Design of a Solar Energy System for a Shop In Nigeria Providing Community Cellphone Charging Service.

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Outline.

- Introduction.
- Literature Review.
- Objectives of the study.
- System design and analysis with Homer pro.
- Dynamic simulation of system.
- Design and Simulation of Cellphone Charging System.
- Conclusion.
- Research Contribution.
- Future work.
- Publications.
- References.

Introduction.

- Communication and the internet have become a wonderful tool in our modern-day world.
- Smart gadgets like the mobile phones makes use of internet connection.
- PV technology is one of the renewable sources of clean energy.
- Nigeria has a great potential of photovoltaic energy. she receives an average sun irradiation of 5.4 kWh/ $m2$/day.
- Her growing population and economic activities has led to high demand for electricity supply.
- Geographically, Nigeria is located between latitude 4–14N and longitude 3-15E latitude.

Introduction.

- Charging of cellphones in Nigeria faces the challenges of unreliable power supply.

- In this presentation, different types of mobile phone chargers will be examined, and their technology and specifications will be compared.

- A proposed cellphone charging station that will be situated at Better Mart, Remlek, Badore Road, Ajah, Lagos, Nigeria will be discussed in this presentation.

Literature Review.

Author.	Paper Reviewed.
N.V. Emodi and N. E. Ebele,	“Policies enhancing renewable energy development and implications for Nigeria,” Sustain. Energy,
J. Ozogbuda and M. Iqbal	“Sizing and analysis of an off-grid photovoltaic system for a house in remote Nigeria,”
. Olvitz, D. Vinko, and T. Švedek	Wireless power transfer for mobile phone charging device.
X. Lu, D. Niyato, P. Wang, and D. I. Kim.	Wireless charger networking for mobile devices: fundamentals, standards, and applications.
S. P. Wyche and L. L. Murphy	Investigating and designing for mobile phone use in rural Africa.
Hope Orovwode et al.	Development of a solar system for charging mobile phones with customized DC chargers for rural areas in Nigeria.

Literature Review.

Author.	Paper Reviewed.
Chaudhari et al.	Designed and implemented a solar mobile phone charging station in a campus.
Catalan et al.	Design of Solar Powered Coin-Operated Mobile Charging Station for Sustainable Energy Access.
Gupta, R. et al.	Survey of the efficiency and reliability of the installed mobile phone charging stations across institutions to determine their nature of operation.
Darbha et al	'In DC-DC Chargers for Efficient Utilization of Renewable Energy, it stated that one of the major problems facing rural areas is lack of electricity.
M. Umar	Renewable Sources of Energy for Economic development in Nigeria.
A. A Sambo	Strategic developments in renewable energy development in Nigeria.

Objectives of the study.

- To do a literature review of a microgrid system.

- To size the existing solar system of a supermarket and new system design for cellphone charging facility.

- Dynamic simulation of the solar energy system using MATLAB/Simulink software.

- To do a literature review on cellphone charging system.

- Design and simulation of a cellphone charging system.

System design and analysis with Homer pro.

- Site Location.

The proposed site is located at Better Mart, Badore Ajah Lagos State Nigeria. The google coordinate is (6˚30.0N, 3˚35.9E).

Fig 1. Google map of selected site.

Site Details

Fig 2: Better mart front view.

Better mart is a big instore pickup supermarket with a hybrid power supply system. The supermarket is duly registered under the Company and Allied Act Matters of 2004, its mission is to continue to lower the prices of goods for the residents.

Daily Electrical Energy Consumption.

Daily Energy consumption of Better mart .

Appliance	Quantity	Power Rating (Watts)	Total Wattage	Duration(Hours)	Total Energy (kWh)
LED lighting	40	20	800	10	8
High Intensity Lamps.	10	100	1000	12	12
Open Display Refrigerator	4	750	3000	12	36
Freezers	3	1000	3000	6	18
POS Terminal	5	30	150	12	1.8
Scanners	3	20	60	10	0.6
Computers	10	100	1000	10	10
Monitors	8	45	360	12	4.32
Oven	2	4000	8000	5	40
Mixer	2	2000	4000	3	12
Microwave	2	1000	2000	3	6
Water Heater	1	4000	4000	6	24
CCTV Cameras	30	30	900	24	21.6
50” LED TV	2	100	200	24	4.8
Air Conditioner	10	1500	15000	5	75
Ceiling fan	8	100	800	8	1.6
Total			44.205 Kw		275.72 Kwh

Existing PV System Analysis

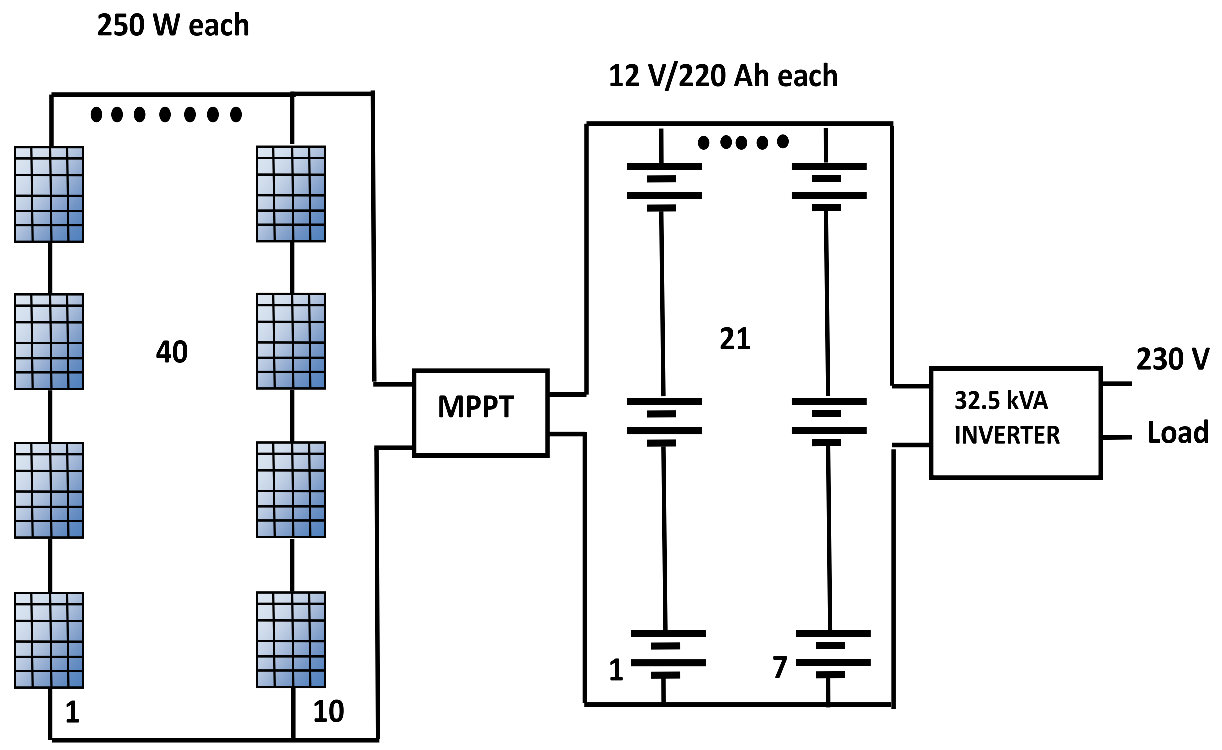


Fig 3: Block diagram of existing PV system.

The existing solar system at Better Mart consists of 40 pieces of 250W monocrystalline solar panels mounted on the roof, 21 pieces of 12V/220Ah batteries, 5MPPT charge controllers and 4 inverters (three 7.5kVA and one 10kVA which is 32.5kVA total).

Electrical Load of Existing System.

Appliances powered by the existing PV system at Better mart.

Appliance	Quantity	Power Rating (Watts)	Total Wattage	Duration(Hours)	Total Energy(kWh)
LED lighting	15	20	300	8	2.4
High Intensity Lamps.	4	100	400	5	2
Open Display Refrigerator	2	750	1500	4	6
Freezers	1	1000	1000	4	4
POS Terminal	5	30	150	8	1.2
Scanners	3	20	60	8	0.48
Computers	8	100	800	8	6.4
Monitors	4	45	180	8	1.44
CCTV Cameras	30	30	900	24	21.6
50" LED TV	2	100	200	24	4.8
Total			5.490 KW		50.32 KWh

System Component

Generator Specification

Specification	Value
Model	Perkins Generator
Prime Power (kVA)	50
Standby Power (kVA)	45
Noise	64 db(A)@7 m dB
Warranty (years)	18 months
Dimension	2888 x 1100 x 1852
Fuel Capacity	240 Litres
Fuel Type	Diesel
Phase	3
Hertz	50 HZ
Starting Method	Electronic
Maintenance cost per hour	0.001$
Diesel cost per liter	1$
Price of generator	5,000$

Better Mart supermarket has a 50 KVA generator that serves as backup in case of power outage, the generator plays an important role by making sure that there is a reliable power supply at the supermarket.

System Component

Monthly grid electricity consumption.

