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EXPERIMENTAL DEMONSTRATION OF ELECTRICAL POWER GENERATION USING STATIONARY EXERCISE BICYCLE COUPLED WITH WIND TURBINE REGULATOR

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ABSTRACT

The small power generation using exercise bicycle is one of the current areas patronized by researchers. This is due to the two major benefits obtainable from the exercise machine, the benefit of exercising one's body and the utilization of electrical power generated. Wind turbine regulator is specifically designed to regulate the output voltage of a wind turbine generator, which is characterized by varying speed and hence varying output power. The exercise bicycle driven alternator has a similarity with wind turbine generator in terms of variable speed, especially when ridden by different personalities. This paper demonstrates how small power can be generated using exercise bicycle. Further, the paper analyzes the performance of the by regulating its output using small wind turbine regulator. The result shows that, a regulated output within the range of 12V is obtained for all the tested loads, which makes the system more compatible with all types of 12V DC loads. Also the excitation voltage of the machine is improved from 4.5V (1.22A) using the diodes rectifier to 2.5V (0.81A) when the wind turbine regulator is used. With the improved power generation in this work the exercise bicycle will be a better alternative source for small power generation which can be used in DC lightings, DC fans, charging batteries and laboratory experiments.

Keywords: Stationary bicycle, automotive alternator, wind turbine regulator, voltage regulation, RPM

INTRODUCTION

The use of alternator in DC generation is replacing the use of conventional DC generators, this is because when an alternator is used in DC generation, the use of brush and commutators are eliminated. Brush and commutators in the conventional DC generator come with major challenges including losses and lower efficiency. However, with alternator as the generator, solid state devices can be used to facilitate the DC generation instead of the inefficient brush and commutators (Hashfi et al., 2018). Moreover, with the solid state devices, the output can be generated at lower revolution per minute (rpm) and with accurate voltage regulation. With such modifications, an automotive alternator can provide a wide range of DC supply for domestic purpose such as DC lightings, DC fans and battery charging at lower cost than the conventional generators (Yuri, 2012).

The stationary bicycle is a kind of fixed bicycle used in exercise, mostly for health improvement purposes, but when it is coupled to an appropriate electrical generator, it can convert the energy exhausted by the exerciser into a useful electrical energy especially in DC form. The exercise bicycle which is driven by individuals through cycling, is a low rpm machine, thus it is motivated that when it is coupled to an appropriate, designed and refurbished automotive alternator, a good and precise output is expected. There are many ways by which electricity can be generated, in small scale, which get less attention of the researchers, yet they can be near-future sources of energy with good potentials (Rashid & Joardder, 2022). The output of the automotive alternator driven by an exercise bicycle is varying due to the different efforts applied by different exercisers. This makes the generation from the exercise bicycle system to have similarities with wind turbine generator which varies significantly with variation in wind speed. The output voltage before rectification is the same three phase waveform, in both cases, which varies with different speed of the rotating source. Here it is also motivated that the use of a small wind turbine regulator as the rectifying system of the exercise bicycle system has the potential of providing a smooth and more accurate performance of the system. The main target of this research work is to determine the improvements possible when the ordinary diode rectifying system in the designed and fabricated exercise bicycle based electrical generation system is retrofitted with an appropriate wind turbine regulator.

