Memorial University of Newfoundland
(Faculty of Engineering and Applied Science)

Design and Analysis of a Hybrid Power System for an Offshore Aquaculture Site in Newfoundland, Canada

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Background

- The World Population is continuously increasing, and it needs more food resources.
- Fish is an excellent source of food having an abundance of protein, rich in nutrients, fatty acids, minerals, and vitamins and superior in value to other meat sources
- The amount of universal protein intake in 2019, after dairy products, aquatic food provides the largest percentage of animal protein needs, at 7%.
- A positive trend in human consumption of aquatic animals, grew at an average annual rate of 3% from 1961 to 2019, more than the global population growth rate.
- The average global per capita consumption trend of aquatic foods over the last years has significantly increased, in 1961 it was 9kg whereas it has reached 20.2 kg in 2020.
- The world saw the historic production of 178 million tonnes of aquatic animals in the year 2020.
- The demand for fish cannot be addressed by the ocean/wild fish alone therefore, it creates an opportunity to produce fish through commercial farming.

Introduction to Fish Farm

- Fish are bred, raised, and harvested as part of fish farming, known as aquaculture, in a setting that closely resembles their natural habitat.
- North America and Europe mostly have net pens where the cage is fastened to the ground in the ocean, mostly close to the coastal area.
- The complete system comprises flexible but floating collars, weights tied to the bottom surface, a net, and an anchorage system connected to the seabed.
- The typical system comprises the cage, the feeding mechanism, and the energy network, and the production cycle takes around 24 months.
- A ship called a feed barge holding the complete infrastructure comprising of power supply, feed, automated monitoring system, and crew is stationed near the cluster of net pen sites.
- The power supply is arranged by DGs because of the non-availability of the grid/transmission network at the offshore location.

Introduction to Fish Farm

Site Description

- The site is located near Red Island, Placentia Bay, North of the Atlantic Ocean, Newfoundland province of Canada which has a historic association with the fish.
- It has a total of eight cages, seven have fish and one is kept spare. Each cage has 160,000 fish.
- The feed is stored in eight silos and is supplied to each cage with the help of three feed blowers, the power rating of the feed blowers is 30kW, 22kW & 22kW.
- There are two fuel tanks with a cumulative capacity of 30,000 Liters and are usually refilled after every two weeks.
- The power infrastructure consists of three diesel gensets each having a power rating of 99kVA.
- There are two air compressors of 30kW to collect the waste/dead fish from the cage and supply the oxygen.
- The cameras are installed at each cage that helps the operator to monitor the fish.
- The dissolved oxygen and water salinity level are monitored through sensors.

Project Site

Literature Review

Reveiwed Paper	Description
Garavelli, Lysel, et al.	The offshore fish farms' operations rely heavily on electricity, feeding machines, air compressors, lighting arrangement for the cages, sensors, refrigeration, and instrumentation for monitoring are the primary consumers.
Syse, H., 2016 & Møller, S.	A study conducted on a coastal fish farm in Norway states that electricity required for carrying out the growth-phase activities is around 700kWh/day, with a peak load of 100-120kW during the feed time
Syse, H., 2016 & Bujas, Tena, et al	The feeding mechanism is one of the most electricity-consuming units with a share of 50% of the daily required electricity
Menicou, M., & Vassiliou, V.	The energy needs of an offshore fish farm site located in the Mediterranean Sea having underwater lighting, sensors, cameras, and remote video is recorded as 4783.88 Whr/day
Betanzo-Torres, E.A. La	The overall production cost of the fish farms has a significant share of energy expenses, 10% to 15%

Literature Review

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Reveiwed Paper	Description
Bridson, P.B.; Stoner, J.M.S.	To bring more sustainability and betterment in the aquaculture industry, it is very important to apply environmentally friendly technologies.
Sadat, S.A.; Faraji, J.; Babaei	The potential of solar power for aquaculture is found to be very convincing
Solangi, K.H.; Islamb, M.R.	By 2030 solar power shall be the future energy source of aquaculture in the USA, Japan & Europe
Al-Saidi, M.; Lahham, N.	The usage of solar power for the aquaculture industry has been increasing significantly each day due to minimized operational costs, environmentally friendly nature
Tina GM, Rosa-Clot M	Using PV-powered equipment can reduce noise levels which can help reduce stress levels and enhance fish health
Choi Young-Kwan	With no moving parts, PV modules require very little maintenance, reducing downtime and increasing overall reliability

Literature Review

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Reveiwed Paper	Description
Bayrak G, Cebeci M	An off-grid solar power system of 1.1kW is designed for a fish farm in Turkey to supply the energy and its performance is evaluated using HOMER software
Jamroen, C.; Yonsiri, N.	An independent solar PV system with power storage (battery bank) is implemented to provide continuous electricity to the water monitoring system of fish farm in Thailand
Qays, M. O., Musse, M. A.	An IoT-based open-source low-cost SCADA system comprising current/voltage sensors mounted on Arduino UNO, Raspberry Pi2, and EmonCMS is implemented
Zare, A.; Iqbal, M.T	A SCADA system was implemented to monitor the electrical parameters (power, voltage, current) of a hybrid system comprising wind, PV, and energy storage systems
Iqbal, A., & Iqbal, M. T.	A SCADA system is developed for the renewable energy-based microgrid that has ability to send data to a server using LoRA gateway

Research Objectives

- Determine the energy needs of offshore fish farms and design a FSPV system (with a backup power supply) to power up the operations completely.
- The optimization analysis of the designed FSPV system on HOMER Pro and drawing its economic viability with reference to the existing power source.
- Model the designed FSPV system's performance under different dynamic conditions to improve its reliability and performance.
- Design a low-cost solar power monitoring system having the capability of remote transmission with the aim of meeting the system requirements.

Design and Simulate a Floating Solar Photovoltaic System for an Offshore Aquaculture Site in Canada

Load Profile/Energy Demand

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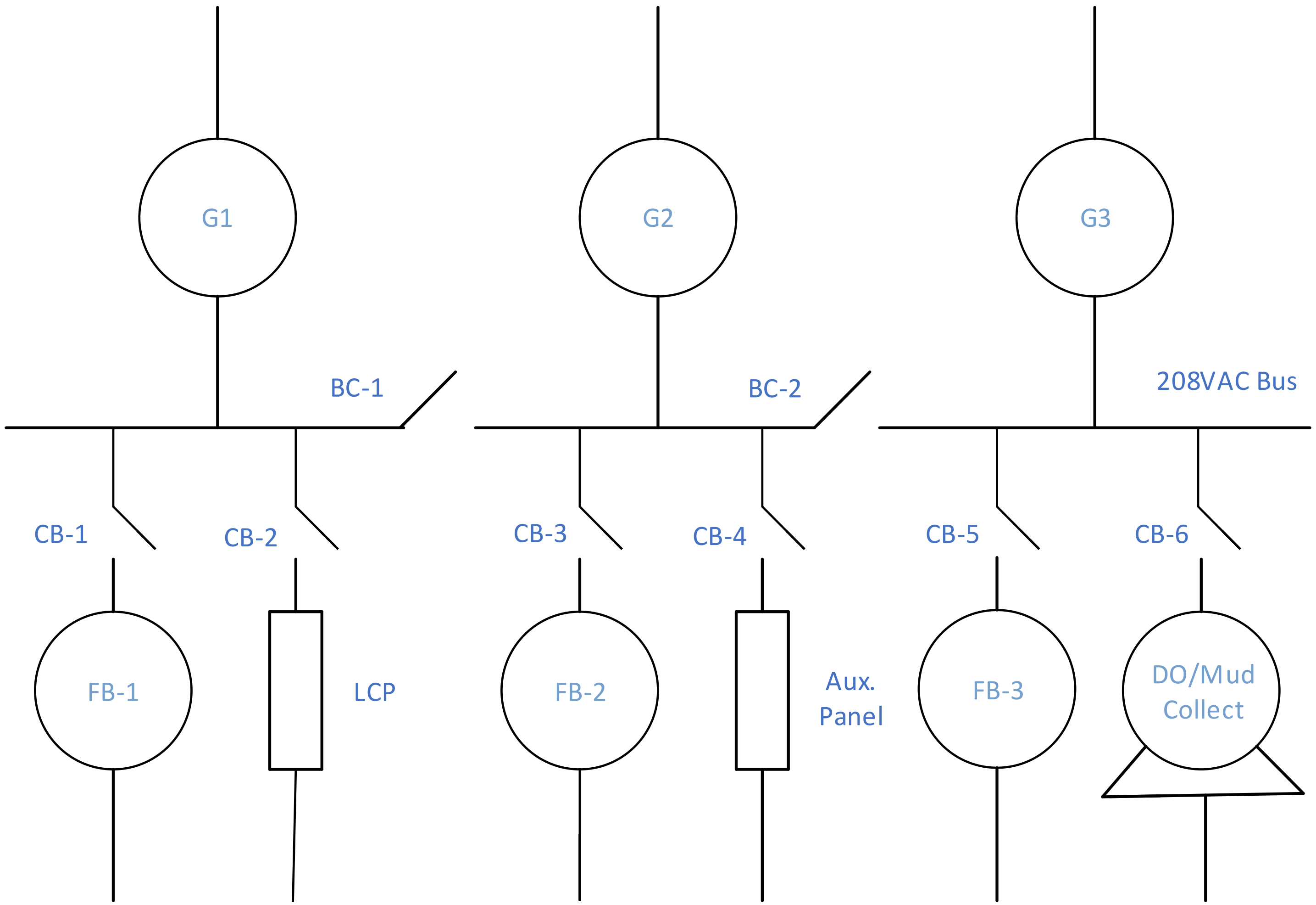
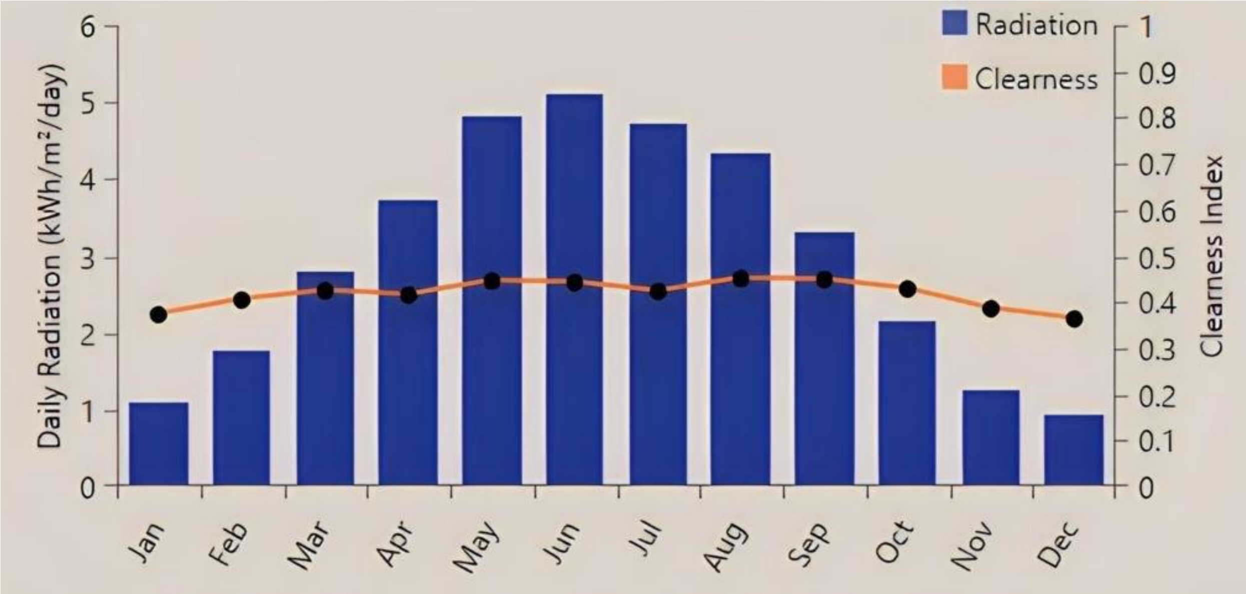
Sr	Load	Rated Power (kW)	Avg. Power (kW)	Op. Time (Hrs)	Consumed Power (kWh/day)
1	Feed Blower-1	30	21	10	210
2	Feed Blower-2	22	15.4	10	154
3	Feed Blower-3	22	15.4	10	154
4	Air Compressor (Aeration & Mud Collect)	30	21	4	84
5	Indoor LED Lights: (60Nos)	0.72	0.72	24	17.28
6	Outdoor LED Lights: (20Nos)	2	2	9	18
7	DO Sensors (8Nos)	0.008	0.008	24	0.192
8	Salinity Sensors (8Nos)	0.008	0.008	24	0.192
9	Fridge	0.8	0.8	24	19.2
10	Microwave Oven	0.9	0.9	0.5	0.45
11	LED TV (2 Nos)	0.17	0.17	8	1.36
12	Electrical Crane	50kW	10	1.5	15
13	Control and Automation Equipment	3kW	2	24	48
14	**Total**	**110.2**	**79**	**115**	**721.7**

