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HUMAN POWERED DC MICRO GRID ELECTRIFICATION

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Abstract - *Finding new energy sources is an important challenge in the current generation. Presently research is being done to optimize the already existing sources of renewable energy, which are time consuming and requires a lot of investment. The other option available to us to find new and innovative techniques to find a new source of renewable energy. In this project we wish to utilize the motion of a bicycle to generate electricity and eventually simulate design where we can power a dc micro-grid. The idea came to being when we noticed that a major portion of the population of our country use bicycle as a means of transport, so we look forward in designing a system where the motion of the bicycle coupled with a generator can charge a battery pack. This accumulated charge can then be discharged into a micro grid. Currently energy generated by a person while cycling is utilized for the motion of the cycle and the rest is lost as heat and other mechanical losses. In this project we want to design a low cost and effective system where we can scavenge and utilize the energy.*

***Key Words*: Renewable Energy, Automotive, Power Electronics, Speed multiplication system, Li-ion Battery**

1. INTRODUCTION

In order to meet our energy demands we have increased our consumption of conventional energy resources that leads to release of harmful and toxic gases in atmosphere, thus completely disturbing our eco-system. This imbalance in the ecosystem we are living in has led to complete environmental degradation and leaves a disastrous effect on human health. The power demand across the world is increasing day by day which redirects us to new power generation and conservation techniques that can bridge the energy gap between power demand and generation. We particularly need to adopt power generation approaches that have less environmental impacts. In the field of power research, scientists are looking for alternate sources of energy. The human population is an ever increasing entity and if we are able to use this entity as an asset we can bridge the energy gap to some extent and make progress.

The current trend in the generation of new renewable energy has been a hurdle in our country. In this project we wish to develop a new system where we can generate clean energy from human exercise. In India a vast number of student and middle income people use a bicycle for their daily commute, we propose a system where through this bicycle motion we can generate electricity and utilize them to power up low powered dc loads. Using human energy as a source of power generation motivated us to design a system that traps the mechanical energy of pedaling cycle and convert it into electrical energy. Bicycle, is the main mode of transport and easily available in villages in developing country like India. This paper focuses on generation of electrical power using different types of generators, storage and its application.

This idea although prevalent for some time now has not been developed much further, the concept of generating energy using a bicycle which existed in our country was powered by the friction of the rear wheel with that of the shaft of a small dynamo which in turn powered a small bulb. This idea was developed further in other countries by making a static system; where the rear wheel is connected to a flywheel which is there by connected to a generator.

The main hurdle with such system is the speed multiplication i.e. increasing the speed such that optimum generator output can be achieved, this was previously achieved by attaching a fly wheel making it a static system. We decided to come up with a solution through our project such that the speed can be multiplied and the system can be dynamic i.e. the system can be mobile and the cycle can be used for daily chores of a person and this will be a simple add on which can generate and save the energy generated.

In the models which were prevalent in the market all either had no place to save the energy generated or used (in case of a static system) a lead acid battery bank. This being our second objective of distributing the energy requirement such that per bicycle the energy generated can be optimum and the we can select a cell chemistry which will have suitable energy density as well as small in size.

2. ANALYSIS OF THE PROPOSED DESIGN

The project that we are describing in this report is just a small part of a much bigger system. Our model is inspire from the concept of isolated or decentralized grid system. In a conventional electrical grid, it consists of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage at which it connects to the electric power transmission network.

The bulk power transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local electric power distribution network).

On arrival at a substation, the power will be stepped down from a transmission level voltage to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

The system we propose is a distributed system where every location has its own local grid and each grid is isolated from other grids, here the cycle is a key component. This system is applicable where people live in a cluster and they travel within that specified location. The user uses the cycle to commute from one point to another in the meantime generating energy and storing in the battery pack. On reaching the destination, the user plugs into the destination grid and discharging the generated energy. Another user can take that same cycle or a different one that is parked in the stand can travel to another destination where enroute can generate energy and on reaching the destination can plug into the destination grid through the stand which is the terminal and discharge the energy.

