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Abstract

The implementation of the replacement of a conventional semaphore system with one powered by photovoltaic energy in the city of Manaus. Nowadays, energy generation has been approached as one of the vitally important issues. The increasing demand for energy in the country and the importation of new technologies conditioned to the use of electricity have been demanding better energy planning, given the energy potential of the northern region for the implementation of a photovoltaic system directed to the semaphore system. In this scenario it is important to identify the impacts caused by the replacement of incandescent lamps with LED technology with the consequent reduction of energy consumption and maintenance costs. In addition, the purpose of this study is the inclusion of photovoltaic panels in traffic lights, seeking a sustainable form of operation. It is noteworthy that the process of analyzing the results of this project was based on measurements made before and after the replacement of the equipment, thus reflecting the actual values of electricity consumption and active power demand.

Keywords: Solar energy; Traffic lights; Energy efficiency;

1. Introduction

Some energy efficiency projects focused on traffic lights have been carried out in Brazil in recent years. One of the major changes to increase efficiency at a second traffic light [1] is the replacement of incandescent bulbs with light assemblies composed of light-emitting semiconductors, called LEDs - Light Emitter Diode, which convert electricity into light radiation.

With the purpose of seeking greater energy action, reducing demand during peak hours and reducing electricity consumption, as well as improving the conditions of signaling services, these incandescent bulbs are being gradually replaced by LED light assemblies. [2]. For intersection interventions with maintenance traffic lights, the less time the equipment is turned off or defective, the better the traffic flow.

The text also highlights its maintenance, given the facts it is clear that the country has a large number of traffic lights in continuous operation and consuming energy 24 hours a day. In this type of signaling, according to [3] incandescent lamps have always been used, whose use is being abolished for the inclusion of new more economical technologies. To reduce all this installed power, energy efficiency measures are required in this equipment.

In this line of thought with the constant growth of electricity demand, it is increasingly necessary to search for projects that aim at energy self-sufficiency, thus reducing the overload on the national electricity system and developing the concept of distributed generation. In this regard, the viability of the photovoltaic power system in a semaphore array system powered by photovoltaic solar panels becomes quite reasonable for the Municipality.

With regard to the photovoltaic generator system, the studies by Edmond Becquerel, who in 1939 first observed the photovoltaic effect, when dipping silver and platinum metal plates in an electrolyte, noticed a small potential difference when the plates were exposed to light. About fifty years later, Hertz, when experimenting with electrolytic cells, observed that when exposed to the incidence of ultraviolet light, it caused air to rupture with a smaller potential difference between its electrodes and then deduced that metals emitted electrons by the action of light [4].

In 1873, W. Smith observed the ability of light to conduct selenium, called photoconductivity, where Siemens designed a photometer, emphasizing the phenomenon. Seven years later Fritts built the first photovoltaic cell, with approximately 1% efficiency [5]. Only in 1954 was the first photovoltaic cell presented, which was developed half a year earlier by Bell Labs scientists (Calvin Fuller and Gerald Pearson), with approximately two square centimeters in area and 6% efficiency, generating approximately 5 mW of power. Around 1956, photovoltaic cells began to be produced industrially taking advantage of new microelectronics solutions and driven by the need to supply electricity to remote regions [6].

Solar energy is a term that refers to the energy coming from the light and heat of the sun, used by different evolving technologies such as solar heating, solar photovoltaic energy. The solar ray is transformed into electricity in a photovoltaic cell, made of materials called semiconductors, with silicon being the most used. Sunlight, made up of small elements called photons, when they reach the photovoltaic cell, part is absorbed by arousing the electrons of the semiconductor material, thus generating electricity.

The greater the intensity of sunlight, the greater the flow of electricity. In other words, we can say that the generation of electricity through light is via the use of photosensitive cells or commonly called photovoltaic

cells, which grouped in modules or panels make up the photovoltaic solar panels [7]. In the authors' conception a system is composed by the panel, charge controller, accumulator and accessories, called as photovoltaic generator.