Existing System SLD



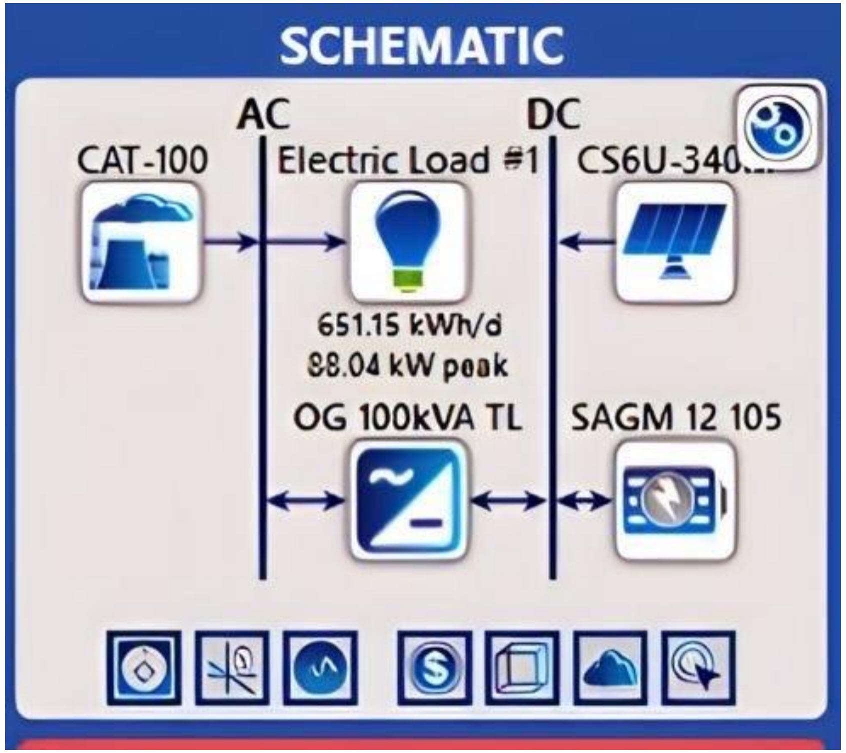
Solar Resource

- The determination of solar resources is the most fundamental step while designing the solar system for a particular site and it also helps to verify the techno-commercial feasibility of the project.
- The Homer Pro software provides reliable calculation while computing the monthly Global Horizontal Irradiance (GHI) based on the average of 22-year data taken from NASA meteorology.



System Design

- The load profile determined above for the summer and winter months is given as input to Homer Pro.
- The annual average load per day is computed as 651.15 kWh/day.
- AC bus operates at 208V whilst DC bus voltage is 360V



Sensitivity Analysis

- Two different sensitivity variables are introduced to determine the techno-commercial feasibility of the designed system.
- The variation of 10% in solar resource and annual average per day load is assumed, and three different cases ideal, base & worst case are developed.

RESULTS

Summary | Tables | Graphs | Calculation Report

Export... | Export All... | Compare Economics | Column Choices...

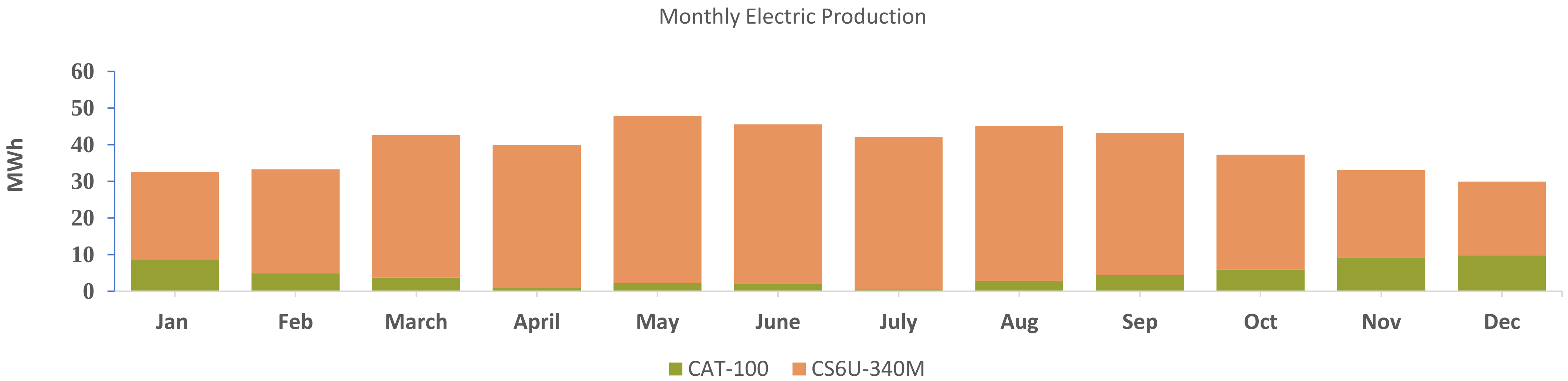
Sensitivity Cases

Left Click on a sensitivity case to see its Optimization Results.

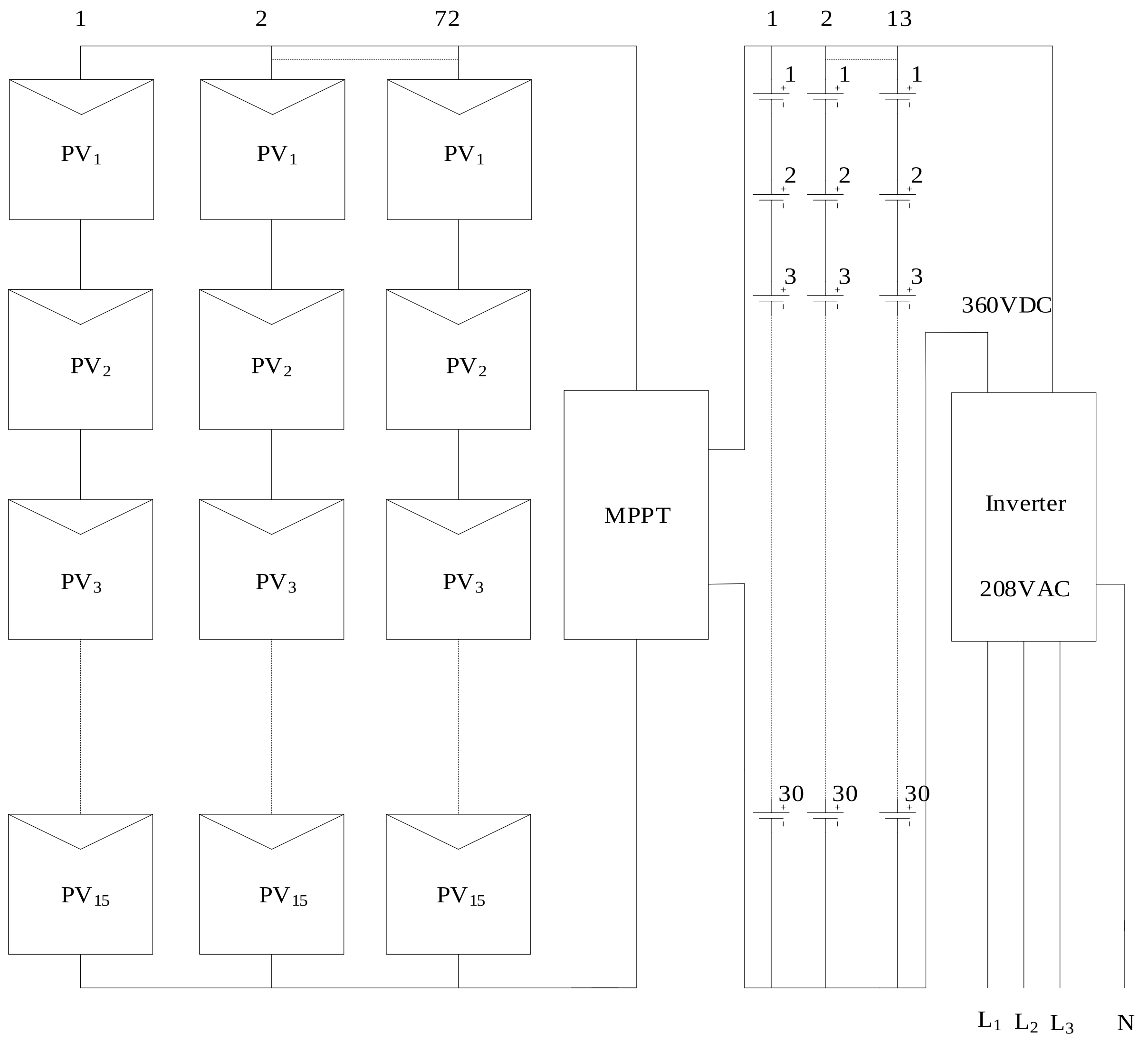
Sensitivity		Architecture						Cost				System		CAT-100					CS6U-340M		S.
Electric Load #1 Scaled Average (kWh/d)	Solar Scaled Average (kWh/m²/day)	CS6U-340M (kW)	CAT-100 (kW)	SAGM 12 105	OG 100kVA TL (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost ($/yr)	Fuel Cost ($/yr)	Capital Cost ($)	Production (kWh/yr)	Autonom (hr)	
586	2.70	332	80.0	360	80.3	LF	$1.41M	$0.509	$59,646	$635,487	75.7	16,160	2,107	51,899	16,160	10,535	29,087	439,418	330,954	14.4	
586	3.00	312	80.0	330	81.0	LF	$1.34M	$0.484	$57,503	$594,195	76.8	15,446	2,023	49,553	15,446	10,115	27,802	412,988	355,325	13.2	
586	3.30	289	80.0	360	79.7	LF	$1.28M	$0.462	$54,137	$578,915	79.1	13,973	1,834	44,805	13,973	9,170	25,151	382,979	368,654	14.4	
651	2.70	408	80.0	360	88.6	CC	$1.59M	$0.519	$66,203	$737,773	75.2	18,260	2,320	58,995	18,260	11,600	32,869	540,052	406,748	12.9	
651	3.00	366	80.0	390	88.6	CC	$1.52M	$0.493	$63,325	$697,598	76.7	17,107	2,175	55,260	17,107	10,875	30,792	484,873	417,172	14.0	

