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Self – Rechargeable Electric Cycle for Rural Cargo Mobility

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Abstract*: This paper proposes the design and development of a self-recharging electric cycle tailored for rural cargo mobility. The concept integrates renewable energy sources to ensure sustained operation in remote areas with limited access to charging infrastructure. By harnessing solar or kinetic energy during operation, the cycle autonomously replenishes its battery, enhancing its practicality and reducing reliance on external power sources. The proposed solution addresses the challenges of rural transportation, offering a sustainable and efficient means of transporting goods in off-grid environments.*

Keywords: electric cycle

I. INTRODUCTION

India is the developing country from many years, because of the issues like population, poverty, pollution etc. To be developed country these parameters should be controlled or we should find an alternate solution for this. Focusing on the subject like pollution, this year India became the fifth most polluted country among 117 countries, regions and territories around the world, assessed. The country's annual average PM2.5 levels reached **58.1 micrograms per cubic meter** (µg/m3) in 2021, returning to pre- quarantine concentrations measured in 2019. To resolve this problem Indian government is promoting the alternate fuels such as hydrogen cars, ethanol-based cars, hybrid vehicle, Electric Vehicles, etc. Among all these alternatives, EV is playing an important solution. In recent years, the increased sensibility for environmental problems and the growth of carbon dioxide has brought greenhouse effects. People have been focused on the energy issues and promoted the use of less-polluting vehicles, such as electric Vehicles.Nowadays Indian market is full of EV vehicles like cars, bikes, scooters, and cycles. But also, in the 21st century the progress of electric vehicles is slowing down because of some reasons like lower battery range, Inadequate charging infrastructure, cost of an electric vehicle, less awareness in rural areas. Looking toward the issue of charging infrastructure as the number of electric vehicles on road will increase the numbers of charging infrastructure will also increase. To promote the number of vehicles charging stations, Indian government is providing subsidies to entrepreneurs. The second issue of the cost is an important factor for the development of the vehicle. The 50% cost of the electric vehicle is covered by the cost of its batteries. Still for the batteries India is depended on the countries like China and Korea. To control the cost of EV's the batteries should be manufacture in India itself. As time elapsed all these problems will get solved automatically but except the core problem of electric vehicle like improving battery range which needs to be studied by group of educated engineersIn rural areas of India, the development of electric vehicles is less as compared to the urban areas; this is because of less awareness. Still there are many if and buts in mind of rural peoples with electric vehicles. Due to the limited exposure and information about electric vehicles, rural residents are not familiar with the benefits, cost savings, and advancements in EV technology. In rural areas farmers can be the largest consumer of EV if a vital solution is provided. On Daily basis farmers have to carry a bulky can of milk from his farm to the dairy. Not only the milk cans, the grain sacks, grass bundles, wood, sacks of fertilizers, pesticides and seeds are being carried by the farmers with many difficulties. Indian farmers are not as rich as each of them can by own tractor or other cargo vehicle to carry these entire luggage's. So, they have to call the cargo vehicles by baying rent among group of 4-5 farmers.Not only in rural areas same problem of carrying luggages is being faced in urban areas with cycle or human rickshaw drivers and lorry pullers. In cities like Delhi, Allahabad, and Nagpur the tourist use to travel by cycle rickshaw for a shorter distance and these rickshaw drivers must pull all these loads without and artificial power source. No doubt cycling is good for your

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health, but excessive cycling can cause a harmful effect in human body. The same things happen with lorry pullers as they pull 200 to 300 kg load on their cart without any help for their bread and butter. Both peoples have to take lot of efforts to complete their work without care of their health.By concerning all above mentioned issues there is a need to provide a best solution for betterment of these peoples, which will help to reduce poverty and to increase development rate of India. Based on the research available the solution is to design and manufacture an electric cargo tricycle which will be self-rechargeable. A cargo tricycle means a cycle with attached trolley. The aim is to carry 170 kg load. 170 kg load in the sense 70 kg weight of the passenger, 70 kg weight of the cargo / luggage, and 30 kg self-weight of the tricycle. The electric cycle in the market is dependable on external charging; it means the driver has to look out for vehicle charging stations while driving. The function which we are providing is to recharge the batteries of the tricycle with the help of wheel rotation by using charging units like dynamo or alternator. From the previous research the alternator is capable to charge only 8 to 10% of the battery, which is the main issue with it. By extracting and researching on the solution the charging percentage can be increased by 15 to 25 % of overall battery capacity. This solution will help to make awareness in the rural areas about the electric vehicle that the range of travelling is maximum, dependency of charging infrastructure, less fear of battery explosion, most useful product for cargo vendors, which will help to reduce the human efforts.

