Smart Spring Powered Generator

Mohd Syahir Bin Abdul Rahman, Mohamad Annas Bin Lop, Mohamed Farid Bin Abdul Samad, Zulfakri Mohamad, and Rosalena Irma Alip

Abstract*—Recently, 94.8% of Malaysia's electricity has been generated from fossil fuels, which also the main polluters for the atmosphere in Malaysia. Efforts have been made to generate electricity via renewable energies, but the percentage is still low. To overcome this problem, this project proposes a low cost spring powered electric generator. The spring powered electric generator model will be constructed with multiple spring controlled by hydraulic system. The actual system will be embedded under the road since it needs the pressure of the vehicles to stretch the spring coil. Pressure exerted by the vehicle's weight from the road users will be delivered in the spring by the hydraulic system and will be stored as spring force. When the spring is fully stretched it will alert the sensors and will move the motor. This process will generate electricity continuously for several hours depends on how many springs have been fully stretched by the weight of the vehicles. The generated electricity can be used to power up roadside facilities such as traffic lights, street lights and public toilets. This can help to cut down the electricity cost without any pollution to the atmosphere. For this system, NI myRIO-1900 will be used to control the hydraulic system and the monitoring system. As for conclusion, this project will present a model that can generate electricity through spring force to fulfill the demand of generating electricity through renewable energy at low cost. A prototype of a new renewable energy system that produce electricity at low cost have been designed. DC generator 2 with the gearing system has been selected for use in this Smart Spring Powered Generator system based on their best performance and increase the speed of the DC generator shaft that produce the highest electricity. The higher speed shaft of the DC generator rotate will increase the output power of this system. The output power of this project prototype system is 26mW. For now, the application that can used from this project prototype are turn ON the LED lamp.

***Index Terms*—Renewable energy; spring; DC generator; hydraulic system**

I. INTRODUCTION

Electricity is one of the vital energy in our daily needs. It is largely being used in homes, offices and factories. The highest electricity consumption is used in public places such as street lights, traffic lights, parks and other recreation places. As being reported in 2011, 94.8% of Malaysia's electricity is being generated from fossil fuels, 4.2% from hydro and about 1% from renewable sources. Since fossil fuels are the main polluters of the atmosphere in Malaysia. Besides, the life expectancy of Malaysia fossil fuel reserves is also worrying [1]. Efforts have been made to generate electricity via renewable energies and also, Malaysia is aiming for a low-carbon economy for the people of Malaysia enjoy a good quality of life.

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To overcome this problem, this project proposes a spring powered electric generator, as one of the efforts to help reduce pollution at low cost. The objectives of this project are to produce electricity by using Smart Spring Powered Generator.

The system from figure 1 will be installed under the road, since it needs pressure from things that are heavy in weight. When a vehicle passed by the road, it will give pressure to the piston, causing the hydraulic oil to move to spring A through the open valve A1. As time passes, lots of vehicles will pass by and give pressure to spring A, making it fully stretched. This will trigger the sensor at spring A. Then, Valve A1 will be closed and Valve B1 will be opened, allowing the pressure from the vehicles moved to spring B. At the same time, Valve A2 will be opened to release the spring energy of spring A to rotate the rod, enabling rotation of the motor to generate electricity. This process will be the same for spring B, then spring C and so on, in order to generate electricity continuously.

