Design and Analysis of Fully Solar driven Mini-Food Processing Unit

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Abstract: *This paper comes with an optimized design to drive the mechanical agricultural processing units associated with the existing underutilized solar photovoltaic (SPV) power, available at solar water pumping (SWP) system. This enables energy independent solar driven mini-processing units. The fabricated system is designed to operate at a low cost, as energy storage system is not being utilized, and it aims to retain the DC power supplied by SPV via DC-DC power conversion stage. The PV system is integrated with a power electronic interface to supply power BLDC motor drive coupled with wet grinder. The developed hardware was tested under different load conditions and data was analyzed through graphs. The experimentation is carried out in fabricated setup to validate the design and results indicates the operational efficacy. Additionally, the impact of weather intermittency is considered on proposed system to confirm its effectiveness. This proposed system is well suited for rural areas to reduce the grid dependency and boost rural economy utilizing the under tapped SPV power.*

Keywords: Brushless DC motor, PV fed wet grinder, boost converter and renewable energy sources.

1 Introduction

The rising rate of energy demand knees the power sector towards (RES) renewable energy sources. Another reason for going towards RES is the depleting fossil fuels used in generation. Coming to Indian sub-continent in spite of having rich and growing power sector, providing electrification is an agony to rural part of the country [1-4]. The cost of power supply in these remotely isolated areas can be expensive. Poverty, resource limitations, political constraints, inappropriate planning, and electricity theft are some of the major reasons for disparities in the availability of electricity for rural areas with your urban counterparts. Low income families find it difficult to afford the high cost and many utility companies don't want to supply these areas with the quality and quantity of electricity they need. In many villages, people are not getting good quality electricity despite it is electrified. Many villages still don't have access to better power and their usage as there are restricted to less than 50kWh per month/household. The solution for the above problem is distributed power generation for rural electrification in India and developing and undeveloped countries [5-6]. The term 'distributed generation' is used when electricity is generated near the point of demand, typically from renewable sources such as solar panels or wind turbines [7]. This can reduce the net carbon footprint because its emissions are created in a closer proximity to where they will be used.

India is an emerging global leader in renewable energy sector for installing wind and solar plants to overcome the energy crisis in conjunction with long running conventional power plants. It is also attracting other renewable energy countries for investing their fund in renewable sector area in India [8]. India needs to take a hard look at switching to renewable sources as the only way forward. India should be using renewables as its primary source of power production if it wants to do its part to reduce global CO_2 emissions. Solar power is a great and environmentally friendly option for India to satisfy its energy demands, as well as those of 50% of rural residents who still lack electricity [9-10]. Considering the geographical benefits, India can produce sufficient energy for local consumption and for neighbor developing countries. India cannot only produce enough energy to meet its own requirements, but also produce enough energy for the entire world! Because it falls in the tropical region, it receives generous amounts of solar radiation all through the year amounting to nearly 3,000 long hours of sunshine. For solar power to become the future of India’s electricity, harnessing its energy and using it for a variety of purposes will be key. In particular, solar panels are an important tool since they form the backbone of any solar system. It is true that solar systems and solar panels will cost some money to buy, but once set up they provide energy for free [11-15]. They also last a very long time and don’t need replacing in every respect. It has no dependency on the availability of electricity in order to work. This is a great alternative for people who don't receive the necessary amount of free electricity through their homes.

The policy makers of India are providing subsidies of average 40% through varies schemes through JNNSM, UDAY, SECI and etc. to uplift the installation by peoples in various sector including agriculture, industry and commercial. Recently, India has been ranked 5th in the world for solar power deployment, surpassing Italy. Solar power capacity has increased 11times in just five years, from 2.6GW in March 2014 to 30GW by July 2019. Presently, 57.7GW solar powered plants has been installed which contributes 51% of energy for RES leaving behind the wind power to utmost 40.8GW. This makes a bench mark creating jobs in various sub-field of solar is approx. 1.1 million throughout nation [16-18].

Despite being a small and recent formed state, Chhattisgarh with a population of 3.1 million and 13.5 million hectares, yet 1,406 MW (1.85% of the total) is installed here - it ranks 11th on the list of total contributing states. Up to 60 solar power projects are in the development or planning phase by state Government, private industrialist or by both joint ventures [19]. A benchmark of total 60,000 solar pumps has been installed and are in operating mode, in addition more 20,000 are been planned before the financial year 2023. The utilization factor of pre-installed solar pump is less than 50% (reference) and almost un-operational during rainy season since precipitation rate is enough for irrigation in such areas. However, solar PV panels are generating electrical power but this power is untapped in current setup. Moreover, generally the solar pumps installed in agricultural land have the capacity of rating 3kW and above. This indicates that such PV system has significant untapped power which can further utilized to drive other agricultural appliances to obtained the effective utilization of available PV power and to boost the rural economy by inclusion of green energy.

Increase research and innovative ideas are highlighting to reduce the gap to use power from both conventional and non-conventional. Among the various available RES, Solar is gaining the popularity because it is readily available in every part of the earth and free in nature. It has many advantages such as low maintenance, less semiconductor components and ease of scalability with increasing demand. Due to the above factors the solar power plants can be useful to rural and backwards areas where power connectivity is not up to the mark. Solar PV generators plus battery bank is one of the most important factors for reducing the grid dependency for locally isolated areas. As they are installed near by the consumer or load end making them to reduce transmission loss and increase the efficiency [20]. This concept can be used by the farmers to yield their financial status by processing the agriculture-based products without grid power.

By combining solar-powered innovations into agriculture, on-farm cultivation systems will become less reliant on conventional energy sources, reducing Green House Gases emissions. On the other hand, rural farms which facing issues relating power grid connections are best suited for stand-alone PV systems. However, none of them have in a single report shown the depth of the possibilities for solar energy technology to be applied in farming. Solar PV systems could potentially be utilized to create electrical power or heat to meet the energy needs of various agricultural operations [21]. The advancement of state of art technology in solar-powered technology and its practical use in many agricultural and livestock production sectors are thoroughly investigated and stated.

SPV has tremendous potential which can be seen in many of the publications by the researchers showing different approaches for applying solar power to drive agricultural and farm machineries. Solar energy powered applications include;

1. PV-water pumping and irrigation systems
2. PV desalination
3. PV-solar dryers
4. PV-greenhouses
5. PV-livestock, and dairy farming systems
6. PV-crop security systems
7. PV wet grinders and dough maker

This paper is organized as follows. Section 2 presents the hardware implementation procedure to drive the wet grinder fully on solar power. Section 3 shows the analysis and performance of the experimental setup through the data collected in data logger and depicted in form of graphs plotted. Section 4 draws the conclusion of the experimented hardware system with its robustness.

