Final report on EV Conversion

Submitted by: Prajwal G Anchan

About

Comprehensive Analysis and Exposition of the Mathematical Modeling Process for Electric Vehicle (EV) Integration, along with a Detailed Discourse on the Sequential Phases and Intricate Simulations Necessary for the Conversion of Conventional Internal Combustion Engine (ICE) 2-Wheeler Vehicles into High-Performance Brushless DC (BLDC) Propelled Electric 2-Wheelers

Content

The report is organized as follows:

Market analysis

Market analysis plays a crucial role in the electric vehicle (EV) industry as it helps stakeholders understand and navigate the complex landscape of EV adoption and development.

Vehicle	Range [Km]	Battery Type	Battery Capacity [KWh]	Battery Voltage [V]	Motor Max Power [kW]	Motor Max Torque [Nm]	Motor Type	Top Speed [kph]	0-100 kph [s]
Ather 450	75	Li-ion	2.4	51.1	5.4	26	BLDC	75	7
Revolt RV 400	150	Li-ion	3.24	72	3	170	BLDC Mid.	100	8
Okinawa I-praise	160	Li-ion	3.3	72	1	NA	BLDC Hub.	60	11
Revolt RV 300	180	Li-ion	2.7	60	1.5	54	BLDC Hub.	80	15

Reason for selection:

Based on the market analysis provided in the table, it's important to consider the desired characteristics for a metropolitan area. Here are the suggested criteria:

- Desired Range: 80-150 km
- Motor Type: BLDC (Brushless Direct Current)
- Battery Chemistry: Li-ion (Lithium-ion)

Looking at these specifications we are going to focus on the conversion of an urban Scooter with an internal combustion engine into a fully electric vehicle. The model of choice will be the **Honda Activa,** with the main parameters defined in the table below:

Host vehicle and Target specifications.

Engine	**Fan Cooled, 4 Stroke, 100cc SI Engine**
Maximum torque [Nm]	8.79 Nm
Engine speed @ maximum torque [rpm]	4500
Maximum power [HP]	7.6
Maximum power [Kw]	5.73
Engine speed @ maximum power [rpm]	8000
Transmission type	Automatic, CVT
Tire symbol	90/90 R 10
Vehicle mass (kerb) [kg]	90/90 R 10
Aerodynamic drag, Cd [-]	0.52 (Assumed)
Frontal area, A [m2]	0.46
Top speed [kph]	80
Acceleration time 0-100 kph [s]	22 s

High-level requirements of the electric vehicle

Based on the analysis of the current EV market and the performance parameters of the base vehicle (internal combustion engine, Honda Activa 6g), we are now going to summarize the high-level requirements of our electric vehicle conversion.

Battery

- Nominal voltage [V]: 48
- Chemistry: Lithium-ion

Powertrain

- Electric motor type: Permanent magnet/Synchronous (BLDC motor),
- Vehicle Range [km]: 100,
- Top speed [kph]: 90
- Time 0-100 kph [s]: 20
- Kerb weight [kg]: 110

Calculating Traction Force

One key requirement of our battery electric vehicle conversion is to reach 100 kph from standstill in 15 seconds (to compete with the ICE version)
From this requirement, knowing the vehicle weight, we can calculate what is the total traction force and torque. Also, we can check if the wheel (tire) friction can sustain the required traction force.

The input data in our calculation is:

Parameters	**Value**
Vehicle total weight (vehicle kerb weight x mass factor + driver weight**)	180 kg
Vehicle initial speed	0 kph
Vehicle final speed	100 kph
Vehicle initial time	0 s
Vehicle final time	20 s
Tire radius*	0.208 m
Tire friction coefficient	1.0
Gravitational acceleration	9.81 m/s^2

According to Newton's second law of motion:

$$F = m * a \text{ --(1)}$$

From (1) we can write the equation of the required traction force on Dry Concrete/Asphalt as:

$$F_t = m_v * (\frac{v_f - v_i}{t_f - t_i}) \text{ -------------(2)}$$

where:

Ft [N] – total traction force
mv [kg] – total vehicle mass
vf [m/s] – final speed
vi [m/s]– initial speed
tf [s] – final time
ti [s] – initial time

Solving Traction force equations

Replacing the input data into equation (2), gives the total traction force required to achieve 0-100 kph in 20 s:

$$F_f = 180 * (\frac{27.78 - 0}{20 - 0}) = 250N$$

Solving Friction Force equations

In terms of friction, we can calculate the available friction force as:

$$F_f = G_v * \mu_f = m_v * g * \mu_f \text{ -------(3)}$$

where:

Ff [N] – friction force
Gv [N] – vehicle weight
g [m/s2] – gravitational acceleration
μf [-] – friction coefficient (wheel-road)

Replacing the input data into equation (3), gives the available friction force:

$$F_f = 180 * 9.81 * 1 = 1765N$$

Since the available friction force is bigger than the total traction force, assuming that there is no slip between the wheels and road, the total traction force can be applied at the wheels to achieve the 0-100 kph acceleration time.

Enter finalized required torque.