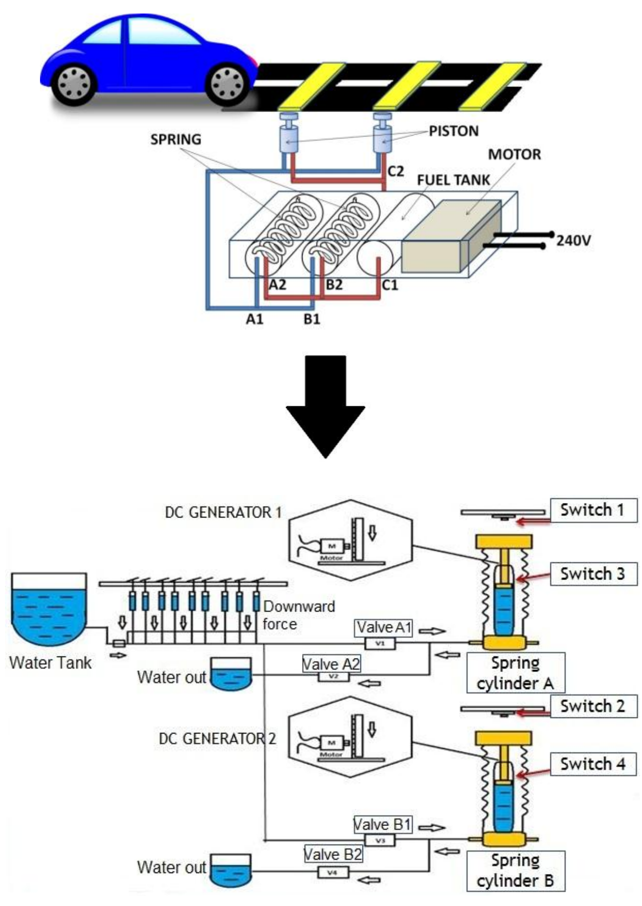

Fig. 1.System of the project

NI myRIO-1900 was used in this project to control the hydraulic system for storing, releasing each spring energy, and to control the speed of the motor to generate electric current. In addition, all data can be stored and spring energy can be monitored by using wireless systems.

From the calculation, the weight of each car that passes by that give pressure to the piston will be able to generate approximately 20 Wh of electric power. If 30 pistons are installed under the road, each car can generate for about 600 Wh. For example, if the system is implemented at the entrance of a shopping mall parking space that can occupy at least 500 cars, with the estimation of 1000 cars per day that go in and out the parking space, the generated electric power through the system will be approximately 600 kWh.

From the TNB tariff calculation, 600 kWh will cost RM 290.60. If the system can generate 600 kWh/day for a month, the total electric power consumption cost can save up to RM 8,718. The generated electrical power can be used to power up the facilities around the shopping mall, for example the street lights, basement parking area lightings and many more.

The estimated installation cost for the whole system is around RM 20,000. From the above calculation, it takes less than 3 months to make a profit out of it. This low cost system has a promising future and can be used widely in Malaysia, such as at the shopping malls, factories and toll plazas.

II. METHODS

This project has been implemented through three phases of development. It was first started with the development of model structure. The second phase is continuing with the development of the controlling system through LabVIEW. The third phase is development of DC Generator. Finally, the last phase involved monitoring process and data collections. The details of each development phase are explained in its respective subsections.

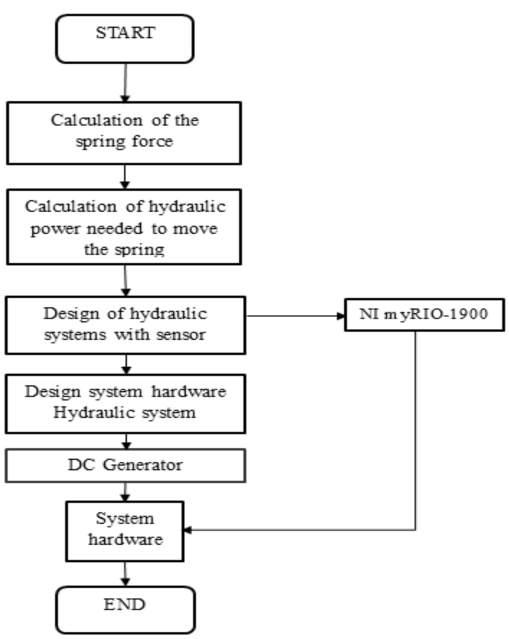

Fig. 2.Flow of the project

A. The development of hydraulic system

The first phase is the development of the model structure, hydraulic system and spring energy storage.

i. Hydraulic System

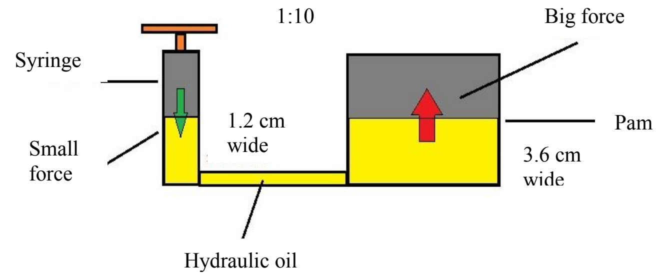

Fig. 3.Simple Hydraulic System

Based on figure 3 shows that have two pistons (1. Piston syringe 2. Piston pump)that filled with oil-filled pipe and connected to one another with an oil-filled pipe.We apply a downward force to one piston (left one in this drawing), then the force is transmitted to the second piston through the oil in the pipe. The piston on the left is 1.2 cm diameter (0.6 cm radius), while the piston on the right is 3.6 cm diameter (1.8 cm radius). The area of two pistons is Pi*r2. The area of the left piston is $1.130m^2$, while the area of the piston on the right is $10.17m^2$.So we can assume the piston on the right is 10 times larger than the piston on the left. What that means is that any force applied to the left piston will appear 10 times greater on the right piston. So if we apply a 10KG downward force to the left piston, a 1000KG upward force will appear on the right.

