A Project Report Stage-II

on

SMART ELECTRIC TRACTOR

Submitted in Partial Fulfilment for the Degree of **Bachelor of Engineering** in **Electrical Engineering** by

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2021-22

CERTIFICATE

This is to certify that the project report entitled

"A SMART ELECTRIC TRACTOR"

submitted by

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is a record of Bonafide work carried out by them under my guidance in the partial fulfilment of the requirement for the award of the degree Bachelor of Electrical Engineering Savitribai Phule Pune University, Pune.

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"**A SMART ELECTRIC TRACTOR**"

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Declaration

We hereby declare that the work presented in this project report entitled "**A SMART ELECTRIC TRACTOR**" is an original work carried out by us under the supervision of **Prof. Dr. Sharad Dhamal**, Electrical Department, K. K. Wagh Institute of Engineering Education and Research, Nashik.

We further declare that work reported in this project report is our original and independent work and has not been previously submitted to this or any other University for the award of the degree, diploma, associate-ship or any other similar title.

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Rachcha Anish Anil

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Abstract

Due to the environmental threats associated with the combustion of fossil fuels the hike in fuel prices and, everyone is looking for an alternate energy sources to propel the vehicle. One such solution is the adoption of electric vehicles, which accounts for high degree of sustainability as compared to the conventional fuel vehicles. This work presents the working prototype of a Smart Electric Tractor. Description of the subsystems which includes the steering system, braking system, electric powertrain, and the chassis frame will be delineated precisely. Major focus will be to infuse IOT in dynamics and its automation. Design calculations will be carried out to obtain an optimized powertrain.

Keywords: Adoption of electric vehicle, Electric powertrain, IoT in automation.

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CHAPTER 1:

Introduction

Increasingly massive range of cars and fossil gas-primarily based totally mobility in use round the arena are inflicting extreme fitness problems, deteriorating air high-satisfactory and developing worldwide warming issues. Progressively greater rigorous emissions and gas performance requirements are stimulating the competitive improvement of safer, cleaner, and greater green vehicles. Electric mobility the use of renewable reassets of strength is the important thing to a sustainable destiny with substitute of fossil strength reassets within side the lengthy term.

The worldwide call for for meals and different agricultural merchandise is growing due to growing human population. Farmers are going through developing stress to boom productiveness in line with hectare across the world. Climate alternate in addition to strict law to be used of insecticides and chemical fertilizers worsen this stress. In this context, function of virtual technologies, IoT and hi-tech farm equipment the usage of renewable strength come to be inevitable to make farming smarter and profitable. Sustainable agriculture with optimization of farming approaches and most usage of system and sources is the important thing for survival in agricultural enterprise and upload price within side the agricultural price chain.

Agriculture region make use of big equipment and automobiles for numerous responsibilities and tactics to be executed. Tractors may want to carry out responsibilities successfully and constantly for numerous hours, thereby significantly lowering the time required for planting, irrigating, developing and harvesting. This has ended in elevated crop manufacturing with better frequency. Traditionally, like several different automobiles, agricultural automobiles are Internal Combustion (IC) engine-primarily based totally machines and consumes big quantity of fossil gas and as a result make contributions good sized quantity of pollution into the surroundings. Lack of right pollutants manipulate policies of agricultural automobiles and terrible upkeep compounds the surroundings pollutants as a result of such automobiles. There is an pressing want for electrification of farm equipment.

1.1 Motivation

The aim of this project was to overcome flaws in conventional tractors and to give a contribution in greener, cleaner and economically stable country. To the reduce fuel consumption, electric tractors are important for farming. It operates on batteries, making farming easy and economical. Even as farming income is to some extent boosted by the use of technology, more can be done to lessen the burden on the farmers.

1.2 Scopes

Beyond this working prototype model, advanced technology can be opted to extend battery life, infusing solar in the system can be one lookout, battery pack can be compacted.

1.3 Objectives

The objectives taken into consideration while working on this project are:

1. **Environmental concerns**
   The conventional tractors emit fumes that are very hazardous for the user as well as for the environment. Also the depletion of fuel is itself a threat to the environment and this battery operated tractor does not raise concerns of degradation of environment.

2. **Reducing Manpower**
   These tractors would reduce the work load and extra efforts of the farmer since plan is to make the tractor smart, the physical involvement of the user will be reduced and they can easily operate the vehicle remotely.

1.4 Literature Survey

In [1], Hans Heinrich Vogt and Daniel Albiero studied changes required for agricultural programs in faraway regions with or without getting admission to the grid, the electrical tractor gadget affords the choice to make use of regionally generated renewable strength. In equatorial areas with a dependable and low-price strength supply withinside the shape of a PV-plant, the idea of an electric powered tractor represents already these days an financial and technical viable answer the usage of exchangeable battery packs.

