MINI PROJECT.

DESIGN AND SIMULATION OF AN OFF-GRID PV SYSTEM FOR RESIDENTIAL APPLICATION.

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SUBMISSION DATE : 12/01/2024.

01. Electricity consumption data.

ELECTRICITY ACCOUNT STATEMENT

Jaffna Area,
Northern Province,
Ceylon Electricity Board.

1605498408

Domestic (11) Ordinary
1317073.30
BASKARAN VAXSALA
PALALY ROAD, KONDAVIL EAST, KONDAVIL.

Brought forward balance /LKR : **513.72 DR**

Search

	Billng Month	Days	Units /kWh	Reading Date	Trans. Data	Trans. Type	Trans. Amount /LKR	Balance /LKR
1	2023/Jul	31	154	2023/07/29	2023/08/11	Normal bill	7,723.00 DR	8,236.72 DR
2					2023/07/31	SSCL Tax	198.03 DR	8,434.75 DR
3	2023/Aug	25	132	2023/08/23	2023/09/12	Normal bill	6,825.00 DR	15,259.75 DR
4					2023/08/23	SSCL Tax	175.00 DR	15,434.75 DR
5	2023/Sep	32	127	2023/09/24	2023/10/13	Normal bill	5,718.00 DR	21,152.75 DR
6					2023/09/30	Bank Payment	15,000.00 CR	6,152.75 DR
7					2023/09/25	SSCL Tax	146.62 DR	6,299.37 DR
8	2023/Oct	31	116	2023/10/25	2023/11/10	Normal bill	5,432.33 DR	11,731.70 DR
9					2023/10/25	SSCL Tax	139.29 DR	11,870.99 DR
10	2023/Nov	30	108	2023/11/24	2023/12/13	Normal bill	5,752.00 DR	17,622.99 DR
11					2023/11/20	Bank Payment	10,000.00 CR	7,622.99 DR
12					2023/11/24	SSCL Tax	147.49 DR	7,770.48 DR

Figure 01: Electricity account statement.

Table 01: Monthly unit consumption.

Billng Month	Days	Units /kWh	Reading Date
2023/Nov	30	108	2023/11/24
2023/Oct	31	116	2023/10/25
2023/Sep	32	127	2023/09/24
2023/Aug	25	132	2023/08/23

Daily Energy Usage:

$$Average\ daily\ power\ consumption\ = \frac{total_{units}}{total_{days}} = \frac{483}{118} = 4.09kWh/day$$

