International Journal of Science and Engineering Applications
Volume 14-Issue 02, 01 – 12, 2025, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1402.1001

Design of a Solar PV-Battery Based Chicken De-Feathering Machine

Ekpo, Edet George
Dept. of Electrical/Electronic Engineering,
Akwa Ibom State Polytechnic,
Akwa Ibom State, Nigeria

Umoh, Gideon Daniel
Dept. of Electrical/Electronic Engineering, Maritime Academy of Nigeria,
Oron, Nigeria

Udo, Abel Jacob
Dept. of Mechanical Engineering
Akwa Ibom State Polytechnic,
Akwa Ibom State, Nigeria

Abstract: This Research is aimed to design a Solar PV-Battery Based Chicken De-feathering Machine for small and medium scale poultry farmers and entrepreneurs. Farmers or Entrepreneur can process their poultry birds quicker and cleaner to meet the increasing market demand. The machine comprises of mechanical unit which consists of; metal frame, cylindrical plastic drums, rubber plucking fingers, plucker rotor, driven shaft, pulleys, V-belt, base plate, and bearings and also electrical unit which is made of; solar panels, charge controller, batteries, dc-ac inverter and 1HP single-phase induction motor (SPIM). The mechanical system was designed and evaluated using CAD software (Blender). The dynamic performance of PV array, battery system, and induction motor that drives the load (mechanical system and chicken) were modeled and simulated using MATLAB/Simulink and results observed. The induction motor speed and torque as related to daily the sun irradiation and energy supplies from the batteries system were also observed. The proposed model required; simple solar PV, battery based system and inverter for electric power supply, ac motor to convert electrical energy to mechanical energy, cylindrical plastic drum with rubber plucker, plastic rotor and iron bars for framing in order to keep the cost of implementation low. The De-feathering Machine is modeled to be cheap and powered by solar energy system since electricity supply is unreliable and the cost of fuel is substantially high in Nigeria.

Keywords: AC Motor, MATLAB Simulation, PV-battery system, De-feathering Machine, Inverter

1. INTRODUCTION

In recent years, the global shift towards renewable and sustainable technologies has prompted innovative solutions in various sectors. This paper explores the design of a chicken de-feathering machine powered by a combination of Solar Photovoltaic (PV) and battery systems. This integration aims to address both the environmental impact and energy efficiency concerns associated with traditional poultry processing methods.

The poultry industry plays a significant role in meeting the growing demand for protein-rich food. However, conventional de-feathering machines often rely heavily on non-renewable energy sources, contributing to carbon emissions and high operational costs. In response to this challenge, harnessing solar energy combined with efficient battery storage emerges as a viable solution.

Solar PV-Battery Based Chicken De-feathering Machine is an integration of Solar PV-Battery based system with de-feathering machine used basically for processing of poultry products such as chicken, duck, turkey etc. It consists of DC Electricity Source which is generated from solar system, battery backup system, inverter, ac electric motor and a mechanical unit which forms the structural frames and the rotating parts that plucks bird feathers when rotates.

There are several forms of de-feathering machines used in large scale livestock industries. These machine are still not very popular within the Nigerian poultry processing business/industry, this is basically due to initial cost of machine and unreliable power supply to run the existing one. Most of the poultry products in the Nigerian Market today are been processed manually which is time consuming, has low production rate, has product skin damage, skin rashes, tedious and poor quality of end products. The manual processing method and unreliable power supply has made large scale poultry production uneconomical in Nigeria (Energy Source 2011).

This research outlines the key components and design considerations for a Solar PV-Battery based chicken de-feathering machine. By utilizing solar panels to generate clean energy during daytime and storing excess energy in batteries for uninterrupted operation, this system aims to reduce reliance on national grid electricity and minimize environmental impact. Additionally, the integration of smart charges controls and monitoring mechanisms will optimize energy utilization and overall machine performance.

Through this developed model, we strive to contribute to the sustainable development of poultry processing for urban and rural farmers, aligning with global efforts to reduce carbon footprints and promote cleaner energy solutions. The subsequent sections will delve into the detailed design aspects, performance analysis, and potential economic benefits of the proposed Solar PV-Battery based chicken de-feathering machine.