2 System Development and Testing of Prototype for proposed Mini processing unit

This section is devoted to the design, working and fabrication of proposed green and clean energy based mini-processing units. This section consists of detailed description of power electronic interface, fabrication and installation. In this work laboratory prototypes of PV powered Mini processing unit was developed for non-zero Grid dependency (NZGD) in rural and grid outage areas for uplifting the farmer's self-employability [22-23]. The above mention prototype is explained in the subsequent sections.

2.1 Arrangement of the Proposed Prototype

A solar driven wet grinder has been developed and presented in this article. Fig. 1 and 2 depict the schematic arrangement of the PV-supplied wet grinder and the experimental setup, respectively. Further, Fig. 3 shows the 3D modelling of proposed design. The system comprises of a DC-DC converter, BLDC motor drive and the grinding arrangement. The wet grinder has a cast iron body with stainless steel (SS) grinding stones fitted within it. Subsequently, this BLDC drive is powered by SPV through DC-DC converter and grinder is coupled via a V-belt mechanism, which facilitates smooth rotation for processing the material. The main operational objective is to maintain DC voltage across the BLDC drive. This objective is achieved by adjusting the duty ratio of DC-DC converter supplied by SPV. Here, DC-DC converter is an interfacing unit between SPV and wet-grinder.

The experimental setup consists of a PV array of rating 1000 W (250W_p each) mounted on roof top on a house. The market readily available commercial wet grinder is placed on structed made by L-channel iron material for support on which motor drive is also placed to drive the mini-processor. The load and the drive and connected through V-belt for its operation whenever required for grinding [24]. The drive is able to grind whenever it receives the command by the user on its supply by DC-DC boost converter placed on the side of the fabricated structure. Fig. 1 shows experimental setup of PFWG.

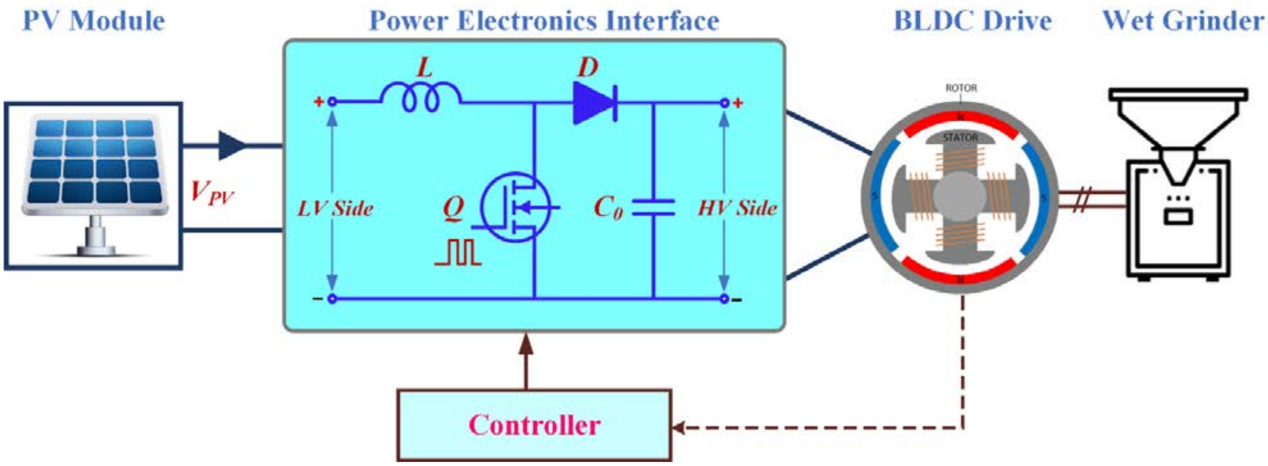
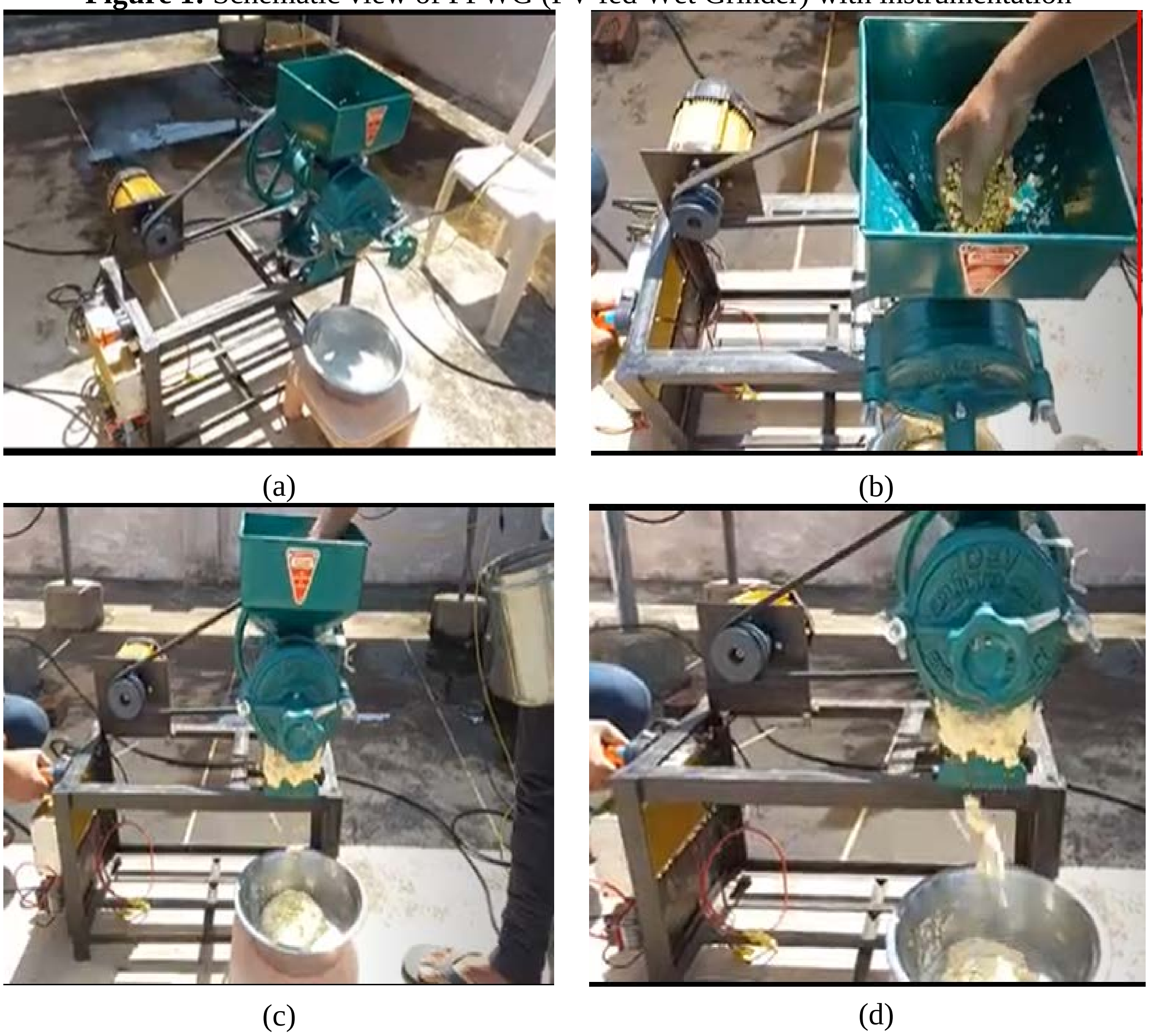
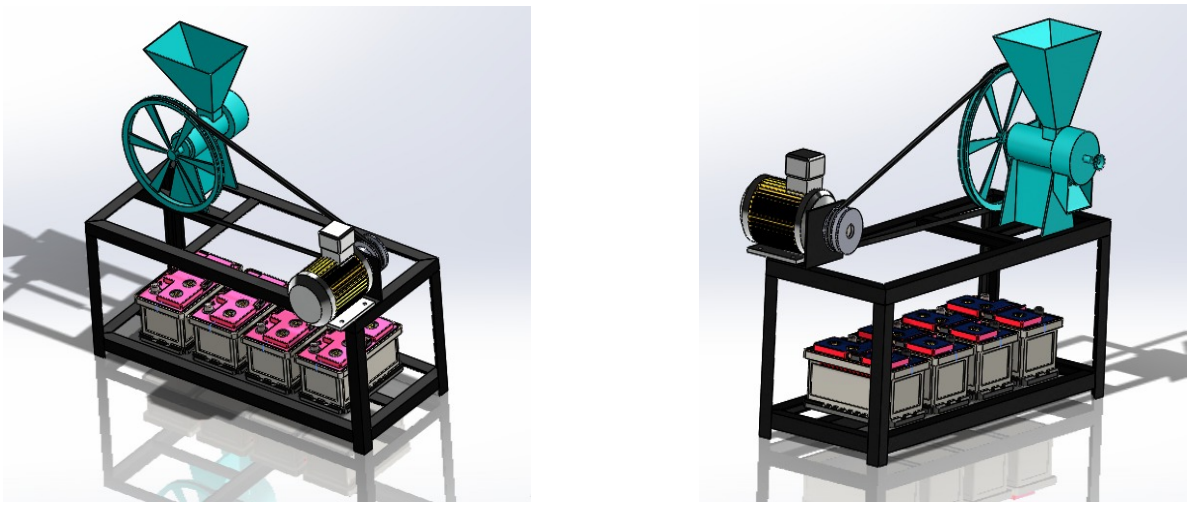


