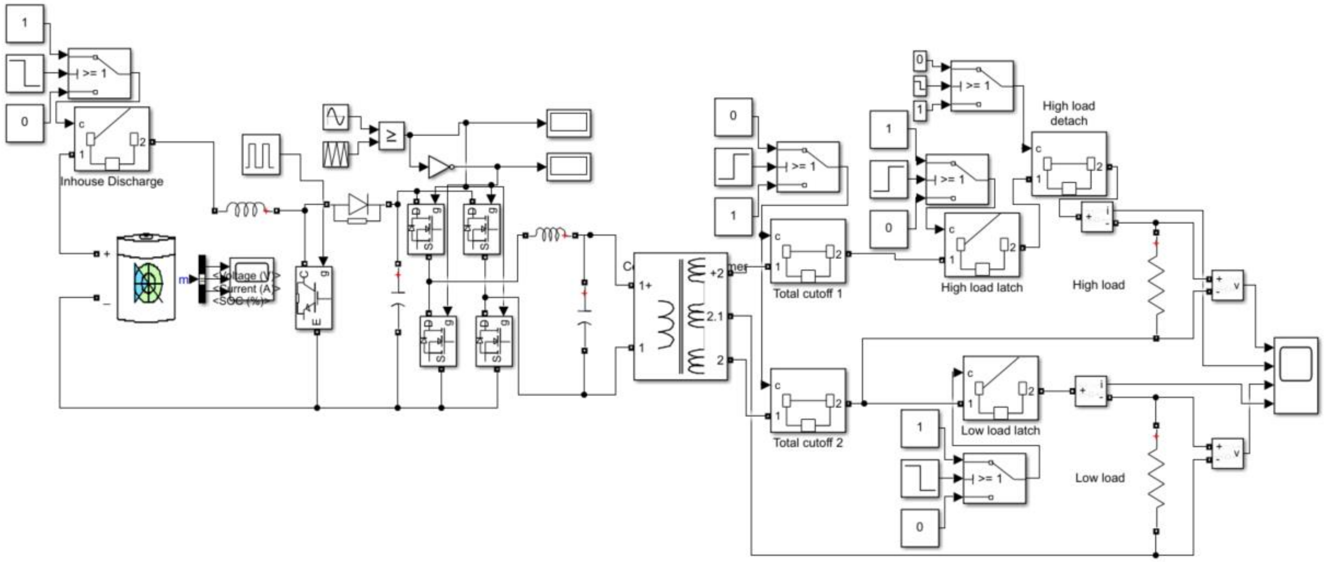
Mode 2 – Inhouse battery discharge mode

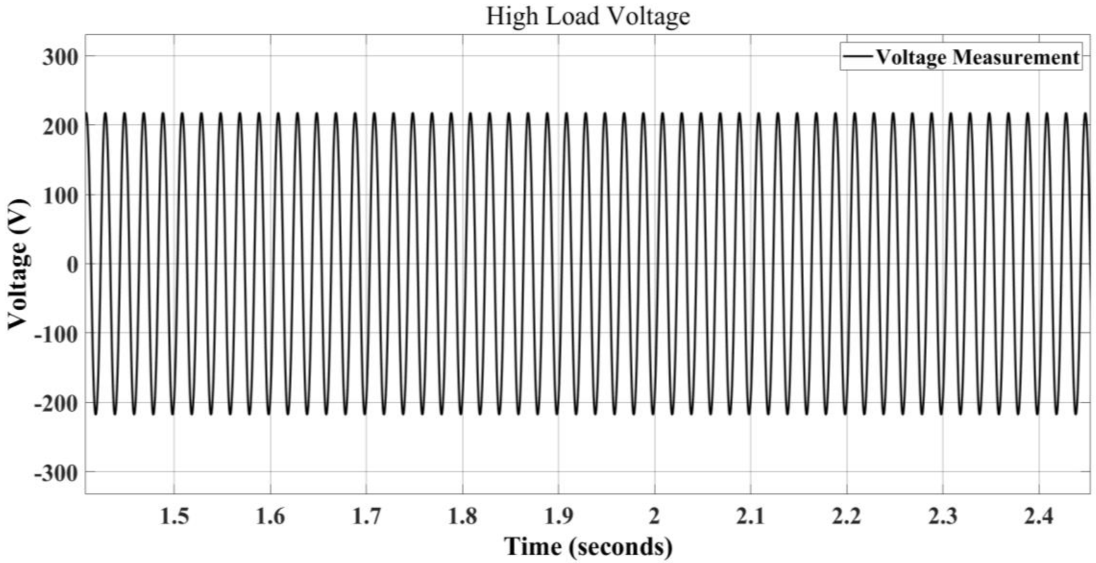
In this mode the output from PV is low compared to the load's energy demand. In this case the inhouse battery is used to power the load.

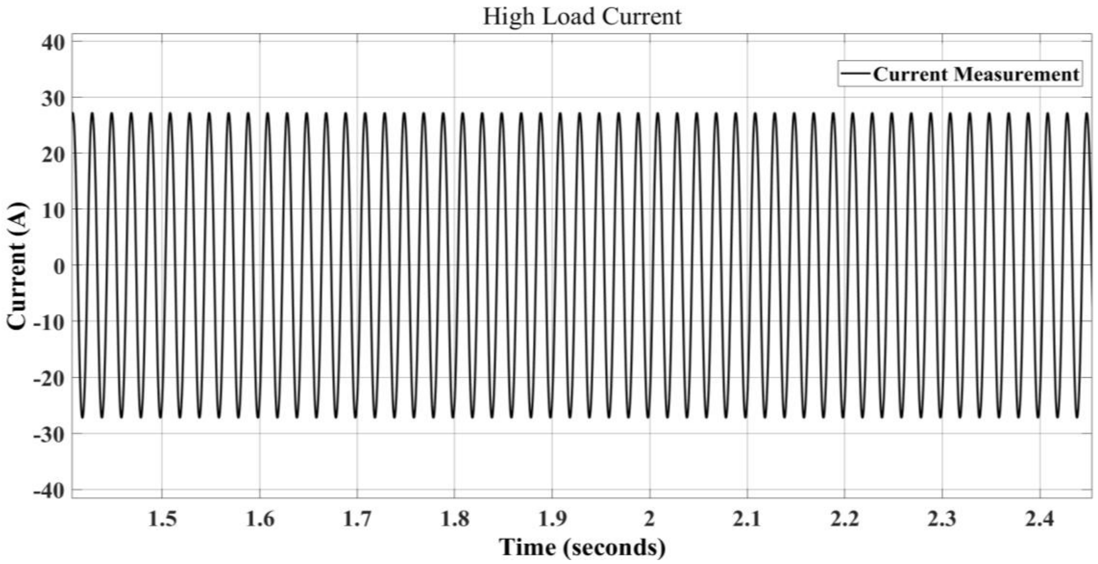
Switches	S3	S8	S10
Mode 2	ON	ON	ON





Mode 2 – Inhouse battery discharge mode

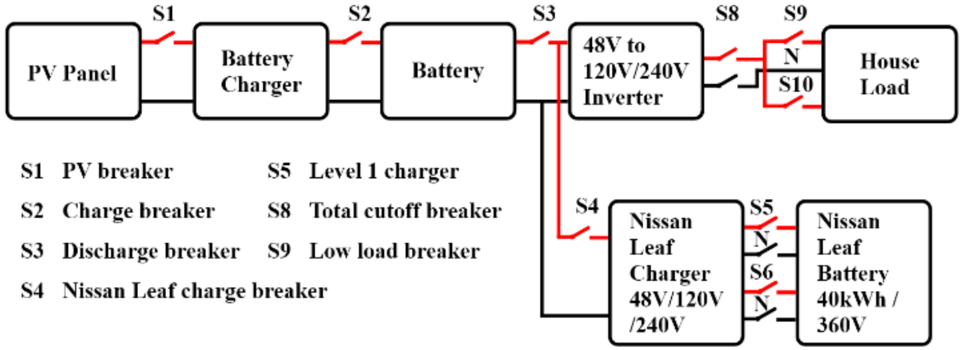




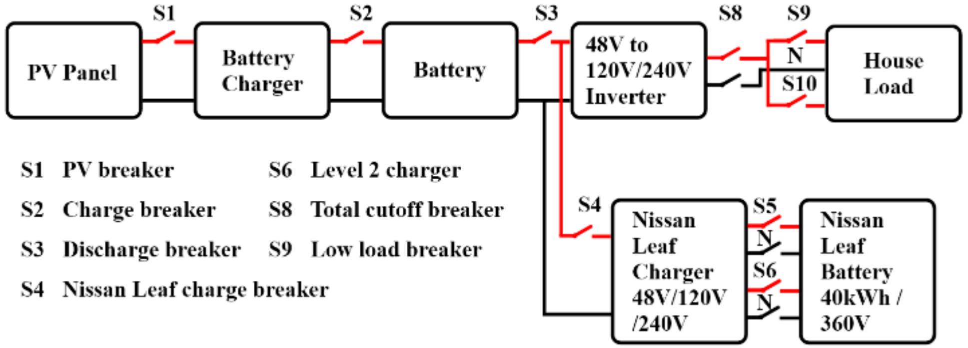
Mode 3 – Nissan Leaf charge mode

In this mode output from PV is higher than the loads energy demand and the inhouse batteries SOC is greater than 60%, the system will charge Nissan Leaf battery. The implemented charger also comprises of level 1 (120V, 14 A) and level 2 (240V, 20A) charging.

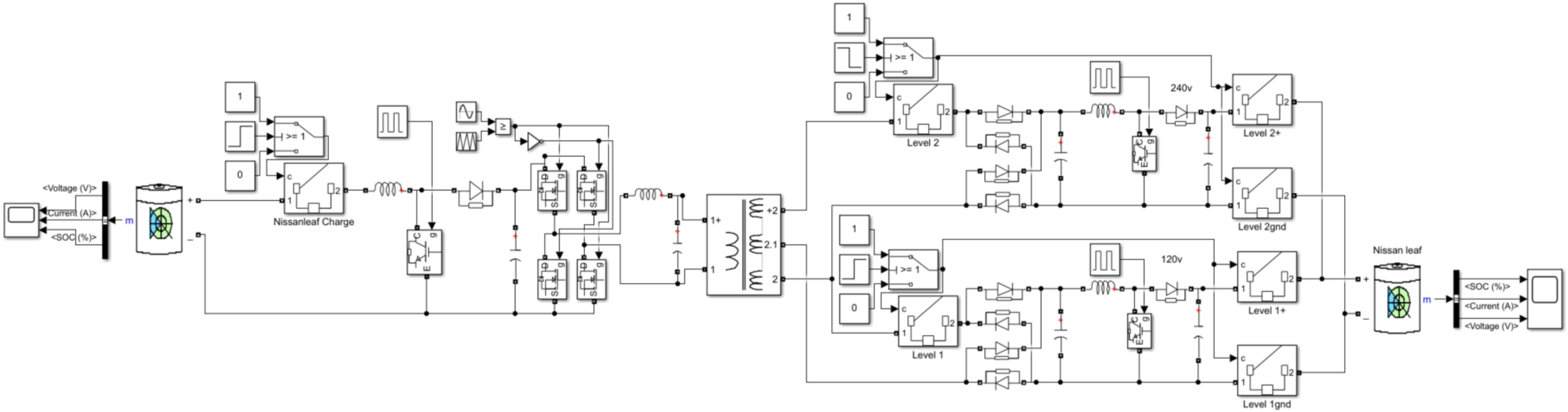
Switches	S1	S2	S3	S4	S5	S8	S9
Mode 3 Level 1	ON	ON	ON	ON	ON	ON	ON



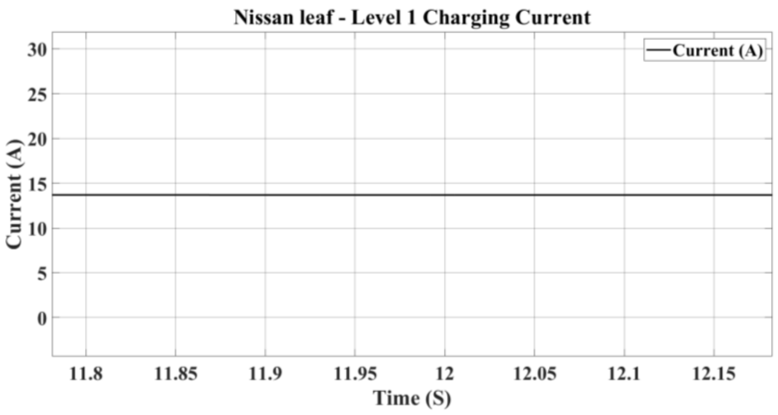
Switches	S1	S2	S3	S4	S6	S8	S9
Mode 3 Level 2	ON	ON	ON	ON	ON	ON	ON