Base Case

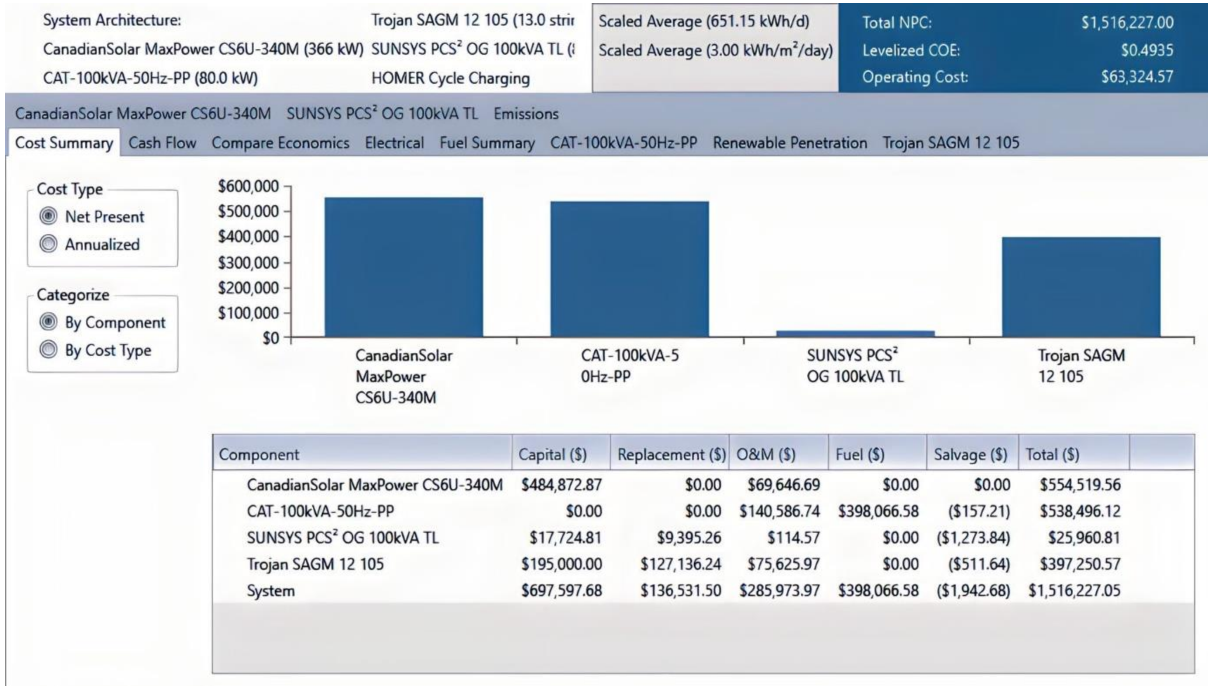
- The base case is the actual prevailing scenario at the project site.
- Solar PV power plant of 366kW, 1077 No of modules each of 340W.
- Battery bank is of 542.1 kWhr.
- Solar production is largely dominant and fulfilling the load requirement comfortably with a share of more than 88%.



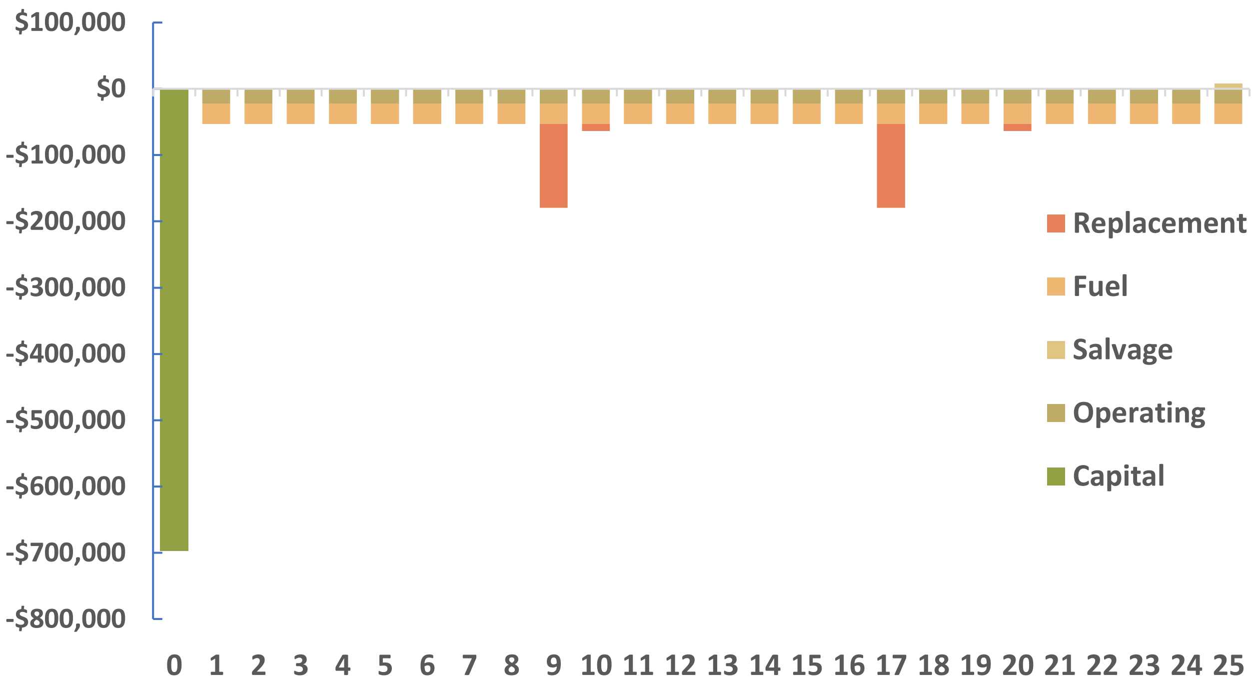
Configuration of PV System



Base Case



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
CanadianSolar MaxPower CS6U-340M	$484,872.87	$0.00	$69,646.69	$0.00	$0.00	$554,519.56
CAT-100kVA-50Hz-PP	$0.00	$0.00	$140,586.74	$398,066.58	($157.21)	$538,496.12
SUNSYS PCS² OG 100kVA TL	$17,724.81	$9,395.26	$114.57	$0.00	($1,273.84)	$25,960.81
Trojan SAGM 12 105	$195,000.00	$127,136.24	$75,625.97	$0.00	($511.64)	$397,250.57
System	$697,597.68	$136,531.50	$285,973.97	$398,066.58	($1,942.68)	$1,516,227.05



Ideal Case

- The annual average per day solar resource is increased to 10% (3.30 kWh/m2/day) and the annual average per day load is decreased by 10% (586 kWh/day).
- The total computed PV capacity is 289kW, 850 No. of Panels of 340 W
- The battery bank is 500.4 kWh
- The renewable penetration is found to be 78.3%.

System Architecture:	Trojan SAGM 12 105 (12.0 strir	Scaled Average (586.04 kWh/d)	Total NPC:	$1,278,775.00
CanadianSolar MaxPower CS6U-340M (289 kW)	SUNSYS PCS² OG 100kVA TL (	Scaled Average (3.30 kWh/m²/day)	Levelized COE:	$0.4624
CAT-100kVA-50Hz-PP (80.0 kW)	HOMER Load Following		Operating Cost:	$54,137.19

CanadianSolar MaxPower CS6U-340M SUNSYS PCS² OG 100kVA TL Emissions

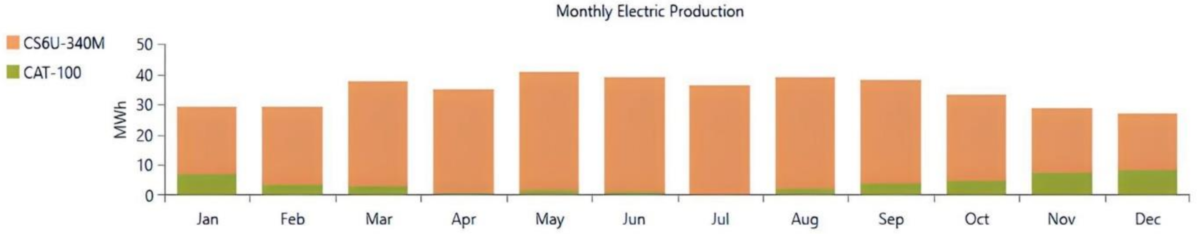
Cost Summary Cash Flow Compare Economics Electrical Fuel Summary CAT-100kVA-50Hz-PP Renewable Penetration Trojan SAGM 12 105

Production	kWh/yr	%
CanadianSolar MaxPower CS6U-340M	368,654	89.
CAT-100kVA-50Hz-PP	44,805	10.
Total	413,460	10(

Consumption	kWh/yr	%
AC Primary Load	213,903	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	213,903	100

Quantity	kWh/yr	%
Excess Electricity	186,566	45.1
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	79.1	%
Max. Renew. Penetration	4,542	%



COE Comparison With The Existing System

- The annual average Cost of Electricity (COE)/kWh comes out to 0.85 USD whereas if we take the base case of the proposed system the LCOE is 0.4935 USD.

- While calculating the (COE)/kWh for the existing system, the capital, replacement, auxiliary equipment (cables, switchgear, etc.), and O&M cost are not considered and only fuel cost is taken into the calculation.

Sr	Description	Jan 22	Feb 22	May 22	Jun 22	Jul 22	Dec 22
1	Monthly Fuel Consumption of Three Gen (Liters)	8970	9034	9246	9600	9660	9142
2	Per day Fuel Consumption of Three Gen (Liters)	299	301	308	320	322	305
3	Fuel Cost per liter (USD)	1.80					
4	Per day fuel cost (USD)	538	542	555	576	580	548
5	Average Load (kWh)	651.5					
6	**COE/kWh (USD)**	**0.83**	**0.83**	**0.85**	**0.88**	**0.89**	**0.84**

Dynamic Modelling and Analysis of a Hybrid Power System of Floating Solar PV System for an Offshore Aquaculture Site in Newfoundland