II. LITERATURE REVIEW

Avesh Khan Et.al. Manufactured a bicycle trolley which is a motor less wheeled frame with a hitch system for transporting cargo for bicycle. It can greatly increase a bicycle cargo capacity. The trolley may be required for a specific use, such as the transport of passengers or the movement of a particular type of cargo, or it may be needed as a general-purpose goods carrier. The trolley has been in existence since a very long time and has been providing human with ease of carriage of loads rather than carrying it by themselves.

Rupesh Nair et.al. Designed and fabricated a hand truck/trolley that can be connected to the front part of a bicycle which would convert the bicycle into a tricycle in a way such that the cycle can be used as a bicycle trolley which can be used for outdoor purchasing as it can carry more load compared to the commercially available bicycles. This trolley can be detached from the cycle and can be used as our primary cart.

Prof. M. P. Wasnik et.al. Published a paper which deals with the modification of luggage trolley. It is all to increase the load carrying capacity and reduce human efforts to carry the load. The extra component used for modification of the trolley consists of dynamo and motor which helps in reducing human efforts to carry load. Addition of extra wheels distributes the load and hence load carrying capacity increases. We are going to use the renewable energy produced by the dynamo to run the motor. The mechanism we are using promises to carry a good sum of load with fewer efforts.

Shimamura et.al. Studied the performance requirements of advanced batteries for EV or HEV application, focusing in particular on the critical aspects of the battery thermal design and construction for system stability. It also explains how the power output of the lithium-ion battery has been substantially improved for application to HEVs.

Deng, Da studied Li-ion batteries which are the powerhouse for the digital electronic revolution in this modern mobile society, exclusively used in mobile phones and laptop computers. The success of commercial Li-ion batteries in the 1990s was not an overnight achievement, but a result of intensive research and contribution by many great scientists and engineers. Then many efforts have been put to further improve the performance of Li-ion batteries, achieved certain significant progress. To meet the increasing demand for energy storage, particularly from increasingly popular electric vehicles, intensified research is required to develop next generation Li-ion batteries with dramatically improved performances, including improved specific energy and volumetric energy density, cyclability, charging rate, stability, and safety. There are still notable challenges in the development of next-generation Li-ion batteries. New battery concepts have to be further developed to go beyond Li-ion batteries in the future. In this tutorial review, the focus is to introduce the basic concepts, highlight the recent progress, and discuss the challenges regarding Li-ion batteries. Brief discussion on popularly studied “beyond Li-ion” batteries is also provided.

Jenish, Candida et.al. Studied Brushless direct current (BLDC) motors are frequently used in dynamic applications. A Brushless DC Motor is similar to a Brushed DC Motor, except that as the names indicate, they are electronically commutated rather than using brushes for commutation. Brushes are utilized in conventional brushed direct current motors to transmit power to the rotor while they rotate in a fixed magnetic field. Small Brushless DC Motors have flourished as a result of current power electronics and microprocessor technology, both in terms of price and performance. This paper will discuss the history of BLDC motors, their different types, construction, operating principles, and several control mechanisms for driving BLDC motors in various industrial applications.

Salah, Wael et.al. Studied brushless (BLDC) motor control based on rotor position sensing scheme is discussed in this paper. A PIC microcontroller is employed to generate pulse width modulation (PWM) signals for driving the power inverter bridge. Parameters required for power PWM generations have been programmed, which provide flexible and online source code modifications in accordance with the motor and circuit requirements. Hardware implementation and simulation results show the effectiveness of the developed motor drive. The flexibility offered by the developed motor control and drive enables the implementation of difference control algorithms for improving the output characteristics of the BLDC motor.