3. Methodology

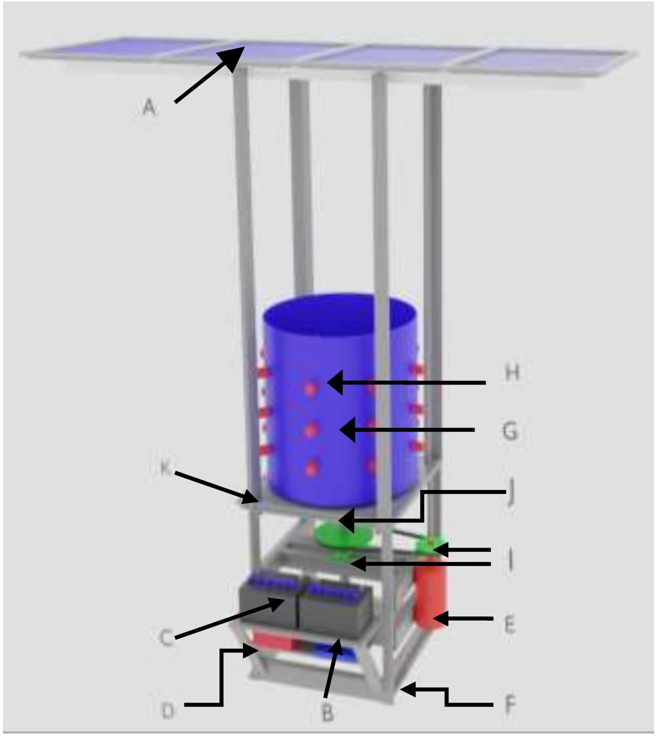

Fig1. Propose model of a solar PV-battery based chicken de-feathering machine designed in Blender

3.1 Component Description:

The choices of assigned material and component used in the design of figure 1 are based on the consideration of the following factors, cost analysis of the materials, durability of the materials, availability of the materials, properties of the materials such as; physical properties, thermal properties, relative properties, chemical properties and mechanical properties. The mayor components of the solar PV-battery based chicken de-feathering machine are:

The electrical system consists of; A. Solar Panel (A), Charger Controller (B), Battery (C), DC-AC inverter (D), AC Motor (E).

The mechanical components of Chicken De-feathering machine consists are; Metal frames (F), Cylindrical Plastic Drum(G), Rubber Fingers (H), Drive pulley and driven Pulleys (I), Shaft and Rotor Plate (J), and Based plate (K).

3.1.1: Solar Panel: - Solar photovoltaic (PV) panels are designed to capture and convert solar irradiation into usable energy. Higher irradiation levels generally result in increased energy production from solar systems, making it a crucial factor in determining the efficiency and output of solar energy installations. This research used four 213W solar panels parameters of table-1 to capture the irradiation of the sun and convert into dc electric energy to run chicken de-feathering machine.

3.1.2: Charger Controller: - A charge controller is a component in solar power systems, especially those involving batteries. It regulates the voltage and current from solar panels going into the battery life. There are different types, such as PWM (Pulse Width Modulation) and MPPT (Maximum Power Point Tracking) each suitable for various solar setups based on efficiency and cost considerations.

3.1.3: Battery: -it's commonly used in various applications, including solar power supplies, backup power supplies etc. In a renewable energy supply system, batteries serve as a critical component for energy storage and management. Battery store excess energy generated by solar panels, and this stored energy can then be used when generation is low or when energy demand exceeds generation. Battery also help to balance supply and demand during low renewable generation, and reducing reliance on backup generators or grid power. It also provide backup during outages or periods when renewable generation is insufficient, ensuring that critical systems and appliances remain operational.

3.1.4: DC-AC Inverter: -Its primary function is to convert direct current (DC) electricity, which is generated by solar panels into alternating current (AC) electricity used by appliances. Many inverters include MPPT technology to optimize the energy harvest from renewable sources by adjusting the electrical operating point to the most efficient level. In a renewable energy system simulation, a DC-AC inverter is modeled to replicate its behavior in converting DC power from solar panels into AC power for use in household applications. In a renewable energy system simulation that includes an AC motor, a DC-AC inverter plays a crucial role in converting DC power from renewable sources into AC power for driving the motor. The simulation includes an AC motor model that receives the AC power from inverter. The motor's performance is influenced by the inverter's output characteristics, including voltage, frequency, and waveform quality. The interaction between the inverter and the AC motor is analyzed in terms of system dynamics. This includes the effects of load changes, startup conditions, and transient responses on both inverter and the motor. The simulation provides tools for analyzing performance metrics such as power output, efficiency, motor speed, and torque. It help in assessing how well the inverter drives the motor and the overall system efficiency.

3.1.5: AC motor: -In renewable energy systems, single-phase induction motor play vital role in low-power energy applications. Single-phase induction motor benefit from their simplicity, reliability, and cost-effectiveness, making them suitable for various low-power machinery. In a renewable energy simulation, a single-phase induction motor is modeled to assess its performance when integrated with a renewable energy system.

3.1.6: Chicken De-feathering Machine is designed to automate the process of removing feathers from chickens after they have been slaughtered. Components of chicken de-feathering machine are; frame and housing, de-feathering chamber (rubber drum), rotor mechanism, and power supply and control panel.