Figure 1: Schematic view of PFWG (PV fed Wet Grinder) with instrumentation



(a) (b) (c) (d)

Figure 2(a), (b), (c) and (d): Experimental setup PFWG (PV fed Wet Grinder) with instrumentation



(a) (b)

Figure 3(a) and (b): CAD /CAM illustration of hardware setup PFWG (PV fed Wet Grinder)

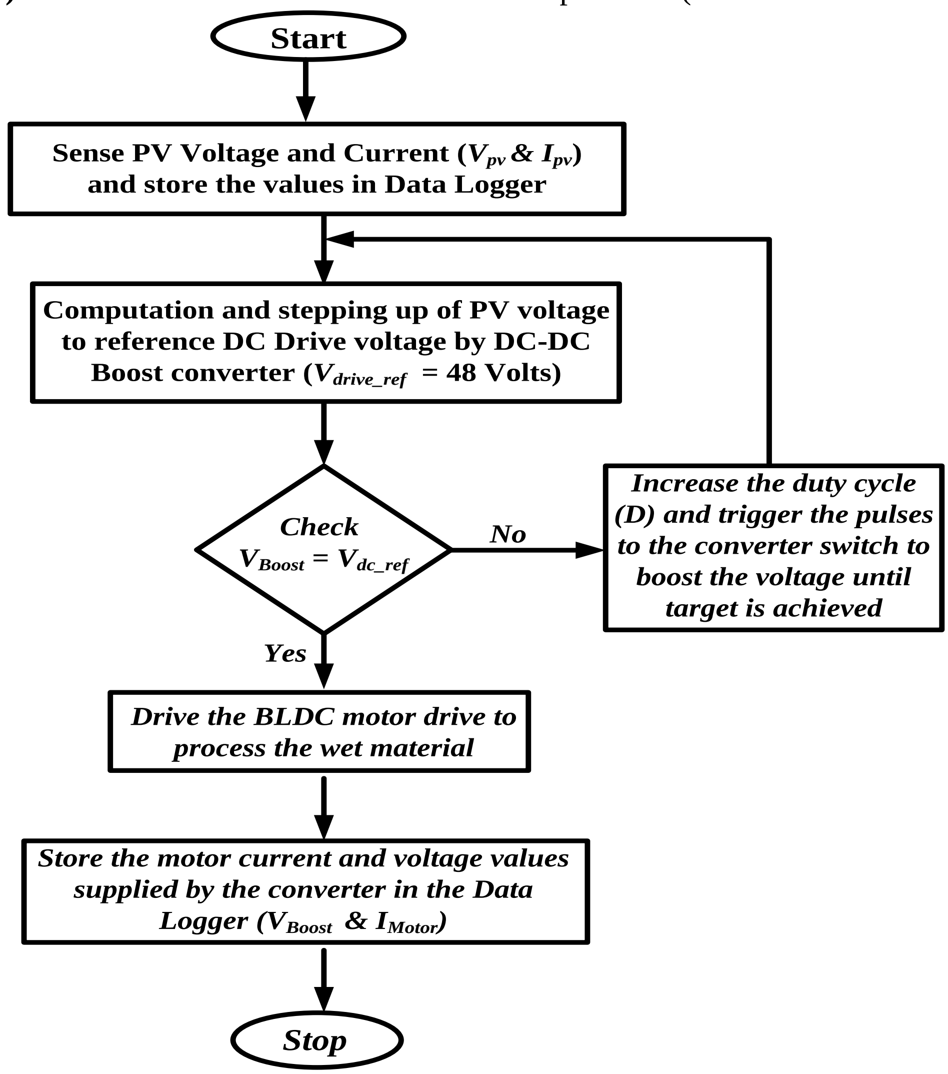


Figure 4: Flowchart for processing the wet material fed to hardware setup PFWG

The flowchart shows the procedure of the hardware set up of the protype developed in the figure Fig 4. The initial stage of the prototype comprises of PV system which harness the power from solar radiations and feds it to the DC-DC boost converter. Computation and save of data will take place and controller will check the output of the converter with reference voltage for operation or not. If it satisfies the condition then the motor drive in conjunction with wet grinder will go for further process. If the condition is not satisfied then the controller will command the processor to increase or decrease the pulses for generating the required output voltage. This process will go on till the grinding procedure takes place.

