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Development of A Solar-Powered Weighbridge System Using Load Cells in Quarry Site

Nur Syahirah Mohd Zamri[1], Khairul Anuar Mohamad[1,2]*, Afishah Alias[3], El-Farabi Razali[4], Mohammad Syahmi Nordin[4]

[1]Department of Electrical Engineering, Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, Johor, MALAYSIA

[2]Microelectronic and Nanotechnology-Shamsuddin Research Centre,
Universiti Tun Hussein Onn Malaysia, Batu Pahat 86400, Johor, MALAYSIA

[3]Faculty of Applied Science and Technology,
Universiti Tun Hussein Onn Malaysia, Batu Pahat 86400, Johor, MALAYSIA

[4]MT Data Driven Sdn Bhd,
Laurel Laman View, Cyberjaya 63000, Selangor, MALAYSIA

*Corresponding Author Designation

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Abstract: Weighbridge gives high accuracy and efficiency in measuring the weights of loads to ensure safety and compliance with road transport legislation. However, at a remote quarry site, the installation of a weighbridge had been an issue as the electricity supply is one of the problems that need to be faced since the operation of the weighing truck may fail whenever an electrical disruption occurs. In addition, the weighbridge that is widely used in industries for weighing vehicles is not flexible especially for temporary worksites as it cannot be moved from one site to another site. This project proposed the photovoltaic system to power the weighbridge system and develop the prototype to represent the element of a real portable weighbridge at the remote quarry site. The standalone photovoltaic system consists of a PV panel, rechargeable battery, PWM charge controller and weighing system which is controlled by Arduino Uno. The measurement results proved that the weighing scale with four load cells mounted separately indicates an accuracy of about 99 % since less difference error from the actual weight. Therefore, the development of portable weighbridges with four separate platforms each platform weighing each of the tire's trucks and powered by the solar system is very suitable to be applied in a real application to obtain accurate measurement data.

Keywords: Weight System, Arduino Uno, PV Panel

Corresponding author: khairulam@uthm.edu.my

1. Introduction

Nowadays, weighbridge become more important for the industries like mining, quarries, iron and steel, and powder industry since these activities help in increasing Malaysia's economy. This is because weighbridge gives high accuracy and efficiency in measuring the weights of loads and also to avoid the vehicles with goods from exceeding the maximum permissible weight established in legislation for road transport of goods[1]. Accurate weight data collection is a vital function within the quarrying industry. This accurate data can minimize wastage onsite and provide precise measurements of incoming and outgoing materials. In fact, not all quarry site is provided with electricity since quarry activities are mostly at remote location. The weight data may not be accurate if there is an interruption of the electricity supply. In Malaysia, many projects have utilized solar energy as renewable energy resources for the replacement of other energy sources such as fossil fuels and coal to produce electricity [2]. Therefore, a prototype of a solar-powered weighbridge has been designed to overcome these limitations of the electrical power supply at a remote quarry site for the operation of the weighbridge. The digital weighing machine proposed in [3] and [4] presents a weighing system with a low-cost, high resolution, can take accurate readings devoid of errors and is also small in size than the others. Other than that, the weighbridge installed in the quarry sites for weighing the trucks is not flexible for the user as it is not designed to move from one jobsite to another. So, they always need to install the new weighbridge platform every time moves to the others quarry sites. Due to this problem, it is also specially designed with a portable function that will incredibly easy to relocate to different locations.

So, three objectives had been set in order to carry out this project which is to design an Arduino microcontroller-based weighing machine using load cells that had been performed in the Proteus software. Then, the application of photovoltaic (PV) as a power supply for the weighing system is sizing by calculating the PV solar system sizing to figure out the suitable parameter of solar panel, charge controller, and battery for the system. Lastly, a prototype of the weighbridge system by integration of hardware and software is developed. In this project, a microcontroller based on Arduino Uno R3 will be used. The load cell is an Arduino weight sensor that will convert the weight into an equivalent electrical signal. The schematic of the hardware part of the system will be modelled by using Proteus and Arduino IDE software. The PV panel will be installed to generate the power source and as backup energy for the system. Meanwhile, the LCD Display will show the output when the Arduino calculates the Hx711 output and convert it into weight values. This weight scale will be mounted with different numbers of load cells which is one load cell, two load cells and four load cells to measure the different weights of load ranging from 0 to 40 kg.