3.2 ELECTRICAL DESIGN CALCULATIONS:

Solar PV system components calculation is explain in the following section. Numbers of Panels:

To determine the number of solar Panels, the equation used is shown in equation (1) (KC Ugwu, 2015).

$$\text{Number of panels} = \frac{1.3 \times \text{Energy Consumption}}{\text{Duration of Radiation} \times \text{Panel peak power}} \quad (1)$$

The duration of radiation is 5 hours. Hence, for 2,800Wh and 213Wp of Solar Panel used, the number of panels needed is:

$$\text{Number of panels} = \frac{1.3 \times 2{,}800}{4 \times 213} = \frac{3{,}640}{852}$$

$$\text{Number of panels} = 4.272 \text{ (4 panels)}$$

Numbers of Battery: -

To determine the number of batteries needed, we firstly calculate the number of energy with average duration of work (2) (AS Martyanov, 2015)

$$\text{Energy} = \text{Power} \times \text{Duration (hours)} \quad (2)$$

Total power of the system is 1000 Watt. For 4 hours of work, the average energy used is:

$$\text{Energy} = 1000 \text{ watt} \times 4 \text{ hours} \;\; \text{Energy} = 4{,}000\, Wh$$

A 220 Amps, 12 V of DC batteries can provide 2,640 WH, hence numbers of batteries is:

$$\text{Number of battery} = \frac{\text{Energy}}{\text{Battery Capacity}} \quad (3)$$

$$\text{Number of Battery} = \frac{4{,}000}{2{,}640} = 1.5 \text{ (2 batteries)}$$

To determine the minimum capacity of the inverter, formula (4) (AS Martyanov, 2015) is used in the calculation.

$$\text{Capacity of inverter} = \frac{\text{Total power}}{\text{Efficieny}}$$

Considering of efficiency of 80% and total power of machine which is about 1000 Watts, the capacity of inverter used is 2000 Watt.

3.2 MECHANICAL DESIGN CALCULATIONS

Certain calculations were made on certain parameters so as to make correct choice in selecting them. Design calculations were carried out on the following: sheave, belt, and shaft and rubber plucker basin.

3.2.1: Plucker System:

The plucker system comprises of the rotor and the drum mounted plucker fingers. The rotor unit is mounted on the shaft driven by the shaft pulley and the drum with fingers, is mounted on the iron frame. Since the diameter of the driver's pulley (motor pulley) is smaller than the driven pulley (shaft pulley), there is reduction in speed (rpm) on transmission to the shaft pulley. The speed of the motor is 1500 rpm. In order to calculate the speed that would be transmitted to the shaft, the following analyses were been carried out:

N1D1 = N2D2 (1)

Where N1 = speed of the motor, 1500 rpm,

D1 = diameter of the motor sheave, 24 mm,

N2 = speed of the shaft/shaft sheave,

D2 = diameter of the shaft sheave, 140 mm

N2 = N1D1 D2 N2 = 1500 × 24/150,

N2 = 36,500/150 = 240rpm

Therefore, the speed that the motor will transmit to the shaft through the belt is 240 rpm.

3.2.2: Construction Technique

The actual construction of the solar power system can be implemented base on the designed and the expected outcome from

MATLAB Simulink simulation. The mechanical fabrication can be implemented base on the designed built using Blender CAD as shown in figure 1.

3.3 Description of Part of the Solar PV-Battery Based Chicken De-feathering Machine

The parts of the machine includes the plastic drum, stationary finger, rotating finger, the rotator plate, bearing, frame, output chute, , shaft, driver pulley, driven pulley, v-belt, toot adjuster, water hoist, solar panel, supporting frame, cable, circuit breaker, charge controller, battery, ac motor and switches.

3.4 Principle of Operation of the De-feathering Machine

Chicken de-feathering machine is a machine driven by an electric motor. These motor drives the dynamic finger studded on the rotating plate at a low speed. A mechanical power is transmitted from the electric motor to the rotator plate through v-belt. A driver pulley is mounted on the electric motor while the driven pulley is mounted on the shaft. The shaft rotates on a vertical axis direction and moving the rotator plate directly. This principle distinguishes between vertical and horizontal retraction system. Chicken is then processed by placing it on the rotor plate. The rotator plate has installed dynamic fingers which are made of rubber with a screw shape that serves to pluck the chicken feathers. When the rotor plate rotates at a certain speed, the chicken which moves round is likely to be thrown into the drum wall due to centrifugal force. The drum wall studded with finger rubbers bind the chicken feathers when chicken thrown into the drum wall. Chicken will fall back to the dynamic fingers due to gravitational forces. Chicken feathers tied in static finger will fall into the fingers plate thereby unplucks from the chicken body.

