A Solar Powered Electronic Device Charging Station

José Haroldo da Costa Bentes Júnior
haroldocostabentes@gmail.com
Centro Universitário FAMETRO – Manaus, Amazonas – Brasil

Rodson Henrique Hatahara da Fonseca
rodson_hatahara@hotmail.com
Centro Universitário FAMETRO – Manaus, Amazonas – Brasil

Livia da Silva Oliveira
oliveira.livia@gmail.com
Centro Universitário FAMETRO – Manaus, Amazonas - Brasil

Marcela Sávia Picanço Pessoa
marcelappessoa@gmail.com
Universidade Estadual do Amazonas UEA – Manaus, Amazonas – Brasil

David Barbosa de Alencar
david002870@hotmail.com
Galileo Institute of Technology and Education of the Amazon – ITEGAM

Abstract

This paper proposes the development of a mobile device charging station with solar energy as a source of energy to meet the population's need in a sustainable way. To validate the concept of the article, a prototype was built using photovoltaic solar panels, charge controller and battery and tests were done at different times of the day so that it was possible to verify different quantities, such as voltage and electric current and with this data calculate the power supplied and the battery charging time. As a result, it was observed that the best performance was at noon, with two photovoltaic solar panels, but energy was generated throughout the daytime.

Keywords: solar energy; mobile devices; batteries; sustainability.

1. Introduction

Great is the concern of many countries to make better use of natural resources. Initiatives such as the Kyoto Protocol [1], Rio +10 and Agenda 21 have been showing this.

Brazil, for having the largest tropical forest, prioritizes projects that develop clean technologies or allow resources to be used, but that are compensated in some way, either by reforestation, by species preservation projects or by alternative power generation.

Brazil is one of the countries aimed at developing more responsible products and systems through renewable sources and cleaner manufacturing processes that are consistent with environmental policies. In this sense, it maintains the most renewable energy matrix in the world, with 45.4% of its consumption directed to the use of water resources, biomass and ethanol, in addition to the contribution of wind and solar energy, and hydroelectric plants account for over 75% of electricity consumption by the Brazilian population [2].

Among the main alternative sources, it can be highlighted photovoltaic solar energy, as it is characterized as one of the least polluting primary sources, still quoted as silent, needs low maintenance and maintains short installation and operation times. Thereby, it has no high environmental impact, which is almost zero and can easily be integrated into the construction processes [3].

On the other hand, according to the Brazilian Institute of Geography and Statistics– IBGE [4], 93.2% of the Brazilian population had mobile communication devices such as mobile phones or tablets and these, where over 90% spend more than eight hours a day away from home, whether working or studying and the battery charges of their mobile devices lasts around seven hours if heavily used so, most of the time it is necessary to recharge your mobile device battery throughout the day.

Besides the need to recharge the batteries, this work prioritizes the research bias that seeks to use renewable energies, such as wind and solar, since they do not emit greenhouse gases like those generated in thermoelectric plants and neither devastate areas of forests such as those generated by hydroelectric dams. With a view to producing clean energy in the use of numerous other activities that fit this same condition, we have seen in the creation of solar powered stations for charging electronic devices battery, an alternative to decrease environmental and energy impacts and also the opportunity to bring electricity to remote places, like the many that exist in the Amazon.

This paper is organized as follows: Section 2 presents the theoretical framework, Section 3 presents the methodology and tools used, Section 4 presents the tests and discussion of the results, followed by Section 5, which is the conclusion.

2.Theoretical Framework

2.1. Photovoltaic Solar Energy

There are two types of photovoltaic systems, differing in their application forms: the systems connected to the electric grid and the autonomous. A typical home solar system consists of "PV modules, charge controller, batteries, inverter for converting DC to AC voltage and other auxiliary equipment, building materials and mounting of modules, wiring, meters, supervision software and assembly service" [5].

