Experimental Design Electromechanical Machine to Produce Electricity by Vertical Dynamic Load

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Abstract- *In This Paper is designed electromechanical machine and running down the industrial bump untapp..ed so kinetic energy of the vehicle as it passes on the bump, this mechanism working principle of vertical movement of the descent of bump shift about 12 cm certified so the springs and gears group (rack and pinion gear), which kills it for circulation (Large Sprocket), which in turn will rotate (Small Sprocket) with a chain and then rotating the Dynamo and will in turn charges the battery. Practical experiments have been an achieved on the mechanism in the road, used vehicle is kind SAIBA success of mechanism has been proved in bearing the load also good performance; It also features power generation when moving down and reversing movement to the top.*

Keywords- *Electromechanical Machine, energy generation, vehicle kinetic energy.*

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1. Introduction

The problem of power generation continues to supply cleaner and cheaper than conventional energy resources. Turn to sort the energy crisis led to the idea of power generation using wave speed. He was the first to benefit from the state of South Africa, its own electrical crisis has made to implement this method to light up a small village from the highway, and the basic idea is to convert the kinetic energy of the vehicle movement into electrical energy [1]. Santosh, et al. [2] presented that the electro-kinetic power generator is a process of electricity generation through tapping the kinetic energy of automobiles, which drives over the track. The track works by means of a list of specially designed rollers sited on it. When the vehicles pass on the rollers, pressure is applied on them, which leads to develop the mechanical energy and the generator is driven by virtue of specially designed mechanism, which is able to produce AC/DC current. Ramakrishna and Ethira [3] showed how to keep the energy has been wasted when vehicles passes over a speed breaker by using the speed breaker as power generating unit. This mechanical energy will be converted to electrical energy by using generator this energy will be saved with use of battery. Olugboji et al. [4] generated the electricity by the mechanism of speed breaker here the generator is permanent magnet D.C. generator. The voltage of generator is 12 Volt D.C. and a lead to 12-volt battery used for storage the D.C. voltage. The main objective for this work is electricity generation from vehicles move on the road and by using speed breaker mechanism in vehicles road this lead to operate an integrated system which its works based on the applied load (weight of the vehicles) that is rotated this accelerates the perpendicular motion and transfers it to rotational motion and at the end this leads to charge the batteries which can be used later.

2. Design Considerations of Speed Breaker Mechanism

I. Speed Bumps and Upp..er/ Down Bases

Time to accelerate the bump to return to the first situation location, to be calculated from Equation (1), [2]:

$$f_n = \sqrt{\frac{k}{(m_b + m_e)}} \qquad (1)$$

The time between the center of the wheels is the front and the destination of the moving vehicle passes is (Tv) in (sec.), then

$$\frac{1}{4.f_n} \leq \frac{1}{f_v} = T_v \qquad (2)$$

Substitute Equation (1) into (2)

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$$k \geq \frac{(m_b + m_e)}{T_v^2 .16} \qquad (3)$$

Where; f_n is natural frequency of speed bump (Hz), m_b is mass of speed bump (kg), me is equivalent mass of energy harvester (kg).
The time (T_v), estimating the distance between two axes and speed. Speed bump base are carrying the load of the external force to enter. Tensile strength of mild steel is 407 MPa, [5] and [6].
Allowable Stress ($\sigma_{all.}$);

$$\sigma_{all.} = \frac{yield\ stress\ (\sigma_y)}{Factor\ of\ saftey\ (F.o.S)} \qquad (4)$$

$$\sigma_{allowable} = \frac{Maximum\ load\ (F_{max})}{Base\ area\ \ A_b} \qquad (5)$$

The surface area for upper base of speed bump and lower base of speed breaker mechanism is 490 mm × 270 mm, therefore, the allowable maximum load that equal,
$F_{max} = \sigma_{all} \times A_b$
Supports bump at both ends by the springs, leading to reactions R_A and R_B, and due to the applied load (F_{max}). As shown in Figure 1.

