Design and Analysis of Self-Recharging Electric Vehicle

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Abstract: *This paper presents the design and analysis of Self-Recharging E-Bike. The electrical vehicles are powered by electric motor and electrochemical battery. The main drawbacks of the E-Bikes are limited range and it consumes more time to recharge. For charging of E-Bikes, the charging station infrastructure is not fully developed in India.*

This paper proposes the design of an E-Bike such that the E-Bike will recharge its battery while it's in running condition. When the battery is drained out after a distance range is completed, the recharged battery is switched to run the E-Bike. This will increase the distance range of E-Bike per charge. This method of switching the batteries will reduce the frequency of charging from external sources and increases the distance travelled per charge. These bikes can travel longer distance like conventional fuel bikes. Our proposed Self-Recharging E-Bike has the longer distance range for same battery capacity (per charge) of present E-Bike.

Keywords: *- Electric vehicles, self-Recharging, E-Bikes, battery capacity, electric motor, electrochemical battery.*

I. INTRODUCTION

The history shows the research on electrical vehicles started at 1890s. In this period electric bicycle got several patents. Ogden Bolten from United States got patent for bicycle battery with six brush poles, a DC collector and hub motor mounted on the rear wheels in 1895. Later in 1897 Hosea W Libbey from Boston invented an electric bicycle that was powered by a double electric motor. Giant Lafree E-Bike brand use same design in 1990. Transportation is the main sector and every other sector depend on it. But the conventional vehicles which we used today uses petrol and diesel but which are non-renewable energy resources. Moreover, these vehicles increase air and noise pollution which is global problem now. This creates the requirement of clean and renewable energy sources. That's why alternating energy sources getting the attention of the world in last few years. Though electric vehicles has many drawbacks many research are going on electrical bikes because of its nature friendly characteristics. Even many nations depend on other countries for petroleum products and there cost are so high. In order to reduce their dependences on other countries it is necessary to promote electrical vehicles. Indian government also started many schemes to promote electrical vehicles.

The major factors to use self-recharging electrical vehicles are:

- Reducing the use of fossil fuel
- Fast and flexible
- Nature friendly
- Cut back expenses

II. LITERATURE SURVEY

Shubham U. Tayde, Neha W. Makode, Umesh M. Laybar, and Prof. Bhushan S. Rakhonde [1], discussed about mechanical design of the system and also give better knowledge in system integration. This paper also helps us to know more about power transmission system which contain motor, the chain sprockets, flywheel, housing and the rear wheel. We get know how to do some basic calculation relating to energy transfer through the system and how main components such as motor and battery will affect by these calculations.

M.Sathya Prakash [2], provided information about difficulties that faced during the replacement of internal combustion engine by a battery and electric motor drive in personal transportation electric vehicles. The paper provides the information regarding principles of alternating current, direct current, motors, speed controls, batteries, relays and battery.

Yogesh jadhav, Gaurav Kale, Shekhar Manghare, and Sager Patil [3], provided information regarding Self recharging electric bike and electric-engine controlled bikes. And also helps us understand the concept of battery, dynamo as a wind generator, the BLDC engine, controller, charging framework and sun oriented board.

Adithya Kumar, Srirenga Venkatesh, Satheesh Kumar, Pragatheeshwarar [4], helped us by giving the information regarding electric power motor and alternator and how they assist the rider throughout his journey.

The alternator generates electricity which is stored in batteries and these batteries provide propulsion power for the motor. It also provide information of modification required for electric bicycle.

Robert Cong, Rodney Martinez, Mark Casilang ,Peter Vong [5], helped us to know more about the design of E-Bikes and also information regarding lithium-ion battery, the DC-DC boost converter, the solar panel, the motor, and the motor controller. It will also possible to improve them further by future students. And also how to make them very efficient and cost effective.

Prof.S.H.Shete, Nitin Patil, Ganesh Khot, Kiran Kokitkar, Santosh, Vardapgol, Jayashri Sawant [6], provided the information of controller which takes PIC16F72 as a core, introduced some important components and Circuit principle diagram. And also information about controller functions such as over-current protection, under-voltage protection and so on.