TABLE I
DATA FOR TYPES OF CYLINDER THAT WLL BE TESTED

Small Cylinder (syringe) (ml)	**Diameter,m**
5ml	0.13m
10ml	0.17m
50ml	0.3m
Big Cylinder (ml)	**Diameter,m**
300ml	0.45m

From the table I shows, that has two types of cylinder with having data of diameter. The requirement data will be tested to get a suitable cylinder for hydraulic system.

ii. Hydraulic Pressure

The pascal's principle states when give one point force. That force will transmit to another point incompressible fluid[6]. The key point of working hydraulic system is the pressure is the same or equal to input pressure and output pressure in all directions.

$$\text{Pressure} = \text{force} \div \text{area} \quad (1)$$

$$P = F / A$$
$$P1 = P2$$
$$F1 / A1 = F2 / A2$$
$$F2 = F1 \frac{A2}{A1}$$

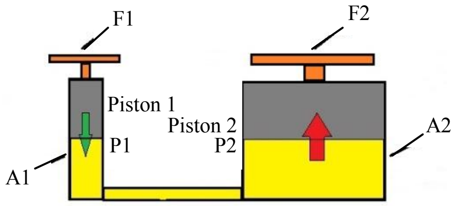

Fig. 4.The operation of hydraulic system

TABLE II
THE DATA OF TESTING CYLINDER A1

Area (Small cylinder) Cylinder A1	F1 assume 1Kg	A2 (Big cylinder)	F2
0.01327 m^2	9.8 N	0.1590 m2	117.4227 N
0.02269 m^2	9.8 N	0.1590 m2	68.6734 N
0.07068 m^2	9.8 N	0.1590 m2	22.0458 N

From the table II shows, the area of the cylinder gives affected to the force at F2. When use a small area cylinder the force at F2 will be increase caused a small area give a low pressure and high output compare on larger cylinder.

iii. Combination Hydraulic System and Spring

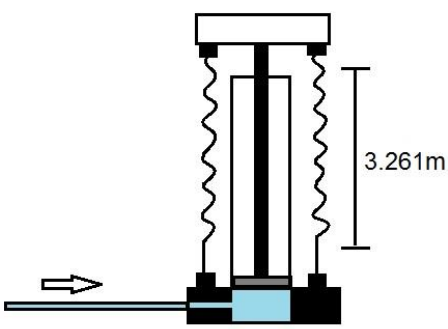

Fig. 5.The combination between hydraulic system and spring

The figure 5 shows, the design hydraulic system combines with spring. This model will be tested with four spring to know how much the spring can store the energy.

TABLE III
THE DATA ABOUT COMBINATION HYDRAULIC SYSTEM AND SPRING

Spring	K, N/m	X, m at max	Work, J
1	42.86	6.4	877.77
2	85.72	6.4	1755.54
3	128.58	6.4	2633.31
4	171.44	6.4	3511.09

Table III shows, from the data taken, it can be concluded as the increment number of springs being applied in the system, may produce a high energy can be stored.

B. The development of the controlling system

The second phase of development involved the automatic controlling system as shown in block diagram Fig. 6 which was starting design the graphical programming using LabVIEW. In the graphical programming, the switch declares as digital input and relay and solenoid valve declare as digital output. Then, the hardware platform using NI myRio-1900 from National Instrument product.