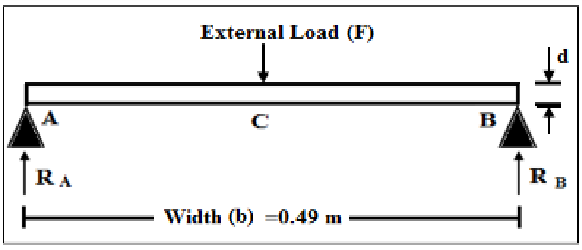


Figure 1: Schematic diagram of the bump base under load.

Using the simple bending theory of beam.

$$\frac{M_c}{I_{xx}} = \frac{\sigma_{all}}{y} \qquad (6)$$

$$I_{xx} = \frac{b.d^3}{12} \qquad (7)$$

and $\quad y = \frac{d}{2}$

$$M_c = \frac{F.b}{4} \qquad (8)$$

Substituting for y and I_{xx} in Equation (6)

$$\frac{12.M_c}{b.d^3} = \frac{2.\sigma_{all}}{d}$$

$$d = \sqrt[2]{\frac{6.M_c}{b.\sigma_{all}}} \qquad (9)$$

Where: b is width (m), d is equal minimum thickness of bump base material (m), I_{xx} is the second moment of area (m^4) and M is bending moment (N.m), see Figures 2 and 3.

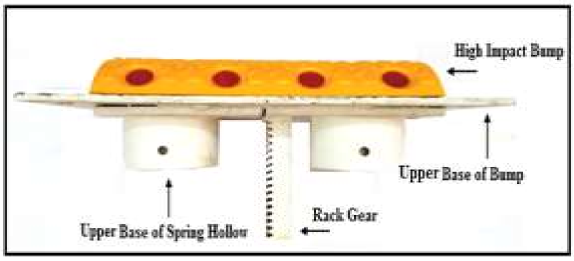


Figure 2: The speed bump with upp..er base.

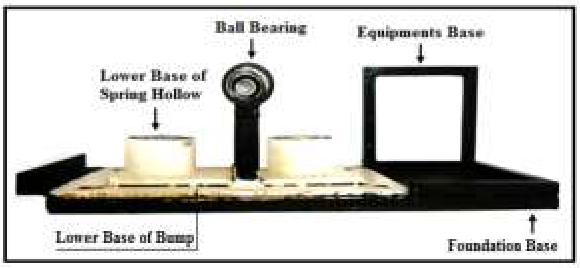


Figure 3: Foundation base with lower base of bump.

II. Helical Spring

Spring is defining as an elastic body whose function is to distort when loaded and to recover its original shape when the load is removed. The dimensions of helical spring (high carbon steel material) used in this paper, length is 32 cm,10 turns, outer diameter is 10cm and wire diameter is 0.8cm, as shown in Figure 4, [7]. Most linear springs and are subject to the law of the hook:

$$\boldsymbol{F = \delta.K} \qquad (10)$$

Where; **F** reactive power, **K** is a constant spring and **δ** is displacement

III. Rack and Pinion Gear

Rack and pinion gear of the transmission system consisting of two as shown in Figure 5. Gear normal helical pinion gear and helical gear rectum is the shelf, [8].

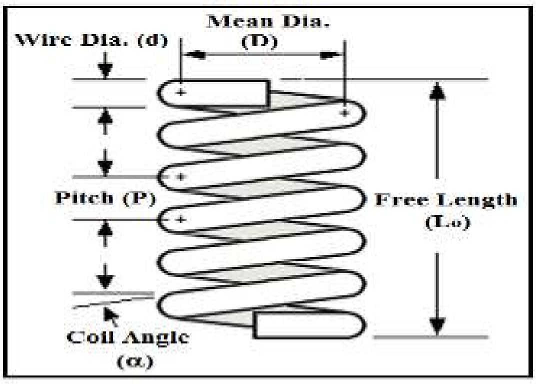


Figure 4: Helical Spring, [7].