02. Components required for the off-grid solar PV system.

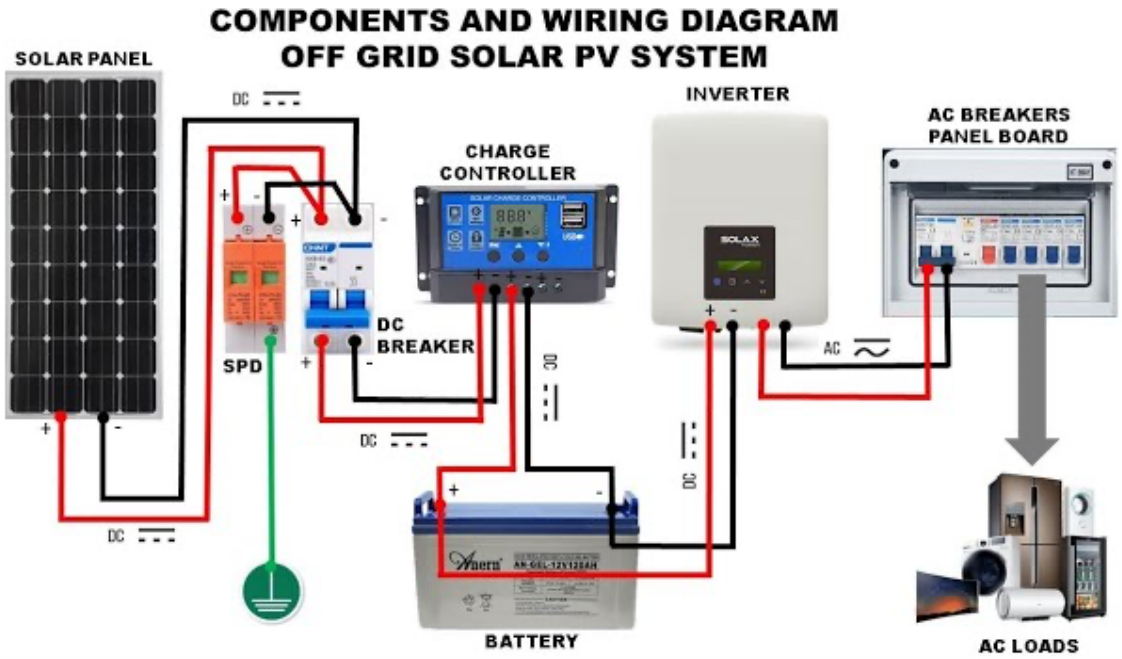

Figure 02: components and wiring diagram off grid solar PV system.

- Solar panels
- Charge controller
- Battery bank
- Inverter
- Brakers
- Other wiring and circuit elements.

03. Required parameter calculation.

1. Solar Panel Sizing

Solar Irradiance:

- Jaffna, Sri Lanka, generally receives good sunlight. For a conservative estimate, let's assume an average solar irradiance of 5 kWh/m²/day.

Accounting for efficiency losses in the system (including inverter and battery losses), lets add about 20% to the required output.

- Total Required Output/Day (with losses): $4.09kWh/day \times 1.20 = 4.91\ kWh/day$

Solar Panel Output Calculation:

SPECIFICATIONS

Module Type	JKM315M-60-V		JKM320M-60-V		JKM325M-60-V		JKM330M-60-V		JKM335M-60-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	315Wp	235Wp	320Wp	239Wp	325Wp	242Wp	330Wp	246Wp	335Wp	250Wp
Maximum Power Voltage (Vmp)	33.2V	31.2V	33.4V	31.4V	33.6V	31.6V	33.8V	31.8V	34.0V	32.0V
Maximum Power Current (Imp)	9.49A	7.56A	9.59A	7.62A	9.68A	7.66A	9.77A	7.74A	9.87A	7.82A
Open-circuit Voltage (Voc)	40.7V	37.6V	40.9V	37.8V	41.1V	38.0V	41.3V	38.2V	41.5V	38.4V
Short-circuit Current (Isc)	10.04A	8.33A	10.15A	8.44A	10.20A	8.54A	10.31A	8.65A	10.36A	8.74A
Module Efficiency STC (%)	18.88%		19.18%		19.48%		19.78%		20.08%	
Operating Temperature (℃)	-40℃~+85℃									
Maximum System Voltage	1500VDC (IEC)									
Maximum Series Fuse Rating	20A									
Power Tolerance	0~+3%									
Temperature Coefficients of Pmax	-0.37%/℃									
Temperature Coefficients of Voc	-0.28%/℃									
Temperature Coefficients of Isc	0.048%/℃									
Nominal Operating Cell Temperature (NOCT)	45±2℃									

STC: Irradiance 1000W/m² Cell Temperature 25°C AM=1.5

NOCT: Irradiance 800W/m² Ambient Temperature 20°C AM=1.5 Wind Speed 1m/s

* Power measurement tolerance: ± 3%

Figure 03: Specifications of the selected Solar PV panel.

- Let's use Jinko solar panel with 335Wp output:

$$Panel\ Output\ per\ Day\ =\ Panel\ Rating\ \times\ Average\ Sunlight$$

Let's assume peak sun hours at Jaffna at deign tilt is 5 hours.

$$Panel\ Output\ per\ Day\ =\ 335 \times 5\ hours\ =\ 1.675\ kWh/day$$

- $Number\ of\ Panels\ Required\ = \frac{4.91kWh/day}{1.675kWh/day/panel}\ \approx 2.931 \approx 3\ panels$

- Ratted PV array output = 335 x 3 =1005W

2. Battery Sizing

Daily Energy Requirement:

- Total Required Battery Storage (1-day autonomy): 4.09 kWh
- Battery capacity needed per day: 4.09 kWh/24V ≈ 170Ah.
- Days of storage desired = 3day
- batteries with an 50% DoD
- Total Battery Capacity Needed: $\frac{170\ Ah \times 3}{0.50 \times 0.85} = 1200\ Ah$

Model	Nominal Voltage (V)	Capacity @C10 up to 1.8VPC at 27°C (Ah)
6LMS75L	12	75
6LMS100L	12	100
6LMS120L	12	120
6LMS150L	12	150
6LMS200L	12	200

Figure 04: available battery models

- Let's select 6LMS200L battery.
- Number of batteries in parallel $= \frac{1200}{200} = 6$ batteries
- Number of batteries in series $= \frac{24}{12} = 2$
- Total number of batteries $= 6 \times 2 = 12$ Batteries.