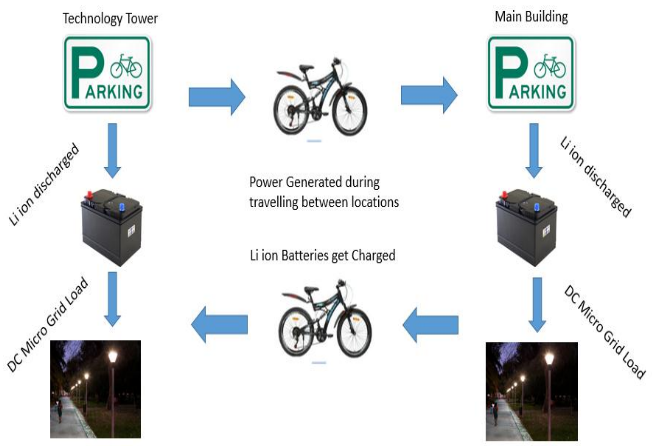

Fig.1 System Overview

The cycle we propose to build through this project is very much different from an average cycle or that of a conventional e-bike. There are a lot if changes both from the mechanical stand point as well as an electrical stand point that needs to be made in order for the cycle to generate appropriate energy. Also we cannot load the cycle with an arbitrary value of the battery pack. The battery pack needs to be designed such that the cycle can charge a significant portion of the battery pack when reaching the destination. After the battery pack power rating has been calculated we need to design the optimum configuration to charge the battery pack in order for the battery pack to be charged properly. In the mechanical section we need to design the right gear ration in order to increase the speed of the generator to get the right output voltage to charge the battery pack. The output current will depend on the load i.e. the battery pack so the output power of the generator will depend on the load it is providing. Below is the systematic diagram of the cycle electrical section where it is given in detail as to how it is functioning.

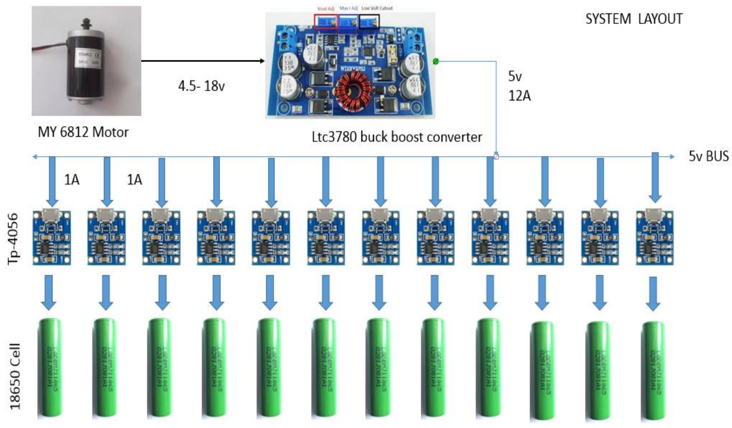

Fig. 2 Electrical Layout

3. SIMULATIONS

The system we propose to make has two significant parts:

- Electrical Section
- Mechanical Section

Here we will show the simulation and results for each section which will give a brief understanding of each section and how they are functioning.

Electrical Section

In the electrical section, we have performed two simulations mainly one is the converter simulation and the other is the battery charging simulation. In the previous section we have shown the electrical layout of the system, where we have shown the use of a buck-boost converter which receives the output from the generator, the purpose of this is to provide a constant 5 Volts output to the battery pack, the reason we used this is because the generator output will range from as low as 2 Volts to a maximum of 12 Volts, so there will be instances where we may need to step up or step down the voltage. We have performed the simulation in PISIM.

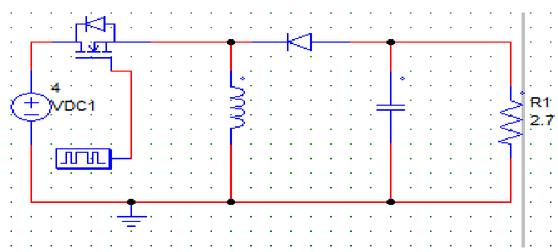

Fig.3 Buck-Boost Converter

In the above Fig.3 we have shown the schematic of the buck-boost converter we have designed, it is calibrated to give a constant output of 5 Volts for an input ranging from 3 Volts to 12 Volts.

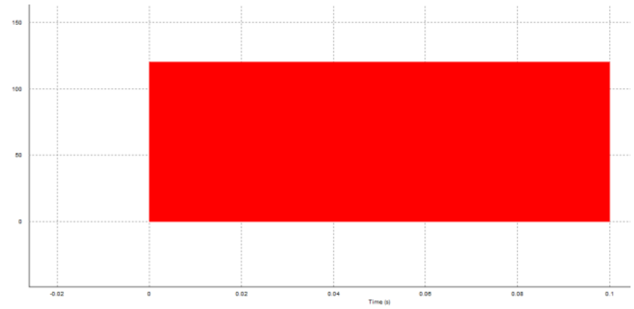

Fig.4 Converter Output

The figure above is the converter output we have received. We received a steady band in the output which shows the triggering of the switch or MOSFET for the operation.