The need for alternative, renewable and green energy is always manifesting throughout the world as the electricity demand is always increasing, most recently (Chen & Yang, 2023) developed a dynamic energy harvester on bicycle which is capable of generating power in very small quantity and facilitating way forward in the area. The use of gym machine in small electricity generation is as well another promising clean and sustainable source of energy and is an area of interest to researchers (Lubis & Cholish, 2019). Several research works have been carried out as regard to small electrical generation using car alternators, (Lubis & Cholish, 2019; Adibowo et al., 2020; Hashfi et al., 2018; Yuri, 2012; Whaley et al., 2004; Omprakash & Gottawala, 2022; Lubis & Cholish 2019) developed a DC generator using car alternator. They were able to obtain 14.56V output voltage at a speed of 1,100 rpm which is satisfactory in providing a useful output voltage but the generation is at relatively higher speed which could be difficult to obtain using low rpm systems like exercise bicycle. Adibowo et al., (2020) experimented the feasibility of using car alternator in pico hydro power plant. The power is generated by coupling the turbine with the automotive alternator and the generation was promising as the more the flow rate from the hydro system the higher the power output, but the power generated in the system is much lower than what can be utilized in most small DC appliances. Hashfi et al., (2018) investigated the possibility of converting an automotive alternator for low cost wind electricity generation, for small scale utilization. Through addition of a permanent magnet in the alternator core, the system was found to have very good potential in wind turbine generation even though it needs very high rpm to produce the rated output voltage.

On the other hands some researchers had proposed many methods of generating electricity using exercise bicycle (Paul et al., 2017; Mocanu et al., 2015; Yadav et al., 2018, Dmini, 2020; & Suhalka, et al., 2014). In their efforts to produce AC power supply, through pedaling of a stationary bicycle. Paul et al., 2017 developed an AC supply system driven by the bicycle, in which the generated DC supply is converted into AC using an inverter. The system could provide what can be described as almost 12V DC and 230V AC supply at low rpm from the bicycle site, though the power output of the system cannot be stated from the results of the analysis. Mocanu et al (2015) developed a system of generator powered by a bike. The system is found to be low cost, that uses existing component to be produced. However the efficiency of the system suffered limitations due to various loses in the system. Dmini (2020) developed a system of isolated AC power supply using pedal system, an all in one system of DC generator, batteries, converter and inverter system. It provides a very good system of alternative energy, even though the cost of the system is higher, compared to other exercise bicycle systems of generating electricity. Omprakash & Gottawala (2022) developed a gym cycle operated DC generator using a permanent magnet alternator. The system was able to deliver an average output of 67.5W, which is good enough to serve many lighting loads. However more proper analysis is needed to ascertain real performance of the system. The need for alternative power supply in Nigeria coupled with the availability of different potentials, make it necessary for the researchers to explore more ways of harnessing alternative energy sources.

To remedy some of the short comings above and derive more benefits, the combination of exercise bicycle and car alternator will constitute an efficient and effective energy conversion system, since it was established that the auto alternator can work very well with low rpm system (Hashfi et al., 2018). Moreover regarding the regulation of the output voltage from the system, the use of wind turbine regulator, instead of ordinary diode rectifiers, will improve the performance of the system since there are similarities between wind turbine and exercise bicycle in terms of speed variation. This will also solve the problem of having irregular voltage supply from the system. The research work in this paper is a pioneered system where the exercise bicycle is combined with a refurbished automotive alternator for better performance and it is the first of its kind where wind turbine regulator is used to regulate the output of the system. Also the utilization of the power in its DC form helps in higher efficient operation since the there is no need of inverter (Villanueva et al., 2021). The remaining parts of the paper are organized as follows: Section 2 gives the materials and method, section 3 gives the results and analysis while section 4 provides the conclusions of the work.

MATERIALS AND METHOD

Power generation using exercise bicycle is logical since the energy dissipated by the exerciser is normally wasted. The refurbished automotive alternator has a very good low rpm characteristic (Hashfi et al., 2018), which makes it suitable for small power generation using exercise bicycle. The wind turbine regulator to be incorporated will help in producing pure regulated output from the system.

The Exercise Bicycle

The exercise bicycle is made from a medium size sport bicycle which has been converted to stationary bicycle by removing the fore wheel and being placed on a rectangular frame (Abubakar, 2012). The rotor of the alternator is connected to the rear wheel of the bicycle through a V belt that makes a speed ratio of 10 when the geometry is analyzed as illustrated in Figure 1.

Figure 1: Stationary bicycle system

The Alternator

The alternator is a refurbished car alternator in which the armature and field windings are redesigned to produce the desired output using the parameters from the stationary bicycle (Abubakar, 2012).