Mazlan, Rozdman et.al. Had done an energy audit on alternator's current output and battery's voltage based on alternator speed. Up until today, the demand for power in automobile is ever increasing. As technology advances, more and more electrical devices were produced and being installed in vehicles. To cope with the demand, alternator has been designed and modified so that it can produce enough power. This research is to study the effect of alternator speed to the charging system. The car used in this experiment is Proton Preve 1.6 Manual. In both ISO 8854 and SAE J 56, alternator testing and labeling standards indicate that the rated output an alternator is the amount of current that it is capable of producing at 6,000 RPM. Three different constant speed of engine which is 750 RPM as idle speed, 1500 RPM and 3000 RPM as cruise speed were taken as parameter. The speed of the alternator was measured using tachometer, digital multi-meter was used to measure battery's voltage, and AC/DC Clamp was used to measure alternator current output. The result shows that the faster the alternator spin, the more power it can produce. And when there is more power, the faster the charging rate of the battery.

Adamiec, M et.al. Discussed the methodology of testing an alternator at a stand to determine its energy efficiency. The efficiency was calculated on the basis of the measurement of the electric power supplied to the drive motor and the power generated by the alternator, taking into account the mechanical and electrical losses of the motor and the belt drive. The efficiency of the machine as a three-phase synchronous generator, without rectifier and voltage regulator, was also determined in order to assess the influence of electronic components on the overall efficiency of the machine. The tests were performed for various rotational speeds and loads. Various physical factors and phenomena that have a negative impact on the efficiency of energy conversion in the vehicle electrical supply system are discussed.

Et.al manufactured system for automatic generation of energy required to run a bicycle by providing an alternator to recharge continuously a battery of said bike. First, we are using the existing model of electric vehicle it is run on the electric capacity of battery. After that we provide the magnetic alternator to generate power for the battery charging. In self-recharging unit due to the magnetic effect which provide the constant rpm for the rotation of alternator which produces the electricity which is use for the charging of battery. After rotation of the alternator, it should generate the electricity at the rpm of near about 3000rpm and when electricity generated after that the battery should charge on the electricity which provide by the alternator. For the purpose of alternator rotation, we provide torque for the same bicycle pedal operation to initially rotation of the same alternator after that due to magnetic field effect of the alternator it should be rotated at near about 3000rpm.

Shubham U. Tayde et.al. manufactured a electric vehicle which is very important our fast life for traveling and this is also playing very important role in growth of economy but main drawback this bike and vehicle is produce pollution in environment because of burning fuel. For this reason, increases global warming and also storage of fuel is limited. Due to that now days need of eco-friendly technology for traveling .e-bike (electrical bicycle) this is nothing but one example of eco- friendly technology but this technology having some drawback to overcome the drawback of e-bike I have develop now design self-power generating electrical bike. This design overcomes all the drawback of ebike. Self-power generating electrical bike is nothing but the self-power generating bike that generate own power by using some arrangement of equipment and drive the bike without any external energy. This type of bike no need to any external energy just like fuel or charging of battery by externally .this is charge internally without any effect on operation of self-power generating electrical bike.

EVTIMOV, Ivan et.al. Constructed an experimental electric bicycle for evaluation of the energy efficiency. The bicycle is equipped with board computer which can store the information about motion and energy consumption. The result Concerning power, energy consumption, recharging during brake process, etc. are given. Energy consumption for 3 typical city routes is studied.

GIRISH B KALLIHAL et.al. Described a traction system useful for an autonomous Electric Vehicle of individual use. The developed system is constituted in a first approach by two different power sources: one is constituted by batteries and the other by the dynamo. This paper describes a technical solution joining and accomplishing the usage of two energy storage systems in the same traction system. In the developed system, the dynamo run as element that store energy temporarily and that can be used to retrieve energy. Starting from the functional characteristics of typical electrical vehicles and characterization of a typical routing profile, the energy consumption is obtained. In order to characterize and design the system, this is described in detail, namely the battery, the dynamo, the power converters and the implemented strategy of control. According to the obtained results, a control strategy that allows an effective management of the stored energy in the system regarding the vehicle's optimal functioning and increasing its autonomy is also presented and discussed.