The next section of the electrical segment is the battery charging simulation. In our project we are using li-ion 18650 cells for the purpose of retaining charge. But lithium chemistry cells are to be handled with a lot of care and their charging must follow a certain pattern in order for the cells to remain healthy. The advised charge rate of an Energy Cell is between 0.5C and 1C; the complete charge time is about 2–3 hours. Manufacturers of these cells recommend charging at 0.8C or less to prolong battery life; however, most Power Cells can take a higher charge C-rate with little stress. Charge efficiency is about 99 percent and the cell remains cool during charge.

Full charge occurs when the battery reaches the voltage threshold and the current drops to 3 percent of the rated current. A battery is also considered fully charged if the current levels off and cannot go down further. Elevated self-discharge might be the cause of this condition.

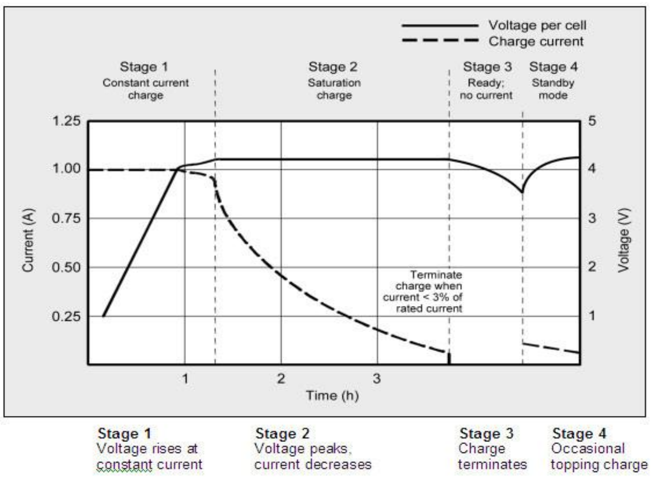

Fig.5 Li-ion Charging stages

Increasing the charge current does not hasten the full-charge state by much. Although the battery reaches the voltage peak quicker, the saturation charge will take longer accordingly. With higher current, Stage 1 is shorter but the saturation during Stage 2 will take longer. A high current charge will, however, quickly fill the battery to about 70 percent.

We have performed the battery charging in MATLAB where we have obtained the results as per the stages of the battery charging.

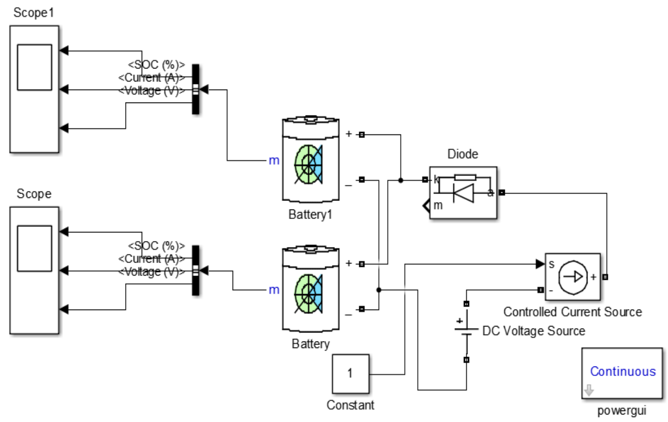

Fig.6 MATLAB Model LI-ion Charging

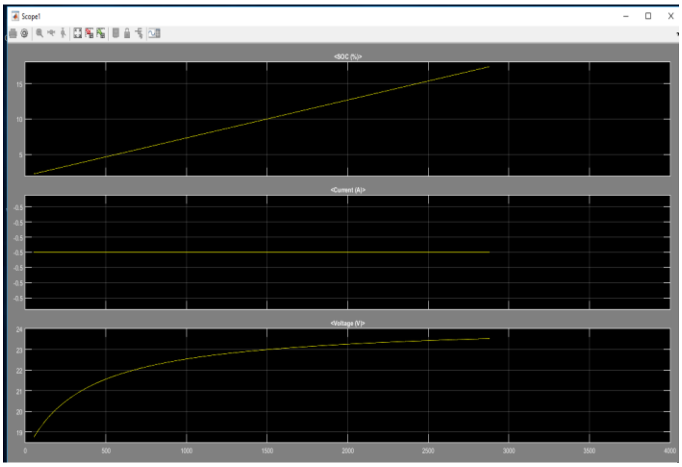

Fig.7 MATLAB Output

Mechanical Section

The most important aspect of this section is the speed multiplication system, where e have used a gear and sprocket system to increase the speed at the generator shaft to give a desirable output.