A semaphore set can, from this idea, use plates that capture sunlight on top of the device, where the traffic light uses an LED light that allows both the green, yellow and red signal to occupy the same single space, instead of three, thus being easier to supply it with solar energy, the differential of this type of traffic light for the others is the fact that it works by means of energy from the sun [8].

Unlike most semiconductors, the cell used in the manufacture of photovoltaic equipment does not use the normal silicon structure, as in LED and diodes, to increase the electrical conductivity of the material, a thin layer of transparent oxides is inserted [9]. In silicon, solar irradiation is converted into electrical energy through the photovoltaic effect, which consists in the generation of an electric potential difference through radiation. LEDs have great potential in the street lighting market. The energy savings that can be achieved and the improved lighting quality of cities due to the high color reproduction rate can now be seen in existing installations around the world.

The same author mentions that the photovoltaic effect occurs when photons strike atoms, causing the emission of electrons, generating electric current. This process does not depend on the amount of heat, on the contrary, the yield of the solar cell decreases when its temperature increases. The conversion efficiency of solar cells is measured by the proportion of solar radiation incident on the cell surface that is converted into electrical energy.

Like the weather-dependent photovoltaic panel, the use of equipment that ensures the power supply to the load during periods of insolation and at night is indispensable. In the design of the battery bank, two parameters must be considered: system autonomy (number of days the battery can meet the energy demand without the need for photovoltaic panels), and the depth of discharge (life-determining factor). , given the number of charge and discharge cycles) [2].

In some photovoltaic installations you can see a single panel made up of a large number of modules, but in fact you can have several panels from an electrical point of view. When the power of a panel is high, such that the generated electric currents are too large for the control devices, it is preferable to subdivide it into smaller panels, which can be accommodated in a single structure, and their connectors will be led to different connection boxes, and hence to the corresponding control devices.

The photovoltaic system is a process where the conversion of solar radiation into electricity occurs using a set of equipment for photon capture and absorption, even on cloudy or rainy days, but the greater the solar radiation the greater the amount of electricity produced. This system comprises a grouping of photovoltaic panels and other conventional equipment that transform, convert or store electrical energy so that it can be used in homes under the same conditions as conventional electrical energy [10]. Importantly, the photovoltaic system can be implemented as a power source in a semaphore system.

Among other factors, the design of a photovoltaic system involves the correct direction and inclination of the photovoltaic modules, availability of area for installation, the solar resource and the demand to be met [11]. With population growth and modernization of roads in the early twentieth century, cities began to offer increasingly current products and new inventions such as cars, being one of the first motorized, the Ford T model, where only in the United States, the vehicle fleet jumped from 8,000 in 1900 to 2.5 million

in 1908.

On American streets and in cities like London, England, cars mingled with carriages, bicycles, and pedestrians, who had less space. Soon several attempts to control traffic began to emerge. For [12] the first traffic light, dated 1868 was installed in London, with gas lights to be seen at night. It had two arms, moved by police: when they were horizontal, they indicated that the vehicles stopped; at 45 degrees, they should follow for less than a month since it exploded, injuring the policeman who was handling it.

Shortly after, in Berlin, Germany, towers were built in the middle of intersections with booths where police officers sat changing lights throughout the day. This type of tower has been altered for decades, used in New York since 1916.

From 1912 onwards, successive inventions gained notoriety in the United States, including the three-color sign, suitable for crossroads invented and installed by police officer William Potts in 1920 in Detroit. [12] Today, with an explosion in the increase of the vehicle fleet and, consequently, with the increasingly saturated streets and avenues, there are numerous conflicts at intersections. Coupled with this need for traffic organization, the safety of drivers, cyclists and pedestrians must be ensured.

Therefore, it is necessary to use traffic control equipment, as is the case of traffic lights, or simply traffic lights, which aims to optimize, standardize and control the right of passage of vehicles and pedestrians. For [12], the traffic light is a set of components that are installed at road intersections and is responsible for the light signals that indicate the right of way for drivers and pedestrians. To provide this light signaling, a whole structure capable of generating and bringing the color information of the controlling electronic element to the respective pathway is required. Being part of the composition elements as: semaphore controller; focus group; cables; pipes; columns and arm (Figure 1).