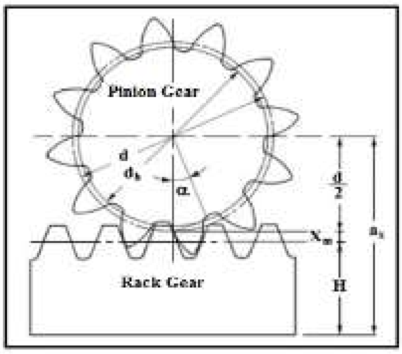


Figure 5: Meshing of Profile Shift Rack and Pinion, [8]

Now for determining the tangential force can be used these formulas, [10]

$$a = \frac{V}{t_b} \qquad (m/s^2)$$

$$F_u = \frac{m.g + m.a}{1000} \quad (kN) \quad (for\ lifting\ axle)$$

$$F_u = \frac{m.g.\mu + m.a}{1000} \quad (kN) \quad (for\ driving\ axle)$$

$$F_{u\ perm} = \frac{F_{u\ Tab}}{K_A.S_B.f_n.L_{KH\beta}} \quad (kN) \quad (11)$$

The Condition $F_u < F_{u\ perm.}$ must be fulfilled, [8].

Where: $L_{KH\beta}$ = Linear Load Distribution Factor, S_B= Safety Coefficient, m= Mass to be Moved (kg), v= Speed (m/s), t_b= Acceleration Time (sec.), g=Acceleration Due to Gravity (m/s^2), μ= Coefficient of Friction, K_A= Load Factor, f_n =Life-Time Factor.

IV. Sprockets and Chain

Used mostly chains of transmission and power from one shaft to another. When the distance between the centers of their shafts be short, such as machinery and equipment. Used chains to speeds of up to 20 m / s and the power of 95 kW, as shown in Figure 6, [10].

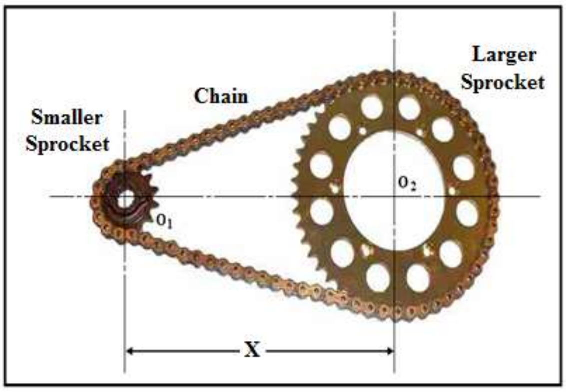


Figure 6: Sprockets and chain, [10]

a) Velocity ratio of chain drives

The velocity ratio of chain drive is given by:

$$Velociy\ Ratio\ (V.R) = \frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (12)$$

The average velocity of the chain is given by:

$$v = \frac{\pi.D.N}{60} = \frac{T.p.N}{60} \quad (13)$$

where; N_1 and N_2 speed of rotation smaller and larger sprocket respectively(r.p.m) and T_1 and T_2 Number of teeth on the smaller and larger sprocket respectively

b) Length of Chain and Centre Distance

The system shows the open chain connecting the two sprockets as clear in Figure 6. The chain length (L) equal to the product of a number of chain links (K) and the pitch of the series (P). Mathematically

L=K.P (14)

$$K = \frac{T_1 + T_2}{2} + \frac{2.x}{p} + \left[\frac{T_2 - T_1}{2.\pi}\right]^2 . \frac{p}{x} \quad (15)$$

The distance is given by [9]:

$$x = \frac{p}{4}\left[K - \frac{T_1 - T_2}{2} + \sqrt{\left(K - \frac{T_1 + T_2}{2}\right)^2 - 8\left(\frac{T_2 - T_1}{2.\pi}\right)^2}\right] \quad (16)$$

In order to accommodate the first sag in the chain, should the value of the distance down the center were obtained from the above Equation by (2-5 mm).