In systems connected to the electricity grid, the use of photovoltaic generators is necessary; panel protection equipment to prevent reverse currents; inverter, which acts in the transformation of the energy in direct and alternating current, maintaining the compatibility with the electric network, as shown in the Figure1 [6].

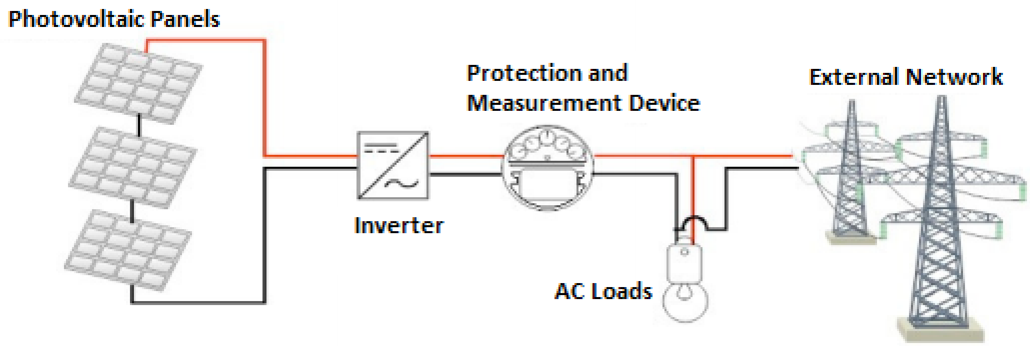

Figure 1: Photovoltaic system connected to the electric grid

Source: [6]

Autonomous systems, in its turn, consist of an energy storage system whose action is performed by batteries, which also need protection equipment against overvoltage and excessive discharges, such as a charge controller. It is essential that the connected loads be compatible with the battery voltage and be transformed into alternating current using a converter or inverter [6], based on the Figure 2.

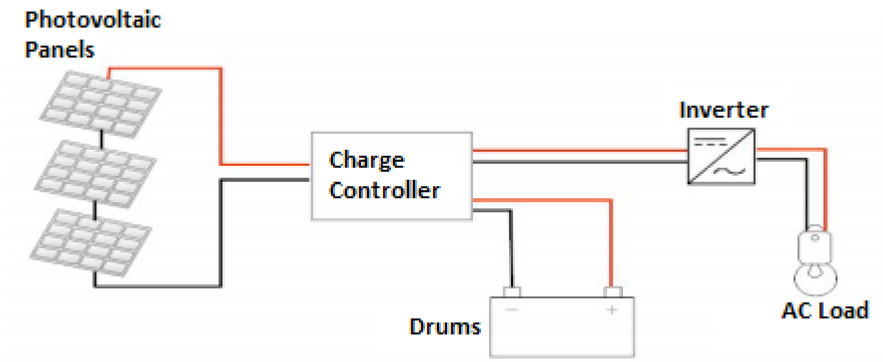

Figure 2: Autonomous Photovoltaic System

Source: [6]

By converting solar energy into electrical energy, photovoltaic cells utilize the properties of semiconductor materials, mostly silicon, which when combined with chemical elements such as boron and phosphorus, give rise to the PN function, concentrating on the one hand the positive charges and the another, negative charges. This permanent electric field prevents the passage of electrons from side to side. When a photon has enough energy to excite an electron, there is the circulation of electric current, and then the generation of continuous energy, obtaining the photovoltaic effect [6].

Figure 3 presents a symbology commonly used in the representation of photovoltaic cells and panels, as well as the constitution of an electrical circuit facing the solar cell:

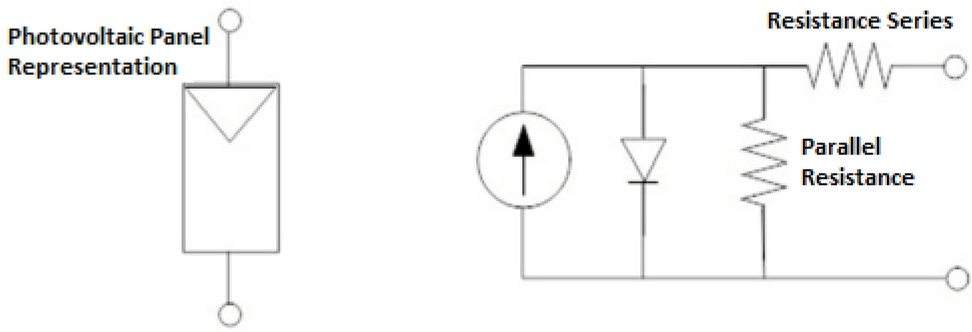

Figure 3: Representation of a photovoltaic cell

Source: [6].

Photovoltaic solar panels are designed and produced to be exposed outdoors, subject to sun, rain and other weather agents, operating with satisfactory results for at least 30 years. They can be housed in building wraps, maintaining the dual function of generating electricity and serving as an architectural element in covering roofs, walls, facades and windows [7].

In the field of civil construction and electrical installations, the implantation of photovoltaic solar panels is already supported by well-established technologies and projects that make this practice increasingly common in buildings [7]. The electrical connection to the network and the peripheral devices that act as interconnectors can be easily found in the market, meeting any type of configuration or size.

Most photovoltaic systems are connected to the conventional grid and nowadays have become more accessible [3]. Although Brazil is located in a high insolation area, photovoltaic energy is little explored. This is due to the fact that Brazil is rich in water resources, encouraging the generation of electricity from the most accessible large hydroelectric plants. On the other hand, centralized power generation presents its needs, being normally located far from the consumer centers, requiring the installation of large transmission lines, leaving in some cases to serve isolated communities. Thus, it is understood that besides offering economic and environmental advantages to consumers, it is able to serve these communities.

With the use of solar energy and consequently the reduction of conventional electricity consumption there are economic and environmental advantages, as well as ensuring the construction of environmental and socio-cultural awareness through the application of clean and free energy [8].

2.2. Solar Power for Mobile Phone Chargers

There are few studies on the development of solar powered mobile phone charger prototypes. According to [9], Charge Controllers are referred to as "electronic circuits that manage the energy in and out of batteries to protect them from the effects of overcharging and deep discharge by adjusting the actuation points of the circuits of load and consumption". They can be developed from two types of physical configuration: in series, when the photovoltaic panel of the charging circuit is disconnected as soon as the battery reaches almost its full potential; and in parallel, when there is a short circuit during power generation, both of which are able to decrease the charge current offered to the battery.

In the study by [9], it was stated that "because it depends on the intensity of radiation, the generation of electric energy from solar sources presents great variability, thus requiring the use of batteries for storage". The author also points out that this does not affect the efficiency of the system, since the use of batteries enables the proper functioning of the proposed system. However, the biggest difficulty of the project was to find the availability of photovoltaic cells to build its own panel.

[10] presented a prototype of a solar cell battery charger, demonstrating that the auxiliary battery is fundamental for the system to operate at night and in unfavorable locations for photovoltaic panels. The charger under study adopts photovoltaic cells as a sustainable source of energy, and also consists of the auxiliary battery that provides greater charging efficiency, accumulating energy and providing greater benefits to the user.

Figure 4: Prototype of photovoltaic cell phone charger

Source: [10]

The charger architecture developed by [11] was made up of a photovoltaic panel, responsible for transforming solar energy into electrical energy, which remains connected to a charge controller and the cell phone. You can also connect it to a rechargeable battery whose purpose is to ensure energy use at times when solar incidence cannot be obtained, illustrated in the Figure 5.