Month	Energy Used (kWh)	Cost of Energy Used ($)
January	308	17.86
February	246	14.28
March	458	26.56
April	258	14.96
May	627	36.37
June	1,043	60.47
July	1,243	72.12
August	1,619	93.90
September	1,313	76.13
October	310	17.95
November	379	21.97
December	240	13.90
Annual Use	8,042	466.46

The grid system that is connected to Better Mart is a 3-phase 230 V line to neutral system with an operating frequency of 50 Hz. Better Mart uses EKO distribution Company and their charge is 0.585$ per Kwh

Solar Irradiation.

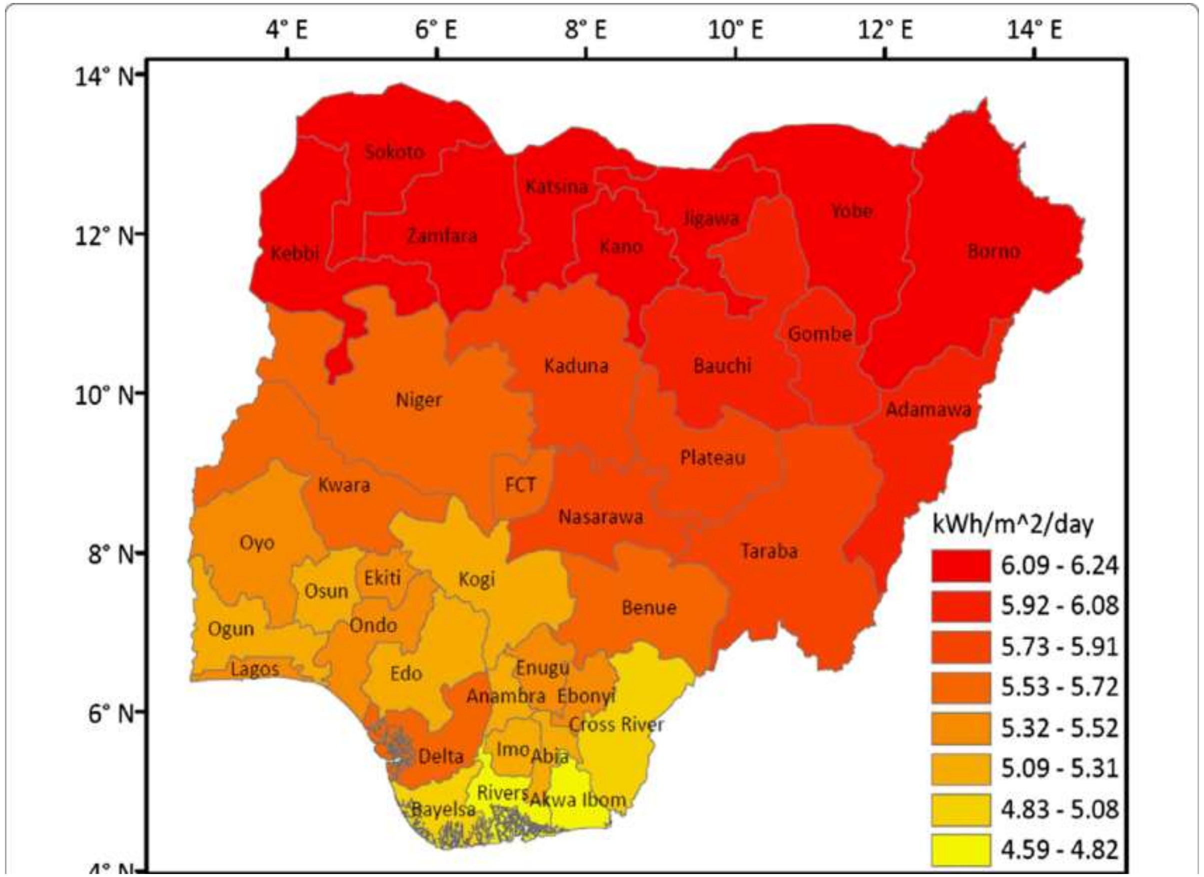


Fig 4: Solar irradiation map of Nigeria .

- Nigeria has a tropical climate with diverse sun distribution, she receives an average annual sun irradiation of about 4.74kwh/m^2/day.
- The country is blessed with abundant sunlight especially the northern part of Nigeria.

Solar Irradiation.

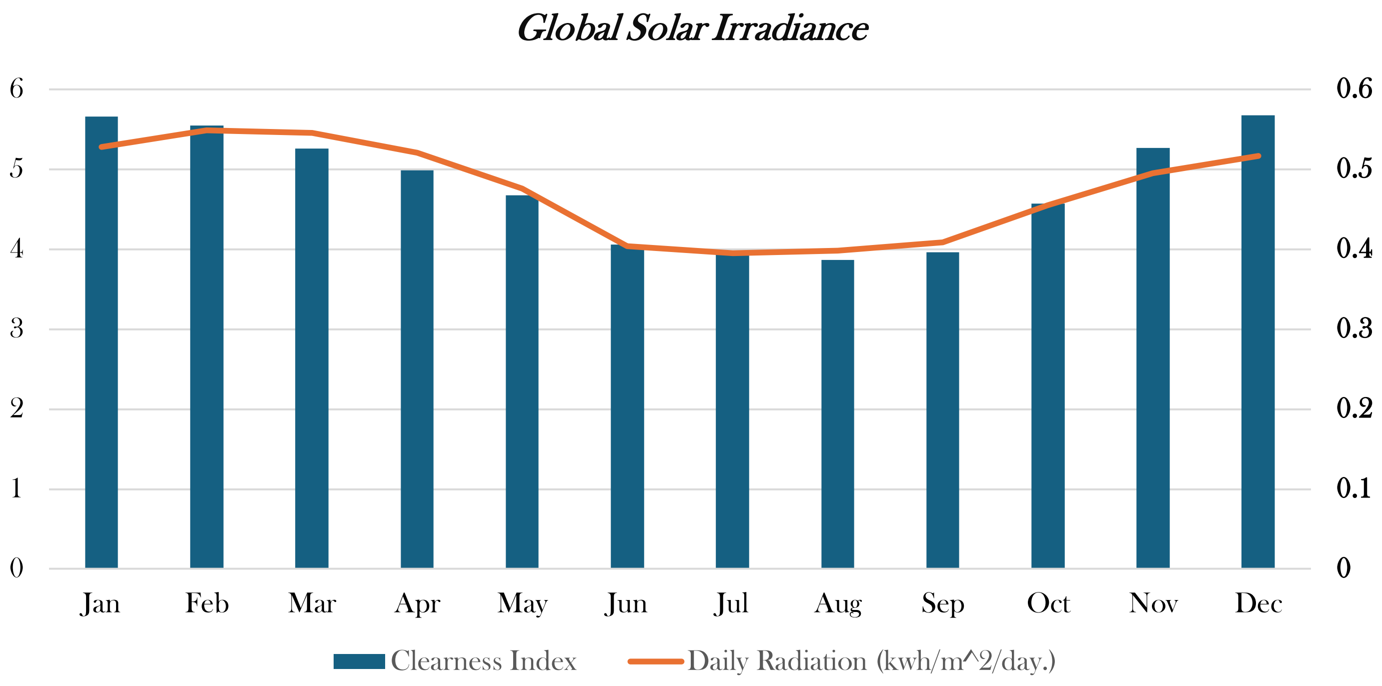


Fig 5: Monthly Solar Global Irradiance of selected site.

Solar irradiation of an area is considered when designing a solar energy project, it is the total amount of solar irradiation received in a unit area, the unit of solar irradiation is(kwh/m^2/day). The average daily solar irradiation of Better Mart is 4.74 kwh/m^2/day.