The total required traction torque can be calculated as:

$$T_t = F_t * r_w$$ ----------------------(4)

where:

Tt[nm] – total traction torque
rw[m] – wheel radius

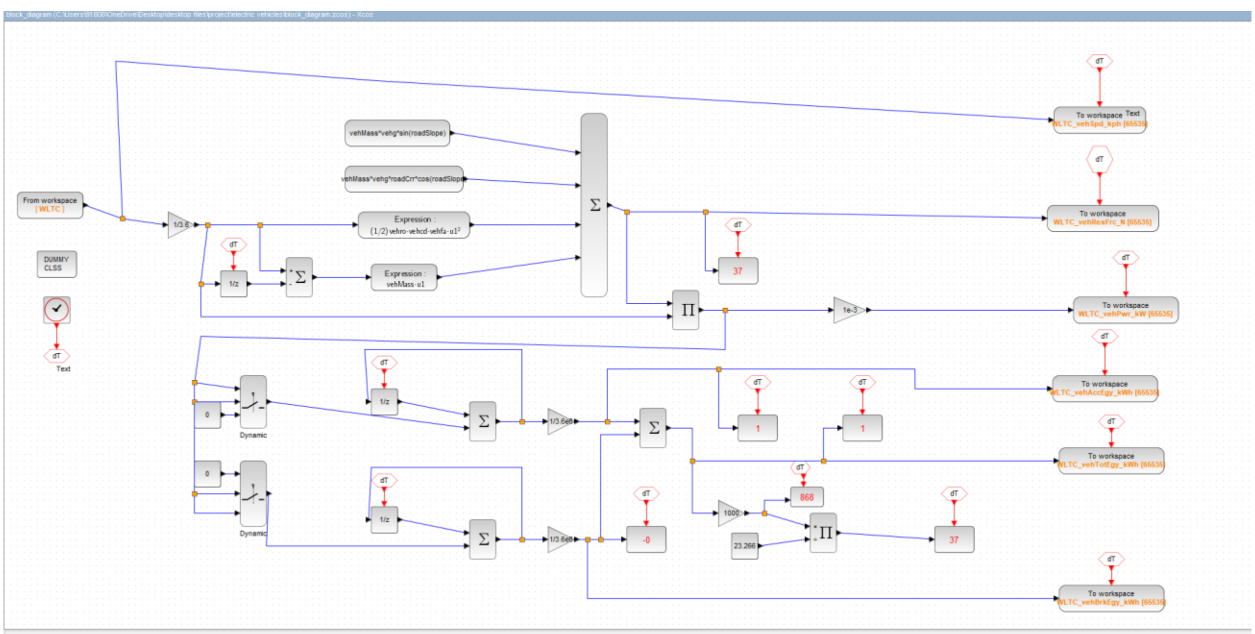
Replacing the input data into equation (4), gives the total traction torque required to achieve 0-100 kph in 20 s:

$$T_t = 250 * 0.208 = 52nm$$

Simulation parameters

```
vehMassKerb = 105 [kg]
vehMassDriver = 175 [kg]
vehMassfm = 1.05
vehMass = 285.25 [kg]
vehg =9.8 [m/s^2]
vehcd =0.55.
vehfa = 0.56 [m^2]
vehro =1.202 [kg/m^3]
roadSlope = 0 [rad]
roadCrr = 0.02
```

Xcos Block Diagram after simulation



Simulated energy consumption during propulsion

The average energy needed for propulsion of the vehicle over the WLTC drive cycle.

Value: 37 Wh/km.

Total energy consumption by the vehicle during the WLTP cycle

The total energy consumption by the vehicle is given below and the battery pack should be designed based on this value.
Value: 41.58 Wh/km.

Selecting a Battery to get the needed range

List of batteries compared:

Manufacturer	**Power-sonic**	**Samsung**	**Sony**	**LG chem**	**CATL**
Type	Pouch	cylindrical	cylindrical	Cylindrical	pouch
Model	Phr-121000	INR18650-15Q	US18650VT C3	18650 HE2	Type 60AH
Length [m] (For cylindrical)	0	0.0646	0.0649	0.065	0
Diameter [m] (For cylindrical)	0	0.0182	0.0181	0.0183	0
Height [m] (For prismatic or pouch)	0.175	0	0	0	0.217
Width [m] (For Prismatic or pouch)	0.164	0	0	0	0.135
Thickness [m] (For prismatic or pouch)	0.125	0	0	0	0.029
Mass [kg]	10	0.048	0.0432	0.048	1.92
Capacity [Ah]	27	1.5	1.08	2.5	60

Voltage [V]	12	3.6	3.6	3.6	3.6
C-rate (cont.)	1	0.2	0.82	0.2	2
C-rate (peak)	20	6.66	9.25	8	3

Datasheets of chosen batteries

Battery 1: Power-sonic Phr-121000

Datasheet:
https://www.power-sonic.com/wp-content/uploads/2018/12/PHR-12100%20technical%20specifications.pdf

Battery 2: Samsung INR18650-15Q

Datasheet:
http://www.batteryspace.com/prod-specs/6615.pdf

Battery 3: Sony US18650VT C3

Datasheet:
https://www.megacellmonitor.com/pdf/vendor_specs/SPEC_SONY_US18650VT.pdf