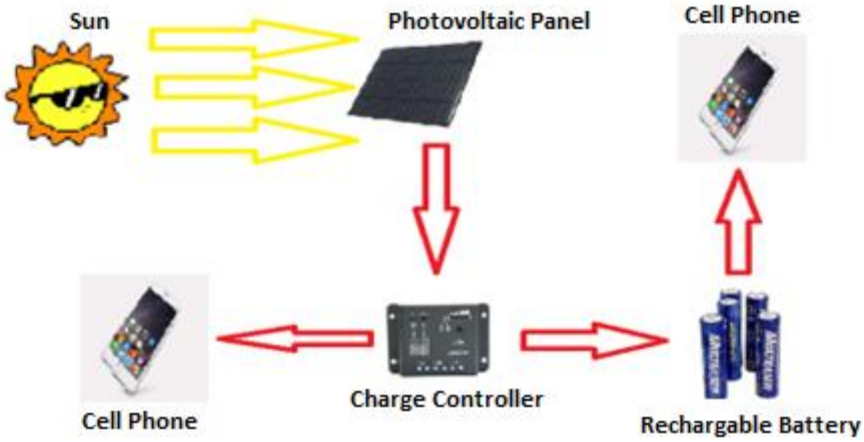

Figure 5: Design Architecture of a Photovoltaic Cell Charger

Source**:** [11]

3. Applied Methodology

After the bibliographic research, the steps towards the execution of the project began. As illustrated in figure 6, the methodology followed three steps which are: Component survey, prototype assembly and testing and are described below.

Figure 6: Development Steps

First the components were selected. The main element is the 2 W and 5 V photovoltaic solar plate, there is also i) the charge controller, which uses the HT4936S integrated circuit and has two outputs with limited voltages of 3.6V and 5V, making it possible to connect directly to a battery and the connection of an electronic device and ii) 3.7V and 2000 mAh lithium polymer battery and iii) the connecting peripherals such as cables and USB sockets.

Next, the electronic charging station architecture was designed and executed. This architecture followed the model proposed by [11], presented in Figure 5, in which the positive and negative poles of the solar panel were connected to the charge controller input and its 3.7 V output was connected to the battery. In this way, the battery is protected against very high electrical charges and very fast discharges, which extends battery life and optimizes battery operation, preventing accidents such as explosion caused by overcharging. USB ports for direct charging of devices have been connected to the controller's 5 V outputs, as this is the voltage that devices work to recharge their internal batteries.

Finally, tests were performed to validate whether the station was turning solar power into electrical power, if the controller was limiting the charge, if the USB port output was reaching the expected voltage, and if the battery was charging as planned.

The tests were divided into two parts: one with one photovoltaic plate and other with two 5 V photovoltaic plates in parallel. The tests were repeated at different times of the day, so that the incidence of sunlight was different in each test.

4. Analysis and Discussion of Results

4.1. Test using one photovoltaic solar plate

The first tests, with a single photovoltaic solar plate, were done at 06 a.m., 10 a.m., 12 p.m., 03 p.m., 04 p.m. and 05 p.m. The voltages and currents at each time were measured and it was calculated the power provided by the plate and how long it would take the battery to fully charge at that power, as shown in Table 1.

Table 1 - Results of the experiments using a single photovoltaic plate

Time (h)	Power (watt)	Current (mA)	Voltage (V)	Charging Time (h)
06 a.m.	0.53	173	3.07	11.56
10 a.m.	1.15	254	4.52	7.87
12 p.m.	1.60	300	5.32	6.67
03 p.m.	1.38	279	4.96	7.17
04 p.m.	1.06	244	4.34	8.20
05 p.m.	0.70	199	3.54	10.05

The Figure 7 illustrates the relationship between the time of day, represented on the abscissa axis, and the power supplied by the photovoltaic plate, represented on the coordinate axis. It is possible to observe that as the hours of the day go by, the intensity of solar radiation changes, peaking at noon and, consequently, has the highest power provided by the solar plate.

