BASIC WORKING OF ELECTRIC VEHICLE AND PRIDICTION MODEL ON ELECTRIC CONSUMPTION AND CRUISING DISTANCE OF AN ELECTRIC VEHICLE

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ABSTRACT: This paper summarizes the basic working of an electric vehicle. Various components are described with detailed working. While developing Electric Vehicle, it is essential to know the characteristics of electricity consumption, cruising range, etc. It is difficult to predict various characteristics because of varying driving condition and no detail specification of these terms by manufacturer. In this paper a prediction method to construct these approximate characteristics from the given data.

Key Words: Induction motor, Electric vehicle, Invertor, Regenerative Braking, Single speed transmission, Differential, Cruising range, heat transfer.

INTRODUCTION:

Due to adaptation of various environmental friendly norms and due to increase in environmental concern, many automobile manufacture are shifting to pollution free locomotive systems. This led to an increase in demand of electric vehicles. Electric vehicle is as old as gasoline engine vehicles, but due to cruising range and limited technology at that time they eventually went out of race. By the year 2025 European countries are aiming towards 100% electrification/ Hybridisation of automobile. Either Hybrid or fully electric. Various advantages of electrical vehicle is it emits '0' emission, moreover with state of the art technologies such as Higher torque output, Lower vehicle weight, replacement of LSD (Limited Slip Differential) and use of Li-ion batteries it is becoming replacement for Gasoline vehicles. In this paper I have developed a prediction method model with many factors taken into account such as practical driving condition's with heating air condition and various other factors to predict the cruising range of an electric vehicle. The only major disadvantage of an electric vehicle is its cruising distance. So I decided to prepare a model predicting various conditions. An electric vehicle basically consists of an induction motor, invertor, battery pack, gearbox, regenerative braking system and many more.

1.1 INDUCTION MOTOR

An induction motor is the main driving member of electric vehicle. It generally consists of a magnet and conducting coil. It works on the principle of induced current and flemings right hand rule. There are many types of induction motor used in automobile. For example- DC Brush Motor, DC Brushless Motor, Permanent Magnet Synchronous Motor, three Phase AC Motor. The most advanced type and preferred now a days is AC Three Phase motor. Earlier DC brushless motor were used. A three phase AC motor consists of a Stator and a Rotor. Rotor is collection of conducting bars short circuited by end rings. A stator is 3 coil winding and a 3 phase AC current is supplied to it. The stator has slots into it through which coil windings are passed. A stator is made up of thin steel laminates to reduce eddy current losses. When 3 phase current passes through it the stator produces a RMF (Rotating magnetic Field) [2] . This rotating magnetic field then induces current on rotor bars and causes it rotate (Faradays Law) Faraday's law states that "A current will be induced in a conductor which is exposed to a changing magnetic field". Similarly it will produces a force which will turn the Rotor (Lorentz Force Law). Lorentz Force law states the "Whenever a moving charged particle is in the presence of a magnetic and electric field the Lorentz force law tells us that the total force from these fields acting on the charged particle is equal to the sum of the electric and magnetic forces." The main advantage of induction motor is it neither has brushes nor a permanent magnet (Which are costly and involves a complex method for production). Rotor speed and RMF speed plays a major role in Induction motor For RBS(Regenerative Braking System) and for reverse gear in automobile.

1.2 Battery Power Pack

DC current is stored in Electric vehicle battery. The most widely used battery in Electric vehicle is Li-ion Battery. The main component of Electric vehicle battery comprises of basically 3 elements. First ANODE(Mostly made of Graphite), Second CATHODE(Various combination of metals are used), Third Electrolyte Solution (Lithium Salt). The Anode is made up of Graphite which has high electrochemical potential, it means it can store more amount of electrons. On the other hand on cathode which consists of various combination of metals such as Lithium+ aluminum +cobalt +magnesium are used in various combination depending upon requirements. The Cathode has the tendency to release the Electron (Due to Lithium present in it) and the Anode Attracts it due to Graphite. When we press the accelerator pedal and induction motor comes into action the Stored electrons and Lithium ions stored in Graphite moves towards cathode due to difference in higher and lower potential [3]. The current stored in the battery and when the vehicle is in motion heats up and needs to be cooled. Therefore a glycol solution is passes through the outer surface of the batteries, then this heated glycol is cooled in radiator and again passed through the battery power pack

1.3 INVERTOR

The main function of the invertor is to convert the DC current from the battery into AC current. The battery is connected to invertor and the invertor is connected to the induction motor. The speed of the induction motor is controlled by varying the frequency of AC power supply which is done using Controllers in Invertor. The controller in the invertor will change the frequency and Wavelength of Sine Wave pattern, which will in turn control the induction motor torque, speed, etc. A typical 4 switch circuit is used to convert DC into AC. It produces a Square wave pattern and the edges of square wave pattern are dangerous, therefore to increase fast switching application we use special electronic components such as IGBT, MOSFET. This components are connected to a controller which in turn regulates and controls the switching speed, thereby controlling induction motor speed. “Pulse Width Modulation” technique is generally used. The controller Decides the time through which the current will pass a specific loop [4] . The current is reversed around 60 times per second or 60 Hertz. Thus by this conversion a Square wave is converted into a sinusoidal wave. The more the fast switching of DC current by the controller the smooth AC current we can obtain.