Table I displays the design specifications of the SPV panel, BLDC drive, wet grinder and peripherals utilized in the experimental setup. The SPV interfacing boost converter is maintaining a steady output voltage range from 48 to 49V, desired for satisfactorily operation of attached BLDC drive. The boost converter's duty cycle is adjusted in accordance with change in load and input voltage to obtain constant voltage across load terminal. The boost converter operates at 100 kHz and is designed with a 2.5mH inductor (L) and a 470F capacitor (C). Fluctuations in sun irradiation generate variations in SPV output. The boost converter's output is fed to a BLDC motor-driven wet-grinder system. To obtain the requisite voltage and current, the suggested DC wet-grinder requires only four SPV panels. Commercially available AC motors have voltage ratings of 220-240 V for the same hp rating. When the same number of PV panels are combined with a boost converter for a BLDC motor, the converter output current increases with a 48 V voltage reduction. As a result, the BLDC motor-driven wet-grinder system requires at least four panels (250 W_p) to provide the necessary voltage and current for operation.

Table I: Design Specification for PV Panel, BLDC Motor and Wet-Grinder.

Parameters	Values
Solar PV module	
Peak Voltage (Vmax)	36 V
Open circuit voltage (V_{OC})	44 V
Current (I_{max})	6.95 A
Short-circuit current (I_{SC})	7.60 A
Nominal peak power (P_{max})	250W
Module efficiency	15.27%
Gross Weight	19 Kg
Fill Factor	75.31%
Maximum operating cell Temperature	47 ± 2% ºC
Dimensions (L xWx D) mm	1640 x 960 x 42
BLDC motor drive	
Output Power rating	1000 W
Armature voltage (V_a)	48 V
Armature current (I_a)	25 A
Rated Speed (N)	3000 rpm

Domestic Wet-grinder	
Body dimensions (W x H x D) mm	(452 x 388 x 385)
Table Type	top
Grinding drum	SS material
Body cast material	Food grade material
Stones	2
Capacity	3 kg
Gross Weight	14 Kg

2.2 Operation of DC – DC converter

The wet grinder is powered by a 48V, 1000W BLDC motor as its prime mover. A MOSFET device is used for ON and OFF switching cycle of DC–DC boost converter to obtain the desired voltage. The pulse width modulation technique is used to control the duty-cycle of the boost converter [25]. The control pulses are desired to obtain gate driving signal, generated using IC incorporated microcontroller. The output voltage of PV array is typically changes in the range of 30–40V in day time. Fig. 5 shows the installed DC – DC boost converter to run the BLDC motor drive for grinding the wet materials [26]. The experimental PV fed wet grinder has been fed with a voltage of 39 V from a PV array comprising of four panels that are connected in parallel to form the array with specification as mentioned in Table I.

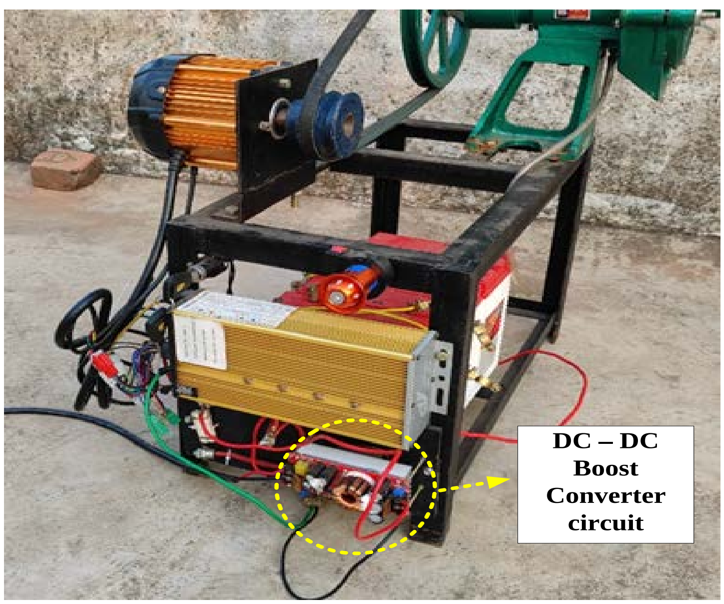


Figure 5: Schematic of DC – DC Boost converter for PFWG

The electrical circuit of a boost converter is shown in Fig. 5. By its name it is named as boost because the gain output voltage is greater than the input. It consists of boost inductor, electronic switch device, diode and output filter capacitance [27]. It operates in two modes depending on opening and closing of the electronic switch used. Mode1 begins when switch is on at t = 0 and ends at $t = t_{on}$ and diode is off so the current passes through the inductor L and the energy is stored in it and current in the circuit linearly increases. Mode 2 begins when switch is off at t = ton and ends at t = T. The sum of energy stored in the inductor during mode1 and the supply current will flow through the load and the capacitor C and the output voltage appears across the load and the capacitor will store energy. The inductor current decreases until the switch is turned on again during next cycle.

The output voltage of boost converter is given by:

$$V_{out} = {}^{V_{in}}/_{1-D} \quad (1)$$

Where "*D*" is the duty cycle of the switch, $D = t_{on}/T$ and $T = 1/f_s$.

V_{out}: the gained output voltage of supplied power.

V_{in}: supplied power from available source.

t_{on}: switch on period.

T: switching period.

f_s: supply frequency.

2.3 Design Guidelines for DC-DC Boost Converter

The operation of a DC-DC boost converter is primarily dependent on four components. These include a power electronics switch, an inductor, a capacitor, and a diode. The following is how these four components are chosen:

2.3.1 Semi-conductor component for switching

The semiconductor component is the main switching element of an DC-DC power conversion device which can withstand the maximum possible in terms of voltage and current dynamics. In this converter, a low resistance N-channel MOSFET with a switching characteristic of [Ton= 14 ns, Toff= 50 ns] is been used for operation. The below Table II shows electrical characteristics has been listed.

Table 2: Specification of Switching Device Used.

