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Energy Dimensioning for the Mobility of a Single-Occupant Electric Vehicle

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Abstract: In the present study, it is presented the dimensioning of the power required to start up a single-occupant electric vehicle with an autonomy of 35 km with an average speed of 60 km/h and a mass of approximately 700 kg. Dimensioning is based on the requirement of the basic and common needs of conventional vehicle users. Each of the elements is described and analyzed from the energy point of view where the energy of the vehicle supplied by batteries which as load support, use solar panels strategically located in the vehicle. By means of an electrical and electronic conditioning, this energy is supplied to a DC motor. The power of the motor is transmitted to the vehicle's wheels through a sequential mechanical transmission which is regulated in different speed ranges to efficiently take advantage of the energy.

Key words: Battery, energy, electric motor, solar panels, advantage, sequential

INTRODUCTION

As since, the invention and commercialization of the car and given the fact that it requires a source of combustion, the demand for fossil fuels, the main source of automobile combustion has grown dramatically. It is estimated that in the near future, the oil reserves will be no longer available, in addition, the sum of environmental problems are added, due to the pollution generated by the use of such fuels. Many people make use of cars for multiple activities because of this there is a need to evaluate alternative methods for starting the car.

This problem has generated a change in the automotive industry. The directors of recognized companies in this sector have managed the development of aerodynamic, small and light models in order to minimize energy consumption to the point of opting for new energy alternatives such as electric, hybrid and hydrogen cars. In spite of having problems of efficiency and performance in some terrains, these cars are a good alternative to solve the problems derived from the use of fossil fuels in conventional cars (Damiano *et al*., 2012).

In India, national plans for electric mobility have been deployed in order to reduce energy consumption. One obstacle to these plans is the impact that a large number of electric vehicles would have on the electric grid. For this, research has been done to ensure how much energy 1 km is consumed on different vehicle models. Among the results obtained with respect to consumption in the city, under average driving conditions, it was obtained for an electric motorcycle, a consumption of 33 Wh/km for vehicles of 3 wheels, 61 Wh/km and finally for vehicles of 4 wheels a consumption between 84-123 Wh/km. With these data, it was found that there was no major effect on the electrical networks but there were great benefits of energy saving compared to traditional systems (Rupchand, 2011). On the other hand in Flores Island in the Azores archipelago, great economy growth was shown between 1994 and 2010, due to investments in the energy sector. The introduction of electric vehicles in the Azores has recently contributed to the reduction of primary energy by approximately 0.9% and CO_2 emissions decrease of 1.4%. These results are obtained even though the energy used for the energy recharge of the vehicles comes from fossil sources as diesel generators. This shows that electric vehicles can help improve the sustainability of energy systems (Pina *et al*., 2014).

Behavioral studies of commercial electric vehicles such as Fiat Seicento Elettra have been developed using two simulation models. The first one where mechanical parameters and forces applied to the chassis are used; The second where typical forces are applied to the chassis. The study was carried out in order to observe the performance of the power, autonomy and duration of the battery charge, finding that the model to which the resistive forces were applied at different points in the chassis was more accurate to study the behavior of the moving vehicle (Terras *et al*., 2011).

In relation to the costs caused by mobility, a comparative study was made for a range of 100 km with internal combustion vehicles and the two simulated electric vehicle models, resulting in a lower cost, up to

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46%, using the electric models (Terras *et al*., 2010). In an analysis of the impact of electric vehicles in the future, it was found that they will not only bring development thereof but that will give opportunity to the electricity sector to improve considerably since the electrical capacity of the networks is very low in relation to the massification of electric vehicles. In order to supply the energy demanded in the course of improving the networks, load control systems have been implemented at different times in order not to saturate the networks (Bremermann *et al*., 2014). Regenerative braking systems have also been developed to recover energy in electric vehicles. These systems operate by means of a careful configuration in the motor that provides the movement, acting upon braking as a generator of energy in this way, it recovers part of the energy that was traditionally wasted in friction (Cipollone *et al*., 2014).

In this way, the avid interest in the development of electric vehicles and their referents is evidenced. For this reason the purpose of this study is to establish the bases of electrical design necessary for its construction, providing as a variant a solar panel system as charge support. It starts from an approximate calculation of the power and the maximum distance range which allows to choose the necessary electrical elements. It constitutes a guide for the optimal energetic dimensioning that allows the functionality of an electric vehicle.

Power calculation: The power of a single-occupant electric vehicle is an important factor for dimensioning the necessary electrical elements for its displacement. In order to calculate the power, it is necessary to take into account the resistive forces that impede the movement, the total mass of the vehicle including passenger and the speed at which it is desired to arrive at a given time. At the moment that an electric vehicle is started with a speed (v) and acceleration (a), there is also a resistance effect to the movement described by several forces such as: acceleration resistance (Fa) which is defined as the force that prevents the mass from moving and is described by Eq. 1:

$$Fa = m*a \tag{1}$$

Where:

m = Vahicle mass
a = Vahicle acceleration

For this research the acceleration taken to perform the calculations is 1.666 m/sec^2, since, 10 sec to obtain the speed of 16 m/sec that is equal to 60 km/h is a comfortable acceleration for the user and is between the averages of a common vehicle.