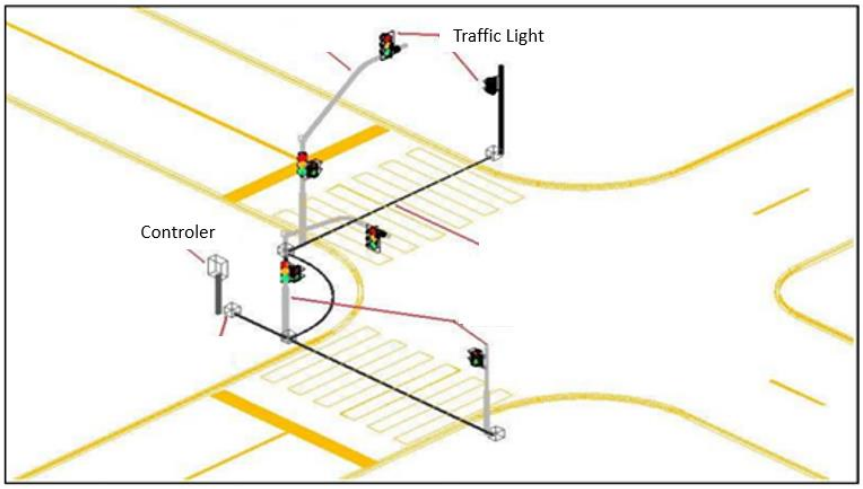

Figure 1 - Main structures of a traffic light
Source: [12]

The use of traffic lights at intersections is intended primarily to ensure two operational attributes: safety and flow. By alternating the right of use of the intersection area, the traffic light can contribute to reducing the time wasted on it, and the number of certain types of accidents. The design of operating a traffic light consists of the development of traffic light plans that optimize vehicle control at road intersections to the best of their ability. The semaphore plane of a semaphore network consists of four elements: phase, cycle, interval and offset or offset. [13]

The semaphore control is the equipment that controls the color sequence and determines the signaling time of the traffic light by switching its lamps. It can be of the electromechanical type in simpler and older models, or electronic in current models. Nowadays automatic controllers that operate in different ways are used, depending on the type of equipment used, and are classified in three basic ways: fixed time controller, semi-actuated and actuated controller [14].

A. Fixed time semaphore controller: most common controller, operates following a predetermined time schedule. The determination of these parameters is based on the characteristics and average volumes of local traffic. When programmed, phase indication orders and durations will occur at the intersection until the controller settings are manually reprogrammed or the fixed duration setting is selected.

B. Semi-actuated controller: uses uncoordinated phase detectors to provide more flexible use of green time. A fixed length cycle remains in effect and the timing of each phase may vary. The addition of this degree of freedom in green time management is achieved by detectors installed and monitored.

C. Traffic-actuated semaphore controller: operate in real time, i.e. according to changes in vehicle or pedestrian traffic at the intersection. Environment information is captured through pedestrian crossing detectors or pushbuttons and sent to the controller who processes the information and responds according to the control strategy to which it was programmed. Its purpose is to dynamically adjust the traffic light control according to the traffic fluctuations that may occur at the intersection.

Given the facts, traffic lights depend essentially on a source of electricity and a light source for operation. In the case of traditional traffic light systems, which use tungsten filament incandescent lamps, in addition to low efficiency, the existence of a single filament results in frequent maintenance and increased traffic incidents due to faulty lamp inactivity. In these situations, the system may be compromised, malfunctioning and flashing yellow indicating signal failure [15]. In semaphore modules based on LED technology, printed circuit boards are used where several LEDs are fixed [3].

In this context, some studies suggest a semaphore signaling system independent of the electricity distribution network. In this case, the proposed system operates on solar energy aided by a battery bank with autonomy of one or two days to supply electricity at night or in cloudy periods [13] [16]. Also, in the design of [16] they highlight the advantage that photovoltaic power generating equipment can be installed in remote places where there is no connection to the power grid.