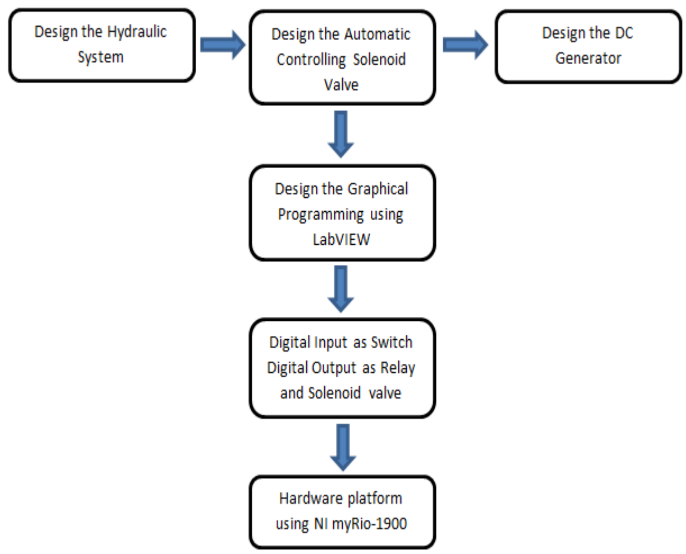

Fig. 6.Block Diagram of the Automatic Controlling System

The automatic controlling system development has two types of design which include software design and hardware design. In this development are use LabVIEW as the software and NI myRio as the hardware.In this project, use NI myRIO-1900 as the main board. The function of hardware is to control the solenoid valve. Furthermore, it is multifunctional that NI myRIO uses the latest Zynq technology from Xilinx featuring an FPGA integrated with a processor running a real-time OS [4]. Other than that, in this project uses the LAB view system as design software providing the solenoid valve interface to the system for easier controlling and monitoring process. It is a graphical programming platform that to control the system in this project. Moreover, the LAB view software provides tools to solve the problem even faster and more effectively.

i. Software Design

LabVIEW is software developed by National Instrument for measurement or control system. LabVIEW is a graphical programming platform for engineers to interface devices such as sensor, cameras and other devices. The unique difference between LabVIEW software with other programming softwares is a LabVIEW involved place and drop action of the block diagram operation and graphical operation for looping and iteration without need to write 100 lines instruction [4]. It is a simple graphical programming for data acquisition and processing.

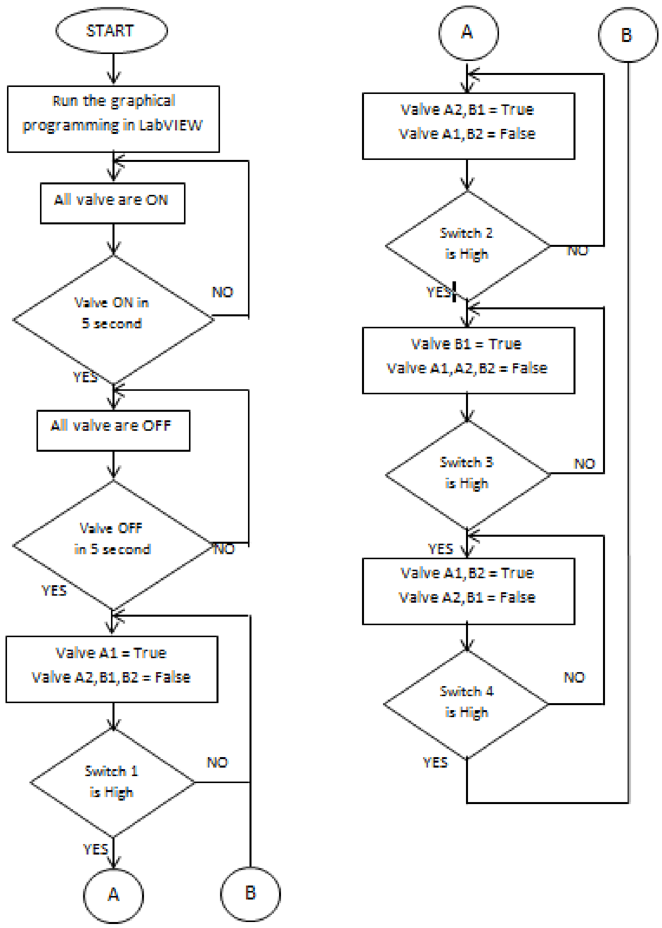

Fig. 7.The Flow chart of the controlled solenoid valve

The figure 7 shows the flow chart of the controlled solenoid valve which starting run graphical programming in LabVIEW. All valves are ON in 5 second, then OFF in 5 seconds also in while loop respectively. Then, the flat sequence is created in one while loop for continuous controlling valve. Firstly, valve A1 is True while valve A2,B1,B2 is False. Then, when switch 1 is high, the programming can move to the next loop. The second loop is a valve A2 and B1 is True while valve A1 and B2 is False. Then, when switch 2 is high, the programming can move to the next loop. The third loop is valve B1 is True while valve A1, A2 and B2 is False. Then, when switch 3 is high, the programming can move to the next loop. The last loop is valve A1, B2 is True while valve A2, B1 is False. Then, when switch 4 is high, the programming can move to the first loop. After than, the programming will be continuing to control the solenoid valve. To stop this program, just click on button stop in LabVIEW.