Rolling resistance (Fr) is the force exerted by the ground on the wheel, causing a deformation and is expressed in Eq. 2:

$$Fy = (m*g*\cos\alpha) \tag{2}$$

Where:

m = Vahicle mass
g = Gravity acceleration
μ = Friction coefficient (Asphalt = 0.011)
α = Angle of inclination of the terrain

Air resistance (Fk), this force is proportional to the vehicle speed and has dependence on the shape of the vehicle. This force is represented in Eq. 3:

$$Fk = \frac{1}{2}\rho C_x A_f V^2 \tag{3}$$

Where:

ρ = Air density
C_x = Vahicle aerodynamic coefficient
V = Speed of circulation

Tilt resistance (Fg) in this force appears a perpendicular vector due to the inclination and is expressed in Eq. 4:

$$Fa_x = m*g*\sin\alpha \tag{4}$$

The sum of all resistance forces results in Eq. 5:

$$F = Fa+Fy+Fk+Fg \tag{5}$$

The mechanical power required to move an electric vehicle is given by the Eq. 5 and expresses the product of the resulting force, applied by the velocity (Tanaka *et al*., 2008):

$$P = F*V \tag{6}$$

It is necessary to know an approximate mass of the vehicle to perform the calculation of power, taking into account that the mass of potential users is different for this case will be taken as base 80 kg (average weight of an adult Colombian). The approximate mass of the vehicle is composed of the following groups of elements: batteries 220 kg (five 44 kg batteries), motor 39 kg (electromagnetic induction motor), body 134 kg (aluminum fiber reinforced sheets), electric control and power systems 7 kg and chassis 220 kg (structure in cold rolled steel 1020), obtaining a resulting mass of 700 kg. The aerodynamic coefficient is taken from the average of a modern car which varies between 0.29 and 0.33. For the present case the average of these two values is taken which is 0.31. The coefficient of rolling used is 0.011 which corresponds to an asphalted ground. Because the vehicle is single-occupant, its proportions are small, the geometry is approximately 1.43 m high and 1 m wide, so, the surface area taken for the calculation of air resistive forces is 1.43 m^2.

Table 1: Ratio of transmission speed in different gears of Hyundai Atos 1998 GLS

Gear	Ratio
First gear	3.53
Second gear	1.95
Third gear	1.31
Fourth gear	0.91
Fifth gear	0.78
Reverse gear	4.00
Differential	4.52

Table 2: Calculation parameters to find the necessary power of the electric vehicle

Variables	Values
Mass	792 kg
Gravity	9.8 m/sec^2
Acceleration	1.666 m/sec^2
Air density	0.879 kg/m^3
Aerodynamic coefficient	0.31
Rolling coefficient	0.011
Superficial area (S)	1.43 m^2

Table 1 illustrates the relation of the transmission of a common vehicle worldwide, obtained by the manufacturer's manual which will be used for the power calculation. The vehicle was selected for having small dimensions in addition to being one of the most commercial vehicles. For this calculation, it will be used the fifth gear as it has the best ratio to achieve speed, this is convenient because the power is directly proportional to the speed. It should be noted that when calculating power, the ratio of the differential must be taken into account, since, it is fixed and is combined with all the transmission gears. Table 2 shows some important variables for the power calculation.

Using Eq. 5, the power necessary to start the electric vehicle is calculated, using a wheel of 491 mm in diameter and at a speed of 60 km/h (maximum speed allowed in Bogota). For this analysis a speed range of an electric motor between 200 and 4000 (rpm) is taken, since, it is the average speed range of an internal combustion engine used in conventional vehicles, taking 20 samples to show the changes of speed, the resistive force of the air, the total force when moving and power required. These data are exposed in Table 3.

As the vehicle moves faster, the resistance of the vehicle to the air is increasing, hence, more power is required by the engine, up to approximately 30 HP to reach a speed of 60 km/h. Figure 1 shows the resulting curve.

In order to determine the final power, a real test path is established, from Nueva Granada Military University located in Bogota (located at 100th street) to its campus located at km 2 via. Cajica-Zipaquira where it is necessary to travel 35 km. Taking this as the minimum distance that will travel the electric vehicle at a speed of 60 km/h, it has a required time of 35 min or 0.583 h. With the time necessary to make the journey and the power required to reach 60 km/h (Table 3), the amount of power required to cover the journey is 14181.465 Wh.