III. PROPOSED PLAN

The proposed self-rechargeable E-Bike, where the batteries can be charged continuously while the E-Bike is in running condition, so that E-Bike can travels longer distance, the range of our E-Bike concept gives 1.5 to 2 times longer range than present E-Bikes. The power generated by such regenerative braking is 2 to 3 times higher than present E-Bike due to the presence of two HUB generators. Hence our E-Bikes gives longer range, for same charging time and battery capacity available in present E-Bikes. The anticipated idea is more efficient in terms of distance travelled by the vehicle per charge compared to existing methods. The block diagram of the proposed Self-Recharging E-Bike is shown fig.1

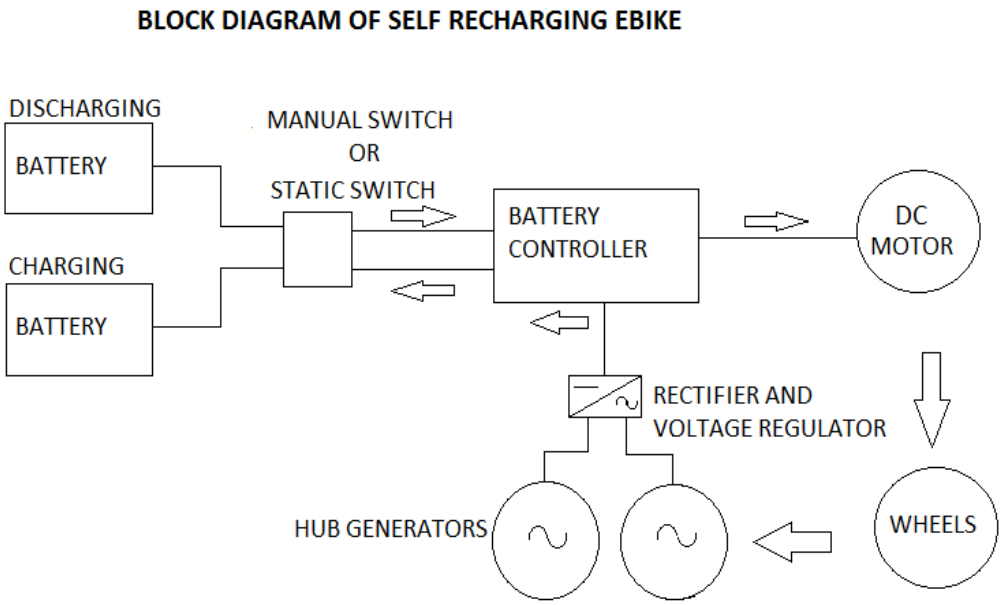

FIGURE 1: BLOCK DIAGRAM

The figure 1 shows that block diagram of self-chargeable E-Bike, the main components of E-Bike are motor, batteries, battery controller, and HUB generator, Rectifier and voltage regulator. The working of self-rechargeable E-Bike is similar to conventional E-Bike. Two or more batteries can be included in the battery bank. One can supply the motor for propulsion, one will be charged while E-Bike is running. The two HUB generator generate electric power while E-Bike running. The battery controller used to charge and discharge the battery safely, and regulate the speed of motor.

The components we are used in our E-Bike are a 250 watts brushed DC motor, Uni-directional motor speed control, 2 no's of lithium ion batteries, 350 watts hub generator, DC motor controller module, throttle, boost-converter, and DPDT switch.

Hub Generator:

HUB generator is an electrical generator built into hub of a bike. Generator converts mechanical rotational energy into electricity. HUB generators have stator armature winding and rotating field system. When rotor field rotates the generators generate electric energy, these generator are used to recharge batteries when bike is running. The HUB generators used for E-Bike have low friction, low rpm, and high efficiency generators.

In our projects we modified a simux hub motor into hub generator because cost of hub generator is high and our requirement doesn't match the market availability. Construction of hub motors and hub generators are

similar, so it is easy to convert motor to generator. If we convert directly hub motor into hub generator, it acts as 3 phase hub generators but we require 1 phase supply. So that the 3 separate winding of hub motor make it into single winding. These single phase supply is fed to battery through battery charger. We planned to use two hub generators at front and rear wheels but due to higher cost we only use one hub generator at rear wheel.