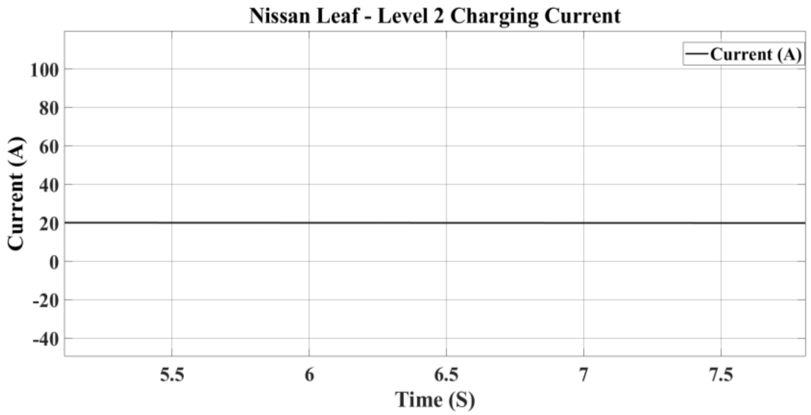


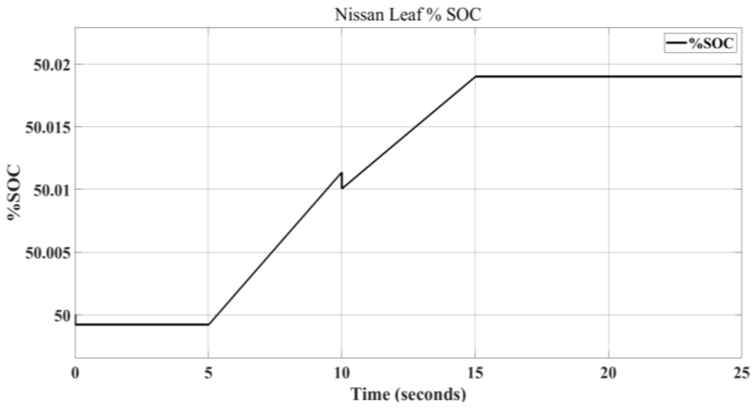
Mode 3 – Nissan Leaf charge mode



Mode 3 – Nissan Leaf charge mode



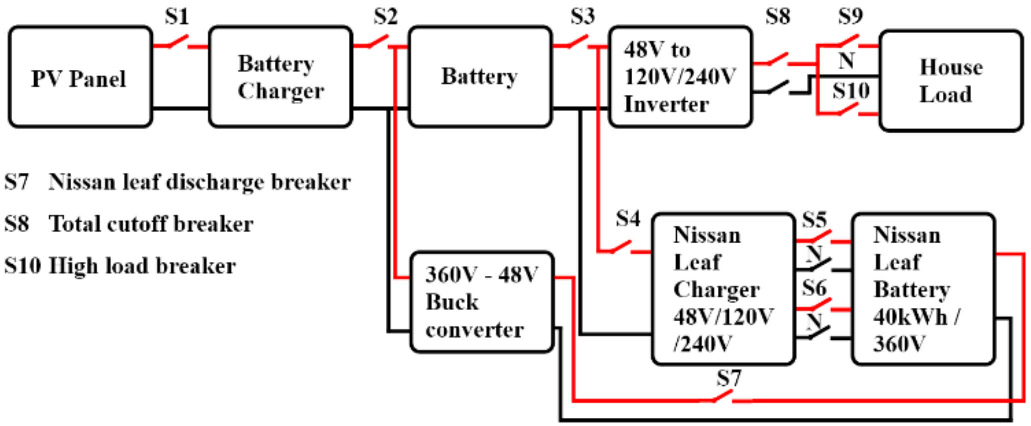


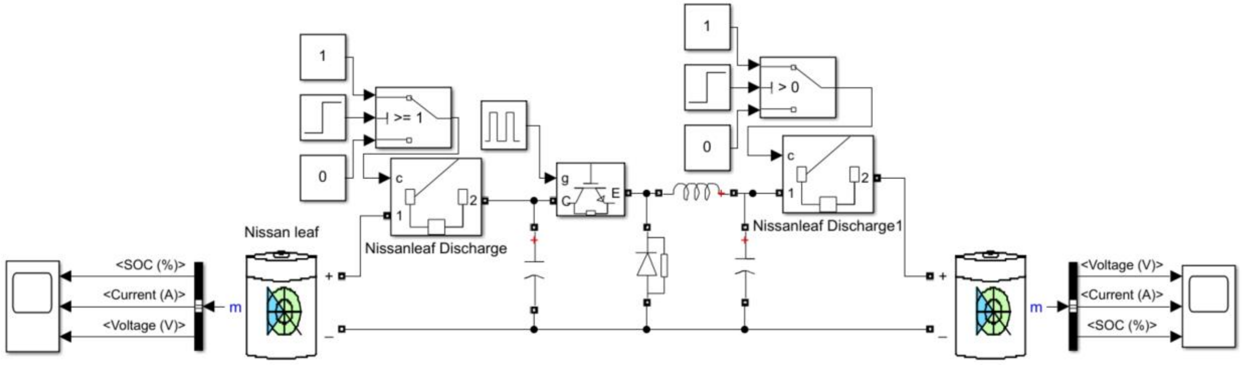


Mode 4 – Nissan Leaf discharge mode

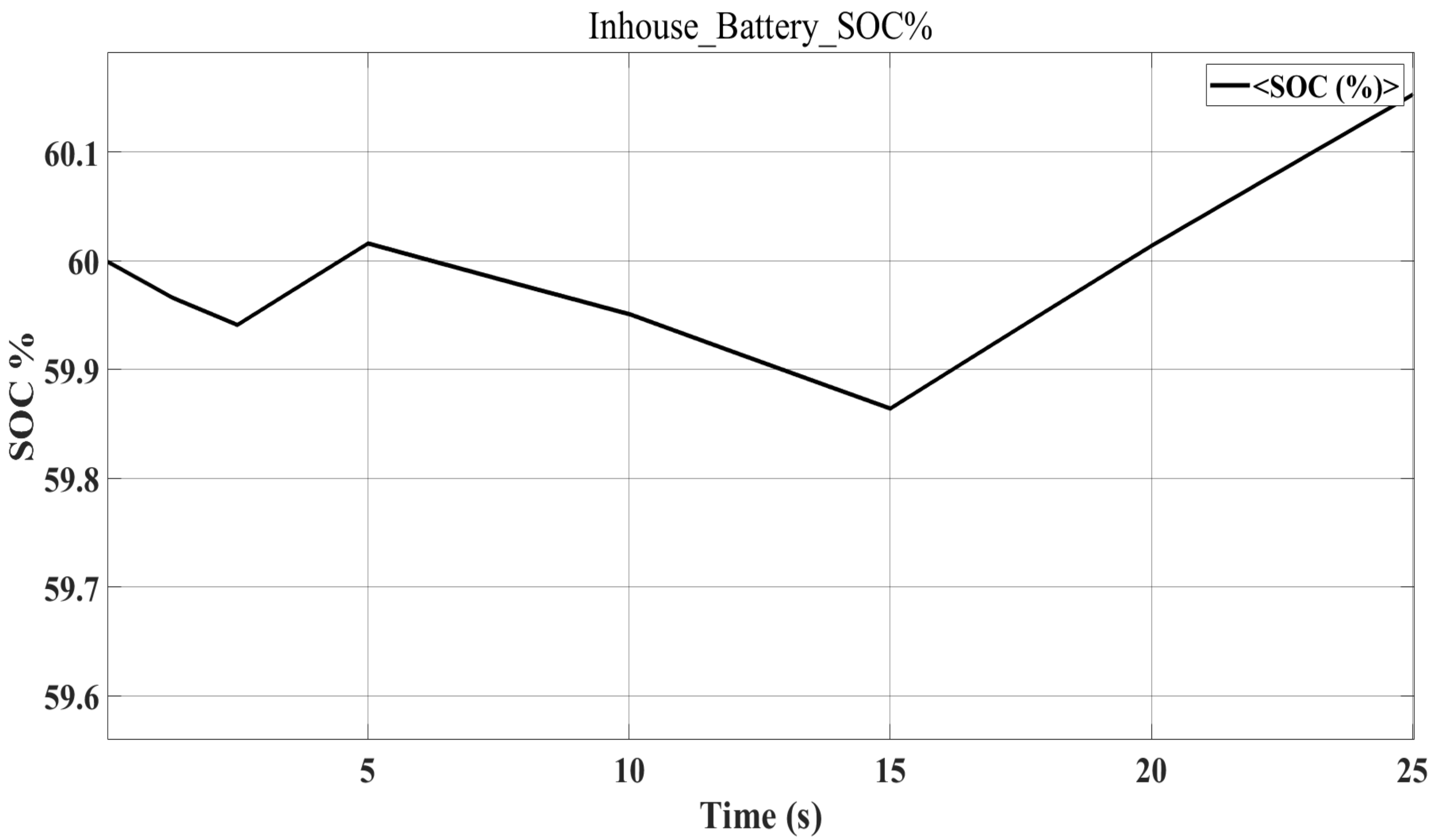
In this mode output from PV is less than the loads energy demand and the inhouse batterie SOC is less than 30%, in this case Nissan Leaf is reels out the stored power to the house to meet the loads energy demand.

Switches	S7	S8	S10
Mode 4	ON	ON	ON





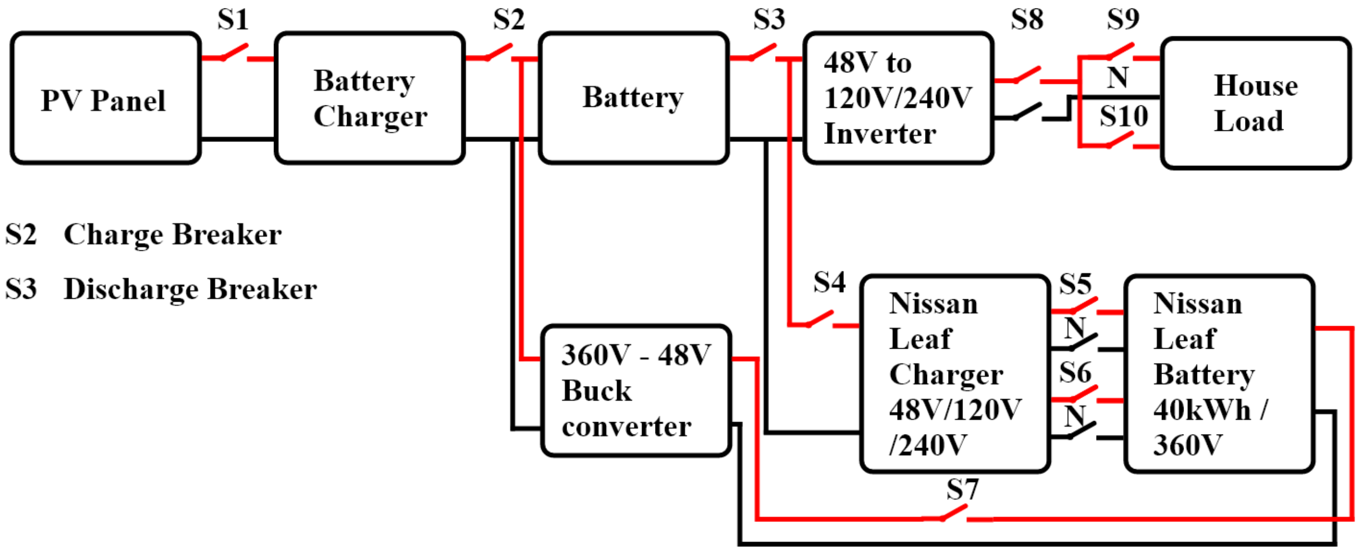
Mode 4 – Nissan Leaf discharge mode



Mode 5 – Inhouse battery protection mode

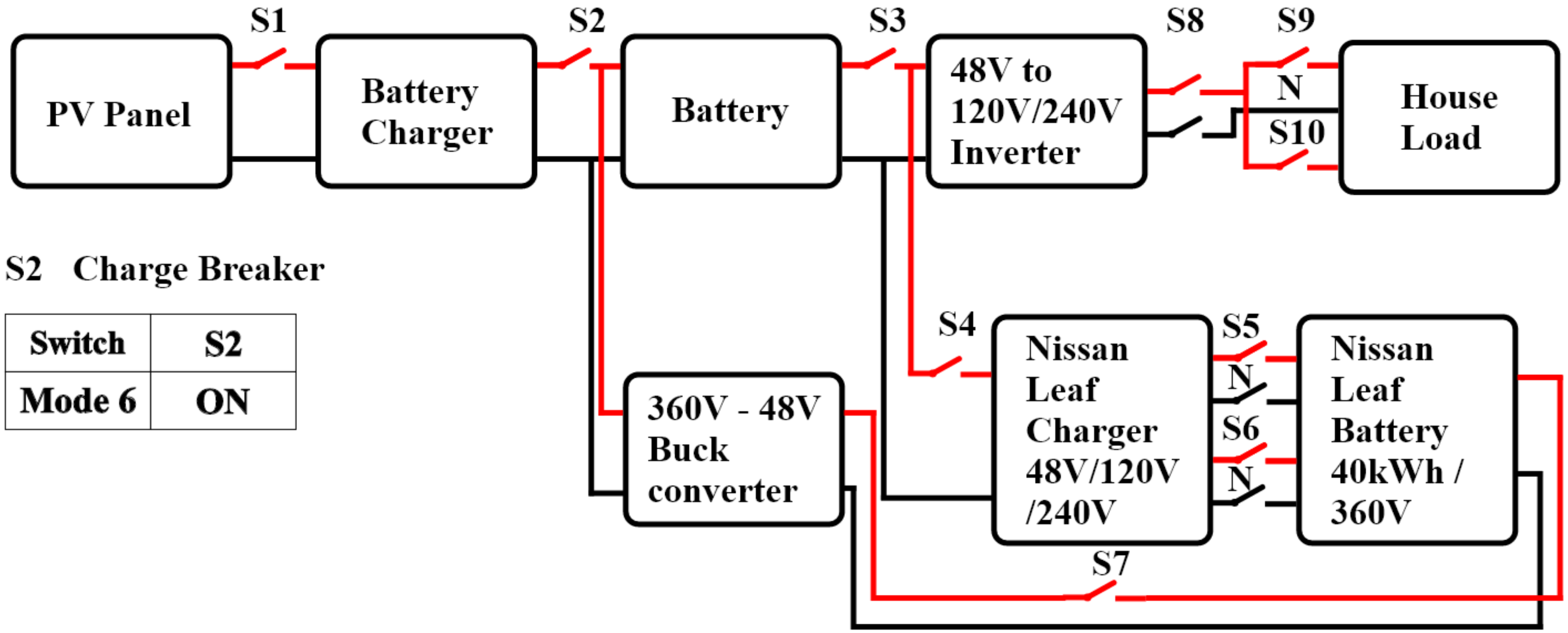
This mode is incorporated to help in saving the inhouse battery by monitoring the SOC of the battery. When inhouse batteries SOC falls to 30% SOC, the 30%SOC breaker goes HIGH and the 30% SOC charge on breaker goes HIGH to charge the battery.