Table 3: Variation of speed, air resistance, up to the total force and the power required at intervals of 200 rpm

Vel. Mot or (rpm)	Wheel Vel. (km/h)	Wheel Vel. (m/sec)	Air resis. (N)	Total Forces (N)	Power (W)	Power (Hp)
200	5.250	1.458	0.414	1320.414	1925.698	2.581
400	10.501	2.917	1.658	1407.035	4104.052	5.501
600	15.751	4.375	3.730	1409.107	6165.144	8.264
800	21.001	5.834	6.631	1412.008	8237.115	11.042
1000	26.251	7.292	10.360	1415.737	10323.591	13.839
1200	31.502	8.750	14.919	1420.296	12428.198	16.660
1400	36.752	10.209	20.306	1425.683	14554.563	19.510
1600	42.002	11.667	26.522	1431.899	16706.312	22.395
1800	47.252	13.126	33.567	1438.944	18887.071	25.318
2000	52.503	14.584	41.441	1446.818	21100.467	28.285
2200	57.753	16.042	50.144	1455.521	23350.125	31.300
2400	63.003	17.501	59.675	1465.052	25639.672	34.370
2600	68.253	18.959	70.036	1475.413	27972.735	37.497
2800	73.504	20.418	81.225	1486.602	30352.939	40.688
3000	78.754	21.876	93.243	1498.620	32783.912	43.946
3200	84.004	23.334	106.089	1511.466	35269.278	47.278
3400	89.254	24.793	119.765	1525.142	37812.665	50.687
3600	94.505	26.251	134.269	1539.646	40417.699	54.179
3800	99.755	27.710	149.603	1554.980	43088.005	57.759
4000	105.005	29.168	165.765	1571.142	45827.211	61.431

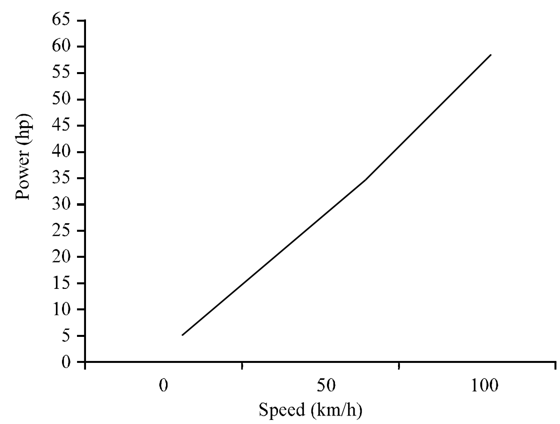

Fig. 1: Variation of the total required power as a function of speed

MATERIALS AND METHODS

Starting from the power necessary for the mobility of a single-occupant electric vehicle, the choice of elements is simpler. The main element to be taken into account is the motor because it drives the vehicle. The second most important element are the batteries, since, they are the source of energy supply and as a charge support, the solar panels which will work as long as there is solar energy in the environment. Each of these will be presented.

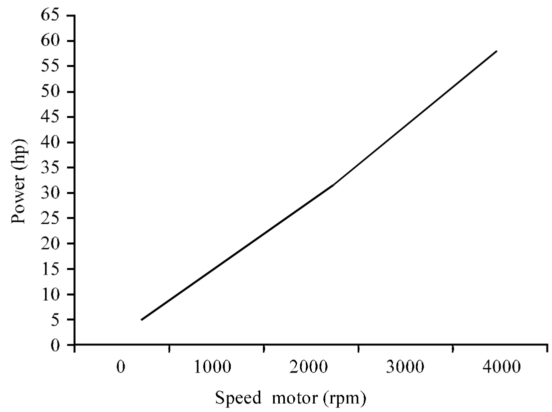

Fig. 2: Variation of the total required power as a function of speed

Electric motor: The motor is a machine that converts electrical energy into mechanical energy though an electromagnetic interaction. The ideal motor for an electric vehicle is DC, since, the source of remote power storage is of this type (DC batteries). If you use an AC motor, you could use a DC-AC converter but you will lose some power in the conversion process.

DC motors are classified according to the way the inductor and induced coils are connected (West, 1994), e.g.: Independent excitation motor: the rotor and the stator are fed from independent sources. Series motor: the stator and rotor are in series. Shunt motor or shunt motor: the stator and rotor are connected in parallel. Motor compound: this has two inductive windings, one is in series with the induced winding and the other in parallel.

For this vehicle is recommended to use an induction motor with connection between inductor and induced in series because it is characterized by being efficient have a high torque in small speed, precise speed control, few operation problems and are found in the market at moderate prices (Terras *et al*., 2010).

One of the generalities of the motors is that when they deliver their maximum power, they increase their temperature considerably. As much as possible, the body of an electric vehicle, must have a cooling system to avoid internal damage and efficiency losses (Shumei and Chen, 2008).

In order to achieve a speed of 60 km/h, the electric motor must have approximately 30 hp of power (Table 3). It must also have a speed range of 0-2400 rpm (Fig. 2).

Due to the fact of supplying the power, revolutions and necessary range, it uses a motor “Golden motor” reference BLDC-HPM-20KL power-full which has a power range of 20-25 kW, DC voltage between 75 and 120 V, a maximum of 5000 rpm and a mass of 39 kg, additionally, it has a liquid cooling system that allows to maintain a 90% efficiency in high demand energy moments. The motor specifications previously described meet the needs stated.