The essential technical undertaking is with different electric powered automobiles to shop enough electric strength at the tractor for an extension of its working time. On the opposite hand, financial competitiveness with similar combustion engine tractors is a prerequisite for the project’s success.

In [2], Ilhoon Yoo, Taehyung Lee, Gyeongeun Kim, Byeongwoo Kim, Jin Hur have studied the changes in version electric tractor’s machine and riding elements the use of version-primarily based totally layout (MBD) and an car simulation version (ASM). Conventionally, researchers have used empirical tactics or have analyzed partial elements of the machine so one can broaden an electrical tractor. It involves making use of MBD to the elements and whole machine of the electric tractor, it were subsequent to non-existent. Therefore, they used the Simulink-primarily based totally ASM and the Carsim, which simulate and interpret the dynamic traits of tractors, and analyzed the layout elements of an electrical tractor. By simulating the riding machine and undertaking a real check of the electric tractor, decided whether or not the electric tractor is appropriate substitute for the prevailing mechanical tractor. This may want us to function the idea for studies at the complete dynamic interpretation vital for designing an electrical tractor and can also offer hints for designing an electrical motor-primarily based totally machine.

In [3] , Diego Troncon, Luigi Alberti, Silverio Bolognani, Federica Bettella, Alberto Gatto have observed feasibility for the electrification of off-avenue vehicles mainly farming tractor for specialised software in orchard and vineyard. In such an software the operating cycle isn't that trivial after which the machine layout isn't straightforward. Specialized tractors are characterised through compactness, this contain a venture in the hybridization because of confined area to be had for electric powered components. Therefore, the reason is to locate the desired performances for the electrical machine and to show the electrification feasibility via initial layout and thermal evaluation of a proper electric powered motor. The hybridization degree is moderate hybrid and the powertrain structure is parallel hybrid.

In [4] , Shahriar Sharifan, Seyyedmilad Ebrahimi, Ashknaz Oraee and Hashem Orae have carried out extensive study about Hybridization of vehicles. Hybrid electric powered cars are getting extra famous because of environmental consciousness. Hybrid electric powered cars include a combustion and an electric powered motor. In practice, the impact of choosing suitable electric powered motor is observable on all the principle indices of automobile overall performance consisting of most speed, gradeability, pollutant emission, gas consumption, etc. Different research was accomplished to evaluate diverse electric powered machines working as vehicles or generators. However, investigating the overall performance of electrical vehicles as electric powered traction structures in hybrid electric powered cars has now no longer been emphasised in literature. In this paper, the overall performance of induction and PM vehicles were investigated in hybrid automobile software via simulation results, reaping benefits ADVISOR software.

In [5], Swaraj Ravindra Jape, Archana Thosar the upcoming technologies for better efficiency and comparison of E vehicles with conventional ones has been discussed,. Electric automobiles with better power efficiency, low renovation price and pollutants unfastened operation, are imparting excellent opportunity to famous traditional IC engine automobiles. Also, with the development in technology, electric powered car producers are capin a position to conquer the conventional drawbacks of electrical automobiles, making it increasingly appropriate for cutting-edge day transportation. A motor in an electric powered car offers the important pressure for the propulsion of a car, which makes it the coronary heart of electrical automobiles. Different sorts of electric powered cars are in comparison on the idea of positive parameters

which ought to be taken into consideration for choosing a specific motor kind for electric powered car application. Comparison is tabulated for a few parameters. Also, function graphs of various cars are protected at a few points.

In [6], Nasser Hashernnia and Behzad Asaei have studied exceptionally well electric powered vehicles and a comparative study of different motors. There are 5 principal electric powered motor types, DC, induction, everlasting magnet synchronous, switched reluctance and brushless DC vehicles are studied. It is concluded that despite the fact that the induction vehicles generation is greater mature than others, for the EV packages the brushless DC and everlasting magnet vehicles are greater appropriate than others. The use of those vehicles will bring about much less population, much less gas intake and better strength to quantity ratio. The lowering costs of the everlasting magnet substances and the fashion of growing performance withinside the everlasting magnet and brushless DC vehicles lead them to an increasing number of appealing for the EV packages.