1.4 REGENERATIVE BRAKING SYSTEM

The main advantage of an electric vehicle is its ability to convert the brake energy(which is typically wasted in an gasoline car) into electrical energy and then stored in the battery. Regenerative braking system uses the cars kinetic energy and converts it into electrical energy. During the regenerative braking the same induction motor acts as a generator. When the car accelerates the Rotor speed of induction motor is always less than that of rotating magnetic field. If the rotor speed is greater than rotating magnetic field then the system act’s as generator and converts the rotating shaft (mechanical energy) into electrical energy. This will generate electricity in the stator coils. A controller is also used to measure the amount of electricity which can be stored in battery to avoid over charging, therefore cars are also fitted with disc or drum brakes for completed and immediate halt.

1.5 GEARBOX

Rotational Torque produced by the induction motor is transferred to drive wheel through a gearbox. There are mainly 2 components of a electric vehicle gearbox. First a single speed transmission, second differential.

1.5.1 Single speed transmission

Unlike gasoline engine which used mostly 7 speed gearbox, an electric vehicle uses a single speed gear box. Single speed transmission is used because they have very broad revolution range and can produce torque at even lower RPM. They usually have a higher gear ratio(Mostly above 10:1 gear reduction). Because Motor speed goes up to 20000 RPM in an induction motor, as compared to gasoline engine which is about 7000 RPM. Single speed gearbox eliminates Crankshaft, Layshaft, Dog clutches, Flywheel, counter weight for balancing which seriously reduces weight [5]. The less components the more will be transmission efficiency. A single speed also aids in Regenerative braking, otherwise a 7 speed gearbox will not efficiently charge the battery as a single speed gearbox.

1.5.2 Differential

More advanced version of Limited slip differential is used in modern electric vehicle. The main reason is the correct tractive effort. Electronic limited slip differential are used, they have a controller and several sensors such as steering wheel sensor, wheel sensor, motor speed sensor. All these sensors collectively send the signal to controller and the torque division is accurately measured. It consists of a pinion gear attached to ring gear. Spider gear are attached to ring gear and engaged with a side gear. More over series of friction and steel plates are placed between side gear and due to axial thrust of bevel gears, the plates move together and torque is transferred. Also the space between the side gear is fitted with a pre-loaded spring for additional force on Clutch mechanism. Now a days in tesla cars they used an open differential fitted with various sensors and a single controller, as the open differential has less parts and is more rugged and can carry more torque and high RPM of induction motor [5] . Traction problem in open differential can be tackled by various method such as selective braking or introduction of an small induction motor.

2. DRIVING PERFORMANCE PREDICTION MODEL

$P_{drv} = P_{rr} + P_{ad} + P_{acc} + P_{gr}$ ...

Where, P_{drv} -power to drive, P_{rr}-Dynamic friction resistance component, P_{ad}- Air resistance, P_{acc}- Acceleration component, P_{gr} – gradient component.

$P_{rr}=u_r*m*g*v$

Where, u_r-Rolling friction coefficient, v- vehicle speed, m-mass, g- Gravity

$P_{ad} = ½d*C_d*A*V^3$

C_d- Air resistant coefficient, A- Frontal projection area, d- density

$P_{acc} = [(m+m_p+m_r)/2] *dv^2/dt$

$P_{gr}=0$, if gradient is considered zero.

Inertor generates heat while conversion of DC into AC current. N_{iv}- Invertor efficiency.

Friction loss in Motor and driveshaft, N_{tm}- transmission efficiency.

Total energy consumed (E_{drv}), $E_{drv}=P_{drv}/(N_{iv}*N_{tm})$

Around 35% battery energy is consumed by Air conditioning (E_{ac}) and Auxiliary devices(E_{aux})

Electric energy consumed, (E_{cons}) = $E_{drv}+E_{ac}+E_{aux}$

Considering Regenerative braking during deacceleration, $E_{dcc}=R_r*[(m+m_r)/2]*dv^2/dt$, where R_r is regeneration ratio.

Final equation, $E_{cons}=-E_{dcc}*N_{iv}*N_{tm} + E_{ac} + E_{aux}$

2.1 Evaluation conditions for driving performance

In this report, driving performance such as electricity costs and cruising distance is evaluated

Evaluate when running in specific driving cycle is shown in FIG 1.

Both city driving and high-speed driving are included.