V. Guides

Four dampers of SAIBA car, placed in the corners linking the upper base and lower base for balancing the rise and descent of the springs when the passage of vehicles over the bump, as shown in Figure 7.

VI. Flywheel

This element was used in this work, as is evident Figure 8 the following reasons limit the momentum side and thereby reducing the rotational speed fluctuations in the system and makes axle spins quickly stable. Factory mainly of cast iron with a mass is about 7 kg, to limit the shaft in a vertical direction.

Figure 7: The Guide of SAIBA car

Figure 8: Flywheel use in this work

3. Electrical Parts Properties of the Speed Breaker

I. Dynamo

This dynamo specification is 12 V, Dc type, 30 amp, No of pair 16 and No of coil 2.

II. Rechargeable Battery

In this work the use of Aswar with battery type 12V-7AH.

III. Inverter Circuit

The Components required for DC to AC Inverter as follow:

-IC CD4047
-Resistors (1KΩ, 50Ω)
-Capacitor (0.047µF)
-12V rechargeable battery
-IRF3205MOSFET x 2
-Step down transformer (220 V, 50 Hz primary 12V-0-12Vsecondary) (Transformer connection inverted).

4. Harvested Electrical Power

Movement of speed bump cover drives up and down movement of rack and pinion that drive the rotation shaft of the generator. Voltage (U), produced by generators that commensurate with the rotational speed of the generator, which can be described as follows:

$$U=k_g.\omega \quad (17)$$

Where; ω is rotational velocity of generator (rad/sec) and K_g is voltage constant. Which can be calculated on the basis of the speed rack, which is the same speed bump cap speed [11].

$$\omega = \frac{n.\dot{x}_b}{r} \quad (18)$$

Where: n is the gear ratio, r is the radius of the pinion gear and x_{bis} the speed, [7].

$$U = k_g \frac{n.\dot{x}_b}{r} \quad (19)$$

When you connect the R_e external electrical load to the output of the generator, will produce an electric current in a close circle with the internal resistance of the generator R_i and resist non internal load of R_e, then energy production as follows,[12]:

$$P = \frac{U^2}{(R_i + R_e)} = \frac{k_g^2.n^2.\dot{x}_b^2}{(r^2(R_i + R_e))} \quad (20)$$

5. Speed Breaker Mechanism Construction

This work harvests energy from speed breaker mechanism by making gear arrangement and using electronic equipment. Large amounts of electricity can be generated when vehicle is in motion it produces various forms of energy like due to friction between vehicle wheel and road surface. The materials and equipment, which are used in constructing the speed breaker mechanism and the work principle, were explained in this section as shown in Figure 9. The design of speed breaker mechanism in this work consist of two lines of electricity generation which are right and left sides of mechanism, the right side generates electricity when the bump moves downward and the left side generates electricity when the bump moves upward.

6. Results and Discussion

I. The Time Effect between the Front and Rear Axles of Vehicle Wheels

To estimate the value of (fn) by used Equations (1) ,(2) and (3) as shown in Table 1 shows the time interval between the front and rear axles wheel (Tv) of vehicle is about 2.415 m, will be less whenever the wheels speed is increased and the distance between the front and rear wheels. Nevertheless, this time will effect majorly on the value of spring stiffness of the system as well as the natural frequency of speed bump will more a significantly.

(a)- Front View (b)-Back View

Figure 9: Speed breaker mechanism

Table 1: Show the time between the front and rear axles of vehicle model is SABIA passing through the speed bump is (t_v) for difference speeds vehicle

Speeds Vehicle		Time Between The Front and Rear Axles (T_v) in sec.	Spring Stiffness (k)	Natural Frequency of Speed Bump
Km/hr	m/sec.		$k=\frac{(m_b+m_e)}{T_v^2 .16}$	$f_n=\sqrt{\frac{k}{(m_b+m_e)}}$
30	8.333	0.2899	47.990	0.8625
40	11.111	0.2174	85.2272	1.1495
50	13.888	0.1739	133.4850	1.4385
60	16.666	0.1449	192,8827	1.7292
70	19.444	0.1242	229.0482	1.8844
80	22.222	0.1087	341.6313	2.3014
90	25	0.0966	433.4677	2.5923
100	27.777	0.0869	537.500	2.8867