Sl. No.	Parameter	Symbol	Value	Unit
1.	Drain-Source Voltage	V_{DSS}	60	Volts
2.	Drain Current (continuous)	I_D	± 3	Amps

3.	Gate-Source Voltage	V_{GSS}	± 20	Volts
4.	Gate Resistance	R_G	5	Ohm
5.	Permissible Junction operating temperature	T_J	-55 to 150	ºC

2.3.2 Inductance selection for the converter

A well-designed inductor is the fundamental element of a good boost converter and of other switching power converters. When the value of inductor has the proper inductance, then it is capable of handlining the peak and RMS values currents over the wide range of input and output voltages (V_{in} & V_{out}) specifically taking frequency of the circuit in consideration. The maximum permissible ripple current (ΔI_L) is 30% of maximum value of load current (I_L) used in the converter at the least duty cycle. If $fs_{/w}$ is the converter's switching frequency, to determine the value of ideal inductor value should be:

$$L_{ideal} = \frac{V_{in} \times D_{max}}{2 \times I_L \times f_{s/w}} \tag{2}$$

2.3.3 Capacitance selection for the converter

The capacitors placed at output terminal are seen as filter in a boost regulator to overcome output voltage ripples and high RMS current stress. The maximum allowable voltage ripples (ΔV_L) is dependent on minimum value of output capacitance at steady state in boost converter. At given limits of output ripples (ΔV_L), the expression for calculating the minimum value of capacitance required for the converter is given as:

$$C_{ideal} = \frac{V_{o/p}}{R} \times \frac{D \times T}{\Delta V_L} \tag{3}$$

2.3.4 Diode for the converter

The key factor for selecting a diode is its ability to block the required off-state voltage stress, have sufficient peak and average current handling capability, fast switching characteristics, low forward voltage drop and low reverse-recovery time. In DC-DC boost converters, the diode selected should be of value twice or thrice higher than the peak to peak current fed to inductor at the input side of conversion stage.

2.4 BLDC Motor Drive

The Brushless Direct Current (BLDC) motors are one of the most popular motor types which is an ever-decreasing trend. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. BLDC motors are brushless, as the name suggest they don't use brushes for commutation as they are electronically commutated instead [29]. Brushless DC motors offer many benefits over other motor types, in addition to their main quality: torque per size ratio. Space and weight are critical factors when it comes to motors. The typical BLDC drive set is shown in below Fig. 6.

The recent inventions and advancements in permanent magnets attracts the researchers to show the high performance and high flux density of Permanent Magnet Brushless DC Motor (PMBLDC) drives in various fields. The performance of PM-BLDC motors is evaluated in two different realistic applications: Electric Vehicle Transportation system and water pumping irrigation systems in renewable sector. The goal of most of researchers and organization in these days is to minimize the carbon footprint and be more power efficient. So, to calculate the CO2 emissions: power consumption (kWh) and CO2-based emission factor (kgCO2/kWh) are considered. And in this BLDC's comes to reduced around 50 -65% reduction in carbon emission compared to conventional AC motor drive which uses Inverter for its operation when fed with power from SPV systems.

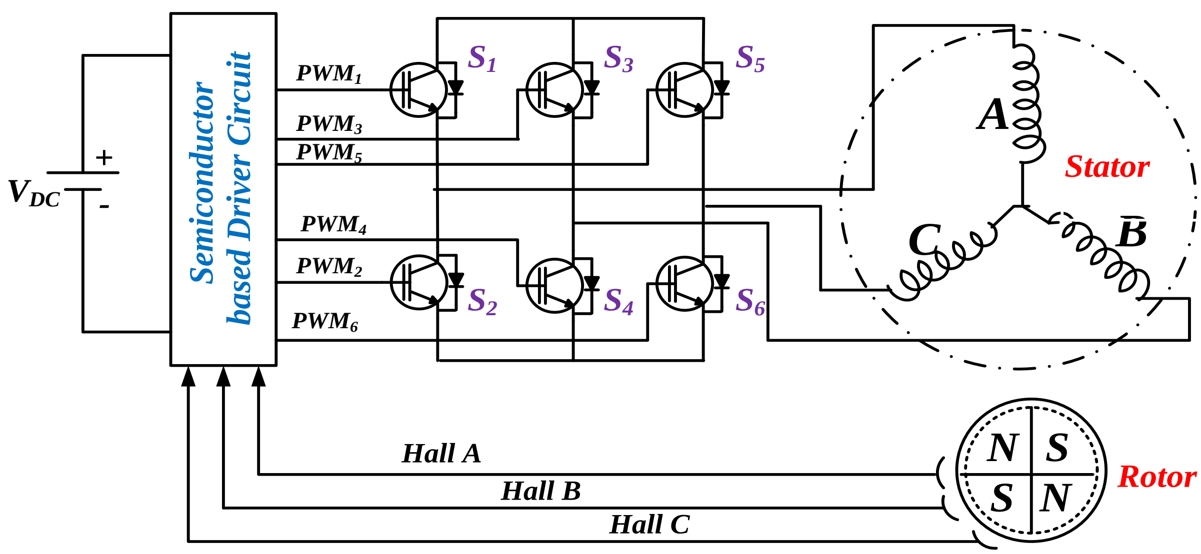


Figure 6: Schematic view of BLDC motor control

Generally, the BLDC motor drive require sensors elements for sensing the rotor position information for energizing the stator windings as an electronic commutation process for a continuous movement of rotor. To detect accurate speed, phase currents, and rotor position information is important. For this, complex circuitry is needed and thus these speed sensors require a higher cost which id attained by Hall sensors system to generate signals. The switching signals generated for the electronic commutation BLDC motor drive is shown in Table II. Subsequent the rotor position, the Hall sensors provide three Hall-effect signals on 60° span. These Hall-effect signals are logically converted into six switching pulses used to operate the motor for grinding. Table-II shows the switching states of electronic circuit for each set of Hall-effect signal states [30]. The conduction of only two switches at a time results in a reduced conduction loss.

Table 3: Hall Effect Based Switching Sequences for BLDC Motor

Angle(θ)	Hall Signals			Switching States					
	H_a	H_b	H_c	S_{w_1}	S_{w_2}	S_{w_3}	S_{w_4}	S_{w_5}	S_{w_6}
NA	Off	Off	Off	Off	Off	Off	Off	Off	Off
0º - 60º	**On**	Off	**On**	**On**	Off	Off	**On**	Off	Off
60º - 120º	Off	Off	**On**	**On**	Off	Off	Off	Off	**On**
120º - 180º	Off	**On**	**On**	Off	Off	**On**	Off	Off	**On**
180º - 240º	Off	**On**	Off	Off	**On**	**On**	Off	Off	Off
240º - 300º	**On**	**On**	Off	Off	**On**	Off	Off	**On**	Off
300º- 360º	**On**	Off	Off	Off	Off	Off	**On**	**On**	Off
NA	**On**	**On**	**On**	Off	Off	Off	Off	Off	Off

3 Result and Analysis of Tested Prototype

The verify the effectiveness of wet grinder operating purely on Solar energy, it has been tested under three operating conditions (i.e., No-Load, On-Load & sudden transients in speed and loading). To validate the proposed solar driven grinder, a 1kW solar system was taken as a source to provide power to the BLDC drive. The dynamics occurring in both input and output side can be seen through results depicted which were stored in the data logger while operations.