Zhang, S et.al. Studied a method for estimating the efficiency of electric bicycle power train systems consisting of typical components, such as an electric motor, gears, sprockets, and chains is presented. To calculate the efficiency of a power train system, the relationship between the drive motor torque and the road-load that is exerted on the rear wheel was derived, considering kinematic inertia effects and friction losses between power transmission elements. Among the factors that influence efficiency, it was found that friction losses play a dominant role, while the effects of inertia are insignificant. The factors that influence the efficiency of electric bicycles due to friction losses, such as the transmission efficiency of the chain system and the bearing in the sprocket and wheel, were quantified. To validate the proposed efficiency calculation procedure, an experimental electric bicycle was used, in which the driving torque and road-load could be quantitatively assessed, and the actual efficiency was measured on a chassis dynamometer. It is shown that for a given motor torque, a measured and estimated dynamometer torque obtained by the proposed method exhibits a good correlation, and the transmission efficiency of each component was quantified. This method provides a practical and accurate means to calculate the drive train efficiency of electric bicycles at the design stage to improve the efficiency of electric bicycles.

Nagaraj Sindagi et.al. Designed and analyzed 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 Ebike has the longer distance range for same battery capacity (per charge) of present E-Bike.

III. AIM & OBJECTIVES

Aim –To Manufacture a Self-Rechargeable Electric Cycle for Rural Cargo Mobility

Objectives –While executing this project our objectives will be –

- Increasing the self-charging efficiency of the E cycles
- Manufacturing a cycle which will be able to carry a 70 kg cargo wei
- Building a minimum cost product
- Vision to reduce air pollution (Green India)
- Improving Battery Management System
- Reducing Human Effor

IV. METHODOLOGY

The solution for the mentioned problem will be the electrified cargo tricycle which will not be dependable upon external battery charging rather the recharging of the battery will be done using inbuild system such as alternator or dynamo. As

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the dynamo is not capable to generate large amount of electricity the focus will be on the alternator. To execute such idea the methodologies will be as follows.

Electrical System –

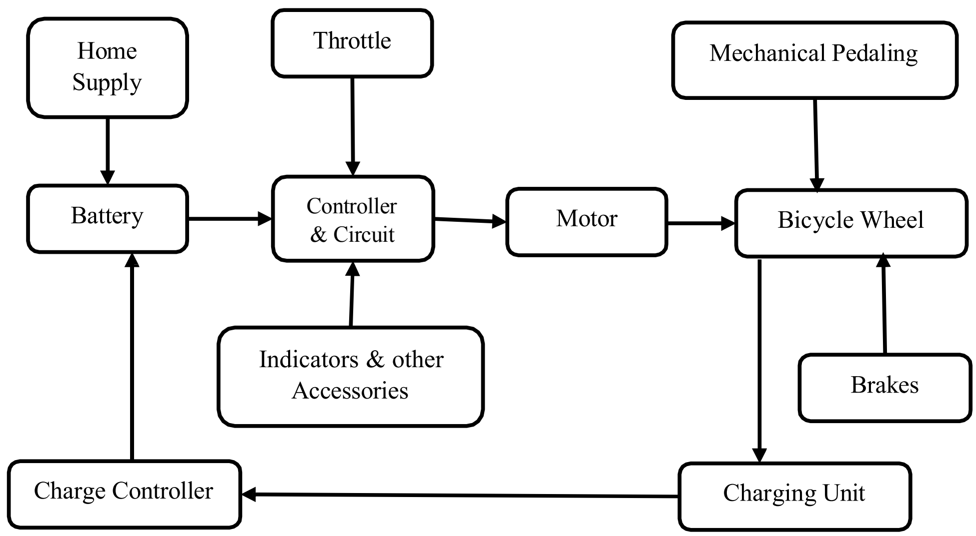

Fig 1. Electrical system

Essential System Components

Motor –

As per the requirement that motor must be able to carry the 170 kg load with the full speed of 25 km/hr the motor must be powerful. By Design calculations mention in the next section the motor we are going to use will be the 1000 W Brushless DC motor. It will be the hub motor (Assembled within the tire assembly) mounted to the front wheel of the cycle. We have chosen front wheel to assemble the motor to get higher starting torque and higher speed.