II. Upper/ Down Bases of the Mechanism

The tensile strength of mild steel is 407 MPa. Yield Stress of Mild Steel, σ_{Yield}=210MPa. For determinate the value of allowable stress (σ_{all}) and max allowable load (F_{max}) from Equations (4) and (5), but take the value factor of safety (F.O.S) is 2.

$$\sigma_{all}=105 \text{ MPa}, \quad (F_{max})_{all.}=9.261 \times 10^6 \text{ N}$$

Now assume the maximum load can be supported on the bump is about 1000 kg.
Maximum weight =1000 x 9.81 =9810 N
Working stress

$$(\sigma_{work.}) = \frac{9810}{0.27 \ x \ 0.49} = 74149.659 \ N/m^2$$

By using Equations (10) and (11) can be estimated the value of thickness of the upper and down base.

$$M_C = \frac{F.b}{4} = \frac{9810 \quad x \ 0.49}{4} = 1201.725 \ N.m$$

$$d = \sqrt{\frac{6x \ M_C}{b \ x \ \sigma_{all}}} = \sqrt{\frac{6 \ x \ 1201.725}{0.49 \ x \ 105 \ x \ 10^6}}$$

$$= \sqrt{0.0001}$$

d=0.01 m (Minimum thickness of the bump base material). The mass of upper base when the thickness (0.01 m) is about 78.5 kg/m^2, Now the mass (m_{base}) is about=78.5 x 0.49 x 0.27=10.3856 kg.

III. The Practical Test for Speed Breaker Mechanism

Steps of the test as follow:

a)- After that the mechanism was placed in the hole so that the electromechanical bump rise by (15cm) above the ground level, thus ensuring that we maintain ascended bump more than the limit set (15cm), no matter what the weight of the vehicle. The difficulty of implementing practical test on Asphalt Street. The hole was made and localized in a muddy ground, were placed on the top of the hole and attached to the upper part of the Speed Breaker Mechanism that allow the wheels of the vehicle passing over it easily as shown in Figures 10 and 11.

b)- The total mass of the vehicle that was used in the test is 1300*kg*, this means quarter of the mass passing over the bump, the effect of this mass caused the descent of the springs about 12*cm*, which led to the movement of the rack gear down , thus we obtained the following rotations: in the large sprocket about 386*rpm and* the dynamo by chain at rate 1090*rpm*.

c)-The battery charges will be continuously because the two sides (right and left) of speed breaker mechanism will generate electricity as shown in Figurers 12, 13 and 14.

Figure 10: Before passage of the front wheel over the speed breaker mechanism

Figure 11: Passage of front wheel over the speed breaker mechanism

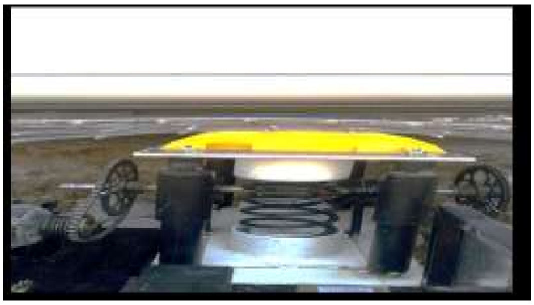


Figure 12: After passage of the front wheel over the speed breaker mechanism

Figure 13: During passage of the back wheel over the speed breaker mechanism.

Figure 14: After Passage of the Back Wheel over the Speed Breaker Mechanism

IV. Output Power of Speed Breaker Mechanism

a) Output Power Calculation

-The mass of vehicle moving over the speed breaker = 1350 *kg* (using mass for one wheel equal to 337.5*kg*).