Proposed Hybrid Power System Design

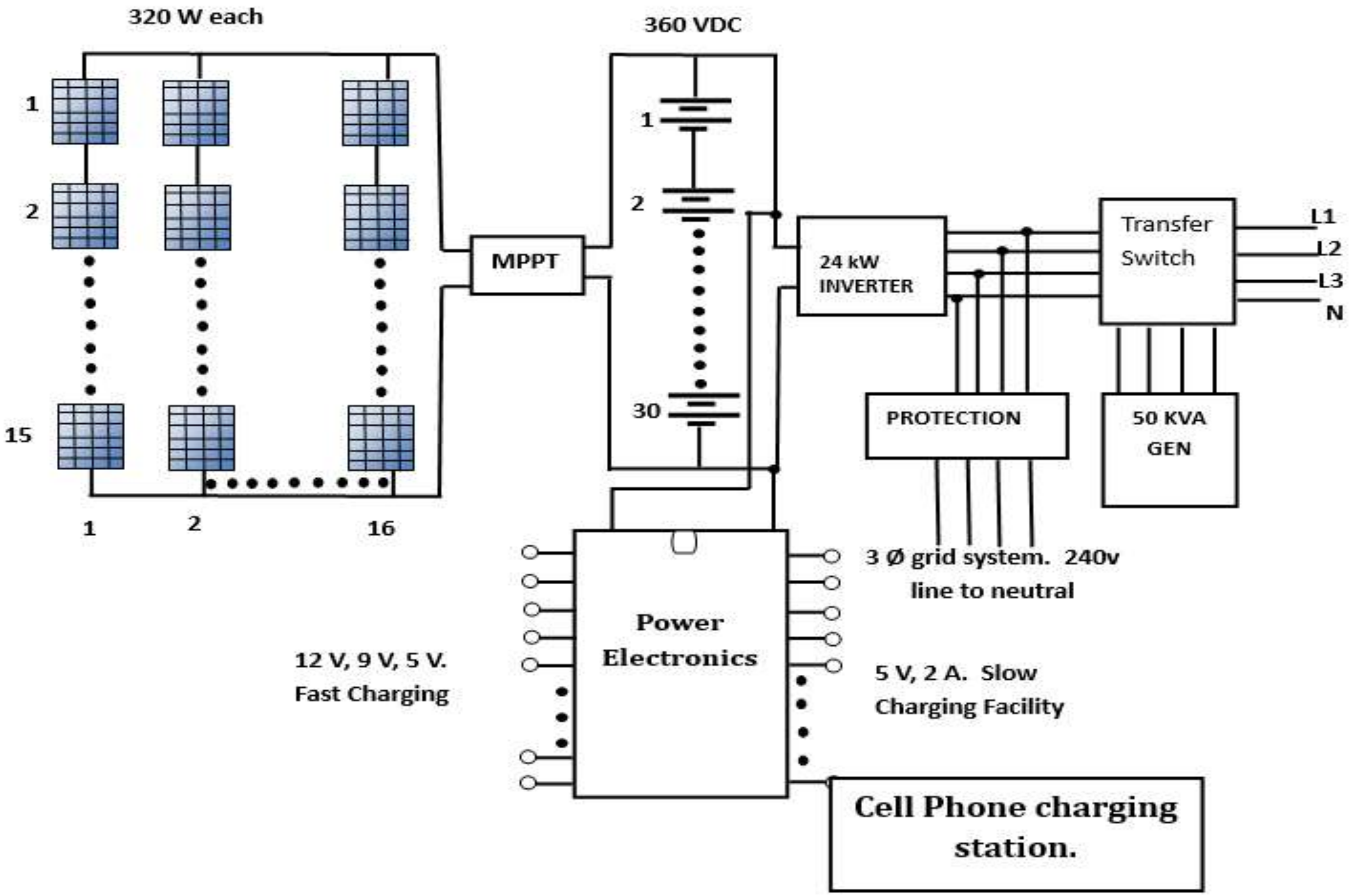


Fig 6: Block diagram of the proposed System.

Components of the proposed System.

- 76.8 KW rated capacity of Trina Duomax, 320 W solar panels.
- 50 KVA Caterpillar generator.
- Grid System.
- 24 KW Fronious Symo Inverter.
- Charge Controller.
- 30 pieces of 12 V/220 Ahr EnerSys PowerSafe 1800 battery Storage.

Homer Pro Schematic diagram.

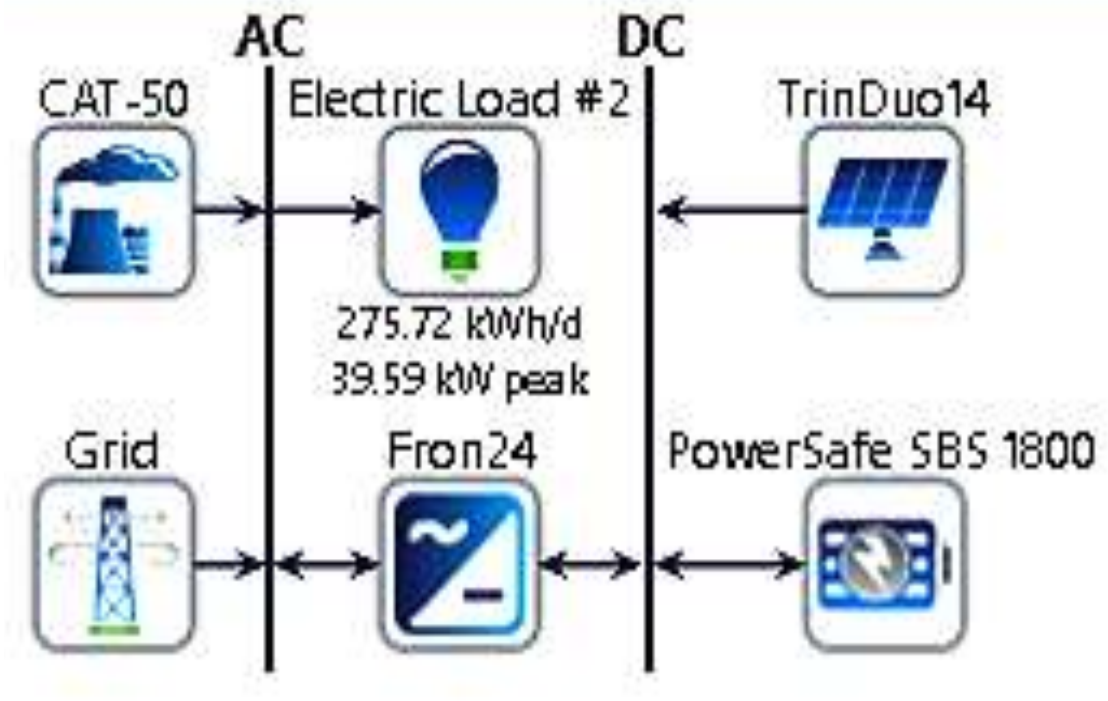


Fig 7: Homer Pro schematic diagram of the hybrid system.

Homer Pro runs the simulation and brings out optimized results, simulation result which contains cost summary, cash flow, compare economics, electrical, emission, renewable penetration and the details of each of the component used in the design.

Homer Pro Optimized Result

Simulation Results

System Architecture:	Fronius Symo 24.0-3 480 (24.0 kW)
Trina Duomax PEG14 (75.4 kW)	Grid (999,999 kW)
EnerSys PowerSafe SBS 1800 (1.00 strings)	HOMER Load Following (1)

Fuel Price (1.00 $/L)

NominalDiscountRate (12.00 %)

Total NPC:	$31,364.22
Levelized COE:	$0.03671
Operating Cost:	$931.04

Emissions

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | EnerSys PowerSafe SBS 1800 | Trina Duomax PEG14 | Grid | Fronius Symo 24.0-3 480

Production	kWh/yr	%
Trina Duomax PEG14	108,003	93.1
Grid Purchases	8,042	6.93
Total	116,046	100

Consumption	kWh/yr	%
AC Primary Load	100,638	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	100,638	100

Quantity	kWh/yr	%
Excess Electricity	12,190	10.5
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	92.0	%
Max. Renew. Penetration	1,158	%

Fig 8: Result of the proposed System.

- Total Net Present Cost NPC is the capital cost of the installation and running of the designed system minus the present value of the revenues that it earns.
- Levelized Cost of Energy (L.C.O.E) is the average cost per kWh of useful electrical energy produced by the system.

Homer Pro Optimized Result.

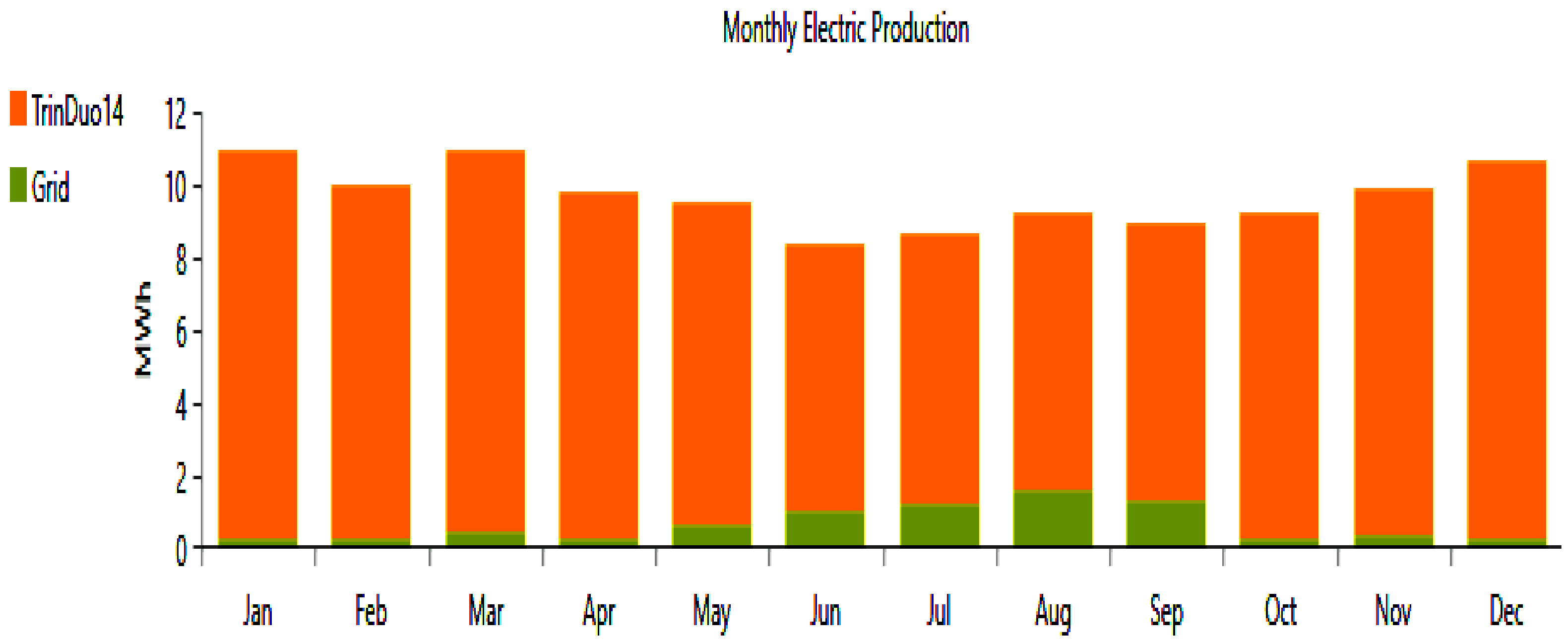


Fig 9: Monthly Electrical Production of the Proposed System.