Fig no 2. BLDC Hub Motor

Battery –

As per the motor specification the battery should be capable to provide enough amount of voltage. So, by the calculation we decide to use Lithium-ion battery because of its advantages like High energy density, Low maintenance, Performance and longevity, Versatility, Improvement of safety performance. The Power output of the battery will be 48v voltage and 24ah current. As per the calculation battery is capable to drive the motor.

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Fig 3. Lithium Ion Battery

Controller

Generally, here the controller is supplying a voltage to the motor to drive it, and the motor is generating a back emf, proportional to its speed. If the motor goes faster, its back emf rises and the current (caused by the difference between the controller's output voltage and the motor's back emf) falls. If the motor speed very fast, then the current falls to zero, as back emf equals controller's output. It the motor goes even faster than the current must go negative (feeding back into the controller), as the back emf is now greater than the controller's output voltage. So, braking starts to occur. The controller must do something with this current. Crude designs simply dump it as resistive heating, but it is more efficient (and not difficult) to feed the current back into the battery.

Fig 4. Charge Controller Connections.

Charging Unit – The Alternator

An alternator is a key component in the generation of electrical power in various applications, most notably in automobiles. Its fundamental purpose is to convert mechanical energy, often derived from an engine's rotation, into electrical energy. As per the requirements we are going to use alternator used in Maruti Suzuki Swift car

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Figno.4 Charging Unit

Charge Controller – The Voltage Regulator

A voltage regulator is a critical component in electrical systems, tasked with maintaining a stable and controlled output voltage within a specified range. It plays a crucial role in various applications, including power supplies, automotive systems, and generators. There are different types of voltage regulators, such as linear and switching regulators, each with its own characteristics. Linear regulators use a series pass element to regulate voltage, while switching regulators rapidly switch the input voltage on and off, providing higher efficiency. The primary functions of a voltage regulator include ensuring voltage stability, regulating the output despite changes in load or input voltage, and providing protection mechanisms against overvoltage and undervoltage. Some regulators also include features like current limiting and temperature compensation.

Working Principle –

In this electrical system, the tricycle is propelled by a motor powered by a battery. As the wheels rotate during movement, this mechanical motion is harnessed by an alternator connected to the wheel rotation. The alternator converts this mechanical energy into electrical energy. The generated electrical energy is then used to charge the battery, creating a closed-loop system.The battery initially provides electrical power to the motor for tricycle propulsion. Simultaneously, the rotation of the wheels activates the alternator, transforming mechanical energy back into electrical energy. This electrical energy is rectified to direct current and used to recharge the second battery. AS the first working battery get discharged the battery swapping will get placed and the vehicle will be driven by the second battery. Consequently, the system maintains a continuous cycle of converting between electrical and mechanical energy, ensuring a sustained power supply for the motor and other electrical components as the tricycle moves.If somehow battery get discharged the tricycle can be driven and charged by means of mechanical pedalling, the chance of happening such incidence is about 1% only

Mechanical Arrangement

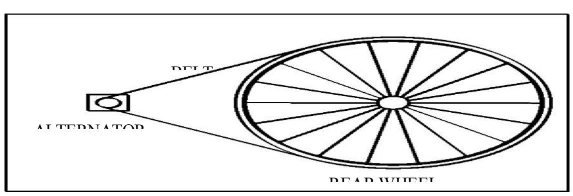

Fig 5. Alternator Arrangement

Here the tricycle will look like an ordinary tricycle with back trolley only the change we have made to increase the recharging efficiency is to be attached extra rim to rear wheels which will act as a large pulley. The belt on the rim will be attached to the alternator pulley (rotor). This system will make multiple rotations of alternator against one rotation of the wheel