TABLE IV
THE OPERATION OF A SWITCH AND THE SOLENOID VALVE

Switch (INPUT)				Solenoid Valve (OUTPUT)			
Switch 1	Switch 2	Switch 3	Switch 4	Valve A1	Valve A2	Valve B1	Valve B2
0	0	0	0	ON	OFF	OFF	OFF
1	0	0	0	OFF	ON	ON	OFF
0	1	0	0	OFF	OFF	ON	OFF
0	0	1	0	ON	OFF	OFF	ON
0	0	0	1	ON	OFF	OFF	OFF
1	0	0	0	OFF	ON	ON	OFF
0	1	0	0	OFF	OFF	ON	OFF
0	0	1	0	ON	OFF	OFF	ON
0	0	0	1	ON	OFF	OFF	OFF

The table IV shows the operation of a switch and solenoid valve that operate at graphical programming by using National Instrument Lab view software. In the table consist of Input and Output. Firstly, graphical programming had been done to check all the component's functionality. From the result, when all the switch is 0, only valve 1 is ON the other valve is OFF. Next, when switch 1 is 1, the solenoid valve 2 and 3 is ON. Then, when switch 2 is 1, the solenoid valve 3 has only been ON. Next, when switch 3 is 1, the solenoid valve 1 and 4 is ON. Lastly, when switch 4 is 1, the solenoid valve 1 has only been ON. From here, it can be concluded that the program is continuously running.

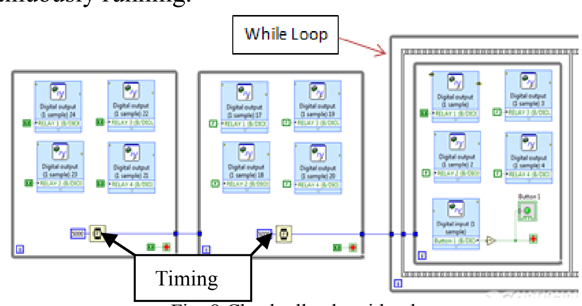

Fig. 8.Check all solenoid valves

Figure 8 shows programming that have been done the functionality of all solenoid valves. The solenoid valve will be switched ON in 5 seconds for waiting time, then will be switched OFF in 5 second. Lastly, the programming will move to the main program that are shown in the above table.

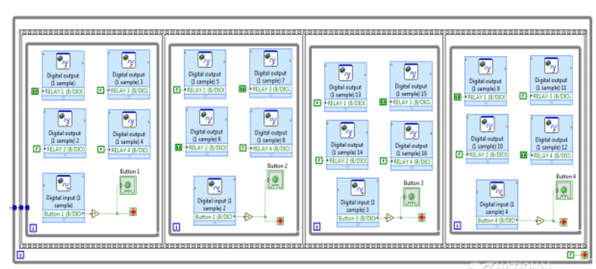

Fig. 9.The whole system consists digital input and digital output

Figure 9 shows the whole system of the solenoid valve, which consists of 2 main parts: the Digital Input as the switch and Digital Output as the solenoid valve. In this programming, the digital output will be created as constants that will be set True is ON and False is OFF. All the processes are put in a while loop for a continuous real-time reading, with a start and stop button to initiate or halt the program, respectively.

C. *The development of DC Generator*

In this analysis have consisted of testing direct coupling DC motor with DC generator. Secondly, testing the gearing system and thirdly is an implementation of DC generator at real Spring Powered Generator.

i. Testing direct coupling DC motor with DC generator

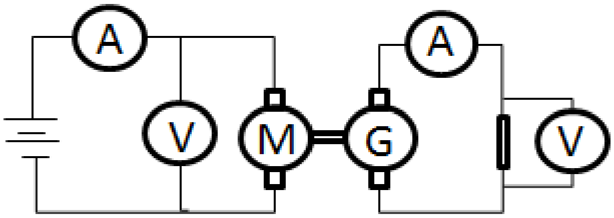

Fig. 10.Schematic diagram direct coupling

The figure 10 shows the schematic diagram of the experiment of testing DC generator. This test is to analyze the DC generator performance. DC power supply is used to supply the power to DC motor drive for rotating the shaft, the speed of the shaft rotating controlled by the power input. When the shaft rotated after DC motor turn ON, shaft of DC generator will be rotated and then produce the electricity. Three different brands of DC motor have been selected. This DC motor is converted as generator in this experiment