2. Materials and Methods

This project consists of the components of a solar panel, solar charger controller, battery, an Arduino Uno R3, 10kg load cell, Hx111 module, and 20x4 i2c LCD display. The layout in Figure 1 is the component connection of the weighing system. Solar energy utilizes to power up the system while the solar charger controller is being used to control the charging and discharging of the battery. The load cell detects weight and transmits mechanical weight output signals to the Hx711 module. The Hx711 amplifies and sends the load cell output to the Arduino microcontroller. The Arduino calculates the output of Hx711 and converts it into the weight values and displays it on the LCD.

Figure 2 shows the workflow of the whole system. The system starts to operate once the PV system supplies the power to the system. For the calibration test, two different methods of mounted load cell which separates and combine mounted method were applied by using one load cell of 10kg to weigh the load and then repeating by using two load cells and four load cells. Two different calibration weights were used which 100g for the eccentricity test and 400g for the repeatability test and hysteresis test. Next, for the weighing phase, the most accurate method was chosen and used in this part. Two different sizes of truck scale, large truck scale, and small truck scale were used and a load of 100g was placed on both truck scales and then repeated by using 600g load. The weight of the loads was displayed on the

LCD. However, if the weight of loads that are put on the weight scale exceeds the limit of 40kg, the value of the load weight will not be displayed on the LCD. The process of taking the weight values for each truck scale was repeated 100 times to identify the accuracy and the error.