-Maximum of speed breaker distance from the weight of the vehicle =15*cm*.

-Descent of speed breaker distance from the weight of the vehicle =12*cm*.

-Work done = force x distance

Here,

Force = weight of one wheel of the vehicle weight of one wheel of the vehicle = mass of one wheel x *g*

where ***g*** : ground acceleration in m/s^2

Force = 3310.875*Newton*

Work done = 3310.875 x0.12 = 397.305*j*

Output power = Work done / Time in second

= 397.305/ 60

= 6.62175 W for one stroke.

Power developed for one wheel of vehicle passing over the speed breaker arrangement for one minute= 6.62175W .

Power developed for 60 minutes (1 hr.) = 397.305W.

Power developed for (24 hr.) = 397.305 Wx *24* = 9.535 kW.

Torque produce in one push:

the generation power for one stroke is about= 6.62175 W

$$T = (P * 60)/2\pi N_1$$

$$= (6.62175 * 60)/(2 * \pi * 932.4)$$

T = 0.0678 N.m (for one stroke)

b). Output Power Developed For one Vehicle Passing over the Speed

-In this work, have two power strokes one in down and another in up.

- Breaker arrangement for one minute = 2 x 6.62175 =13.2435 W
- Power developed for 60 minutes (1 hr) = 13.2435 x 60=794.16 W
- Power developed for 24 hours = 794.16x24=19.07 kW
- Power developed for one month = 19.07 x 30 = 572.119 kW.
- Power developed for one year = 572.119 x 12 = 6865.43 kW.

c).Actual Calculation

-Generated output voltage in one pushing force (one stroke) of speed breaker = 11.8 v.

- Current in the circuit in one pushing force of speed breaker = 0.48 A.

As per ohm's law

-Power developed for one push= V x I = 11.8x 0.48 = 5.664 W

Power developed for one hour = 60 x5.664 = 339.84 W

Power developed for one day = 24 x339.84 = 8.15616 kW

Power developed for one month = 30 x8.15616 = 244.6848 kW

Power developed for one year = 12 x 244.6848 = 2936.2176 kW

7. Construction of Real Simulation Test

A real simulation had been done for mechanical requirement and scientific calculation by using AC motor with properties (220 volt, 50 hertz, 380 watt, 2850 rpm) for shaft rotation and is connected to the same mechanical bump dynamo by chain and the motor connected electrically to auto variable transformer that changes the motor speed, that points to speed changes in shaft rotation as well as the motor connected to a control circle contains 4 signal lights (LEDs):the 1st light points the repeating passage of vehicles, the 2nd light points to the passing time the front wheel of vehicle, the 3rd light points to the time distance between the front wheel and the rear wheel and the 4th light points the passing time the rear wheel of vehicle, as shown in Figure 15.

Figure15: Real Simulation Mechanism

It can control separating time between two vehicles and between the front and rear wheels and the distance between the two wheels (axial distance) by changing the resistance value that connected with each light. After that a generator connected to load (Rechargeable battery 12 volt, 7 amp hour) and we recorded the changes that appeared on results and readings as well as made a calculation for direct continuous load (DC loads), time of battery charge then connected to inverter circuit, this circuit convert DC voltage to an AC voltage (12DC Volt, 220 AC Volt, 50 hertz) so connected to alternative load and recorded readings such as load current and load resistance.

I. Work Principle of Control Circuit

Control circuit was designed to show us the repeating time between passing vehicles in street as well as speed of the vehicle found by knowing the time of the distance between the front and rear wheels of each vehicle also showed us the speed of front and rear wheels and the time of survival on the speed breaker and all this through four signal lamps, the first lamp indicates repetition between the vehicle and the next, the second lamp refers to the duration of the front wheel on the speed breaker, The third lamp refers to the speed vehicle time that indicates to the distance between the front and rear wheels and finally the fourth lamp refers to time of the rear wheel stay on the speed breaker, see Figure 16 .