TABLE V
SPECIFICATION OF GENERATOR

Specification of generator	**DC generator**		
	1	***2***	***3***
Brand name	Mitsumi	Mabuchi	OEM
Voltage	7V	7V	5.9V
Type	DC motor	DC motor	DC motor

The table V shows the specification of generator based on brand name, voltage and type.

ii. Testing gearing system

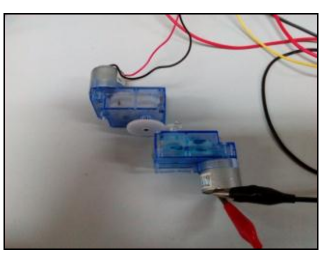

Fig. 11.Multiple gears connection

The figure 11 shows the connection of multiple gear of gearing system applied to DC motor and DC generator. This test is to analyze the DC generator performance when added the multiple gear. The multiple gear used in this test by using compound gearing. The table VI below shows the specification of the gear used in this test.

TABLE VI
SPECIFICATION OF GEAR

Gear	**Specification of gear**		
	Teeth	***Diameter***	***Total Use***
1	50	2.5 cm	1
2	22	1 cm	1
3	35	2 cm	8
4	9	0.5 cm	2

iii. Implementation of DC generator at real Spring Powered Generator

Fig. 12.Implementation of DC generator at Spring Powered Generator

This test is to analyze the DC generator performance and gearing system when applied in the system. Three of DC generators have been tested with single gear and multiple gear in this test. 5 compounds of gear constructed in multiple gear system and one gear at single gear test. Figure 12 shows the place of DC generator with multiple gear (gearing system) have been placed in the system. The gear rack is placed stick together with the gear at DC generator. When the gear rack moves down when get the force of the spring, gear will be rotated and then produce the power output.

iv. Data collections

The fourth phase is data collections. The data have been taken through the current sensor with multimeter. A current sensor with a multimeter function for measure the output power produced from DC generator. While, tachometer function to measure the rotation speed of gear at the shaft of DC motor. Current sensor used in this study is ACS712. This sensor was measured the current up to 5A with 66 to 185mV/A output sensitivity. The sensor has 3 pins, Vcc,Vout and GND. This sensor requires 5V supply, so the Vcc pin is connected to 5V Arduino and GND pin connected to GND Arduino. Vout of the sensor is connected to the analog pin of Arduino to read the bit. Some formula is used to convert the bits from the sensor to an Ampere [5]. Below is the formula used to convert the bits to ampere.

$$A = (0.0049 * X - 2.5) / 0.185 \quad (2)$$

The current reading while show in the serial monitor of Arduino.

III. RESULTS AND DISCUSSION

The overall system of Spring Powered generator has been designed. Figure 13 shows the image of a prototype of the system.

Fig. 13.Spring Powered Generator prototype

The figure 13 shows that the prototype of Spring Powered Generator. Overall of the system has been designed for development of the model structure for the development of the controlling system. The result of this analysis is from the data have been collected in experimental work and the data from the implementation of DC generator at Spring Powered Generator system.

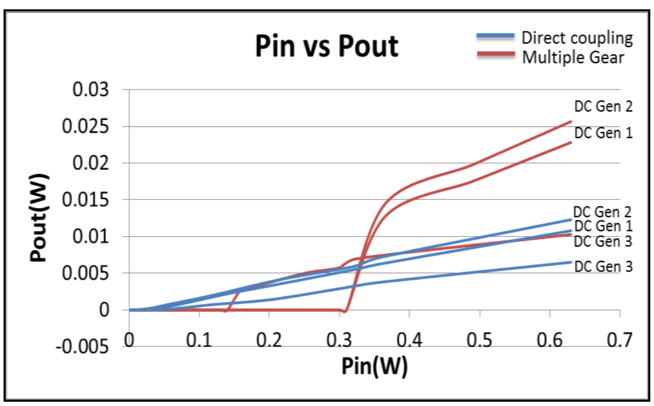

Fig. 14.Power input vs Power output of Direct coupling test and Multiple gear test

The figure 14 shows that Power input vs Power output of Direct coupling test and Multiple gear test. Based on the graph above shows that DC generator 2 with multiple gear produces the highest output, 25.6mW at Pin=0.63W and DC generator 2 with direct coupling produce the highest output, 12.3mW at Pin=0.63W. It shows that the comparison between Direct coupling test and Multiple gear test. The multiple gear of gearing system can increase the power output by 2 times compared with direct coupling. By applying multiple gear, the input power is high compared to direct coupling. From the tests, it shows that, DC generator 2 have the highest performance based on power output compare with DC generator 1 and DC generator 3 and gearing system multiple gear will increase the power output.