Switches	S2	S3
Mode 5	ON	ON



Mode 6 – System isolation mode

In this mode output from PV is less than the loads energy demand, the inhouse batteries SOC is less than 30% and the Nissan leaf SOC is less than 40%, [21] the total cutoff breaker is turned ON



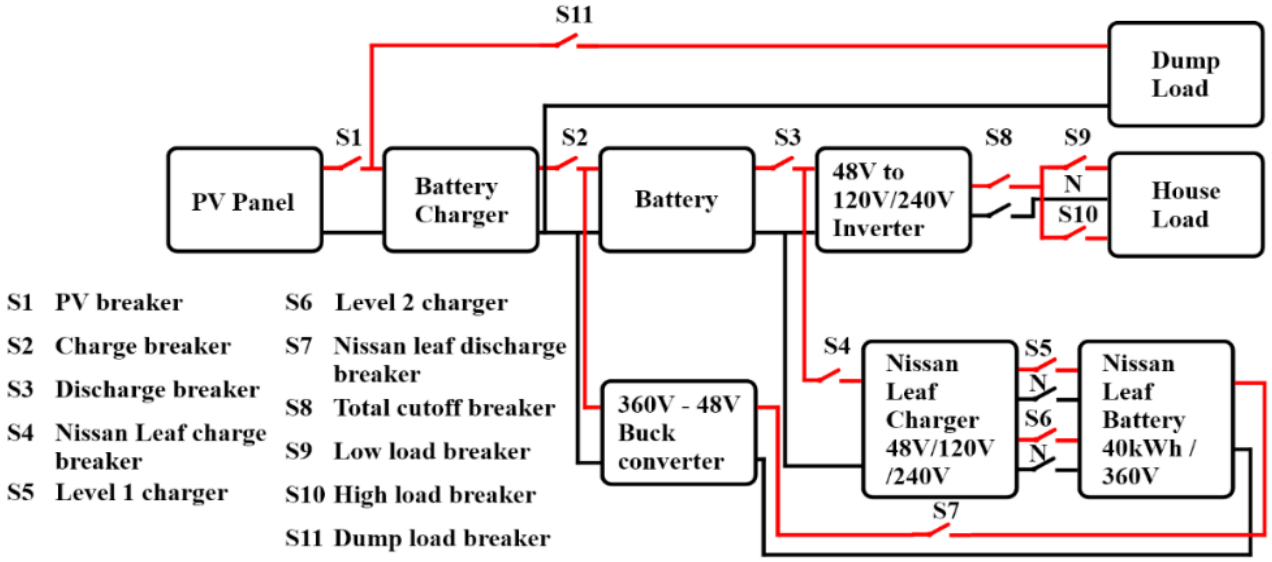
S2 Charge Breaker

Switch	S2
Mode 6	ON

Mode 7 – Excess power handling mode

In this mode the power produced from PV is higher than the loads energy demand, the inhouse battery and Nissan Leaf's battery is charged, a dump load is implemented to dissipate the excess power.

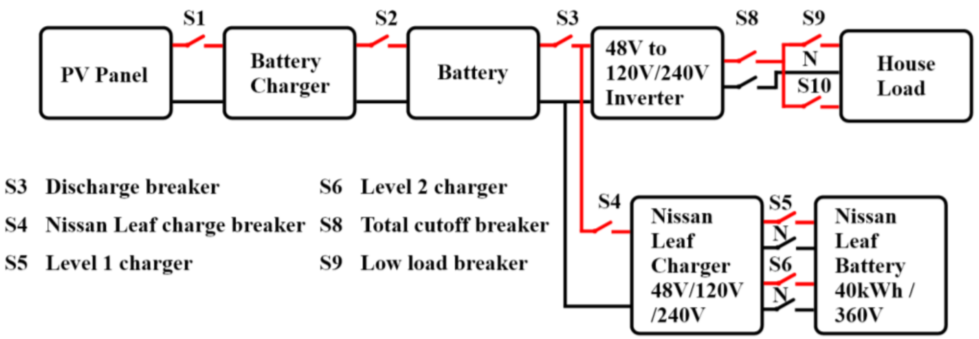
Switches	S1	S11
Mode 7	ON	ON

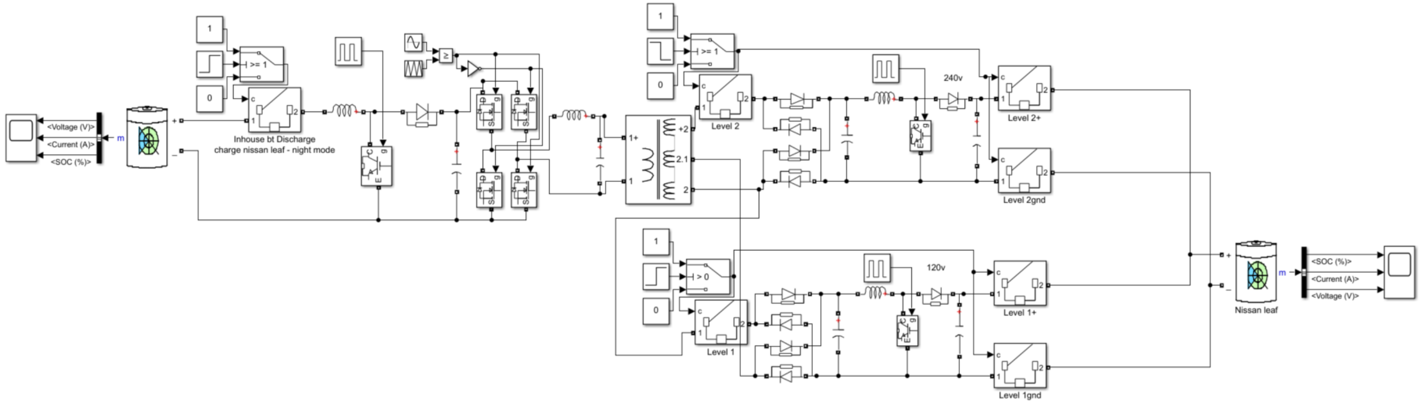


Mode 8 – Nighttime Charging mode

In this mode is the power stored in the inhouse battery is used to charge Nissan leaf's battery at nighttime when the loads energy demand is considerably less and the inhouse batteries SOC is greater than 60%.

Switches	S3	S4	S5	S8	S9
Mode 8 Level 1	ON	ON	ON	ON	ON
Mode 8 Level 2	ON	ON	ON	ON	ON





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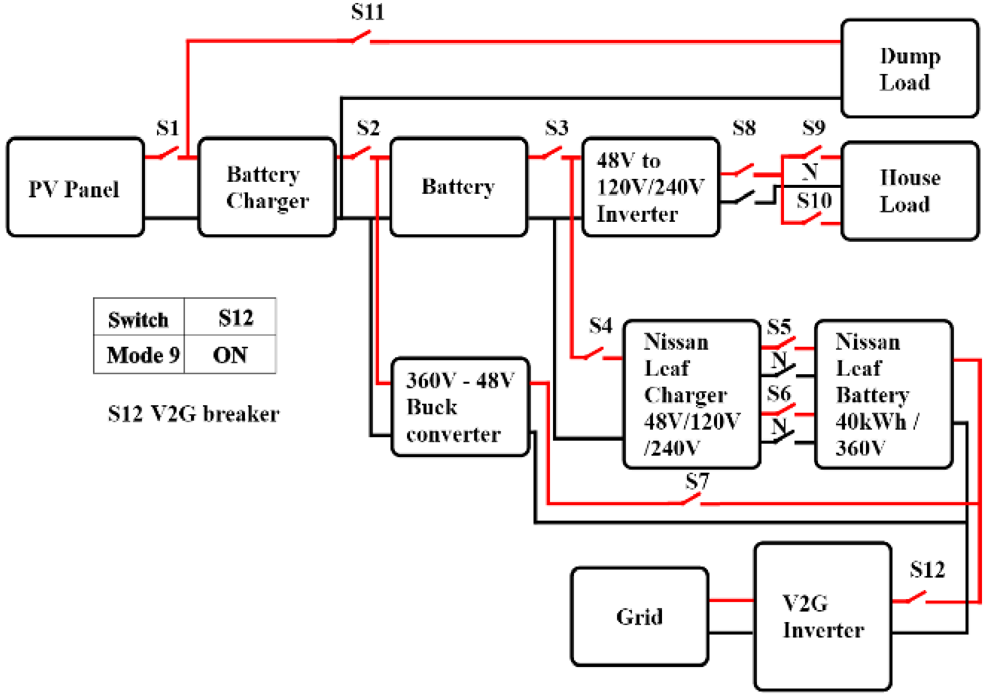
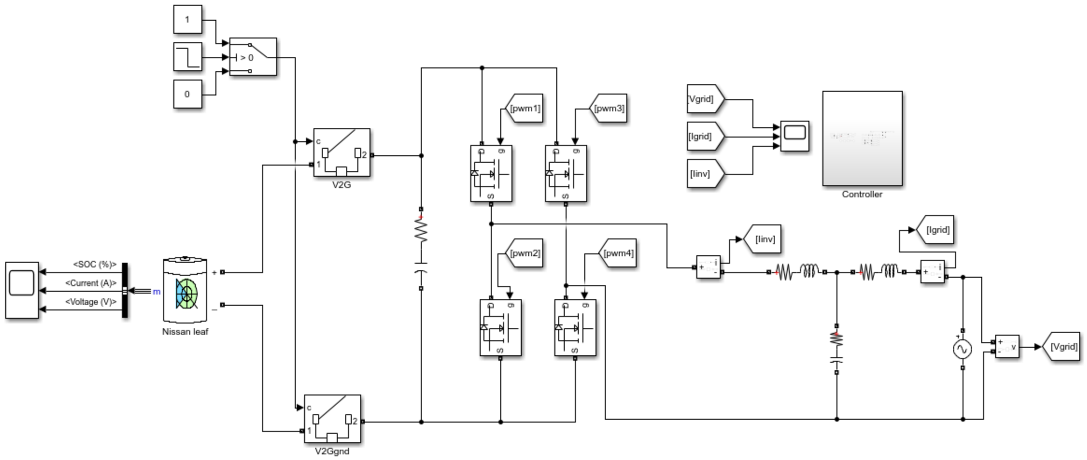
Mode 9 – Vehicle to Grid (V2G)

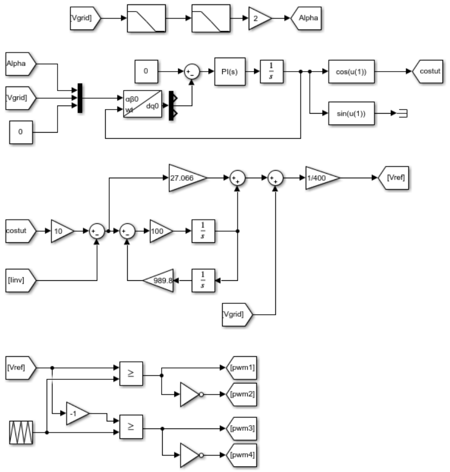
In this mode the vehicle isolates itself from home and reels power to the grid.



Switch	S12
Mode 9	ON

S12 V2G breaker





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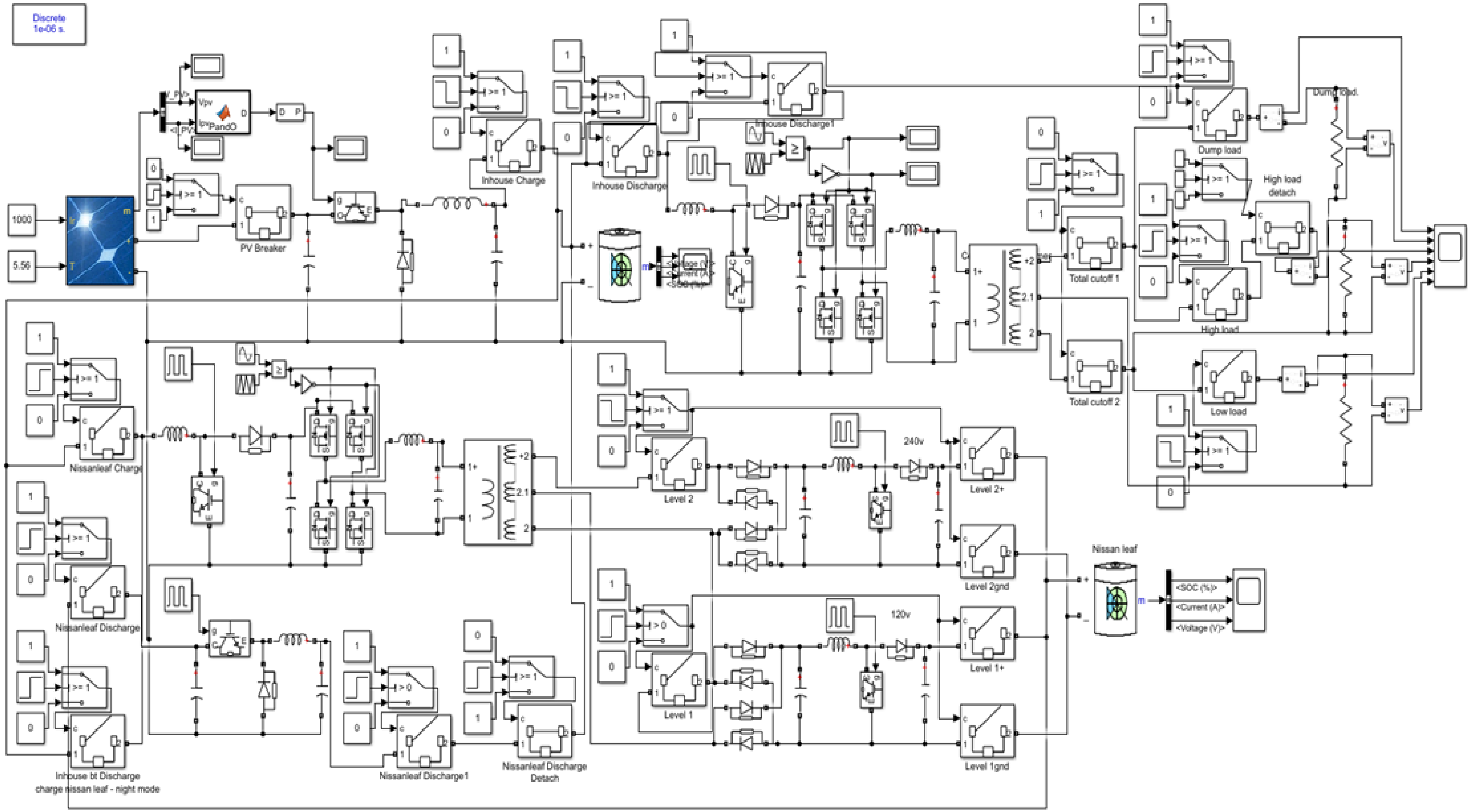
Dynamic Modelling of V2H system