3. Inverter Sizing

Table 02: load profile,

Appliance	no of appliances	Rated power (W)	Total wattage(W)
Water pump	1	750	750
Washing machine	1	500	500
Ceiling fans	3	50	150
TV	1	100	100
Bulbs	8	20	160
Laptop	2	35+65	100
Phone chargers	3	20	60
Router	1	25	25
others	-	100	100
Total wattage			1945

- Peak Load: 1945 W
- Inverter Size Recommendation: Slightly above the peak load, say, a 2.5 kW inverter.

4. DC braker sizing

Short circuit current $I_{SC} = 10.36A$

Dc rating $= I_{SC} \times 1.25 = 10.36 \times 1.25 = 12.95A$

$$Maximum\ DC\ load\ current\ =\ 1945/12 = 162.08A$$

5. AC Braker sizing

$$AC_{rating\_inverter} = \frac{inverter\ ratting}{utility\ voltage} = \frac{2500}{230} = 10.869$$

Other than these separate brakers for pump and the washing machine.

For these brakers we need to choose the brakers rating slightly above these current ratings.

04. MATLAB Simulink modeling

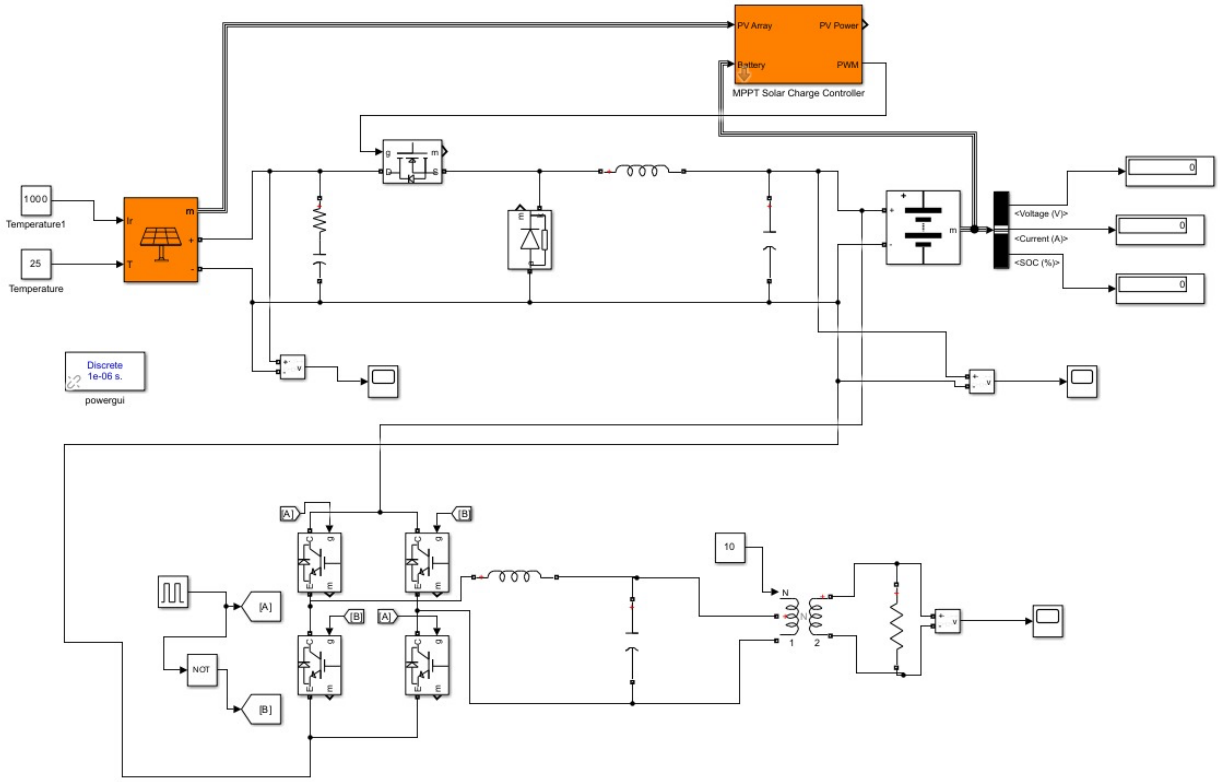

Figure 05: Simulation Diagram of the Off grid Solar System

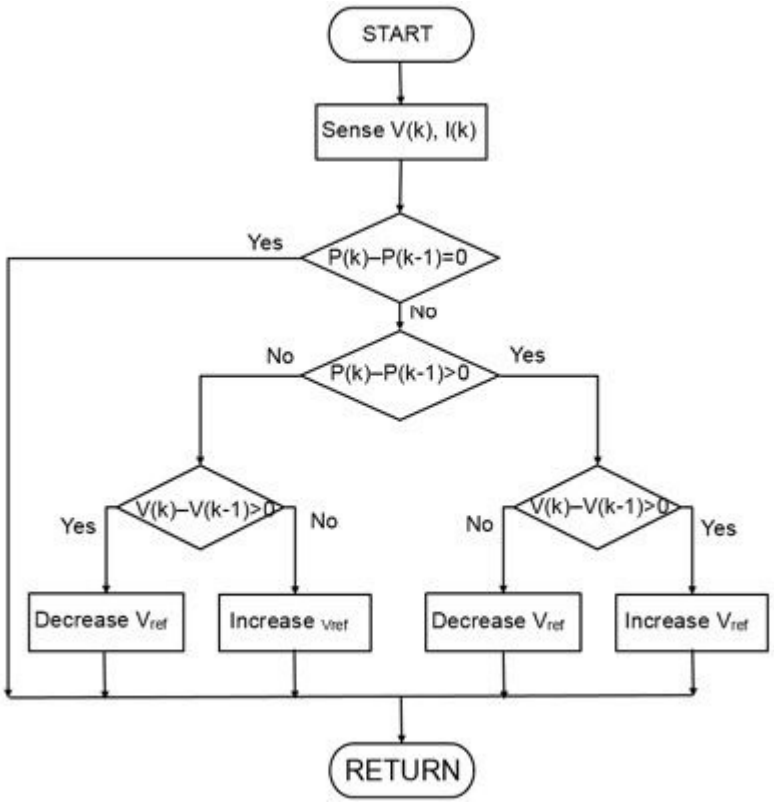

Figure 06: Maximum Power Point Tracking based on Perturbation & Observation algorithm.

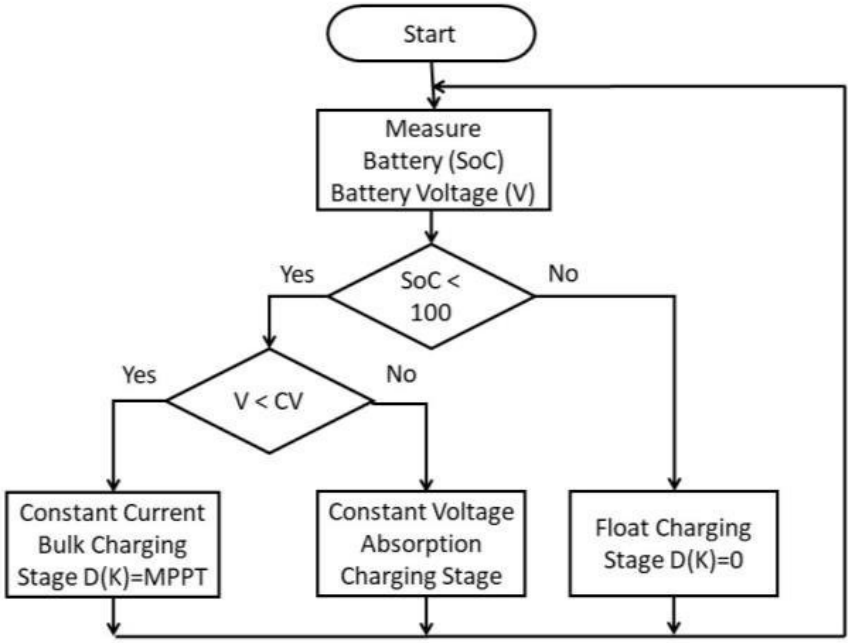

Figure 07: Three stage charging algorithm for charging lead acid battery

Simulation results.