By selecting sprockets larger or smaller relative to the input sprocket, we can either increase the output speed or increase the output torque, however the total power is not effected. When a larger sprocket drives a smaller one, for one rotation of the larger sprocket the smaller sprocket must complete more revolutions so the output will be faster than the input. If we reverse the situation and a smaller sprocket drives a larger output sprocket, then for one rotation of the input the output will complete less than one revolution resulting in a speed decrease from the input. The ratio of the sizes of the two sprockets is proportional to the speed and torque changes between them.

The ratio in size from the input (driving) sprocket to the output (driven) sprocket determines if the output is faster (less torque) or has more torque (slower). To calculate exactly how the sprocket size ratio effects the relationship from input to output we can use the ratio of the number of teeth between the two sprockets. Sprocket and chain is a very efficient way to transmit torque over long distances. Modest reductions can be accomplished using sprockets and chain, but gears typically provide a more space efficient solution for higher ratio reductions.

The ratio of the number of teeth from the input sprocket to the output sprocket = 300T / 9T. Which means the output would turn 33.33 rotations for the input to complete one rotation
Speed Multiplier Ratio (M) = 300 / 9 = 33.33
Wheel Diameter of Cycle (D) = 620 mm
Average Speed of Cyclist (S) = 15.5 km/hr = 258.33 m /min
Perimeter of Wheel (P) = Distance covered in one rotation = 2*π*(D/2)
Average RPM of Wheel at S speed (R) = S / P = 132.2 Rpm
RPM at Generator Shaft end = R * M = 132.2 * 33.3 = 4,402.26 Rpm
The CAD model we designed on the basis of the above mentioned calculations is given below.

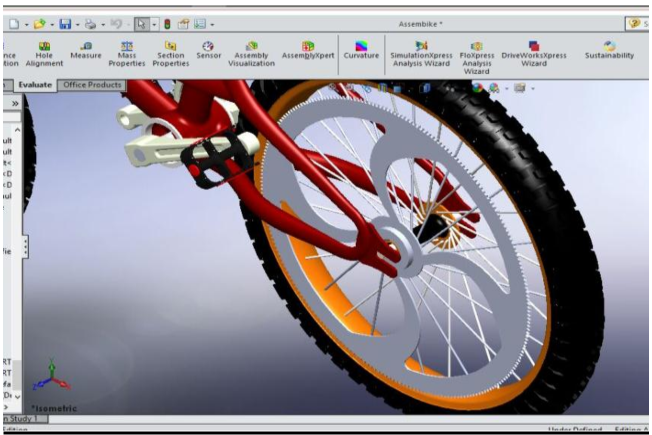

Fig.8 CAD model

4. HARDWARE SETUP

Similar to the simulations we have done the hardware setup is also divided into the (i) electrical section and the (ii) mechanical section.

Energy Section

The energy generation unit mainly comprises of the DC Generator and the voltage regulator which in our case we used a buck boost DC-DC converter. The dc generator serves the purpose of the energy generation, we are currently using a MY6812 DC motor which has 100Watts of power at full load and operates at 12 Volts and can take up to 24 Volts. The generator has the following specifications:

- Voltage- 12 Volts
- Current- 1 Amp/ 11.9 Amp with load
- Max speed- 3200 rpm
- Torque-0.35Nm

Fig.8 MY6812 DC motor

The generator has a lower initial starting torque, this gives us the added benefit as the user can provide the required torque, an average human can provide as much as 1 to 1.5 Nm of torque which is above that required by the generator to start. But the generator requires a particular speed at which it must be rotated to generate a minimum of 5Volts (which required by the regulator), this speed is being achieved by designing a speed multiplier in the rear wheel.