- MPPT
- Battery Charger
- Inverter
- Level 1 and level 2 EV charger
- DC-DC converter
- Switching logic



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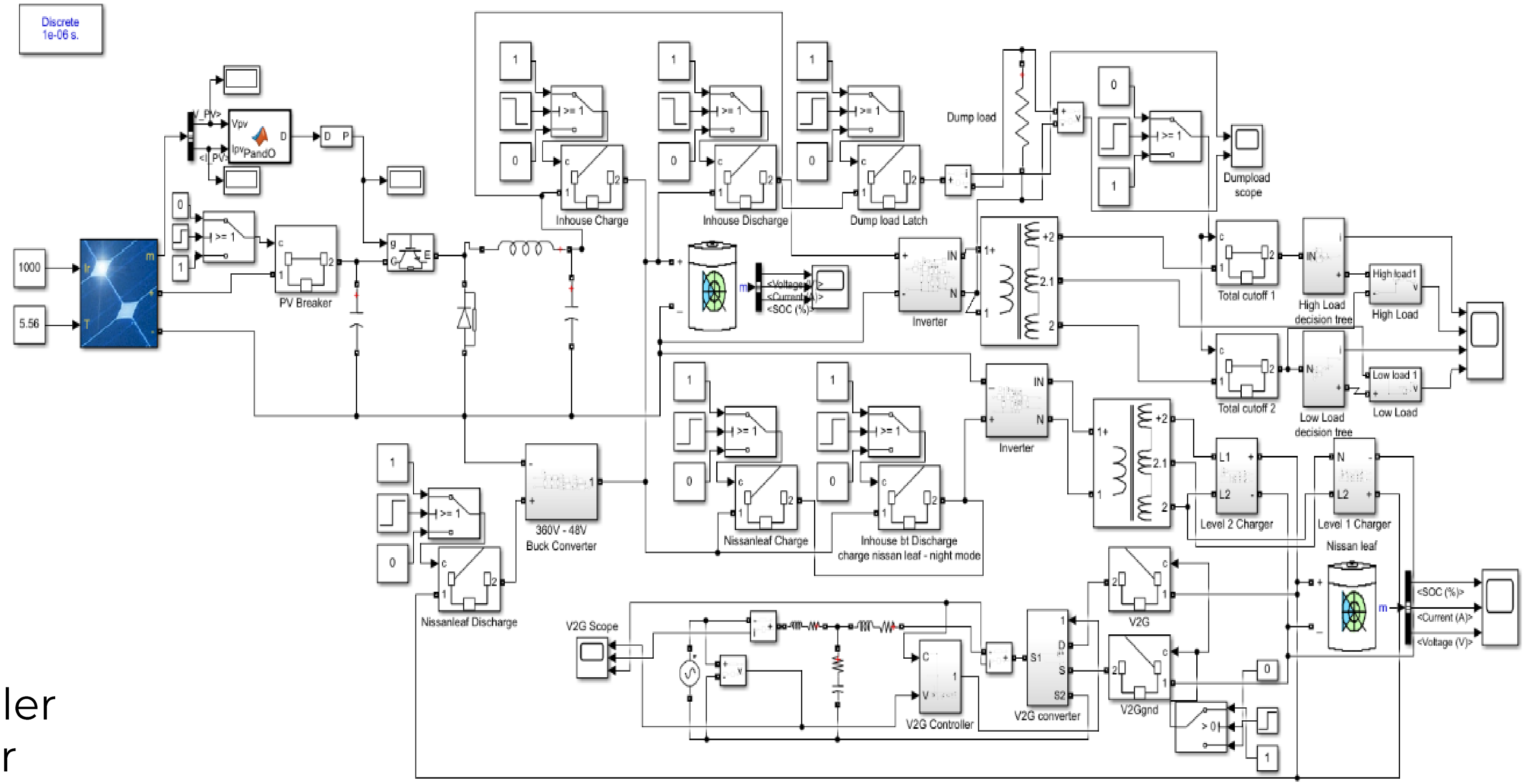
Dynamic Modelling of V2H and V2G system

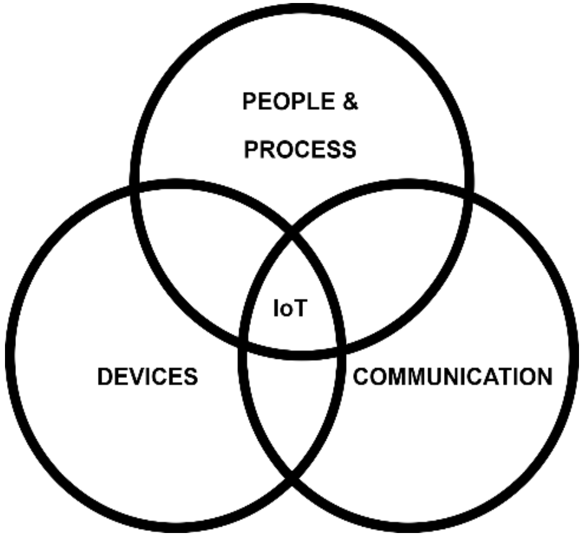
- MPPT
- Battery Charger
- Inverter
- Level 1 and level 2 EV charger
- DC-DC converter
- Switching logic
- V2G controller
- V2G Inverter



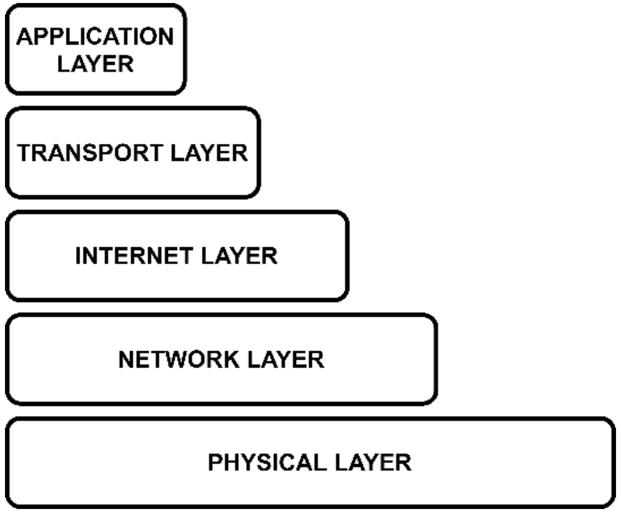
IoT

“ The Internet of Things (IoT) is a framework in which a network of physical things, such as devices, buildings, and vehicles, are connected with electronics, software, and sensors to give unique identities and the capacity to send data across a network.”

