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A study on the use of renewable energy for coconut dehusking

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Abstract. A solar photovoltaic (PV) coconut dehusking machine may become one important application of renewable energy especially in rural areas like in Sarawak. It will not only enhance the socio-economy in such areas but also indirectly reduce the risk of injuries from the process of dehusking coconuts manually. Thus the purpose of the study is to simulate the performance of the PV coconut dehusking machine by circuit modeling in Simulink and PVsyst software. Simulation results showed that it could match the rpm and torque required in the dry coconut shear test. Furthermore, when implemented, such a PV-powered machine is expected to offer better cost of ownership in the long term when compared to a dehusking machine that runs on fossil fuel based on the PVsyst software analysis.

1 Introduction

Coconut dehusking machines are capable to improve production and efficiently eliminate injuries to operators while performing the coconut dehusking task. These difficulties might change people's mind set to perform this job fulltime as their core business. While the government implement continuous drive to improve the rural economy, coconut production must not be neglected as it has high potential to generate consistent income. Thus, coconut dehusking machine is a critical element for successful production of coconut products, yield better productivity and save time. The coconut husk waste is also be used for both commercial by-products and environmental protection.

The recent increase in coconut milk demand for the past few years has contributed to a rapid growth in coconut dehusking activities. In 2009, coconut crops were planted in 12.23 million hectare throughout various places in the world. Malaysia, among other coconut producers, yields about 400 million coconuts which is still short of the 543 million coconuts for domestic demand [1]. Thus, this is quite an impressive opportunity and handsome pay for some of the rural communities especially in Malaysia.

The safety of the operation is taken into consideration at this stage. Thus, many versions of the machine has been developed to meet the challenge. In 1998, Kwangwaropas used a single-phase 1.5 kW electric motor to design an electric dehusking machine [1]. It comprises of two revolving cylindrical rotors with six fins on each rotor. Like previous designs, the operator needs to force the coconut by pushing it toward the rotors, but this time it is done by using a cover. Another successful version of the dehusking machine uses double spike rollers with a hydraulic-actuated mechanism. It incorporates a 4.1 kW petrol-powered motor to generate the hydraulic pressure which is used to drive the double spike rollers. The coconut is fed between the two rollers to remove its husk.

All the technologies and mechanisms of the dehusking machines available might be functional and efficient but they might not suit everyone's needs especially where the area lack basic facilities such as road access, electricity and petrol stations. Thus, this paves the way for a new innovation to develop a green energy dehusking machine for rural people of Bintulu division to equip them well and boost their economic capabilities. Renewable energy alternatives are also necessary for sustaining the environment, affording the basis for shrewd long-term rural production system. This would also minimize direct costs to producers for preserving good environmental quality and indirect costs caused by consumers when environmental quality declines. Furthermore, users may benefit greatly from the high environmental quality in air, soil and water.

A coconut is a well-known favourite fruit and can be found easily in the tropics. Young coconuts are harvested for its juice and flesh which bring sweet taste. The old coconut is a source for coconut milk which also an ingredient in consumer food. This basic crop is greatly in demand particularly in Bintulu, Sarawak. There, the coconut trees can be found widely in rural area such as *Sebemban, Setulan, Serupai* and other areas along the seaside. It becomes one of the main economic

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sources of income besides the palm oil for people living in those areas.

Dealing with coconuts can be considered lucrative for the farmers. The current market price for husked coconut varies from RM 1.00 to RM 1.80 each. Normally, the farmer can easily sell up to 100 kernels daily as they do this by a conventional dehusking method. Most of the farmers are old as the young ones work in the cities. Thus, doing this daily could drain their energy, time and jeopardize their health. Unfortunately, they cannot afford to stop doing their routine, as they also need some income to support their own livelihood.

A new techniques or a mechanical dehusking machine is what they might be craving for to support their production. Currently, they need something that is portable and not powered by electricity, at least not from the grid. Some areas are on-grid while some are not. Even in the areas with electricity, their farms can be far from power socket points. Thus, electric-powered dehusking machines cannot be used directly. Another solution is probably to introduce a petrol or diesel engine to power the dehusking machine.

