PROJECT BASED LEARNING SYNOPSIS

On

“*Converting ICE four-wheeler to electric vehicle*”

DATE: 26/02/2022

Prepared by Team 7

S SARAVANAN – NOV

RAHUL RAJIV RANJAN – NOV

SUSHANT MAYEKAR – OCT

NITIN VITTHALRAO RANE- OCT

SHUBHAM KISAN SARPATE- OCT

Table of Content

List of Tables

List of Figures

Chapter 1: Details of the Team members

S.No	Name	Engineering Field	Occupation	Role in Project
1.	S SARAVANAN	Electrical and Electronics	Student	Calculations, Checking correctness, information gathering and Preparing synopsis
2.	SUSHANT MAYEKAR	Mechanical	Evaluator	Preparing synopsis and information gathering
3.	RAHUL RAJIV RANJAN	B.Computer science	Student	Preparing synopsis and information gathering
4.	NITIN VITTHALRAO RANE	Mechanical	Student	Thermal Calculation
5.	SHUBHAM KISAN SARPATE	Mechanical	Student	Thermal Calculation

Chapter 2: Project Description

Fig: 1

The objective of the project is to create a step-by-step process that can be repeated and used by others too converting an ICE vehicle to an Electric Vehicle by replacing its IC engine and fuel system with an electric motor coupled with a traction battery. It would be an effective way of reusing the IC engine vehicles then going to scrap for reprocessing and it also eco-friendly. The vehicle selected for project is Maruti Swift because it has low maintenance cost and decent interiors.

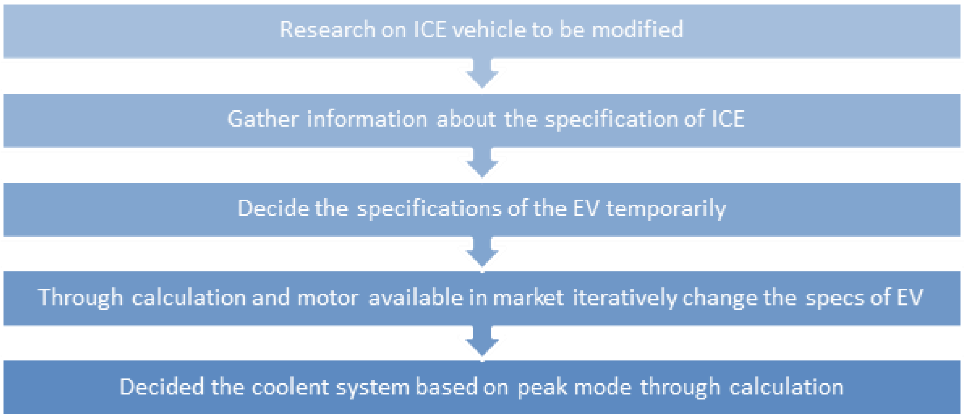
The conversion requires removing the engine from the car and all other associated hardware such as fuel tank, exhaust, starter, transmission system (excluding the final drive), clutch and the radiator.

As well as inclusion of traction motor, traction battery pack, BMS, charge port (On-board charger, External charger), power electronics controller, and vehicle control unit is needed.

Expected Krebs weight of the vehicle will be 1100kg (by removing the engine, cultch, transmission system (excluding final drive), fuel tank and engine control system).

Battery Chemistry is Li-ion (Panasonic cylinder cell) with capacity of 70Ah and voltage of 416V. The vehicle will have range of 170-210km (verified by MIDC) with top speed of 110km/h and acceleration time (0-100km/h) of 12.6 sec*.

Chapter 3: Research Methodology



This project began by surveying and researching available ICE cars in order to find the optimal ICE vehicle for the project.

Once a decision was made, the requirements needed for conversion were acquired.

Then, in order to get the EV up and running, assumptions were made about its specs. evaluated the forces operating on the vehicle to determine the traction force and torque needed for vehicle traction.

Motors available in market were researched, and EV parameters were altered based on calculations and available motors.

Battery capacity decided based on motor needs, range, and available space.

Finally, the calculation data is used to design the isolation and cooling systems.