The high electricity supply from grid from the months of May to September is due to better hydropower output from rain.

Homer Pro Optimized Result.

Homer Pro Optimization Result.

Export... | Export Details...

Optimization Results

Double click on a system to see its Simulation Details.

Categorized | Overall

Architecture						Cost				
TrinDuo14 (kW)	CAT-50 (kW)	PowerSafe SBS 1800 (#)	Grid (kW)	Fron24 (kW)	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)	Ren Frac (%)
75.4		30	999,999	24.0	LF	$31,364	$0.0367	$931.04	$23,460	92.0
137			999,999	24.0	LF	$43,586	$0.0510	$2,016	$26,472	70.0
67.0	40.0	30	999,999	24.0	LF	$80,352	$0.0941	$6,283	$27,017	81.2

Homer Pro suggested the system with the solar panel, Battery storage system and the grid because it is cost effective and meets the electrical load demand at Better Mart.

Homer Pro Optimized Result.

Cost Analysis of the proposed System.

Component	Capital ($)	Replacement($)	O&M ($)	Fuel($)	Salvage($)	Total ($)
Batteries	$7,500.00	$1,463.52	$509.35	$0.00	-$173.50	$9,299.37
Inverter	$3,000.00	$1,153.59	$593.94	$0.00	-$98.07	$4,649.46
Controller	$100	$0.00	$254.68	$0.00	$0.00	$354.68
Grid	$0.00	$0.00	$3,959.89	$0.00	$0.00	$3,959.89
Solar Panel	$12,960.49	$0.00	$140.07	$0.00	$0.00	$13,100.6
System	$23,560.49	$2,717.12	$5,717.12	$0.00	-$271.57	$31,364

Homer Pro Optimized Result.

Sensitivity Cases of the System.

Discount Rate%	Diesel Fuel Price ($/L)	Solar panel (kW)	Battery	Grid (kW)	Converter (kW)	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
12	1.00	75.4	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.00	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.00	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816
12	1.05	75.40	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.05	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.05	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816
12	1.02	75.40	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.02	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.02	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816

Sensitive factors includes;

- ➢ Fuel price.
- ➢ Inflation rate.
- ➢ Grid tariff.
- ➢ Discount rate.
- ➢ Solar irradiance.
- ➢ Component cost.
- ➢ Temperature etc

Summary.

- The sizing of the hybrid power system at Better Mart was carried out with Homer Pro software.
- The proposed hybrid power system was modelled with Homer Pro.
- Homer Pro optimizes the input variables to output a base system and a proposed system.
- The Net Present Cost (NPC) of the proposed system is $31,364.3 while that of the base system is $82,686.
- The proposed hybrid system is the best because it is cost effective.

Dynamic Simulation of Solar Energy System for A Shop in Nigeria Providing Community Cell phone Charging Service.

Power Distribution

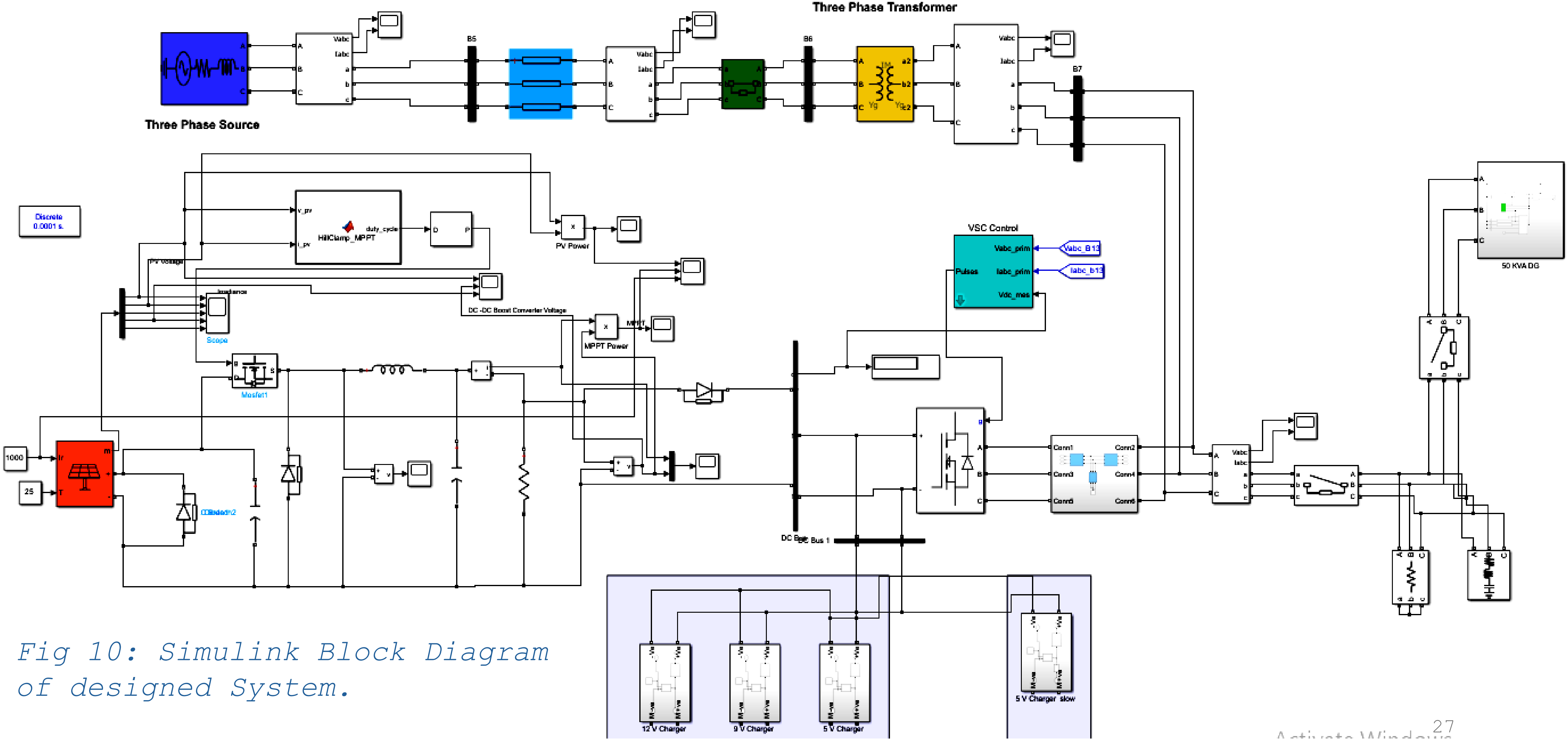


Fig 10: Simulink Block Diagram of designed System.

Dynamic Modeling & Simulation

Photovoltaic Panel (PV);

PV Array is made up of

- 15 PV Modules connected in Parallel.
- 16 PV modules connected in Series.
- Model used is 240 Trina Duomax PEG14 PV panels.
- Each module is rated 320 Watts
- The total output of the PV array is 76.8 kW
- The Output is connected to a 360 VDC bus.