In [7], Mr. Anurag M. Lulhe, Mrs. Tanuja N.Date various drives used in Electric vehicles and hybrid electric vehiclcle is discussed. These electric powered cars are pushed via way of means of an electric powered motor can be AC or OC fed via way of means of battery via electric powered converter. The diverse drives used for the EVs & HEVs are mentioned on this paper. The primary forms of pressure primarily based totally at the deliver are used OC or AC pressure. The AC drives inclusive of 3 segment everlasting magnet synchronous motor (PMSM) is maximum famous among them. The different broadly used drives are 3 segment Induction motor (IM), Switched reluctance motor (SRM), Brushless OC motor (BLDC). These motor are fed via way of means of one of a kind strength digital converters together with OC-OC converter, OC- AC converters in line with the deliver requirements

In [8], P. Enrici (Member IEEE), N. Boubaker, D. Matt have studies the layout of a strong bar winding for everlasting magnet synchronous motor devoted to the electrical power of a complete electric powered tractor. The desire of a seventy-five Vdc low-voltage strength distribution calls for resorting to a strong bar winding with 1 bar in step with slot (unmarried turn). This sort of motor operates at excessive frequencies (as much as 1600 Hz). Hence, the strong conductors burn up extra copper losses (better AC resistance). An evaluation of those extra copper losses became accomplished to as it should be investigating the powerful AC resistance of the winding and, hence, the performance of the electrical motor. The tractor prototype and the traits of its electric powered motor had been provided here. A complete scale prototype of the electrical tractor became synthetic and examined on actual situations with a view to validate the layout.

In [9], Jacek Caban, Jan Vrabel , Branislav Šarkan , Janusz Zarajczyk, Andrzej Marczuk have chalked out the needs of electric tractors for farms and presents the possibilities of developing electro mobility in this sector of the economy. Questionnaire was presented, data were collected from those working in the agricultural sector. The data will be used to gauge attitudes and opinions towards alternative power systems implemented in agriculture.

1.5 Problem Definition

The existing issues with the conventional tractors in use today and they are:

1. **Fossil fuels:** In India, almost 97% of vehicles are dependent on petrol or diesel for working.
2. **Global warming:** Nearly 43% of greenhouse gases are contributed by transportation i.e. by use of combustion vehicles.
3. **Cost:** Again 97% vehicles in India uses petrol, diesel or CNG and the inflating fuel prices are not kept undercover.

The agenda behind actualisation of this idea is to overcome these flaws in conventional tractors and to contribute in greener, cleaner and economically stable country. The vehicle will be designed such that it meets all required functionalities as well as making it affordable and useful for the farmers. The IC engine of conventional tractors will be electrified along with it we will merge IOT to switch the tractor to an autonomous vehicle.