4. MATLAB SIMULATION:

4.1 The performance of the system is simulated in MATLAB Simulink with no-load and load conditions;

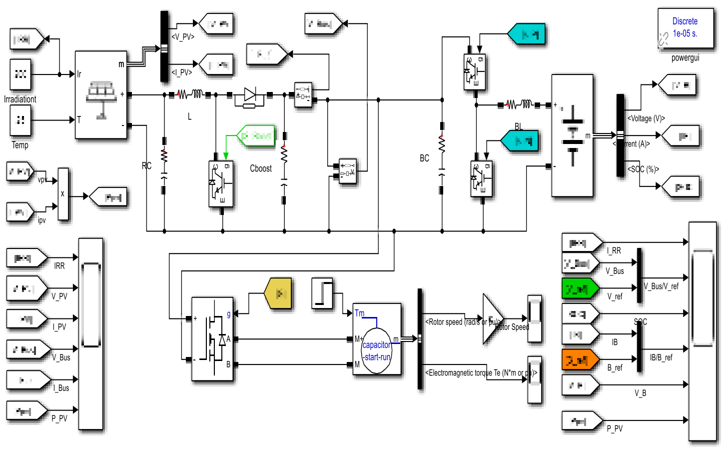

Fig2. Simulink block diagram showing solar PV, battery, inverter and ac motor of a chicken de-feathering machine.

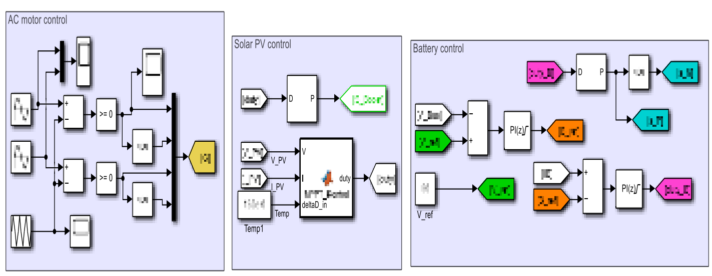

Fig3. Simulink block diagram showing solar PV control, battery system control and ac motor control of a chicken de-feathering machine

4.2. Steady State Performance At 1000W/m^2

Transient and steady state performance of PV array, battery system and induction motor are shown in fig 3, 4 and 5

4.2.2. Solar PV Array Performance:

The panel voltage VPV, current IPV, power PPV, bus voltage V_Bus and bus current I_Bus are exhibited in fig 3 at an irradiance of 1 kW/m^2. The starting duty cycle and its step size are chosen properly to obtain safe motor starting.

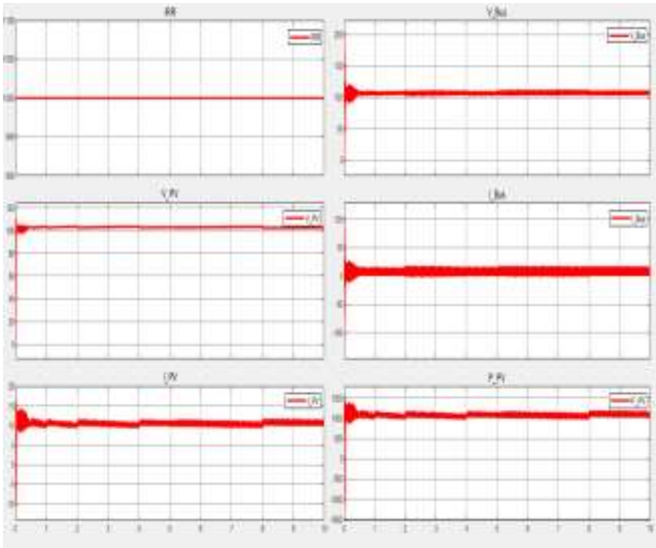

Fig4. Steady state performance of solar PV array at 1000W/m^2 with load of 3Nm at 5sec

4.2.3. Single-phase Induction Motor Performance:

Fig 5 shows the motor maximum speed of 1500rpm and a drop of speed to 1300rpm on application of 3Nm load at 5 second. The motor speed stabilized at low speed at the time motor develops the rated torque. A small ripple appears in the torque because of bus resistance-inductance branch current and sensor-less operation of the motor. It causes vibration in the motor at no-load. The system is designed to run de-feathering rotor mechanism and chicken at low speed range in order to carryout successful feathers plucking. The torque ripple reduction may lead to an enhancement in the efficiency of motor. The bus current I-Bus of fig.5 and battery current IB of fig.6 and the front end converters of fig3 provide various solutions for the torque ripple reduction. It current ripples causes complexity in the system design, it causes torque ripples to increases at higher speed range. In this proposed system, a minimum speed required to operate the machine is achieved. The system gets higher efficiency at lower speed as shown in the speed and torque plot of figure 5. So the AC motor offers good amount of torque delivery at lower speed range.