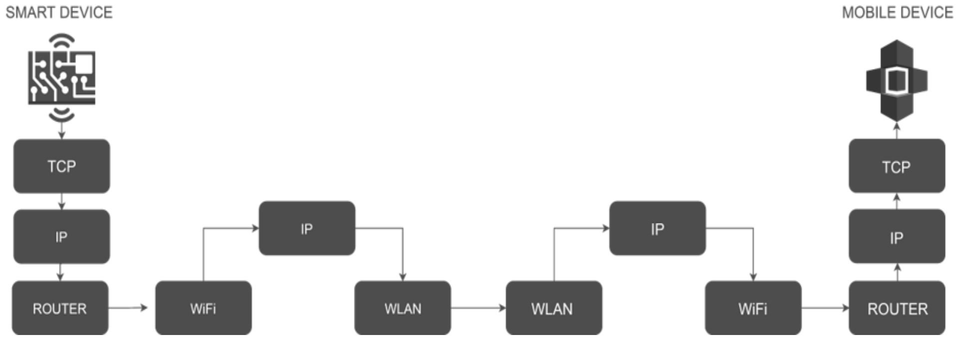
Pillars of IoT



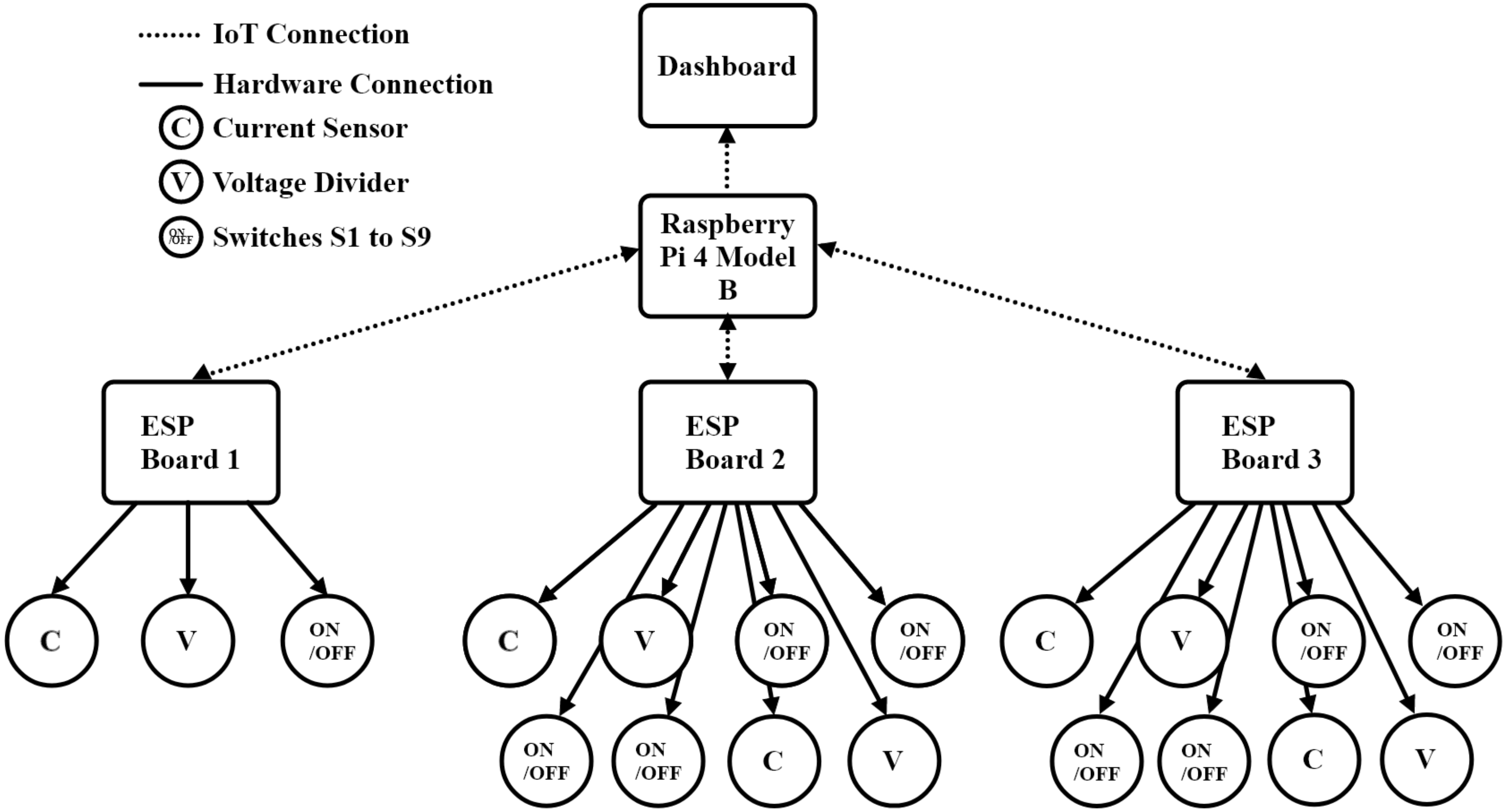
Layers of IoT



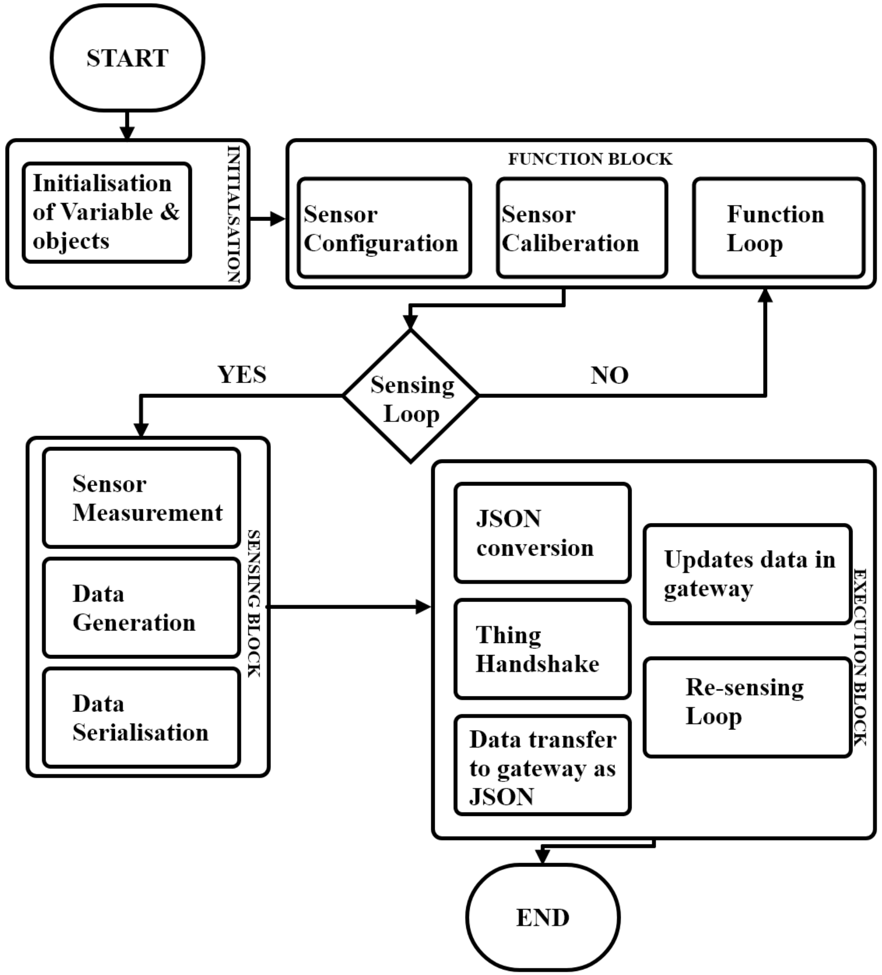
Information flow in IoT



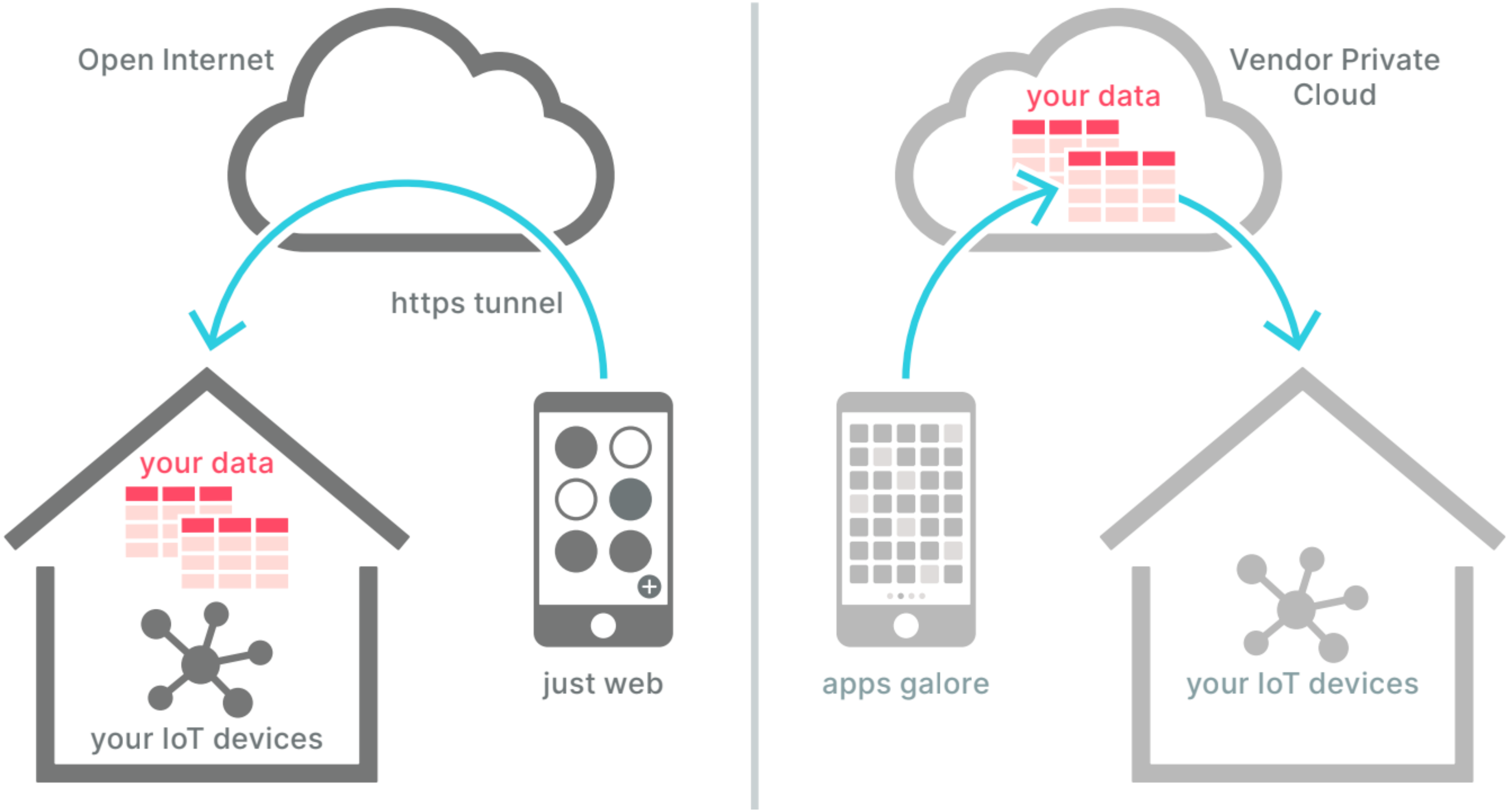
Implemented system – Block diagram



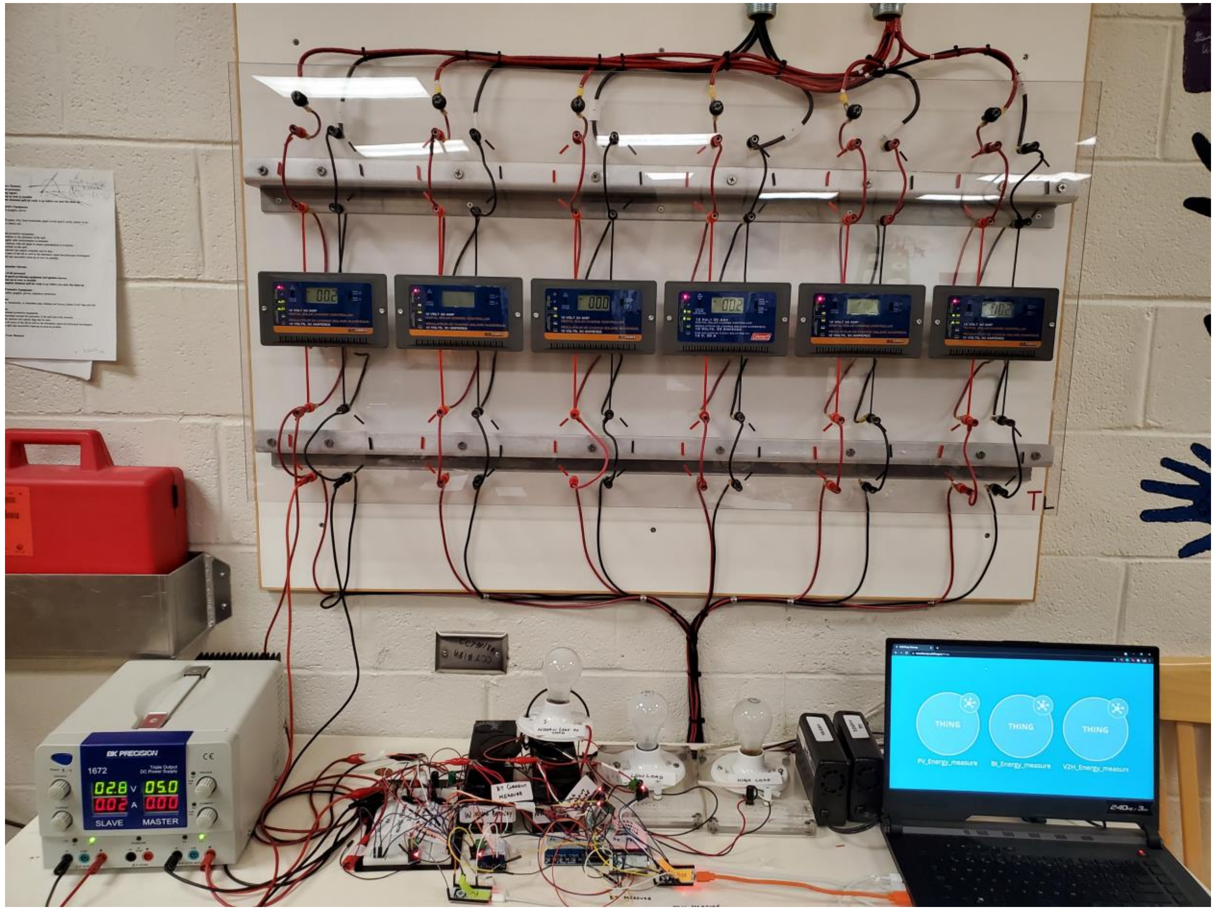
Overall Sensing Algorithm

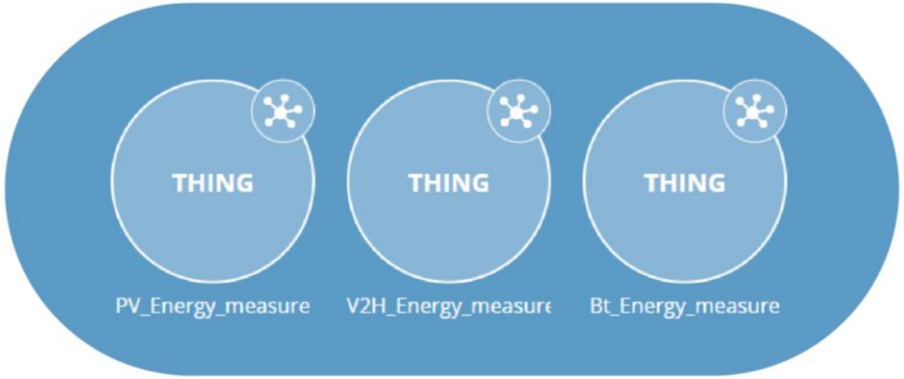


Mozilla IoT Privacy

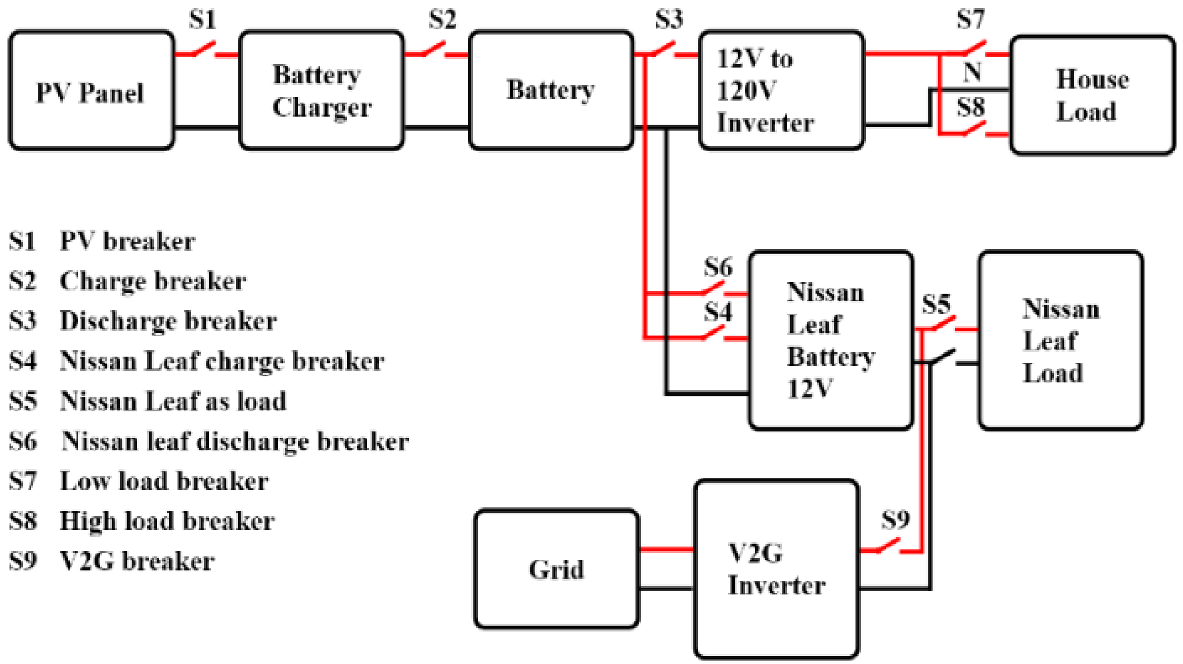


Experimental Setup and Mozilla IoT Dashboard



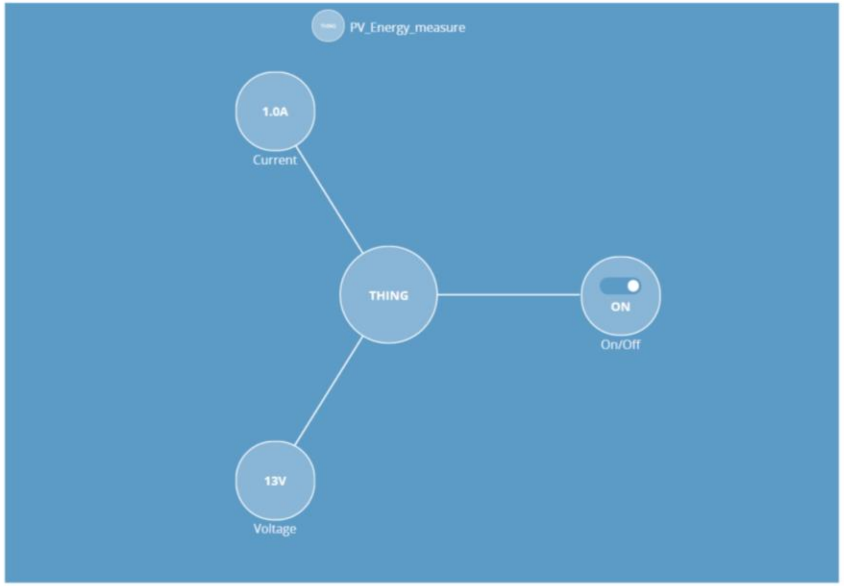


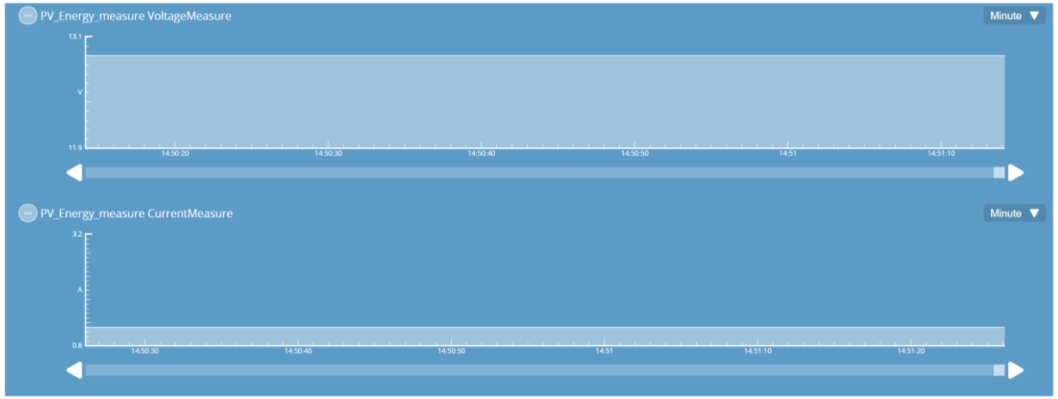
Switching control logic

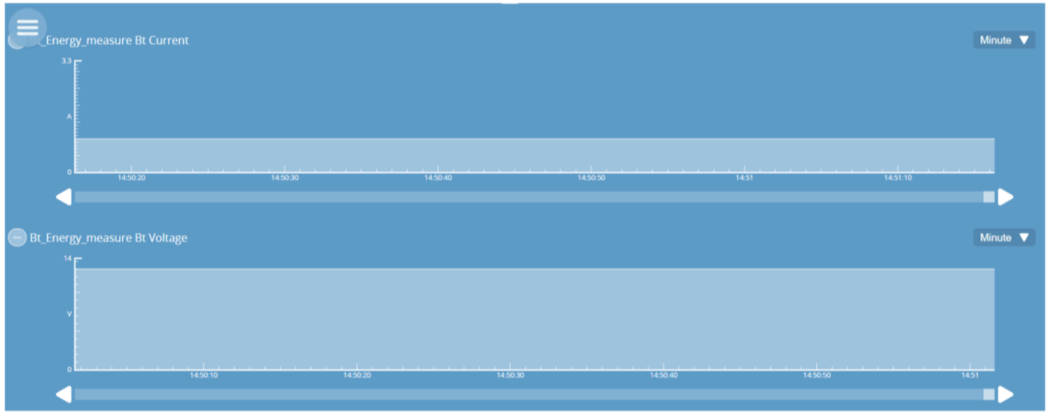


MODES	S1	S2	S3	S4	S5	S6	S7	S8	S9
Mode 1	HIGH	HIGH	HIGH	LOW	LOW	LOW	HIGH	LOW	LOW
Mode 2	LOW	LOW	HIGH	LOW	LOW	LOW	LOW	HIGH	LOW
