2019 International Nuclear Atlantic Conference - INAC 2019
Santos, SP, Brazil, October 21-25, 2019
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-08-3

MEASUREMENT OF THE GENERATION OF ELECTRICAL ENERGY IN A PHOTOVOLTAIC SYSTEM GRID-CONNECTED IN THE AMAZON REGION IN THE RAIN PERIOD

Adriana B. Coelho[1] and Thadeu Neves Conti[2]

[1] Instituto Federal de Rondônia
Rodovia BR 174, KM 3, nº4334
76982-270 Vilhena, RO, Brazil
adriana.coelho@ifro.edu.br

[2] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP, Brazil
tnconti@ipen.br

ABSTRACT

Since 2012, when Resolution No. 482 of ANEEL (National Agency for Electric Energy) created the Electric Energy Compensation System, it was possible for Brazilian consumers to generate their own electricity from renewable sources or qualified cogeneration, supply the surplus to the distribution network of your locality. This milestone motivated the industry to develop technology in the area of photovoltaic energy. In light of this new perspective, the objective of this article is to compare the generation of electric energy by Grid-Connected Photovoltaic Power System 3.1 kWp installed in the rural area of the State of Rondônia located in the Amazon region, where the climatic seasons are rain and dry, with the generation estimate of the PVSyst program. The results of this analysis suggest that the industry develop projects and research to improve the program when it involves grid-connected photovoltaic (PV) power system in the northern region.

1. INTRODUCTION

In Brazil, distributed generation became available as of December 2012, after Aneel approved regulation No. 482 on April 17, 2012, where it allowed the final consumer to generate their own electricity and negotiate the surplus with the concessionaire local through mini and micro generation distributed through specific requests. The ANEEL (2012) regulation defines the photovoltaic energy grid connected to the grid in Brazil and establishes parameters for access to the distribution system, other considerations of the electricity compensation system, measurement, responsibilities and other provisions.

Today, after seven years of approval of the resolution, there are 86,706 photovoltaic (UFV) installed and connected to the grid according to ANEEL, with 119,223 consumer units receiving credit for generation. Of this amount, only 169 are located in Rondônia. The state had the first UFV connected to the grid on 27.03.2015, and the system studied was the 20th power plant connected to the grid, the first being in the rural area.

With the objective of studying the behavior of photovoltaic solar systems connected to the grid for the region of Ouro Preto do Oeste - Rondônia through a case study of a system installed in a dairy farm in the rural region of the municipality, this work seeks knowledge on systems photovoltaic connected to the network to serve the rural producers of the region and assist in the economic development of the region.

With the motivation to assist the rural producers so that the development of the region can be reached, without waiting so long for the utility to expand the network and with the same energy quality. It is believed that in the short term it will be able to supply the region's energy demand and increase milk production in a sustainable and economically viable way.

2. CONTEXTS

2.1 Energy Context

According to the Brazilian Energy Review (EPE, 2014), in recent years the energy matrixes of Brazil and the world presented significant structural changes. Table 1 shows the energy matrix in the last 40 years, where the reduction of the share of oil and oil products is well known, and in the case of Brazil, the reduction of 6.3 percentage points between 1973 and 2013 shows that the country, following the world trend, has also developed a significant effort to replace these fossil fuels.

Table 1 - Internal Energy Supply in Brazil and the World (%).

Fonte	Brasil		OECD		Mundo	
	1973	2013	1973	2013	1973	2013
Petróleo e Derivados	45,6	39,3	52,6	35,8	46,1	29,3
Gás Natural	0,4	12,8	18,9	26,6	16,0	21,6
Carvão Mineral	3,1	5,6	22,6	18,8	24,6	30,9
Urânio	0,0	1,3	1,3	9,4	0,9	4,8
Hidráulica e Eletricidade	6,1	12,5	2,1	2,3	1,8	2,3
Biomassa/Eólica/Outras	44,8	28,6	2,5	7,1	10,6	11,1
TOTAL (%)	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

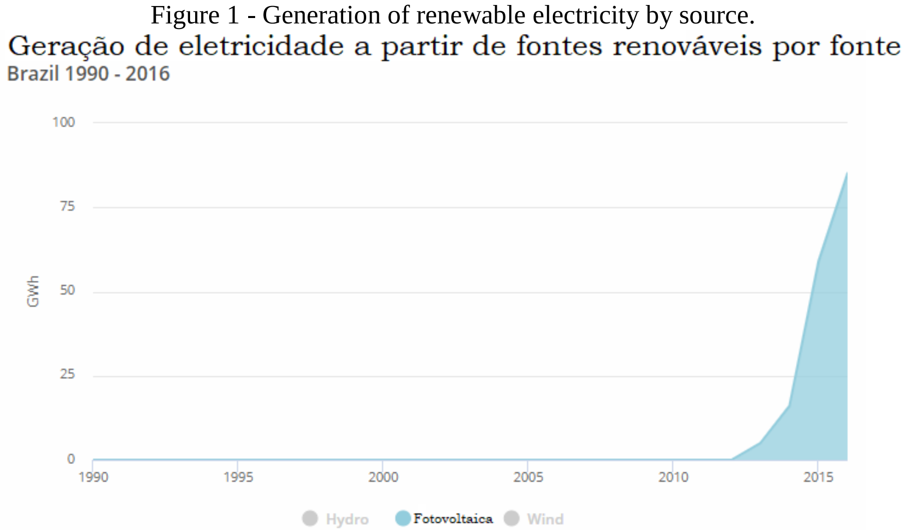
Source: (Adapted from Brazilian Energy Review, 2014).

In Brazil there are many options for generating energy because of its large territory and biodiversity, according to PACHECO (2006) "alternative or renewable energy projects are aimed at the development of new projects in energy production, from organic matter of animal origin and biomass; from the force of the winds, the so-called wind energy; through the capture of sunlight, solar energy, and from small hydroelectric plants, which meet demands in areas peripheral to the transmission system. "For this reason, the sources of renewable energy in Brazil are diverse and small percentage to be counted individually, but adding all has a large numeric expression.