Batteries: The main element of energy supply for the electric vehicle is the batteries. These devices store energy in electrochemical form, i.e., that they store the energy doing a double conversion. The first conversion occurs in the charge where the electric energy is converted into chemical energy and the second conversion occurs in the discharge when the chemical energy is converted into electrical energy (Cicconi *et al*., 2013).

One of the disadvantages of batteries in general is the reduction of useful life. In case it is exposed to high temperatures over 25°C (ambient temperature), every 10°C increase will lose 50% of useful life compared if used at room temperature (Kolbel, 2002).

Therefore, cooling systems for the motor must be implemented, for example, in the design of the body of the vehicle, a duct that allows cooling the battery compartment to avoid by means of increase of temperature, diminution of its useful life. The most used batteries in electric vehicles are lead acid with VRLA technology, since in the market they are the most economical with acceptable efficiency.

The VRLA method maintains a small positive pressure with respect to the external environment using a throttle valve. This method corrects deficiencies in lead acid batteries such as: excessive gas production and eliminates the problem of corrosion evident in the battery compartments (Wertz and Clough, 1999).

AGM and GEL batteries are batteries with high efficiency which differ in the type of material they use to change the acid state of lead. AGM (Absorbent Glass Mat Technology) are batteries that use glass fiber as the main element for the absorption of liquid electrolyte by capillarity in a fiberglass mat located between plates, allows a more efficient use of the cells allowing to deliver currents very high in short periods (Pridie and Huster, 2011). GEL or gelled batteries are used as the main material to change the state of the electrolyte, silica gel, resulting in a gelatinous compound, avoiding leakage of lead acid. Lithium ion batteries, used as main material to change the state of the electrolyte, lithium salt. The anode is made up of graphite and the cathode is made of lithium oxides.

These batteries are characterized by having no memory, this means that they do not need to be completely discharged in order to charge them.

Table 4: Comparative table of the characteristics of the different types of batteries

Characteristics	Gel	AGM	Ion-Lithium
Voltage range	12 V	12 V	12 V
Capacity	225 Ah (Amps hour)	255 Ah (Amps hour)	200 Ah (Amps hour)
Temperature range	-20 a 50°C	-15 a 50°C	-15.556 a 70°C
Average mass	70 kg	78 kg	32 kg
Max. charge cycles	600 cycles	1200 cycles	3000 cycles
Max. discharge capacity	75%	100%	80%
Mounting position	Hasta 180°	Any position	Any position
Price	$400	$600 USD USD	$2399.99 USD

One of the advantages is that the temperature does not affect them so much, compared to lead acid, although, its disadvantage is that they are sensitive to deep discharge and overload, this can cause irreversible damage to the battery (Ranjbar *et al*., 2012).

The main characteristics of AGM (MTek 122550), GEL (Alphacell 220 GLX), Lithium-ion (12 V, 200 Ah) batteries are shown in Table 4. This information is obtained through manufacturer's manuals to demonstrate their behavior and main characteristics.

The data obtained show that Lithium-ion batteries are the best alternative offering higher charge/discharge cycles and lower average mass. These factors are important to take into account in the selection of batteries for an electric vehicle, however, the disadvantages of this type of batteries is their high cost and difficult acquisition in the market, hence, the second best option is evaluated which is AGM type batteries that has an acceptable efficiency, easy acquisition and good price-cost ratio. For the energy dimensioning of this vehicle, AGM type batteries will be used, although, they are not the best option, they have acceptable charge-discharge cycles, 100% of discharge and are easily obtained in the market at a low cost.

Based on the need to supply the power of 14181.465 Wh, the number of AGM batteries required is calculated, depending on the capacity and volume for a range of batteries of 12 V from 75-255 Ah from Mtek brand. By means of three tables, the number of batteries required are showed in relation to the power supplied (Table 5), the volume of the batteries (Table 6) and the mass (Table 7).

The data obtained in Table 5 demonstrate that only three types of batteries meet the power requirement. For 12 V 120 Ah type, 10 batteries are needed. 12 V 155 Ah batteries require 8 batteries. Finally, batteries 12 V of 255 Ah demand 5 batteries. For a better distribution, it is searched a type of batteries that has smaller dimensions. For the three types of batteries that meet the power requirements, it was found in Table 6 their different dimensions. For the battery type of 12 V of 120 Ah the volume is 161964 cm^3. The 12 V of 155 Ah require 160166 cm^3. Finally, those of 12 V of 255 Ah demand 154164 cm^3, finding a minimum advantage in 12 V type batteries of 255 Ah.

In relation to the mass of the three types of batteries seen in Table 7, 12 V 120 Ah have 350 kg, 12 V 155 Ah have 368 kg and finally 12 V 255 Ah have 390 kg, evidencing a lower mass in the type 12 V of 120 Ah.

The information of capacity, mass and dimensions of each battery was obtained by the manuals of manufacturer MTEK. With the data and analysis made, it is decided to use ten batteries in series of 12 V of 120 Ah because they meet the necessary power in addition, its mass is the smaller in comparison to the other types and although, the volume is not the best this amount of batteries allow to distribute them throughout the vehicle to increase the stability.