Battery 4: LG Chem 18650 HE2

Datasheet:
https://cdn.shopify.com/s/files/1/0674/3651/files/LG_18650HE2.pdf?827

Battery 5: CATL Type 60AH

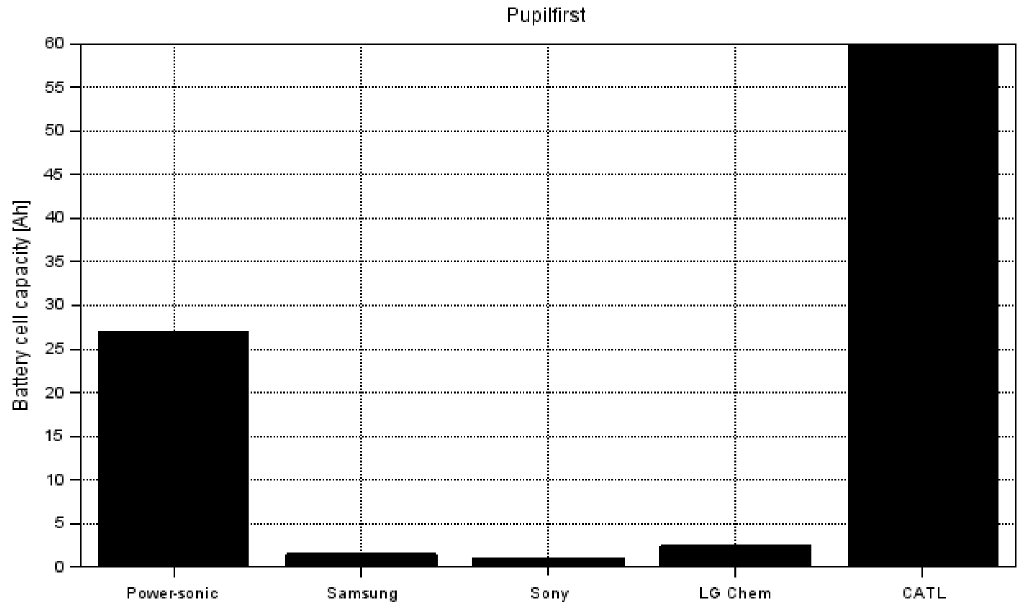
Datasheet:
https://www.genuinepower.co.in/lithium-ferrous-phosphate-battery.html

Data

- **Voltage** = 60 V
- **Range** = 173.160 Km
- **Energy consumption** = 37 [Wh/km]