Armature Winding

The armature of the car alternator is a three phase type, which generate a three phase voltage supply that can be rectified using three phase rectifier. It has a total of 36 slots making 12 slots per phase. The standard induced EMF equation (Equation 1) per phase is used to determine the number of turns per slot of the armature.

$$E = \frac{4K_f K_p K_w NP\Phi N_1}{120} \ldots \qquad (1)$$

An American wire gauge (AWG) 16AWG was chosen to suite the 42V open circuit voltage for a system of 12V (Odendals, 1998) from which 18 coil side per slot where found. As shown in Figure 2, the armature is star connected to allow accessible neutral.

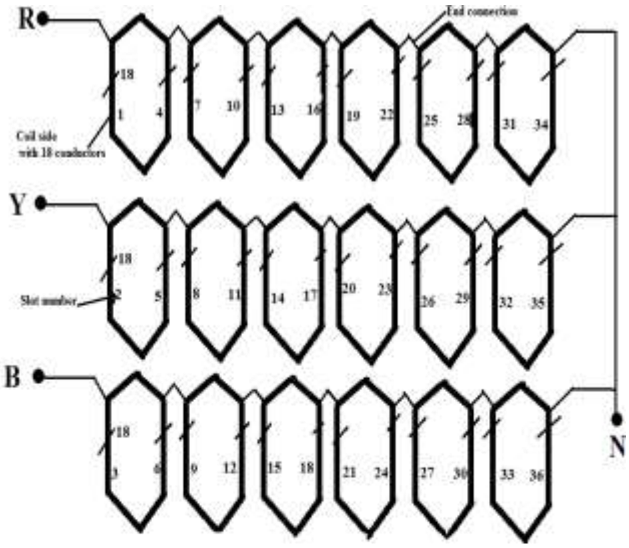

Figure 2: The armature structure, star connected with 36 slots and 18 coil side per slot

The Rotor/Field Winding

The field winding on the rotor of the alternator are responsible for providing a uniform and alternate N and S poles as shown in Figure 3, (Whaley, 2004). The total flux generated by N_2 turns of the field winding with the exciting current I through a core material of reluctance R is given in Equation 2. Therefore the magnetic flux can be set to any desired value by controlling the field current (Odendals, 1998).

$$\Phi = \frac{NI}{R} \quad \ldots \qquad (2)$$

The Wind Turbine Regulator

The wind turbine charge regulator module is a device normally found in small wind turbine generator system, which limits or control the battery charging (Chirapongsananurak, 2012).

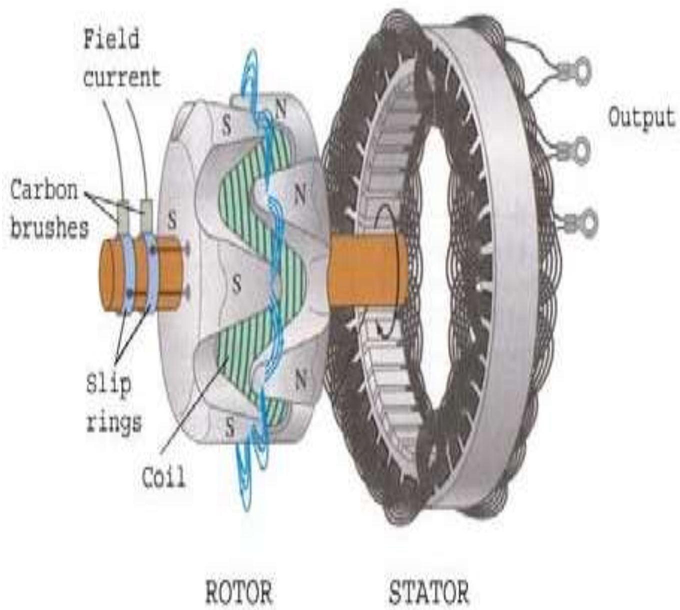

Figure 3: The rotor of the alternator

It is designed to work accurately with varying speed so that it prevents over charging as the results of higher wind speed, which has a cubic relationship with the generated power in the wind turbine system. A 12V, 300W wind turbine charge regulator (shown in Figure 4) is proposed for this work, because its capacity can work perfectly in this project and it is the smallest capacity available for small scale project like this. The fabricated stationary bicycle, refurbished automotive alternator and the wind turbine regulator in this work will facilitate the reuse of those components like old bicycles and old car alternator for other benefits. Figure 5 shows the block diagram of the generator system.