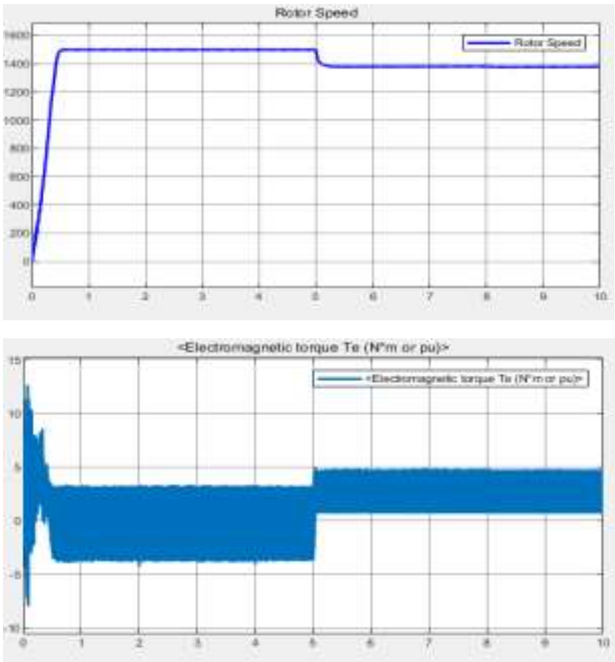

Fig5. Single-phase induction motor rotor speed and torque at 1000W/m^2 with load of 3Nm at 5sec

4.2.4. Battery System Performance at 1000W/m^2

Figure 6 shows the bus voltage V_Bus and reference voltage V_ref, battery current IB and battery reference current IB_ref, and the battery state of charge SOC at sun irradiation of 1000W/m^2. The SOC plot indicates that the battery is in charging mode at the sun irradiation above 50%. Increase in loads reduces the battery rate of charge, the voltage and inversely increases the load current.

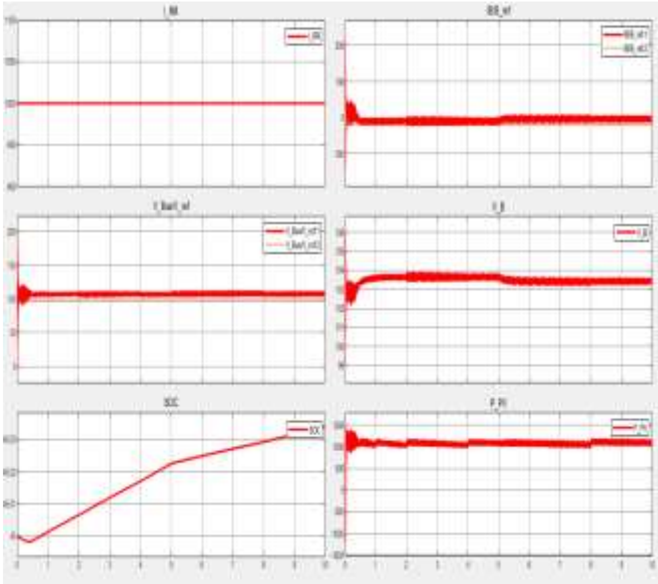

Fig6. Steady state performance of Battery system at 1000W/m^2 with load of 3Nm at 5sec

4.3. Steady State Performance At 200w/m^2

Fig 6 shows the starting performance of solar PV array, battery system and motor at the condition of 200 W/m^2 sun irradiation.

4.3.1. Solar PV Array Performance:

The system performance at 20% of irradiance is shown in figure 7. The MPP tracked the irradiation at 200W/m^2 by adjusting the duty ratio of VSI, the speed of the de-feathering machine is maintained while gradually switch to battery mode. This control is done by an optimum duty ratio.

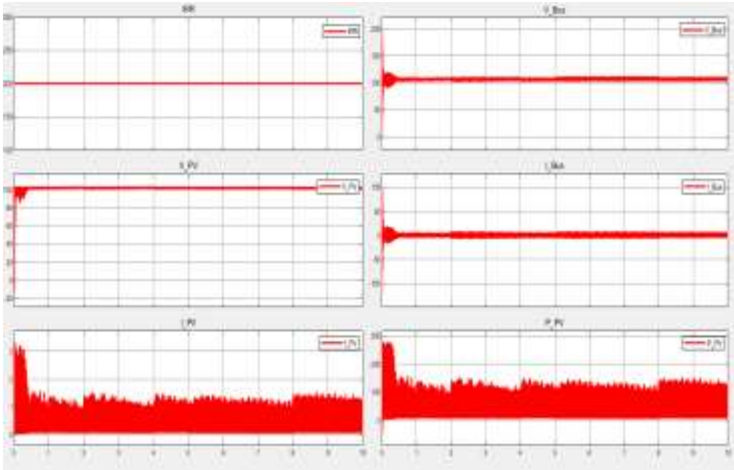

Fig7. Steady state performance of solar PV array at 200W/m^2 with load of 3Nm at 5sec

4.3.2. AC Motor Performance at 200w/m^2:

The motor attains the speed range of 1500rpm at 200w/m^2 as shown in fig8 and is similar to that of figure 4 at 1000w/m^2. The de-feathering process is successfully done below 30% irradiance level. The motor power supplied switches from PV-array to the battery as indicated by the battery state of charge SOC of figure 8. Moreover, a soft switching is observed under such circumstances.