Regular when conducting experiments the value of current drawn will change between the minimum and the maximum value for the instantaneous current, was the current values that were measured are 0.1 and 0.4 mA, depending on the amount of battery charge and will be seen clearly through the practical results that have been proved by the Oscilloscope signals which pointed to the growing electric charging process.

Connect the electrical load on the system effect directly on the amount of charging and this is a clear through the form the Oscilloscope signal which showing change the amount of charging, we note when the battery is displayed to high load and during the few passing vehicles that will lead to consumption the charging of battery. Installed vehicle speed time with resistance No. (3), to make the confined space between the front and rear wheel fixed note that the distance is 2.415 meters. Changed repetition time what is meant the time of passage of the vehicle and the next on the bump any the less time the number of vehicles passing through and it will be a time for battery charging less and vice versa. It was installed resistance No. (3) with value 10 kΩ, install vehicle movement time (the time it takes to movement the vehicle to the confined a distance between the front and rear wheel) calculated through law is below 1.1 sec.

$\tau=1.1xRxC$

$\tau=1.1x10x10^{3}x100x10^{-6}$

$\tau=1.1$ sec. (Theoretically)

$\tau=1.5$ sec. (Practically)

II. Analyzing the Results of the Real Simulation

To make sure that the charging process is occurring properly and accurately has been seen through the sensor (DC lamp 12 volt, 21 watts) connecting in series between the ends of the dynamo and battery as shown in Figure 17 has been linked to Oscilloscope device in parallel with the sensor terminals to observe the form of current signals.

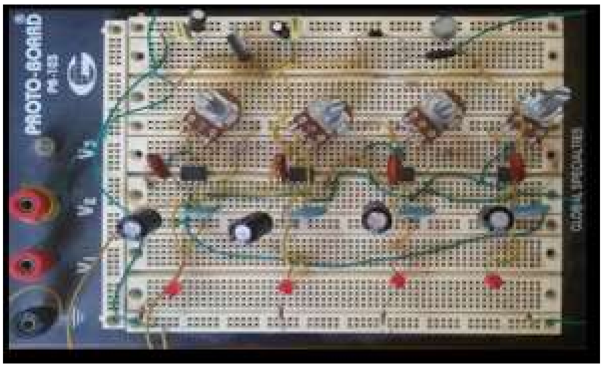


Figure 16: Control Circuit

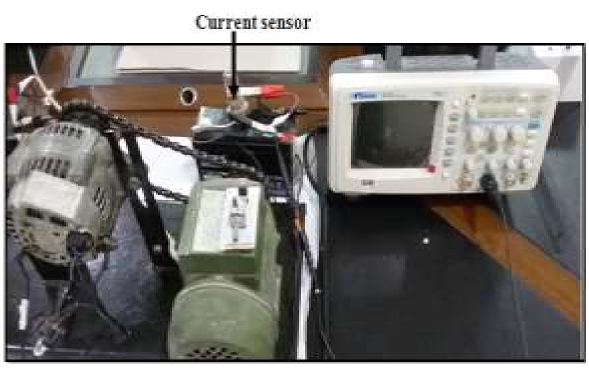
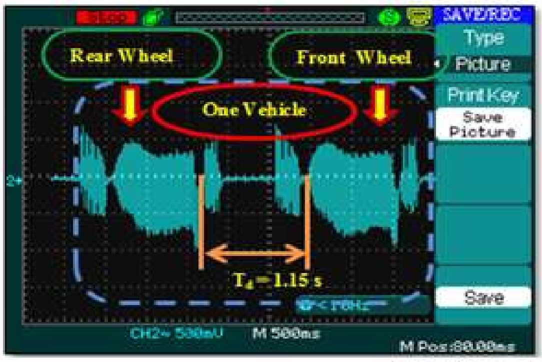


