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Designing & Analysis of Supercapacitor Hybrid Battery System with Regenerative Braking

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Abstract: This work implements the help of a super capacitor hybridized with a battery pack to power a motor to work an electric bike. The supercapacitor of specification is built in combination with the battery pack to work in pair at instances where more load in needed. For example in situations like accelerating, decelerating, and climbing a slope. The supercapacitor is recharged while in motion using two different technologies: 1. Regenerative Braking and 2. Generator incorporated into wheel hub. Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy into a form that can be either used immediately or stored until needed. In this mechanism, the electric traction motor uses the vehicle's momentum to recover energy that would otherwise be lost to the brake discs as heat. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat due to friction in the brakes, or with dynamic brakes, where the energy is recovered by using electric motors as generators but is immediately dissipated as heat in resistors. In addition to improving the overall efficiency of the vehicle, regeneration can significantly extend the life of the braking system as the mechanical parts will not wear out very quickly. The system uses Faradays Law of Electromagnetic Induction to induce an EMF and generate voltage by passing a current carrying conductor through a rotating magnetic field. Using this implementation, it has been noted that the battery life has been increased significantly and the total range of the bike has also increased considerably.
Keywords: Batteries, Battery pack, Supercapacitor, Hybrid power system, Dynamo mechanism

I. INTRODUCTION

In all parts of the world especially including developed countries like USA, Germany, Japan etc are moving towards an era of Electric Vehicles. Vehicles running on exhaustible sources of fuel are becoming lesser in demand as the technology of Electric vehicles are advancing. Electric Vehicles are being favoured considerable because of advantages like: The cost of the electricity required to charge an EV is around 40% less than the cost to use petrol for a similar sized vehicle driving the same distance. The cost will be lower if you charge your EV from your solar PV system or at free charging stations. Cheaper to maintain A Battery Electric Vehicle (BEV) has fewer moving parts than a conventional petrol/diesel c ar. Servicing is relatively easy, less frequent, and overall cheaper than a petrol/diesel vehicle.

All EV batteries degrade (become less efficient). Most car manufacturers warrant EV batteries to not degrade below a certain level for around eight years. By choosing to drive an EV you are helping to reduce harmful air pollution from exhaust emissions. An EV has zero exhaust emissions, but still creates a degree of greenhouse gas emissions when it is charged from the electricity grid. If you have a solar PV system and charge your EV during the day, you can reduce your greenhouse gas emissions even further. Another way is to purchase Green Power from your electricity retailer. Then, even if you recharge your EV from the electricity grid, your electricity is coming from renewable energy sources. Reduced harmful exhaust emissions is good news for our health. Better air quality will lead to less health problems and costs caused by air pollution. EVs are also quieter than petrol/diesel cars, which means less noise pollution.

The work presented in this thesis carries a supercapacitor hybrid battery pack system working in correlation with regenerative braking and generator incorporated into wheel hub. On implementing this system, it drastically increases the range of the E-bike thus makes it economically feasible. This in turn increases the battery life and makes it ecofriendly.

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II. COMPONENTS OF THE BATTERY SYSTEM

The components included in our battery system are as follows:

A. Battery Pack

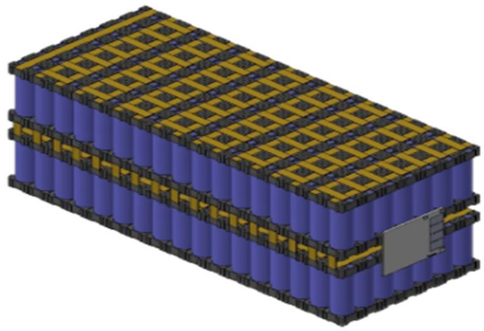

Fig.1 Battery Pack (SolidWorks 2018)

The design of our battery pack is shown if Fig. 1. Individual cells are arranged to achieve the required voltage and capacity. Since the required capacity of the battery pack is large the number of parallel cells also increased. Fig.2 shows the casing of our battery pack.