Chapter 4: Calculation

Maruti Suzuki Swift (2021):
Power= 83BHP @6000 RPM
=61893.1W
Torque= 115 @4000 RPM
Mileage (on avg) =18km/L
Tires-185/65 R15
Top speed=165km/h
Acceleration time (0-100km/h) = 12.6 sec
Transmission type-Manual/automatic
Gear ratio (final drive) - 4.388
Kerb weight= 875-905 kg
Length

3845 mm
Width

1735 mm
Height (Unladed)

1530 mm
Front area =0.85*1.735*1.53
=2.26 m^2
Cd= 0.34
ICE---> Electric specification:
Battery voltage =416V
Chemistry- Li-Ion
Kerb weight= 1100kg (by removing the engine, cultch and transmission system (excluding final drive), fuel tank and engine control system)
Top speed =110km/h
Range=175-210km (Verified using MIDC)
Acceleration time (0-100km/h) =12.6 sec

Calculation:
Tire radius= 15in/2 +18.5*.65

=0.31m

Mass factor=1+0.04+0.0025Ntf^2

=1.0881

Total mass = (kerb mass*mass factor) + driver avg weight

=1100*1.0881+75

=1275kg

$F_{tract}= F_a + F_{rr} + F_D + F_g$

$F_{g=}0$ (considering travelling in flat surface)

F_a=m*a

=1275*100/ (3.6*12.6)

=2810.85N

F_{rr}=μ*m*g

=0.01*1275*9.81

=125.08N

F_D=0.5*ρ*C_D*A*V^2

=0.5*1.2*0.36*2.42*(110/3.6) ^2

=430.4463N

F_{tract}=3366.38N

While considering the gradient force F_g

$Theta_{max}$=15 degree

F_g=m*g*sin (Theta)

=1275*9.81*sin (15)

=3235.64N

As the car climb the uphill the velocity will be less on avg would be 30Km/h

So $F_{tract}= F_a + F_{rr} + F_D + F_g$ (while climbing up hill acceleration would be less round 0.3 to 0.5)

=635.955+125.08+32.02+2915.458 (Vehicle max Gradeability restricted to 9.8 based on excel calculation)

=2915.458N

While consider the max gradient at 30 km/h and 0.5m^2/s acceleration we get the as F_{tract}=3708.914, Power required = 31KW, and Torque required =1149Nm (but this case is every rare as max inclination in roads is 3 degrees and our motor can supply the required power and torque)

Vehicle Specifications								
kerb mass (kg)	1100							
g (m/s2)	9.81							
Roll Res µ	0.01		mass factor	1+0.04+0.0025Ntf^2	1.0881			
Cd (Drag)	0.34							
Dens ρ (kg/m3)	1.2		Driver and added mass (kg)	315			gradient max (degree)	0
Top speed(km/h)	90							
Acc(0-100Kmph)(m/s2)	1							
Tire radius	0.31		Total mass (kg)	1515				
Proj Area A (m2)	2.26							
Nf	4.388							
Drive cycle	MIDC-4W							
FORCES ACTING								
Fd(nm)	m*a	1515						
Frr(nm)	µ*m*g	148.6215						
Fg(nm)	0.5*ρ*C_D*A*V^2	288.15						
Fa(nm)	m*g*sin (Theta)	0						
Ft(nm)	Fd+Frr+Fa+Fg	1951.772						
Power and Torque requried								
Peak Power (KW)	Force*velocity	49						
Peak Torque (Nm)	Force*Tire radius	605.0492						

Fig: 2

Energy Consumption:

As per MIDC cycle the max speed is 90 km/h and for approx 20 min (1180 sec). As the vehicle limited with top speed as 110km/h, so the max speed in MIDC is consider to be 80km/h (advisable speed of the converted electric vehicle).

E_{avg}=94Wh/Km (without regenerative breaking)

E_{avg}=86.63 Wh/km (considering regenerative breaking of 30%)

$E_{total}= E_{avg} + E_{aux}$

$=86.63+30$

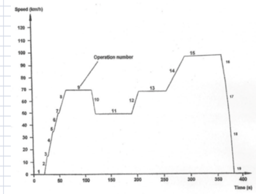
$\sim=117$ Wh/Km.