1.6 Methodology

MECHANICAL SYSTEM SCHEMATIC

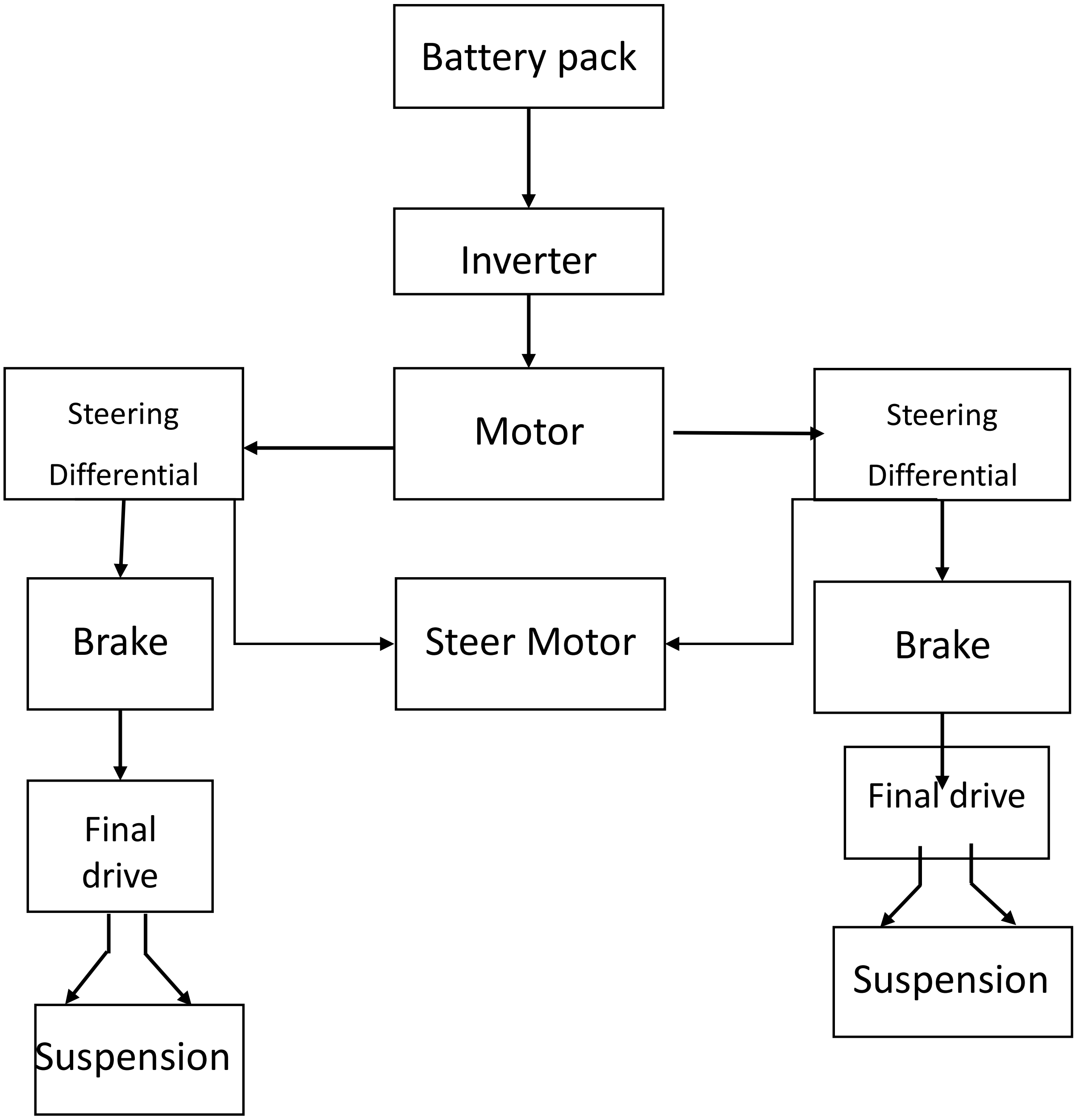

Fig 1.1 Mechanical System Schematic

Fig.1.1 shows the general block diagram of the mechanical system of the vehicle. The main power source is the battery which is shown which powers the motor through an inverter because the motor being used is an induction motor and power source is a DC source. The motor provides power and torque to the differentials and these differentials rotate the wheels. The steering is also coupled by the differential itself. These differentials are directly linked to the braking system. The final drive has suspensions coupled to it.

Fig. 1.2 Electrical System Schematic

Fig. 1.2 shows the electrical subsystem schematic The power source here is the grid power we receive. The charger symbolises the charging path from the grid to the battery pack. The charging power is monitored by the Battery Management System(BMS) and thereby given to battery pack. The battery delivers power to motor and controller. The controller gives signals to control the motor functioning's. The motor then powers the differentials for propulsion.

1.7 Organization Of Report

Chapter-1 gives brief introduction of the entire project, scopes and objectives, literature survey of the research papers that have been referred to. The problem which is identified in the referred papers are also illustrated in Chapter 1.

Chapter-2 gives a detailed insight to the different subsystems that constitute the whole model. **Chapter-3** gives the mathematical modelling applicable subsystem.

Chapter-4 gives a summarised brief about all the hardware specifications.

Chapter-5 gives the final implementation visuals

Chapter-6 Conclusion

CHAPTER 2 : System Over View

2.1 Introduction

This chapter will give a brief idea about the subsystems used in the project. The main idea is to emulate the same performance as of conventional tractor. To emulate such kind of performance the following subsystems are required. This project is diverged into the main system and their respective subsystems that are:

1. Electrical System
2. Mechanical System
3. Electronics System

Fig, 2.1 shows complete overview of the entire system

In this schematic block diagram subsystems of various systems are outlined. Basically this system consists of three major systems that are Electrical system, Mechanical system and Electronics system. In electrical system Motor and Battery components are discussed and in Mechanical system, Chasis, Drivetrain and Tyres are discussed.

Elucidation of the system is given below.