In short term, this might be the best solution but the nearest gas filling station might be around 80 km away in many areas. Another weakness is the regulation, which discourages one from simply filling their empty drum or fuel canisters. Thus, an alternative approach is to use solar (photovoltaics) PV coconut dehusking machine in order to meet their needs. It can be made portable, without the need for fossil fuel or the electrical grid. Hence, this would enable the users to produce at least the same amount of work.

This paper consists of five sections. The background of study is already presented in Section 1. In Section 2, the review of related works like PV systems, energy storage technologies, and food production technologies are given in brief. Section 3, the discussion is on the methodology to achieve the objectives. In addition, Section 4 reports the results and discussions. Lastly, Section 5 highlights the conclusions of this work and suggestions that can be done to improve this study.

2 State of the art

2.1 Understanding coconuts

Coconut dimension is a critical element in designing the dehusking machine. The dimensions of a mature coconut vary depending on the area it is planted and its variant. An efficient machine has to meet a range of coconut sizes and able to increase productivity. Venkataramanan et al. in [2] conducted a research to measure the dimensions of the coconut by using external callipers. Most of coconuts appeared to have almost identical dimensions in term of the Y and Z directions. However, the most similarity had been found in the X dimension [2]. The dimensions of X, Y and Z are shown in Figure 1.

The data was collected from various places in order to get the average measurement of the coconut. Table 1 shows the dimension range of the coconut with husk. Meanwhile, Table 2 lists the dimension range of the husked coconut.

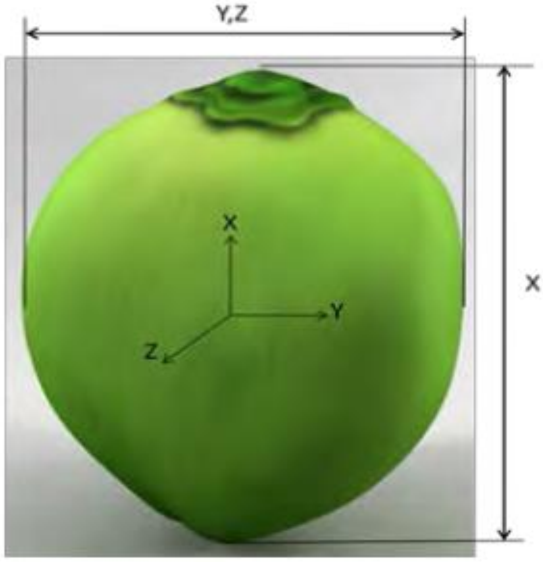

Fig. 1. Mature coconut dimensions [2].

Table 1. Dimension of the coconut with husk [2]

No	X-axis (mm)	Y-axis (mm)	Z-axis (mm)
1	121	113	109
2	157	146	142
3	182	161	165
4	246	218	214
5	276	230	227

Table 2. Dimension of the dehusked coconut [2].

No	X-axis (mm)	Y-axis (mm)	Z-axis (mm)
1	97	86	86
2	114	98	96
3	125	115	109
4	147	129	125
5	162	135	134

Another criterion required to synthesise the coconut dehusking machine is the force required to remove the coconut crown. To find the force needed, or the shear load, the coconut is tested with the Universal Testing Machine (UTM). Dry and mature coconuts in various sizes as mentioned in Table 2 were tested and the results shown in Table 3 and Table 4.

Table 3. Shear load required to dehusk mature coconuts [2].

No.	X-axis (mm)	Shear Load (kN)
1	128	0.32
2	145	0.35
3	178	0.39
4	212	0.45
5	248	0.52

Table 4. Shear load required to dehusk dry coconuts [2].

No.	X-axis (mm)	Shear Load (kN)
1	133	0.24
2	154	0.26
3	174	0.29
4	208	0.36
5	252	0.42

2.2 Cutting torque

Based on the experimental data, the torque required in dehusking a coconut can be calculated. From this torque value, the drive reduction between the motor and the rollers can be designed.

$$T_s = n_s F r \tag{1}$$

where $n_s = 1.25$ is the service factor. F is the cutting force from the shear load whereas r in the average radius of the coconut. If, for instance, the average radius considered is 80 mm while the force is taken to be 450 N, the resulting cutting toque is 45 Nm. Next, torque at the motor can be determined as

$$P_m = T_m \omega \tag{2}$$

Here, some parameters are decided for the electric motor that include ω = 1445 rpm and the power set to be 5.5 kW. Hence, the torque is found to be $T_m \approx 36$ Nm.