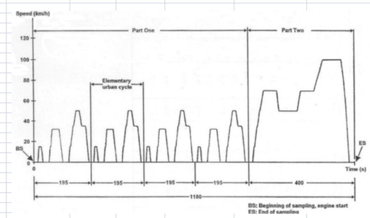
While consider all the factors

1) Passenger and luggage weight (75*4 kg+15kg)
2) Inefficiency
3) Considering DOD as 80%

MIDC

Vehicle Specifications	4-wheeler				
Mass (kg)	1515	wheel radius(m)	0.31	regen factor	0.3
g (m/s2)	9.81				
Roll Res μ	0.01				
Cd (Drag)	0.34				
Dens ρ (kg/m3)	1.2				
Proj Area A (m2)	2.26				
Drive cycle	MIDC-4W				





operation	Time	Velocity	Velocity	Acceleration	Gradient	Fa (N)	Frr (N)	Fd (N)	Fg (N)	F_{trac} (N)	Torque (Nm)	Average acc power Pa (W)	Prr (W)	Pd (W)	Gradient power at V/3 Pg (W)	Ptrac (W)	Traction Power (kW)		Energy with R%
	t(sec)	v (kmph)	mps		θ (deg)	Mdv/dt	Mgμ	0.5ρCd	mgSinθ	Fa+F_R+FD+I	Ftrac*r	Fa*(v/3.6)	Frr*(v/3.6)	Fd*v/3.6	Fg*((v/3)/3.6)	Pa+Prr+Pd+Pg	(F_{trac}, R*Ftrac when negative)*v	Ptrac*dt	
Idling	1	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000			
Idling	2	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	3	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	4	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	5	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	6	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	7	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	8	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	9	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	10	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Idling	11	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
Acceleration	12	4	1.0400	1.0400	0	1575.6000	148.6215	0.50	0.0000	1724.7202	534.6632	1638.6240	154.5664	0.5186	0.0000	1793.7090	0.896854484	0.000249	0.2491
Acceleration	13	7	2.0800	1.0400	0	1575.6000	148.6215	1.99	0.0000	1726.2161	535.1270	3277.2480	309.1327	4.1489	0.0000	3590.5296	2.692897184	0.000748	0.9972
Acceleration	14	11	3.1200	1.0400	0	1575.6000	148.6215	4.49	0.0000	1728.7094	535.8999	4915.8720	463.6991	14.0024	0.0000	5393.5735	4.494644564	0.001249	2.2457
Acceleration	15	15	4.1600	1.0400	0	1575.6000	148.6215	7.98	0.0000	1732.2001	536.9820	6554.4960	618.2654	33.1909	0.0000	7205.9523	6.305208269	0.001751	3.9971
Steady Speed	16	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	4.1781
Steady Speed	17	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	4.359
Steady Speed	18	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	4.54
Steady Speed	19	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	4.721
Steady Speed	20	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	4.9019
Steady Speed	21	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	5.0829
Steady Speed	22	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	5.2638
Steady Speed	23	15	4.1600	0.0000	0	0.0000	148.6215	7.98	0.0000	156.6001	48.5460	0.0000	618.2654	33.1909	0.0000	651.4563	0.651456307	0.000181	5.4448
Deceleration 1	24	12	3.4700	-0.6900	0	-1045.3500	148.6215	5.55	0.0000	-891.1772	-276.2649	-3627.3645	515.7166	19.2631	0.0000	-3092.3848	-1.019952264	-0.000283	5.1615
Deceleration 1	25	10	2.7800	-0.6900	0	-1045.3500	148.6215	3.56	0.0000	-893.1654	-276.8813	-2906.0730	413.1678	9.9054	0.0000	-2482.9998	-0.837342561	-0.000233	4.9289
Deceleration 2	26	7	1.8600	-0.9200	0	-1393.8000	148.6215	1.60	0.0000	-1243.5835	-385.5109	-2592.4680	276.4360	2.9667	0.0000	-2313.0653	-0.865534106	-0.00024	4.6885
Deceleration 2	27	3	0.9400	-0.9200	0	-1393.8000	148.6215	0.41	0.0000	-1244.7711	-385.8790	-1310.1720	139.7042	0.3829	0.0000	-1170.0849	-0.522803873	-0.000145	4.5432
Deceleration 2	28	0	0.0200	-0.9200	0	-1393.8000	148.6215	0.00	0.0000	-1245.1783	-386.0053	-27.8760	2.9724	0.0000	0.0000	-24.9036	-0.179305677	-4.98E-05	4.4934
Idling	29	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0.001486215	4.13E-07	4.4938
Idling	30	0	0.0000	0.0000	0	0.0000	148.6215	0.00	0.0000	148.6215	46.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	4.4938

