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"DESIGN AND IMPLEMENTATION OF AN ELECTRICAL CHARGE GENERATOR SYSTEM, USING SOLAR PANEL, FOR AN INCREASE THE AUTONOMY OF AN ELECTRICAL VEHICLE KIA SOUL"

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Agradezco a Dios, mis abuelos y mi madre por brindarme todo el tiempo su apoyo incondicional en cada una de las etapas más difíciles de la universidad y de la vida. Siempre tendré ese hermoso recuerdo de verlos dándome concejos y guías para no desmallar en el camino. También quiero agradecer a mi tío y padre que desde siempre estuvo conmigo en cada momento guiándome y resguardando mi vida y mi prosperidad.

DEDICATORIA

Dedico este artículo académico a todas las personas que estuvieron en el camino desde mi infancia hasta el momento de culminar mi etapa en la universidad, en especial a los docentes que en el camino muy aparte de ser docentes fueron amigos.

DESING AND IMPLEMENTATION OF AN ELECTRICAL CHARGE GENERATOR SYSTEM, USING SOLAR PANEL, FOR AN INCREASE THE AUTONOMY OF AN ELECTRICAL VEHICLE KIA EV SOUL.

Cárdenas Andrade Rene Leonardo.

***Abstract*— This research deals with the study of efficiency in the implementation of solar panels in an electric vehicle of the KIA brand, model SOUL EV, version 2015, to recharge the vehicle´s auxiliary battery. In Ecuador, mainly in the city of Loja, a fleet of electric vehicles was implemented, as time went by, problems began to appear in the reduction of the real autonomy of the vehicles. For this reason is necessary to find ways to implement systems that increase the autonomy of the vehicle, in this research it was carried out experimentally on routes planned by the city of Cuenca and also monitoring the weather of the days in which the tests are carried out.**

Key words— charge controller, solar panel, solar radiation.

I. INTRODUCTION.

The principal problem of the electric vehicles is their autonomy. The autonomy described by the manufacturers is affected when the vehicles are put into circulation. According to the investigation of BORIBOONSOMSIN y BARTH [1], he principal factors are sloped roads, road roughness, wind speed, occupant weight, use of peripherals, driver's way of driving, selection of conduction mode, pressure that applied to the brake pedal, traffic conditions, ambient temperature and wind speed, driving aggressiveness by the driver and the selection of the driving mode. For this reason, this research focuses on the charge importation by the high-voltage battery to the vehicle's auxiliary battery, which is responsible for providing power to all the vehicle's peripherals. Due to this named fact, it is proposed to implement an auxiliary battery recharge system by installing solar panels to charge the auxiliary battery, in such a way that the high voltage battery suppresses this consumer, causing its autonomy not to be affected but Rather, it is increasing, given the case that the solar panels will be the source of charging and recharging the auxiliary battery that is responsible for providing power to all the vehicle's outlying.

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II. ESTUDY OF SOLAR ENERGY AND ITS TYPES.

According to the magazine CIENCIAS [2], the sun is the only source of energy that keeps planet earth alive. It continuously emits 62,600 K / w for every square meter of its surface. It is known that in a period of 48 hours the planet receives an amount of energy similar to all known reserves of gas, coal and oil.

There are two ways to take advantage of this energy emitted by the sun, the first is thermally

and the second is photovoltaic.

A) CALORIC ENERGY.

In Figure 1 we can see how caloric energy works. This is a classic system of solar heaters, these are responsible for taking advantage of the energy provided by the sun, which is thermal energy capturing the sun's rays, through solar heaters, this energy is responsible for heating the water system of a house , since the water is passed through the tubes of the solar heaters so that it absorbs the heat from the heaters, this water will be destined for different uses such as: showers, washing clothes, washing dishes, heating the water of a swimming pool and even the generation of mechanical energy that can be used to produce electrical energy [2].

Figure 1. Representation of thermal energy in a house.[2]

B) RADIATION SOLAR.

The basis on which current commercial photovoltaic systems are based is the so-called photoelectric principle, by means of which the radiation of sunlight can be transformed into electrical energy. This effect occurs in the so-called photoelectric cells, the basic unit that make up the photovoltaic modules or panels. [3].

All sunlight radiation is made up of elementary particles, called photons. These particles are associated with an energy value *(E)*, which depends on the wavelength *(λ)* of the radiation, where *(h)* is Planck's constant and *(c)* is the speed of light, and whose quantitative value It is expressed as follows:

$$E = h * c/\lambda \quad (1)$$

When a photovoltaic module receives solar radiation, the photons that make up said radiation hit the photovoltaic cells of the panel. These can be reflected, absorbed or pass through the panel, and only the photons that are absorbed by the photovoltaic cell are those that, finally, will generate electricity as shown in Figure 2 [4].

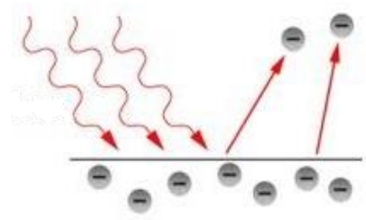

Figure 2. Photovoltaic cells [4]

Figure 3 shows it can be seen that, when the photon is absorbed by the cell, the energy carried by the photon is transferred to the atoms that make up the material of the photovoltaic cell. With this new energy transferred, the electrons that are located in the most distant layers are able to jump and detach from their normal position associated with the atom and become part of an electrical circuit that is generated [4].

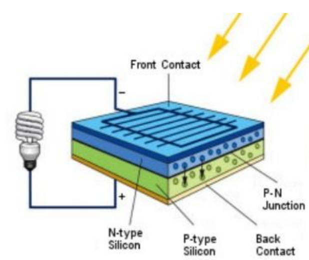

Figure 3. Contact of photons with solar cell.[4]

C) *PHOTOVOLTAIC ENERGY*.