RESULTS AND DISCUSSION

The results of several tests are presented in this section. Open circuit characteristics of the system at different excitation where carried out, also the characteristics under load condition are experimented. Detailed analysis and discussions that point out the achievements in the research work are also provided.

Figure 4. The wind turbine charge regulator

Open Circuit Analysis

The per phase output voltage of the alternator at different excitation voltage is experimented and Tables 1 through 8 gives the output of the analysis at variable alternator speed. The expected average DC output is determined using the relationship of the three phase rectified voltage given by Equation 3.

$$V_{dc} = 2.34V_{rms(phase)} \quad \ldots \quad (3)$$

The Load Test

By analysis and observation the excitation voltage of 2.5V (Table 4) gives closest output voltage to the desired value of 42V (Odendal, 1998) at the average speed of 900 rpm of the machine (Abubakar, 2012). Therefore the excitation voltage of 2.5V at 0.81A exciting current is considered to be the right excitation for the system. Various loads are connected to the system for load analysis (Figure 6) and Table 9 gives the voltage output at various loads connected to the system, through various load combination. The load characteristic is also given in Figure 7.

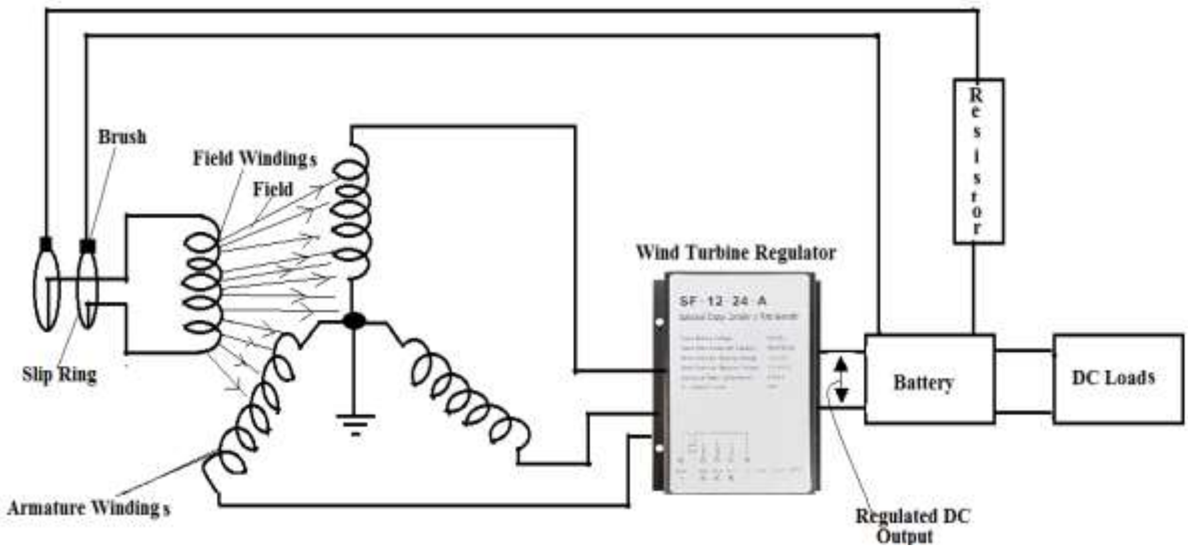

Figure 5: The generator system

Table 1: Excitation voltage of 1.0V and current of 0.35A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	3.35	7.84
2	400	4.61	10.79
3	600	8.04	18.81
4	900	10.38	24.29