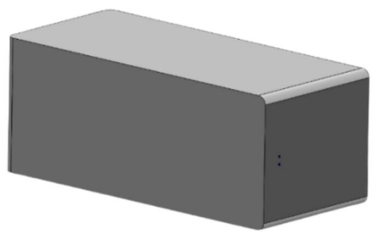

Fig.2 Battery Casing (SolidWorks 2018)

Specification of battery pack:

1) Cell used – Samsung 18650 25R
2) Voltage & Current – 3.6 V, 1.25 A
3) Battery Capacity – 34.7 A
4) Connection type – 17S17P
5) Total No. of cells – 238
6) Weight of a single cell – 50g
7) Weight of 238 cells (50 x 238) – 11.9 Kg
8) Weight of whole Battery Pack – 13 Kg

B. Supercapacitor Module

Fig.3 Supercapacitor Module

As battery powers the motor in a typical E-bike, the life of the battery degrades as battery needs to provide enough current in higher loads of motor. So, to avoid this, a supercapacitor module is used parallel to the battery module. This Supercapacitor is powerful enough to power the motor in higher loads such as the climbing a steep road, acceleration, etc. To achieve the voltage of the motor, a DC-DC converter is used, and it boosts the voltage of the capacitor from 48V to 68V. This supercapacitor not only prevents fast degradation of battery module but also gives double the range of the E-bike compared to the system where battery alone powers the motor. The fig.3 shows the selected supercapacitor in the battery system.

Specification of supercapacitor module:

1) Rated Capacitance: 3,000 F
2) Voltage: 48 V
3) Stored Energy: 53 W/hr
4) No of cells: 18
5) Mass: 14.2 Kg
6) Environmental Protection – IP65
7) Colling: Natural Convection
8) DC-DC converter Booster: which boosts up to 20V
9) Range of working temperature: -40^{0}C– 65^{0}C
10) Up to 1,000,000 duty cycle or 10-year DC life

C. Regenerative Braking System

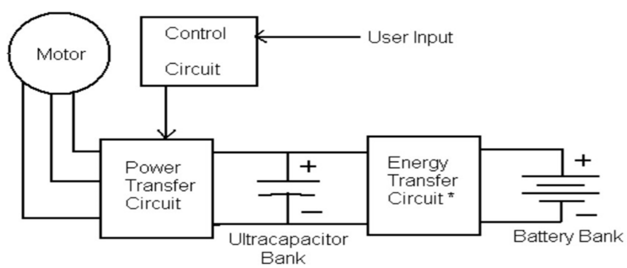

Fig.4 Regenerative Braking System [1]

In urban areas we tend to apply brake more often when compared to highways. As we apply brake in urban areas the energy loss is more. Regenerative braking system is used to recover the kinetic energy dissipated as heat during braking in the traditional braking method. By this method significant amount of kinetic energy can be converted and stored in Supercapacitor as shown in Fig. 4.

D. Generator Incorporated into Wheel Hub

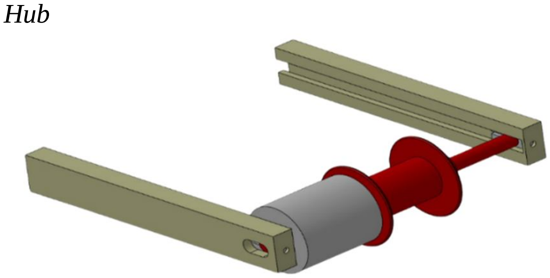

Fig.5 Implementation of generator into the wheel hub

To recharge the supercapacitor, regenerative braking is a solution as explained in the previous section. But this regenerative braking system will not do much in case of highways and other long drive where braking is so less. This regenerative braking can help only in high traffic areas and urban roads. So, to overcome this problem, a generator incorporated into the wheel hub is a solution. The mechanism is shown in the fig. 5. This generator can generate a voltage greater than the voltage of the supercapacitor. Hence in highways and in long drives, the rider can switch the charging system from regenerative braking system to this generator system.

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III. SUPERCAPACITOR HYBRID BATTERY SYSTEM

Our battery pack system consists of both supercapacitor module and battery module which combines and drives the electric bike. Supercapacitor has more advantage compared to normal cell battery pack like Provide peak power and backup power, extend battery run time and battery life Reduce battery size, weight, and cost. When the E-bike normally runs on a flat road, it is powered by the battery alone, but in the stage of starting, climbing, accelerating and other needs of instantaneous high power, the supercapacitor supply power to the motor which is the main application on supercapacitor in this system. When the electric bicycle is braking, the motor generates electricity, and the super capacitor stores energy to realize energy recycling, which is known as the regenerative braking system. The combination of super capacitor and battery can complement each other and improve the performance of existing battery and prolong its service life.