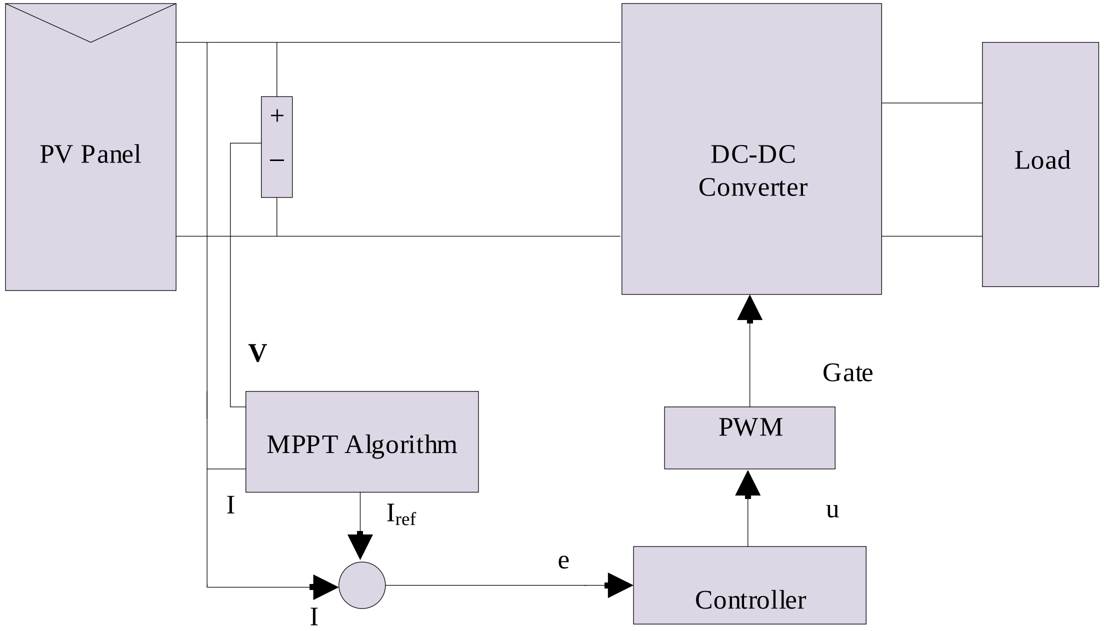
MATLAB/Simulink Modeling

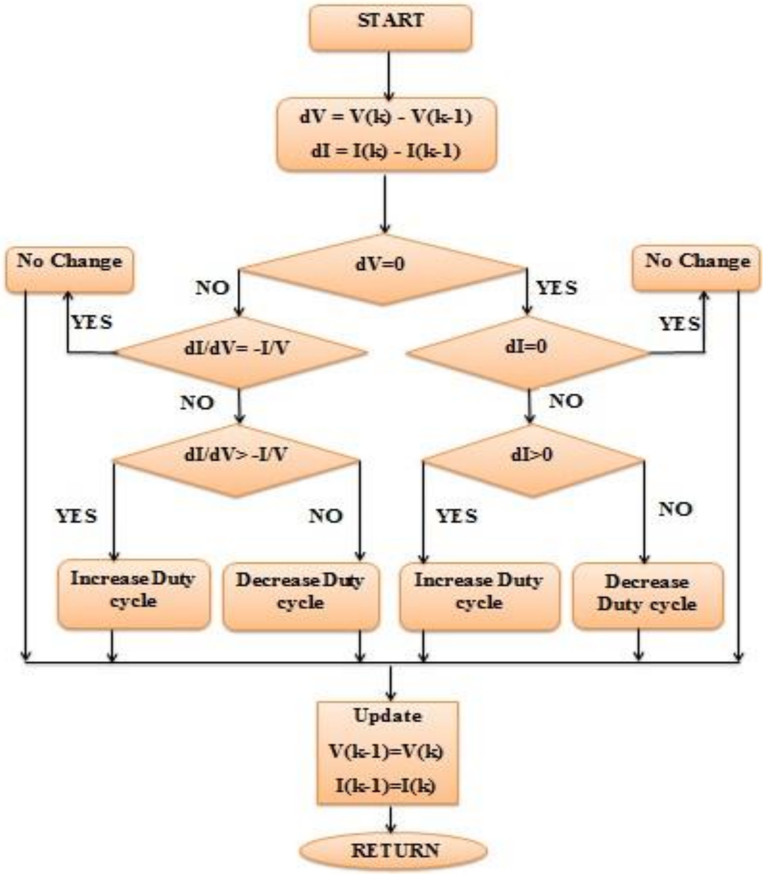
- The primary building blocks used to model the hybrid power system
- PV Panels
- MPPT Controller
- DC-DC Converter (Buck Converter)
- DC-AC Inverter
- LCL Filter
- Battery Bank and its Charge Controller
- PLL Loop
- Synchronous Generator
- Variable Load

Maximum Power Point Tracker (MPPT)

- The relation between I-V and P-V is not linear in the case of PV cells.
- Therefore, the output of the PV cells is constantly changing.
- There is only one specific and unique point where the most optimized power can be obtained from the PV module, called the “maximum power point (MPP).
- MPPT is a device, essentially a DC-DC converter, equipped with an intelligent algorithm in a microprocessor that helps to track the output power of a PV array.
- Since PV cells are exposed to fairly changing irradiance and temperature, MPPT remains constantly busy in finding the MPP with respect to changing weather, load etc.

MPPT Controller and Algorithm





DC-DC Converter

- DC-DC converter is implied in the system as part of the multi-stage power processing system
- The buck converter is used as a DC-DC converter due to its high efficiency, simple configuration, and low voltage ripple.
- DC output voltage level in accordance with the inverter DC link is maintained by the buck converted which is 360V DC in our case
- The output voltage (V_0) is lower than the input voltage (V_i) and this is achieved by controlling the duty cycle (D) of switch

  ($V_0 = D.V_i$)

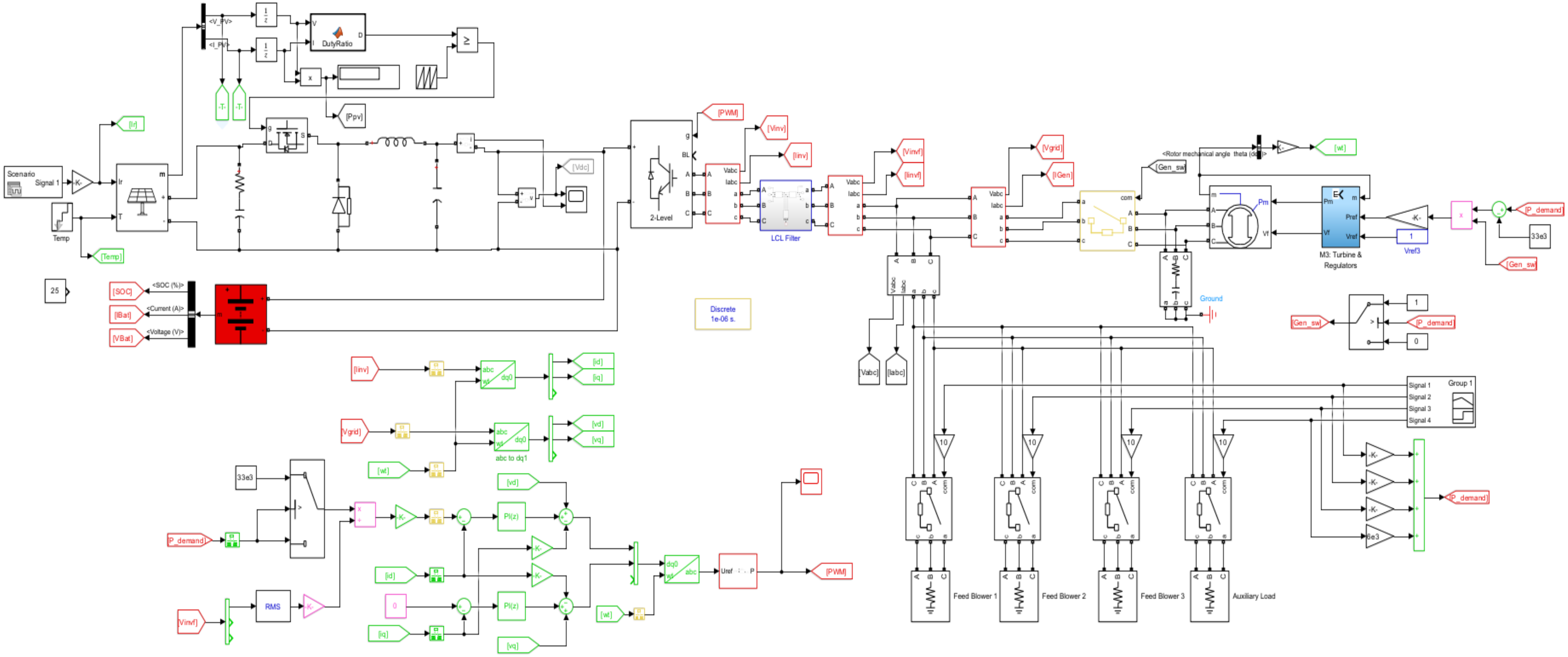
DC-AC Inverter

- Stable DC output from the buck converter is fed to the three-phase Voltage Source Inverter (VSI) which converts it to the desired AC voltage i.e. 208V (phase-phase).
- Sinusoidal Pulse Width Modulation Technique (SPWM) is used because of its unique offerings i.e. low Total Harmonic Distortion (THD), simplicity and better controlling schemes.
- The desired output voltage waveform and reduction in THD is achieved by controlling the width of SPWM pulses.
- THD is a very relevant and concerned parameter when non-linear components are involved, most of the semiconductor devices which are the heart of renewable energy systems, depict non-linear behavior.

LCL Filter

- The level of power quality supplied to the load is gaining more and more attention due to its direct effects on the performance of the connected load.
- Higher the power quality, lower the losses and better the performance of load.
- LCL filter is used to reduce the harmonic distortion in the inverter output waveform and low ratings of inductor and capacitor are used to make the system more economical.

MATLAB/Simulink Modeling

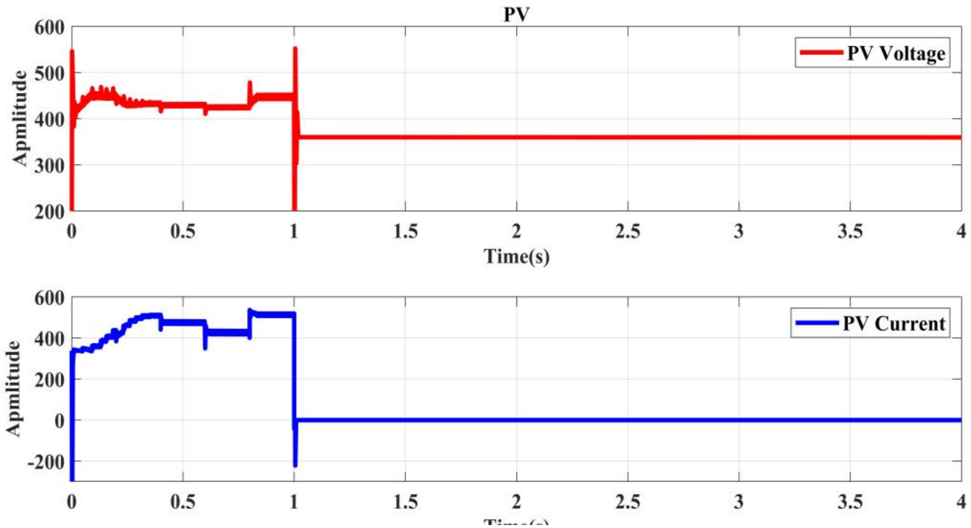


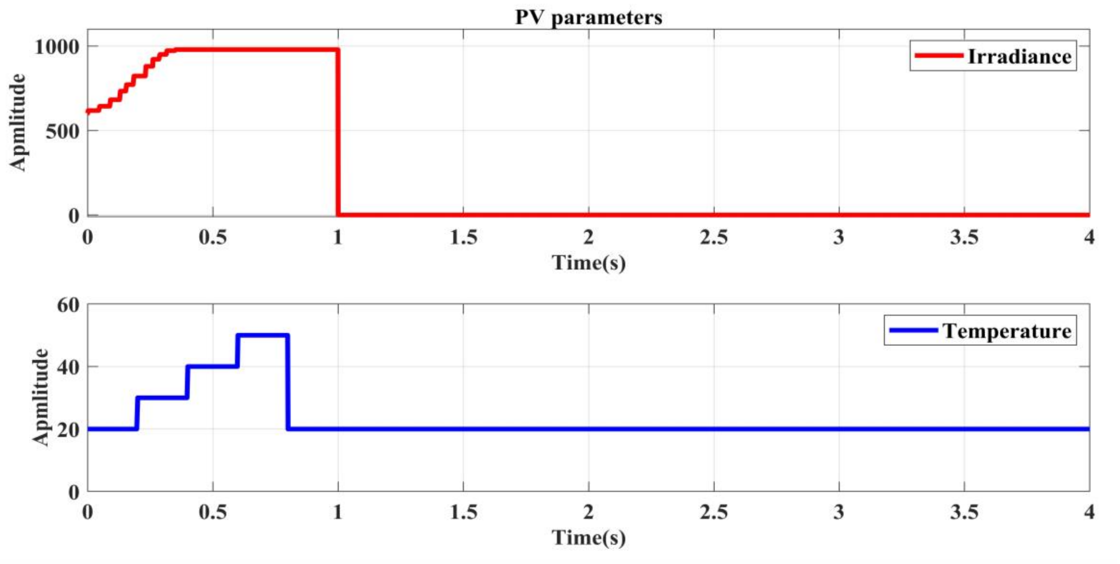
MATLAB/Simulink Modeling

- PV system: 366kW (72 parallel & 15 series strings).
- Each PV module is of 340W (CanadianSolar CS6U-340M).
- Battery bank: 1365Ah/542.1kWh (15 parallel & 30 series strings).
- Each battery is 12V & 105Ah/1.39kWh.
- Synchronous Generator: 99kVA
- Variable Load: 30kW, 22kW & 22kW