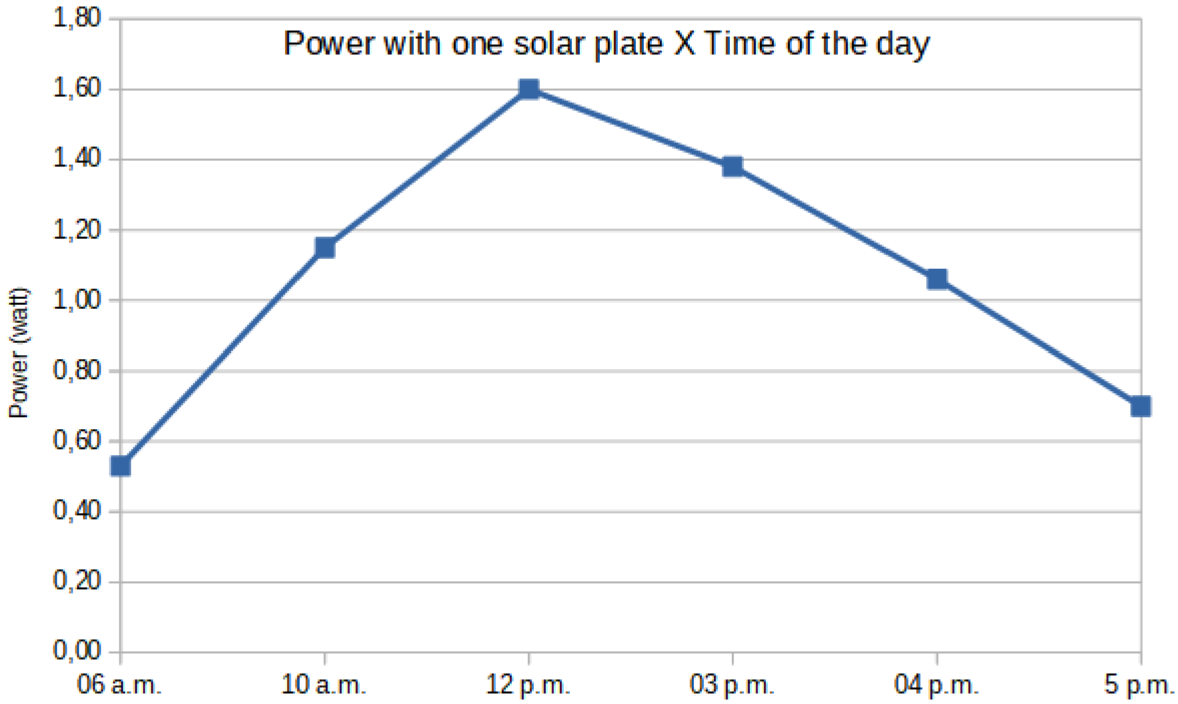

Figure 7: Information on the power supplied by the board versus the time of day.

By analyzing in Table 1 the time when the solar plate provides the most power (at 12 p.m.), it can be seen that the battery would take 6 hours and 40 minutes to fully charge. However, despite being a source of clean energy that justifies the proposal, it was observed that the recharge time is longer than the market offers. Given this, tests were performed by adding another photovoltaic plate in parallel to the existing one, which is being described in the following section.

4.2. Test using two solar photovoltaic plates

The second stage of the tests followed the same times as the first, which are: 06 a.m., 10 a.m., 12 p.m., 03 p.m., 04 p.m. and 05 p.m. The parameters of voltage, electric current was measured and the power and time required for full battery charging were also calculated. With the addition of the second photovoltaic plate, it was possible to reduce the charging time by half, causing the electric current to double in value and the voltage to remain at the same level. These results can be better seen in the Table2.

Table 2 - Results of the experiments using two photovoltaic plates in parallel.

Time (h)	Power (watt)	Current (mA)	Voltage (V)	Charging Time (h)
06 a.m.	1.06	346	3.05	5.78
10 a.m.	2.28	508	4.48	3.94
12 p.m.	3.15	600	5.25	3.33
03 p.m.	2.78	558	4.99	3.58
04 p.m.	2.15	488	4.4	4.10
05 p.m.	1.42	395	3.6	5.06

When the new solar plate was added in parallel, the electric current doubled and the charging time decreased since they are inversely proportional quantities, so at the time of maximum solar incidence, which previously took 6.67 hours for a full battery charge, after coupling the new solar plate, it only takes 3 hours and 19 minutes.