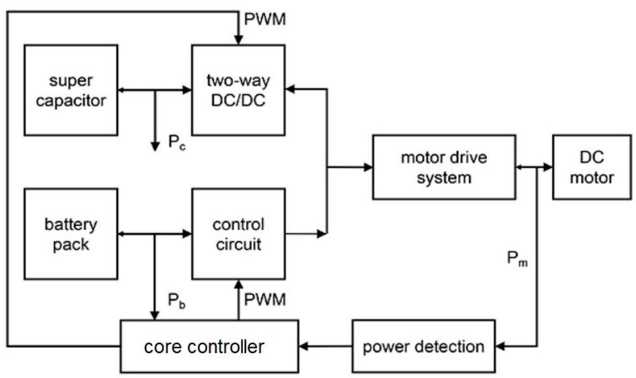

Fig.6 Hardware Structure Diagram [2]

A two-way DC/DC converter is connected in parallel to the supercapacitor thus allowing charge to flow to and from the supercapacitor. The flow of charge is controlled using a controller. In normal working condition the controller allows flow from battery pack to the motor drive system to run the motor and the supercapacitor is now in charging mode. It means that charge is being supplied to the supercapacitor through the DC converter. In higher load conditions such as start, stop or climbing a hill the controller switches the DC converter to allow flow from the supercapacitor to facilitate the power needs of these higher load conditions. Thus, the supercapacitor works in conjunction with the battery pack so less energy is needed from the battery pack which thereby increases the range of the E-Bike and increases the battery life.

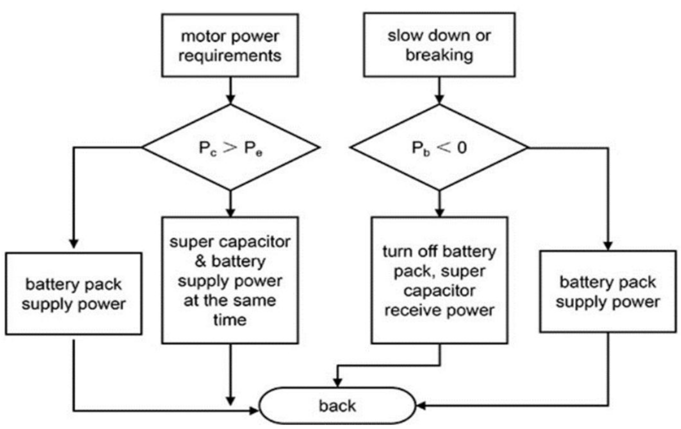

Fig.7 Flowchart of Dual Power Control System [2]

The Fig.7 depicts the condition for breaking and slowing down wherein the battery power is cut off and the regenerative braking comes into work. The regenerative braking converts the kinetic energy of the wheel to charge the supercapacitor and the latter receives power. On the other case wherein, the conditions can either differ between normal working conditions and high load working conditions like starting, climbing a slope etc, the motor can either receive power from the battery pack alone or the battery pack and supercapacitor together. It will depend upon the situation and the motor power requirements.

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IV. DESIGN OF GENERATOR INCORPORATED INTO WHEEL HUB

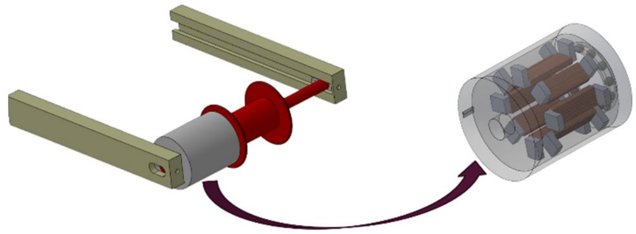

Fig.8 Implementation of generator into the wheel hub

This innovative design as shown in the above fig 8, is likely to be a bigger version of the dynamo we see in bicycles. The wheel hub is represented in red colour and the magnet is represented in blue colour. This generator is made by modifying the wheel hub. As the bike runs at a constant high speed, this generator produces enough current that could charge the supercapacitor. This whole design is very compact and minimal as you can see in the Fig 8.