To take advantage of the sun's energy and convert it into photovoltaic energy, solar panels are used that are made of various materials, but their main compound is silicon, in this way the sunlight that falls directly on the panel plate causes the photovoltaic cells to produce an electric potential difference, this causes electrons to circulate, producing electric current [5].

In Figure 4 we can see the architecture of a solar panel installation to generate electrical energy for a house, as the first component is the solar panels of semiconductor material that is silicon, this energy produced passes to a charge regulator, this will be the one in charge of controlling the charge in the accumulator, then the same regulator sends the electric current from the accumulator to the inverter, since the energy produced and stored is DC and AC current is needed for a home, once the energy leaves the inverter it is sent direct to the consumer or consumers.

Figure 4. Photovoltaic system for houses.[5]

III. ANALYSIS OF THE FACTORS THAT INFLUENCE ON THE DECREASE OF AUTONOMY OF THE ELECTRIC VEHICLE.

It is essential to take into account the different factors that affect the decrease in autonomy of the electric vehicle, there are different types of factors such as: drive style, road architecture, ambient temperature, wind speed, the weight of the occupants, selection of drive mode and use of vehicle accesories.

According to the webportal HIGHMOTOR [6] One of the things that most affects the autonomy of an electric car is stepping on the accelerator. The more it is accelerated, the more energy is consumed. This causes the vehicle to circulate faster, but the number of kilometers to travel is reduced. To avoid this, it is necessary to take more advantage of the vehicle's inertia, without using the accelerator. In this way, not as much energy is used to travel the same distance. It is estimated that for every kilometer traveled, stepping on the accelerator increases the range by about 300 meters, so it is a good idea not to use aggressive driving with an electric car.

The portal GEOTAB [7] assures that it is often assumed that the loss of autonomy in conditions with low temperatures is due to a worse battery performance. Although lithium ion batteries are slower in extreme temperature conditions; cold temperatures affect their ability to store and release energy, this has a much lower impact on the autonomy of the auxiliary charge.

The road architecture generates a very significant decrease in autonomy showed in the investigation of SOLANO y CABRERA [8], It is established that in a city at sea level like Machala, for every 10 km traveled, the KIA SOUL electric vehicle needs 4.24% of its battery capacity, while in a city like Cuenca that is located at 2200 meters above sea level, 6.06% of the battery charge, therefore in cities with high relief the vehicle will have a less autonomy.

The consumption presented by the uses of peripherals showed in the investigation of ARMIJOS y GOMEZ [9], It is said that they have an independent consumption each one but added all the peripherals such as lights, radio, audio, air conditioning system, among others, their consumption can vary from 1 A to 12.5 A so that it represents a high charge and decreases the autonomy of the electric vehicle.

IV. HYPOTHESIS AND SIMULATION.

An important element for the operation of low-power systems in electric vehicles is the low-voltage battery. In order to know the consumption values of the low voltage battery, data is taken through the EMOLAB software in a period of time of one hour and fifteen minutes, under the conditions of ignition of the vehicle peripherals, these are the following:

- Ligthing system.
- Air conditioning system.
- Audio system.
- Interior ligths.

In Figure 5 we see the results obtained in the driving test, it can be seen that Figure 5 has negative values, these represent a battery charge provided by the LCD (low voltage DC-DC converter) and the positive values are those of the battery discharge within the set handling time.

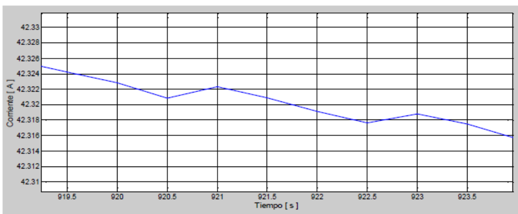

Figure 5. Current fluctuation as a function of time

In order to determine the actual battery discharge value, it is necessary to separate the battery charge and discharge values in the test period that the data was taken in such a way that a straight discharge graph is generated as shown in the figure. 6.

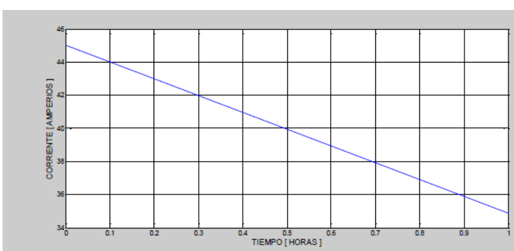

Figure 6. 10.13 Amp current discharge line.

To calculate the discharge current according to PARAPI y PEZANTES [10], the equation for calculating the slope of the line is used, the variable "m" indicated in equation 2 being the discharge current of the vehicle's auxiliary battery as shown in the following equation (2):

$$m = \frac{y2-y1}{x2-x1}$$

(2)

For its calculation using the previous equation, we have as values of "y2" the final value of the current that is seen in figure 6, 34.87 A and as "y1" the initial value of the electric current of the battery being 45 A and for " x2" takes a time value of 1 and for "x1" a time value of 0. Solving the equation we obtain the following result:

$$m = \frac{34.87-45}{1-0} \qquad (3)$$

$$m = -10.13 \qquad (4)$$

Observing this negative result, it is confirmed that the battery discharge is 10.13 A.

A) ELECTRIC RECHARGING SYSTEM.

As the first part of the research, the design of the regenerative system is proposed, in Figure 7, based on an isolated photovoltaic system with a battery.

Figure 7. Regenerative system design flow diagram.

Once the design of the regenerative system has been proposed, it is simulated, in Figure 8, to obtain theoretical operating values, according to REYES [11], for this, two input variables are required with respect to the photovoltaic module, which are temperature and solar irradiation with a value of 25ºC and 1000 W / m respectively, these values are taken as theoretical constants for the simulation of the system for study reasons , for the output variables we have the voltage (Voc) and the current (Isc).