FIGURE 2: HUB GENERATOR

HUB generator specifications:

- Power : 350w
- Rated voltage :36v
- Rated current: 10A,
- company: SIMUX
- Distributors: Roboscraft
- numbers: 2no
- weight: 6 kg

DC Motor Controller Module:

The Speed control of the dc series motor is a combination of electronic circuit that include speed control circuit and motor protection circuit. The controller unit uses battery pack power as input power and run the motor at different speed. Different motor controller types are used for brushed and bldc2 motors. The DC motor speed controller sends signals in different voltages to the motor. According to the different voltage signal the speed of motor changes. The function of a speed controller the control and it also provides protection to the motor.

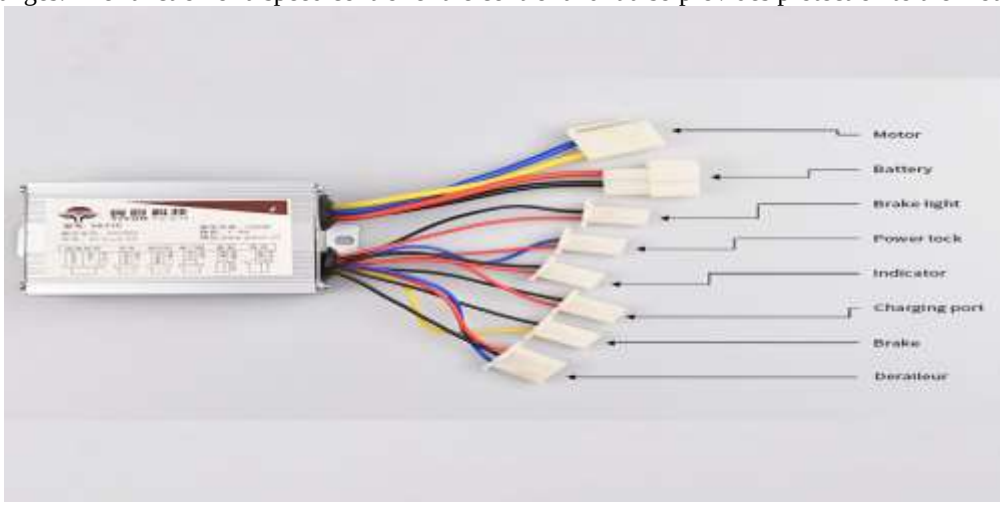

FIGURE 3: DC MOTOR CONTROLLER MODULE

Specifications of the controller module:

Voltage (Rated)	24 Volts
Rated power for motors	250Watts
Maximum current	13.5 Amps
Rated current for chargers	Up To 3 Amps
Efficiency (Conversion)	95%
Rated under voltage protection	20.5 Volts ± 1.0 Volt
Fuse size (recommended)	40 Amps

Battery Charger:

The battery charger is design to charge 24V lithium ion battery at 3 amps charging current. The battery charger circuit has 3 sections; the power supply circuit, current limiting circuit, float charge stage circuit. In this battery charger circuit, 24Vac (rms) to 24Vdc bridge rectifier was used. From this rectifier we get a 24v dc supply. This dc supply is filtered in capacitor filter. So that the rating of rectifier diodes are selected in such way that it should match the charger ratings.

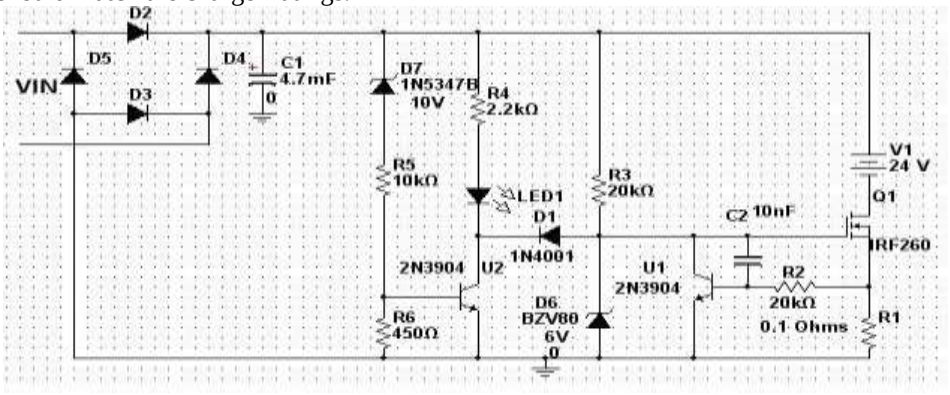

FIGURE 4: BATTERY CHARGER CIRCUIT

IV. METHODOLOGY

Working:

FIGURE 5: FINAL COMPLETED MODEL OF THE VEHICLE

The Figure 5 shows Final Completed Model of the E-Bike and it powered by 250watt permanent magnet dc motor which runs at 2650 RPM. The dc motor operates at 24V and maximum current rating is 13.7A. The motor is to chain drive through the 1:6 speeds reduction sprockets which reduce the speed of motor by 6 times to increase the torque produced by motor. The chain drive supports both pedal assist and motor drives. This can be achieved by use of freewheel sprockets. The chain drive linked to the rear wheel freewheel sprockets by a chain.

FIGURE 6: MOTOR CONNECTED WITH MULTI CRANK FREEWHEEL

The figure 6 shows the motor shaft linked with speed reduction sprockets. As explained above the speed of motor need to reduce because the torque produced by a motor at rated speed is not sufficient to run an E-Bike.

So that as know that if speed reduce proportionally torque increases. Therefore we reduce the speed of motor by a 6 times that is 441RPM. This results in torque increased by 6 times. The chain drive from this speed reduce is directly connected to hub generator .the chain drive allows motion of hub generator when motor rotates. When the motor turn on it draws the supply from the one of the lithium ion battery. The lithium ion battery rated at 24v and 10ah, this means the lithium ion battery can discharge maximum at 10amps.the speed of motor is controlled by throttle. The motion of dc motor actuates the wheel of E-Bike.

FIGURE 7: REAR WHEEL HUB GENERATORS

The chain drive freewheel is mounted on hub generator as shown in figure 7. Mechanical energy is converted into electrical in hub generator. We modified a simux hub motor into hub generator because cost of hub generator is high and our requirement doesn't match the market availability. Construction of hub motors and hub generators are similar, so it is easy to convert motor to generator. If we convert directly hub motor into hub generator, it acts as 3 phase hub generators but we require 1 phase supply. So that the 3 separate winding of hub motor make it into single winding. These single phase supply is fed to battery through battery charger. We planned to use two hub generators at front and rear wheels but due to higher cost we only use one hub generator at rear wheel. The hub generator generates electric power at speed of 10km/h and above. The output of hub generator various according to the speed of E-Bike, So that the output of hub generators step up by use of boost converter to required valves. This output is rectified and recharge the battery of E-Bike. If rider rides E-Bike faster than the faster change in magnetic field and this results higher voltage induced.

FIGURE 8: TWO BATTERIES MOUNTED ON E-BIKE FRAME

There are two lithium ion batteries are mounted on E-Bike frame as shown in figure 8. one battery is placed horizontally on front frame and this battery supplies the motor. Another battery is placed vertically on middle frame and this is used to recharge from generator. The battery gives range of 30 to 50 km per charge. Once first battery fully discharged then the terminals of two batteries are interchanged by use of DPDT switch. Now the first

battery is connected to the generator and second battery supplies the motor. These operations are can be repeated continuously, but this operation is limited to few cycles to increase the battery charging cycle.

V. RESULTS

TABLE 1: HIGHER GRADIENT TEST RESULTS

SPEED (Km/h)	POWER (Watts)	GRADIENT (%)	OUTPUT VOLTAGE (Volts)	OUTPUT POWER (Watts)
10	86	0	13.7	24
	125	3	13.7	24
	170	6	13.7	24
15	100	0	20.4	55
	155	3	20.4	55
	195	6	20.4	55
20	130	0	24.8	70
	180	3	24.8	70
	210	6	24.8	70
25	150	0	27	84
	190	3	27	84
	240	6	27	84