V. DESIGN CALCULATIONS

Human Effort

Human effort to move a bicycle in a steady state = Speed x (Gravity force + Air drag force + Rolling resistance force + Wheel bearing resistance force + Bump resistance force + Wheel air resistance force)

Gravity force = 0 N (because the slope is zero)

Air drag force = 1.93 N (assuming a density of air of 1.2 kg/m^3, a cross- sectional area of 0.5 m^2, a drag coefficient of 1, and a speed of 10/3.6 m/s)

Rolling resistance force = 8.33 N (assuming a coefficient of rolling resistance of 0.005 and a normal force of 170 x 9.8 N)

Wheel bearing resistance force = 0.5 N (assuming a coefficient of wheel bearing resistance of 0.0003 and a normal force of 170 x 9.8 N)

Bump resistance force = 0 N (assuming a smooth surface)

Wheel air resistance force = 0.1 N (assuming a density of air of 1.2 kg/m^3, a wheel radius of 0.35 m, a wheel width of 0.03 m, a drag coefficient of 0.5, and a speed of 10/3.6 m/s)

The total resistance force is the sum of these forces, which is 10.86 N.

The power output is then equal to the product of the speed and the resistance force, which is 30.11 W.

This means that the minimum human effort required to move a bicycle having a total weight of 170 kg at a speed of 10 km/h on a flat surface with no wind is 30.11 W, which is about 0.18 W/kg of power.

Electrical System Calculation

Motor

As mentioned earlier, consider the combined weight of the tricycle and the load.

Let's assume it's 170 kg (70 kg load + 70 kg human weight + 70 kg tricycle). As we wan to drive tricycle ot the speed of 20 km/hr = 5.56 m/sec

Rolling resistance - Rolling resistance is the force required to overcome friction between the tires and the road. It depends on factors like tire type, inflation, and road surface. Let's assume a rolling resistance coefficient of 0.02.

Rolling Resistance = Rolling Resistance coefficient * Weight

= 0.02 * 170 * 9.81

= 33.27 N

The total force (F) required to move the tricycle at a constant speed on a level surface is the sum of the force needed to overcome rolling resistance and the force needed to accelerate the tricycle (assuming no incline or headwind):

Acceleration force = Weight * Acceleration

= 170* 0.556 = 94.52 N

Total Force = Rolling Resistance + Acceleration Force

= 33.27 + 94.52 = 127.79 N

Torque = To calculate the torque required at the wheel (without considering a gearbox), we need to know the radius of the wheel (r)

T = F * r

T = 127 * 0.3 … (Assuming wheel radius 250 mm = 250 mm) T= 31.9475 N m

Rotation per Minute

RPM = [Speed (m/s) * 60] / Wheel circumference

Where,

Wheel circumference = 2 * π * r

= 2 * 3.14 * 0.25

= 1.57 m

RPM = (5.56 * 60) / 1.57

= 212.69 RPM

Power Output = (Torque * Angular Speed) / 9.5488
= (31.95 * 212.69) / 9.5488
= 0.7115 KW
By the calculation 800 W motor is sufficient but going on safer side we decide to use
1000 W BLDC motor.

Battery Requirement
Energy consumption = 711.5 W
Vehicle travelling range 50 km.
Total Energy Required
= power * Time
= 711.5 * (50,000 m / 20000 m/hr)
= 1778.75 Wh
Battery Efficiency
Assuming 20 % loss
Total energy with efficiency = 1.2*1778.75 Wh = 2134.5 Wh
Battery Capacity
= Total energy / Battery voltage … (assuming 48 V)
= 2134.5 / 48
= 44.47 ah

EXPECTED OUTCOMES
After finalization of the project our Expected outcome will be –
Increase in self-charging efficiency by 15 to 20%.
Increase in range of the vehicle.
Carrying 70 kg load with max speed

EXPECTED PROJECT COST
By considering the component cost & manufacturing cost as compared to available electric cargo cycle our overall cost will be,

Parameters	Available Market Product	Proposed Product
Overall cost	Rs 150000	Rs 70000 to Rs 80000

Table 1. Project cost comparison

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