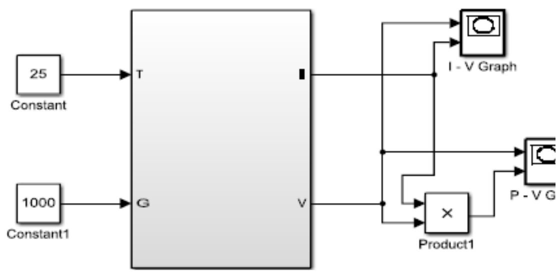

Figure 8. Simulation in the simulink software of the regenerative system.

Once this system is simulated, work curves of the designed system are obtained, these curves are intensity vs voltage (I-V) and power vs voltage (P-V).

In the I-V curve shown in Figure 9, the data is calculated in an open circuit, resulting in 5.89 A and 22.10 V.

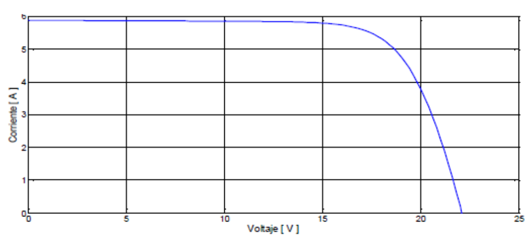

Figure 9. Consumption vs voltage curve.

In the P-V curve shown in Figure 10, the data is calculated in an open circuit, resulting in approximately 100 W and 22.10 V.

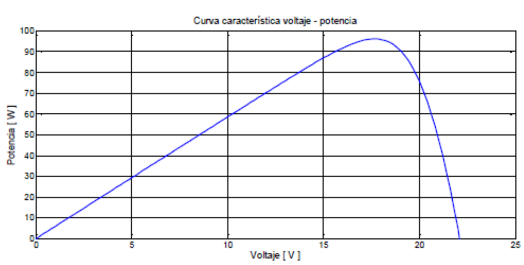

Figure 10. Power vs. voltage curve.

These results are not satisfactory for supplying the accessory battery that is being designed, as it was calculated the system needs a demand of 10.13 A to charge the auxiliary battery of the vehicle, so it is proposed to use two solar panels in parallel, being This is the exact configuration to meet the 10.13 A need for the electric vehicle's auxiliary battery, as shown in Figure 11.

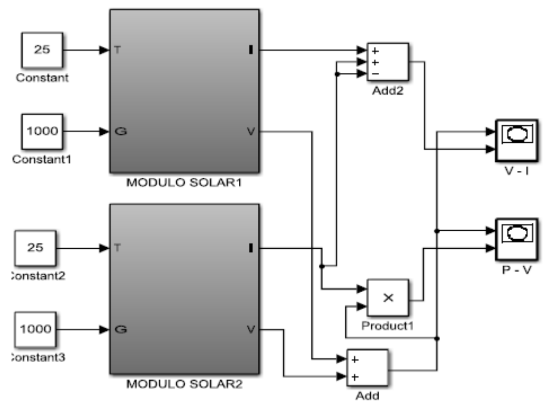

Figure 11. Parallel configuration of the regenerative system.

The parallel connection of the solar modules generates an increase in the electric current intensity to 11.78 A and maintaining a voltage of 22.10 V. Meeting the charging needs of the electric vehicle auxiliary battery.

B) DESIGN AND STRUCTURAL SIMULATION OF SOLAR PANEL SUPPORT.

For the assembly of solar panels in the electric vehicle, the following conditions are considered: size and weight.

These being the most important due to the loads they must bear.

Prior to the design, data such as the weight of the solar panels that add up to 14.58 lb and the surface to be occupied by the vehicle in the upper part are obtained, obtaining 1588mm long and 1053mm wide with a tolerance of 5mm.

For this reason, Figure 12 shows the structure to be used in aluminum with profile J.

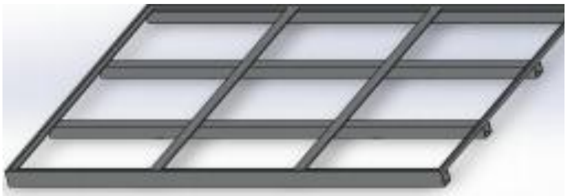

Figure 12. Mounting structure for solar panels.

C) AERODYNAMIC ANALYSIS.

For the aerodynamic analysis of the design, a mechanical design software was used, according to PARAPI y PEZANTES [10], you must take into account the driving conditions in Ecuador and also the maximum speed of the KIA SOUL electric vehicle.

In addition, the meteorological conditions of the city of Cuenca where the driving tests were carried out are taken into account.

According to the entity SES (Safety Enforcement Systems) [12], speed conditions are maintained on the equatorial roads depending on the type of road. There are four types of road: school zone, urban, perimeter and straight on the road; detailing in table 1 the speed limits for each type of road, which were taken into account for the aerodynamic analysis.

Table 1. Types of roads and speed limits.

Type of road	Speed limit
School zone	30 Km/H
Urban	50 Km/H
Perimeter	90 Km/H
Straight on road	100 Km/h

The authors PARAPI y PEZANTES [10], establish that the speed ranges are used to determine maximum stresses, as design parameters in the construction of the structure. For the simulation of aerodynamics in the mechanical design software, two fixed variables are established: minimum travel speed 30km / h and maximum vehicle speed 145 km/h.

For the first part of the simulation, the speed of 30 km/h is taken as the least critical condition on which the vehicle will act with the structure and the solar panels mounted on its roof, since this speed is the minimum that the vehicle will legally reach. in a street, therefore under these parameters we proceed to simulate as shown in Figure 13.