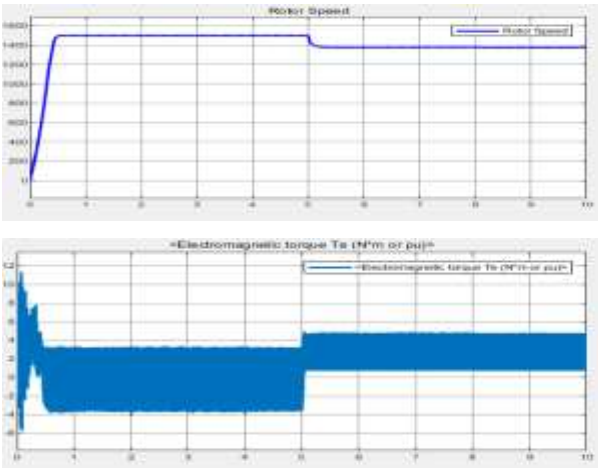

Fig8. Single-phase induction motor rotor speed and torque at 200W/m^2 with load of 3Nm at 5sec.

4.3.2. Battery System Performance at 200w/m^2:

Figure 9 shows the battery state of charge SOC at sun irradiation of 200W/m^2. The SOC plot indicates that the battery is in discharging mode at the sun irradiation above 30%. Increase in loads increases the battery rate of discharge, battery voltage drop and the current drawn.

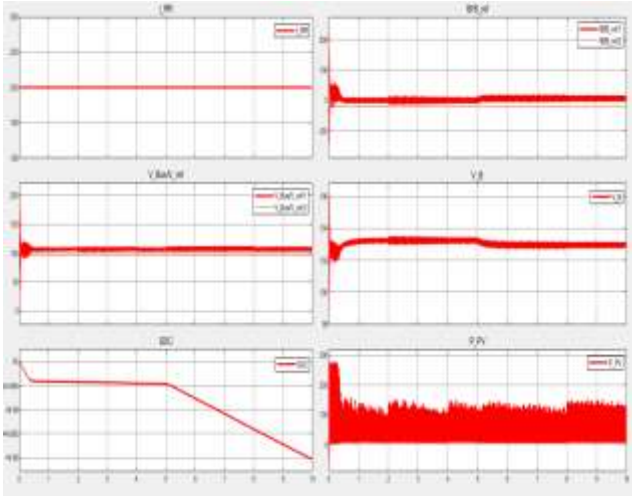

Fig9. Steady state performance of Battery system at 200W/m^2 with load of 3Nm at 5sec

4.4: Dynamic Performance

Fig 10 shows the dynamic operation of the system under various irradiance conditions. The performance of solar PV array, battery and single-phase motor explains in follows.

4.4.1. Solar PV Array Performance:

The PV array power is optimized successfully under various dynamic conditions. The irradiance level is reduced from 1000W/m^2 to 200W/m^2. The duty ratio is generated for each irradiance level and it is used to control the speed of motor.

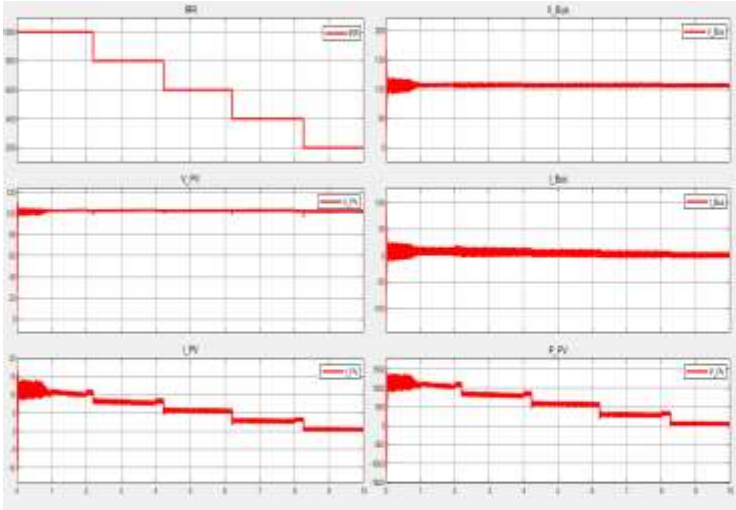

Fig10. Solar PV and bus showing irradiation from 1000w/m^2 – 200w/m^2 with load of 2Nm at 0sec.