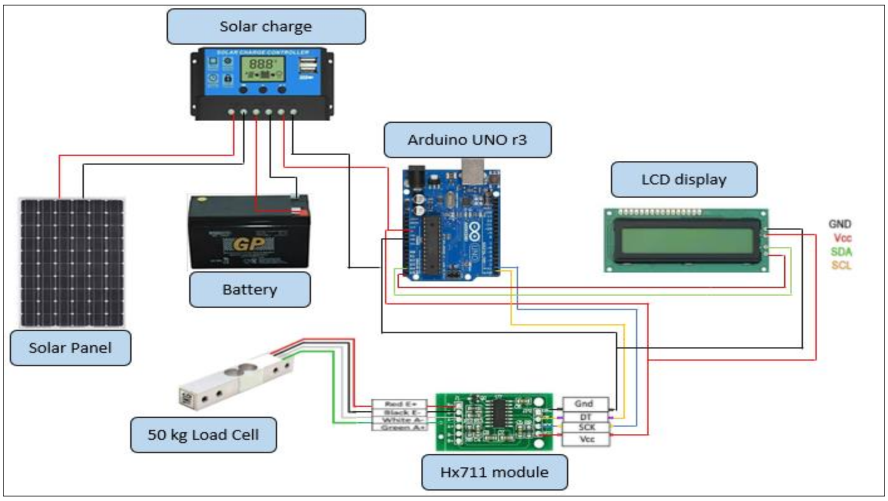

Figure 1: Component connection of the weighing system

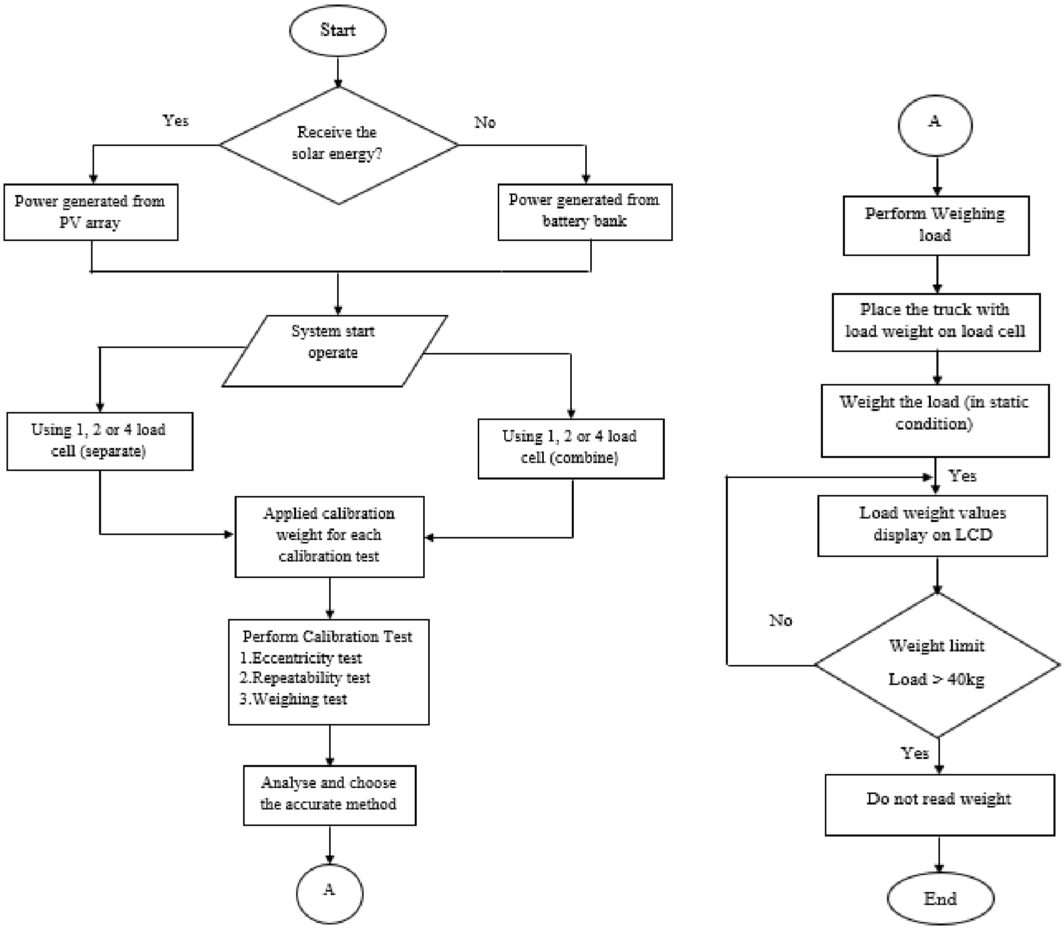

Figure 2: Flow chart of solar powered weighing system

3. Results and Discussion

This section explains the results of the project. It covered the result of the simulation and hardware of solar-powered weighing system.

3.1 Simulation Result

The simulation circuit consists of the designed circuit of the system configuration. Simulation of weighing scale circuit was done by using the Proteus software and the coding file written in Arduino IDE is loaded onto the Arduino Uno to simulate system operation. In this weighing scale simulation, the total weight of the load was displayed in grams on the LCD. The LCD displayed the total weight of 100g after the weight load was entered at the load cell. The measurement was repeated for 200g, 300g, 400g, and 500g of load. The results prove that the system was accurate as the output of the weight display on the LCD is the same as the applied weight at the load cell. Figure 3 shows the weight applied to the load cell and the weight value on the LCD.

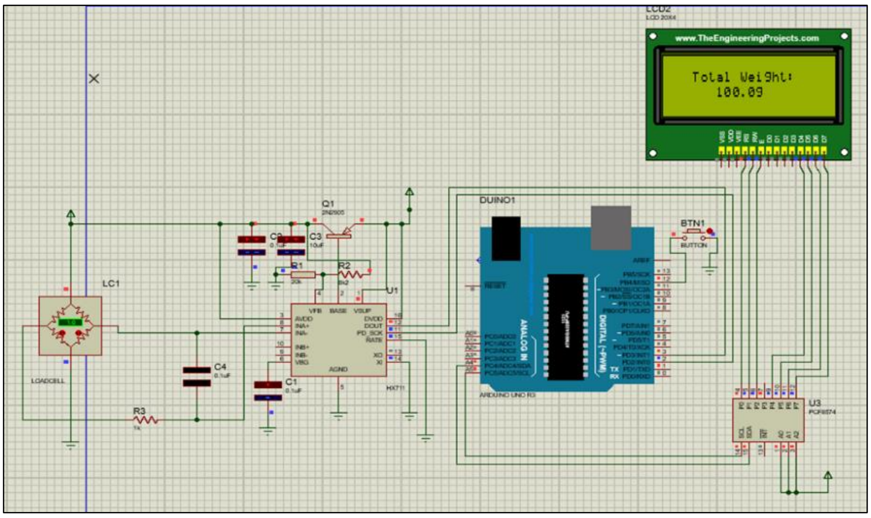

Figure 3: The weight applied to the load cell and the weight value on the LCD.

3.2 Calibration Test

The calibration test was performed in three different types of test which eccentricity test, repeatability test and hysteresis test.