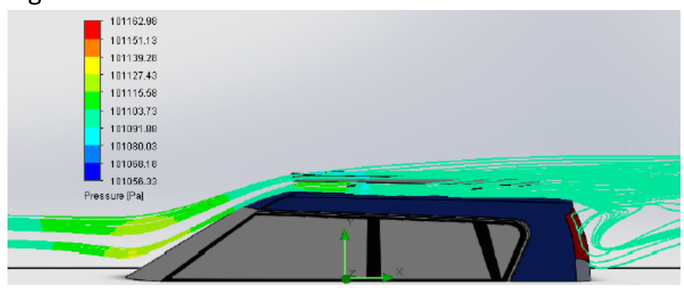

Figure 13. Aerodynamic analysis evaluated at 30 km /h.

As a result in Figure 13, there is no accumulation of flow in any area of the structure, therefore, it can be assumed that there is no considerable effort affecting the vehicle body, much less the structure as such, in Table 2 shows the values obtained.

Table 2. Maximum pressure and speed conditions at 30Km / h.

Maximum pressure and speed conditions at 30 Km / H		
	Maximun pressure	Maximun Speed
First panel	101115,00 Pa	29,20 Km/H
Second panel	101096,60 Pa	24,45 Km/H
Third panel	101097,33 Pa	19,67 Km/H

For the second part of the simulation, the speed of 145km/h is taken as the most critical condition on which the vehicle will act with the structure and the solar panels mounted on its roof, since this speed is the maximum at which the vehicle it would arrive under given conditions, therefore under these parameters we proceed to simulate as show in Figure 14.

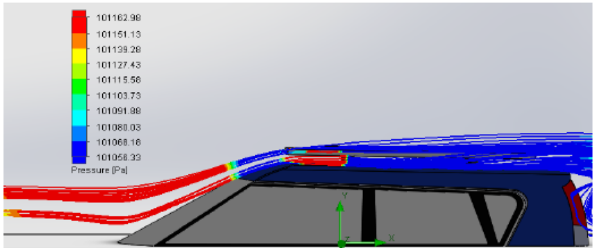

Figure 14. Aerodynamic analysis evaluated at 145km/h.

In Figure 14 a pressure is noted in the lower front part of the structure, causing a boxing of the flow, but its trajectory causes a decrease in pressure and flow velocity in the central and rear part, obtaining the values shown in the table.

Table 3. Maximum pressure and speed conditions at 145 km/h.

Maximum pressure and speed conditions at 30 Km / H		
	Maximun pressure	Maximun Speed
First panel	101471,02 Pa	135,28 Km/H
Second panel	101024,56 Pa	116,28 Km/H
Third panel	101032,05 Pa	97,28 Km/H

Based on the results obtained in table 2 and table 3, we observe that the first panels are the most affected by the air circulation flow at the handling speeds mentioned above.

Therefore, based on these results, we see that the structure will not present problems in terms of aerodynamics in question and neither will it present a drastic change in the aerodynamics of the vehicle, because there is a pressure difference of 91 356.02 Pa between the first simulation and the second in the first panel.

D) STRESS SIMULATION.

First we have to bear in mind that for the stress simulation we do not want any material to reach its plastic deformation zone, therefore the efforts that will be vectorized in the program will be simulated perpendicular to the structure with the solar panels for that reason. Two simulations are carried out at 30km/h as the minimum speed and 145km/h as the highest speed the vehicle will reach.

In the simulation at 30km/h the maximum deformation is recorded in the first panel due to the pressure concentration due to its position in the structure as shown in Figure 15.

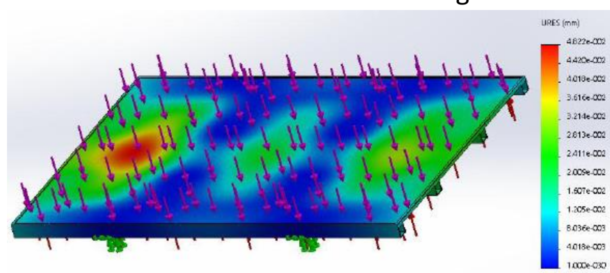

Figure 15. Analysis of deformation and maximum stresses at 30 km / h.

And as can be seen in Figure 16, the deformation value is minimal, maintaining a high safety factor.

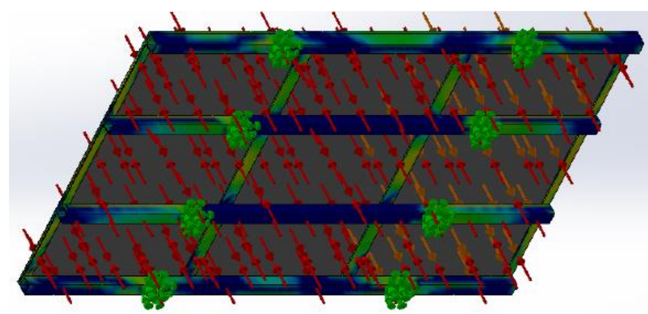

Figure 16: Minimum safety factor at 30 km / h.

In Table 4 we can see the deformation and safety factor values obtained from the simulation.

Table 4. Analysis of efforts at 30 km / h.

Stress analysis an 30Km/H	
Maximum deformation	Minimum safety factor
0,048216 mm	28

In the second part of the simulation we are going to work with a speed of 145km/h, so that in the simulation we obtain a deformation of less than 1 mm as shown in Figure 17.

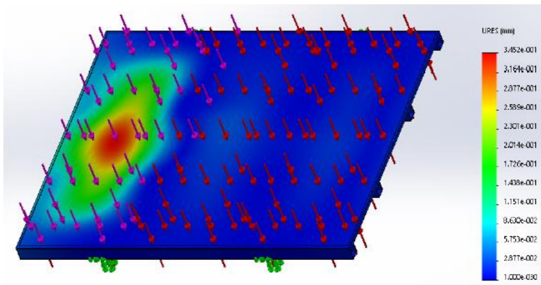

Figure 17. Deformation analysis with maximum efforts at 145 km / h.