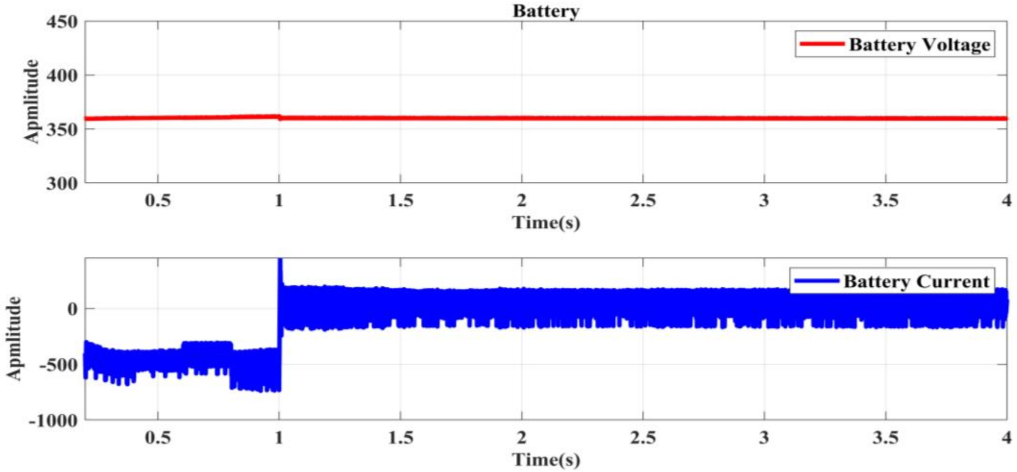
Dynamic Response of the System

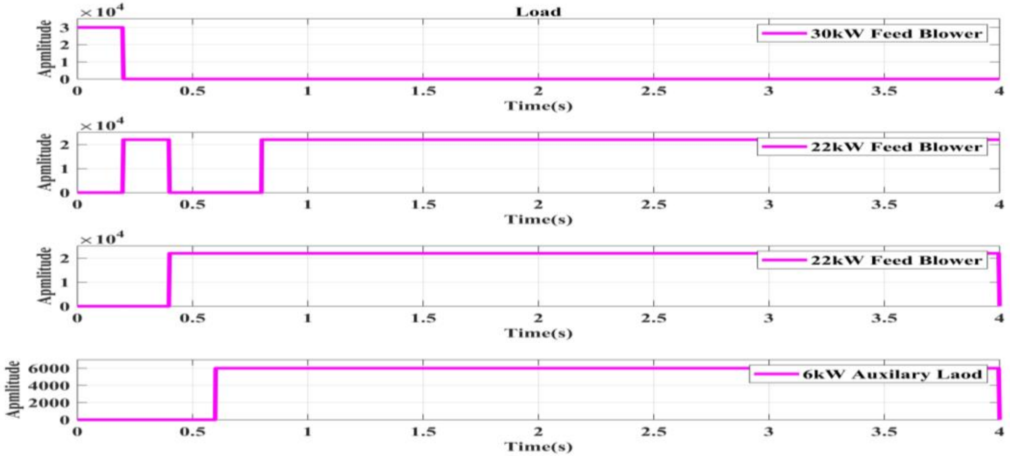
- The dynamic response of the system is evaluated by exposing it to variable irradiance and temperature.

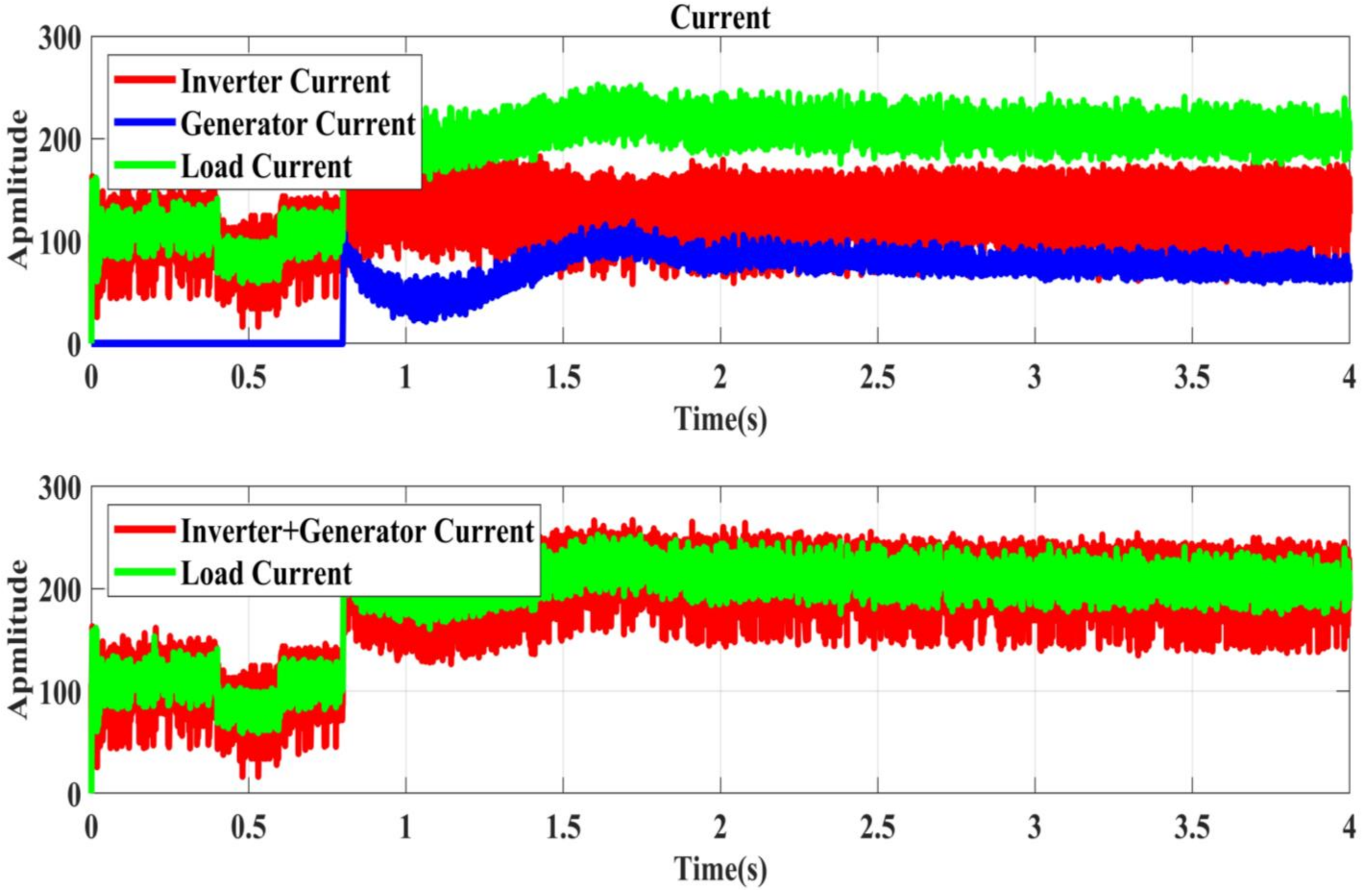




Dynamic Response of the System

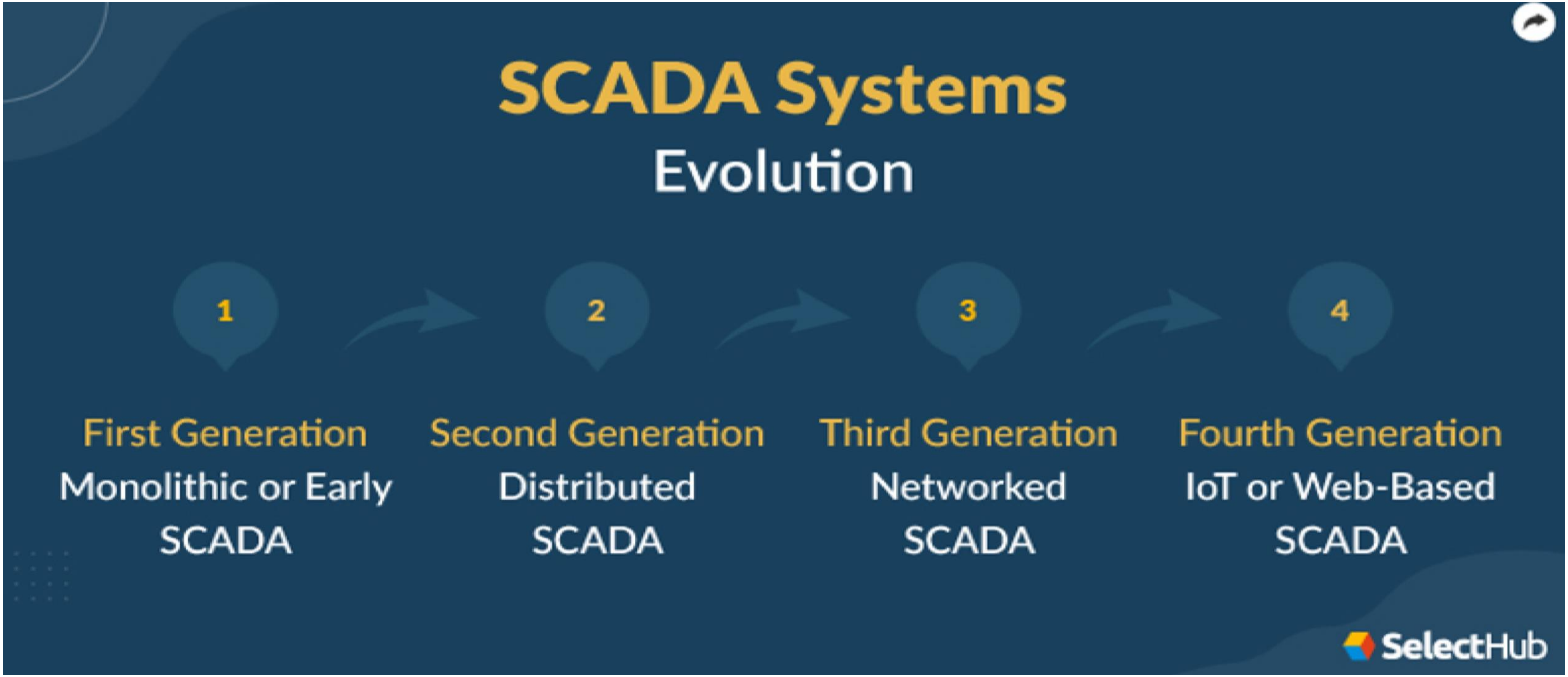






Development of a Low-Cost, Open-Source LoRA based SCADA System for Remote Monitoring of Hybrid Power System for an Offshore Aquaculture Site in Newfoundland