Mode 3	HIGH	HIGH	HIGH	HIGH	LOW	LOW	HIGH	LOW	LOW
Mode 4	-	-	-	-	HIGH	-	-	-	-
Mode 5	LOW	LOW	HIGH	LOW	LOW	HIGH	HIGH	LOW	LOW
Mode 6	-	HIGH	HIGH	-	-	-	-	-	LOW
Mode 7	LOW	LOW	HIGH	HIGH	LOW	LOW	HIGH	LOW	LOW
Mode 8	-	-	-	-	-	-	-	-	HIGH

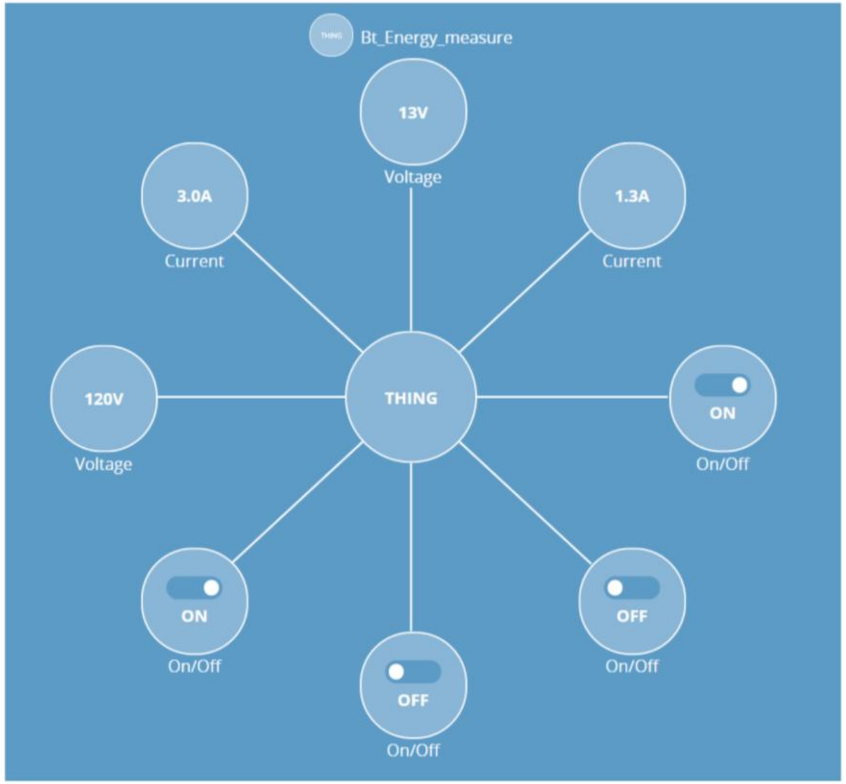
Inhouse battery Charge Mode







Inhouse battery discharge mode



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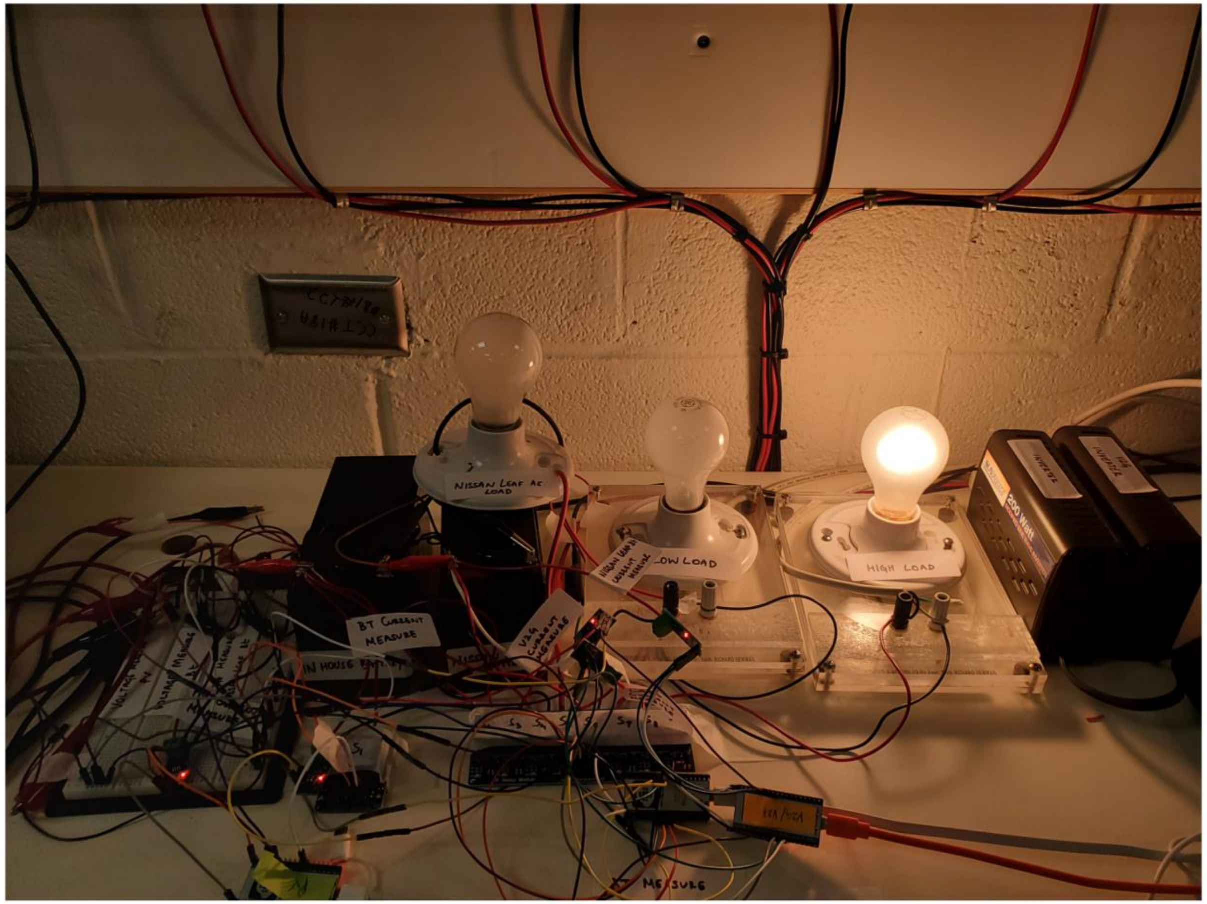
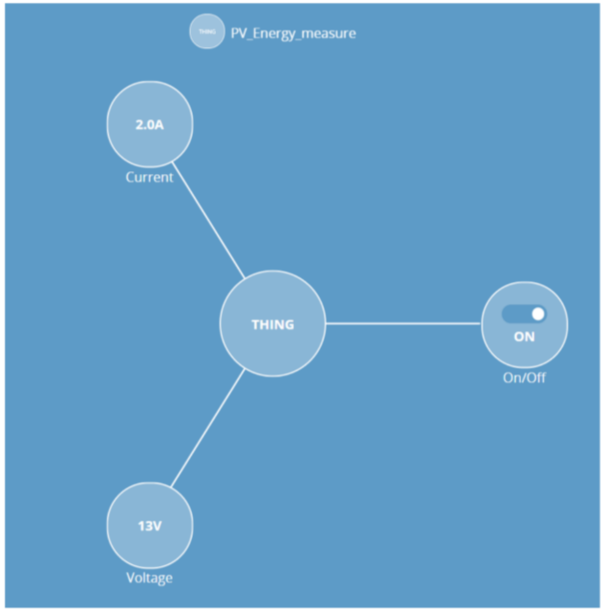
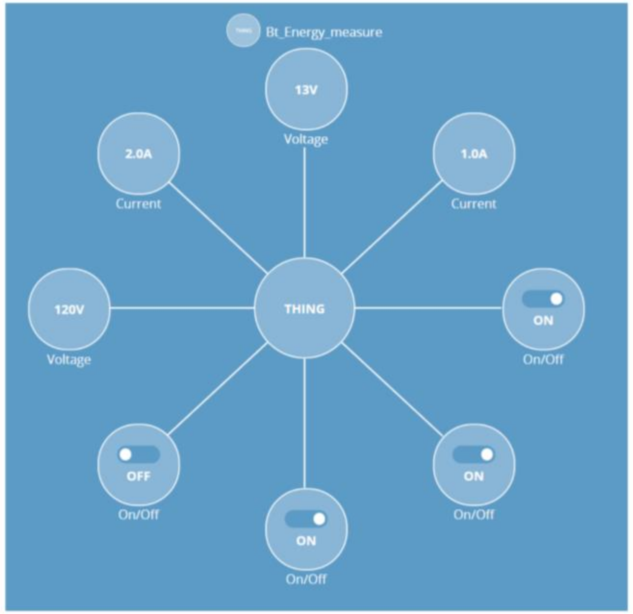
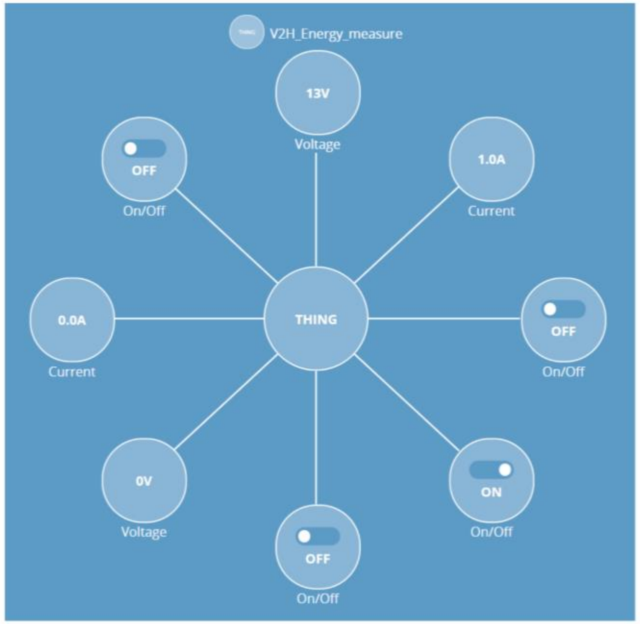
Experimental Setup – inhouse battery in discharge mode



Nissan Leaf charging mode







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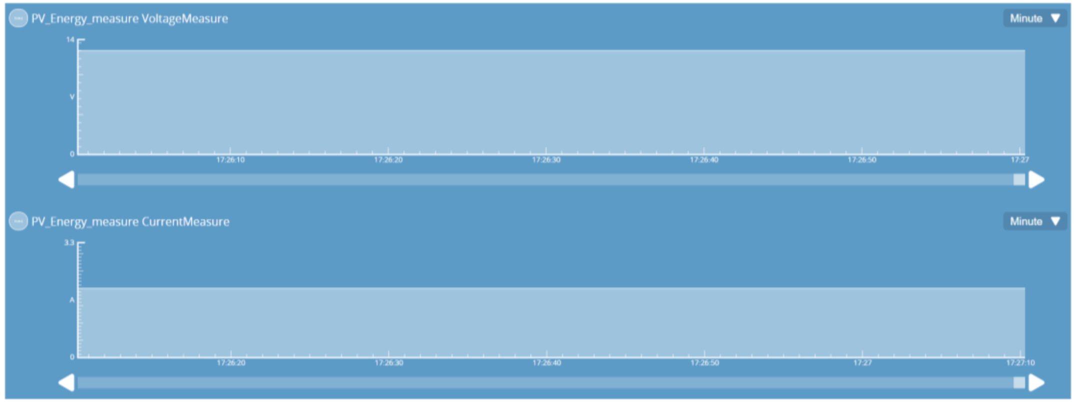
Nissan Leaf charging mode