Table 5: Power supplied from batteries, in relation to the type quantity

No.type	12 (V)				
of batteries	75 (Ah)	100 (Ah)	120 (Ah)	155 (Ah)	255 (Ah)
5	4500 Wh	6000 Wh	7200 Wh	9300 Wh	**15300 Wh**
6	5400 Wh	7200 Wh	8640 Wh	11160 Wh	18360 Wh
7	6300 Wh	8400 Wh	10080 Wh	13020 Wh	21420 Wh
8	7200 Wh	9600 Wh	11520 Wh	**14880 Wh**	24480 Wh
9	8100 Wh	10800 Wh	12960 Wh	16740 Wh	27540 Wh
10	9000 Wh	12000 Wh	**14400 Wh**	18600 Wh	30600 Wh

Table 6: Volume of batteries, in relation to the type and quantity

No.type	12 (V)				
of batteries	75 (Ah)	100 (Ah)	120 (Ah)	155 (Ah)	255 (Ah)
5	46082 cm^3	54558 cm^3	80982 cm^3	100104 cm^3	**154164 cm^3**
6	55299 cm^3	65470 cm^3	97178 cm^3	120125 cm^3	184997 cm^3
7	64515 cm^3	76382 cm^3	113375 cm^3	140146 cm^3	215829 cm^3
8	73732 cm^3	87293 cm^3	129571 cm^3	**160166 cm^3**	246662 cm^3
9	82948 cm^3	98205 cm^3	145768 cm^3	180187 cm^3	277495 cm^3
10	92165 cm^3	109117 cm^3	**161964 cm^3**	200208 cm^3	308328 cm^3

Table 7: Mass of batteries, in relation to the type and quantity

No.type	12 (V)				
of batteries	75 (Ah)	100 (Ah)	120 (Ah)	155 (Ah)	255 (Ah)
5	115 kg	135 kg	175kg	230 kg	**390 kg**
6	138 kg	162 kg	210 kg	276 kg	468 kg
7	161 kg	189 kg	245 kg	322 kg	546 kg
8	184 kg	216 kg	280 kg	**368 kg**	624 kg
9	207 kg	243 kg	315 kg	414 kg	702 kg
10	230 kg	270 kg	**350 kg**	460 kg	780 kg

Bold values are significant values

Solar panels: One of the alternative energy sources for electric cars is solar panels which through a process of collecting electrons, transform solar energy into electrical energy. For the electric vehicle, the solar panels will serve as charging devices, allowing to recover part of the energy that the batteries lose by supplying this for the movement of the vehicle (Pires *et al*., 2012).

There are 3 different types of solar panels: Thermodynamic solar panels, characterized by being light and capture energy from any weather. Thermal solar panels, characterized by containing a heat transfer liquid which is heated by solar rays and this thermal energy can be used in different applications. Photovoltaic panels, characterized by an array of photovoltaic cells that receive positive and negative charges in two nearby semiconductors of different types which produce electrical energy from the light that falls on them (Alurralde *et al*., 2004).

The electric vehicle will use photovoltaic panels for that reason, electric power is needed. To take advantage of the maximum solar energy in the vehicle, it is necessary to use the largest surface of the vehicle. To meet this need, it will be implemented 5 solar panels which will be located on the sides, top, bonnet and back door.

In order not to affect the aerodynamics of the vehicle, it is necessary a flexible shape of the solar panels in order to adopt the shape of the vehicle, without affecting its aerodynamics.

The nominal power supplied by a solar panel is given by different conditions such as: radiation, angular position, system voltage, module characteristics and devices used. It should also be taken into account that the contribution of the panels depends on the time of the year in which it is and the climatic behavior. Taking as an example to know approximately irradiation, according to statistics made by the IDEAM (Institute of Hydrology, Meteorology and Environmental Studies of Colombia), average radiation during the day for Colombia (Cundinamarca) are 4-4.5 kWh/m^2 daily (Anonymous, 2012). The Peak Solar Hours (HSP) for Colombia (Cundinamarca) are approximately between 4 and 5 h in which the radiation is approximately 1000 W/m^2 which is appropriate to comply with the standard of radiation of photovoltaic panels. Throughout the year, the range of hours (HSP) are from 10am-2pm which indicates that for the use of photovoltaic panels those hours are appropriate to perform the charge.

The dimensions of a single-occupant electric vehicle are approximately 2×1.43×1 m, taking as a reference the approximate measures of the commercial vehicle Renault Twizy, since, this model is one-man type, ensuring adequate space to drive. Due this, the surface area that the photovoltaic panels would adopt is about 2 m^2.

A Wp represents the electric power supplied by the photovoltaic panel when the irradiation on it is approximated 1000 W/m^2, according to standardization, at a temperature of 25°C.

The total available peak power of the 5 panels is 200 Wp and are distributed as follows: A main panel located at the top of the vehicle, supplying a power of 80 Wp and on each side (side doors, bonnet and rear of the vehicle), panels of 30 Wp. This distribution is made in order to take advantage of most of all solar energy.