Evolution of the SCADA System



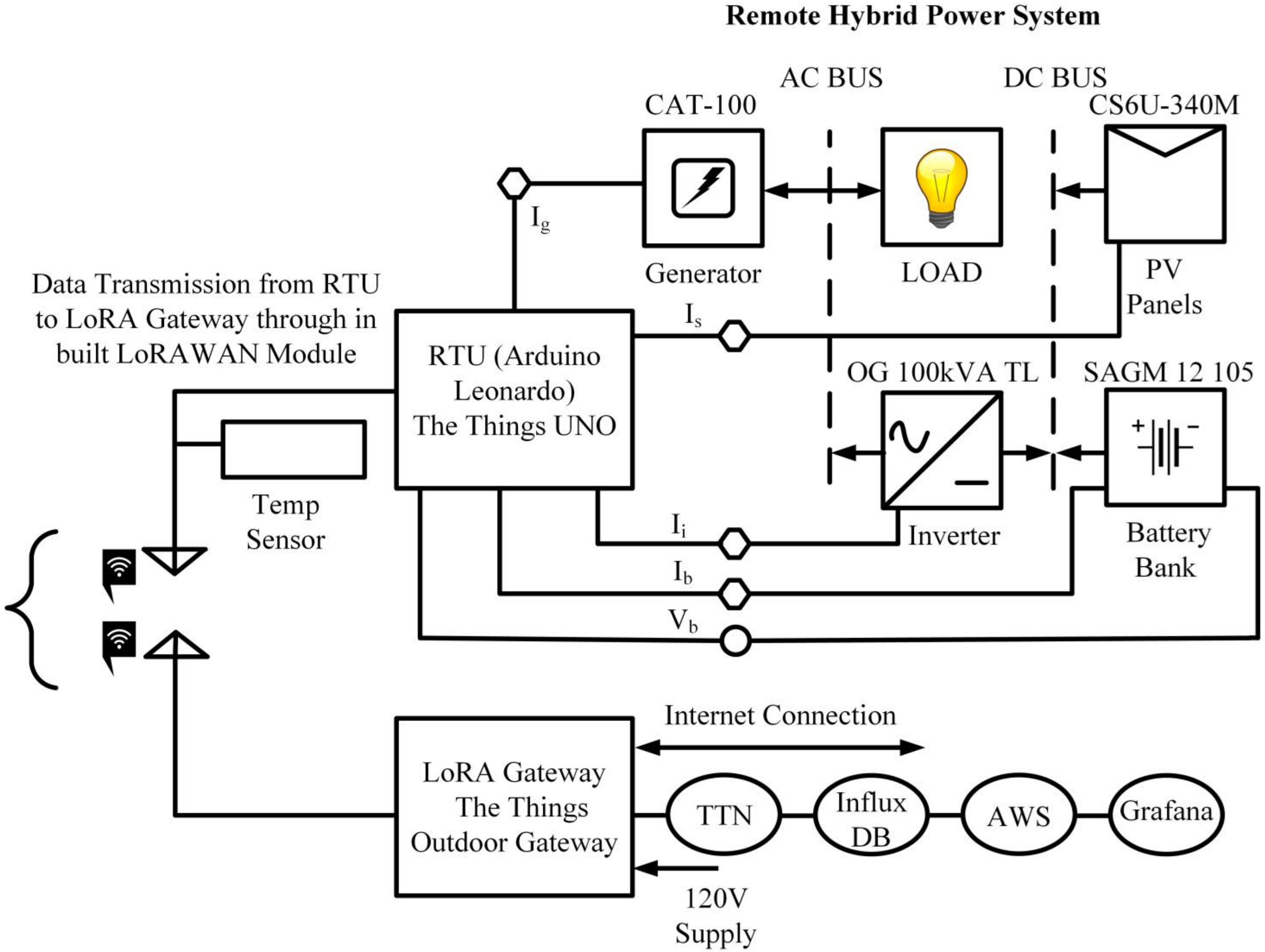
Proposed System Description

- The open-source SCADA systems offer a unique and competitive offering by combining different low-cost but compatible equipment together to provide similar services as a proprietary system.
- The cost is always a concern in proprietary SCADA systems and often they are not very welcoming in interfacing with the other manufacturer's equipment.
- Amongst the variety of prevalent communication technologies to transmit data from RTUs, LoRA (Long Range) is preferred for long-range communication.
- LoRA is also energy efficient (low power consumption) and offers wide area coverage where conventional technologies like Wi-Fi or cellular service is not feasible.

Proposed System Description

- A prototype in accordance with the actual system is developed
- The output of the DG, PV, and battery bank is measured through sensors.
- Arduino Leonardo is the RTU that collects data from sensors and has the capability to transmit it to TTN through an in-built LoRAWAN module without any additional hardware.
- LoRA gateway receives the data from RTU and pushes it to TTN cloud.
- Using the MQTT communication protocol, the data is pushed to InfluxDB for storage.
- Amazon Web Services provided virtual cloud computing services (EC2), Telegraf and Grafana are used to receive, process, and display historical and live data through interactive charts.

Proposed System Description



Components of the System

- Sensors

➢ Current Sensor

➢ Voltage Sensor

➢ Environmental Sensor

- Arduino Leonardo
- LoRA Gateway
- InfluxDB
- Amazon Web Services
- Grafana

Current Sensors

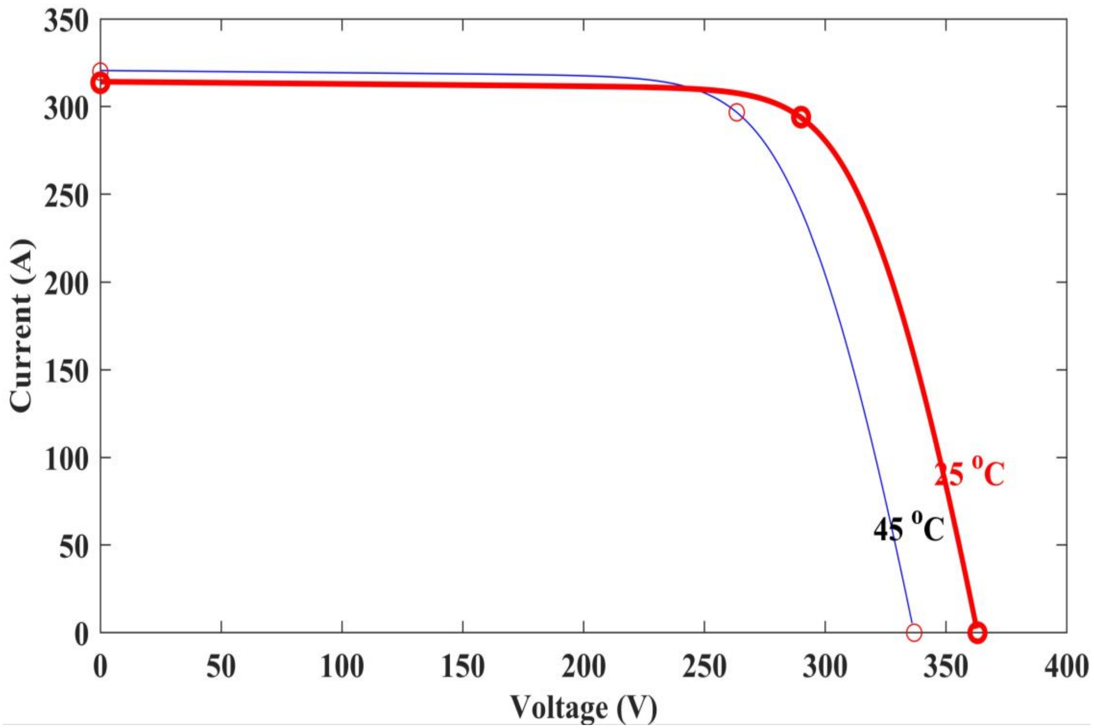
- The currents of PV solar modules, battery bank, inverter, and generator are measured using ACS712 Hall effect sensor.
- The sensor can measure AC & DC current and has three different types based on its current measurement rating, 05A, 20A & 30A.
- For the actual system, to measure PV modules' current, four CR5210 DC current sensors can be used, each has current range of $200A_{DC}$.
- One CR5210 sensor can be used to measure the battery bank.
- For the inverter and Generator, CSCA-A Series Hall effect-based sensor manufactured by Honeywell can be used.

Voltage Sensors

- The voltage sensor is used to measure the output voltage of the battery bank.
- A very simple but precise voltage sensor having a range of 0-25VDC is used for our prototype.
- It works on the principle of voltage divider and reduces the input voltage with a factor of 5.
- It is made using two resistors of 30kΩ & 7kΩ.
- The DC bus voltage of the actual system is 360VDC therefore, CR5310 having a voltage range of 0-600VDC can be used.

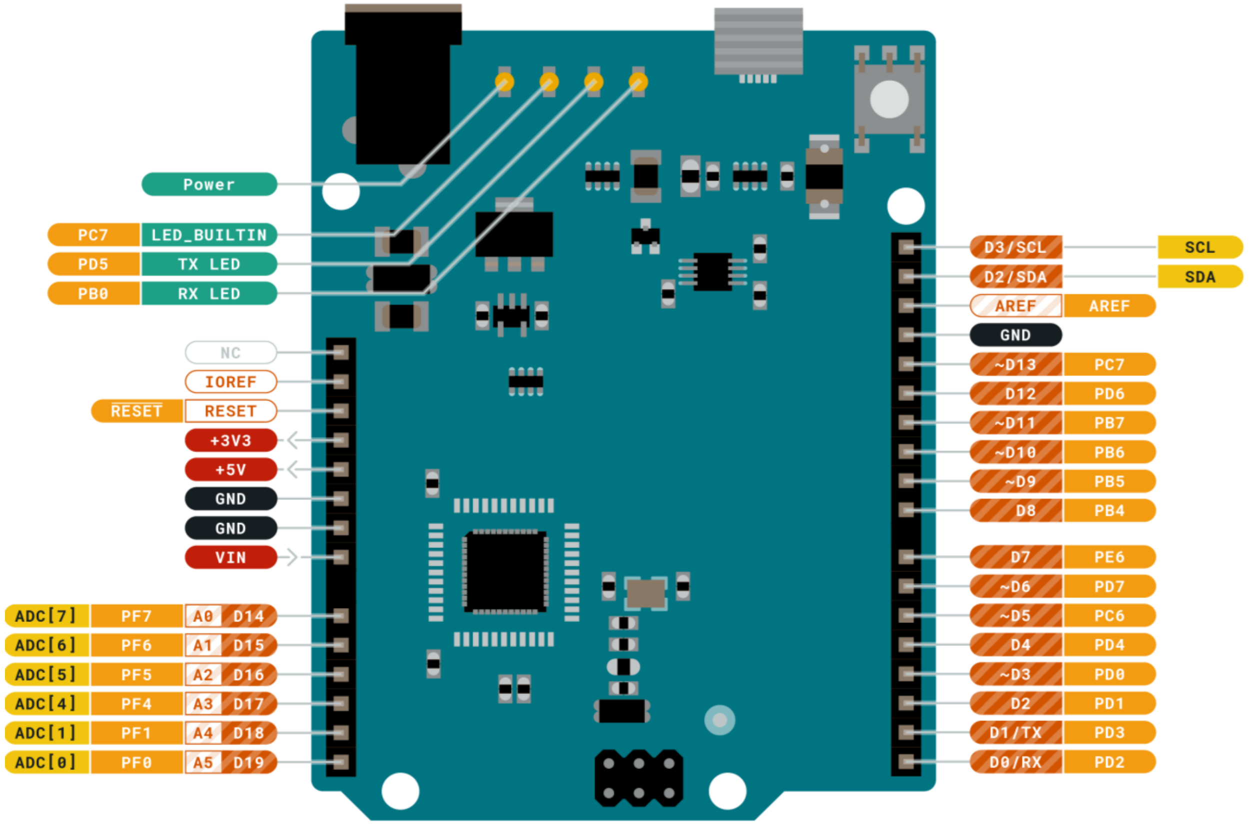
Environmental Sensor

- With the increase in temperature, the open circuit voltage of the panel decreases and its short circuit increases.
- The Things Node which is a smart temperature sensor with in-built LoRAWAN module is used.
- The Things Node is a very friendly device and can be added as an end device to (TTN) under applications.
- Once it is connected, it monitors the real time temperature and sends to the TTN cloud.



Environmental Sensor

- Arduino Leonardo is a very useful, widespread and open-source microcontroller used in developing IoT-based projects.
- The microcontroller used here is also called The Things UNO which is based on Arduino Leonardo added with a Microchip LoRAWAN module and is a product of The Things Network.
- The product is programmed through IDE.
- All the sensors are connected on ADC pins, from A0 to A4



Algorithm of the Proposed System

Algorithm for sensor data reading at Arduino (RTU)

1. Add the appEUI and appKey of RTU from TTN.
2. Define the analog inputs of RTU.
3. Set the floats for resistor values in voltage sensor.
4. Define and set the sensitivity of ACS712.
5. Determine samples of measurement from sensors and take the average.
6. Convert the average value of measurement to the actual value considering the sensitivity of sensor.
7. Print the live measurements at serial monitor.
8. Go to step 5 and repeat.