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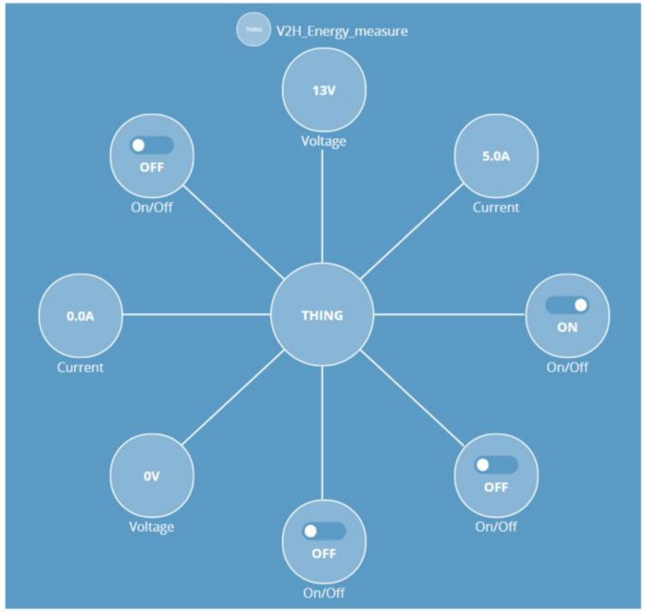
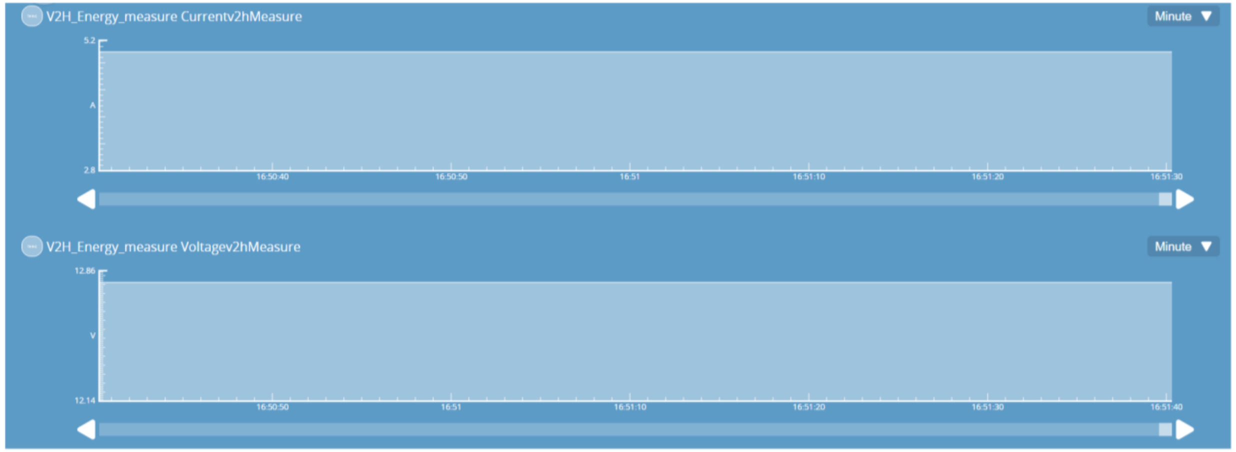
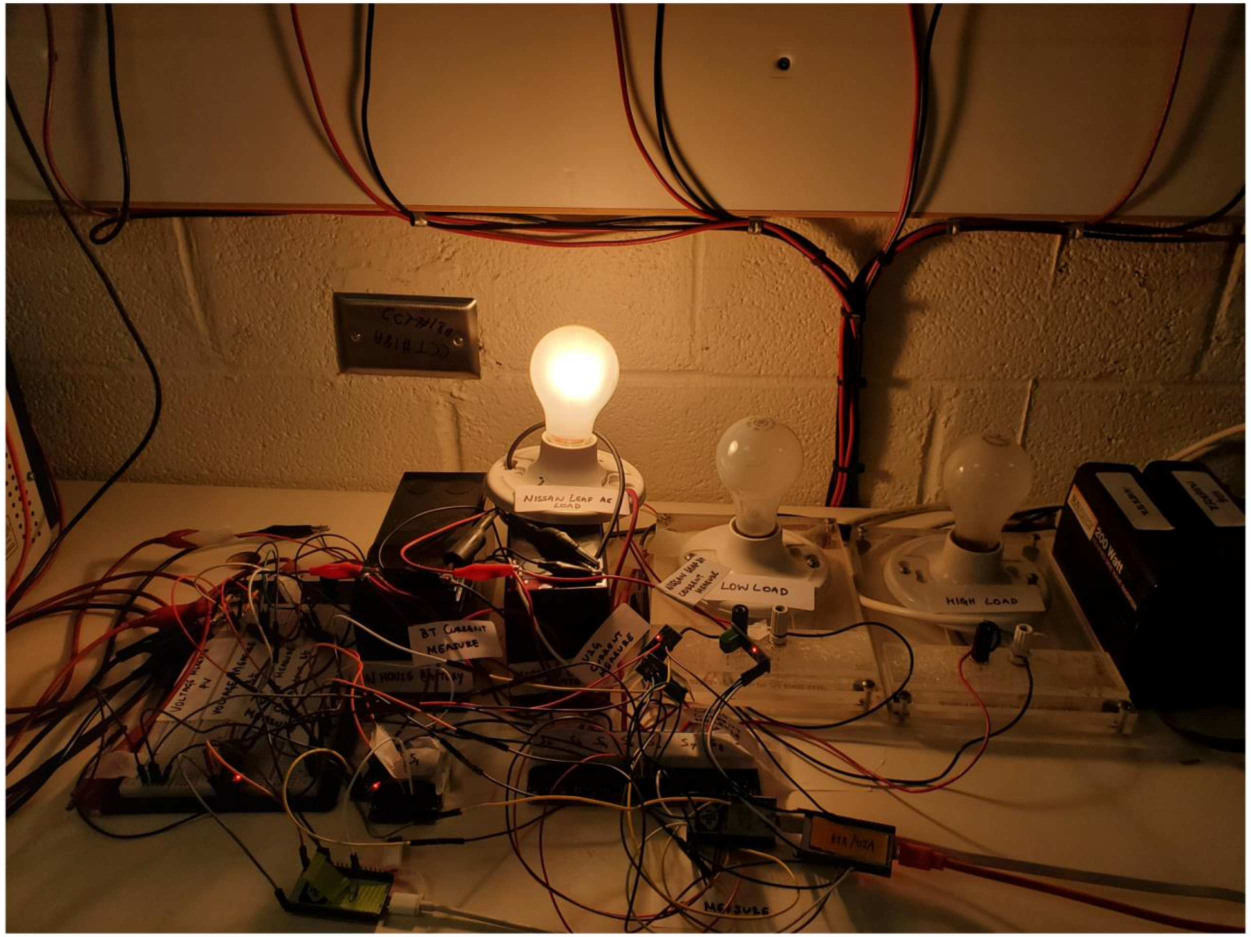
Nissan Leaf as load

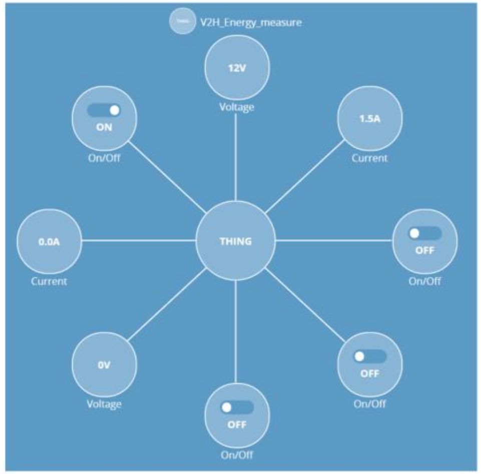


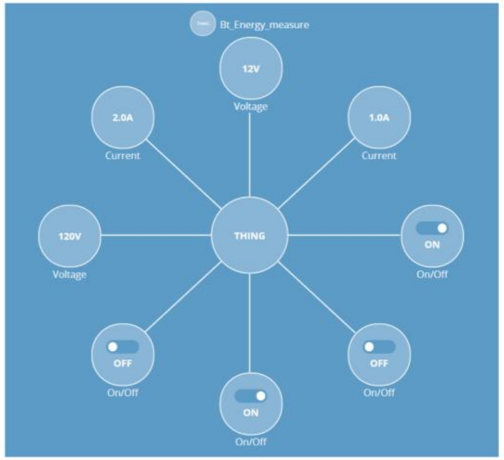


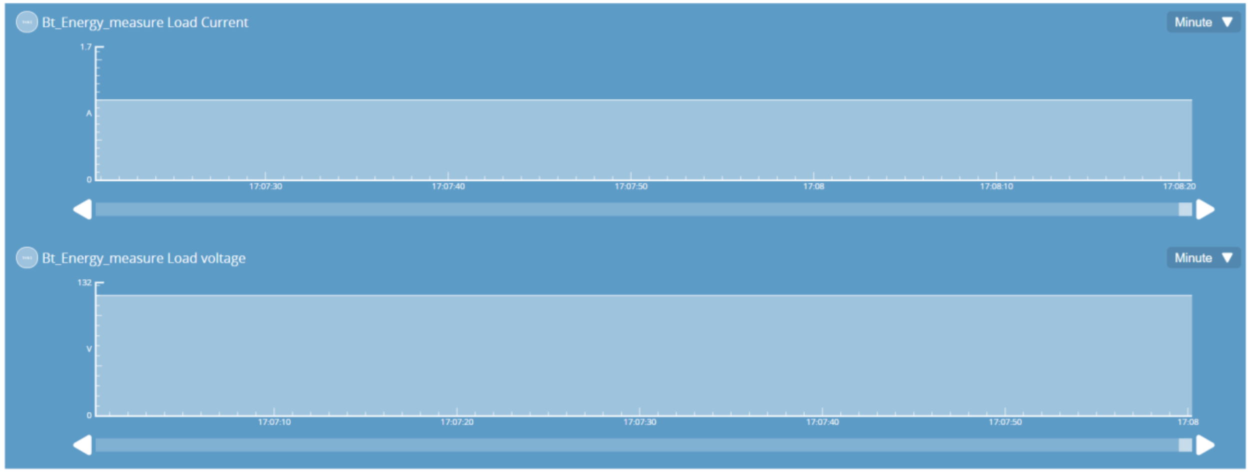
Nissan Leaf as load



Nissan Leaf in discharge mode







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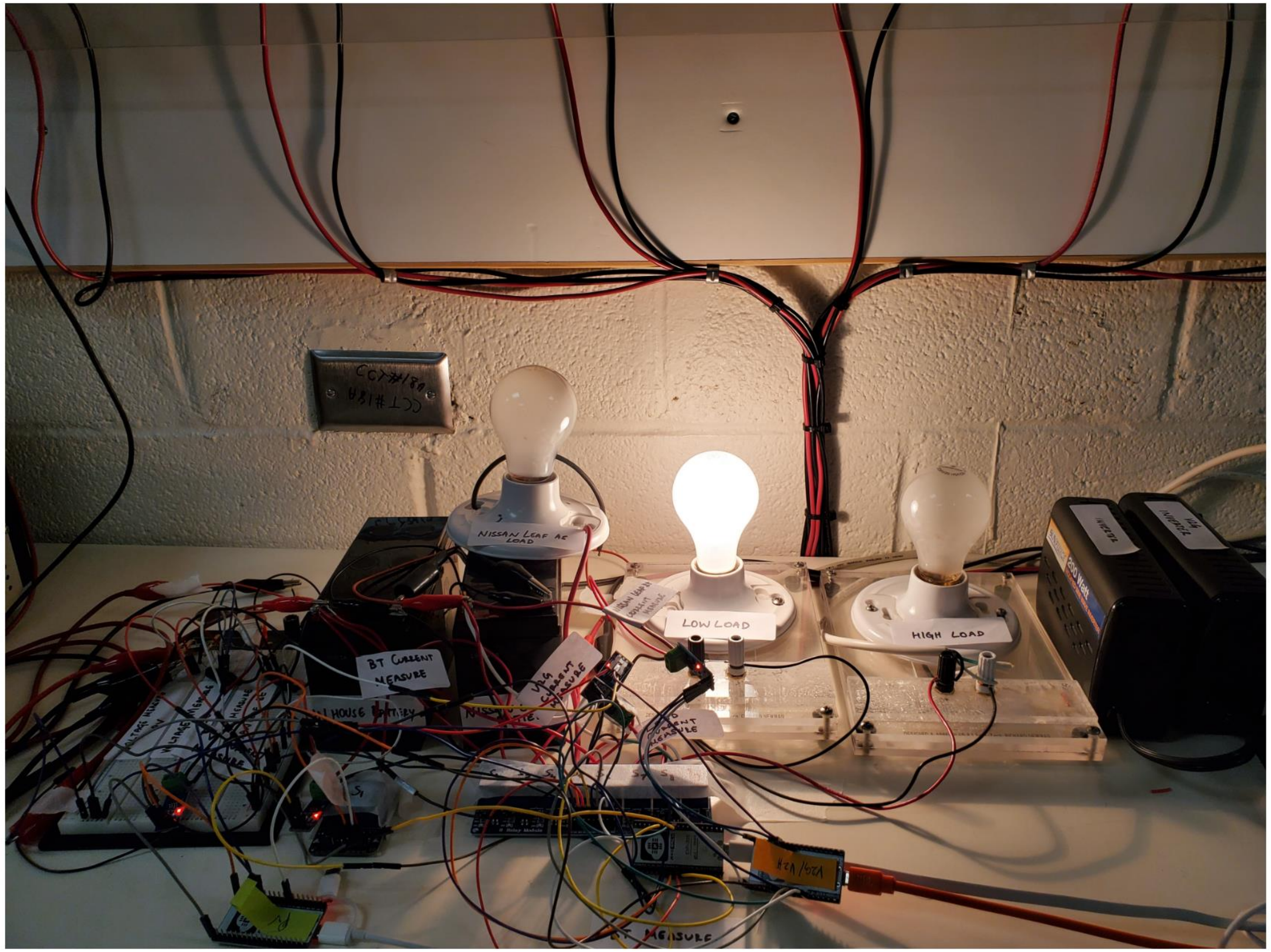
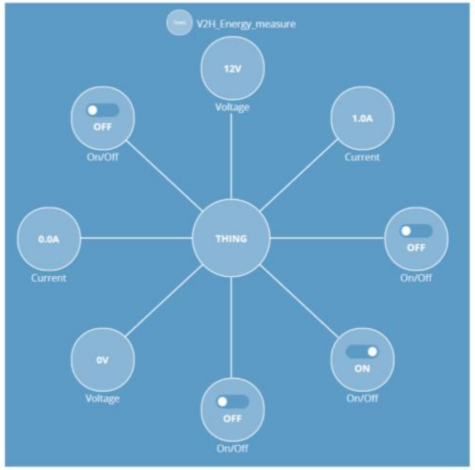
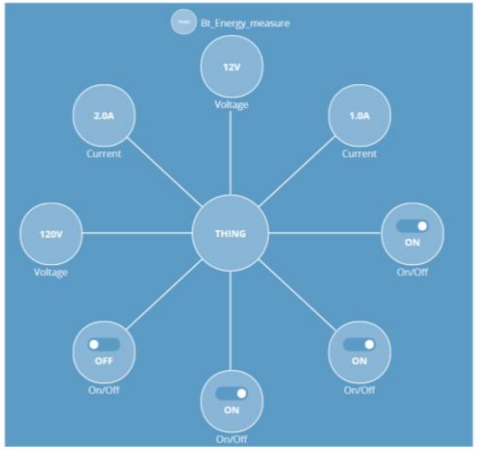
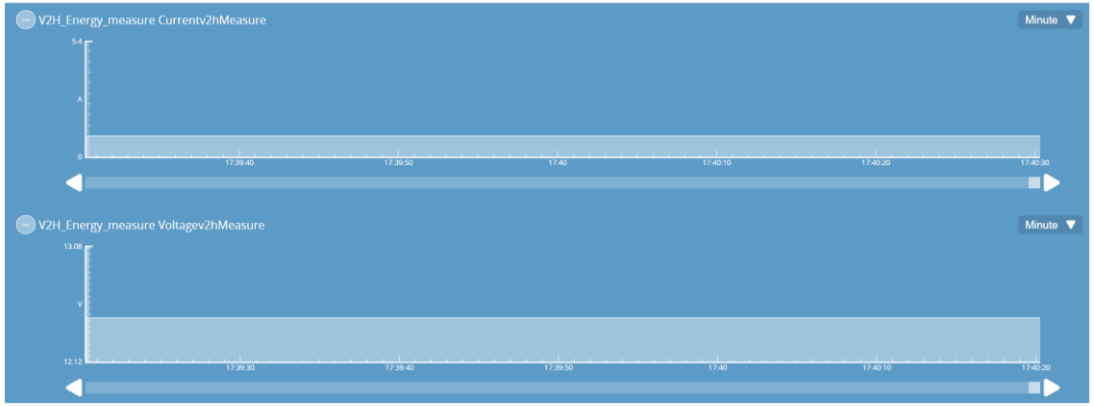
Nissan Leaf in discharge mode