A. Eccentricity Test

A 100gram calibration weight was used and the indications were recorded after each removal of the load for each of the five positions. Table 1 shows the results of the eccentricity test performed on one load cell of the round platform, two load cells, and four load cells on the square platform. From the data, it can be concluded that the round platform of one load cell was the most accurate as all the output weights in every position were 100gram. However, tests on the square platform show that they still achieved the accuracy at position 1 which is at the center of the platform.

Table 1: Results of Eccentricity Test

Round 1 Load Cell		Square 2 Load Cell		Square 4 Load Cell	
Position	**Output Weight(g)**	**Position**	**Output Weight(g)**	**Position**	**Output Weight(g)**
1	100	1	100	1	100
2	100.1	2	100.1	2	100.2
3	100	3	100.2	3	100.4
4	100	4	100.4	4	98.59
5	100	5	100.3	5	99.79
1	100	1	100	1	100

B. Repeatability Test

For the repeatability test, the average value for the weight of the load was determined by taking 10 times. This test was performed in three different conditions which weighing the load using one load cell, two load cells, and four load cells for 400 grams of loads. Figure 4 shows the error that had been calculated based on the results of the 400g load used that was obtained for each of the different mounting methods of the load cell. The highest repeatability error with 0.8g was the test when using 4 load cells that combined together on one platform. Then, the lowest error among all was the test when using 4 load cells mounted separately on each of the four platforms. However, the error can be further reduced by adjusting the calibration factor but it is almost impossible to totally eradicate the uncertainties as the error may occur from a few factors such as not placing the load at the center of the platform, environment effect, and the load cell platform.

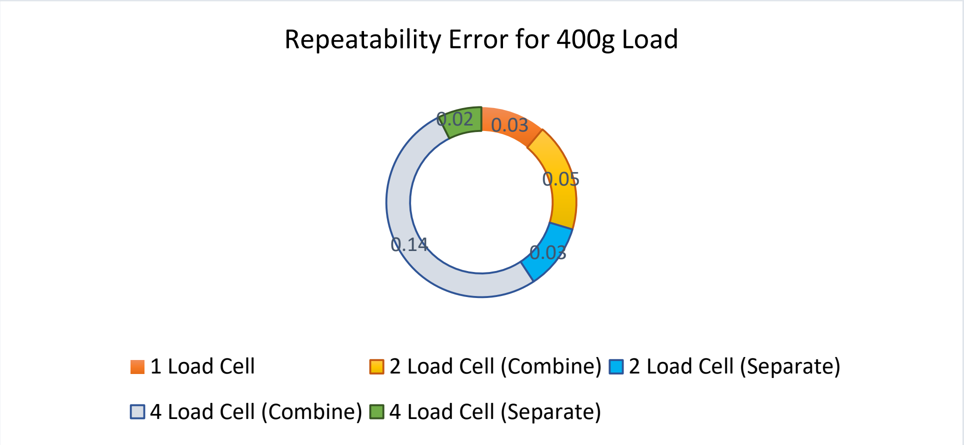

Figure 4: Repeatability error for every types of load cell platform

C. Hysteresis Test

Hysteresis was tested by gradually adding weights on the sensor platform and recording the output values. This phase is called loading, and the reverse is called unloading. This test was performed in three different conditions which weighing the load using one load cell, two load cells, and four load cells ranging from 100g to 400g with 100g increment or decrements at a time. The results show the hysteresis test performed on the platform of one load cell, two load cells and four load cells that mounted separately was more accurate as the weight difference in measurement was 0.2g.

3.2 Hardware Result of Proposed System Development

In this section, the prototype scenario of the loaded truck weighing on the weighbridge platform was demonstrated. Based on the results of the calibration tests, the method of four load cells that were separately mounted in each of the four platforms was used in this experiment test as it was the most accurate method among the others method that had been tested. The testing measurement was performed using two different sizes of truck scale which one large truck scale with 183g and 65g of a small truck scale. Figure 5 shows the prototype build of a solar-powered portable weighbridge system using four load cells that are mounted separately over the weighing platform.