Algorithm of the Proposed System

Algorithm for sending data from RTU to Grafana

- **TTN**

1. Register LoRA gateway and RTU on TTN
2. Set the Payload format at TTN
3. Create API key in TTN
4. Get MQTT Credentials from TTN

- **Influx DB**

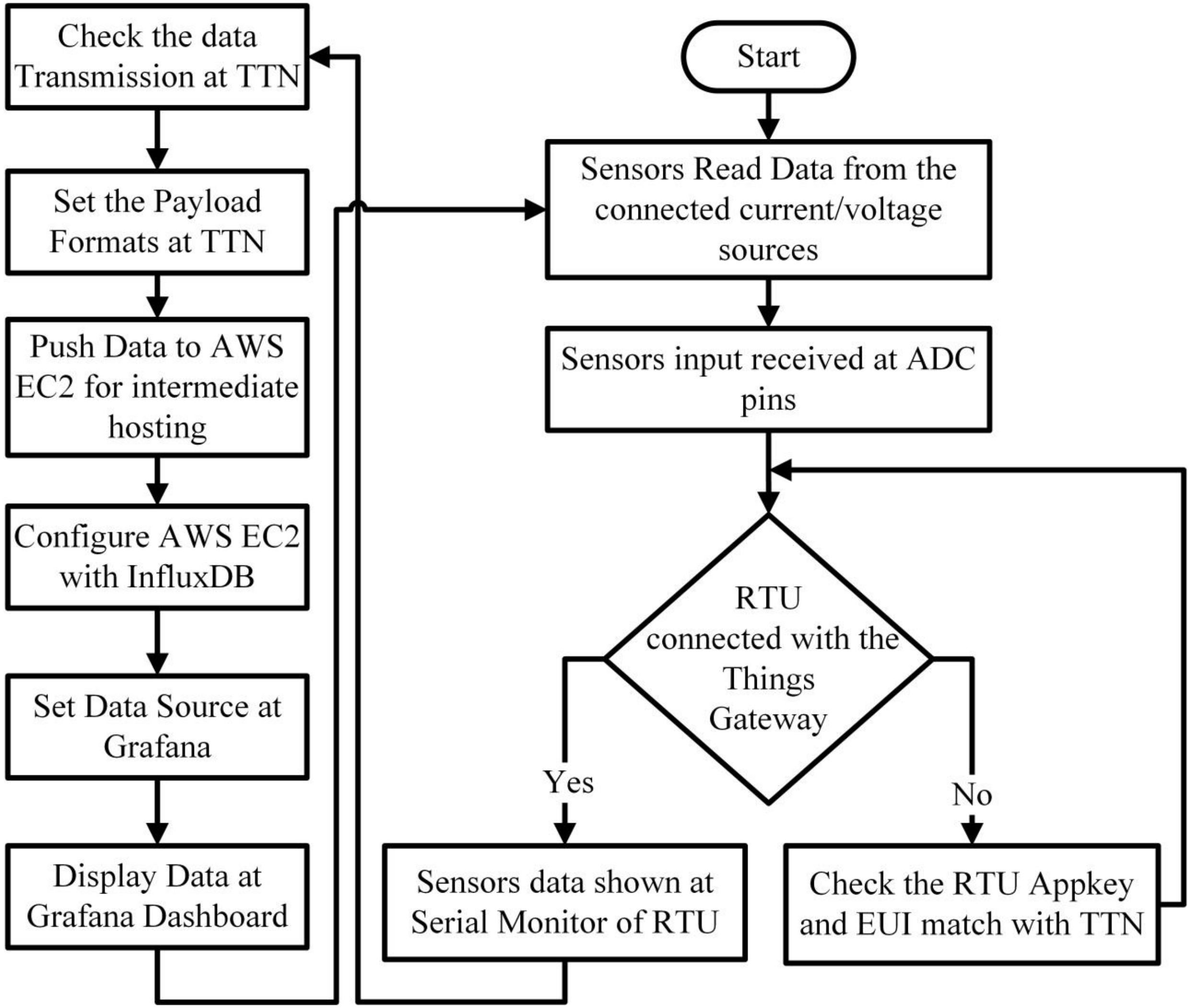
1. Sign up for Influx DB Account.
2. Create the database for TTN Data.
3. Setup Telegraf Config by entering the MQTT Credentials you got from TTN.

Algorithm of the Proposed System

- **AWS EC2 with Grafana and Telegraf**

1. Sign up for AWS Free Account
2. Connect to AWS EC2.
3. Access Grafana Cloud by using the EC2 IP and port set to run the container.
4. In Grafana, go to Data Sources and select Influx DB.
5. Input the Influx DB Credentials and Database.
6. Create the dashboard in Grafana.
7. In the dashboard using InfluxDB as the data source set up the charts and visualization
8. Go to Dashboard to visualize the data.

Flowchart of the Proposed System



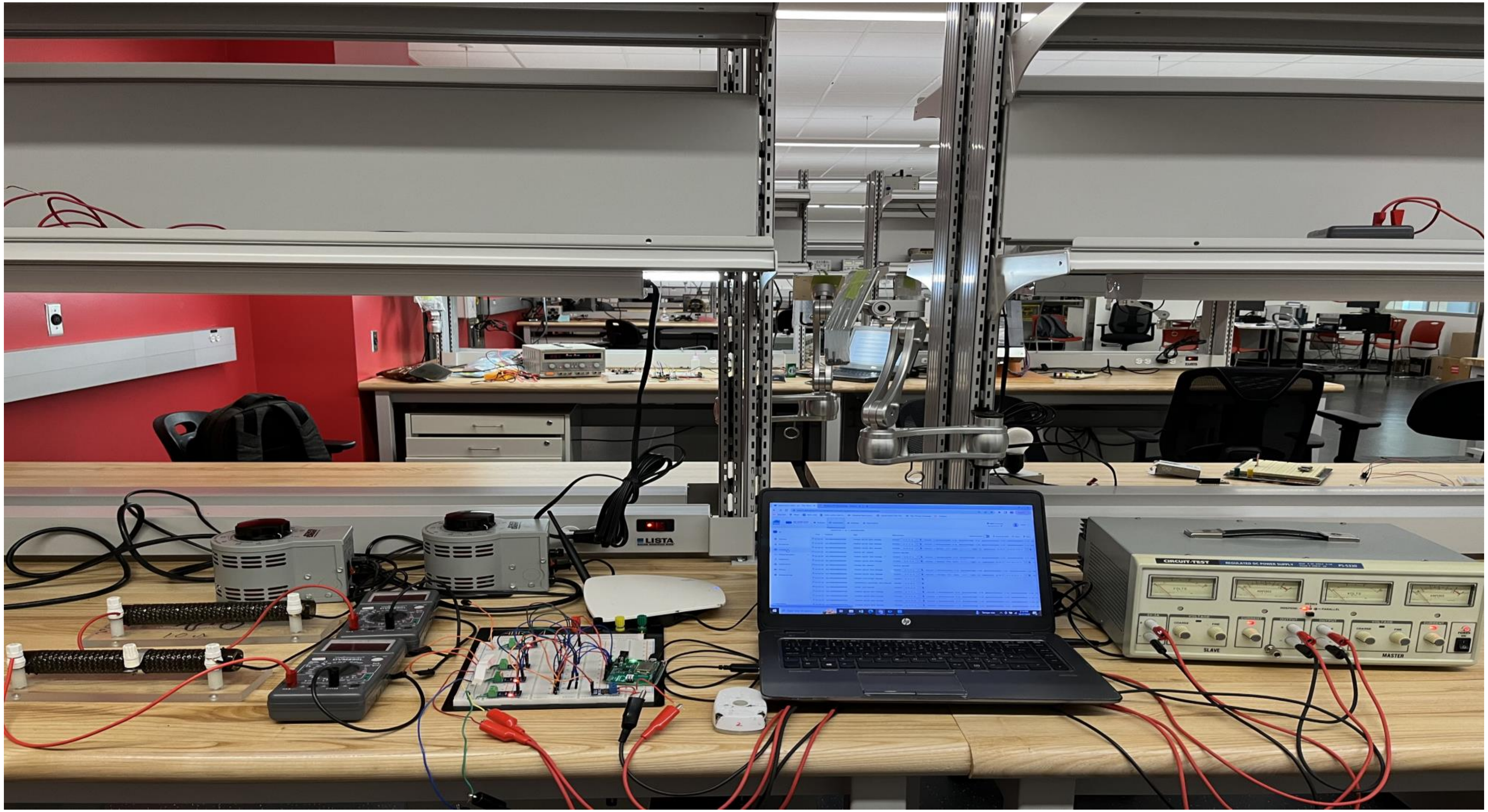
Implementation Methodology

- Solar and Battery current sensors are supplied with the DC current source through a shunt resistor having a power rating of 7W and 2.2Ω.
- The generator and inverter current sensors are supplied the AC current via autotransformer, model no is 3PN1010B.
- The AC current is supplied to sensors via a rheostat of 10Ω & 300W of power rating.
- The voltage sensor which has the capability to measure voltage in the range of 0-25V is connected in parallel to the fixed DC voltage source.
- The temperature is measured through the Things Node.
- Although the readings taken from sensors can be seen at HMI but to check the accuracy of the developed system, multimeters are connected at several points to take the continuous and live readings of current and voltage of all the sensors to ensure the accuracy of sensors and subsequent deployed system.

Implementation Methodology

- The RTU takes the readings from the sensors and reports it to the Arduino IDE software.
- Since the RTU is configured as end device as TTN so the live data reported by RTU can be seen at the cloud that can be accessed by the authorized users on internet anywhere in the world.
- The data is logged for three continuous hours, all the sensors were connected with the explained setup and continuously sending data.
- The sensors sends the live readings at IDE after every 40 seconds and the same readings are reported at TTN after one second on average.
- The data received at TTN is saved at InfluxDB and 30 days of storage is supported in a free version.
- A graphical user interface is developed on Grafana and the graphs of each current sensor can be seen under the dashboard.