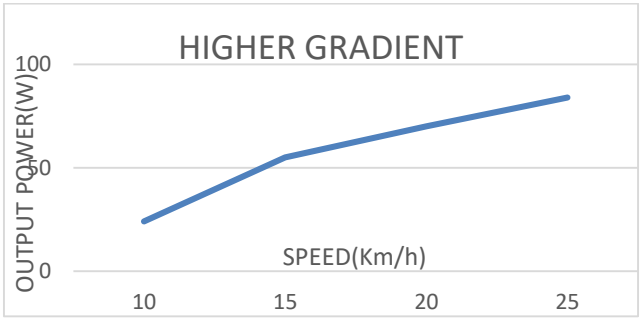

FIGURE 9: OUTPUT POWER VS SPEED

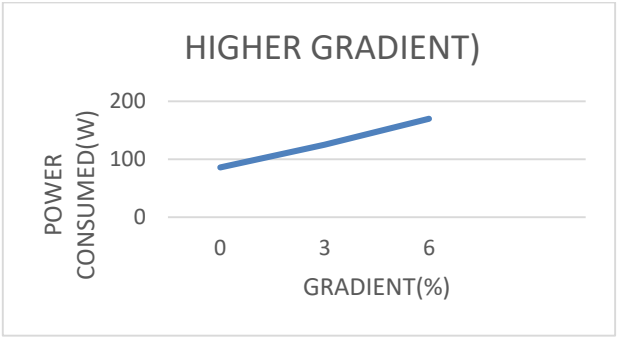

FIGURE 10: POWER CONSUMED VS GRADIENT

The high gradient test results are shown in the table 1. When the vehicle moving at a speed of 10 km/hr the power consumed by the battery is 86 watts and the power regenerated is 24 watts, at 0 gradients. When the gradient is, power consumed will be more but the power regenerated is same. And this is similar for all the speeds at which the vehicle is moving.

The figures 9 and 10 above shown are the characteristics of higher gradient tests. in the graph of output power vs speed the curve is linearly increasing, it means when the vehicle is moving at higher speed ,then the power regenerated is high. And in the graph of power consumed vs gradient, as the gradient is increased the more power should be given to the battery in higher gradients. Our project gives an economical solution for the energy

crisis. Since the output power regenerated is high at the higher speeds. The main disadvantage of the E-Bike comes when the vehicle is moving in the higher gradients like uphill, more power should be given to the bike so that it can move fast.

TABLE 2: LOWER GRADIENT TEST RESULTS

SPEED (Km/h)	POWER (Watts)	GRADIENT (%)	OUTPUTVOLTAGE(Volts)	OUTPUTPOWER (Watts)
10	86	0	13.7	24
	50	3	13.7	24
	35	6	13.7	24
15	100	0	20.4	55
	75	3	20.4	55
	45	6	20.4	55
20	130	0	24.8	70
	80	3	24.8	70
	65	6	24.8	70
25	150	0	27	84
	100	3	27	84
	70	6	27	84

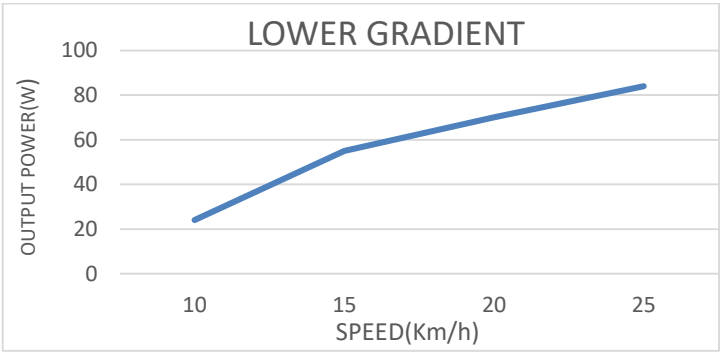

FIGURE 11: OUTPUT POWER VS SPEED

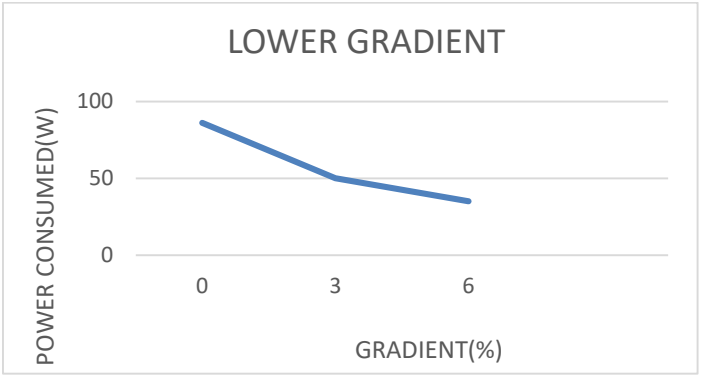

FIGURE 12: POWER CONSUMED VS GRADIENT

The low gradient test results are shown in the table 2. When the vehicle is moving at a speed of 10km/hr the power consumed by the battery is 86 watts and the power regenerated is 24 watts at the 0 gradient. When the gradient is increased, the power consumed by the battery will be decreased. And the power regenerated is same.