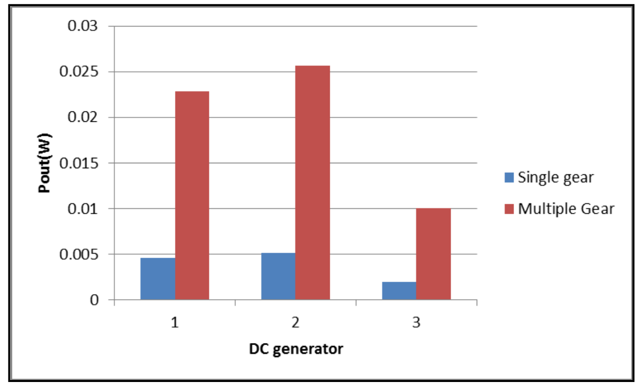

Fig. 15.Power output of implementation of DC generator with single and multiple gear implementation

The figure 15 shows the output of the three DC generator with single gear and with multiple gear implement at Spring Powered Generator system. Based on the bar graph, DC generator 2 with multiple gear produce the highest value of power output, 26mW compare with another DC generator. The output power produced by using single gear is lower than output power using multiple gear. It is because DC generator with single gear have less speed. Single gearing is not suitable to use for Spring Powered Generator system, it is because the force of the spring produce in Spring Powered Generator is high and time on the gear rack moving to rotate the single gear is slow, so less rotation will be occur at single gear. While, DC generator with multiple gear of gearing system produces high output in Spring Powered Generator system because it have more gear to rotate, the spring force from the system is high, so the gear can start to rotate when get the high force from the spring, although the gear rack moving to rotate the gear is slow and it will produce higher output and it is most suitable for applying in the Spring Powered Generator system. From the testing and the implementation of DC generator of Spring Powered Generator system, DC generator 2 with the multiple gearing system is the best and most suitable of DC generator and gearing system to use in Spring Powered Generator system.

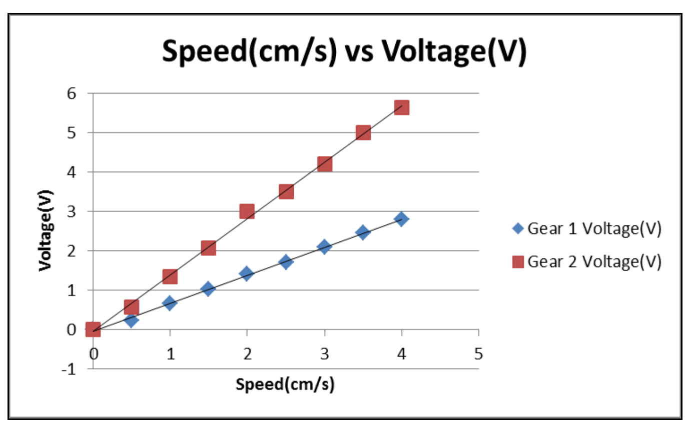

Fig. 16.Speed (cm/s) vs Voltage (V)

The figure 16 shows the relation between the speed (cm/s) with the voltage(V). In this project, two different sizes (diameter) of gear, small gear (gear 2) and big gear (gear 1) was tested to see the effect of the gear size (diameter) for the gear rotation speed and the voltage of the output.

From the figure 16, for this test, big size of gear (gear 1) produce the output voltage 0.23V with 0.5cm/s until the speed is 4cm/s with 2.8V output voltage had been obtained. For the small size of gear (gear 2), the output voltage 0.56V with 0.5cm/s until the speed is 4cm/s with 5.64V output voltage had been obtained.

From this test, it can be concluded that the smaller size of gear (gear 2) with less diameter produce more output voltage from the DC generator with the same speed of gear moving. For this project, the time of releasing the spring power is very crucial in order to produce sufficient energy to generate power. To enable this, the spring needs to release the stored energy slowly. In other words, it needs to have a longer length of time to release its energy. So, from the experimental result, the smaller size of gear (gear 2) produced longer time to release the stored energy of the spring. As a conclusion, the smaller size of gear (gear 2) is suitable to be to use for generating the output voltage from the DC generator.