Fig: 3a

idling	386	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	387	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	388	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	389	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	390	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	391	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	392	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	393	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	394	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	395	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	396	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	397	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	398	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	399	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
idling	400	0	0.0000	0.00	0	0	148.6215	0	0	148.6215	46.072665	0	0	0	0	0	0	0	639.2
		distance(m)	6312																

		DISTANCE	6.312		
		WH	639.2043239		
		TOTAL			
		DISTANCE(Km)	10.36	auxilary(wh/km)	30
		WH	998.2525072	inefficeincy	0.9
		WH/KM	96.31402656		
			mileage(km)	wh/km	137.0155851
battery E(kwh)	23400		170.78349		
total battery E(kwh)	29250		213.47936		

Fig: 3b

Etotal= 137Wh/Km.

<u>Battery packs calculation:</u>

Let's use Panasonic cylinder cell

Cell length =0.0653 m

Cell diameter= 0.0185 m

Cell Mass = 0.0485 kg

Cell Voltage= 3.6 V
Cell Capacity= 3.2 Ah
Internal Resistance= 45mΩ
Charging and discharging rate=1C
DOD =85%

Vpc=volume of cell

Vpc=π*(d/2) ^2 * L

= π*(0.0185/2) ^2 *0.0653

=17.55cm^3

E_{cell} =V *Ah

=3.6*3.2

=11.52Wh

E_b =$E_{avg * Range}$

=117*200 (Consider only with driver mass and without considering the inefficiency)

=23.4KWh

E_b (considering DOD% of 80) = 23.4/.8 (considering for worst for case scenario)

=29.25KWh

No. of cell in series =416V/3.6

~=116cells (for cell balancing)

No. of cell in parallel=23.4Kw/416*3.2

=18cells

No. of cell in parallel (considering 1.25 factor for DOD compensation) = 18*1.25 or 16/0.8

=22cells

No. of cells=116*22

=2552 cells

E_{cf}= 23.4*1.25

=29.25KWh

Battery configuration is 22P116S
Mass of Battery pack=124kg
Battery voltage= 417.6V

Battery capacity=70Ah
Volume of battery pack=44787.6cm^3(without cell holder)
Volume of battery pack adding cell holder will be =2*2*7*2552
=71456cm^3
Battery dimension will be
L= cell holder length*128
=2*116
=232 cm
W=cell holder width*22
=2*20
=44cm
H=6.53cm
Hood space dimension is 600mm*400mm*350mm (L*W*H).

Fig: 4

Volume of the hood after removing the engine, transmission, battery, radiator etc. is,
Volume of the hood is 84000cm^3.
As the Length and Width of battery pack exceed the length and Width of the hood,
Let’s divide the battery pack into 4 modules of configuration 22P29S
So dimension of modules will be
L=29*2
=58cm
W=22*2
=44cm
H=8(considering bus bar, plastic mold, base plate, wire harness)

Now we need to connect the modules in series in order to achieve 22P116S configuration.

It is done placing modules top over the other.

As the height of the hood is 35cm and 4 module with height will be about 32cm (may be little more) which will fit inside hood.