Figure 8 shows the relationship between time of day and power provided by two photovoltaic plates connected in parallel with each other. The curve of this graph is very similar to the graph in Figure 7, but through the power values shows that they present an increase of about two times the value of when using only one plate.

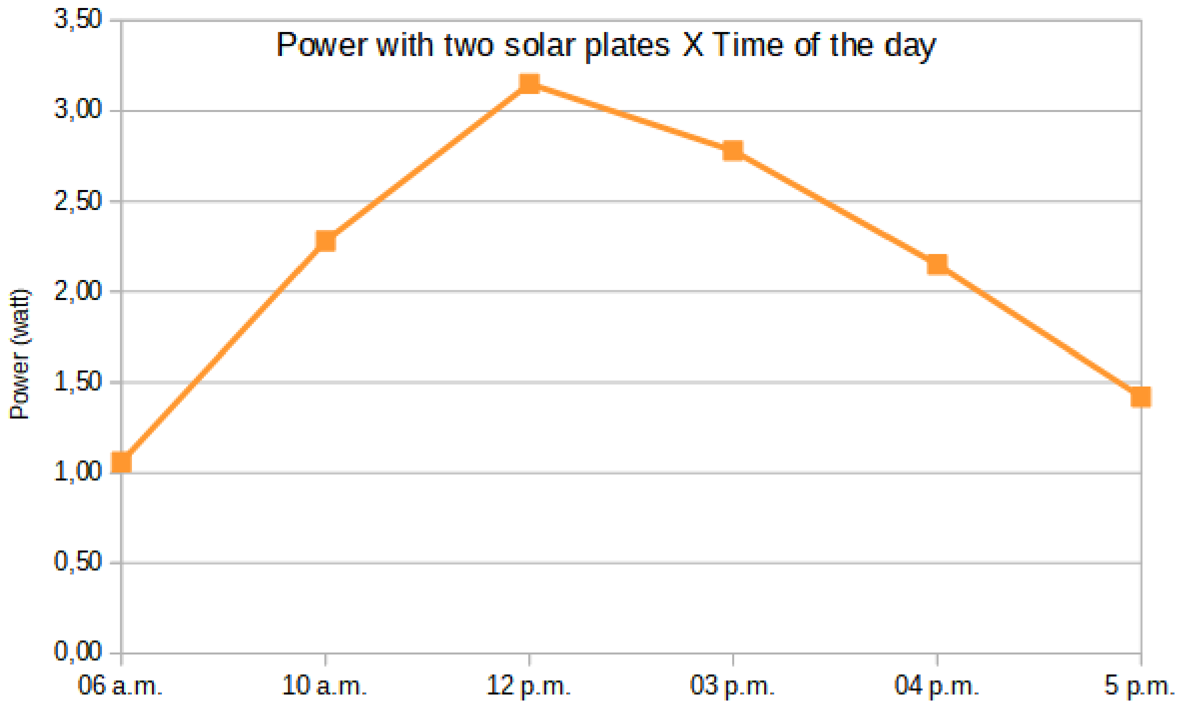

Figure 8: Two Solar Plates Power vs. Time of Day Information

5. Conclusion

This work presents an alternative and sustainable proposal to solve the problem of discharged batteries, with the implantation of a mobile device battery charging stations, which can be used in urban or rural areas, only with sunlight. To validate this concept a smaller scale prototype was built using photovoltaic solar panels, a charge controller and a battery.

After the construction of this prototype, several tests were made and the results showed that, to a smaller scale, there is a much higher efficiency if two 5-volt, 2-watt solar photovoltaic plates are used in parallel, thus, the total charging time of the battery drops by half from 6.67 hours to 3.33 hours, almost equaling conventional high-efficiency chargers that require a traditional power source.