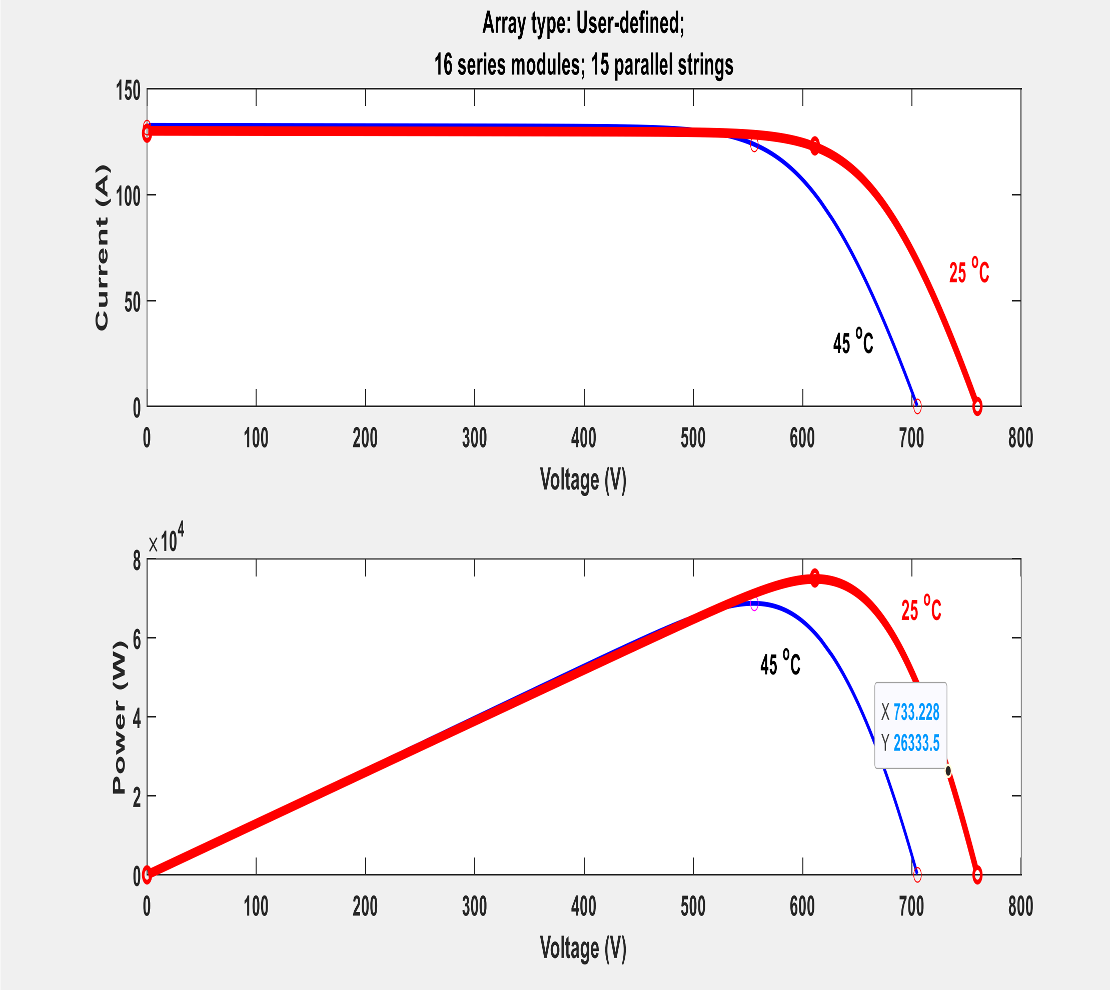


Fig 11. PV Array current and power output

Dynamic Modeling & Simulation.

- Maximum Power Point Tracking (MPPT)

➢ conventional Hill Climbing method was used.

➢ It works by continuously perturbing (changing) the duty cycle of the

DC-to-DC converter connected to PV system output.

➢ Pertubation moves to same direction if there is an increase in the output.

➢ Pertubation moves in opposite direction if there is a decrease.

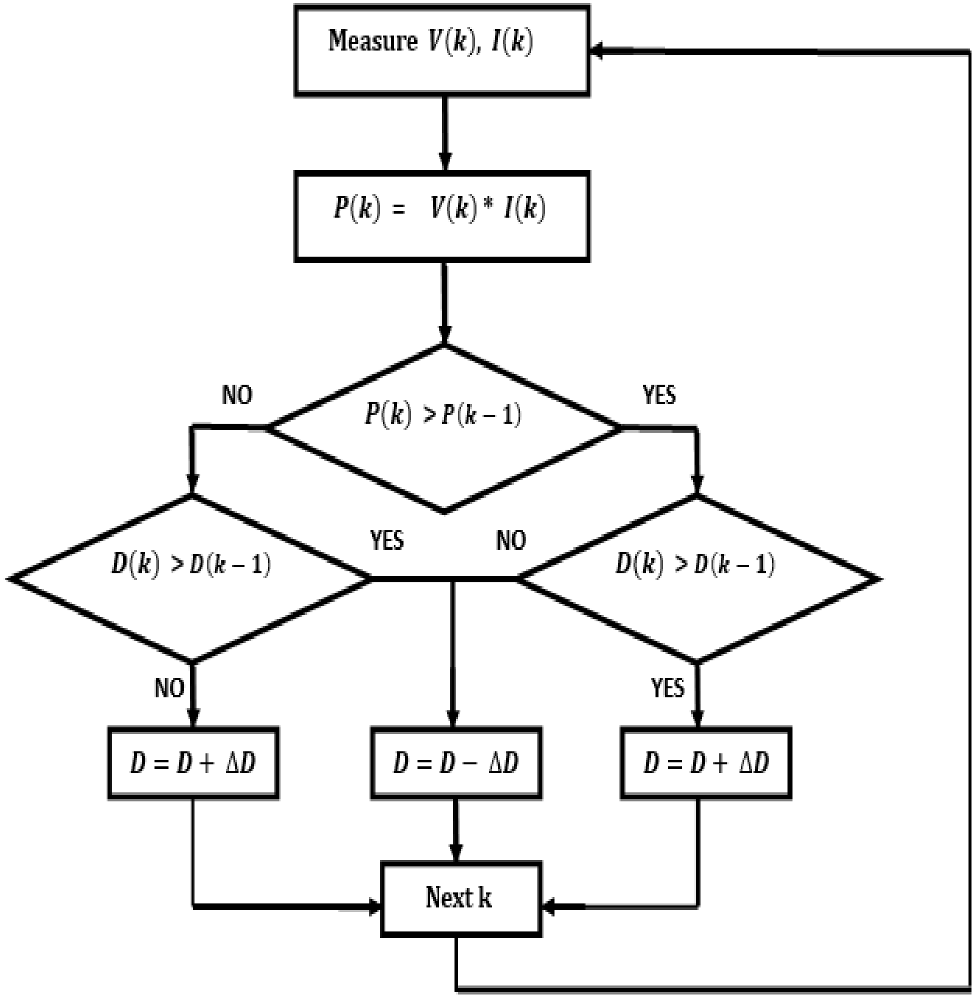


Fig 12. MPPT Flowchart

Dynamic Modeling & Simulation.

DIESEL GENERATOR.

➢ The Diesel Generator consists of:

1. Synchronous Motor.
2. Excitation System.
3. Diesel Engine Governor.

➢ It is a 3 phase generator with a 50 KVA capacity.

➢ It serves as a backup power system.

➢ It is separated from the PV and grid system by a breaker.

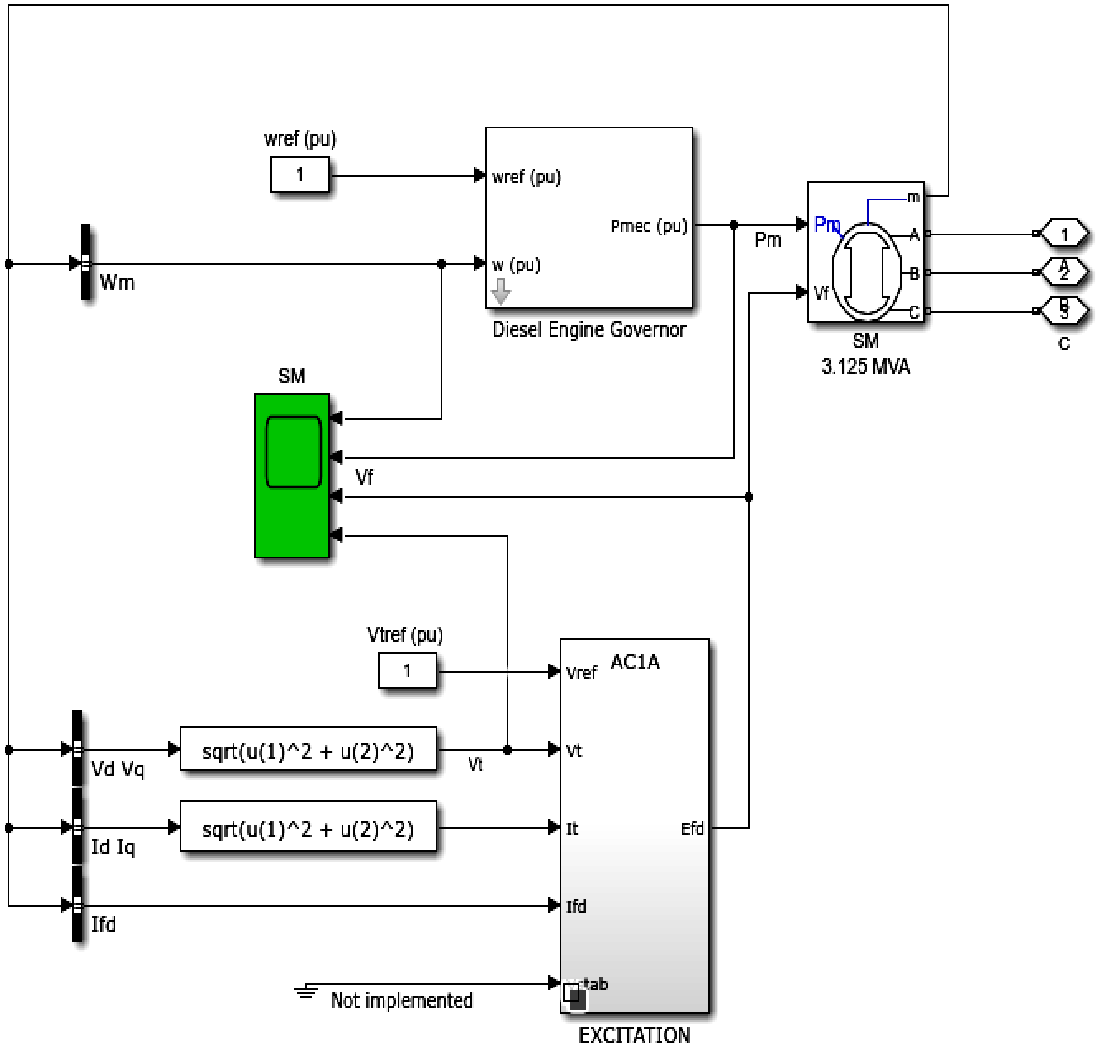


Fig 13. Diesel Generator Simulink Design

Dynamic Modeling & Simulation.