4.4.2. Single-Phase Induction Motor Performance:

The motor indices when any variation occurs in atmospheric condition. Fig 11 shows smooth dynamic performance of the motor. By controlling the input voltage of the motor, the speed of motor is adjusted through the optimum duty ratio D

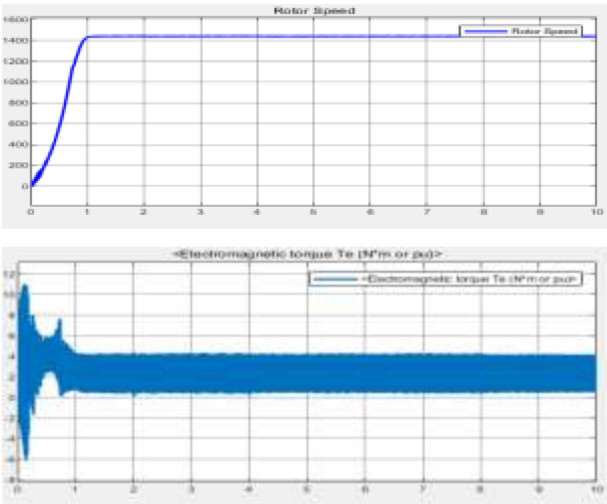

Fig11. Single-phase induction motor rotor speed and torque at sun irradiation of 1000-200W/m^2 with load of 2Nm from 0sec

International Journal of Science and Engineering Applications
Volume 14-Issue 02, 01 – 12, 2025, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1402.1001

4.4.3: Performance under Partial Shading

An output power of solar PV array is reduced under partial shading condition. The PV array operating at an MPP at the time motor pump is able to deliver the water. Fig 12 shows the responses of PV array and AC motor under such conditions. The AC motor response properly according to the power from solar PV array being high efficiency motor, the AC motor delivers good amount of mechanical torque even at low input power.

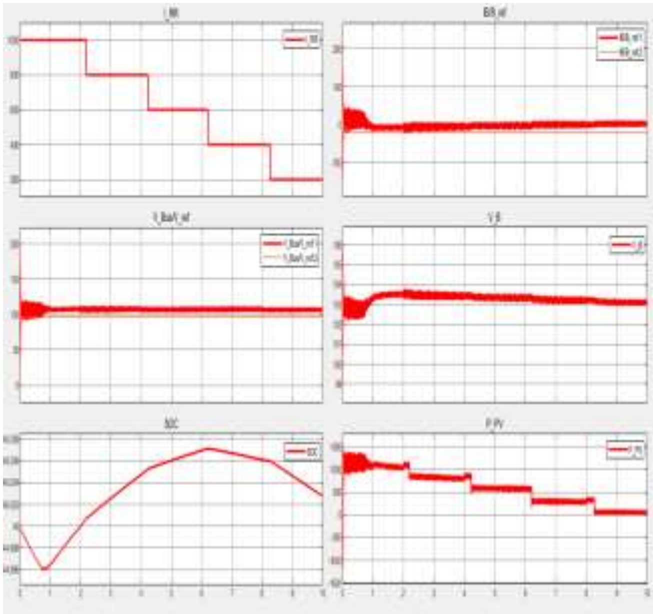

Fig12. Battery responds within sun irradiation of 1000w/m^2 – 200w/m^2 with load of 2Nm from 0sec.

Table 1: Parameters of Array type: A10Green Technology A10J-M60_240; 3 series modules; 2 parallel strings

Parameters	values	Parameters	Values
Max. power	**213.15w**	**Voltage at max. power point Vmp (v)**	**29v**
Cell per module	**60**	**Current at max. power point Imp (A)**	**7.35**
Open circuit voltage Voc (v)	**36.3 v**	**Parallel strings**	**2**
Short circuit current Isc (A)	**7.84 A**	**Series connected modules per string**	**2**

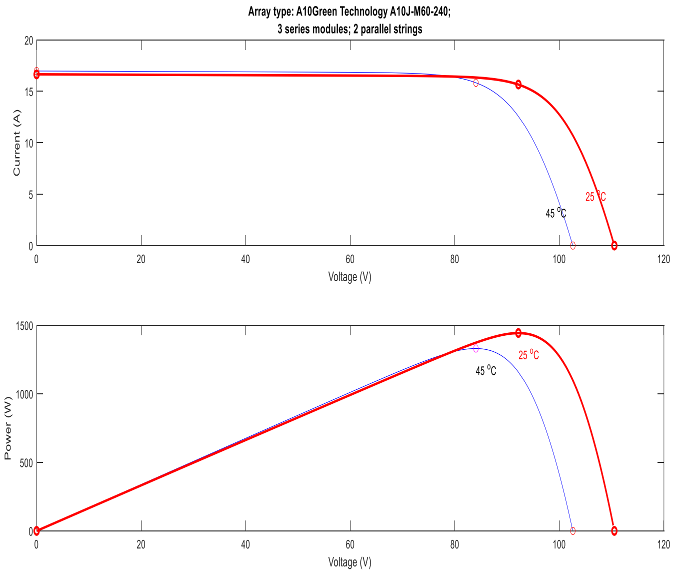

Table 2: CSCR-SPIM parameters from MATLAB Simulink block

International Journal of Science and Engineering Applications
Volume 14-Issue 02, 01 – 12, 2025, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1402.1001