In parallel, observing data from the National Energy Plan 2030 (PNE 2030), it is estimated that the increase in population in Brazil is expected to reach 238.6 million inhabitants in 2030, with growth rates around 1.1 % per year between 2010 and 2020 and 0.8% per year between 2020 and 2030. Concomitant to this demographic increase is the increase in per capita energy consumption. As a result, the final increase in energy consumption varying between different scenarios can grow from 2.2 to 4.2% a.a. reaching the mark of 474 Mtoe in 2030 (EPE, 2007).

By looking at the data presented it is seen that there will be a greater intensity in the use of renewable sources in order to improve the energy matrix and the sustainable development in the world. Even though Brazil is above average in the renewable energy supply and there is a lot of potential to be used, including in the solar energy sector, it is observed in figure 1 that the representativity is still low in the country.

Figure 1 - Generation of renewable electricity by source.



Source: IEA Renewables Information 2018 (Adapted)

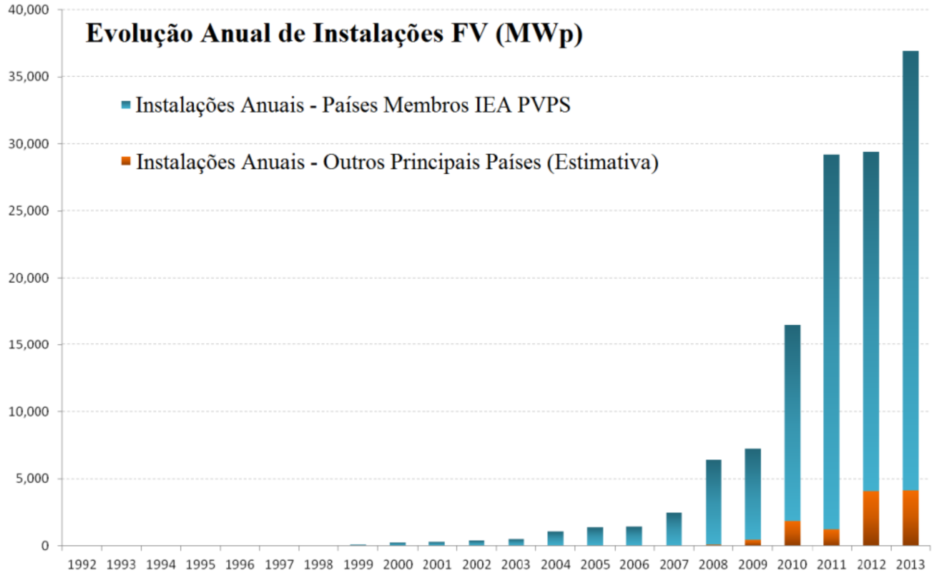
In the search for alternative sources Brazil presents great differentials in relation to other countries, such as favorable geographical and climatic conditions besides its immense biodiversity. These characteristics make possible the generation of energy by various means, including photovoltaic solar energy, which besides favoring the diversification of the energy matrix, assists in the increasing demand for energy (RUTHER et al., 2008).

Therefore it is observed that solar energy can be a way in the expansion of the energy matrix of the country due to its great potential and new technologies in the area.

2.2 Solar Energy Context

Worldwide, the application of photovoltaic solar energy started from isolated systems in telecommunications systems, space and in places of difficult access of the energy network. However, its use only intensified from the beginning of the 90s, after the development of technology and legal and political support for the use of photovoltaic systems connected to the grid. After this milestone, the growth of the industrial production of modules and equipment for solar systems was quite pronounced, culminating today in a large market (APOLONIO, D.M. 2014), as can be seen in Figure 2.

Figure 2 - Annual evolution of installation of photovoltaic systems.



Source: IEA-PVPS, A Snapshot of Global PV 1992-2013, 2014.

Although photovoltaic generation is an expensive solution nowadays compared to other solutions, it is the technology that presents the highest rate of growth and fall in costs. Technological advances are very promising to make their costs even cheaper and to enable the consolidation of this technology (JANNUZZI, 2009).

According to GT-GSDF (2009) without these solar roofing programs, it is possible that the annual production of photovoltaic modules would be only 13% (756 MWp) of the total production achieved in 2008, but the results achieved were much better due to the mechanisms of countries that have opted for the use of photovoltaic solar energy.

One of the pioneer countries in the use of distributed solar energy is Germany, which between 1990 and 1995 promoted a program of installation of photovoltaic panels connected to the network in 1,000 roofs. There was a great success and reached the mark of 2,250 equipments, with average power of 2.6 kW per roof, being the surplus energy generated sold to the concessionaire by the residential consumer. After this project, the program was launched 100,000 solar roofs with the objective of reaching 500 MW of solar energy generation.

Despite the many challenges of the industry in the year 2011, technological innovation continued along the value chain with advances in efficiency, process improvements, developments in organic materials, plastics, improvements in finance, among others, and the reduction of continued its downward trajectory, with an average reduction of 7-8% per year (REN21, 2012).

In Brazil, distributed generation became available as of December 2012, after Aneel approved regulation No. 482 on April 17, 2012, where it allowed the final consumer to generate their own electricity and negotiate the surplus with the concessionaire local through mini and micro generation distributed through specific requests.

With the change of legislation, the network is preparing to add new sources due to installation and energy exchange relationship with the concessionaire including photovoltaic solar energy connected to the grid. The form of contract and compensation is defined by ANEEL (2012) according to the section:

> *III - electric energy compensation system: a system in which the active energy injected by a consumer unit with distributed microgeneration or distributed minigeneration is transferred, through a free loan, to the local distributor and subsequently compensated by the active electric energy consumption of that same unit consumer or other consumer unit with the same ownership of the consumer unit where the credits were generated, provided that it has the same Individual Taxpayer's Registry (CPF) or Legal Entity Register (CNPJ) with the Ministry of Finance.*

The ANEEL (2012) regulation defines the photovoltaic energy grid connected to the grid in Brazil and establishes parameters for access to the distribution system, other considerations of the electricity compensation system, measurement, responsibilities and other provisions.