Cellphone Charging Station;

- The Charging station has three reduced voltages, 5 v, 9 v, 12 v.
- The input is 360 VDC from the bus voltage.
- It is designed for cellphone charging purpose.

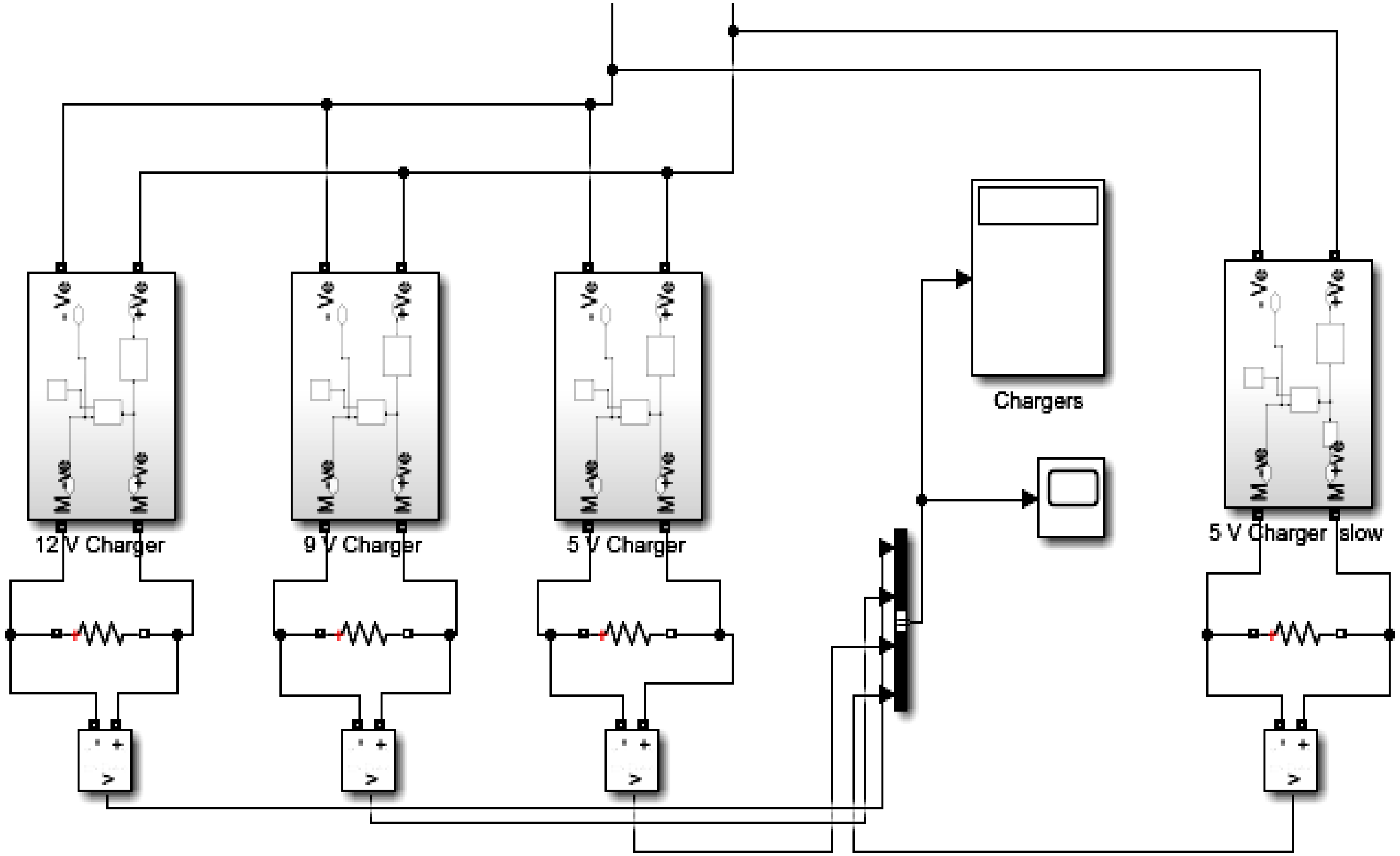
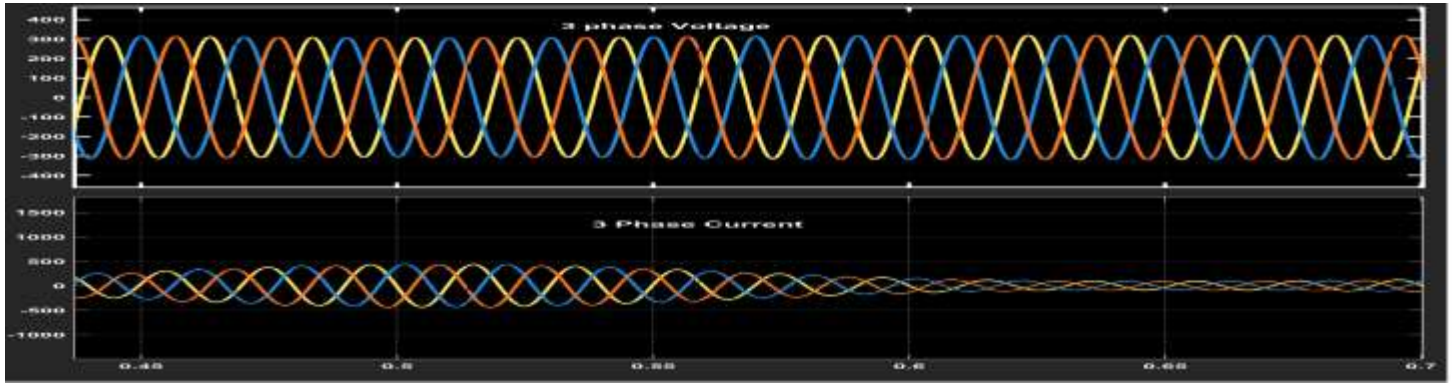


Fig 14. Cellphone Charging Block

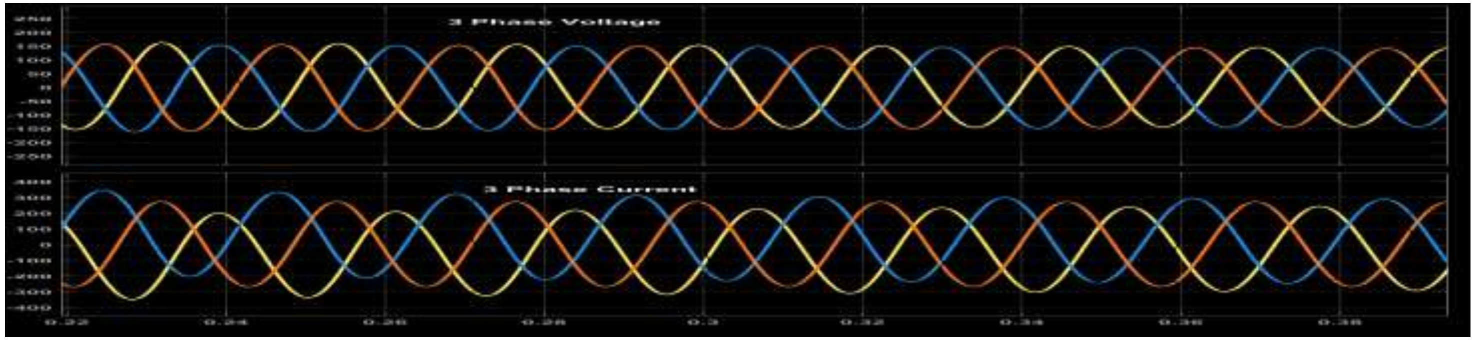
Dynamic Modeling & Simulation.

SIMULATION RESULT.

- Voltage and current output from the diesel generator when the circuit breaker is closed.



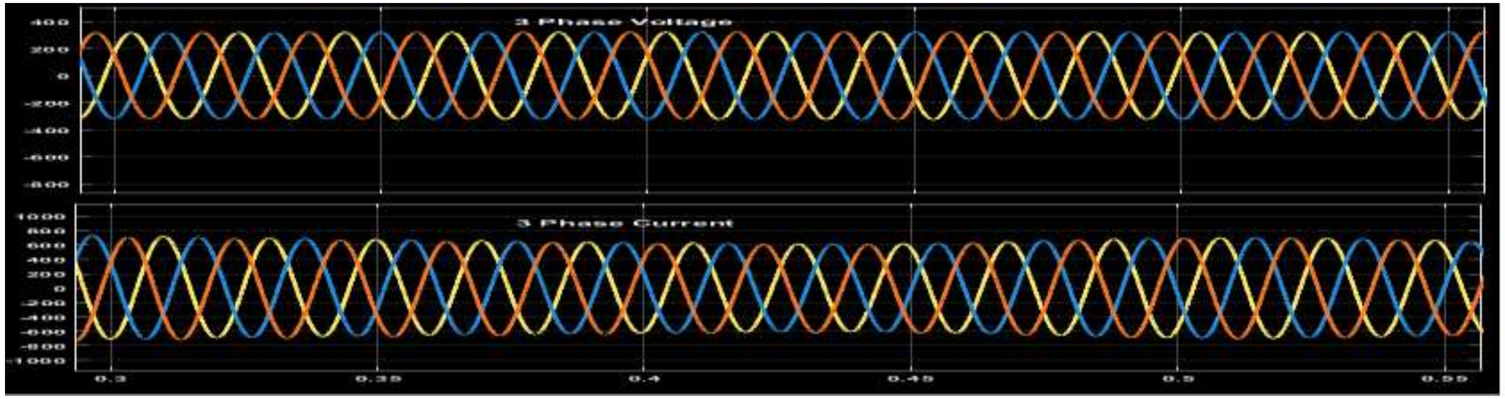
- Voltage and current output from the diesel generator when the circuit breaker is opened.