This system has the efficiency for about 15% , and it depends fully on the power stored in the spring. The more vehicles pass by the system, the higher effciency it will be. Eventhough, the efficiency percentage is still small compared to the existing power generation system such as solar energy system and wind energy system, this system possess lots of advantages such as free anergy, no pollution and also low cost. For solar cell and wind turbine, it depands 100 % from the sun and also the wind. The efficiency will be low if these energy sources is low, for example during a cloudy day or when there is no strong wind blowing. For this smart spring power generator, it can generate power 24 hours because it depends on the road users. Lastly, based on the development cost of the system, smart spring powered generator is less expensive because it is a self poweres system. While, solar energy system and wind energy are more expensive. Solar energy system is more expensive based on the solar module, battery charger price and etc. For the wind energy system, it is also more expensive because the wind turbine development needed high cost.

IV. CONCLUSION

In conclusion, this project will present a model that produces electricity by using multiple springs installed under the road through the users vehicle's weight as the pressure to stretch the springs. This project, will help to fulfill the demand of generating electricity through renewable energy at low cost and reduce the pollution. From the designed model, the important point is that, to produce more power from the output, the system is depending on the speed of the shaft on the DC generator rotating. If the shaft of the DC generator can be rotated in higher speed, the output power from this system will be increased. For now, the application that can used from this project prototype are turn ON the LED lamp.

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Mohd Syahir Bin Abdul Rahman was born in Kampung Tengkawang, Kuala Berang, Terengganu, in 1991. He received Diploma in Electrical Engineering (Electronics) from Universiti Teknologi MARA (UiTM), Terengganu, in 2012 and the Bachelor (Hons) in Electronic Engineering from Universiti Teknologi MARA (UiTM), Shah Alam, in 2015.

From July to September 2014, he was a trainee at The New Straits Times Press (NSTP) Ajil, Terengganu. His research interests include the analysis of DC generator for renewable energy application such as Smart Spring Powered Generator.

Mr. Mohd Syahir and his group was the second place winner in Innovate Malaysia Design Competition (IMDC) 2015 under National Instruments Track. The title of the project is Smart Spring Powered Generator.

Mohamad Annas Bin Lop was born in typical village, Kerteh 3 Terengganu, in 1991. He actually has a background in electrical engineering in electronic since in primary school. He also loves gadgets and IT. From that he wants to further study in electrical (electronic) because want deep learning in that major. He received the D.S. and B.S. diploma in electrical engineering Hons electronics from the University of Technology Mara at Dungun branch in 2012 and degrees in electrical engineering electronic from the same university at Shah Alam branch in 2015.

From July to September 2014, he was done industry training at JKR Besut, Terengganu. He wants to increase his knowledge and experience in industry level. Then his research interests include the analysis of hydraulic system and spring force for creating a new renewable energy source for sources energy in Malaysia.

The highest achievement of his wins second place in the IMDC 2015 competition under track National Instrument.

Mohamed Farid bin Abdul Samad was born on August 16, 1991 in Tanjung Karang, Selangor. Currently pursuing a bachelor's in electrical, electronics engineering at Faculty Electrical Engineering, Universiti Teknologi Mara Shah Alam (UiTM). Was the second of five siblings. He graduated from the diploma in 2012 in the field of electronic engineering as well.

He was done industry training at Smart Meters Technologies, Selangor. His passion for the field of new technologies has led him to create a new electricity without causing environmental pollution.

The highest ever achieved was to win the second place in Innovate Malaysia Design Competition (IMDC 2015) in National Instrument track. The title of the project is Smart Spring Powered Generator.

Zulfakri Mohamad received his PhD in Nano-Material Systems Engineering from Gunma University, Japan, in 2007. His dissertation was on MFM, SNOM and magnetic patterned media.

He is a lecturer in University Technology MARA, Malaysia and has been teaching for five years. His major subject is Circuit Analysis. He has the experienced researching on biosensor, humidity sensor, solar cell, magnetic data storage and nanodevices.

Rosalena Irma Alip received both her Bachelor degree in Electronics Engineering and Master degree in Nano-material System Engineering from Gunma University. Currently, she is a second year PhD student at the same university. She has experience working in various fields such as biosensors, humidity sensors, solar cells and non-volatile memory. She is also a lecturer at University Technology MARA, Malaysia. She has been teaching Circuit Analysis for undergraduate students for almost two years. She is also a member of Nano-Electronics Centre at the Graduate School of Electrical Engineering in University of Technology MARA, Malaysia.