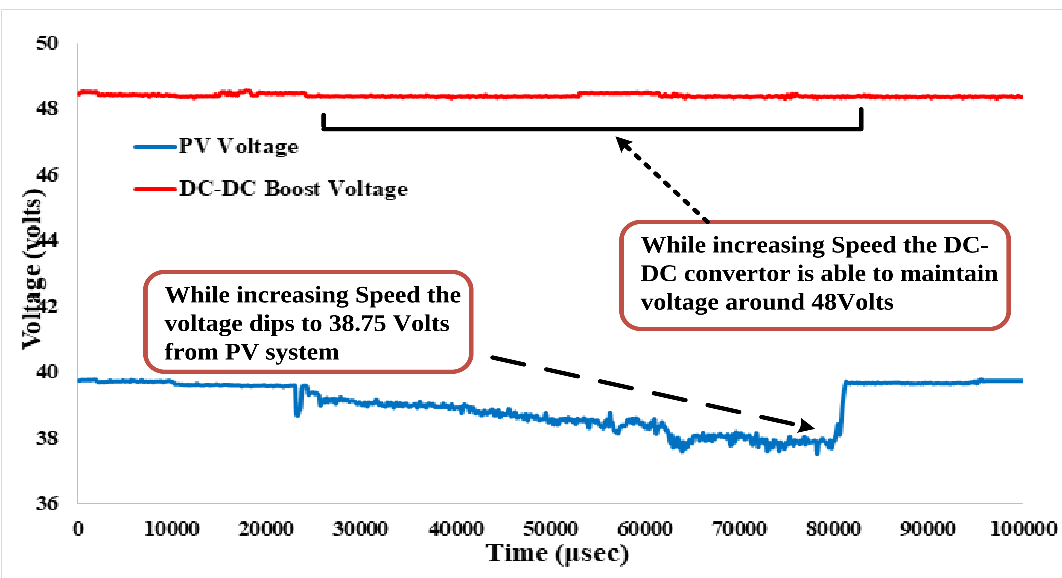


Figure 7: Experimental results of the designed system at No-Load for PV and DC-DC converter voltages.

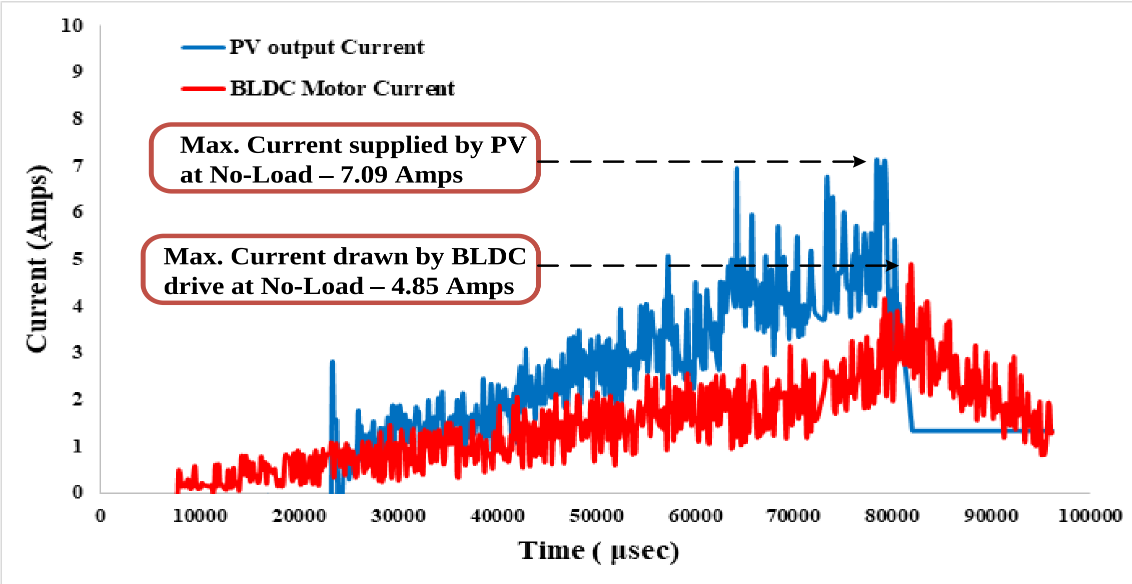


Figure 8: Experimental results of the designed system at No-Load for PV and DC-DC converter currents.

From the above figure it can be notice that the output voltage produced by PV panel at No-Load is around 39 volts. Whereas the voltage is stepped up by DC-DC converter is reserved around 48 volts. When there is gradual increase in speed of the motor drive to its maximum speed, the voltage supplied by the PV system dips to 38.75 volts. But the duty cycle produces by the converter makes the voltage to maintain around 48 volts throughout its operation. Hence the plotted graph in Fig. 7 show the durability of the designed systems at no load condition. It is worth to see that the maximum current drawn by PV system when it reaches its maximum is 7.09 Amps but the boost converter supplies only 4.85 Amps to BLDC drive for driving the wet grinder. The above stated current description can be seen in Fig. 8 which is real time data plotted in MS excel worksheet from the stored values with respect to time from data logger.