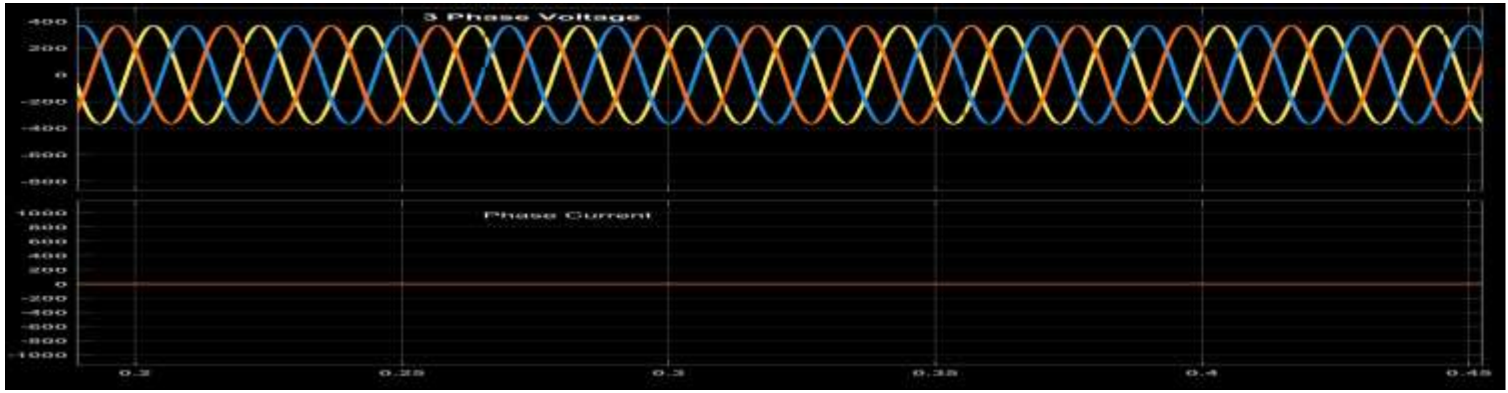
Dynamic Modeling & Simulation.

SIMULATION RESULT

- Voltage and current output from the hybrid system when the circuit breaker is closed.



- Voltage and current output from the hybrid system when the circuit breaker is opened.



Design and Simulation of Cellphone Charging System for a Shop in Nigeria.

Objective.

- Review of different types of cellphone Chargers.
- Design of cellphone charging circuit.
- Architectural design of proposed cellphone charging station.

Introduction.

- The business of mobile phones in Nigeria is growing tremendously.
- Mobile phones have helped in the globalization and digitalization of our world today.
- Batteries of cellphones needs to be charged so as to make maximum use of them.
- Chargers work by converting the alternating current from the socket to direct current.
- To charge a phone, it is advisable for users to check compatibility between the mobile phone and the charger.

Cellphone charger Review.

- **Base Plug Chargers.**

Fig 16: Motorola Base Plug Charger.

- Motorola invented the first mobile phone with base plug chargers, Motorola DynaTAC 8000X in the year 1983.
- Base-plugged chargers are portable and mobile.
- It takes 10 hours to charge a battery that will last only for 30 minutes.
- It has a voltage and current output of 5 V and 2 A.

Cellphone charger Review.

- **Integrated Chargers.**

- Nokia corporation made available its first portable phone, Nokia 1011 in 1992.
- Nokia 1011 with an intergrated charger.
- the charging cable and plug of the integrated charger were inseparable.
- It has voltage and current output of 5V and 350 – 500mA.
- It can only be used by Nokia users.

Fig 17: Integrated Charger.

Cellphone charger Review.

- **Universal Chargers.**

- Universal chargers flooded into the market in the year 2003.
- The invention came because of non-standardization in the chargers made by phone industries.
- The universal charger is made up of two adjustable metal contact springs.
- Universal chargers work with a voltage range of 5 – 20 V and current range of 1 – 5 A.

Fig 18: Universal Chargers.

Cellphone charger Review.

- **USB-A Chargers.**

➢ USB – A (Universal Serial Bus) charger is a type of charger that is directed towards the host, it has a plug on each head.

➢ USB – A charger is compatible with many mobile devices.

➢ It works with 5 V and current range of 0.5 A to 2.4 A.

➢ USB technology has been selected as the standard charging format for mobile phones.

Fig 19: USB-A Charger.

Cellphone charger Review.

- USB – C Charger.

➢ USB – C charger provides power to modern phones, laptops and handheld devices.

➢ USB – C is used by both USB technology and other protocol used in connecting and sending data.

➢ USB- C technology was developed in 2012 by a group of companies.

➢ USB – C operates with an amperage of 5 A and a maximum voltage of 20 V.

Fig 20: USB – C Charger.

Cellphone charger Review.

- **USB 3.0 Chargers.**

➢ USB 3.0 chargers are the 3rd version of Universal Serial Bus (USB).

➢ It is known as Super Speed USB because of its fast-charging capability.

➢ The data transfer rate of USB 3.0 is 5 gigabits per second with a charging current of 900 mA.

Fig 21: USB 3.0 Chargers.

Cellphone charger Review.

- **Wireless Phone Charging Technology.**

➢ This type of technology functions by transferring energy from a charging pad to a compatible device.

➢ Charging pad/station contains a coil of wire that generates magnetic field.

➢ The receiver which is the phone that contains a built-in-coil captures the energy from the charging pad.

➢ The major drawback in this technology is low charging speed.

Fig 22: Wireless Phone Charger.

Cellphone charger Review.

- Other Latest Phone Charging technology includes:

➢ Fast Charging Technology;

- ❖ Power Delivery PD.
- ❖ Quick Charge QD 5 by Qualcomm.
- ❖ VOOC/Dart charging by Oppo, Realme and Oneplus.

➢ **Gallium Nitride Chargers (GaN).**

MODELLING OF CELLPHONE CHARGING CIRCUIT.

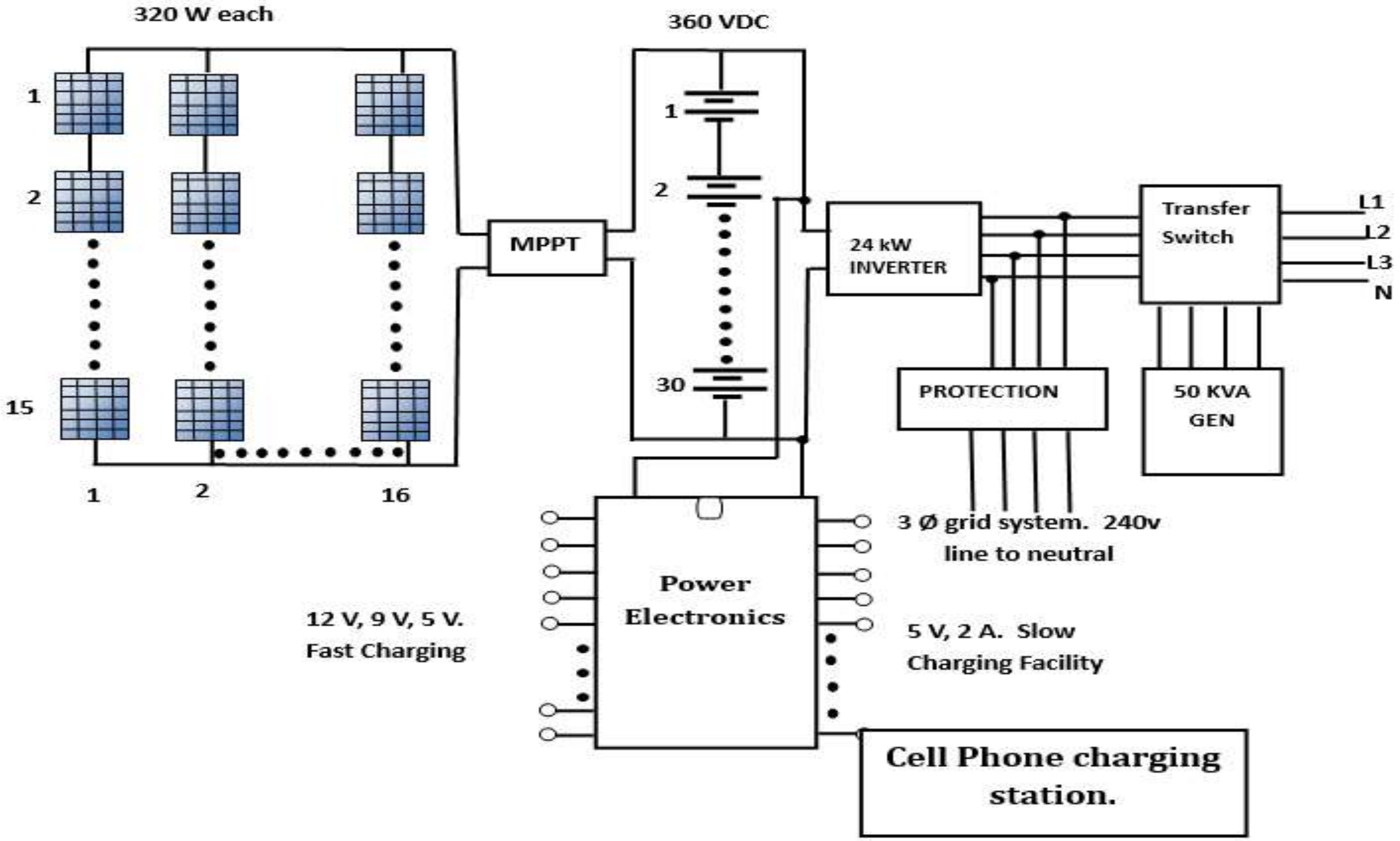


Fig 23: System block diagram of the cellphone charging system connected to the solar system.