2.2 System Over-view Block Diagram

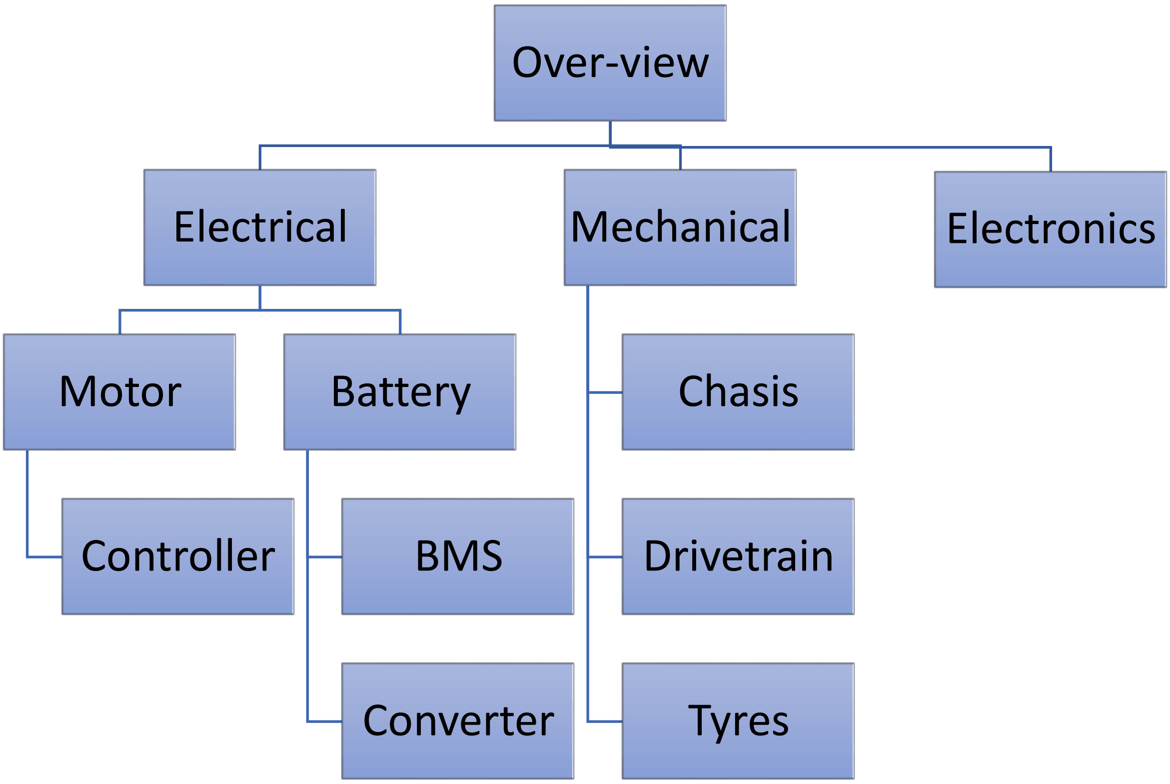

Fig.2.1- Block diagram

Fig 2.1 Shows the overview of block diagram of the system. The system consists of three major subsystem. Electrical, Mechanical and Electronics. Electrical subsystem consist of motor, battery, motor controller, BMS. Mechanical subsystem consist of chassis, drivetrain and tyres.

2.3. Electrical Subsystem

2.1Introduction

In this section, the aspects that need to be considered while selecting electrical components are discussed.

1. MOTOR

Low weight and excessive energy density is a prime attention in electro mobility. The maximum not unusual place traction vehicles for car packages are synchronous vehicles or induction vehicles while synchronous vehicles are favoured due to their benefit concerning energy density and weight. But every of the motor principles has its blessings and disadvantages. With this adaption it's miles viable to lessen the load and because of this defining parameter the induction motor has in precis extra blessings as compared with the synchronous motor. Therefore it could be the higher desire for electro mobility. Due to excessive beginning torque and coffee inrush modern consistent with NEMA standards, Design D turned into maximum appropriate option.

Power-to-weight ratio for electric powered vehicles is typically calculated the use of the height strength of motor. Power-to-weight ratio for an electric powered motor is received via way of means of dividing the height strength output of motor in KW via way of means of weight of motor in Kg. Unit of strength-to-weight ratio of motor is KW/Kg. A motor with better strength-to-weight ratio is extra appropriate for EV application. Same kind of motor with equal rankings is designed and synthetic in a different way via way of means of exclusive electric powered motor producers and for this reason there may be a moderate distinction of their weights. Here, we can recall imply weight of motor to calculate their strength-to-weight ratios. Now, if we recall exclusive sorts of electric powered vehicles with equal strength, voltage and pace rating

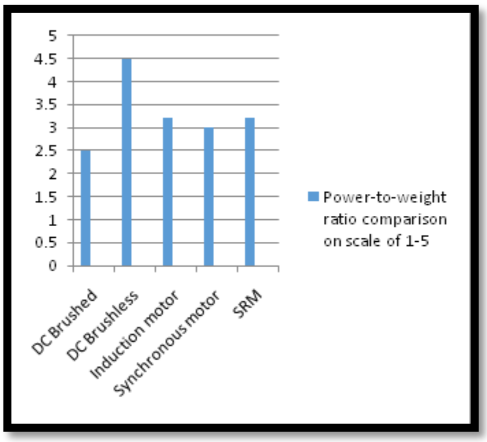

Fig 2.2 Power-to-weight ratio comparison
[Ref.**-** P-ISSN: 2395-0072]

Figure 2.2 depicts Power to weight ratios of various of electrical motors. DC Brushless motor clearly leads the graph followed by Induction motor.