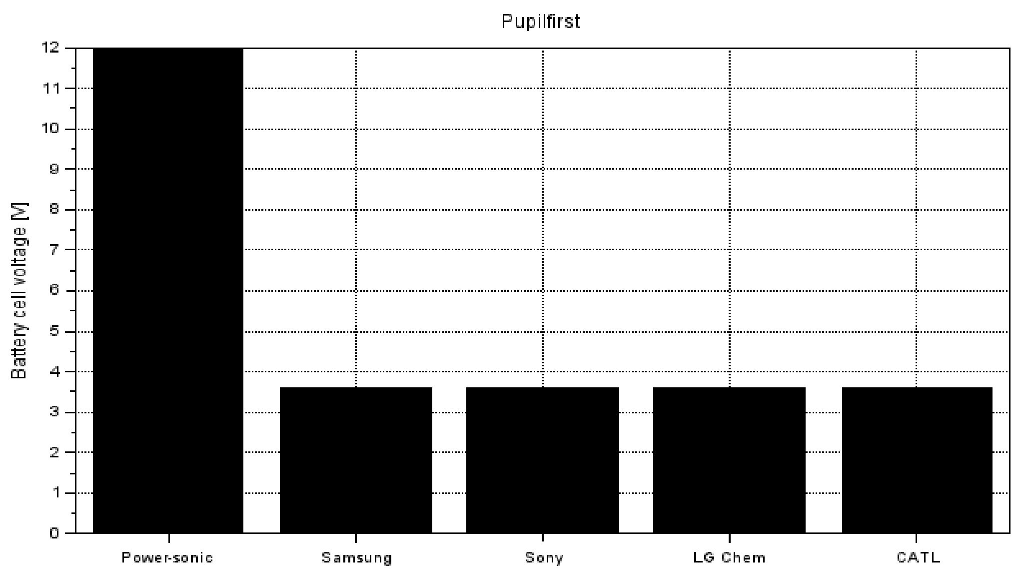
Scilab plots

1. Battery cell capacity



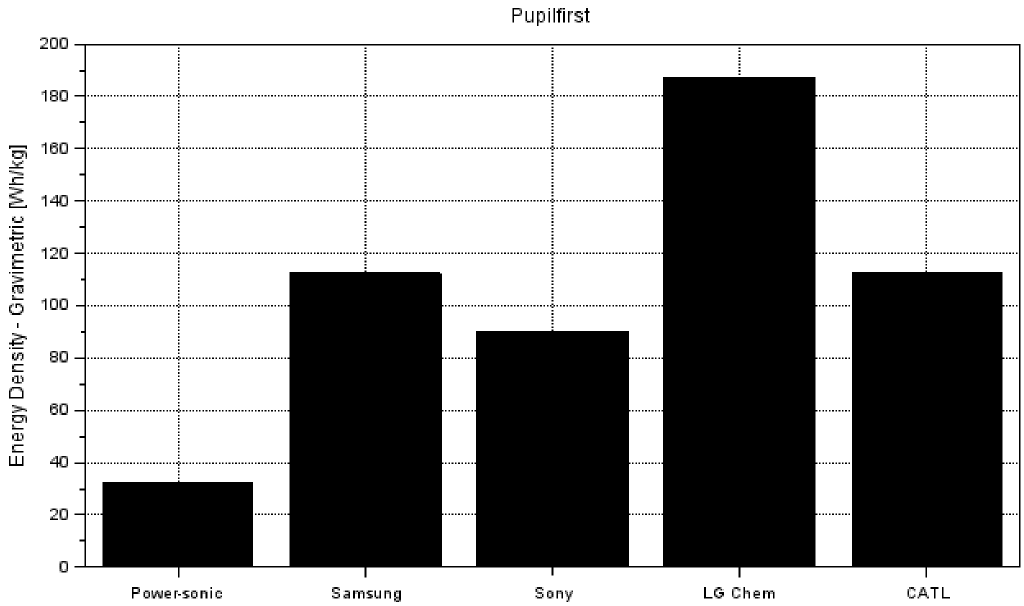
Observation: From the above plot we find that the cell capacity of CATL is much higher when compared to the remaining four batteries

2. Battery cell voltages



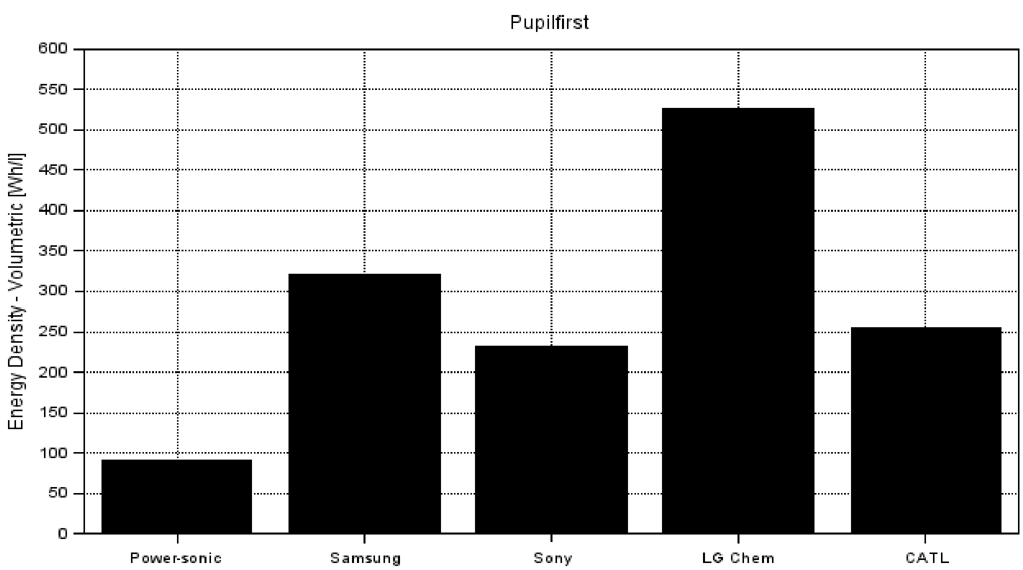
Observation: From the above plot we observe that the battery voltage provided by the Power sonic battery is higher than other 4 batteries while the remaining four have relatively similar cell voltages

3. Energy Density - Gravimetric



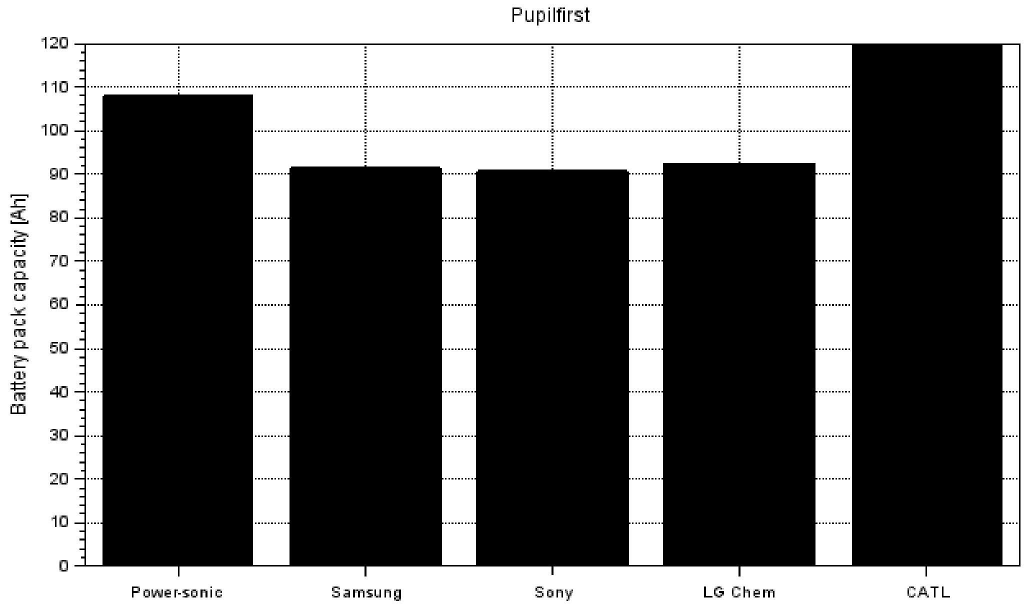
Observation: From the above plots we can observe that LG chem has the most gravimetric energy density while the power sonic has the least and the rest have similar energy densities