2.3 Grid Connected Photovoltaic Systems (GCPVS)

Photovoltaic generation has the advantage of distributed generation, in which, the generator systems can be installed near the loads avoiding losses and new investments in transmission and / or distribution lines. The distributed generation allows to obtain greater energy efficiency in the use of energy and greater stability of the electric power service. There are several ways to realize distributed generation, such as: co-generators, generators that use process fuels, emergency generators, generators for operation at peak hours, small hydroelectric plants and photovoltaic panels (INEE, 2013).

Grid connected systems are used by the distribution grid as a source of charge storage. For when it injects its generation into the grid it acts as a complement to the electrical system by reducing power generation by large power plants, increasing the levels of hydroelectric reservoirs and reducing the burning of fossil fuels.

According to GREENPRO (2004), the grid-connected photovoltaic system (GCPVS) is normally composed of the following components: photovoltaic generator, junction box, DC-AC cables, frequency inverter, protection mechanisms and measuring devices . The inverter must meet quality and safety requirements so that it does not affect the distribution network.

The inverter used in this case is specific for this purpose, because when it is not connected to the network it does not convert the direct current to alternating current. It must have an anti-islanding device, because if there is an interruption in the power supply by the dealer, the inverter will automatically shut down. The energy delivered by the inverter has the characteristics of the network energy: voltage, frequency and phase (RÜTHER et al., 2007).

3. METHODOLOGY AND MATERIALS

3.1 Design and implementation of the system

The photovoltaic power generation system was designed to serve a milk tank with a power of 2 HP, approximately 1.47kW. It is usually powered from 6 o'clock in the morning, just after milking the cattle, and stays on until 4 o'clock, when the dairy truck fetches the cooled milk. So stay connected 10 hours a day. If it were being used at its maximum load / capacity, it would consume 14.7 kWh / day.

However, in periods when milk production decreases - and the tank does not fill in one day, milk collection is performed on alternate days, keeping the tank on for longer. In this way it would be necessary to make a measurement of the energy consumed, but there were some setbacks during the consumption analysis. Several other loads are connected to the energy meter in question, which makes it difficult to analyze the account. In addition, the owner reported that due to power grid deficiencies, there are times when it is not possible to connect certain loads together with the tank, making it necessary to use a diesel generator.

As the dairy has an agreement with Mr. Aurindo regarding the energy consumption of the milk tank, the calculation was made in relation to the power of the tank. In this way, the calculation was based as follows:

Etotal = Ptanque x thoras/dia x tdias/mês
Etotal = 1,47kW x 10 x 30 = 441kWh

Thus, it would be necessary for the boards to produce at least 441KWh of power per month to meet demand for the property. Therefore, taking into account that the maximum intensity of the sun in this region is 5 hours / day, and that the month has 30 days, it would be necessary to install a set of plates with a total power of 2.94kWp.

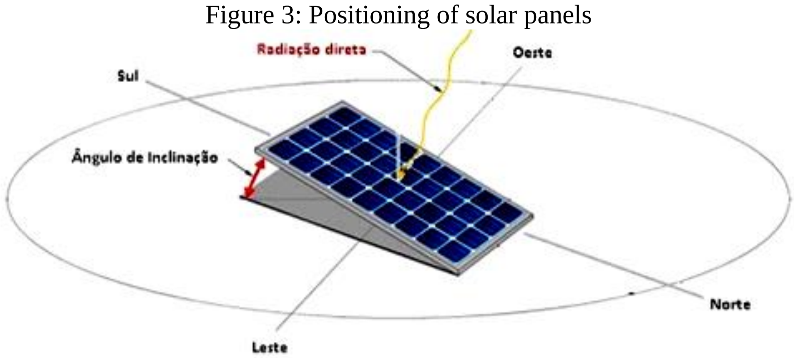
When searching the photovoltaic panels, we chose a set of 3.1 kWp, consisting of 10 photovoltaic panels of 310Wp.

3.2 Corrections in the positioning of solar panels

It is known that the modules need to be positioned in a location that receives the highest possible solar radiation, which in the southern hemisphere normally occurs in the north orientation and slope close to the local latitude (Brogren, Green, 2003; Burger, Rüther, 2006). Figure 3 helps to visualize the suggested positioning.

Although this orientation is a good indication in the attempt to maximize the solar resource incident in the generator plane, the results presented by ZILLES et al. (2012) show that the improvement of catchment also depends on the specificities of each site and that a wide variety of guidelines, around the aforementioned orientation, can be used without incurring significant losses, and in some cases even improving the incidence of the resource solar.

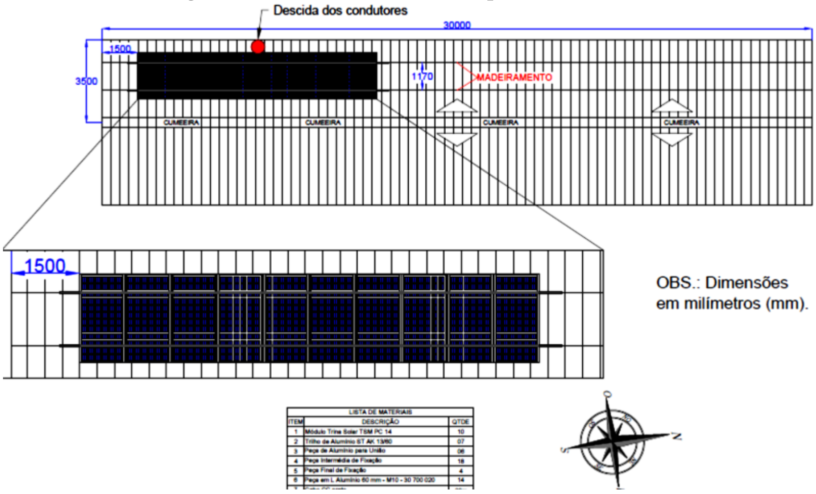
Figure 3: Positioning of solar panels



Source: Courtesy Image of Image Science & Analysis Laboratory, NASA Johnson Space Center, the portal for the photograph of Earth astronauts

However, when looking at Figure 4, notice that the plates were in the northeast position and that the roof has a slope of 15º, as if it took advantage of the existing structure, there was a need for correction in the project.