One contemporary machine includes rotating rollers with sharp pin blades designed to remove the husk. Although it consumes less time, it still depends on the capability of an operator. The operator still needs to apply a downward force on the coconut using a special clamping tool or even their bare hands to avoid the coconut from being thrown out of the blades. Figure 2 displays the horizontal roller dehusking machine.

Fig. 2. A horizontal roller dehusking machine [2].

Venkataraman et al. [2] noted the current machines or tools are very useful for removing the husk and crown before the coconuts can be processed. The crown of the coconut is also a crucial part of the coconut that is removed by the newly proposed machine. The crown is the fibrous portion that is protruding from the top of a coconut. It is usually seen covering the eyes of the coconut. As mentioned before, it can be very difficult to manually separate the crown from the nut.

2.3 Energy source

Energy source is one of important selection criteria for designing a mechanical. Energy source can be from fossil fuel like gasoline or kerosene, wind, solar and biomass to name a few. Next, each will be elaborated further.

Wind turns out to be mechanically helpful when convective streams made by the sun empower air spread over the surface of the Earth. When sun radiation reaches the Earth and warms its surface, impression of the warmth heats up the ambient air. Warm air, which is less dense than cool air, rises and chill air slips off. In this procedure, the cool air gets the chance to be warmed when it accomplishes the Earth surface and rises up to the higher height [3]. The cycle continues when it brings warm air up and in the long

Wind speed changes directly with stature over the ground [4]. Wind moving over the Earth surface overcomes grinding brought on by turbulence over and around structures, trees, mountains, and different deterrents. This rubbing process diminishes with expanding height over the surface until unhampered wind stream is accomplished.

The most confounding thought in wind power estimation is the mean force in the wind. Contingent upon the wind speed scattering (or the recurrence of event of various wind speeds), two indistinguishable wind machines situated at various destinations won't as a matter of course deliver the same force yield at the same mean wind speed [3]. The reason is that the mean force in the wind identifies with the mean of the blocks of the wind speeds over that time and this is distinctive to the shape of the mean wind speed.

The recurrence of frequency of various wind velocities can be assessed by a factual bend utilizing the Weibull dissemination [5].

Another source of energy is the sun, which is commonly used in crop drying and sun oriented warmth gathering. Sunlight based schemes can be specifically changed to produce power by utilizing either thermoelectricity or PV cells [6].

Despite the efforts of many researchers, the highest general efficiency could not exceed 18% at present with the best conductivity materials and innovation [7]. Since PV cells for direct generation of power from the sun are as of now the most encouraging and broadly accessible innovation, PV is underlined in this work.

The measure of sun based radiation impinging on the surface of the PV array originates from the edge at which the sun's beams strike. As the PV surface is slanted far from the sun, the force of the radiation on the array becomes less intense. The measure of sun oriented radiation caught by the surface differs as the cosine of the occurrence point between the sun's beams and the normal of the surface [8].

In light of the mind boggling geometry of the position of the sun in connection to the Earth amid different seasons, a framework is needed to track the sun for PV arrays [9]. The following framework can be introduced for better focused PV modules. However, frameworks that take into account the concentrated daylight can by and large acknowledge just beams crossing a constrained scope of edges.

The configuration of PV frameworks depends basically on the accessibility of exact sunlight based radiation information set. This depends not only on gross topographical traits like scope, elevation and atmosphere classes, but also on land highlights [10].

Sadly, exact sun based radiation information are not really available from secluded rural places where numerous PV frameworks are to be introduced. In any case, a few methodologies for anticipating sun orientation stations have been developed taking into account regularly accessible daylight hours and satellite overcast spread information set or on direct nearby estimations [3].

3 Methodology of Research

This section lays out the methods of study employed in this research. Some methods were applied in order to accomplish the objectives which included simulation using Simulink, calculations and comparison based on the data obtained through the simulation.