The figures 11 and 12 shows the characteristics of lower gradient tests.in the graph of output power vs speed, the curve is linearly increasing. It means when the vehicle is moving at higher speed, then the power regenerated is high. And in the graph of power consumed vs gradient, as the gradient is increased the power given to the battery is decreased in lower gradients. The advantage of the E-Bike when it is moving in lower gradients like downhill, the battery consumes less power. Hence E-Bike gives more economical solution.

Typical Self-recharging E-Bike:

The connection of our E-Bike is as follows , this E-Bike shown in figure 13 consists of one mid drive BLDC or Brushed motor, Battery bank, Battery controller, Automatic static switch or manual switch, Two HUB Generator and Rectifier and Voltage Regulator. Battery bank have two or more number of batteries, each one is of same rating. The two HUB generators fixed at two hubs of E-Bike which generate an electricity when E-Bike is running. The E-Bike running by the electric motor, which will be powered by one of electrochemical battery among the battery bank. When E-Bike is at running condition the two HUB generator start generating electricity (AC).The generated AC can be converted into DC by means of rectifier. This DC power is used to charge another battery in the battery bank. The process ensures extent the range of E-Bike and it can repeat any number of times.

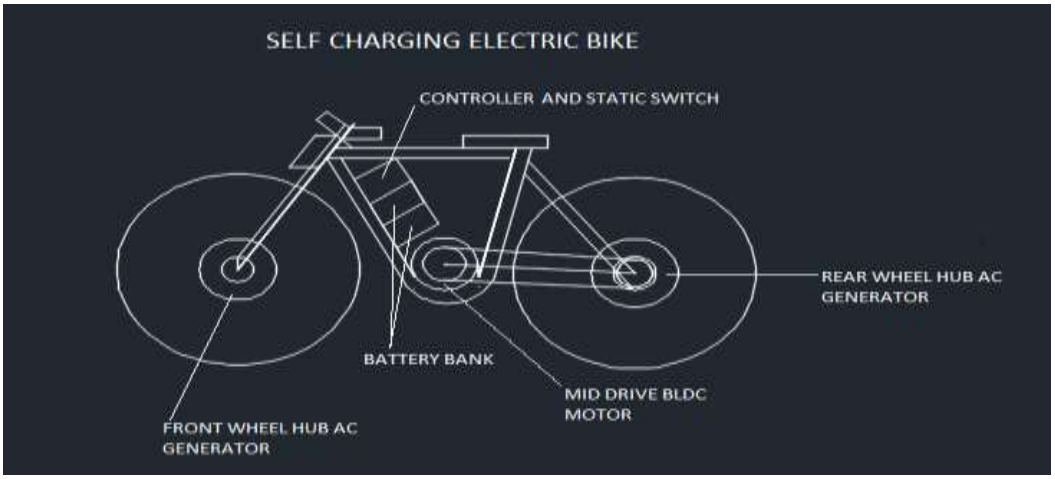

FIGURE 13: TYPICAL SELF RECHARGING ELECTRIC BIKE

V. CONCLUSION

Design and analysis of Self-Recharging E-Bike is presented. Our designed Self-Recharging E-Bike, where the batteries can be charged continuously while the E-Bike is in running condition, so that E-Bike can travels longer distance. The main drawback of limited range of conventional E-Bikes is solved by our project. Our E-Bike can run double distance range as compared to the conventional E-Bikes. As results the E-Bikes can also use for longer transportation rather than limited for short transportations. Our E-Bike partially independent on external power supply and it may be used for charge free transportations. It is free from pollution so it can help to reduce global warming. In the future years all petrol bikes are replaced by E-Bikes and this reduces fuel energy crisis. The analysis of power consumption and power output of the Self-Recharging E-Bike are presented in the paper for both lower gradient and higher gradient test. Our E-Bike project offers 50% lesser running charges compared to conventional E-Bikes. The E-Bike also provides a safety to rider because of its speed is limited.

VI. REFERENCES

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