2. EFFICIENCY

Motor is an electromechanical device which converts electrical energy into mechanical energy. Whole of input electrical energy is not converted into mechanical energy but is lost due to various factors. Electrical efficiency of an electric motor gives us relation between electrical input and useful mechanical output of motor and is generally given by ratio of shaft power output and motor input power. Generally, all electric motors are designed to operate at maximum efficiency at rated output of a motor. When an electric motor is used in electric vehicle, motor will be operated at different loads. Therefore, peak efficiency and efficiency at different loads of a motor must be considered before choosing it for an electric vehicle application. Efficiencies of different electric motors at peak load and at 10% load

Table 2.1 Motor Efficiency Comparison
[Ref. p-ISSN: 2395-0072]

Motor Type	Peak Efficiency (Percent)	Efficiency at 10% load (Percent)
DC Brushed Motor	85-90	80-85
DC Brushless Motor	>95	70-80
AC Induction Motor	>90	>90
Synchronous Motor	>92	80-85
Switched Reluctance Motor	<95	>90

Fig 2.1 shows the comparison between different motors.

3. CONTROLLER

Cost of Controllers Motor controllers are an important part of drive system of an electric vehicle. Motor controller in electric vehicles offers improved performance, efficiency and controllability. If an electric vehicle manufacturer wants to build a low cost electric vehicle, then choosing a low cost controller would eventually affect his choice for motor. For low voltage electric motor widely used in electric vehicle cost of controllers of different electric motors with same voltage and output power ratings, is as shown below.

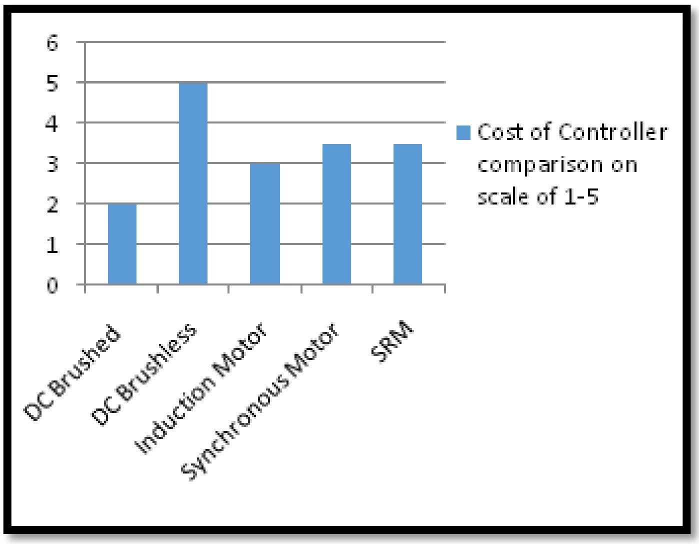

Fig. 2.3 Controller cost comparison
[Ref. p-ISSN: 2395-0072]

Figure 2.3 depicts Controller cost comparison. DC Brushless motor controller clearly the highest of all other controllers in the graph. Induction motor comes third in this comparison, which is a better choice for this purpose.

4. COST OF MOTORS

One of the important challenges ahead of electric vehicle manufacturers is to provide consumer with an electric vehicle which is as good as gasoline vehicle but within an affordable price. Cost of different electric motors with same voltage and output power ratings are compared as shown below.

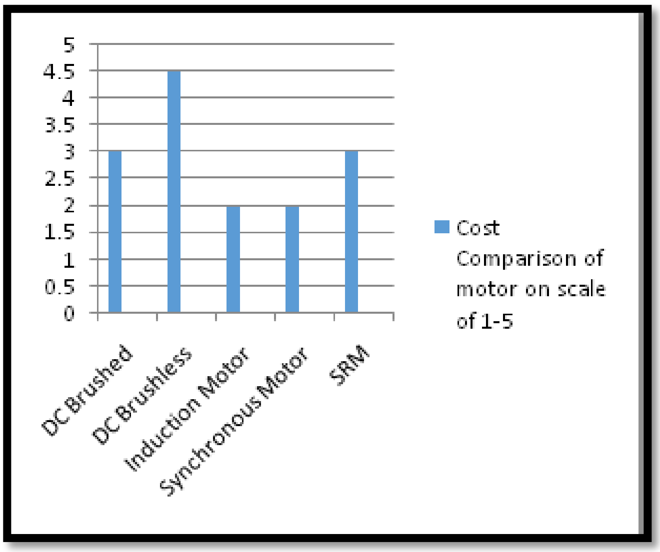

Fig.2.4 Motor Cost Comparison
[Ref- p-ISSN: 2395-0072]

Figure 2.4 depicts Motor cost comparison of various of electrical motors. DC Brushless motor clearly the costliest of every other motor. Induction motor is the cheapest among all these which is also suitable for the purpose.