3.1 Simulink

Simulink is used create direct models to investigate more practical nonlinear models, considering in contact, air resistance, gear slippage, hard stops, and alternate events that portray real system dynamics. Simulink tries to simulate in the PC what should be done in a physical laboratory for displaying and breaking down frameworks that would not be conceivable in a real experiment [11].

After a model is characterised, it can be represented in a schematic fashion to see the dynamic response using scientific methods, either from the Simulink pull-down menus or by entering orders in the MATLAB Command Window. The re-enactment results from Simulink can be placed in the MATLAB workspace for extra post preparing and representation [11].

In this work, the modeling system design processes started by modeling the PV system with storage system. The design is based on the basic designing for a PV system. Then, the total load and rpm will be simulated to ensure the machine able to reach the target. The modeling of the PV system is based on the basic design that contains loads, energy storage technology (batteries), charger, and PV module. The model is then constructed in Simulink as shown in Figure 3.

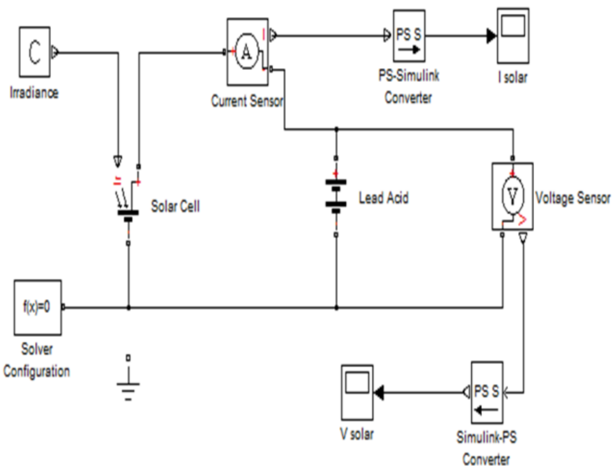

Fig. 3. A solar cell model in Simulink.

For the load inputs, there are lots of optional data to be filled. Firstly, it must be defined of the type of load that will be used in order to operate. There only type of current used was DC. The next step is entering daily profile in the data source. It is easier than choosing import time series data file because the annual average electricity use in kW per day is collected. Furthermore, the data file for electric usage per day for each hour could be imported as a series data file.

Lastly, the data were keyed in to determine the annual average (kWh/d) scale. In the random variability, the data is automatically simulated by the software itself.

For PV inputs, a few things such as the size, capital, replacement, operation and maintenance, lifetime, de-rating factor and output current produce by the PV system have to be considered into an account. In this example, the cost for 230W PV was RM 1300. The cost of replacement was assumed to be the same as the initial cost. Operating and maintenance cost was assumed to be zero since it is negligibly small. In the properties, output current must be selected DC current and the average lifetime of the silicon type solar system is 20 years and the de-rating factor for the PV is 80%. For slope and azimuth, just set it to zero in the ground and 20% according to the default setting of the software.

For battery inputs, there are many types of battery that can be found in the market. All the data that needed can be found from the manufacturer in its recommendation sheet. A serial set of batteries is needed because it is an important storage for the solar system. In this project, the batteries were used is a Lead Acid Energy Storage.

The design is based on electric motor specification that able to dehusk the coconut. All the data that need are being provided by the manufacturer recommendation sheet. In this project, the DC motor was used and the model of it in Simulink is shown in Figure 4.

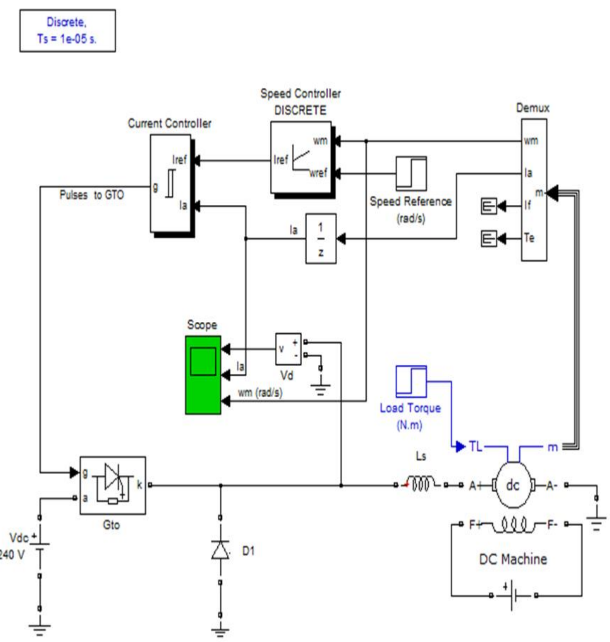

Fig. 4. A DC motor model in Simulink.