Table 2: Excitation voltage of 1.5V and current of 0.50A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	7.30	17.74
2	400	10.14	23.73
3	600	11.73	27.45
4	900	9.88	23.12

Table 3: Excitation voltage of 2.0V and current of 0.67A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	9.04	21.16
2	400	11.29	26.42
3	600	11.60	27.14
4	900	9.65	22.58

Table 4: Excitation voltage of 2.50V and current of 0.81A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	11.54	27.00
2	400	12.26	28.69
3	600	19.71	46.12
4	900	18.39	43.03

Table 5: Excitation voltage of 3.0V and current of 1.01A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	11.96	27.99
2	400	11.12	26.02
3	600	22.24	52.04
4	900	19.66	46.00

Table 6: Excitation voltage of 3.0V and current of 1.15A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	11.05	25.86
2	400	17.96	42.03
3	600	22.23	52.02
4	900	11.13	26.04

Table 7: Excitation voltage of 4.0V and current of 1.31A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	11.07	25.90
2	400	22.30	52.18
3	600	10.25	23.98
4	900	10.26	24.01

Table 8: Excitation voltage of 4.5V and current of 1.46A

S/N	Speed (rpm)	Per phase rms voltage (V)	Expected Vdc (V)
1	200	10.93	25.58
2	400	21.32	49.89
3	600	11.55	27.03
4	900	11.26	26.35

Discussion of Results

The per phase open circuit characteristics shows that a field excitation of 2.5V corresponding to a field current of 0.81A gives the desired no load voltage of 43.03 to 46.1V at the speed of 600 to 900 rpm which corresponds to the desired open circuit voltage of 42V as suggested by Odendals E. J. (1998). Therefore the excitation of 2.5V (Table 4) is desirable since it agrees with the open circuit voltage of 42V at the average machine's speed of 900 rpm.

Some 12V, DC loads including DC fan, DC bulbs and DC security lightings are used to perform the load test in the system (Figure 6). The load characteristic in Table 9 shows that a regulated output is obtained within the range of 12V at different loads, which is good enough to run almost all 12V DC loads within the output range. Also the Load curve in Figure 7 resemble a typical Load curve of DC generator. From this it is established that a load of about 37W at 12V can be served by the system, Hence introducing the wind turbine charge regulator into the system makes it more suitable for 12 Volts loads. This is a great improvement on the work of Abubakar I. (2012), where most of the output voltage in the analysis are quite out of the range of 12V. This will surely improve the efficiency of the system

Figure 6: The Experimental Set up

Table 9: Load characteristic of the system

S/N	Load current (A)	Output voltage (V)
1	1.15	11.89
2	1.52	11.97
3	1.75	12.53
4	1.98	12.47
5	2.12	12.78
6	2.15	12.48
7	2.72	12.15
8	2.94	12.35
9	3.18	11.83
10	5.3	8.81

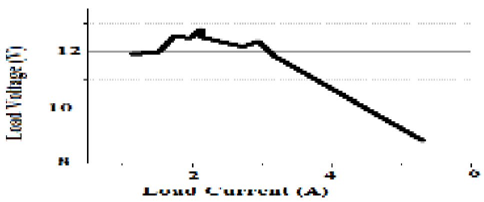

Figure 7: Load characteristic of the system

CONCLUSION

The performance of a DC generation through automotive alternator using stationary bicycle is analyzed using small wind turbine charge regulator for better performance. As the results of regulating the output power using the wind turbine regulator, a better regulated output voltage of 12V at about 37W is obtained. Moreover the excitation of the machine is also improved from 4.5V (1.22A) using the diodes rectifier to 2.5V (0.81A) using the wind turbine regulator. Also with the output voltage closer to 12V at all the tested loads, an enhanced operation of the system is obtained for 12V DC lightings, battery charging, fans and many more. The research work could be improved if multiple systems of the stationary bicycles are used, also integrating the system with another renewable energy sources can boost the output power.

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