4. Energy Density - volumetric



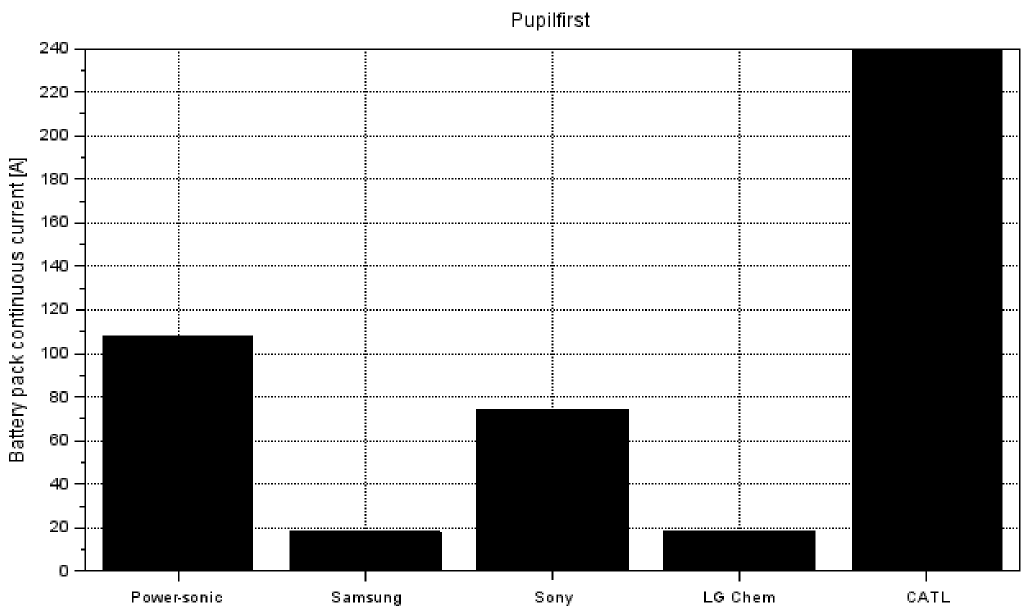
Observation: From the above plots we can observe that LG chem has the most volumetric energy density while the power sonic has the least and the rest have similar energy densities

5. Battery pack capacity



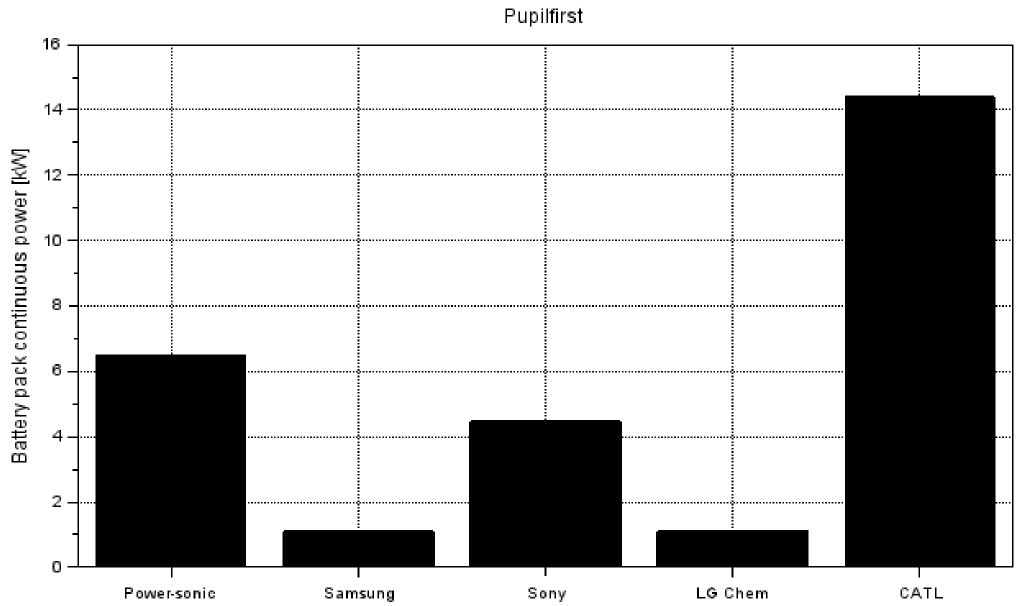
Observation: We now observe that when the batteries are arranged in the form of battery packs their battery pack capacity increases significantly