Thus, this study aims to evaluate the operation and structure components of a photovoltaic power system in a semaphore complex in the city of Manaus, AM.

2. Materials and Methods

The implementation of an independent semaphore energy system, based on solar energy collection technology through solar panels, as a substitute for electric energy contributes to greater traffic safety and also savings in the public electricity system, as well as the possibility of reducing accidents when there is a power outage provided by the utility.

One of the advantages of photovoltaic systems is the absence of moving parts with low maintenance. They have a modular feature (from mW to MW), fast installation and a high degree of reliability. Thus, they enable the integration of the urban environment, quiet, clean and renewable.

Thus, solar energy is a term that refers to the energy coming from the light and heat of the sun. It is used by different technologies that are constantly evolving, such as solar heating, solar photovoltaic energy. The solar ray is transformed into electricity in a photovoltaic cell, made of materials called semiconductors, the most used is silicon. Sunlight is pure energy, made up of small elements, photons. When the photons reach the photovoltaic cell, part of them is absorbed. These photons awaken the electrons of the semiconductor material, thus generating electricity.

The greater the intensity of sunlight, the greater the flow of electricity. In other words, we can say that the generation of electricity through light occurs through the use of photosensitive cells or commonly called photovoltaic cells, which grouped in modules or panels make up photovoltaic solar panels [7]. In the authors' conception, a system composed by the panel, charge controller, accumulator and accessories are called Photovoltaic Generator. In this line of thought the semaphore set system is a common traffic light, such as those installed in streets, avenues, highways and others.

With plates that capture sunlight on top of the device, the traffic light uses an LED light that allows both the green, yellow and red signal to occupy the same single space instead of three, so it is easier to supply it with solar energy. . The differential of this type of traffic light to the others is that it works by means of energy from the sun, solar energy [8].

The system consists of solar panel, the traffic light, the traffic light support arm (pole); photovoltaic plate (s); batteries and the control box where the circuit used in the drive is located. Depending on the type and model of traffic light to be used, the photovoltaic plates will be sized, as well as the batteries to be used, which may be led / acid; nickel / cadmium; nickel / metal hydride, among others, thus adapting to regions with low incidence of sunlight.

Solar-powered semaphore internal circuits may be integrated, electrical and / or electronic, and may contain sensors for warning light triggering, lockout to prevent triggering of identical signals (green / green or red / red), mechanisms sequential drive (green wave) and other technologies, without prejudice to their quality and efficiency.

With this mechanism the inventor provides the saving of conventional electricity and avoids the serious disturbances caused by blackout. Its use is very wide and allows the use of various electro-electronic operating and driving technologies, including printed and / or integrated circuits.

This "solar-powered traffic light supply system" design allows, depending on the location and physical conditions, that the photovoltaic plate (s) and its batteries can be installed on or off the traffic light post or body itself. of the traffic light, forming a single set, in case of support of the traffic light by cables [17].

Currently Manaus, puts in practice in some peripheral areas of the city the traffic light operating with photovoltaic energy. According to information from [18], tests were started on a prototype energy storage device in the Manaus semaphore signaling network. According to the agency, the measure aims to maintain the operation of traffic lights even in the event of interruption of electricity supply.

There are two different prototypes installed on the city's signaling network. Model 1: A solar panel at a traffic light located at the intersection of Avenida Mario Ypiranga and Salvador Street, Adrianópolis neighborhood, South Central Zone of Manaus. Models 2: Traffic light located at the junction of Avenida Constantino Nery and Pedro Teixeira, Alvorada neighborhood, Midwest Zone, a battery prototype was also implemented, but still in the installation phase (Figure 2). In order to guarantee the autonomy of the traffic

light, a switching system has been created for the power grid. This will only come into operation in case of emergency, such as several cloudy days or any other factor that interrupts the traffic light supply by the energy generated through the photovoltaic plate.

Figure 2 - Traffic light with photovoltaic power system in Manaus
Source: [18]

Figure 3 shows the traffic light installed with photovoltaic system, in order to get the most from solar energy, that is, using sunny area available for such purpose. Solar Powered Traffic Light "aims to use solar energy, captured through photovoltaic plates (s), in traffic lights, providing energy savings and low cost.