The importance of accurate project sizing can be noted at the moment when it was necessary to add another solar plate, since without one of them the project would achieve its goal, but would take twice as long.

Future work may include: (i) the study, for the purpose of charging mobile device batteries, of the use of larger solar photovoltaic plates and therefore more power, so that more devices can be charged simultaneously; ii) the implementation of the charging station in an area with difficult access to electricity, to verify its impact on the life of the local population and even to diversify the use of this station.

6. Referências

[1] GODOY, Sara Gurfinkel Marques de. **Projetos de redução de emissões de gases de efeito estufa: desempenho e custos de transação.** Rev. Adm. (SãoPaulo) vol.48 no.2 São Paulo Apr./June2013.

[2] SEGURA, Matheus Lini. **Aevolução da matriz energetic brasileira: O papel dos biocombustíveis e outras fontes alternativas**. In: Âmbito Jurídico, Rio Grande, XV, n. 96, jan 2012. Disponível em: < http://www.ambito-juridico.com.br/site/?n_link=revista_artigos_leitura&artigo_id=11039&revista_caderno=6>Acessoem: 02 de jun. 2019.

[3] SEGUEL, J. I. L. **Projeto de um sistema fotovoltaico autônomo de suprimento de energia usando técnica MPPT e controle digital** (2009) Disponível em: <https://www.ppgee.ufmg.br/documentos/Defesas/850/Julio_Lopez_Versao_Corrigida.pdf>Acessoem: 02 de jun. 2019.

[4] IBGE, Instituto Brasileiro de Geografia e estatística. <**https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/23445-pnad-continua-tic-2017-internet-chega-a-tres-em-cada-quatro-domicilios-do-pais**>Acessadoem 10 de Nov de 2019.

[5] MARQUES, D; BRITO, A; CUNHA, A; SOUZA, L. **Variação da radiação solar no estado do Amapá: estudo de caso em Macapá, Pacuí, Serra do Navio e Oiapoque no período de 2006 a 2008.** Revista Brasileira de Meteorologia, v. 27, n. 2, p. 127- 138, 2012.

[6] SERRÃO, Marcos Antônio dos Santos**. Dimensionamento de um sistema fotovoltaico para uma casa de veraneio em Pouso da Cajaíba** – Paraty (2010) Disponível em: <http://monografias.poli.ufrj.br/monografias/monopoli10000620.pdf>Acesso em: 02 de jun. 2019.

[7] RÜTHER, Ricardo. **Edifícios solares fotovoltaicos: o potencial da geração solar fotovoltaica integrada a edificações urbanas e interligada à rede elétrica pública no Brasil**. Florianópolis: LABSOLAR, 2004.

[8] TIMANE, Hermenegildo Augusto. **Princípio de funcionamento do sistema fotovoltaico ligado à rede pública** (2010) Disponível em: <http://energypedia.info/images/5/55/PT_SISTEMA_FOTOVOLTAICO_LIGADO_Timane.pdf >Acesso em: 02 de jun. 2019.

[9] RIBEIRO, V. T. **Projeto de um carregador de cellular utilizando células fotovoltaicas** (2006) Disponível em: <https://repositorio.uniceub.br/jspui/bitstream/123456789/3282/2/20168727.pdf>Acessoem: 03 de jun. 2019.

[10] JESUS, E. S; SETANI, G. **Análise de um carregador de bateria solar para celular (2016)** Disponível em: <http://conic-semesp.org.br/anais/files/2016/trabalho-1000022598.pdf>Acessoem: 03 de jun. 2019.

[11] RAMOS, E; SILVA, R; PALMA, F. **Projeto e construção de um carregador para aparelho móvel utilizando energia solar** (2015) Disponível em: <http://www2.ifam.edu.br/campus/cmc/pesquisa/anais-concept/i-congresso-de-ciencia-educacao-e-pesquisa-tecnologica/6-7>Acessoem: 03 de jun. 2019.