TECHNICAL AND ECONOMIC ANALYSIS OF DITRIBUTEDS GENERATION IN AGRIBUSINESS: A REAL STUDY CASE

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***Abstract*— The present work is a study of engineering in a rural property. It aiming to analyze the capacity of cost reduction in agribusiness by inserting a Distributed Generation (DG) connected to the electric grid (on-grid). The applied methodology consists in a comparison between photovoltaic generation and the generation by biogenerator. The economic viability is calculated to several scenarios: with DG and without DG, that was developed with the aid of the softwares Homer and Excel, aiming to find the case of greatest attractiveness for investment. The final results are described in terms of Net Present Value (NPV), and including financing of the solutions. It is noted that the importance of choosing the bank and the financing program are as important as a distributed generation study, considering that it was possible to reduce more than R$700.000,00 in NPV just by choosing the attractive financing for this investment in solar energy.**

Keywords— Distributed Generation. Photovoltaic energy. Agribusiness.

I. INTRODUCTION

The electricity generation system is mainly composed of hydroelectric sources in Brazil, due to the abundance of water resources in the country, representing more than 68% of all the energy generated in the country according to the National Energy Balance [1]. Although the country has benefited for decades from such water resources, currently such a strategy is relatively saturated due to several factors such as the complexity of expansion of distribution and transmission systems as well as climatic factors that directly influence hydroelectric generation [2].

Therefore, new strategies are needed to supply the country's energy growth, diversifying the nature of energy sources [3], [4]. One solution is the use systems of distributed generation (DG), that is, electric power generation from small power plants that can use different renewable sources of electricity or cogeneration [5], connected to the distribution network through facilities in the consumer units according to the National Institute of Energy Efficiency (INEE).

Another important factor for this work is the growth of agriculture and agribusiness in Brazil in 2017, which contributed 23.5% of Brazil's Gross Domestic Product (GDP), the largest participation in 13 years according to the Confederation Agriculture and Livestock of Brazil [6], [7]. This favorable scenario of agribusiness and the increasing spread of distributed generation in Brazil are motivators for studies of technical and energy viability for an increasingly sustainable world with the use of renewable sources for electric power generation, another charactistic is that generally the grids on the rural area the investments are low, than can happen long periods without energy.

In this way, this work is divided as: Distributed Generation explaining the Brazilian rules; Tariff Structures that shows how is the electrical energy tariffs with the focus in the agribusiness. After that are two items showing the main characteristics, of electric generation by photovoltaic and by biogas. Then there is the methodology explaining why use the software HOMER Energy, and other characteristics. The study case show all necessary data from a real agribusiness, and how were considered for distributed generation. Finally, are some considerations made after the study with the conclusion of work. For these studies will be considered the software HOMER for DG analysis and too the Microsoft Excel for financial studies considering the financing the value of solutions.

II. DISTRIBUITED GENERATION

Every generation of electricity from a small generator, whether through renewable sources or by fossil fuels, located near the centers of loads, can be called distributed generation. In Brazil, Decree Law No. 5.163/2004 [8] defines DG as renewable sources, small hydroelectric plants and qualified cogeneration. This term has been increasingly disseminated for its great benefits to consumers, such as the improvement of the level of network tension in periods of high consumption, low environmental impact and mainly by the economy and dependence of energy of the utility grid, and in rural areas the investments are lower in grids and periods without energy are common.

In order to encourage the implementation, standardization and definition of guidelines for the use of DG in Brazil, on April 17, 2012, National Electric Energy Agency (ANEEL) established the Electric Energy Compensation System, where all Brazilian consumers can generate and supply their own energy with surplus generation, it can be distributed in the local network [9]–[11].

III. TARIFF STRUCTURE

The energy costs present in the energy bill of the Brazilian consumer currently account for the largest share of costs with the purchase of energy, transmission and sector charges (53.5%), followed by taxes (29.5%). The cost of distributing costs, or the cost to maintain the assets and operate the entire distribution system represents only 17% of the tariff costs [12].

Electricity consumers are classified according to the ANEEL, according to the voltage level in which they are served. Consumers served above 2.3 kV, such as industries, shopping centers and some commercial buildings, with high loads installed in their systems, are classified in Group A, which is subdivided as follows:

- Subgroup A1: 230 kV or more;
- Subgroup A2: 88 a 138 kV;
- Subgroup A3: 69 kV;
- Subgroup A3a: 30 a 44 kV;
- Subgroup A4: 2,3 a 25 kV;
- Subgroup AS: for underground system.

Consumers generally served with 127 V or 220 V, such as homes, shops, residential buildings and federal public buildings, are classified in group B, which is subdivided into:

- Subgroup B1: residential and low income residential;
- Subgroup B2: rural and rural cooperative;
- Subgroup B3: other classes;
- Subgroup B4: Street lighting.