Parameters	Values	Parameters	Values
Nominal Power	1Kw	Auxiliary Winding Stator RS	7.14 Ω
Voltage	220V	Auxiliary Winding Stator LlS	8.5e-3
Frequency	50Hz	Inertia J	0.01
Main Winding Stator Rs	2.67Ω	Friction Factor	0
Main Winding Stator Lls	0.0037H	Pole Pairs	2
Main Winding Rotor Rr	1.8Ω	Turn Ratio (Aux/Main)	1.18
Main Winding Rotor Llr	0.0028H	Capacitor-Start Rst, Cst	2Ω, 254.7e-6F
Main Winding Mutual Inductance Lms	0.5433H	Capacitor-Run Rru, Cru	18Ω, 21.1e-6F

5. CONCLUSIONS

• The Design and implementation of solar PV-Battery Based Chicken De-feathering Machine driven the rotor plate of the system validated under load and no-load dynamic performance in various sun irradiation conditions.

• MATLAB Simulink software is used for the simulation of the electrical system while the mechanical system design is achieve using Blender CAD Software.

•The Solar PV-Battery based chicken de-feathering machine is design to deliver reliable, efficient, and sustainable poultry processing that will meet economic and environmental objectives when implemented.

• Since Nigeria have an abundant source of solar energy throughout the year, this energy can be exploited in the operation of fixed or mobile agricultural machinery, which will save from the consumption of conventional fuel.

• In this research, the chicken de-feathering machine; which is the mechanical load, solar PV array and battery storage system is analyzed using MATLAB Simulink environment.

• As shown in the simulated results, the power generated from PV system was enough to operate the machine from 10 am to 4 pm daily.

• The results also shown that power generated from PV array before 10am and after 4pm was not enough to operate the machine therefore the system smoothly switched to battery storage.

• The system shows PV power output of 1.125 kW from 10am to 4pm and less than 1.2 kW before 10am and after 4pm. During the period of low power supply, the system can be used to power other devices of low energy consumption.

6 REFERENCES

OSHA (Occupational Safety and Health Administration), Prevention of muscle skeletal injuries in Poultry Processing. OSHA 3213-12R, 2013.

Energy Sources; Solar Department of Energy Archived from the original on 14 April 2011, Retrieved 19 April, 2011

Babagana G, Silas K, Ahmed M. (2012), Solar Dryer an Effective Tool for Agricultural Products Preservation, “Journal of Applied Technology in Environment Sanitation” 2(1).

WZ Fan, MK Balachander (1988), Dynamic Performance of a DC Shunt Motor Connected to a Photovoltaic Array, “IEE Transaction on Energy Conversion 3 (3) 613 – 617”.

MM Saied, AA Hanafy, MA El-Dabaly, YA Safar, MG Jaboori, KA Yamin, AM Sharaf (1991), Optimal design parameter for a PV array coupled to a DC motor via a DC – DC transformer. “IEE Transaction on Energy Conversion” 6(4), 593 – 598.

Aleck W, Liping G, Kennedy A, 2012. A Contant Voltage MPPT Method for a Solar Powered Boost Converter with DC motor load. “2021 Proceedings of IEE Southeast con”, 1 – 6.

Adeyinka A, Olawale J.(2015). Development and Performance Evaluation of a Chicken De-feathering Machine for Small Scale Farmers, “Journal of Advanced Agricultural Technologies” Volume 2(1) 71 – 74.

Hatimi M, Chicha B, Felthma M. (2021), Design of Modified Chicken Feather Retractor Machine “Journal of Applied Science, Engineering and Technology”1(2) 44 – 44.

KC Ugwu, SO Agu, NJ Ogbuagu, (2015), Optimization and Performance Evaluation of Chicken Plucking Machine “International Journal of Science and Engineering Research” 6(7) 102 – 108

AS Martyanov, EV Solomin, DV Korobtov (2015), Development of Control Algorithms in Matlab/Simulink “Procedia Engineering” 129, 922 – 925,

Herrick K. (2003). Anyone can build a Tub-Style Mechanical Chicken Plucker. Complete instructions for the Kimball Whizbang, vol 1.

Adetola, S. O., Onawumi, A. S., and Lucas, E. B. (2012), Investigation into mechanized de-feathering process and optimal scalding temperature of exotic and local birds in Southwestern, “Nigeria *Transnational Journal of Science and Technology”* vol. 2, No.3, pp 87- 96.

Barbut S. (2002). Primary processing of poultry (Boca Raton London New York Washington, D.C: CRC Press).

Awotunde, OlawaleWaliyi, Adeyeye, Kehinde, Ponle, EyitayoAdemola and Fatukasi, Samson Olusegun (2018), Development of a De-feathering Machine from Locally Sourced Materials “International Journal of Scientific & Engineering Research”, Volume 9, Issue 5, May-2018 1143 ISSN 2229-5518