In the same stress simulation under the same load conditions, a high safety factor is obtained as shown in figure 18, so that it remains demonstrating that the design of the structure and its assembly fulfills its function..

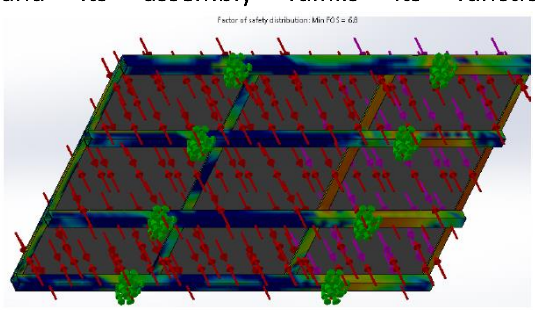

Figure 18. Minimum safety factor at 30 km / h

In table 5 we obtain the deformation values and the safety factor obtained from the simulation for the designed structure in such a way that it is shown that the design fulfills its function..

Table 5. Analysis of stresses at 145Km / h.

Stress analysis an 30Km/H	
Maximum deformation	Minimum safety factor
0,345207 mm	6,8

Based on these results, it is shown that the design fulfills its function and that aluminum is the best option to maintain the minimum weight because its deformation is almost zero, giving an advantage due to the resistance of the material and maintaining a factor of high security.

V. DATA COLLECTION AND ANALYSIS OF RESULTS.

In order to a data collection protocol, it is first necessary to know the average electrical current consumption per kilometer traveled by the vehicle only with the use of peripherals, that is why in the research of PARAPI Y PEZANTES [10], the consumption ratio for each kilometer traveled is established as its values are shown in Table 6.

Table 6. Peripheral consumption analysis.

SYSTEM	% OF CHARGE/Km	CURRENT CONSUMED	
		Min	Max
Lighth system	0,47	1,9	2,5
Headlighth system		2,4	3,2
heating system	0,5	1,9	3,1
AC electric fan		0,2	7,5
Audio system	0,003	0,2	0,2
Total	0,973	6,6	16,5
		Prom=11,55 Amp	

According to these data, the reduction in theoretical autonomy for each kilometer traveled is 0.973% as well as the current consumption varies between 6.6 A to 16.5 A, generating an average consumption of 11.5 A, therefore in the tests that are going to be carried out, it will be verified that consumption has a behavior similar to the theoretical one.

For data collection, two types of tests will be generated, the first will be a static test and the other a dynamic test.

A) ESTATIC TEST.

These tests are performed under the following conditions:

- Outdoor place.
- Constant monitoring of the high voltage battery.
- Constant monitoring of the auxiliary battery.
- Constant monitoring of the state of charge (SOC).

These tests are carried out in two stages, a first stage without connecting the recharging system with solar panels and a second stage with the installed system.

Prior to the start of the static tests, a sampling protocol established in the investigation of PARAPI y PEZANTES [10], the established protocol is shown in Figure 19.

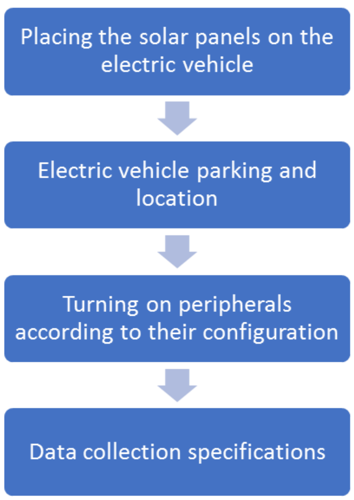

Figure 19. Sampling protocol in static tests.

As indicated in Figure 19, the protocol to follow is as follows:

- First stage, the solar panels are installed on the vehicle..
- Second stage we proceed with the parking of the vehicle, in this part of the protocol we have to be aware that it is an open area where solar radiation directly or partially affects the solar panels.
- Third and most important stage of this protocol is the switching on of peripherals based on an established configuration, this configuration as shown in table 7 is given in such a way that the auxiliary battery of the vehicle provides charge to the peripherals that they are turned on in the order established by the test, so that a growing behavior and trend is generated and in turn a comparison is generated with the same tests without solar panels.
- Finally, the instrumentation for data collection is connected to the OB II port of the vehicle and information is obtained through the EMOLAB software.

Table 7. Consumer ignition configuration.

			Lighting system	
	Solar panel	Radio and heating	Medium light	High light
First configuration	ON/OFF	OFF	OFF	OFF
Second configuration	ON/OFF	ON	OFF	OFF
Third configuration	ON/OFF	ON	ON	OFF
Fourth configuration	ON/OFF	ON	ON	ON

Once the sampling protocol is established, the tests are carried out with solar panels and without solar panels, taking into account the established consumption configurations, it is observed that the fourth configuration established in Table 7 is the one in which the highest consumption is generated. For this reason, Figure 20 shows the battery consumption without the installation of solar panels with a red line and the consumption with the installation of solar panels in the vehicle is shown in blue, analyzing these lines gives two functions, for the red line we have function (5), and for the blue line we have function (6).

$$f(x) = 0.004066x + 0.0979 \qquad (5)$$

$$f(x) = 0.002870x + 0.1580. \qquad (6)$$

Analyzing the fourth consumption configuration of Table 7 we observe that all consumers are activated and based on the graphs in Figure 20 and the functions obtained, it is established that the duration of the electric vehicle battery without the solar panels is 389 minutes while with the solar panels installed the battery life of the vehicle increases to 550 minutes.