Figure 4: Position of the solar panels on the roof



Source: Owner's Project

The choice of the roof of the corral was after analyzing the existing roofs in the property, taking into account the area needed to install the ten plates and the absence of shading.

3.3 Solar panels

A set of individual cells connected in series composes a photovoltaic module that are the main components of the photovoltaic system of generation of energy. These are formed by a set of photovoltaic cells electrically coupled in series and / or parallel depending on the voltages and / or currents determined in design. These modules are called photovoltaic generators and constitute the first part of the system, that is, they are responsible for the process of capturing solar irradiation and its transformation into electric energy (PEREIRA & OLIVEIRA, 2011).

In Rondônia, there were few companies working with photovoltaic solar system at the time, Garcia Solar was chosen to assist in the purchase of the material and in the installation of the system. The boards offered by the company are from the Trina Solar model TSM-310PC14, a module composed of 72 polycrystalline cells totaling 310W.

The solar panels used are polycrystalline of 16% efficiency (Figure 5). The panels are waterproof and resistant to the most severe environmental conditions. The panels purchased for use have the following technical characteristics described in figure 6.

Figure 5: Energy efficiency of the photovoltaic panel model TSM-310PC14

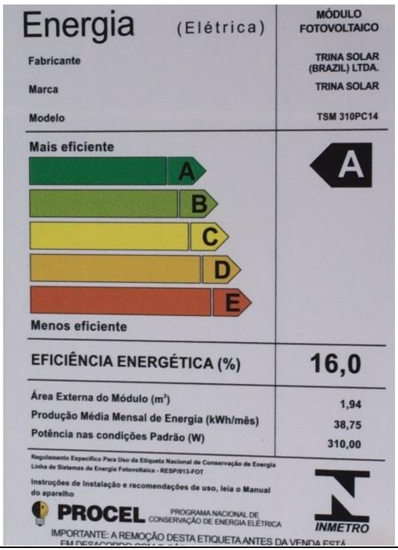


Figure 6: Technical characteristics of the photovoltaic panel model TSM-310PC14

Source: Photo taken from back of solar panel

3.4 Frequency inverter

As the focus of this work are the inverters connected to the grid, and knowing that they are responsible for the direct connection of the photovoltaic generator to the low voltage grid, injecting the generated energy to the electrical installation of the property or the distribution network. They can be single-phase or three-phase according to the power of the installed system, in this case, it is a single-phase inverter with 230V output, according to the manual supplied by the manufacturer (figure 7).

When selecting the plates, there is a 37V Vmp, as shown in figure 6, so the input voltage should be 370V because there are ten plates and the current will be 8,38A (Imp - Fig. 6) because the plates are connected in series . When identifying this information, the selected inverter complies with the manufacturer's manual (Figure 7).

According to Zilles, it is necessary to observe the conversion efficiency, which in this case is 96.1% in addition to having a degree of protection IP65 according to the manufacturer's manual on the general data of the inverter shown in figure 8.

Figure 7: Technical characteristics of the inverter Fronius Galvo 3.1-1

Fronius Galvo 3.1-1

Dados de entrada

Faixa de tensão MPP	165 - 440 V CC
Tensão de entrada máx. (com 1000 W/m² / -10 °C em marcha vazia)	550 V CC
Corrente de entrada máx.	20,7 A
Corrente de curto circuito máx. dos módulos solares	31,0 A
Corrente de retorno de alimentação 4)	13,8 A

Dados de saída

Potência de saída nominal (P_{nom})	3100 W
Potência de saída máx.	3100 W
Tensão nominal de alimentação	1~NPE 230 V
Tensão de alimentação mín.	180 V 1)
Tensão de alimentação máx.	270 V 1)
Corrente de saída máx.	15,0 A
Frequência nominal	50 - 60 Hz 1)
Fator de distorção	< 4 %
Fator de potência cos phi	1 0,85 - 1 ind./cap. 2)
Impedância de rede máxima permitida $Z_{máx.}$ no PCC 3)	nenhuma
Impulso de corrente de ligamento 6) e duração	36,0 A / 9,4 ms
Corrente de erro de saída máx. por duração	43,0 A / 1,24 ms

Source: Fronius Galvo Manual

Figure 8: Fronius Galvo 3.1-1 inverter technical specifications - General Data

Dados gerais

Grau de eficiência máxima	96,1 %
Europ. Grau de eficiência	95,4 %
Consumo próprio de energia durante a noite	0,47 W
Resfriamento	Ventilação forçada regulada
Grau de proteção	IP 65
Dimensões (C x L x A)	645 x 431 x 204 mm
Peso	16,75 kg
Temperatura ambiente permitida	- 25 °C - +50 °C
Umidade do ar permitida	0 - 100 %
Categoria de emissão EMV	B
Categoria de sobretensão (CC / CA)	2 / 3

Dispositivos de instalação de soldagem

Medição de isolamento CC	Alerta/ Desligamento 7) com R_{ISO} < 600 kOHM
Comportamento em sobrecarga CC	Deslocamento do ponto operacional limitação da potência
Disjuntor CC	integrado

Source: Fronius Galvo Manual

3.5 Estimated power generation

In order to estimate the power generation of the system, the PVSYST tool V6.53 was used, Figure 9 shows a graph of a generation projection considering the losses in the plates and in the inverter. Figure 10 shows a projected generation of energy injected into the grid per month, totaling 3928.3 kWh in the year, an average of 327.36 kWh / month.