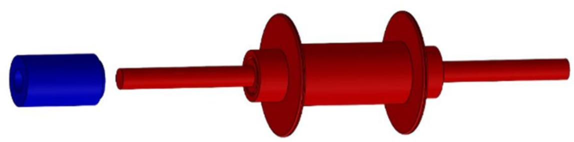

Fig.9 Magnet and Wheel hub

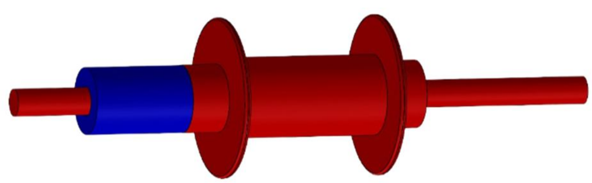

Fig.10 Magnet Inserted to the Wheel hub

The generator is placed and modified in the left side of the wheel hub as the right side is considered to hold the sprocket and chain. A small circular slot is cut to a small depth in the left side of the wheel hub, and a magnet which has an extra material that could fit in the slot is placed as shown in the Fig. 9 and Fig 10.

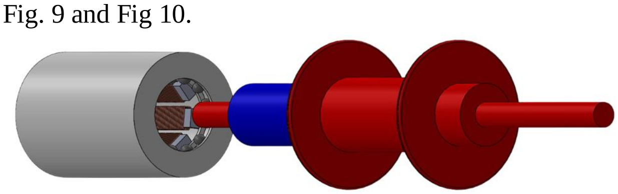

Fig.11 Stator Component inserting to the Wheel hub

Fig.12 Transparent view of the Generator

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The stator is then inserted as shown in the fig 11. The transparent view of the stator is shown in the fig 12. The side of the stator which faces the wheel hub has ball bearings as to prevent the rotation of the stator as shown in the fig 12. This design is practically possible as it shares a lot of similarities to an actual dynamo used in bicycle. This design can output enough current to charge the supercapacitor when the wheel is rotating at constant high speed.

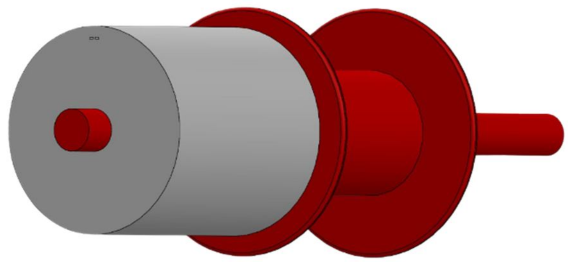

Fig.13 Slots given to the generator to carry out the windings

The opposite face of the generator which has no ball bearing, has two small holes to carry the windings to the external circuit, which is shown in the fig 13.

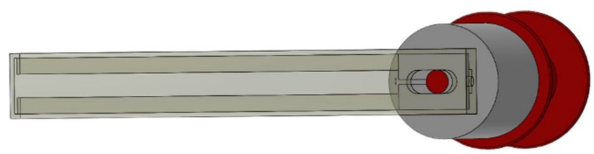

Fig.14 Transparent view of the swingarm attached to the wheel hub

In fig 14, it shows the transparent view of a hollow swing arm which is connected to the end of the wheel hub. This swing arm transfers the circuit from the generator to the main circuit. Thus, it completes the entire battery system.

V. CALCULATION

By doing the theoretical calculations we came into these results:

A. A Standard E-Bike With A Single Battery Module

Total Energy used in 195 sec = 13.24223 Whr
The total Distance covered in 195 sec = 1.001 Km
So, for 120 Km, Total energy used = 1587.48 Whr
Therefore, the battery capacity needed

$$= \frac{total\ energy\ used}{voltage\ of\ the\ motor}$$

$$= \frac{1587.48}{60}$$

$$= 26.458\ Ah$$

Since, only 75 % of the battery can be full used, we need to add an additional 25 % capacity extra to meet our limits, *25 % of 26.458 Ah = 6.6145 Ah*

Therefore, the battery capacity we need

$$= 26.458\ Ah + 6.6145\ Ah$$
$$= 33.07\ Ah$$

Since we use Li-ion cells, we need to multiply the required capacity into 1.05,

$$= 33.07\ x\ 1.05$$
$$= 34.72\ Ah$$

Therefore, the total capacity of the battery pack we required is $34.72\ Ah$
The specification of the battery pack is $17S14P$
with $35\ Ah$ capacity

B. By Adding A Supercapacitor To Above E-Bike

Total Energy used in 195 sec = 5.62253 Whr
Total Distance covered in 195 sec = 1.001 Km
So, for 120 Km, Total energy used = 674.029 Whr
(*Above calculation is repeated*) that gives 14.74 Ah
As our battery pack already has 34.7 Ah which can run 120 km, now only 14.74 Ah is required to run 120 km (by the addition of supercapacitor module.
So, there is still 19.96 Ah remaining which will give us extra range, which will be more than twice the range if the battery module alone powers the motor.
The approximate total range of this supercapacitor hybrid battery pack will be 120 km (14.74 Ah) + 162.4 km (19.96 Ah) = 282.4 km