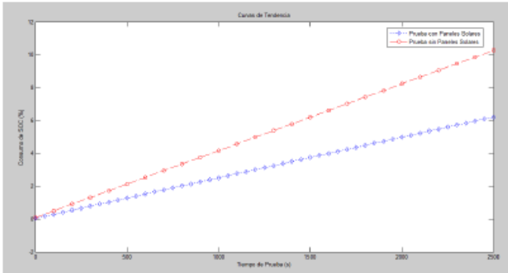

Figure 20. Global trend of the fourth configuration.

B) DINAMIC TESTS.

These tests are carried out under the following conditions:

- Short and long routes.
- Adverse weather conditions.
- Constant monitoring of autonomy per kilometer traveled.

The sampling protocol is based on the same methodology as the static tests with the difference that short and long-haul tests

are added to these tests as shown in Figure 21.

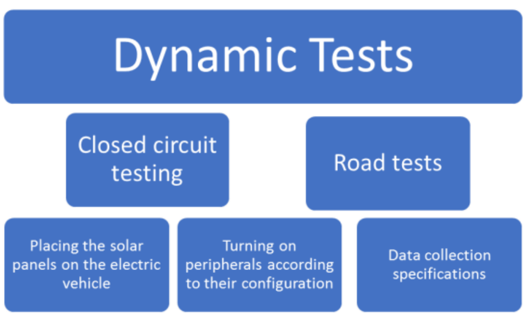

Figure 21. Sampling protocol in dynamic tests.

The short circuit tests are carried out in a designated space of the UPS that has the characteristics of being an oval track of approximately 800 square meters and a 12.3km route is completed.

The road tests are given in a section from the UPS to the viewpoint of three crosses in the Cajas that has a route of 40km.

For this protocol, two ignition settings are established as shown in table 8 for short tests and in table 9 for long tests.

Table 8. Consumer ignition configuration.

			Lighting system	
	Solar panel	Radio and heating	Medium light	High light
First configuration	ON/OFF	OFF	OFF	OFF
Second configuration	ON/OFF	ON	OFF	OFF
Third configuration	ON/OFF	ON	ON	OFF
Fourth configuration	ON/OFF	ON	ON	ON

Table 9. Consumer ignition configuration.

			Lighting system	
	Solar panel	Radio and heating	Medium light	High light
First configuration	ON/OFF	ON	ON	ON

Once the sampling protocol has been established, the short-path tests with solar panels and without solar panels are carried out, taking into account the established consumption configurations, it is observed that the fourth configuration established in table 8 is the one in which the highest consumption is generated, therefore in Figure 22 the battery consumption is shown with a red line without the installation of solar panels and the consumption with the installation of solar panels in the vehicle is shown in blue, analyzing these lines we obtain two functions, for the red line we have function (7), and for the blue line we have function (8).

$$f(x) = 1.425x - 0.2168 \quad (7)$$

$$f(x) = 1.105x + 0.06348 \quad (8)$$

Analyzing the fourth configuration established in table 8 of consumption, we see that all consumers are activated and based on the graphs in Figure 22 and the functions obtained, it is established that the prediction of autonomy of the electric vehicle without the solar panels is 66.81 km while with the solar panels installed, the prediction of the vehicle's autonomy increases to 85.91 km.

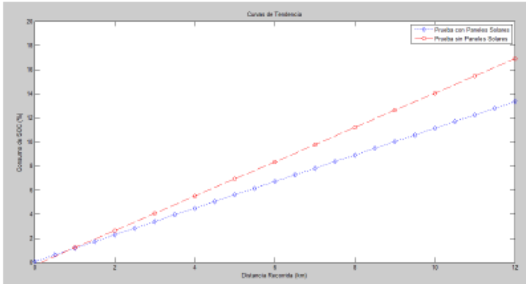

Figure 22. Global trend of the fourth configuration.

Once the sampling protocol is established, long-distance tests are carried out with solar panels and without solar panels, taking into account that for this test many meters above sea level are made, a change in the established functions will be seen due to that there is a higher consumption, it is observed that the first configuration established in Table 9 is the one in which the highest consumption is generated, therefore in Figure 23 the battery consumption without the installation of panels is shown with a red line Solar and blue, the consumption is shown with the installation of the solar panels in the vehicle. By analyzing these curves, two functions are obtained. For the red curve we have function (9) and for the blue color curve we have function (10).

f (x) = - 0.001443x ^ 3 + 0.09723x ^ 2 + 0.3804x + 1.537 (9)

f (x) = - 0.001096x ^ 3 + 0.07164x ^ 2 + 0.5689x + 1.298 (10)

Analyzing the first configuration of consumption we see that all consumers are activated and based on the graphs in Figure 23 and the functions obtained, it is established that the efficiency of the system is 12.82%.

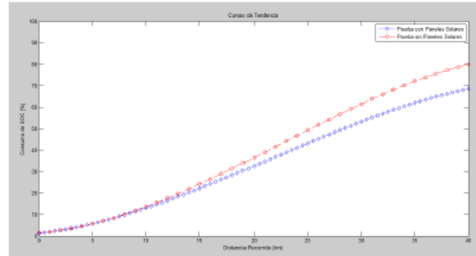

Figure 23. Global trend of the ascent route

For the descent route, the same peripheral configuration established in Table 9 is maintained, in this test we will see how the regenerative brakes intervene in recharging the battery as shown in figure 24, therefore the functions obtained from the Lines change, remember that the red curve represents the test without solar panels and the blue one represents the test with solar panels. By analyzing these curves, two functions are obtained, for the red curve, function (11), and for the blue color curve, function (12)

f (x) = 0.000597x ^ 3-0.02809x ^ 2 + 0.1760x + 0.7349 (11)

f (x) = - 0.000513x ^ 3 + 0.02610x ^ 2 + 0.09436x + 0.7349. (12)

Analyzing the first configuration of consumption we see that all consumers are activated and based on the graphs in Figure 24 and the functions obtained, it is established that the efficiency of the system is 86.27%.