Figure 9: Energy estimate for the 3.1 kW system by PVSYST

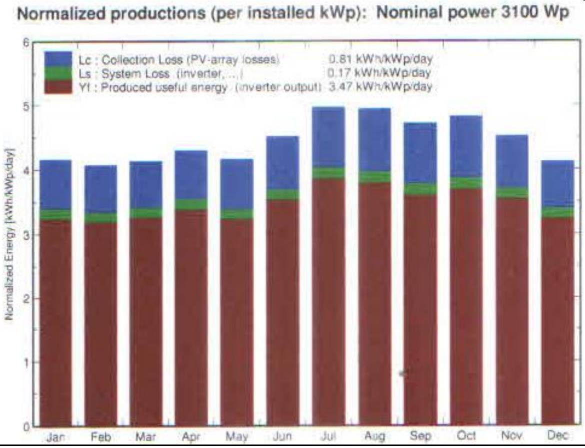


Figure 10: Estimation of power generation for the 3.1 kW system by PVSYST

Variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	140.1	25.50	128.8	124.5	327.6	312.1	13.11	12.49
February	126.8	25.40	113.9	110.0	291.4	277.7	13.18	12.57
March	138.6	25.40	127.9	123.4	329.4	314.2	13.28	12.66
April	137.4	25.40	128.8	124.2	330.4	315.2	13.22	12.62
May	135.5	25.70	128.8	124.2	326.7	311.4	13.07	12.46
June	141.6	26.40	135.1	130.4	344.2	328.7	13.13	12.54
July	162.4	27.00	153.9	148.8	388.6	371.4	13.02	12.44
August	162.1	28.90	153.0	148.1	382.1	364.7	12.87	12.28
September	150.9	29.50	141.4	137.0	351.9	335.4	12.82	12.22
October	160.6	28.60	149.2	144.7	372.6	355.4	12.87	12.28
November	145.5	26.70	135.3	130.9	345.7	330.0	13.17	12.57
December	139.5	25.90	127.5	123.2	327.2	312.1	13.22	12.61
Year	1741.1	26.71	1623.6	1569.3	4117.6	3928.3	13.07	12.47

Legends: GlobHor Horizontal global irradiation; T Amb Ambient Temperature; GlobInc Global incident in coll. plane; GlobEff Effective Global, corr. for IAM and shadings; EArray Effective energy at the output of the array; E_Grid Energy injected into grid; EffArrR Effic. Eout array / rough area; EffSysR Effic. Eout system / rough area

Source: Blue Sol Project delivered to the Energy Concessionaire

3.7 Installation cost

The total value of the products in the note was R$ 24,324.54, however there was a installment in 36 times, being the amount of the installment of R $ 901.30 totaling R$ 32,446.80.

4. DATA ANALYSIS

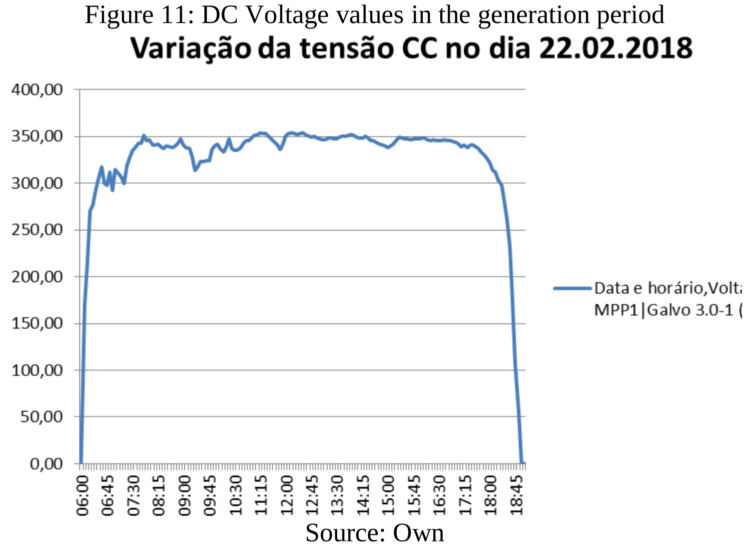
4.1 Direct Current Data

4.1.1 DC Voltage

Each solar panel has a nominal voltage of 37 V, as are ten and are connected in series, the total voltage should be 370 V. However, when choosing a random day, it is noticed that the voltage generated in the photovoltaic arrangement has variations to the during the day and almost does not reach this value of tension.

When analyzing the whole period of 22.02.2018, from 00:00 hours at 06:00 hours and 19:00 hours at 23:55 because there is no tension. When discarding this period, the average voltage during the generation period, which is from 06:00 to 19:00 hours, is 329.97 V, and can be seen in figure 11.

Figure 11: DC Voltage values in the generation period



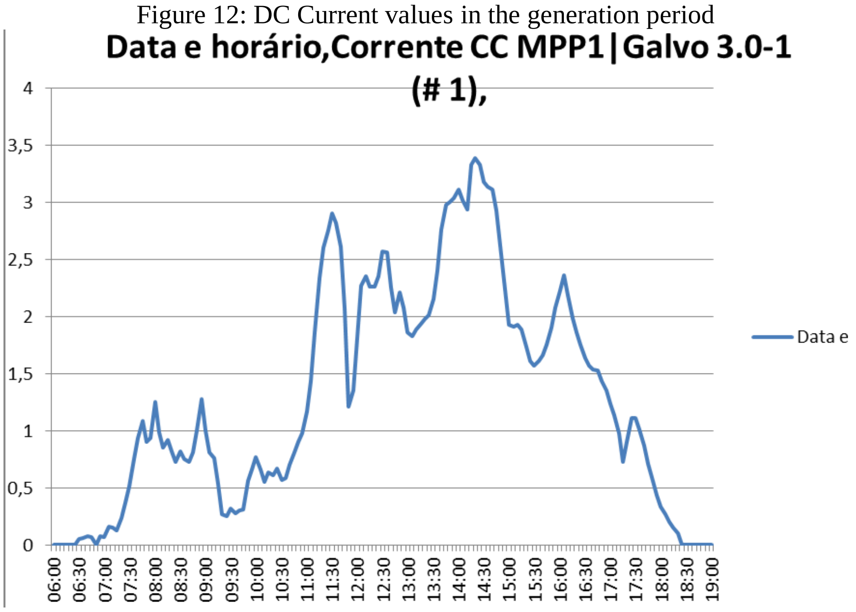
Source: Own

4.1.2 DC Current

Each solar panel has a nominal current of 8.38A, even if it is in ten and connected in series, the current should be 8.38A. However, when choosing a random day, it is noticed that the current generated in the photovoltaic array has variations throughout the day and almost does not reach this value.