3.2 PVsyst Analysis of investment

PV framework size is composed of energy required to run the framework and what number of PV modules are expected to create it. A PV framework needs to create enough energy to cover the energy utilization of the losses (DC Motor) and energy utilized by the framework itself. The exact configuration of a PV framework is completed by utilising PVsyst, which figures the energy yield of the PV framework for a specific area.

The size and arrangement of sun based array is then streamlined keeping in mind the end goal to coordinate the energy yield of the framework to the energy utilization of the framework. The energy yield of a PV framework relies on upon the kind of PV modules, the attributes of a PV inverter, the introduction of the modules, and meteorological conditions.

Here, the solar PV is designed based on the power require to operate the 5.5 kW DC motor in order to achieve the torque for the dehusking the coconut. The system is optimised by using PVsyst simulation and the best power achieved is 6.9 kW.

Table 5. PVsyst parameters for coconut dehusking machine.

Specification	Description	Total Unit
PV module – Si poly	230 Wp / Unit	30
Battery – Lead Acid	24 V/ Unit	20
Inverter	3.5 kW	2
Operation Time	hour/ day	3 hours

From Table 5, 230 Wp Si poly PV module is chosen based on availability of supplier in Bintulu area. Batteries and inverters are acted as an auxiliary device to meet the 6.9 kW design power. Figure 5 shows one of the many window pages in the PVsyst setup before executing the project.

4 Results

The simulation shows motor voltage (V_a), current (I_a) and speed (ω_m) on the scope in Figure 5. The reference rate is expanded from 120 rad/s to 160 rad/s. The pace controller directs the velocity in roughly 0.25 s, and the normal current balances out at 6.6 A. Amid the transient period, the current is still restricted to be under 30 A. The load torque increased abruptly from 5 Nm to 25 Nm.

The PV Solar coconut dehusking machine is driven by the Direct Current (DC) motor and the previous designed which is developed by previous researcher is driven by alternate current (AC) motor. The overall performance is summarised in Table 6. The simulation conduct for the PV solar dehusking machine was able to turn the ABB 5.5 kW DC motor to produce a torque of 36 Nm at 1445 rpm. This would be enough torque if ns = 1 is used in equation 1. However, if the required torque is still expected to be 45 Nm, then a belt or gear system would be able to step up the torque.

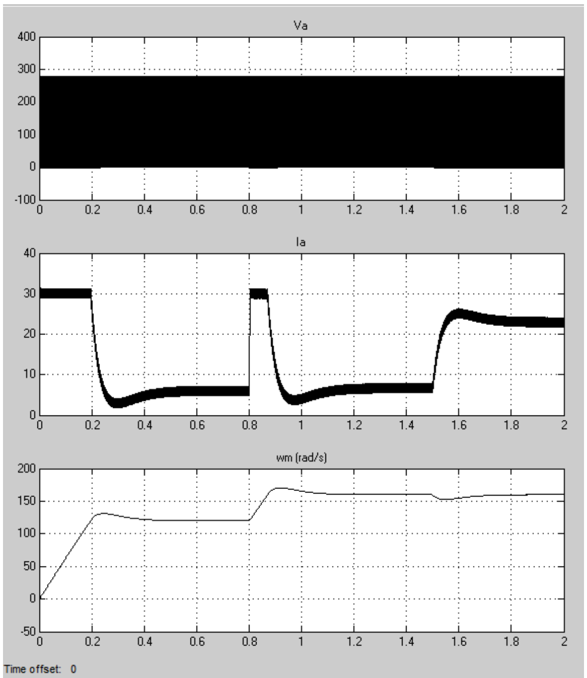

Fig. 5. : Simulation result of DC motor in Simulink.