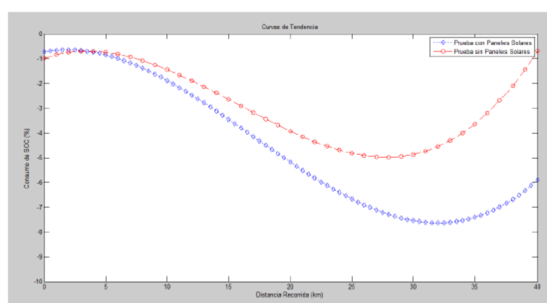

Figure 24. Overall trend of the descent test.

VI. RESULTS OF ANALYISIS.

The analysis of results is based on static and dynamic tests.

A) VALIDATION OF STATIC TEST RESULTS.

This validation is generated with a data source of 7161 data extracted from a set of tests agglomerated and organized as a function of time. The level of incidence of solar charge has a distinction in this configuration because in the regression carried out on the total data of the variables of the tests, 4.5% of uncommon data is observed, which influence the forecast of a given behavior. However, an acceptance of these data is determined because they do not exceed the 5% acceptable variation for this estimate as shown in Figure 25 and Figure 26.

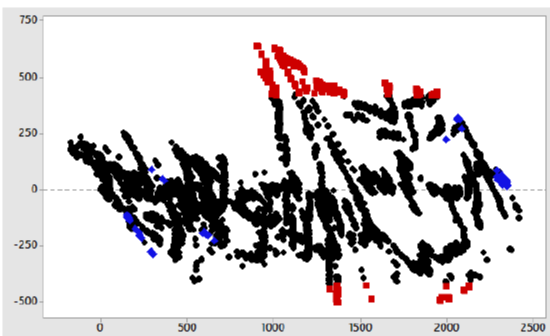

Figure 25. Static test data dispersion.

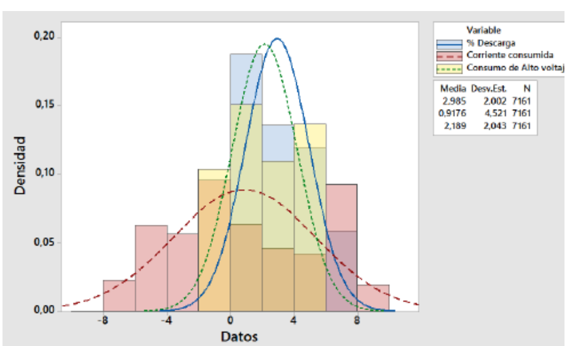

Figure 26. Histogram of the dynamic test.

B) VALIDATION OF DYNAMICS TEST RESULTS.

This validation generates a comparison between tests with and without solar panels, where the mean and standard deviation and the "p" value are specified to determine if there is similarity between tests since the number of elements in each sample is not the same due to its analysis based on kilometers of travel.

For the first dynamic test, it is determined that the variance in the tests are totally different, this given that the p-value is lower than the significance level, but the similarity of behavior is considerable by not maintaining a difference that affects the means that have values of 6.61 and 8.42 respectively with a standard deviation of 4.13 and 5.020 as shown in Figure 27 which indicates an adjusted and correct hypothesis.

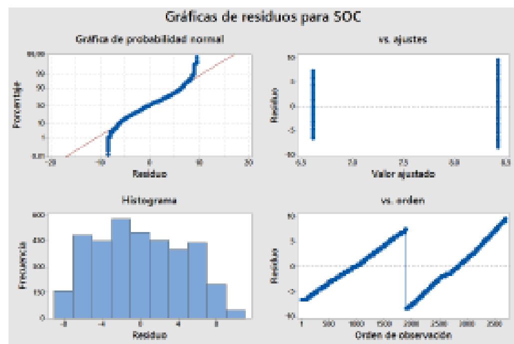

Figure 27. Residual plot for SOC.

Similarly, figure 28 shows the data that were taken into account to perform a regression that determines an existence of 2% of large residuals and 1.8% of unusual values, which indicates that the test is valid with 96.2 % of truthfulness.

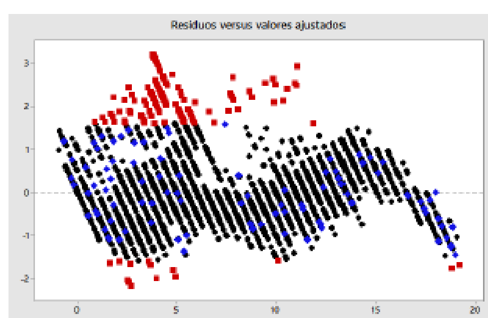

Figure 28. Dispersion of dynamic test data.

For the second dynamic test, which is the route from the UPS to three crossings in the Cajas, values are obtained as shown in Figure 29. The adjustment of data to the dispersion of the tests of all the variables shows 3.24% of data not common that imposes a behavior similar to that of the first dynamic test, this constancy is also determined based on the fact that the mean and standard deviation values of each test performed do not differ significantly.

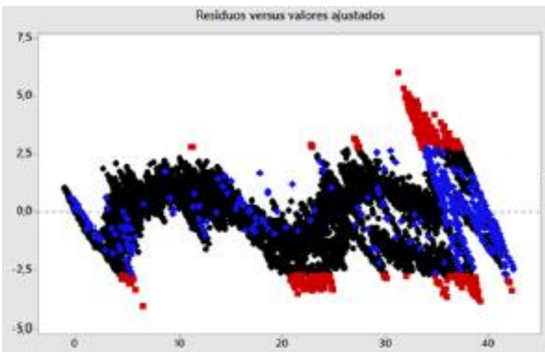

Figure 29. Upward dynamic test data dispersion.