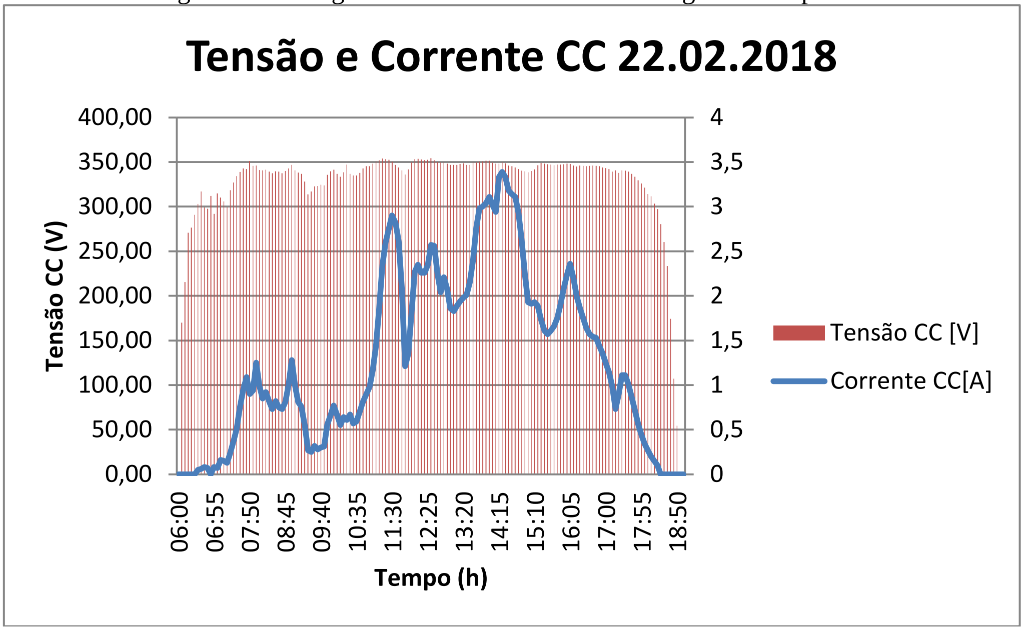
When analyzing the whole period of 22.02.2019, from 00:00 hours at 06:00 hours and 19:00 hours at 23:55 because there is no current. When discarding this period, the average current during the generation period, which is from 6:00 am to 7:00 p.m., is 1.32 A, which can be seen in figure 12, but there is a large difference in the graph generated by voltage and the current, where the current variation is much greater than the voltage, as shown in figure 13.

Figure 12: DC Current values in the generation period



Source: Own

Figure 13: Voltage and Current DC values in the generation period



Source: Own

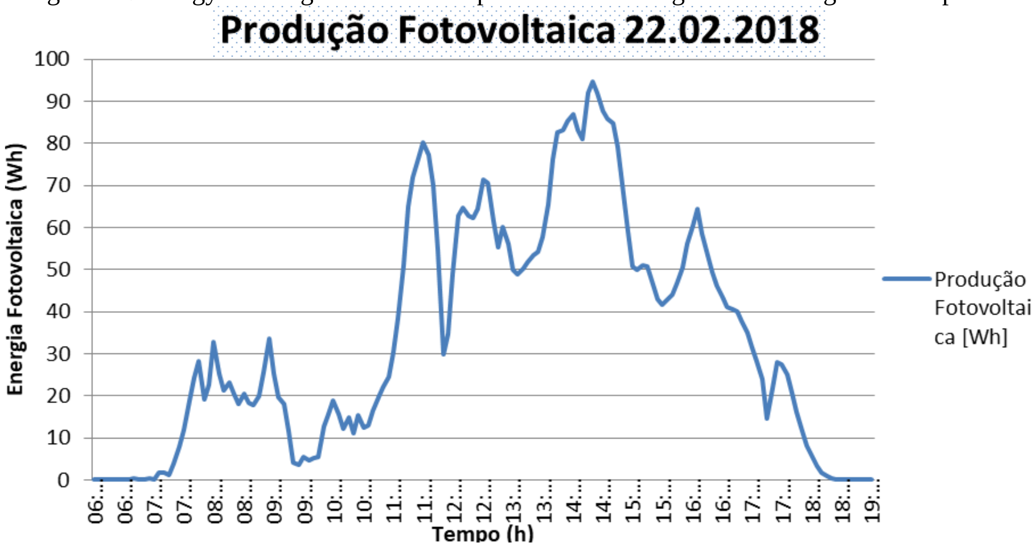
When analyzing figure 13, it is noticed that the voltage has a smaller variation than the current that has peaks at various times of the day.

4.1.3 Power Generation

Each solar panel has a nominal power of 310 W, as there are ten and are connected in series, the total power should be 3100 W. However, when choosing a random day, it is perceived that the energy (power x time) generated has variations and does not reach this value.

When analyzing only the generation period, which is from 06:00 to 19:00 hours, the average energy generated is 34.65 Wh, and can be seen in figure 14.

Figure 14: Energy values generated in the photovoltaic arrangement in the generation period



Source: Own

Observing the graph of the energy generated in the photovoltaic arrangement it is noticed that the production has great variations during the day.

4.2 Alternating Current Data

4.2.1 AC Voltage

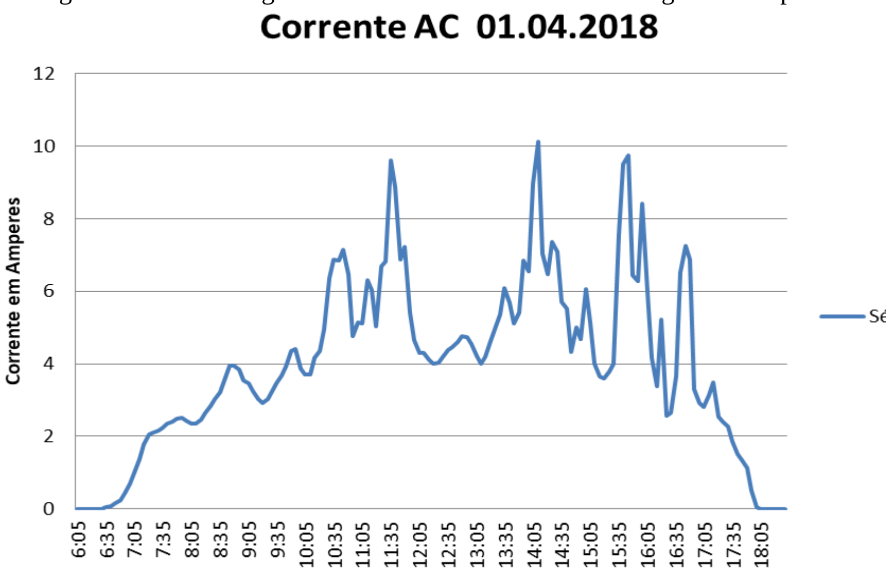
The alternating voltage supplying the inverter is limited by the manufacturer, between 180 and 270 volts, averaging 230V. However, by NBR 16149: 2013 (Photovoltaic Systems (PV) - Characteristics of the connection interface with the distribution grid) there are also limits on the voltage levels by minus 20% and plus 10%, with the turn-off time of 0 , 4s and 0.2s respectively.