Table 6. PV dehusking machines performance

Specification	New PV Drive
Energy source	DC
Power	5.5 kW
Torque	36.33 Nm
Speed of the Motor	1451 rpm

The PV Solar coconut dehusking machine is driven by the Direct Current (DC) motor and the previous designed which is developed by previous researcher is driven by alternate current (AC) motor. The overall performance is summarised in Table 6. The simulation conduct for the PV solar dehusking machine was able to achieve about 5.5 kW power at 1445 rpm. Still from Figure 5, the calculations can be shown as

$$\begin{aligned} P &= IV \\ &= (24\,A)(230\,V) \\ &= 5.52\,kW \end{aligned} \tag{3}$$

and

$$\begin{aligned} \omega &= 152\,rps\left(\frac{30}{\pi}\right) \\ &= 1451\,rpm \end{aligned} \tag{4}$$

Meanwhile, PVsyst was able to report the peak electricity produced each month throughout the year for the designated place, Bintulu. The total electricity produced was predicted to be 6867.6 kWh and at its peak was in December that recorded a power of 648.4 kW. The system simulation produced 6868 kWh annually with RM 51,516 as the initial capital or RM0.60/kWh. Here, a diesel engine coconut dehusking machine becomes the main reference for this simulation.

From Table 7, the initial investment is estimated at RM 51,516 for the PV Solar Dehusking Machine. However, as shown in Figures 6 and 7, the cost to produce energy is at RM 0.82 /kW and this means it could save 69.398 tons of CO_2 emission into the atmosphere over the period of 20 years. In a long term, the PV solar system is considered cheaper as its operational and maintenance cost is at RM 5,634 annually [12].

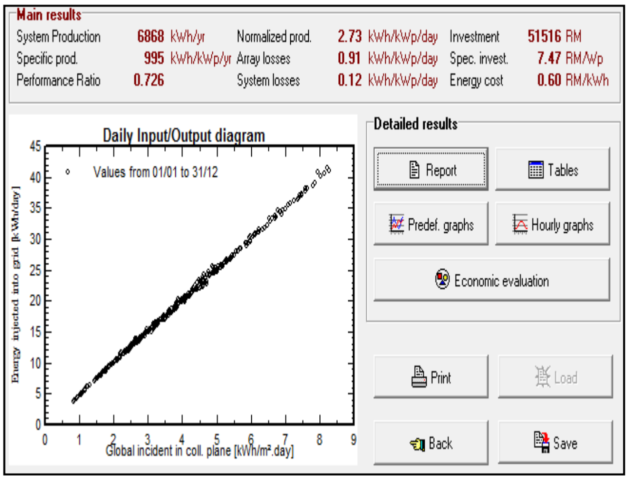

Fig. 6: Simulation input details and parameters.

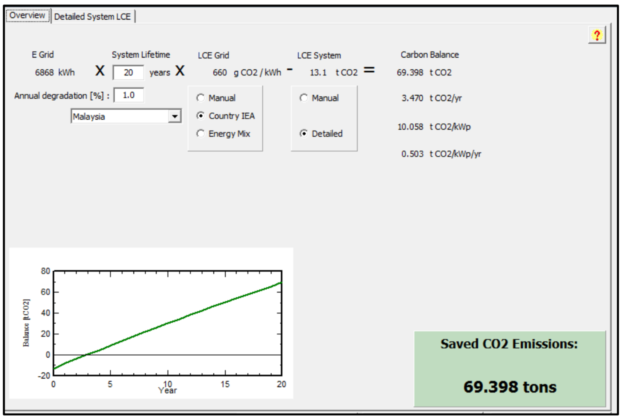

Fig. 7: Saved CO_2 Emissions by Solar PV System.

Table 7. Overall system cost.

Specification	Quantity	Unit Price (Rm)	Total Price (Rm)
Pv Module – Si Poly	30	1,300.00	39,000.00
Battery – Lead Acid	20	300.00	6,000.00
Inverter	2	800.00	1,600.00
Installation and Wiring	Lump Sum	2,000.00	2,000.00
GST	6%	2,916.00	2,916.00
TOTAL			**51,516.00**

The general scheme of this new PV dehusking machine can be seen in Figure 8. The main power should come from the PV module that generates DC current. The voltage can be regulated by the Zener diode system and the power can be supplied directly to the machine. The batteries can also be used to store energy. Alternatively, the machine may also get power from the grid through the use of an adaptor.