The regulator receives the voltage from the generator and removes any noise and provides a constant voltage of 4 Volts and 12Amps; this output is such because the 12 Li-ion cells we have used are arranged in parallel configuration. The regulator we are using is the LTC3780 130 Watts buck boost DC-DC converter. The LTC3780 is a high performance buck-boost switching regulator controller that operates from input voltages above, below or equal to the output voltage. The constant frequency current mode architecture allows a phase lockable frequency of up to 400 kHz. With a wide 4V to 30V (36V maximum) input and output range and seamless transfers between operating modes. The LTC3780 uses a constant frequency architecture and has an internal voltage controlled oscillator. This internal capacitor is charged by a fixed current plus an additional current that is proportional to the voltage applied to the PLLFLTR pin. The frequency of this oscillator can be varied over a 2-to-1 range. The PLLFLTR pin can be grounded to lower the frequency to 200 kHz or tied to 2.4V to yield approximately 400 kHz (maximum switching frequency). When PLLIN is left open, the PLLFLTR pin goes low, forcing the oscillator to minimum frequency. As the operating frequency is increased the gate charge losses will be higher, reducing efficiency.

Fig.9 LTC3780 Board

The charging of the battery pack is monitored by TP4056 li-ion charging board. The charging board is specially designed for the 18650 cells. The TP4056 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its SOP package and low external component count make the TP4056 ideally suited for portable applications. No blocking diode is required due to the internal PMOSFET architecture and have prevent to negative Charge Current Circuit. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The TP4056 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached. TP4056. Other features include current monitor, under voltage lockout, automatic recharge and two status pin to indicate charge termination and the presence of an input voltage.

The main features of the TP4056 cell boards are as follows:

- Programmable Charge Current Up to 1000mA
- No MOSFET, Sense Resistor or Blocking Diode required.
- Preset 4.2V Charge Voltage with 1.5% Accuracy
- Automatic Recharge ·two Charge Status Output Pins
- C/10 Charge Termination ·2.9V Trickle Charge threshold (TP4056).

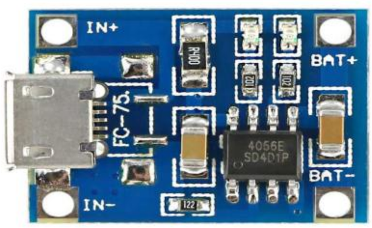

Fig.10 TP4056 Charging Board

We are charging the battery pack in a parallel configuration, as it allows to separately charge each cell without the consequence of a cell failing in the process. In case of series charging, if a particular cell fails, then the entire charging can be hampered which is avoided in case of parallel charging when if a cell fails to charge, the charging process can continue for the remaining healthy cells.

Mechanical Section

In the mechanical section, the most important part of the project is the timing chain and the speed multiplier sprocket. The gear enables us to generate 1500 to 4000 Rpm at Generator end. As per the MY6812 Performance Curve it would be generating 5v to 18v. The gear setup has gear ratio of 33.33 which means an input speed of X Rpm would be 33.33*X Rpm at Generator shaft end. We laser cut the sprocket The Sprocket has been cut out of CR (cold rolled) Mild Steel of 3mm thickness.

Fig.11 Sprocket after Laser Cutting

We have used timing chain or #25 Roller Chain of 8mm pitch for the transmission system. This was the type of chain that was recommended for the sprocket at the generator shaft. While testing of our system we noticed that the transmission system was prone to vibrations in the arising due to slight increase in speed. Even after tweaking the system multiple times the results were unsatisfactory due to the vibrations which caused the chain to fall off.

We were advised to try out a thicker chain in-order to tackle the vibrations. So we went with the standard Cycle chain and implemented a new setup which had a speed multiplier ratio of 4, for which we used a new Sprocket.

5. CONCLUSIONS

Through research and testing, this project aimed to design and implement a first of its kind sustainable energy resources. The project goal was to supply a battery array with a 12 volt DC output. This goal had to be met within the constraints of a low production cost and high safety. We believe we accomplished this goal. The project results were conclusive with the alternator as an energy provider. Generators are great tool when running at a high RPM, but less efficient when running at a lower RPM, like that provided by users pedaling the bike. There are many other options to explore to find the most efficient way of producing

DC power from a bicycle, but we believe modifying a converter is the most cost effective way to reach that goal. Unfortunately, the major problem we faced was with the speed multiplication for reaching optimum speed for the generator give the output. The bike stand and coupling between bike and motor have room for improvement as well like to reduce torque and tension to the stand and reduce slippage between the belt couplings. Further stress tests over a longer period of time would also be beneficial in order to determine the actual average lifetime of our product, and if the cost of production is worth the provided power within that lifetime. Our greatest difficulty came with the charging time of the battery pack. More testing can be done to find the right cell chemistry or to find a new way to reduce the charging time for the battery pack

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