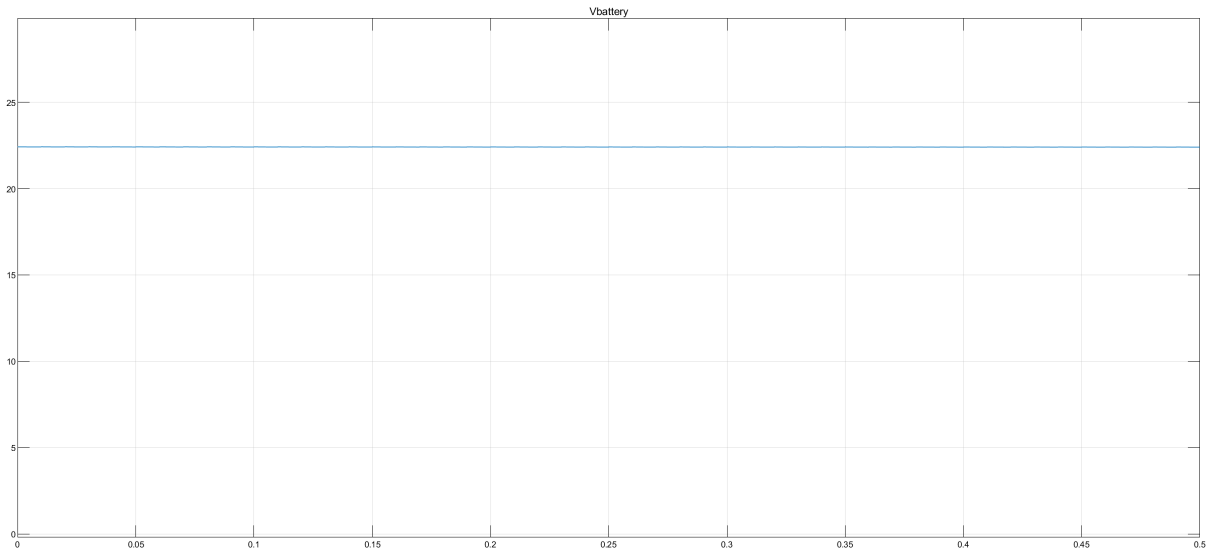

Figure 08: Battery bus voltage.