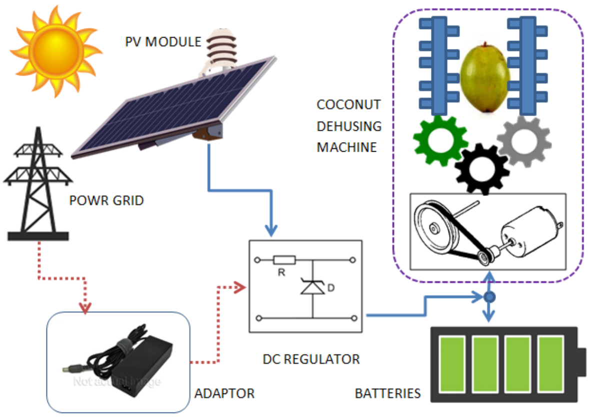

Fig. 8: The general scheme for the new dehusking machine.

Bonny in [12] suggested the machine that resembles much of the good aspects in Venkataraman et al. in [2]. This is evident in Figure 9.

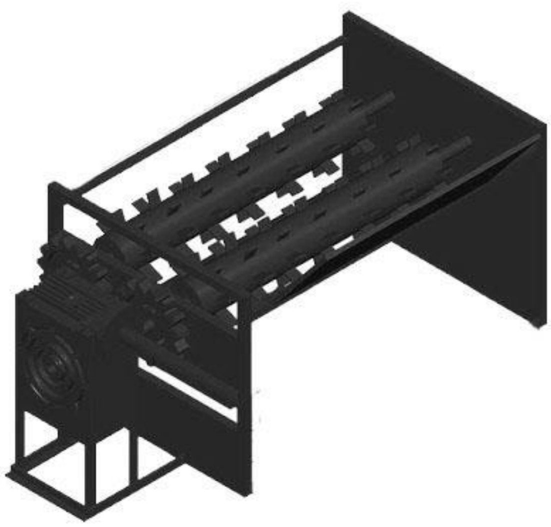

Fig. 9: Solar PV coconut dehusking machine model.

5 Conclusions

The computer simulation results showed that the PV Solar Dehusking Machine was capable to achieve at least 36 Nm of torque at about 1450 rpm which is required to dehusk some coconuts. Furthermore, it offers better cost of ownership in long term when compared to the on-grid coconut dehusking machine. It could give big advantages for the owner not to take care of the fluctuating fossil price which could yield higher operation cost and harm to environment. While this work has not been proven by experiments, the results serve as a guide for future work should a physical machine is to be assembled.

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References

1. A. Taufik, H. Akhir, J. Trop. Agric. and Fd. Sc, **42**, 2 183–190 (2014)
2. S. Venkataramanan, R. Abhinav, R. Rahul, Int. J. of Sciences: Basic and Appl. Res. **13**, 2 183–219 (2014)
3. N. Argaw, R. Foster, A. Ellis, Nat. Ren. Ener. Lab. NREL/SR-500-30361(2003)
4. T. Ackermann, L. Söder, Ren. and Sust. Ener. Rev. **6**, 1 67-127 (2002)
5. M.R.S Siti, M. Norizah, M. Syafrudin, Int. J. Chem. and Environ. Eng. **2**, 4 284 (2011)
6. S. Kamaruzzaman, H. Abdul-Rahman, C. Wang, S. Karim, T. Lee, Maejo Int. J. Sci. Technol. **6**, 2 196-215 (2012)
7. M. Albadia , R. Al Abria , M. Masoud, et al. Int. J. of Smart Grid and Clean Ener. **3**, 4 401-409 (2014)
8. B. Elhab, K. Sopian, S. Mat, et al. Sci. Res. Essays **7**, 42 3758-3765 (2012)
9. O. Idowu, O. Olarenwaju, O. Ifedayo, Int. J. of Ener. and Environ. Eng. **4**, 29 (2013)
10. U. Fumichika, H. Yousay, Y. Hitosi, *The seventh International Conference on Urban Climate* (2009)
11. A. Tyagi, *MATLAB and SIMULINK for Engineers* (2012)
12. B. Dominic Merikan, Master's report, Universiti Teknikal Malaysia Melaka (2016)