Motor spec			
Motor rated power (KW)	22	Top speed required (KM/h)	110
Motor peak power (KW)	55	Peak torque required (Nm)	1150
Motor rated voltage (V)	336	final drive G.R of vehicle	4.388
Motor rated current (A)	65.47619048	G.R of reducer	2.24
Motor peak current (A)	163.6904762	Gear effiency of F.D	0.94
Motor rated Torque (NM)	60	Gear effiency of reducer	0.9
Motor peak Torque (NM)	140	Tire radius (m)	0.31
Motor rated speed (rmp)	4050		
Motor peak speed (rmp)	11000		
		obtained torque (peak) Nm	1164.160973
		obtained speed (peak) km/h	110.6392528
Cell spec			
Cell length (m)	0.0653		
Cell diameter (m)	0.0185	Cell volume (π*(d/2)^2 * L) In Cm^3	17.55280465
Cell Mass (kg)	0.0485	Cell energy Wh	11.52
Cell Voltage (V)	3.6		
Cell Capacity (Ah)	3.2	Energy required (KWH)	23.4
Charging and discharging rate	1C	TOTAL Energy required (dod compensation and losses)	29.25
dod	0.8		
		Battery volume (cm	71456
no of cell in series	94	battery mass (kg)	123.772
no of cell in parallel	21		
No of cells	1974		
lets round of no of cell to get desired number so that the battery pack can fit inside the hood			
		Available volume inside the hood cm^3	84000
no of cell in series	116		
no of cell in parallel	22		
no.of cells	2552		
battery volume without cell holder/insulator cm^3	44794.75746		
battery volume with cell holder/insulator cm^3	71456		

Fig: 5

Power required in motor (P_m) = F_{tract} *V

Let take Vmax =110 Km/h

$P_{m(max)}$ = 3366.38 *110/3.6

=145KW (But this will not be the case)

In above case @ 110Km/h which is the top speed, acceleration factor is considered. Which means speed will increase above the top speed which is not possible, so considering this the peak power was untainted with the help of Microsoft excel.

Vehicle Specifications								
kerb mass (kg)	1100							
g (m/s2)	9.81							
Roll Res µ	0.01		mass factor	1+0.04+0.0025Ntf^2	1.0881			
Cd (Drag)	0.34							
Dens ρ (kg/m3)	1.2		Driver and added mass (kg)	315			gradient max (degree)	0
Top speed(km/h)	90							
Acc(0-100Kmph)(m/s2)	1							
Tire radius	0.31		Total mass (kg)	1515				
Proj Area A (m2)	2.26							
Nf	4.388							
Drive cycle	MIDC-4W							
FORCES ACTING								
Fd(nm)	m*a	1515						
Frr(nm)	µ*m*g	148.6215						
Fg(nm)	0.5*ρ*C_D*A*V^2	288.15						
Fa(nm)	m*g*sin (Theta)	0						
Ft(nm)	Fd+Frr+Fa+Fg	1951.772						
Power and Torque requried								
Peak Power (KW)	Force*velocity	49						
Peak Torque (Nm)	Force*Tire radius	605.0492						

Fig: 6

Vehicle Specifications								
kerb mass (kg)	1100							
g (m/s2)	9.81							
Roll Res µ	0.01		mass factor	1+0.04+0.0025Ntf^2	1.0881			
Cd (Drag)	0.34							
Dens ρ (kg/m3)	1.2		Driver and added mass (kg)	400			gradient max (degree)	0
Top speed(km/h)	10							
Acc(0-100Kmph)(m/s2)	2.21							
Tire radius	0.31		Total mass (kg)	1596.91				
Proj Area A (m2)	2.26							
Nf	4.388							
Drive cycle	MIDC-4W							
FORCES ACTING								
Fd(nm)	m*a	3529.171						
Frr(nm)	µ*m*g	156.6569						
Fg(nm)	0.5*ρ*C_D*A*V^2	3.557407						
Fa(nm)	m*g*sin (Theta)	0						
Ft(nm)	Fd+Frr+Fa+Fg	3689.385						
Power and Torque requried								
Peak Power (KW)	Force*velocity	10						
Peak Torque (Nm)	Force*Tire radius	1143.709						

Fig: 7

$p_{m(max)}$ =40-50KW

Torque required for motor(T_m) = F_{tract} *wheel radius/G.R (with the final drive ratio)

T_m=3366*0.31/4.388

=237.82 Nm

Motor selected:
PMSM motor from - RAWSUNS power generation and propulsion solution.
Model: R55-140
Specification:

Motor rated power (KW)	**22**
Motor peak power (KW)	55
Motor rated voltage (V)	336
Motor rated current (A)	66
Motor peak current (A)	165
Motor rated Torque (NM)	60
Motor peak Torque (NM)	140
Motor rated speed (rmp)	4050
Motor peak speed (rmp)	11000

Table: 1

Even with a final drive gear ratio, motor torque will not satisfy the required torque, i.e., 1150Nm.So a reducer with a gear ratio of 2.24 is added. (Obtained from calculations and assumptions made with the help of Microsoft Excel).