The vehicle is 1200 seconds and the vehicle speed per second is specified.

The cruising range travels by repeating these cycles

Calculated assuming that it was detected under the heating conditions in winter.

When discussing, outside temperature is -4 ℃, relative humidity is 81%

The ventilation rate of air conditioner is 200m^3.

Evaluation was performed assuming the condition of / h.

Average speed- 24.2km/hr, Mileage-8.09 km.

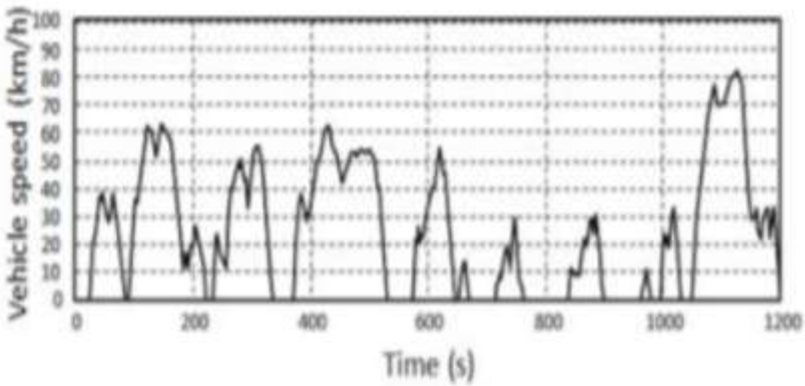
2.2 Calculation of remaining battery power and cruising distance

Battery remaining capacity and cruising distance with time step width Δt = 1 second. Electric energy stored in batteries now (Q_s), Maximum electric energy stored in batteries (Q_c), Unit at time t = Δt × i

When the electric energy consumptioned per hour is $E_{cons\ i}$,

At time step n (Q_s) At t = 0, ($Q_s=Q_c$). Is obtained by the following equation [6].

$$Qs = Qc - \sum_{i=1}^{n} (Econs\ i\ * \Delta t)$$



2.3 Characteristic identification method from published data

Table 1- Specification of a typical hatch back electric car

Coeeficient of aerdodynamic drag	C_d	0.275
Rolling resistance of tyre	ur	0.0063
Mass of vehicle	m	1445
Body width	w	1765
Body Height	h	1555
Battery capacity	Q_c	24kw/hr
Cruising distance	X_d	225km

When calculating driving performance, the specifications that cannot be obtained directly of m_r, η_{tm}, η_{iv} R_r, E_{aux}

The approximate value can be estimated from approximation

Vehicle has fewer rotating parts such as transmissions than internal combustion engine

It was estimated to be a small mr = 0.05 ·m.

Power consumption of external electrical components, controllers, computers and lights(E_{aux})

Assume the longest cruising distance assuming power consumption

E_{aux}= 30W during power saving conditions, during winter night heating

Estimated as E_{aux} = 100W.The total energy conversion in the motor efficiency is up to 97-98%.

It is taken 95% on average = 0.95. The power transmission efficiency is slightly higher than that of internal combustion locomotives.

Considering that it is good, η_{tm} = 0.95.

The R_r is inherently dependent on braking conditions

Here, R_r is constant for simplicity.

R_r = 0.35 here, the cruising range is Xd = 235km

2.4 Calculation method for heat balance during heating

Heating of car under the driving performance evaluation conditions. Based on driving performance of the 60 min. Here, the heating device is assumed to be a PTC heater and assume that 100% heat energy is converted. It is taken into consideration that heat is released from body and window glass of the vehicle. The heat transmissivity k during heating is the heat transfer coefficient of the vehicle body surface, h_{co}, heat of vehicle interior wall and transmission rate is h_{ci}, Heat transfer rate of body and glass are k_b and k_g, heating effect on vehicle interior wall. If the transmission rate is h_{ci}, the following equation is obtained [1].

$$K=1/[1/h_{co} + 1/k_b + 1/h_{ci}]$$

Considering the amount of outside air introduced for air conditioning is V_{ac} = 200 m^3/h. The vehicle interior temperature was maintained at 25 ℃. The number of passengers is five, and the sensible heat component of the passenger 's is per person 69W.It will contribute to heating. K_b and k_g are common to all parts, and average value kb = 1.6W / m^2K, kg = 200W / m^2K is used. h_{co}=25km/h and h_{ci} are flow rates

3. CONCLUSION

In this paper we discussed about various major parts of an electric vehicle that are different from conventional gasoline vehicle. Studied about induction motor working and laws governing it. We came across lithium ion batteries and its working principle. Invertor technology and conversion of DC to AC. We studies why a single transmission gearbox required and different types of differential and its working. We calculated a prediction method for cruising distance with considering various factors such as gradient, driving pattern, heat transmission on body, introduction of air due to air conditioning and heat of per person for more realistic approach and realistic outside and inside vehicle temperature.

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