Implementation Methodology

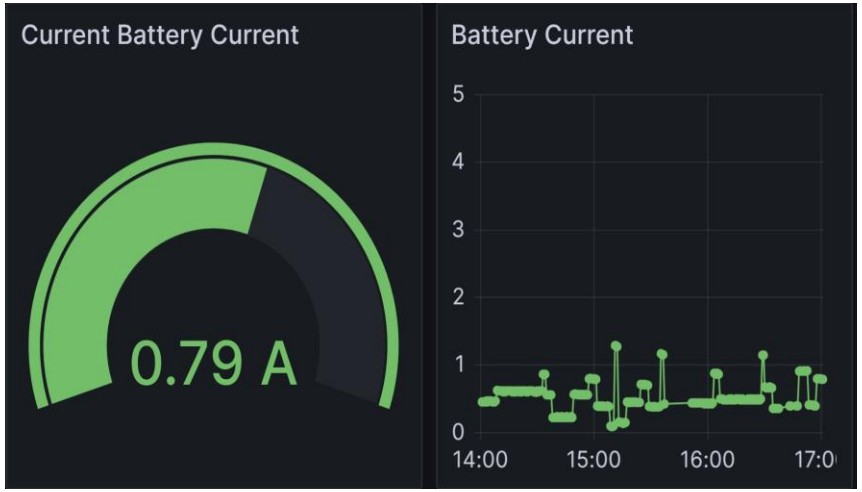


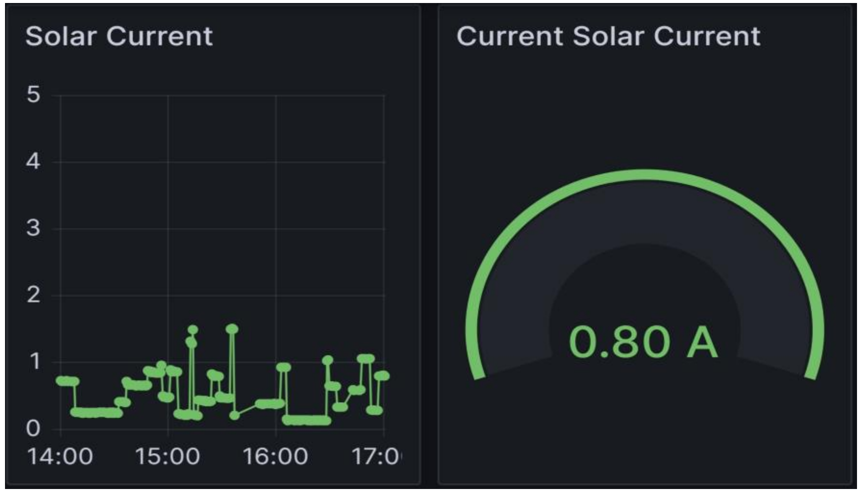
Results

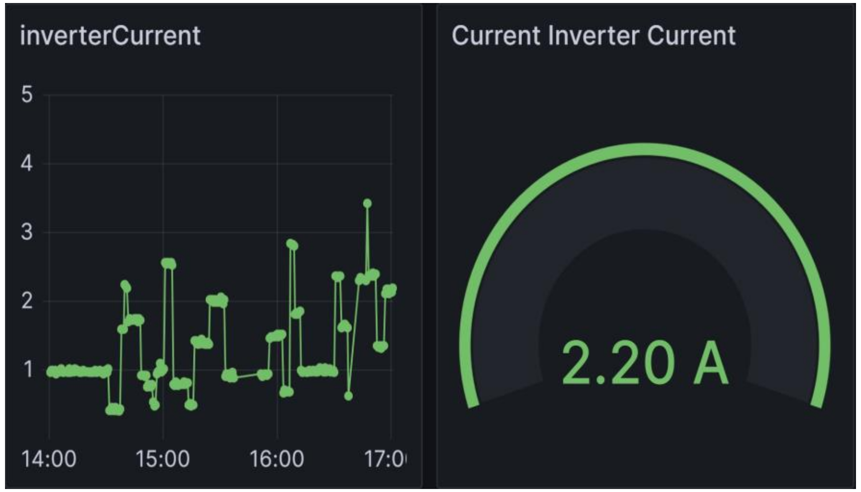
Applications › pv › Application data

Time	Entity ID	Type	Data preview
↑ 22:05:23	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.75, batteryVoltage: 4.85, generatorCurrent: 2.31, inverterCurrent: 1.84, ledState: "off", solarCurrent: 0.71 }
↑ 22:04:40	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.6, batteryVoltage: 4.85, generatorCurrent: 0.89, inverterCurrent: 1, ledState: "off", solarCurrent: 0.56 } 00
↑ 22:03:56	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.59, batteryVoltage: 4.88, generatorCurrent: 0.87, inverterCurrent: 1.02, ledState: "off", solarCurrent: 0.56 }
↑ 22:03:20	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.6, batteryVoltage: 4.88, generatorCurrent: 0.87, inverterCurrent: 1.02, ledState: "off", solarCurrent: 0.56 }
↑ 21:58:20	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.32, batteryVoltage: 4.88, generatorCurrent: 1.71, inverterCurrent: 1.99, ledState: "off", solarCurrent: 0.57 }
↑ 21:57:48	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.34, batteryVoltage: 4.88, generatorCurrent: 1.75, inverterCurrent: 1.95, ledState: "off", solarCurrent: 0.57 }
↑ 21:57:05	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.88, generatorCurrent: 1.77, inverterCurrent: 1.97, ledState: "off", solarCurrent: 0.58 }
↑ 21:56:28	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.9, generatorCurrent: 1.75, inverterCurrent: 1.99, ledState: "off", solarCurrent: 0.58 }
↑ 21:55:51	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.85, generatorCurrent: 1.77, inverterCurrent: 1.95, ledState: "off", solarCurrent: 0.59 }
↑ 21:55:13	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.88, generatorCurrent: 1.75, inverterCurrent: 1.97, ledState: "off", solarCurrent: 0.59 }
↑ 21:54:36	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.88, generatorCurrent: 1.73, inverterCurrent: 1.95, ledState: "off", solarCurrent: 0.59 }
↑ 21:53:58	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.88, generatorCurrent: 1.69, inverterCurrent: 2.01, ledState: "off", solarCurrent: 0.6 }
↑ 21:53:21	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.33, batteryVoltage: 4.88, generatorCurrent: 1.77, inverterCurrent: 1.99, ledState: "off", solarCurrent: 0.6 }
↑ 21:52:43	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.34, batteryVoltage: 4.85, generatorCurrent: 1.75, inverterCurrent: 1.99, ledState: "off", solarCurrent: 1.05 }
↑ 21:52:06	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.34, batteryVoltage: 4.88, generatorCurrent: 1.15, inverterCurrent: 1.79, ledState: "off", solarCurrent: 1.07 }
↑ 21:51:28	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.76, batteryVoltage: 4.88, generatorCurrent: 1.15, inverterCurrent: 1.77, ledState: "off", solarCurrent: 0.75 }
↑ 21:50:51	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.76, batteryVoltage: 4.85, generatorCurrent: 1.1, inverterCurrent: 1.75, ledState: "off", solarCurrent: 0.76 }
↑ 21:50:14	eui-0004a30b00227e20	Forward uplink data message	DevAddr: 26 0C 78 C5 Payload: { batteryCurrent: 0.75, batteryVoltage: 4.85, generatorCurrent: 0.13, inverterCurrent: 0.07, ledState: "off", solarCurrent: 0.76 }

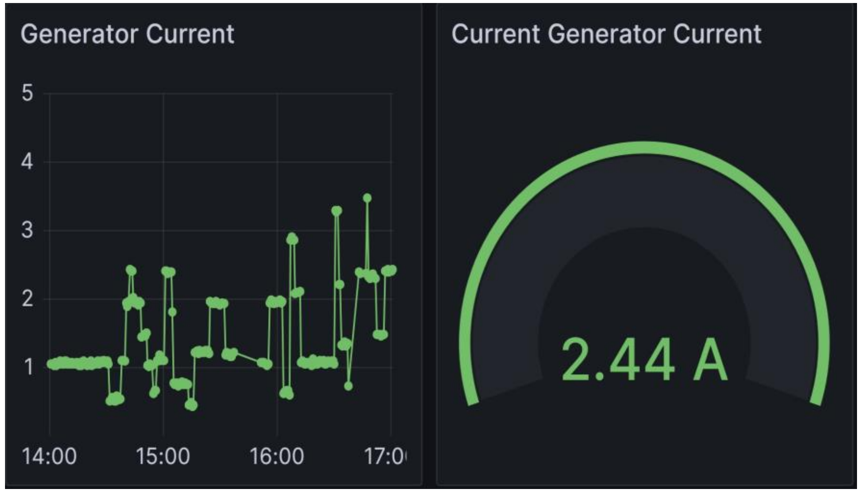
Results

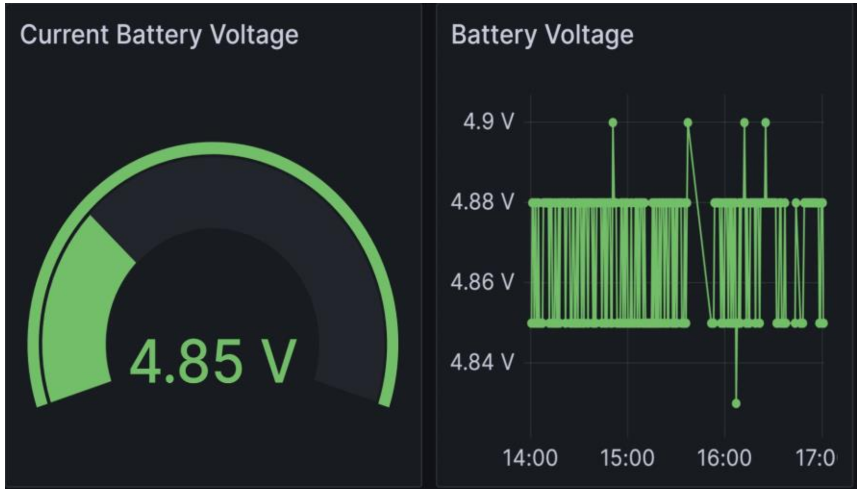

Current Battery Current
0.79 A
Battery Current
5
4
3
2
1
0
14:00
15:00
16:00
17:0

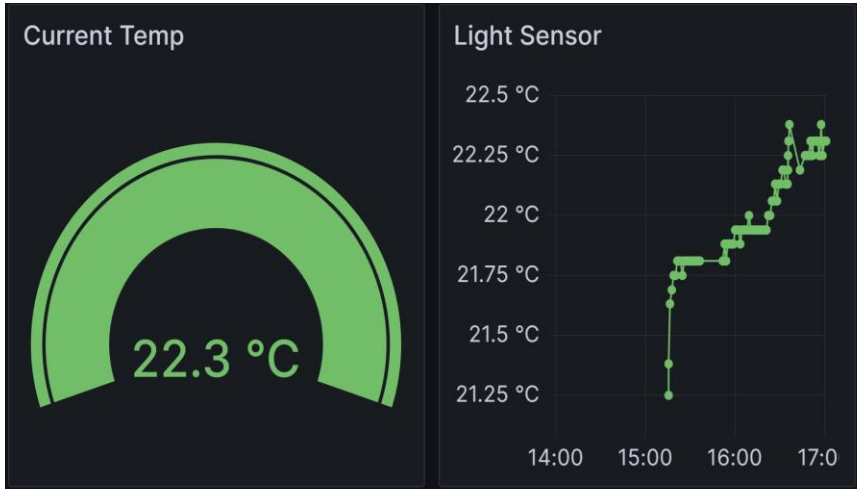

Solar Current
5
4
3
2
1
0
14:00
15:00
16:00
17:0
Current Solar Current
0.80 A


inverterCurrent
5
4
3
2
1
14:00
15:00
16:00
17:0
Current Inverter Current
2.20 A

Results


Generator Current
5
4
3
2
1
14:00
15:00
16:00
17:0
Current Generator Current
2.44 A


Current Battery Voltage
4.85 V
Battery Voltage
4.9 V
4.88 V
4.86 V
4.84 V
14:00
15:00
16:00
17:0


Current Temp
22.3 °C
Light Sensor
22.5 °C
22.25 °C
22 °C
21.75 °C
21.5 °C
21.25 °C
14:00
15:00
16:00
17:0

Conclusion

- An offshore aquaculture site located in the Atlantic Ocean, Newfoundland, Canada is selected, and the actual energy needs for its day-to-day operations were collected to design the renewable energy resource using HomerPro.
- Three scenarios (base, ideal, worst) were developed, by varying the solar resource and average load, to investigate the techno-commercial viability of the designed power system.
- FSPV systems can serve as an excellent resource for delivering both cost-effective and environmentally friendly energy to offshore fish farms.
- The dynamic performance of the designed hybrid power system was evaluated using MATLAB/Simulink.
- A remote monitoring system comprising an open-source, low-cost SCADA system based on LoRA technology was developed and tested in Memorial University's Power lab to monitor and control the performance of the designed hybrid power system.
- The RTU collects data from all sensors and effectively transmits it to the TTN cloud, data storage and visualization are carried out using open-source platforms.
- The thesis provides a comprehensive solution to mitigate the challenges of supplying a reliable, cost-effective, and environmentally friendly power source for offshore aquaculture sites.

Future Work

- A full feasibility study of the FSPV system that includes detailed installation cost, mooring cost, cabling cost, fuel shipment cost etc.
- The reliable buoying mechanism development to hold and ensure the safety of equipment against the tides is crucial thing.
- The impact of ocean waves on the FSPV system needs to be investigated.
- The impact of snow load on the FSPV system needs to be studied.
- More sensors such as each PV and battery string current sensor should be added.
- FSPV motion sensors could be added.
- LoRA private data server without using The Things Network could be added.

List of Publications

- Asgher, M.N., Iqbal, M.T. (2023). Design and Simulate a Floating Solar Photovoltaic System for an Offshore Aquaculture Site in Canada. Jordon Journal of Electrical Engineering (JJEE). The paper is reviewed, accepted by the Journal and in press to be published in the issue of December 2023.
- Asgher, M.N., Iqbal, M.T. (2023). Dynamic Modelling and Analysis of a Hybrid Power System of Floating Solar PV System for an Offshore Aquaculture Site in Newfoundland, presented at IEEE 32nd NECEC 2023. The paper is accepted and presented in NECEC 2023, the same shall be available in MUN research repository.
- Asgher, M.N., Iqbal, M.T. (2023). Development of a Low Cost, Open-Source, LoRA based SCADA System for Remote Monitoring of Hybrid Power System for an Offshore Aquaculture Site in Newfoundland. European Journal of Electrical Engineering and Computer Science (EJECE). The paper is reviewed, accepted by the Journal, and in press to be published soon.


ANY
QUESTIONS?