6. Battery pack continuous current



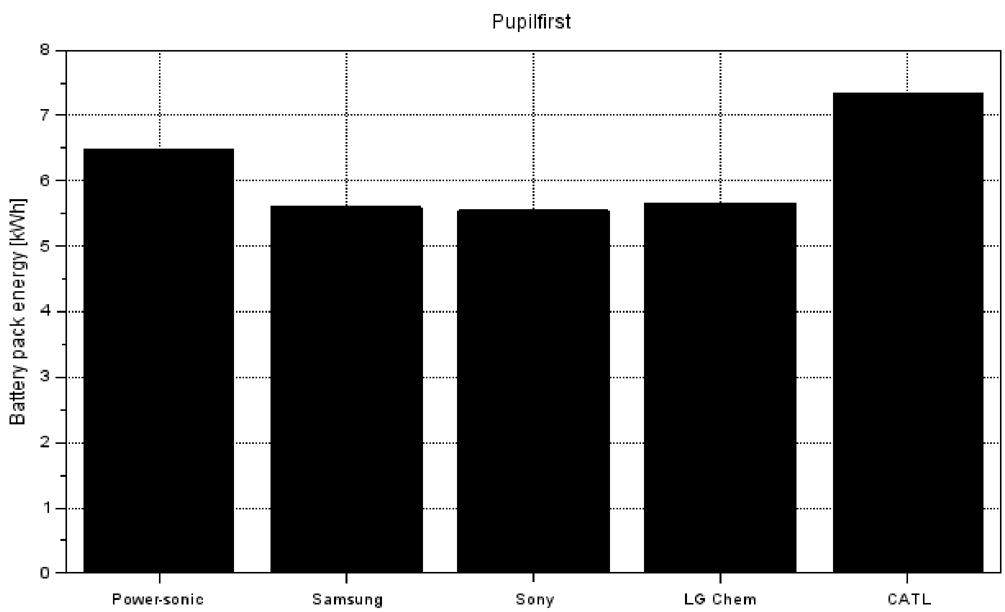
Observation: From the above plot CATL battery pack provides the highest continuous current

7. Battery pack continuous power



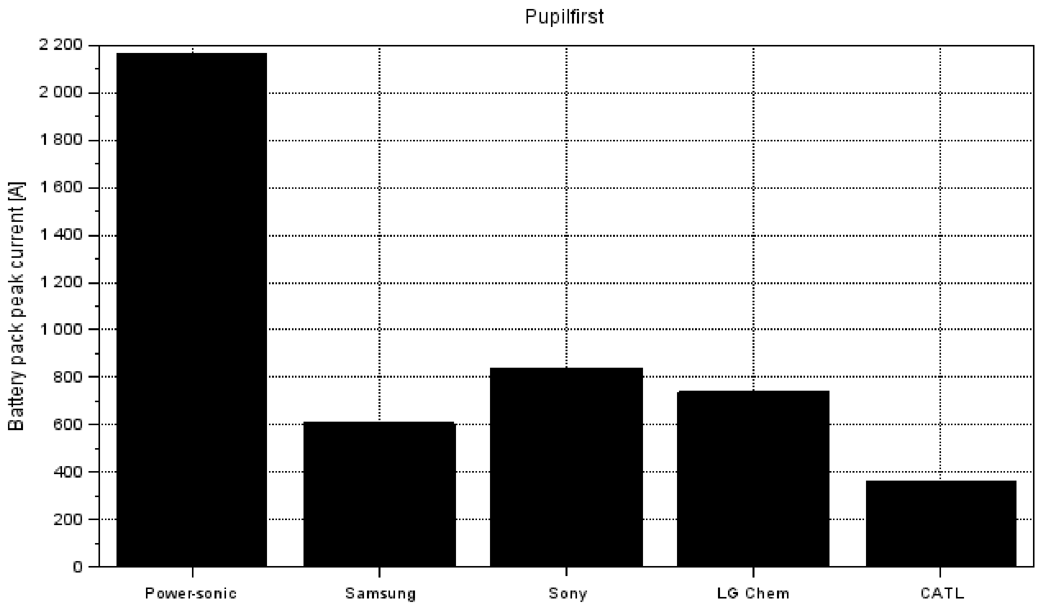
Observation: From the above plot CATL battery pack provides the highest continuous power we observe that the plot values are similar to the continuous current plot.