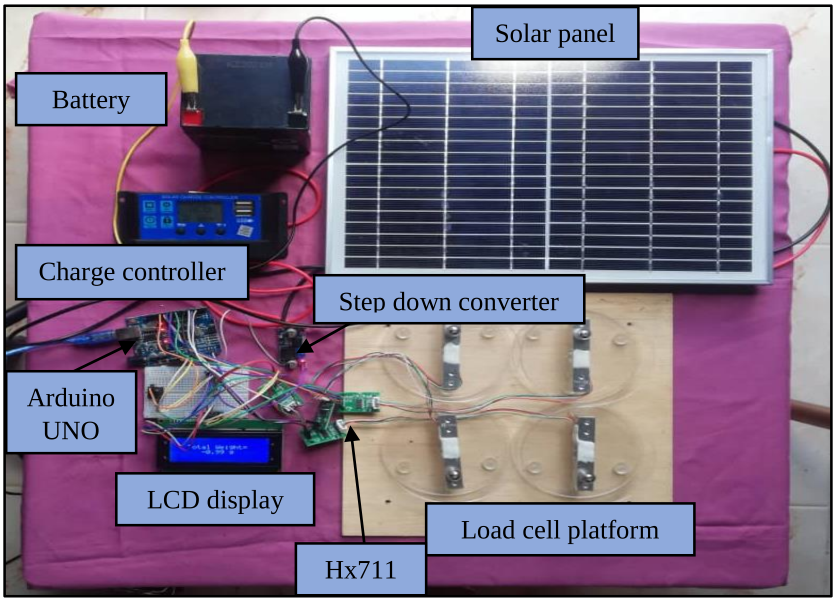

Figure 5: Complete prototype of the project

Figure 6 shows the average readings that had been obtained during the experiment from two different sizes of a truck scale. The aim of using the different size of the truck scale was to identify the performance of the load cell platform whether the load cells will produce an accurate result or not. Based on the bar chart, the difference in the average reading of the large truck from its actual reading was small which is about 0.2g when using 100g of weight load and 0.58g when using 600g of weight load. In addition, the test using the small truck also gave the same results in which the difference gap from its actual weight was small as for the minimum load test, the difference was 0.39g and 0.61g for the maximum load test. Both truck scale tests, proves that by using this weighing scale of four load cells that are separately mounted in each of the four platforms, the results obtained are accurate with less difference error from the actual weight.

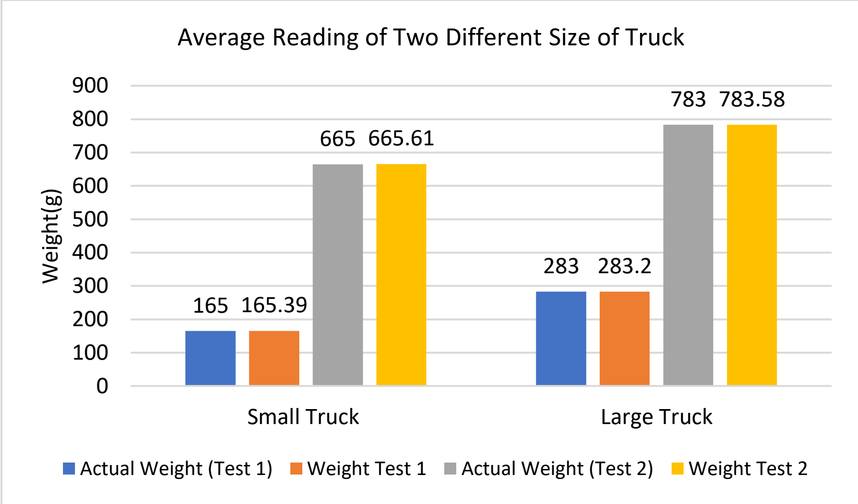

Figure 6: Different average reading of different size of truck

4. Conclusion

In this study, a prototype of solar powered portable weighbridge was successfully developing by solar energy obtained from the solar panel charged to a 12V lead acid battery and it can be used whenever required. From the research, it is analysed that the weight system with four load cells mounted separately on each of the four platforms is the most accurate weight system with the difference of only 0.02g from the actual weight. Then, the performance of this weight system is tested using small truck scale and large truck scale with 100g and 600g loads where both weighing results prove that the system is accurate with only small differences of error from their actual weight. However, the difference error of the weight can be further reduced by adjusting the calibration factor or maybe cause by the environment factor. Therefore, it is clear that the development of the weight scale using four load cells mounted separately on four separate platforms is very suitable to obtain accurate measurement data.

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