Therefore, the inverter has been limited to 180 V and 250 V, so when the voltage limits reach the inverter automatically disconnects.

4.2.2 AC Current

The alternating current supplying the inverter is limited by the manufacturer to 15 Amps, in Figure 15 it can be seen that this value is not reached on a random day such as 01.04.2018.

Figure 15: Alternating current values in the inverter in the generation period



Source: Own

7.4 Operating Failures

7.4.1 High grid voltage

The inverter has an AC voltage limit to operate and during the period from January to June 2018, twenty-one interruptions were recorded due to the grid voltage rise. In this way the utility was asked to regulate the voltage of the system that feeds the property.

When the voltage at the transformer output was analyzed, it was found that the transformer tap was set at the maximum level. Because it is a rural network, the transformer was regulated in this way when installed because it was grid termination at the time. The technician responsible changed the tap to improve the problem.

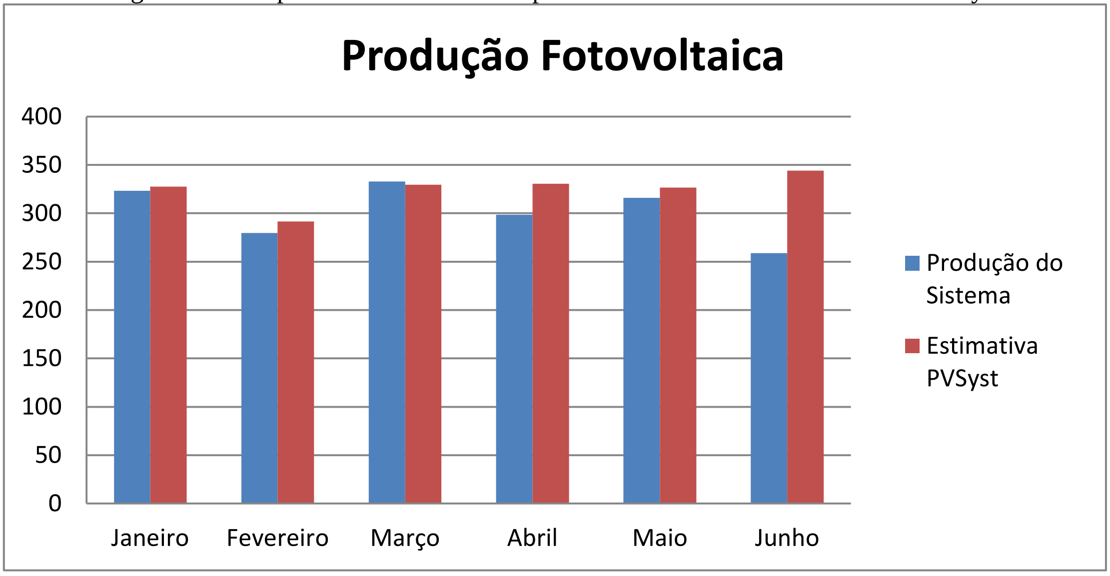
7.4.2 Grid interruption

According to the norms, when grid interruption happens for any reason, the photovoltaic inverter must be able to perceive the islanding and block its operation instantaneously after its emergence to ensure the safety of the maintenance staff of the electrical system and also to avoid damages to the local loads by the voltage and frequency variations that will arise. In addition to protecting the system itself from distributed generation from unforeseen damages.

5. ANALYSIS OF RESULTS

The generation sum in the period from January to June 2018 was 1654.22 kWh, with a daily average of 10.148 kWh / day. In figure 17, this photovoltaic production was represented in month and compared the estimate made in PVSyst made by Blue Sol and delivered to the concessionaire according to figure 10.

Figure 17: Comparison of Photovoltaic production with Estimation made in PVSyst



Source: Own

6. FINAL CONSIDERATIONS

With the objective of studying the behavior of solar photovoltaic systems connected to the grid for the Ouro Preto do Oeste region through a case study of a system installed in a dairy farm in the rural region of the municipality, this work contributed to increase the knowledge about photovoltaic systems connected to the grid. Thus some considerations can be made about the results achieved in this work, the difficulties and the conclusions.

With regard to the design of the photovoltaic system and the execution of the same it was realized that the system could be improved to reduce losses and increase its efficiency.

There were major difficulties in relation to the grid that feeds the system, access to the site, lack of experience of the concessionaire and technical assistance in the state.

Regarding the financial study, there was still no conclusion of data collection, mainly because the concessionaire has had months without measurement, in addition to meter failures and invoice failures.

The state of Rondônia had the first UFV with distributed generation connected to the grid on 03/27/2015 according to ANEEL and until 01.05.2019 there were 139 units installed. These data show how recent the photovoltaic generations are in the state, and as aggravating, there was a change in the energy concessionaire, now the direct are from Energisa S/A.

This work was only a beginning of study on photovoltaic system in the region, being necessary more deepening in relation to the distribution network of the region, the losses of the system due to dust and an improvement of the reading in the rural region of the state for a better definition of estimation of the financial return of the system to rural region mainly to incentivize the producers of this region in sustainable generation and of quality.

7. REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ***Procedimento de ensaio de anti-ilhamento para inversores de sistema fotovoltaicos conectados à rede elétrica***. Rio de Janeiro: ABNT, 2012. (NBR IEC 62116).