8. Battery pack energy



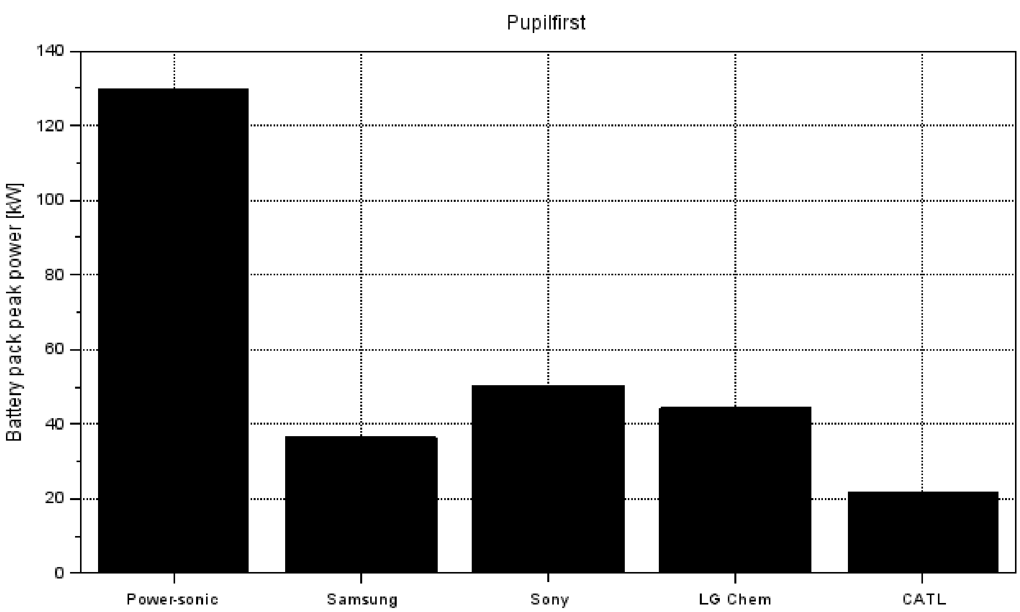
Observation: From the above plot we observe that the battery pack energy by all the five cells is very similar, but CATL battery pack has a slight edge over other battery packs.

9. Battery pack peak current



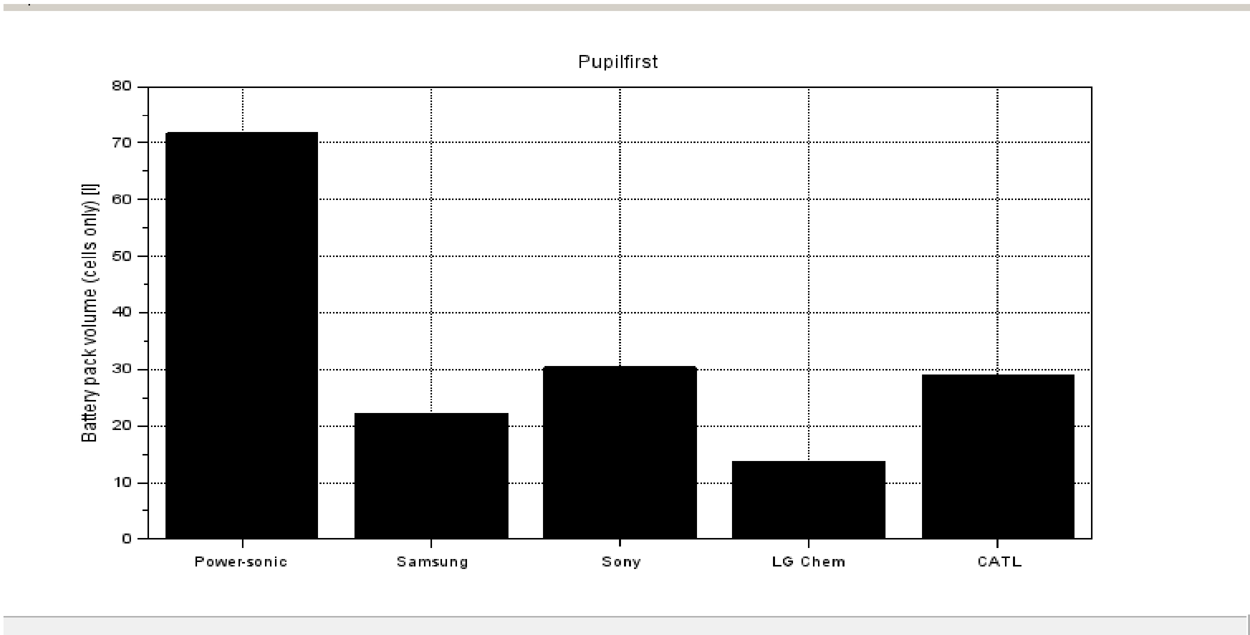
Observation: Here we observe that Power sonic battery pack has an ability to produce high peak current while the all the other cells have approximately similar peak current values.