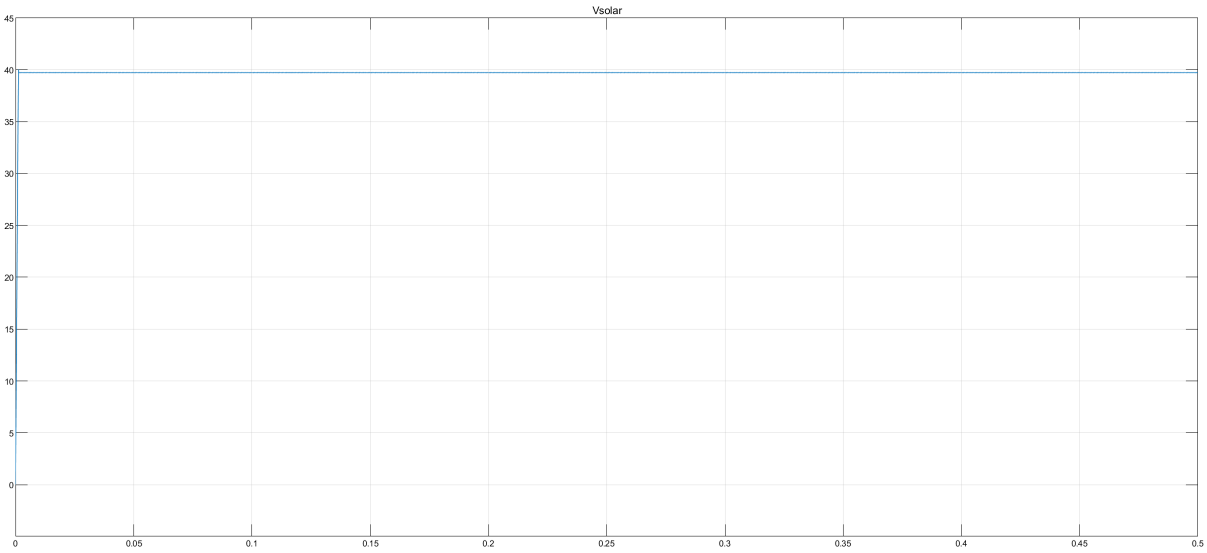

Figure 09: PV array output voltage.

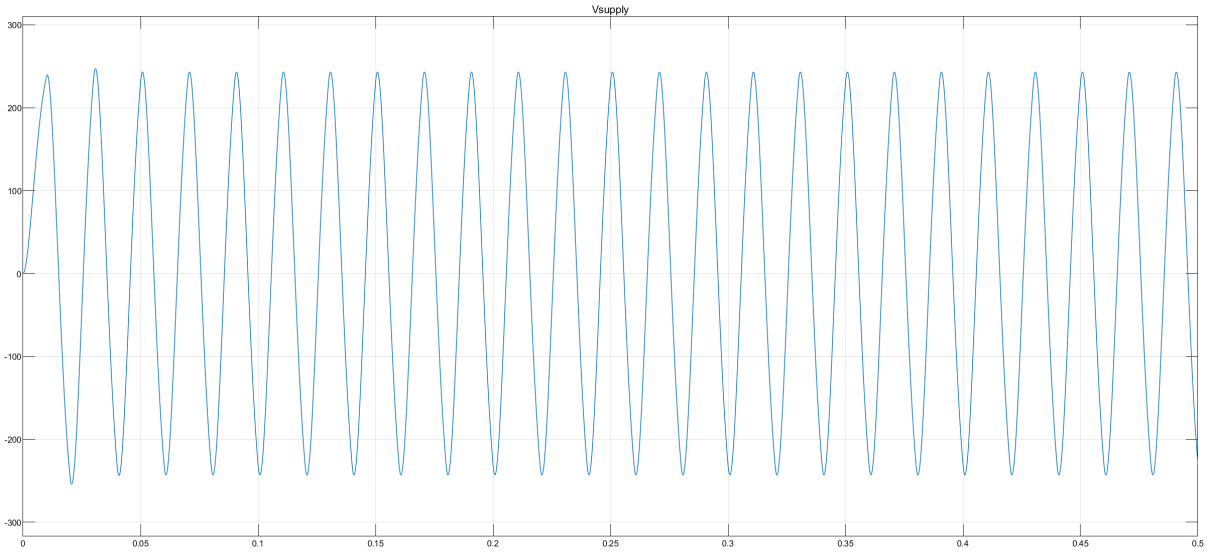

Figure 10: Utility AC supply voltage.

REFERENCE

[1] “Exide Solar Tubular Batteries in Sri Lanka - Brown & Company PLC,” *Brownsgroup.com*, 2024. https://www.brownsgroup.com/brands/product/exide-solar-tubular-range.html?url=exide-industrial-batteries (accessed Jan. 12, 2024).

[2] “JINKO SOLAR PANEL 335W – A Plus Eco.” https://apluseco.lk/eco/product/jinko-solar-panel-335w/ (accessed Jan. 14, 2024).

[3] “Components and Wiring Diagram of Off-Grid Solar System,” *www.youtube.com*. https://www.youtube.com/watch?app=desktop&v=cj2Q44bTCwU (accessed Jan. 12, 2024).

[4] Ashish Dhanowa and Vijay Kumar Garg, “Modeling and Simulation of an off Grid PV system for with Battery Backup for Remote and Rural Area Network,” *International Journal of Engineering Research and*, vol. V4, no. 06, Jun. 2015, doi: https://doi.org/10.17577/ijertv4is060964.