VI. THERMAL ANALYSIS OF BATTERY PACK

A thermal analysis calculates the temperature distribution and related thermal quantities in battery pack. Typical thermal quantities which we are using are:

A. Temperature Distribution

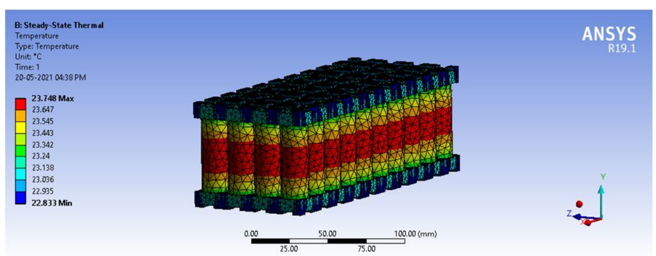

Fig.15 Temperature Distribution on Battery Pack

The above shown figure represents the temperature distribution through battery pack. The maximum temperature distribution is 23.748 degree Celsius, and the minimum temperature distribution is 22.833 degree Celsius.

B. Total Heat Flux

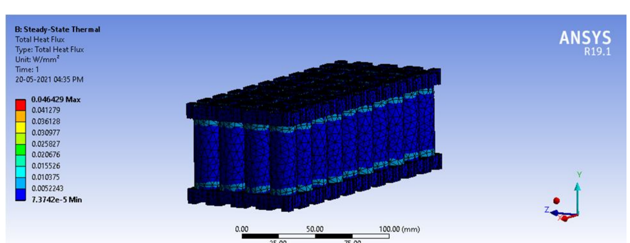

Fig.16 Total Heat Flux on Battery Pack

The above shown figure represents the total heat flux through battery pack. The maximum total heat flux is 0.019343 W/mm^2 and the minimum total heat flux is 7.3742 x 10^{-5} W/mm^2.

C. Total Deformation

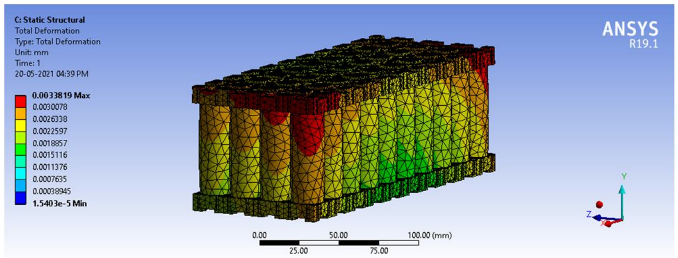

Fig.17 Total Deformation on Battery Pack

The above shown figure represents the total deformation through battery pack. The maximum total deformation is 0.0033819 mm, and the minimum total deformation is 1.5403 x 10^{-5}mm.

TABLE I
RESULT OF ANALYSIS

	Min	Max
Temperature Distribution	22.833^{O}C	23.748^{O}C
Total Heat Flux	7.3742 x 10^{-5} W/mm^2	0.019343 W/mm^2
Total Deformation	1.5403 x 10^{-5}mm	0.0033819

VII. CONCLUSION

The battery module of the vehicle is made to work in conjunction with a supercapacitor module which is powered by both a regenerative braking system and a generator system attached to the wheel hub. By applying the battery module and supercapacitor module to work in combination it is noted that the range will considerably increase. Since the supercapacitor module is charged by two means, it can both be charged in start-stop traffic.; urban areas, and in highways where applying the brakes are less than naught. After performing thermal analysis on the battery module, we can understand the properties of temperature distribution, total heat flux and total deformation of the body. It is finally concluded that using this combination of a hybrid battery system, we can greatly increase the range of the vehicle thus contributing towards the economy of the vehicle and towards the protection of the environment efforts to ensure that the templates have the same appearance.

REFERENCES

[1] [4]_S Mandal, M R I Sarker, M S Rahman, M R A Beg, 2017, An Analysis of Braking Energy Regeneration in Electric Vehicles, INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH S. Mandal et al., Vol.7, No.3, 2017

[2] https://www.greentechee.com/super-capacitor-and-battery-pack-combined-as-power-supply-in-electric-bicycle_n68