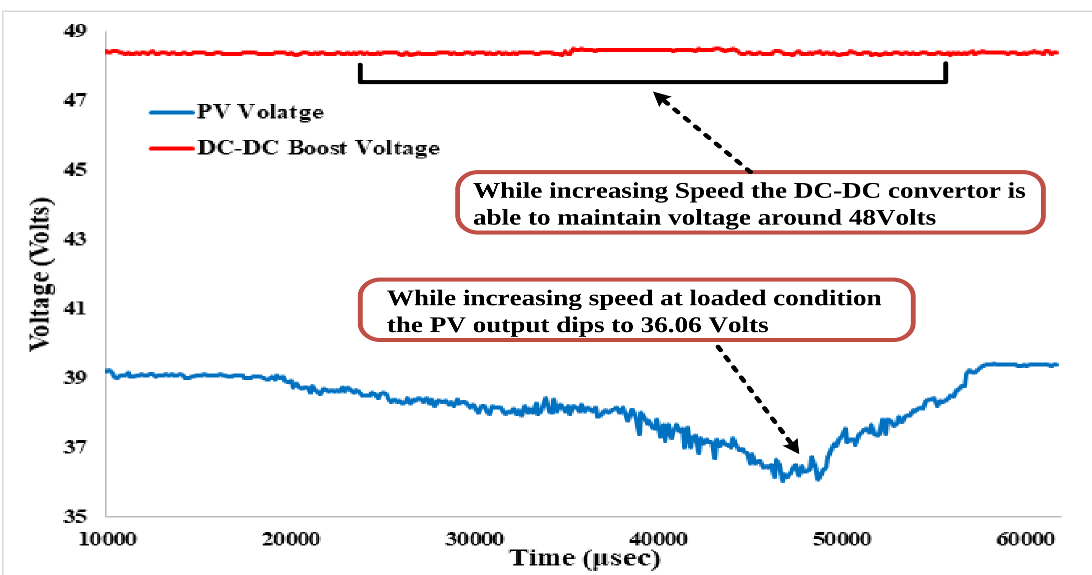


Figure 9: Experimental results of the designed system at Load for PV and DC-DC converter voltages.

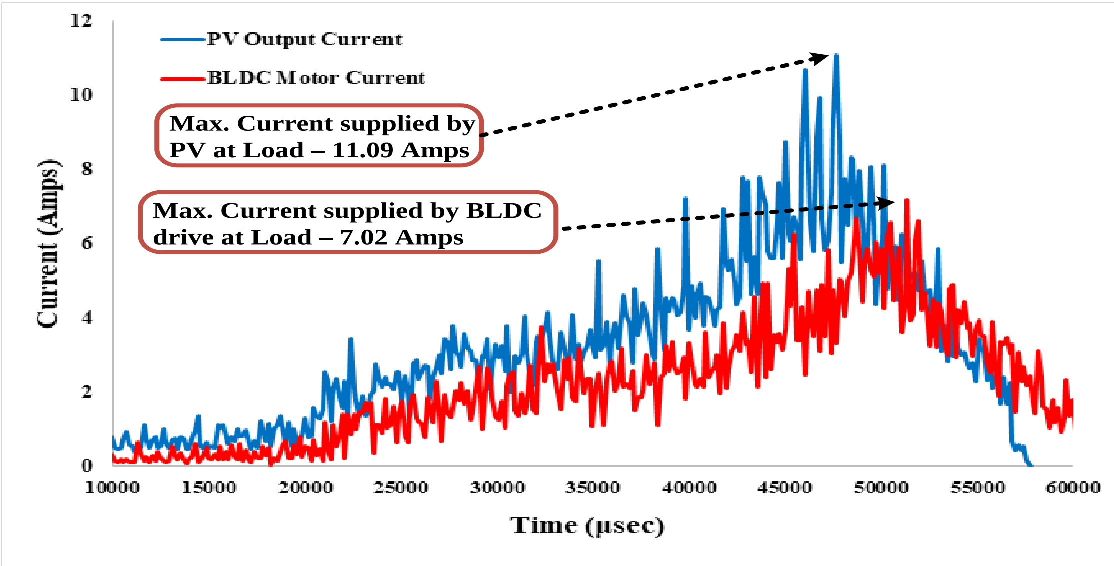


Figure 10: Experimental results of the system at Load for PV and DC-DC converter currents.

It is cleared from the graphs in Fig. 9 and Fig 10 that while the motor was load with wet material for processing, the same condition was repeated as in No-Load condition. Under varying insolation and increasing speed condition the DC-DC boost converter was able to maintain a constant DC bus voltage of 48 volts when PV voltage falls to a maximum dip of 36.06 volts at max speed of BLDC drive during its operation. The above stated incidence can be seen in the Fig. 9 at time interval of 50000 micro-sec. Forthcoming to the current graph shown in Fig. 10, there is a sudden increase in both PV and as well converter current at same time interval stated above. But the current drawn by the drive is very much less than current supplied by the converter, which intends to reduce ohmic loss in the motor.

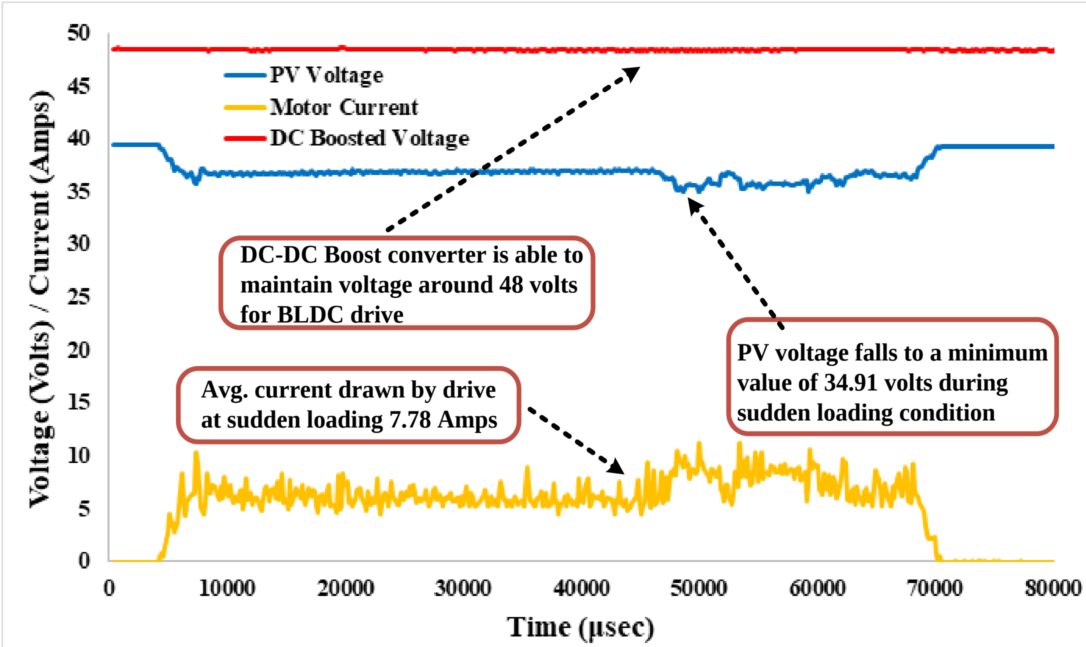


Figure 11: Experimental results of the designed system for sudden dynamics in loading at constant speed.