MODELLING OF CELLPHONE CHARGING CIRCUIT.

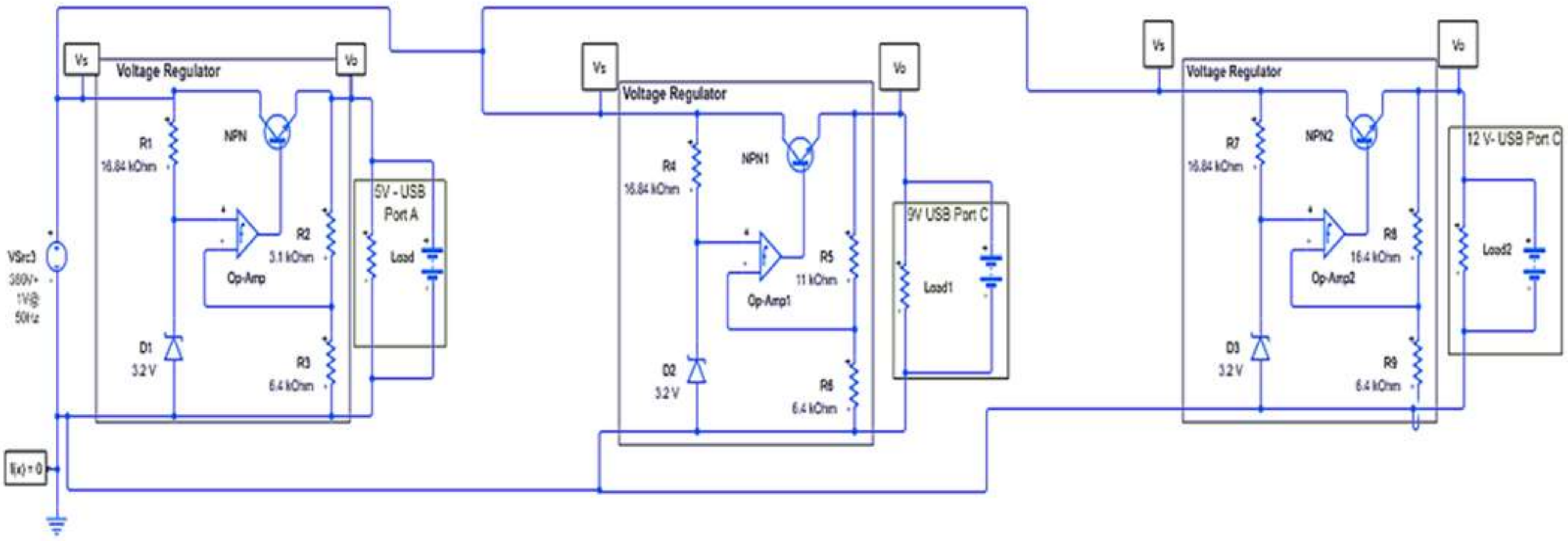


Fig 24: Circuit Diagram of a Cellphone fast charger

Proposed Cellphone Charging Station.

Fig 25: Architectural design of proposed Charging Station.

Proposed Cellphone Charging Station.

Fig 26: Architectural design of the cellphone charging station at Better Mart.

Simulation Result .

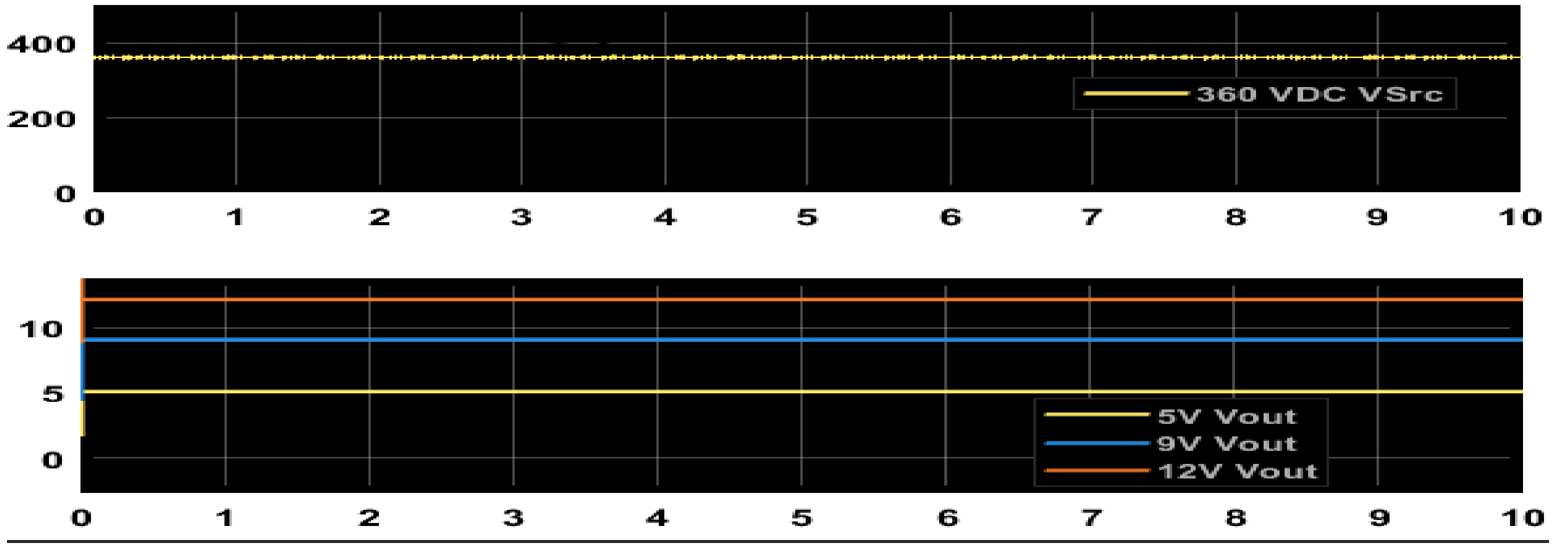


Fig 27: Voltage input and output of the cellphone charger.

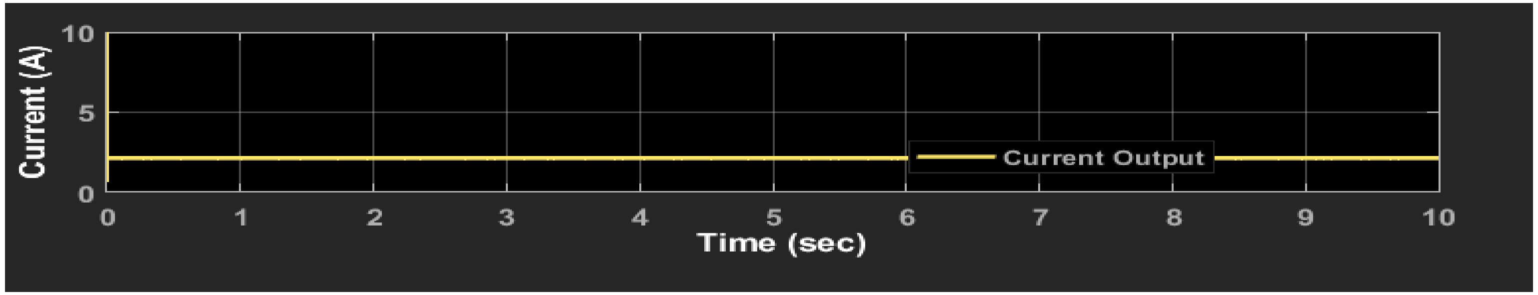


Fig 28: Current Output of the designed circuit.

CONCLUSION.

- The sizing of the hybrid power system at Better Mart was carried out with Homer Pro software.
- Homer Pro optimizes the input variables to output a base system and a proposed system.
- A cellphone charging circuit for a charging station has been designed and simulated using MATLAB.
- The input to the charging station is 360 VDC bus voltage .
- The result of the designed circuit is 5 VDC mini-USB cable 9 VDC micro-USB and 12 VDC USB-C.

Future Work.

- Design and Implementation of Solar Powered Mobile Phone Fast Charging Station for Campus.

- Automation of cellphone charging station.

- Design and Implementation of Solar Powered Wireless Mobile Phone Battery Charger Using Electromagnetic Induction.

- Wireless Power Transfer for Mobile Phone Charging Device.

Publications.

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THANK YOU