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ***Sistemas fotovoltaicos (FV): características da interface de conexão com a rede elétrica de distribuição***. Rio de Janeiro: ABNT, 2013. (NBR 16149).

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL). ***Resolução Normativa nº 482, de 17 de abril de 2012.*** Disponível em: <http://www.aneel.gov.br/cedoc/ren2012482.pdf> Acesso em: 10 jul. 2016

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL). ***Resolução Normativa nº 687, de 24 de novembro de 2015.*** Disponível em: <http://www2.aneel.gov.br/cedoc/ren2015687.pdf> Acesso em: 05 abr. 2017

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL). Relação de Unidades Consumidoras de Geração Distribuída. Disponível em: <(http://www2.aneel.gov.br/scg/gd/GD_Distribuidora.asp)> Acesso em: 30 jun. 2019

APOLONIO, Daniel Moussalem. Energia solar fotovoltaica conectada à rede elétrica em Cuiabá. 2014. 148p. Dissertação (Mestrado em Eficiência Energética) UFMT – FAET – PPGEEA/MT. Cuiabá. Disponível em: <http://ri.ufmt.br/bitstream/1/516/1/DISS_2014_Daniel%20Moussalem%20Apolonio.pdf>, Acesso em: 7 de jan. 2019.

BURGER, B.; RÜTHER, R. ***Inverter sizing of grid-connected photovoltaic systems in the light of local solar resource distribution characteristics and temperature.*** Solar Energy, v. 80, n. 1, p. 32-45, 2006.

CENTRO DE REFERÊNCIA PARA ENERGIA SOLAR E EÓLICA SÉRGIO DE SALVO BRITO (CRESESB). ***Centro de Pesquisas de Energia Elétrica. Grupo de Trabalho de Energia Solar. Manual de engenharia para sistemas fotovoltaicos***. Rio de Janeiro, CRESESB, 2004. Disponível em: <http://www.cresesb.cepel.br/publicacoes/download/Manual_de_Engenharia_FV_2004.pdf> Acesso em: 27 jun. 2017.

EMPRESA DE PESQUISA ENERGÉTICA (EPE). ***Plano Nacional de Energia 2030.*** Brasília: MME/EPE, 2007. Disponível em: < http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/Plano-Nacional-de-Energia-PNE-2030 > Acesso em: 26 jan. 2019.

EMPRESA DE PESQUISA ENERGÉTICA (EPE). ***Balanço Energético Nacional 2014: Ano base 2013. Empresa de Pesquisa Energética.*** Rio de Janeiro, 2014. 288 p. Disponível em: <

http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/Balanco-Energetico-Nacional-2014 > Acesso em: 09 set. 2018.

GREENPRO. ***Energia Fotovoltaica: Manual sobre tecnologias, projecto e instalação***. 2004. Disponível em: <http://www.greenpro.de/po/fotovoltaico.pdf> Acesso em 06 mar. 2018.

GRUPO DE TRABALHO DE GERAÇÃO DISTRIBUÍDA COM SISTEMAS FOTOVOLTAICOS (GT-GDSF). Ministério de Minas e Energia (MME). ***Estudo e propostas de utilização de geração fotovoltaica conectada à rede, em particular em edificações urbanas.*** Brasília, 2009. 222 p.

IMHOFF, J. ***Desenvolvimento de Conversores Estáticos para Sistemas Fotovoltaicos Autônomos. Dissertação de Mestrado apresentada à Escola de Engenharia Elétrica da Universidade Federal de Santa Maria***, Santa Maria. 2007. 146 f.

INSTITUTO NACIONAL DE EFICIÊNCIA ENERGÉTICA (INEE). ***O que é "Geração Distribuída"?***. Disponível em: <http://www.inee.org.br/forum_ger_distrib.asp?Cat=forum> Acesso em 11 abr. 2016.

JANNUZZI, Gilberto de Martino; MELO, Conrado Augustus de. ***Grid-connected photovoltaic in Brazil: Policies and potential impacts for 2030***. Campinas, Brasil. Publicado em Energy for Sustainable Development 17 (2013) 40–46, ELSEVIER.

NASCIMENTO, C. ***Princípio de Funcionamento da Célula Fotovoltaica***. Dissertação de Mestrado apresentada à Escola de Engenharia da Universidade Federal de Lavras, Lavras. 2004. 23 f.

PACHECO, F. 2006. ***Energias Renováveis: breves conceitos. Economia em destaque.*** Disponível em: http://ieham.org/html/docs/ConceitosEnergias renov%E1veis.pdf. Acesso em: 22 de out.2018.

PEREIRA, A. D. S.; OLIVEIRA, M. Â. S. ***Curso Técnico Instalador de Energia Solar Fotovoltaica***. Porto: Publindústria, 2011. 395 p.

PVSYST. ***PVsyst Photovoltaic Software 6.38***. 2015.

RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY (REN21). ***Renewables 2012 Global Status Report***. Paris, 2012. Disponível em: <www.ren21.net>, Acesso em: 7 de jan. 2019.

RÜTHER, Ricardo. ***Edifícios solares fotovoltaicos***. Florianópolis: Editora UFSC/LABSOLAR, 2004. 113 p.

SEVERINO, M.& OLIVEIRA, M. ***Fontes e Tecnologias de Geração Distribuída para Atendimento a Comunidades Isoladas.*** Energia, Economia, Rotas Tecnológicas: textos selecionados, Palmas, ano 1, p. 265-322, 2010.

ZILLES, R.; MACÊDO W. N., GALHARDO, M. A. B., OLIVEIRA, S. H. F. ***Sistemas Fotovoltaicos Conectados à Rede Elétrica.*** 1ª. ed. São Paulo: Oficina de Textos, 2012. 208 p.

ZILLES, Roberto; RÜTHER, Ricardo. ***Telhados solares e a indústria fotovoltaica. Valor Econômico.*** São Paulo, Abr. 2010. Disponível em: <http://www.provedor.nuca.ie.ufrj.br/eletrobras/estudos/zilles1.pdf> Acesso em: 26 jun. 2017.