5. BATTERY

Because the terminal voltage of lithium primarily based totally cells is 80 % to 300 better than different normally to be had chemistries, cells using lithium provide a far better electricity density, each gravimetric and volumetric than all different non-exotic, rechargeable battery chemistries. While the amp-hour ability of the numerous lithium cells is comparable to NiMH and NiCd, the electricity density of lithium is a good deal better because of the better terminal voltage. This function is the overriding purpose for the arrival of lithium primarily based totally batteries in EVs in current years.

Table 2.2- Comparison of various cell chemistries

[Ref.- P ISSN: 1938-8756]

Battery Chemistry	Energy Density (Wh/kg)	Terminal Voltage (Volts)
Lead Acid	12.3	2.0
NiMH	46	1.7
NiCd	56	1.2
NiZn	75	1.7
LiMnO4	100	4.0
LiFePO4	100	3.3
LiNiO2	130	3.6
LiCoO2	140	3.7

Fig 2.2 shows comparison of various battery chemistries

2.2 Conclusion

After considering all the options of Motor and Battery. The motor choose here is 3 ph Induction motor because of its high starting torque and low starting current.

And Battery chemistry choose is Lithium Ion Phosphate (LiFePO4).

CHAPTER 3 : System Modelling

3.1 Introduction

System modelling is required while designing a vehicle so as to select the right motor and battery ratings to suit the area of application.

This section puts forward the calculations that were made to select the right components,

Mathematical Model

- Force calculations

Rolling resistance is gien by **m xg x μ**

(m=mass, g= gravitational constant,u= Coeff of resistance)

Grade Resistance = $m x g x \sin(\text{Ø})$

(m=mass, g= gravitational constant, Ø=inclination angle)

Aerodynamic force = $0.5 x \rho x v^2 x x C_d$

(ρ=Air density, V= velocity, A= Frontal area, C_d= Coeff of Drag)

- Performance Calculations

V=$r\ x\omega$ (r= radius of tyre, ω=angular velocity)

ω= $(2\pi N)/60$ (N= r.p.m)

T=Fx (perpendicular distance)

$\mathbf{P_w}$= $(2\pi N T_w)/60$

Transmission Ratio = $(\omega_{motor})/(\omega_{wheel}) = (T_{wheel})/(T_{motor})$

$\mathbf{T_m}$ (gross) = T_m/motor efficiency

$\mathbf{P_m}$= $(2\pi N T_m)/60$

I_m = P_m/(Battery voltage)

- Battery Pack Calculations

Battery Power = Motor power/ Battery voltage

Battery Current = Battery power /Battery voltage

N_{series}= Battery Voltage / Cell Vtg

$N_{Parallel}$ = Battery capacity / Cell Capacity

N_{total} = $N_{Parallel} x N_{Series}$

Volume of cell = $(\pi d^2 x l)/4$

Cell energy = (Nominal vtg) x (cell Capacity)

Vol. energy density= Cell enrygy/Volume

Gravimetric energy density = Cell energy / mass of cell

Cell current = Capacity$x$c-rate

Cell power = Nominal voltagexCell current

Volume of battery = Total cells$x$vol of cell

Battery Maximum voltage = Maximum voltage$x N_{series}$

Battery Minimum voltage = Minimum voltage$x N_{parallel}$

ACTUAL MOTOR MODELLING

Assumed parameters

m(vehicle)=500kg m(person)=80 kg Supplementary weight=200kg

m(total)=780 kg

Max speed v=5km/hr Diameter of wheel= 18 inch

Frontal area=1095x1500=1.64m^2

CASE 1: PLAIN ROAD

In this case velocity is considered as 5 km/hr , coeff. Of friction is considered as 0.02 and inclination angle is considered 0 degree.

V= 5 km/hr = 1.39 m/s

RR = mxgxCrr = 780x9.81x0.02 =153 N

GR=mxg$x$sin(Ø)=580x9.81$x$sin0=0

Fa=0.5x (Air density) x (Coeff of drag) x AxV^2= 5N

Total Force= RR + GR +Fa = 158N

V=rxw w= v/r =1.39/0.23 = 6.04 rad/sec

w= (2$x$pi$x$N)/60 N= (60xw)/(2$x$pi)= 57.7 r.p.m

T = (Total force) x (Perpendicular distance) = 158x 0.23 = 36.34 Nm

P = (2$x$pi$x$NxT)/60 = 219.5 W

CASE 2: Road with Slope

In this case velocity is considered as 5 km/hr , coeff. Of friction is considered as 0.02 and inclination angle is considered 5 degree.