Thermal Calculation:

Battery configuration is 22P116S.
Battery pack of 4 with a configuration of 22P29S (connected in series).
Cell internal resistance (I_r) is 45mΩ.
Cell capacity=3.2Ah

Heat generated by a cell (Q_{cell}) = $I^{2*}I_r$

$=3.2^2*45*10^{-3}$

$=0.4608W$

Pack configuration 22P29S

Heat generated in pack (Q_{pack}) $=I^2*I_r*$no. of cells in pack

$=3.2^2 * 22*29* 45*10^{-3}$

$=294W$

Heat generated by battery (Q_B) = 4*294

$=1176W$

Peak heat generated by Battery would be 165A so each cell discharge at nearly

2.23C, so let take discharge rate as 2.5C to round it up

$Q_{(peak\ B)} = (2.5*3.2)^2 *4*22*29*45*10^{-3}$

$= 7349.76W$

Battery pack dimension is 58*44*8 cm

Area of heat convection area =4 of (58*8) +58*44=>4408 cm^2 (4 pack of dimension 58*44*8*)

Assuming: The pack temperature is=45 c

The ambient temperature is=35 c

Thermal resistance, $R_{th}=\Delta T/Q$

$=T_{Cell}-T_{ambient} /7349.76$

$=45-35/7349.76$

$=1.3606*10^{-3}$ k/w

Convective $R_{th}=1/h$

$1.3606*10^{-3}= 1/h*4408$

$h=1.6674*10^{-1}$ w/cm^2k (heat transfer coefficient)

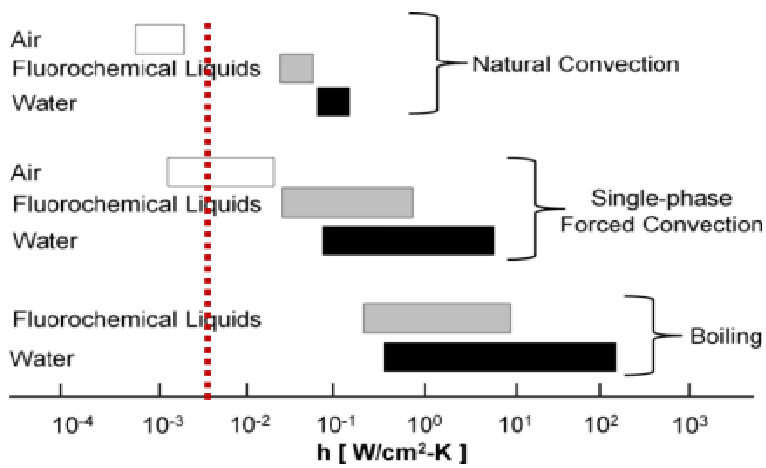


Fig: 8

As the heat transfer coefficient is $1.67*10^{-1}$ w/cm^2 k   forced water convection is preferred.

Chapter 5: Tools Required

1. Microsoft Excel
2. Matlab
3. Maruti Suzuki Showroom manual
4. Internet

References:

- https://evreporter.com/retrofitting-ice-vehicles-to-evs-hemank-dabhade/
- **https://onlinecourses.nptel.ac.in/noc21_ee112/preview**
- https://www.araiindia.com/CMVR_TAP_Documents/Part-14/Part-14_Chapter03.pdf
- https://roymech.org/Useful_Tables/Drive/Gear_Efficiency.html
- https://circuitdigest.com/article/different-types-of-motors-used-in-electric-vehicles-ev
- https://www.motorauthority.com/news/1108398_learn-what-a-final-drive-ratio-is-and-how-it-affects-your-car
- https://wrengineers.in/what-is-the-gradient-of-road-types-of-road-gradient/#:~:text=It%20is%20defined%20as%20the,the%20road%20along%20its%20alignment
- https://www.engineeringtoolbox.com/slope-degrees-gradient-grade-d_1562.html
- https://www.power-sonic.com/blog/how-to-connect-batteries-in-series-and-parallel/
- https://www.rawsuns.com/ev-motor/
- https://xprest.tatamotors.com/electric/specification