In Fig.11 case, the grinder was sudden loaded with material for processing when the motor was running at constant speed. There was occurrence of dynamics in the process at source end, i.e. PV out voltage supplied to the DC-DC boost converter. But a constant 48 volts DC Link voltage was maintained by the converter with less distortion which is clearly observable in the shown above graph. The load current drawn by the BLDC motor drive was of value 7.78 Amps, which was maximum while the dynamics were introduce during its smooth operation. While the voltage got dip to a value of 34.91 Volts of minimum value from it operating point.

In Fig. 12 case, the grinder was suddenly disturbed in speed while material was processing when the motor was operating. There was abrupt occurrence of dynamics in the process at source end (35000 – 55000 µsec interval), i.e. PV out voltage supplied to the DC-DC boost converter. But the 48 volts DC Link voltage was having less distortion which is clearly observable in the shown above graph compare to PV. The load current drawn by the BLDC motor drive was of value 5.84 Amps, which was steady while the dynamics were introduce during its smooth operation.

The virtuous performance for real-time input voltage variation is seen in the graphs by the experimental data results. Also, by the comparing the figures for voltages and current for No-load and Load conditions can be seen in Fig. 7 versus Fig. 8 and Fig. 9 versus Fig. 10, it is clear the good correspondence between source and load for processing the raw material. The load variation, used in the operation of Fig. 11, was implemented experimentally, leading to the results in current shows not so much disturbances. The same variation in speed, shown in Fig. 12, depicts that current drawn was not having large transients.

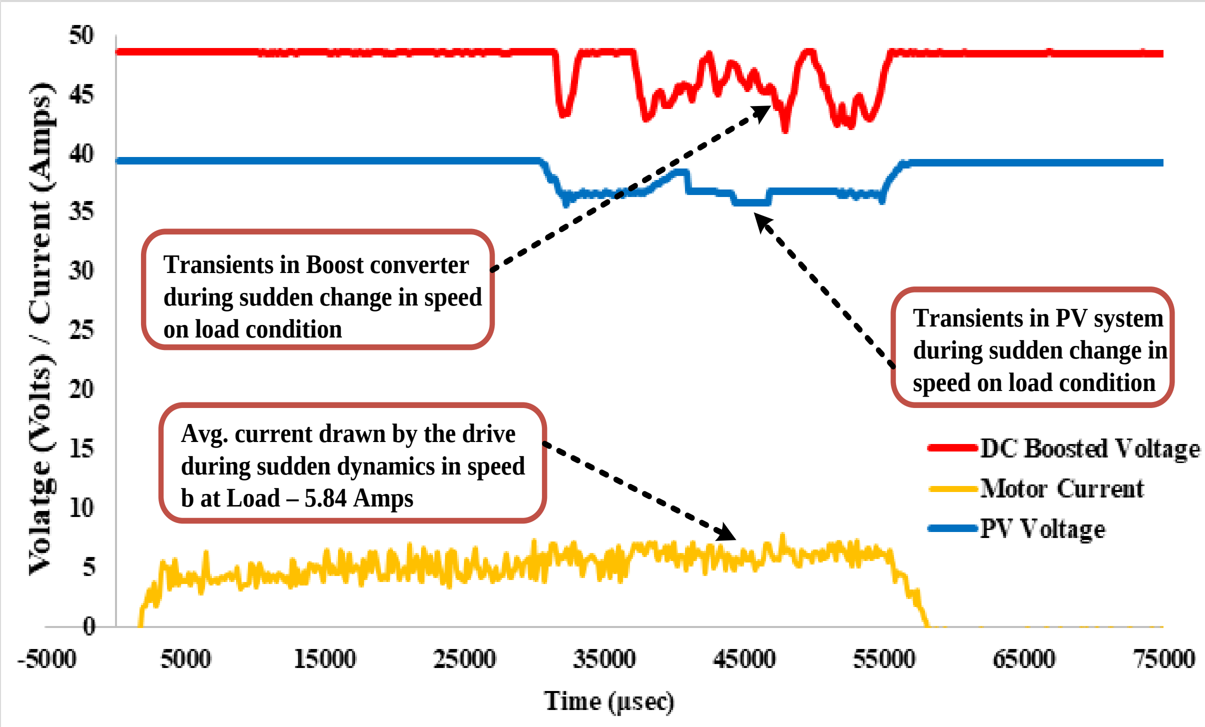


Figure 12: Experimental results of the designed system for sudden dynamics in speed at constant load.

Batter-making efficiency

When the solar irradiation is low, the motor runs at a low speed; as the solar irradiation grows, so does the motor speed. Table II displays the numerical statistics for a PV-powered BLDC motor-driven wet grinder system. It has been discovered that wet grinders powered by PV power are more efficient than wet grinders powered by AC motors. Similar to why they are more efficient, this is because there are no inverter or passive losses in the system between generating power and delivering it to the motor, ensuring higher efficiency when provided with good quality input power.

The performance of fabricated was found to be economical for PV fed Wet Grinder under different loading conditions. The rate of grinding the wet mass and machine output was measured and showed in Table 4.

Table 4: Performance Analysis of PV driven Wet Grinder system.

Sl. No.	Irradiance (W/m²)	Temperature (ºC)	Condition	Operational Status	Input Voltage (volts)	Output Voltage (Approx. volts)
1.	700	38	Loaded	Running Successfully	36.4	48
2.	750	38	Loaded	Running Successfully	37.8	48

3.	800	38	Loaded	Running Successfully	38.3	48
4.	850	38	Loaded	Running Successfully	39.4	48

4 Conclusion

The paper comes with an outcome in aspect of designing and constructing a fully independent solar-powered, mechanical mini-processor for grinding wet material. The device was operated in real time so that it could grind the material as it was being produced and verified experimentally. The numerical data stored in the data logger while the system was operating at different load conditions shows that the efficiency of BLDC drive with SPV is better than the AC drive machine which cause more stress on grid at low and fluctuating voltages. The number of components required and power stages are lesser in the proposed designed than the AC drive driven by existing SPV for processing the wet material. The number components required to drive wet grinder with AC motor are inverter with battery for its operation, where proper switching is necessary for producing proper sine wave. Whereas PFWG requires only DC boost converter which has one switch for obtaining proper voltage level as the power is direct in nature to feed the motor drive. Thus, results confirm that PFWG running purely on solar is an environmentally friendly solar based technology. Nonetheless, its environmental performance could be further optimized through the process optimization in future aspect.

Authors' Contribution: **Shweta Bansal**: Conceptualization, proof of concept, writing-original manuscript **V Hemant Kumar**: Methodology, validation, software, writing-reviewing, **R.N.Patel**: Supervision, writing-reviewing, **Yugal Kishor:** Visualization, and editing, **Manoj Kumar Nigam**: Supervision, writing-reviewing and editing.

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