Figure 17: Shows the sensor between the dynamo and battery

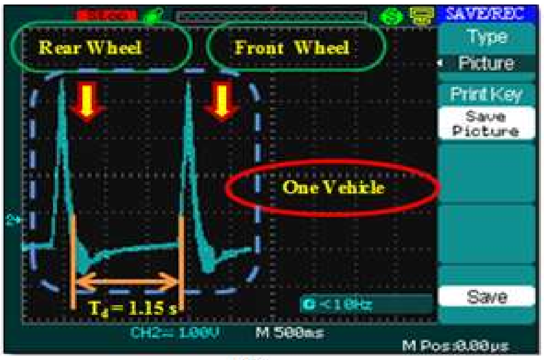
Figures 18 illustrate the current signal to the time of vehicle passes over bump the value of time 1.15 sec (T_d) which indicates to the time of distance traveled between the front and rear wheels of the vehicle which is a function of vehicle speed. Where the resistance No.1 with value15 KΩ, which indicates to the time of repetition between the vehicle and the next. Figure 18a shows the charging signal when the battery voltage 12 volt (fully charging) and the amount of voltage drop (1v) on the load and thus the value of the maximum current (1.125 A). Figure 18b shows the charging signal when the value of the voltage of the battery 7 v (Almost empty) and had maximum current (5.25 A), which is clear from the form of current drawn signal by the battery, where we note when the battery is low charge be the value of current drawn high and this is an indication to the response of system to enhance the value of charging faster through the high value of the current. Further notes in Figure 18a continue to apparent voltages and this is proof that the battery charge status and therefore be fully responsive longest in withdraw current. While in Figure 18b the value of current drawn a time of less and it was due to almost empty charging the battery and this shows that the time it takes to withdraw current from the dynamo any effort-generated consumption by dynamo a time to be very fast.

Figure 19 shows the time of repetition between the vehicle and the next is shown clearly by changing the range of Oscilloscope device 1 sec and the amount of repetition between the vehicle and the next time 2.1 sec (T_r), where this range allows the appearance of two vehicles and also note that the amount of charging has become twice as appeared in Figure 18a.

When increase the range of time measurement for Oscilloscope device to2.5 sec charging was during this period, double what came in the Figure 19, where this range shows the appearance of four vehicles, increase the amount of charging, as in Figure 20.



(a)



(b)

Figure 18: Shows the maximum voltage when (a) Full Charge, (b) Half Charge, for Battery.

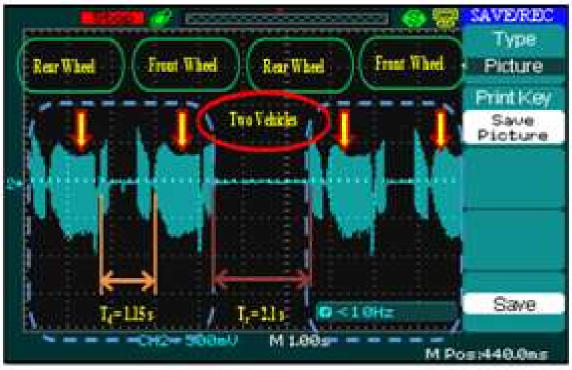


Figure 19: Shows the time of repetition between the vehicle and next

Figure 20: The amount of charging from four vehicles

8. Conclusions

The results showed the possibility of using the mechanism (system) proposed to raise the national grid through smart grid systems because of their high susceptibility to generate the electricity. Review the conclusions of cases of dynamic simulation process, as follows:

I- The results showed a high-speed system for vehicles with a response to maintain the generation of signals on a regular basis.

II- The results showed the possibility of adopting variable speed bump over from (2.1 - 0.05) sec. to ensure the generation of electrical signals effectively.

III- The change results showed high speed with heavy traffic possibility of a bump on the highway vehicles to serve as a generator to generate a continuous generation capacity is considered as a station allows the possibility to use applications high voltage consumption.

IV- Practical tests proved the possibility of the mechanism to compensate the losses made in the battery using intermittent traffic of vehicles in idle times of response, confirming the adoption of the mechanism in practice to compensate for losses caused by the interruption of the long passage.

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