The power supplied by the photovoltaic panels depends on the position, angle and other efficiency factors. For this vehicle the positions and angles of the photovoltaic panels differ and depending on the position of the vehicle, only a side part and an end will take the solar energy, additionally taking into account possible energy losses due to the efficiency of the electrical components, 60% efficiency will be taken. Thus, the peak power is 120 Wp, assuming that the standard radiation conditions for photovoltaic panels are met.

For a real start-up of the vehicle with a duration of 35 mins, the contribution of the solar panels is minimal and approximately 70 Wh.

Due to the fact of obtaining low production of power by the photovoltaic panels, it is evident that to use them at the moment of the commissioning is futile, so, it is advisable to use them in moments where the vehicle is at rest and exposed to the environment under acceptable climatic conditions.

RESULTS AND DISCUSSION

Control systems and elements distributions: The choice of an optimal embedded control system for the vehicle is an important factor, since, the speed with which data is processed and decisions are made will infer the final behavior of the vehicle, resulting in greater autonomy, energy optimization and reliability to the driver. A good distribution of elements will infer in the performance, comfort and reliability of the vehicle, so, it is important to consider concepts such as mass center in geometric center and spatial distribution.

Control systems: There are different systems for controlling an electric vehicle from micro controllers to embedded systems which provide a high range of signal processing resources. After performing a respective processing, these signals are delivered to power systems which interact directly with the systems that provide the movement to the vehicle. For this vehicle, it is recommended to use a RaspBerry Pi embedded control system because it allows to process many data at the same time.

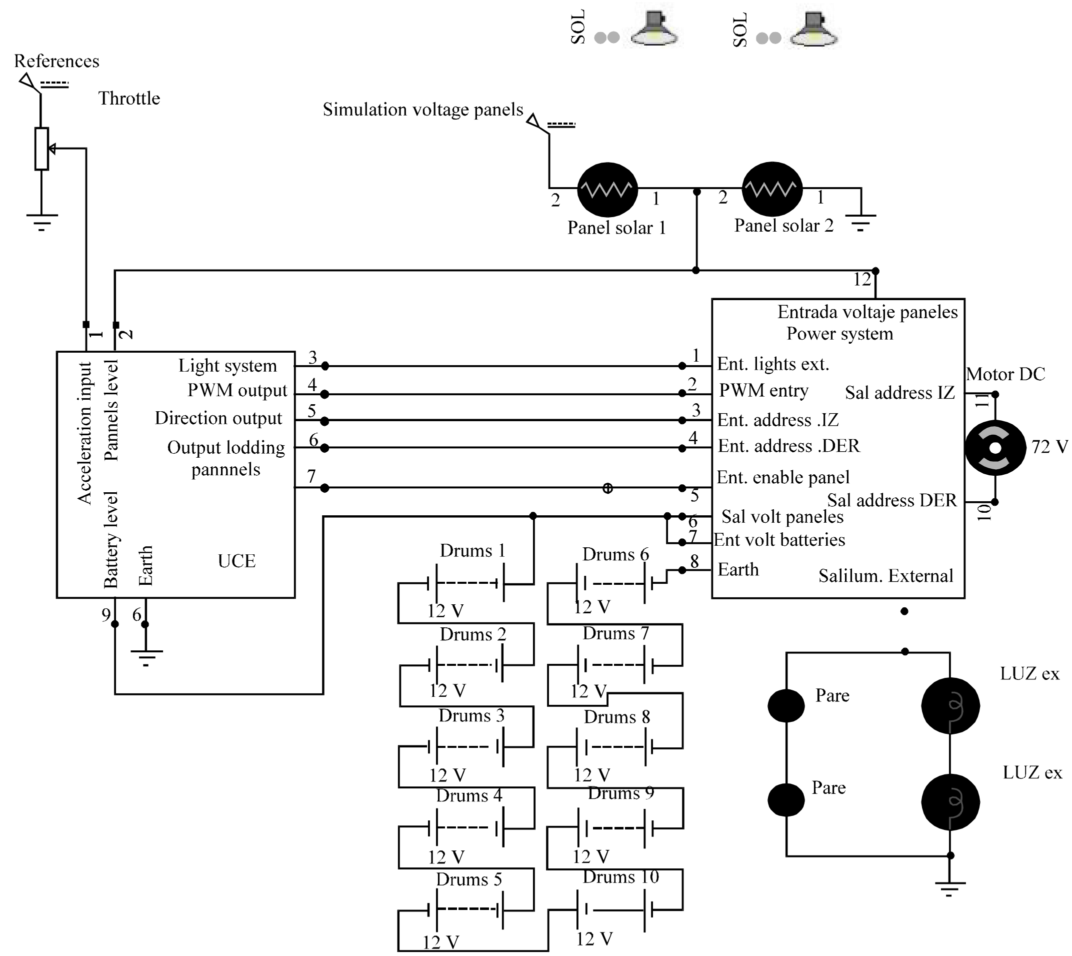

Fig. 3: Electrical circuit of a single-occupant electric vehicle with solar panels as charging support

RaspBerry Pi has a 700 MHz processor and 500 MB RAM. This is an important factor when starting up the electric vehicle because it performs many tasks at the same time with precision such as getting the data of its accelerating and at the same time making decisions for recharging or sensing variables. This hardware also has several connectivity resources for future developments and visualization of the status of variables such as speed, charge, motor RPM, etc.