10. Battery pack peak power



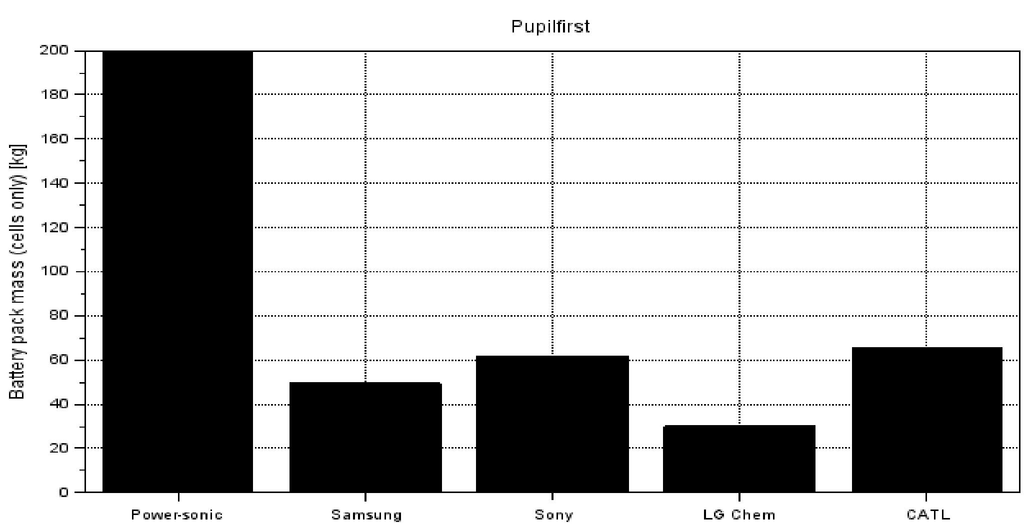
Observation: like the previous plot that Power sonic battery pack has an ability to produce high peak power while the all the other cells have approximately similar peak power values.

11. Battery pack volume



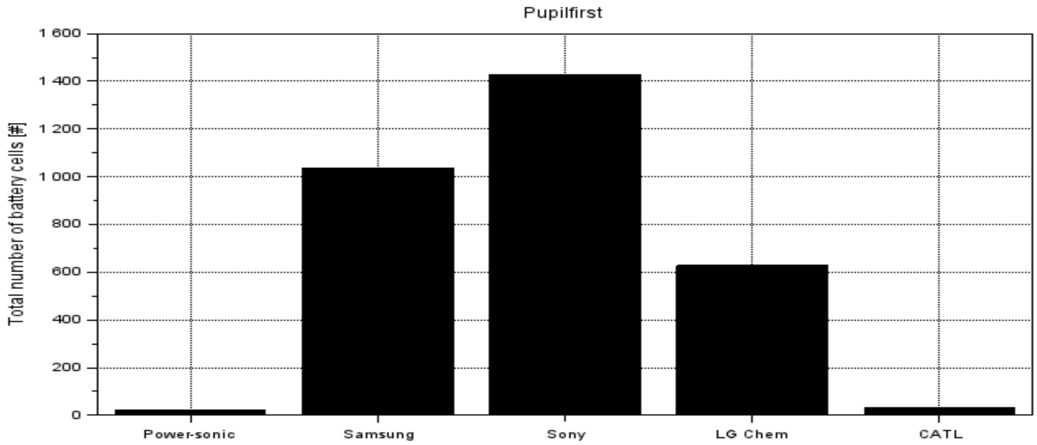
Observation: Panasonic has the highest battery pack volume while LG chem has the least battery pack volume hence LG chem is more beneficial if we have to reduce weight of the vehicle

12. Battery Pack Mass



Observation: Panasonic has the highest battery pack mass while LG chem has the least battery pack volume hence LG chem is more beneficial if we have to reduce the mass of the vehicle

13. Total number of battery cells



Observation: We observe that Power sonic and CATL use the least amount of battery cells while the other two use the most amount of battery cells hence if we must use lesser number of cells, we should opt for Power sonic or CATL batteries

Conclusion of battery comparative analysis

From the comparison of above data of the 5 different batteries, while selecting a battery cell to build a battery pack we must observe whether the battery pack built provides the highest power or capacity to obtain the desired range for the least amount of money spent. considering all these factors CATL Type 60AH battery suits best for the required two-wheeler EV Conversion.

The calculations for battery pack configuration are as follows:

1 CATL cell voltage = 3.6 V

Required battery pack voltage = 60 V

Therefore, No of CATL cells in series should be 17 since 17*3.6 = 61.2 V (required battery pack voltage)

And to obtain the required current rating we must have 2 cells in parallel.

Battery pack capacity= (Total energy consumption) *(Total range)

Battery pack capacity= (41.58 wh/km) / (173.160 Km) = 7200 wh

Values for battery pack configuration below:

- Battery Pack Voltage = 60 V
- Battery Pack Capacity =7200 wh
- Total Number of Cells Required = 34
- Total number of cells in parallel = 2
- Total number of cells in series = 17

Conclusion of the EV conversion

Vehicle and Battery Parameters	
Power of Motor selected	15 Kw
WLTP Class of Vehicle	Class 3
Chosen road slope angle	0
Vehicle kerb Mass	105 Kg
Mass of driver	70 Kg
Coefficient of drag	0.55
Total vehicle mass	175 Kg
Energy consumption from propulsion	37 wh/km
Energy consumption by secondary components	0.8 wh/km
Total energy consumption	41.58 wh/km
Range selected	173.160 Km
Battery cell selected	CATL Type 60Ah
Type of battery cell (Pouch/cylinder)	pouch
Individual cell voltage	3.6 V
Battery pack voltage	61.2 V
Total number of cells	34
Number of cells in series	17
Number of cells in parallel	2