In Figure 30 we have a histogram that determines that the values of the degree of separation maintain little data dispersion, being the high voltage together with the percentage of SOC the most affected reasons for being the estimation of autonomy of the electric vehicle.

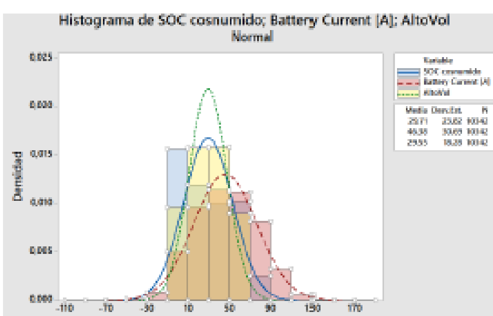

Figure 30. Histogram of the ascending test.

For the third and last dynamic test, which is the return of tres cruces el cajas to the UPS in a descending manner based on the data in Figure 31, it is determined that there is a large set of large residuals that are not considered for the adjustment of Regression, these data represent the discharge at the beginning of the test and the recharge at the end of the test, in such a way that the validation maintains a 95.3% effectiveness.

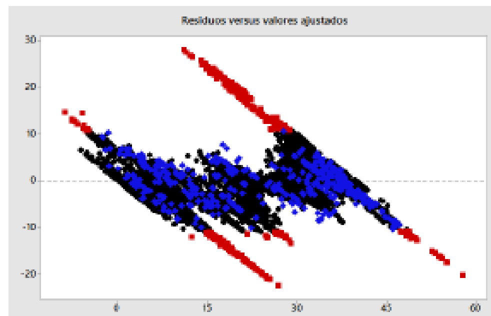

Figure 31. Dispersion of downward dynamic test data.

In Figure 32 we have a histogram that in the same way as Figure 31, the SOC and high voltage values show greater deviation changes, this behavior represents the most noticeable recharge that exists in this test.

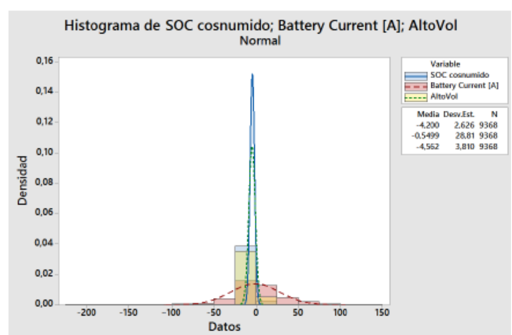

Figure 32. Histogram of the descending test.

VII. CONCLUSIONS.

Because the controller used in the construction of the charging generator circuit maintains a high degree of safety factor, the power generation has no limitations for the charging of the auxiliary battery.

It was shown that the DC-DC inverter circuit that the VE has for the conversion from high to low voltage, also serves to carry out its inverse process, that is, when the power of the auxiliary battery is kept at its maximum load for a long period of time, the high-voltage battery begins to regenerate its cells and maintain or increase its autonomy of usee

It is determined that the structure is vital for obtaining solar radiation incident on the vehicle, it is designed to offer stability, rigidity and ergonomics in the operation of flexible solar panels, its conditions support great efforts produced by the pressure generated by the speed As a reference to avoid possible collapses of the same, it is proposed to adopt safety factors higher than 6, achieving that its maximum deformation is only 0.34 mm.

Given that the power of the load generator circuit is acceptable for supplying the use of the EV peripherals, the tests generated by static and dynamic configurations are correct to estimate the load consumption of the EV, in such a way to determine if the Increased autonomy is useful for taking a planned tour.

It is determined that the energy efficiency of the circuit is superior in stationary tests, or in turn when the route is performed in descent where its efficiency is at 86%, so that the EV recharges faster, however in a test of route such as the one carried out in the section Universidad Politécnica Salesiana - El Cajas Tres Cruces where the factors that affect the consumption of autonomy such as the number of occupants, the slope on the route and the use of peripherals, achieves a significant increase of 11 km, which indicates that this system is beneficial for the type of geography in the country.

It is determined that there are no load production conditions by driving style since the average speeds do not differ from the 0.05% valid for the analysis of the tests, and not by weight variation within the vehicle, this due to the fact that the The load generator circuit together with its structure maintains the 30 kg, which does not significantly affect the load production, in turn the dynamic tests without the intervention of solar panels also maintained the same weighing.

It is predicted that the cells of the high voltage battery together with the auxiliary battery are not in good condition, which is why some data extractions have abrupt behaviors that generate anomalies in the forecast of a behavioral function.

VIII. RECOMENDATIONS.

A variation could be generated in the place where the EV was located for the static tests, so that there is also a comparison between different places in the provincial territory, because it is the area where it is intended to work with increasing autonomy in the EV.

In the dynamic tests, it is suggested to extract a greater amount of data, with longer test periods, so that the trends generate functions more adjusted to the behavior of the situations in which the vehicle is, within the city, this given that the health emergency did not allow this purpose.

Based on the generation of data, an analysis could be carried out by times of the year or by months, since the climatic factors are very changeable in our country, likewise a study would be attached in the different regions so that autonomy predictions can be established for long distance rides.

It is recommended that data collection be carried out with more accurate current meters, analog instrumentation, so that the tests do not show noise interference, which determines an advantage to generate more understandable behaviors.

If the objective of the possibility of recharging the high-voltage battery cells were raised, a type of photovoltaic cell would be designed, which covers the entire body of the vehicle, without affecting its aesthetics, so that the use of solar radiation is possibly total.

It is recommended that the installation be carried out with the ideal components with the best properties such as those existing today on the market, which generate up to four times the power implemented in the project and that these have waterproof characteristics due to the fact that in the places of test, there are misty climates that affect the production of charge due to the possible presence of oxidation in the connections.

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