After performing the signal processing, these are delivered to a power unit which interacts directly with the electrical devices such as: motor, the batteries and solar panels.

The power unit is composed of the motor speed controller a solar controller that is implemented in the photovoltaic panels and a charge switching system. For the choice of the motor speed controller, it must be taken into account that this must be fed back with the relative speed of the vehicle in order to increase the speed when stepping on the accelerator because if the vehicle goes at a higher speed than the one referenced, the possibility is that a sudden deceleration is done to the vehicle, generating traction damages and discomfort to the user the most preferred controller that meets the above specifications is sine wave Vec 700 reference which handles a maximum current of 400 A, direct torque control and weighs 6.5 kg.

Figure 3 shows the electric circuit of the proposed vehicle. In the upper left is the acceleration device which through a voltage difference will indicate to the Electronic Control Unit (ECU) at what speed is desired. The UCE processes the relative and reference acceleration data and sends to the power unit (located on the right-hand side) a Pulse Width Modulated signal (PWM) to move the motor (located at the right end). The solar panels (located at the top) are monitored by the ECU to know the level of energy they are receiving and evaluates if the batteries need charging if necessary, a signal is sent to the power system and the solar panels are used as battery charging support (located at the bottom).

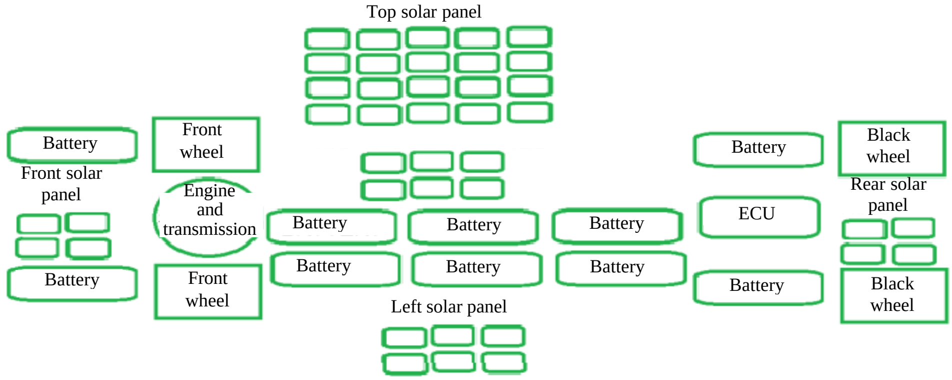

Fig. 4: Distribution of different electrical electronic and mechanical systems

Distribution of electrical elements: An optimum distribution of elements in an electric vehicle, allows to obtain the center of mass in the geometric center. This generates a high index of stability, increasing the reliability and security.

Figure 4 illustrates the possible distribution of electrical elements in a vehicle, so that, all spaces are taken advantage of 292/5000 flexible solar panels are located at the ends, the 10, 12 V and 120 Ah AGM batteries are located at the ends of Fig. 4, the motor and transmission are in the middle left and the electronic control unit is shown in the right middle.

The location of the 5 flexible photovoltaic panels is made to cover the largest surface area of the bodywork in order to maximize solar energy.

CONCLUSION

It was evidenced that for the electrical dimensioning of a vehicle, it is necessary to have an order in the selection of the elements, starting from the power required as the basis for that choice where the battery depends on the type of motor and the motor depends on the proposed scope.

The motor and batteries were selected according to the parameters set, providing specific details of each one. The motor was selected DC type with power and rpm meeting requirements given at a speed of 60 km/h which generates a clear criterion for decision making when buying these elements.

For the batteries it was necessary to make a comparison between the different types that exist in the market, finding that the AGM has the best cost-efficiency. Additionally, characteristics such as power-hour, volume and mass were compared, based on the number of batteries, finding that it is best to use four 12 V and 255 Ah batteries connected in series. Solar panels, despite being distributed throughout the vehicle to increase the area and capacity of energy collection have a small contribution of power at the time of commissioning for this reason it is recommended to use them only as support of charge of the control system and of instrumentation of the vehicle or to use them in the moment in which the vehicle is at rest and exposed to the environment in acceptable climatic conditions.

Taking all selected items, an electronic control hardware and a distribution of these devices were proposed, balancing the space of the vehicle.

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REFERENCES

Alurralde, M., M. Barrera, C.G. Bolzi, C.J. Bruno and J.C. Duran *et al*., 2004. [Latest developments related to the manufacture and testing of solar panels and components for space uses (In Spanish)]. Avances Energias Renovables Medio Ambiente, 8: 04.01-04.06.