V= 5 km/hr = 1.39 m/s

RR = mxgxCrr = 780x9.81x0.02 =153 N

GR=mxg$x$sin(@)=780x9.81$x$sin5= 666.9 N

Fa=0.5x (Air density) x (Coeff of drag) xAxV^2= 5N

Total Force= RR + GR +Fa = 824.9 N

V=rxw   w= v/r =1.39/0.23 = 6.04 rad/sec

w= (2xpxxN)/60   N= (60xw)/(2$x$pi)= 57.7 r.p.m

T = (Total force)x(Perpendicular distance) = 824.9x 0.23 = 189.73 Nm

P = (2$x$pi$x$NxT)/60 = 1146.4W

CASE 3 ON MUD

In this case velocity is considered as 5 km/hr , coeff. Of friction is considered as 0.15 and inclination angle is considered 10 degree.

V= 5 km/hr = 1.39 m/s

RR = mxgxCrr = 780x9.81x0.15 =1147.7 N

GR=mxg$x$sin(@)=580x9.81$x$sin(10)=1328.7 N

Fa=0.5x (Air density) x (Coeff of drag) x AxV^2= 5N

Total Force= RR + GR +Fa = 2481.4 N

V=rxw   w= v/r =1.39/0.23 = 6.04 rad/sec

w= (2$x$pi$x$N)/60   N (wheel) = (60xw)/(2$x$pi)= 57.7 r.p.m

T (wheel) = (Total force) x (Perpendicular distance) = 2481.4 x 0.23 = 570.72 Nm

P(wheel) = (2$x$pi$x$NxT)/60 = 3446.7 W

MOTOR CALCULATIONS

Gear ratio = 50 Motor efficiency = 85%

Gear Ratio = Motor rpm/ wheel rpm = Wheel torque/ motor torque

Motor rpm = $50x57.7$ = 2885 rpm

Motor torque = 570.72/50= 11.4 Nm

Motor torque (after losses) = 11.4/0.85= 13.43 Nm

Motor Power = ($2x$pi$x$NxT)/60 = 4055.36 W = 4.055 kW

BATTERY CALCULATIONS

Battery voltage = 48V

Motor Power = 11.75 kW

Battery Power = $11.75x1.5$= 17.625 kW

Battery current = 17625/48 = 367 A

Battery Capacity = 277.8 x 1 = 367 Ah

CHAPTER 4: Hardware Specifications

4.1 Introduction

After Mathematical modelling, the next step is implementing on paper calculations on actual hardware.

Table 4.1- Specification Sheet

Sr no.	Parameter	Values
1	Vehicle mass	500kg
2	Supplementary mass	200kg
3	Velocity(max)	5km/hr
4	Radius of tyre	18 inch
5	Frontal area	1.65 m^2
6	Motor efficiency	85%
7	Gear ratio	50:1
8	Wheel Rpm	57.7 rpm
9	Motor Rpm	2885 rpm
10	Wheel Torque	570.72 Nm
11	Motor Torque	13.43 Nm
12	Wheel Power	3446.7 W
13	Motor Power	4055.36 W
14	Battery voltage	48 V
15	Battery Current	25 A
16	Battery Capacity	300 Ah
17	N_{Series}	13
18	$N_{parallel}$	15
19	N_{total}	195
20	Battery weight	150 kg

Table 4.1 represents the hardware specifications of the tractor.

CHAPTER 5: Implementation and Testing

5.1 Introduction

The on ground testing of the tractor has been carried out and the expected outcomes have been achieved. The tractor can be used for variety of purposes like ploughing, spraying medicines, carrying loads etc.

Fig. 5.1 Field Ready Tractor

In fig 5.1 Field ready Tractor is shown.

Fig. 5.2 Visuals from field

5.2 Result Table

Sr. No.	Specification	Remark
1	Charging Time	5 Hrs
2	Range	100 Kms
3	Operating Time	22 Hrs

Table 5.2 shows trial and testing of the electric tractor, output results are mentioned in the Result Table.Charger used is of 60W , therefore time needed to charge battery to its full capacity is 5 Hrs.Range is of 100 Kms.

CHAPTER 6: Conclusion

Until here it is clear that the motor and battery parameters have been calculated. The process of putting these on-paper calculations into actual use has been initiated and so far no shortcoming has been witnessed. The motor and battery, being the most important part of the powertrain, utmost care has been taken to avoid skipping any kind of applicable force and since the entire pulling load is on the motor, study has been done to be sure enough that sufficient torque will be generated.

Future Scope

1) Efficient Transmission System

   Transmission system can further be improved by implementing more gears of the ratio 15:1 or 10:1.

2) Solar Implementation

   Solar can be installed to charge LV system of the tractor.

3) Cost Reduction

   Cost reduction can be implied by using other battery chemistries which are cheaper.

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