Figure 3 - Traffic light with photovoltaic power system in Manaus
Source: [18]

Despite the feasibility of implementing the photovoltaic system in a semaphore array system, the disadvantages regarding the initial cost of investment are also highlighted, as the financial return occurs in the long term. However, analyzing the advantages presented by the photovoltaic system, it is understood that photovoltaic solar generation is a source of energy with great potential, although the cost of technologies for harnessing available solar energy is relatively high, and still requires investment for the development of this type. technology and the consequent reduction in these costs.

After data analysis, it was verified that the implementation of a photovoltaic system in a semaphore system is already happening in the city of Manaus, demonstrating that it is a viable system, even though it is still being tested for its continuity.

Some of the characteristics of the semaphore system implemented in the municipality of Manaus were made available [18]. However, due to the lack of detailed information on the consumption of the signal system, it was considered based on the nominal values of the network, the installed devices and the operating cycle of the traffic light. For simplicity, only one traffic light plan was adopted to estimate consumption, not considering the programming difference between one traffic light and another, given the location of each traffic light.

The terminal cables of the photovoltaic modules installed at the traffic lights must be adequately insulated to the maximum system voltage and have the ability to withstand the weather, and are designed for grid-connected applications and are supplied with pre-installed cables with sufficient compliance for its connection to another equal module in its photovoltaic arrangement. In general, these cables have a quick-fit system to ensure good connection quality [19]. It is important to point out that the cables should not be loose and subject to the action of the wind, but attached to the photovoltaic panel structure.

In studies carried out by [20] the result pointed out that there is still no consensus on the efficiency of the photovoltaic energy system, since in most cases it varies between 70% and 90%, indicating that solar radiation levels influence the design of the solar system. average monthly electricity consumption.

Also, according to [20] the photovoltaic panel is weather dependent, the use of equipment that ensures the power supply to the load during periods of insolation and at night is indispensable. In the case of the battery bank, two parameters should be considered: system autonomy, which is the number of days that the battery can meet the energy demand without charging the photovoltaic panels, and the discharge depth, which is the factor. which determines its service life due to the number of charge and discharge cycles.

For the process to be put into practice, the standardization rules that regulate the micro generation and mini generation systems of electric power distribution and compensation systems were followed through its Normative Resolutions [21] and [22]. In accordance with the provisions of Resolution [22], which amends the wording of Resolution No. 482/2012, micro generation is characterized by powers lower than or equal to 75 kW, while mini generation has installed power greater than 75 kW and less than equal to 5 MW in the case of a power generation center using qualified cogeneration or for renewable sources of electricity connected to the grid.

Thus, the calculation of load consumption (Table 1) uses the loads to be fed: Equipment - list the electrical equipment powered by the system; Voltage (Volts) - electrical voltage of the equipment; Power (Watts) - nominal power of the equipment; Current (Ampere) - nominal electric current of the equipment (Power / voltage of the battery bank); Use (h / day) - average number of daily hours for effective use of the equipment; Consumption (Ah / day) - average daily electricity consumption of equipment at battery bank voltage (12 V). Equipment powered by direct current multiplies by Current (A) and Usage (h / day).

Table 1. Application of energy consumption

System Survey						Icc consumption	
Item	**Equipment**	Tension Battery **(v)**	**Power (W)**	Use (h / day)	Consumption (w / day)	Current **(A)**	Consumption (Ah / day)
1	LED traffic light	12	4	24	96	0,33333	7,99992
2	LED traffic light	12	4	24	96	0,33333	7,99992
3	LED traffic light	12	4	24	96	0,33333	7,99992
4	Controller	12	5	24	120	0,41666	10
Total	-	12	17	24	408	1,41665	33.99976

Source: Adapted [23]

It is concluded that the system should generate a minimum of 528 Watts per day for the application, calculating the capacity of the battery bank taking into account the consumption and reliability required for the system. This capacity (Ah) is calculated using one of the two expressions below (consider which results in the highest capacity):

$$\text{Capacity (Ah)} = \frac{\textit{Total Consumption (h / day) * Autonomy (days)}}{\textit{Depth discharge at the end of each night}}$$

Capacity (Ah) = 22,666A h

Total consumption (Ah / day): according to table 1.