Anonymous, 2012. [Global solar radiation map multiannual average month of December]. Institute of Hydrology, Meteorology and Environmental Studies, Bogota, Colombia. (In Spanish)

Bremermann, L.E., M. Matos, J.A.P. Lopes and M. Rosa, 2014. Electric vehicle models for evaluating the security of supply. Electr. Power Syst. Res., 111: 32-39.

Cicconi, P., M. Germani, D. Landi and M. Mengarelli, 2013. Cooling simulation of an EV battery pack to support a retrofit project from lead-acid to Li-Ion cells. Proceedings of the 2013 IEEE International Conference on Vehicle Power and Propulsion (VPPC'13), October 15-18, 2013, IEEE, Beijing, China, ISBN:978-1-4799-0720-5, pp: 1-6.

Cipollone, R., D. Di Battista, M. Marchionni and C. Villante, 2014. Model based design and optimization of a fuel cell electric vehicle. Energy Procedia, 45: 71-80.

Damiano, A., I. Marongiu, M. Porru and A. Serpi, 2012. Electric Vehicle energy storage management for Renewable Energy Sources exploitation. Proceedings of the 2012 IEEE International Conference on Electric Vehicle (IEVC'12), March 4-8, 2012, IEEE, Greenville, South Carolina, ISBN:978-1-4673-1562-3, pp: 1-8.

Kolbel, D.A., 2002. Parameters to consider for installation of VRLA-batteries versus different ambient temperatures. Proceedings of the 24th Annual International Conference Telecommunications Energy (INTELEC'02), September 29-October 3, 2002, IEEE, Montreal, Quebec, Canada, ISBN:0-7803-7512-2, pp: 530-532.

Pina, A., P. Baptista, C. Silva and P. Ferrao, 2014. Energy reduction potential from the shift to electric vehicles: The Flores island case study. Energy Policy, 67: 37-47.

Pires, V.F., A. Roque, D.M. Sousa and G. Marques, 2012. Photovoltaic electric vehicle chargers as a support for reactive power compensation. Proceedings of the 2012 International Conference on Renewable Energy Research and Applications (ICRERA), November 11-14, 2012, IEEE, Nagasaki, Japan, ISBN:978-1-4673-2328-4, pp: 1-6.

Pridie, S.W. and A. Huster, 2011. Qualification of AGM lead-acid batteries for long-term subsea deployment. Proceedings of the International Conference on Oceans, September 19-22, 2011, IEEE, Waikoloa Village, Hawaii, ISBN:978-1-4577-1427-6, pp: 1-6.

Ranjbar, A.H., A. Banaei, A. Khoobroo and B. Fahimi, 2012. Online estimation of state of charge in Li-ion batteries using impulse response concept. IEEE. Trans. Smart Grid, 3: 360-367.

Rupchand, K.V., 2011. A proposal for meeting power demands of electric vehicle transportation in India. Proceedings of the 2011 IEEE General Meeting on Power and Energy Society, July 24-29, 2011, IEEE, San Diego, California, ISBN:978-1-4577-1000-1, pp: 1-5.

Shumei, C. and L. Chen, 2008. Study on efficiency calculation model of induction motors for electric vehicles. Proceedings of the 2008 IEEE Conference on Vehicle Power and Propulsion (VPPC'08), September 3-5, 2008, IEEE, Harbin, China, ISBN:978-1-4244-1848-0, pp: 1-5.

Tanaka, D., T. Ashida and S. Minami, 2008. An analytical method of EV velocity profile determination from the power consumption of electric vehicles. Proceedings of the Conference on Vehicle Power and Propulsion (VPPC'08), September 3-5, 2008, IEEE, Harbin, China, ISBN:978-1-4244-1848-0, pp: 1-3.

Terras, J.M., A. Neves, D.M. Sousa and A. Roque, 2010. Estimation of the induction motor parameters of an electric vehicle. Proceedings of the 2010 IEEE Conference on Vehicle Power and Propulsion (VPPC'10), September 1-3, 2010, IEEE, Lille, France, ISBN:978-1-4244-8220-7, pp: 1-6.

Terras, J.M., D.M. Sousa, A. Roque and A. Neves, 2011. Simulation of a commercial electric vehicle: Dynamic aspects and performance. Proceedings of the 14th European Conference on Power Electronics and Applications (EPE'11), August 30-September 1, 2011, IEEE, Birmingham, England, UK., ISBN:978-1-61284-167-0, pp: 1-10.

Wertz, J.A. and T.J. Clough, 1999. Development of advanced lead acid batteries for electric vehicles: The use of additives to increase performance and extend life I. AGM cells. Proceedings of the 14th Annual Battery Conference on Applications and Advances, January 12-15, 1999, IEEE, Long Beach, California, USA., ISBN:0-7803-4967-9, pp: 189-195.

West, J.G., 1994. DC, induction, reluctance and PM motors for electric vehicles. Power Eng. J., 8: 77-88.