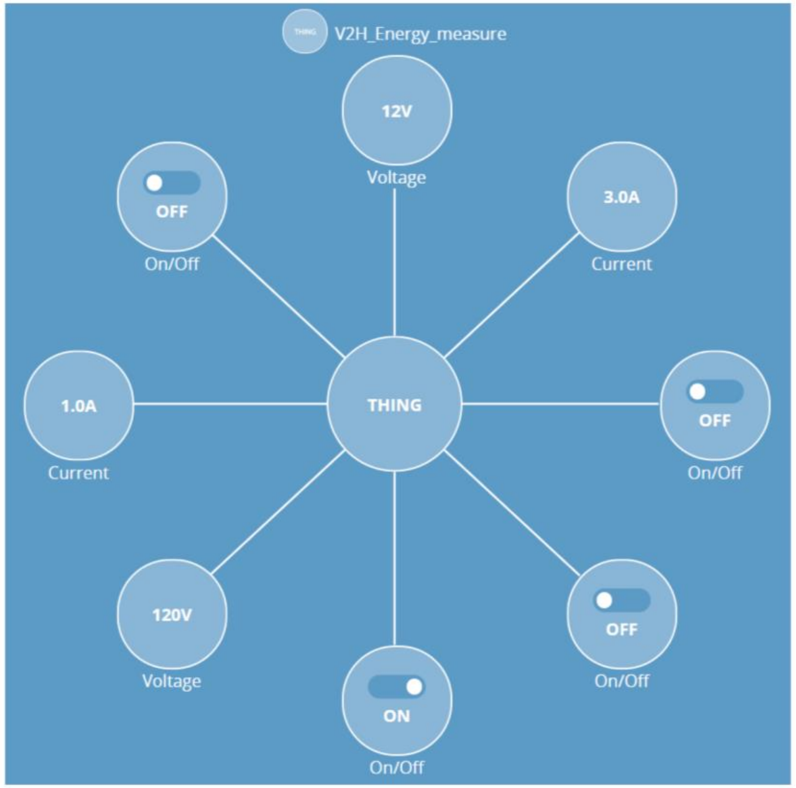
Nighttime charging mode

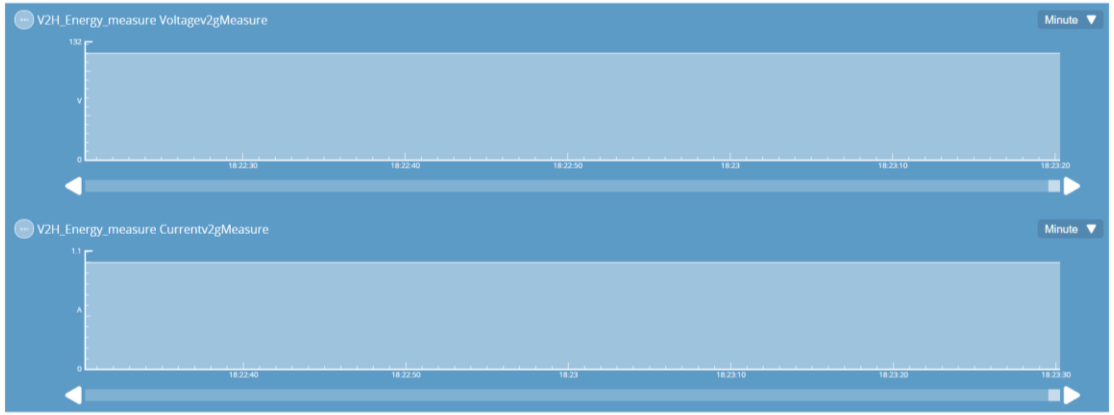


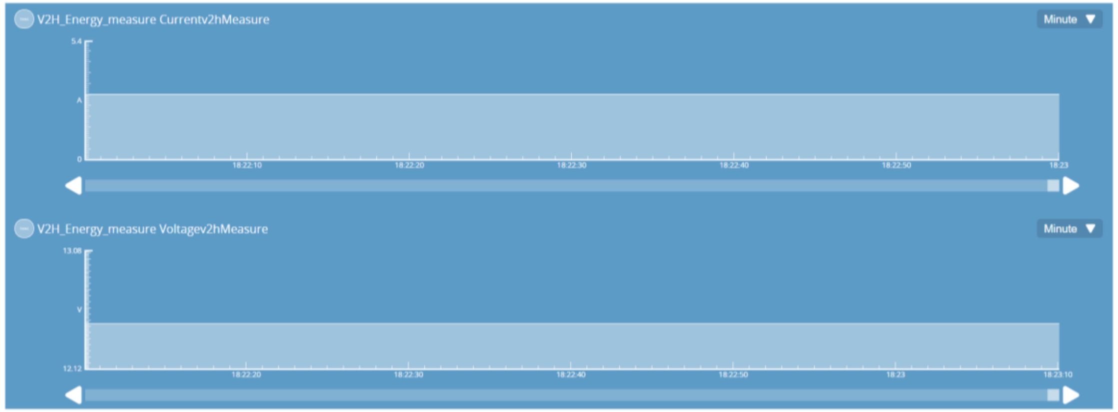




Vehicle to Grid (V2G) mode







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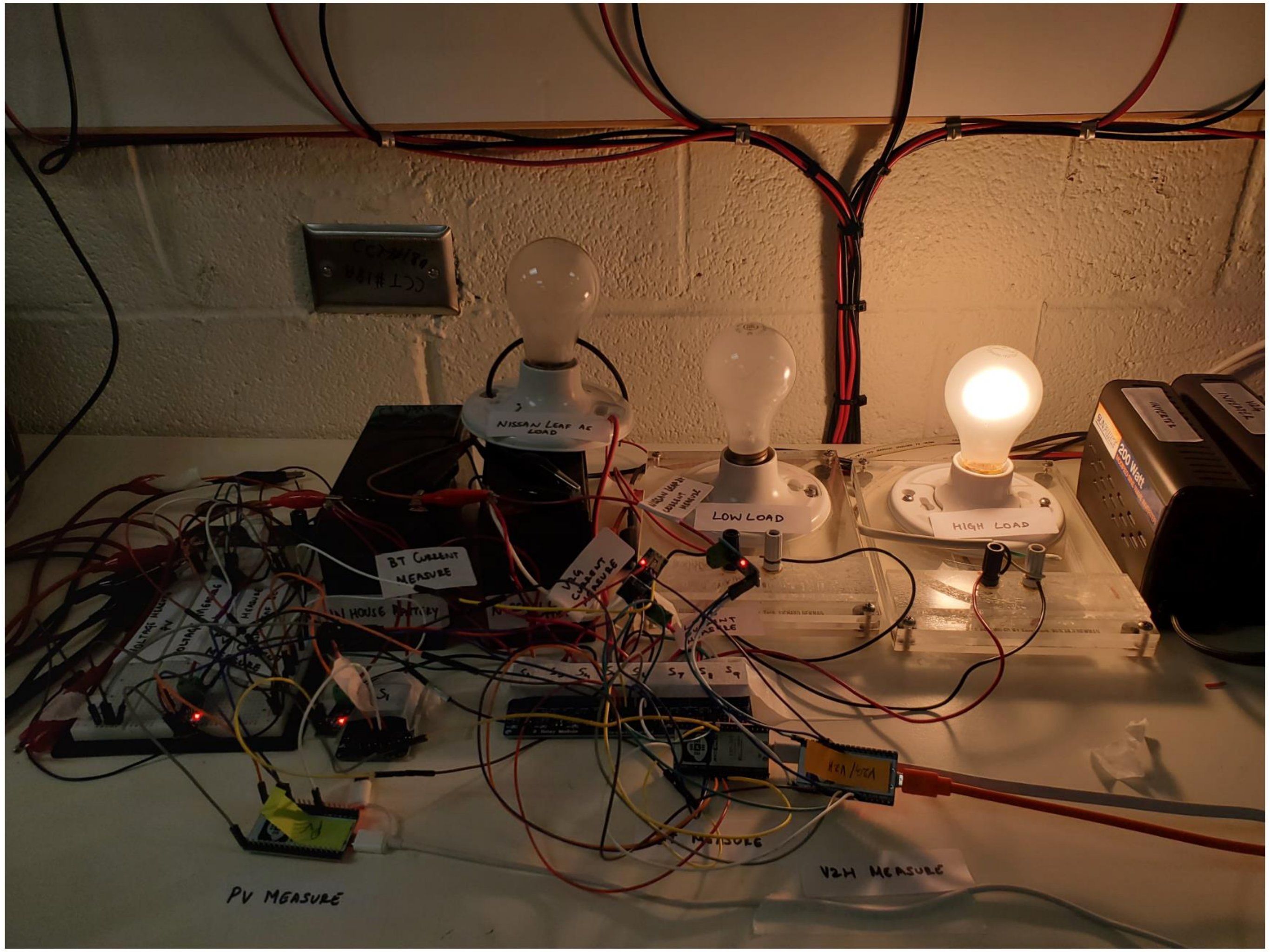
Vehicle to Grid (V2G) mode



Conclusion

- Designed and simulated a solar energy system for a home with V2H option for Newfoundland Conditions.
- Designed and simulated a solar energy system for a home with V2H and V2G option for Newfoundland Conditions.
- Designed a hardware model for solar energy system for a house with V2H and V2G option for Newfoundland through Mozilla IoT.

Acknowledgement

- My sincere thanks to my supervisor, Dr. Tariq Iqbal
- Thanks to my father, mother, brother, grandfather and grandmother
- Thanks to LUX Flavours company for the funding
- Thanks to all the friends

Future Work

The work presented in this thesis points to new directions in the development of a reliable, secure, IoT-based solar energy system for a house with V2H and V2G options. However, the system was intended and developed to be scalable, the following are some ideas for further work:

- Testing the proposed IoT on a real system in St.John's
- Implementing the designed system in EV parking lots
- Connecting number of parking lots together to power several houses or a microgrid or businesses or a city.
- Implement V2X concept, where EVs can be used to schedule loads.
- Providing this system as an application in the Smart Grid.

Published Papers - Journal

- R. Sundararajan, M. T. Iqbal, "Dynamic Modelling of Solar Energy System with Vehicle to Home option for Newfoundland Conditions" EJERS 2021, Volume 6, Issue 5, doi:10.24018/ejers.2021.6.5.2497.
- R. Sundararajan, M. T. Iqbal, "Dynamic Modelling of Solar Energy System with Vehicle to Home and Vehicle to Grid option for Newfoundland Conditions" EJECE 2021, Vol 5, Issue 3, doi: 10.24018/ejece.2021.5. 3. 329.
- R. Sundararajan, M. T. Iqbal, "Hardware implementation of Solar Energy System with Vehicle to Home option for Newfoundland Conditions through Mozilla IoT" JJEE 2021 (submitted).

Published Paper – Conference

- R. S. Sundararajan and M. T. Iqbal, "Design of an IoT interface for a solar energy system with vehicle to home option for Newfoundland conditions," 2020 11th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2020, pp. 0597-0601, doi: 10.1109 /IEMCON51383.2020.9284859.

Published Paper – Regional Conference

- R. S. Sundararajan and M. T. Iqbal, "Design of Solar Parking lot for 20 electric vehicles in St.John's, NL," 29th Annual Newfoundland Electrical and Computer Engineering Conference (IEEE NECEC 2020), St.John's, NL, Canada, November 19, 2020.
- R. S. Sundararajan and M. T. Iqbal, "Dynamic Simulation of an isolated Solar powered charging facility for 20 Electric Vehicles in St.John's, Newfoundland," 29th Annual Newfoundland Electrical and Computer Engineering Conference (IEEE NECEC 2020), St.John's, NL, Canada, November 19, 2020

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