The autonomy (days) should provide for a sunless period of 3 to 5 days according to the local climate and the desired reliability, but normally in telecommunication systems it takes 4 to 5 days, having a discharge depth at the end of the autonomy (pu) - 0.5 to 0.7 (deeper discharges mean shorter battery life). The value normally adopted for stationary calcium lead batteries suitable for photovoltaic systems is 0.6 and for automotive batteries 0.5.

$$\text{Capacity (Ah)} = \frac{\textit{Total Consumption (h / day)}}{\textit{Depth discharge at the end of each night}}$$

Capacity (Ah) = 16,999Ah

Total consumption (Ah / day): according to table 1.

The default value for stationary calcium lead batteries for photovoltaic systems is 0.6. For automotive batteries 0.5 should be considered and the depth of discharge at the end of each night (pu) - 0.15 (battery life 5 years) to 0.20 (battery life 4 years)), with typical values ranging from 0.20 (stationary) to 0.15 (automotive) [24].

For depth of charge we should never completely discharge a lead acid battery. The discharge depth, around 20% of rated capacity, tells us that of the 2.5 Ah of our battery we can only use Ah = 0.5, otherwise we will damage it. Nickel cadmium accumulators, by contrast, must work in full charge and discharge cycles to avoid shortening their service life.

For the design of the photovoltaic panel must be used: Minimum generator power (Wp): Total minimum power of the module set required to produce the energy requested by the load; Vmp module: maximum power voltage of the module to be used (or of the modules in series); typically 17.4 V for isofoton modules on 12 V systems; Loss factor and safety: Considering the reduction of module generation due to

manufacturing tolerance, working temperature, dust, degradation, misalignment shadows, battery losses, controller, installation, consumption uncertainty etc., with typical value: 0.8; equivalent hours of full sun (h / day): depends on the latitude and cloudiness of the site, considering the average level of the most critical month in the chosen plan to install the modules, which should have a slope that favors the worst month.

$$\text{Generator Minimum Power (Wp)} = \frac{\textit{Total Consumption (Ah / day)} * \textit{Vmp Module}}{\textit{Full Sun Equivalent Hours} * \textit{Safety and Loss Factor}}$$

Generator Minimum Power (Wp) = 123.249Wp

3. Conclusion

By analyzing the information, it is possible to state that solar energy is a rapidly expanding reality in many countries around the world. The search for non-polluting sustainable energy forms is a global necessity. Even though Brazil has great potential for photovoltaic power generation, it takes little advantage, the obstacles that impede the growth of the sector in the country are being minimized, but still block accelerated growth.

Finally, it is clear that for Photovoltaic Energy to become representative in the face of the energy matrix there is a long way to go, for this, a set of complementary coordinated actions is necessary to provide an orderly development. In addition to the Energy aspect, it is important to highlight Technological development, since Photovoltaic Energy is not only a sustainable solution to generate Energy, but also a way to generate wealth and knowledge for Brazil.

The traffic lights with photovoltaic system are micro processed and can also be controlled by a traffic monitoring center via Wi-Fi, fiber optic or GPRS / GSM, which in my work is not necessary of the system. The traffic management software has an open protocol, thus allowing integration with the municipality's mobility and security solutions. The LED traffic lights are compact and also operate in sunlight with 12V battery, keeping in operation for several hours after a power outage, and also saving about 80 to 90% energy compared to the common traffic lights.

In addition, the traffic light system has a priority manager, enabling the passage of ambulances, fire engines and vehicles safely through intersections. It can be programmed to prioritize public transport as well. Given this perspective when it comes to the photovoltaic system in a semaphore array system, it is assumed that although still need economic incentives to become popular, the photovoltaic system is already used in some streets of the city of. Manaus.

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