The different types of subgroups are subject to different tax burdens and tariffs on the use and availability of electricity by energy concessionaires. They are also subject to the tariff banners, which characterize a representation in the adjustment of the invoice due to the electric power generation conditions throughout the National Interconnected System (SIN), which is added to the value of the tariff used by each subgroup.

IV. PHOTOVOLTAIC ENERGY

The solar energy is a primary source of energy resources for many other sources, such as hydropower, biomass, wind, fossil fuels and ocean energy. It is also a resource for the heating of fluids and environments, a provider of natural lighting and, when converted, a source of electric energy [12].

The solar irradiation received on the surface of our planet is commonly harnessed from two distinct forms of energy conversion: thermal and photovoltaic. Thermal energy makes use of heating devices, which use such irradiation as a source of combustible heat. Already photovoltaic (PV) energy uses solar radiation for the generation of electric energy through the photovoltaic effect, present in semiconductor devices.

The solar radiation received on the surface of our entire energy radiation from the sun, a portion is reflected by the atmosphere back to space, approximately 30% and the remaining portion is then absorbed by clouds, seas and earth's crust. The portion of radiation that passes through the atmosphere and reaches the crust is decomposed into Normal Direct Irradiation and Diffuse Horizontal Irradiation [13].

In order to take advantage of this incident energy, the presence of an electric field is necessary. To do so, a depletion bed is used, which arises when two semiconductor crystals are joined, one positively doped and one negatively doped [14].

Photovoltaic cells are manufactured with semiconductor material, usually silicon, which has low conductivity. The silicon is then doped, using other elements such as phosphorus and boron, to obtain a negatively charged carrier material (type N), and a material with free positive charges (type P). With the incidence of light on the cell, the photons collide with the electrons and provide them with energy. Due to the effect of the field present at the P-N junction, the electrons are oriented and flow from one layer to the other by external conductors, which connect the two layers, thus generating a flow of electrons [15].

Currently there is generation connected in the network (on-grid) or totally isolated (off-grid). In an on-grid system, the principle is that it is connected to the grid, in other words the photovoltaic system works in tune with the distribution of the electric utility. At the moment that there is more generation than consumption, the bidirectional meter will measure such surplus generation, generating credits that, according to Normative Resolution No. 687, can be used up to 60 months after generation [10].

The solar module generates direct current (DC) energy, but as the main loads are supplied with alternating current (AC), it is necessary to install a power converter. For this, the frequency inverter is used, also responsible for the interconnection between the electric grid and the local distributed generation system.

V. ENERGY FROM BIOGAS

A product of the decomposition of biodegradable organic material, through the action of various populations of bacteria, which can generate energy is biogas. Biogas burning can be an important source of energy and there are technologies to exploit this product.

The energy conversion of biogas to electric energy occurs from the conversion of the chemical energy contained in the biogas molecules into mechanical energy by means of combustion. This mechanical energy is then converted into electric energy with the use of a generator.

For the generation of electricity from biogas, there are three main commercially available technologies: gas turbines, internal combustion engines and microturbines.

VI. METHODOLOGY

For technical and economic analysis, were used the HOMER Micropower Optimizations Model that is a computer software developed by US National Renewable Energy Laboratoy (NREL) to assist in the analysis of DG systems and facilitate the comparison of generation technology through a variety of applications, these will be shown in the study case during the parameterizations of DG data. There are three levels (sensitivity, optimization and simulation) to provide information regarding cost and technical characteristics of generating a system.

These composite models calculate the project with its life cycle cost, that is, its Net Present Value (NPV), which is the total cost of installing and operating the system over its lifetime. Such software also allows the modeler to compare many options of different designs based on their economical technical methods.

For each combinatorial possibility, a simulation is performed, and for each combinatory possibility of the sensitivities another possible analysis is performed, where graphs are provided in the level. In order to show the behavior of the system in the evolution or regression of the values used in the sensitivity and meanwhile, the level of optimization shows the simulation with the lowest cost for each sensitivity factor, in addition to how much energy will be consumed and generated. In addition, the financing will be analyzed, for this will be used the Microsoft Excel, the main data will be explained in the stage of financing during the study case.

VII. STUDY CASE

The study was realized to analyze the technical and economic feasibility of distributed generation connected to the grid in a rural property in the municipality of São Francisco de Assis, being the main generating sources used in the simulation, the photovoltaic energy and generators to biogas. The all property is composed by some different farms. Initially all invoices for the property were required, totaling 2 in low voltage measurement and 5 in medium voltage measurement. However, this study stopped the medium voltage invoices that represent the highest loads and power consumed.

A. Energy data

From the data of energy demand, it is possible to trace the monthly load curve of the property, being as main loads the silos for storage and drying of grains, pumps and irrigation pivot, the main loads are electric motors. To perform this curve, it was necessary a daily sizing of the loads with the technical owners of the property, to be able to be inserted in the software HOMER, being necessary to raise the actual operation of each irrigation pump, of the irrigation pivot and the operation of the silos, presented in Fig. 1.

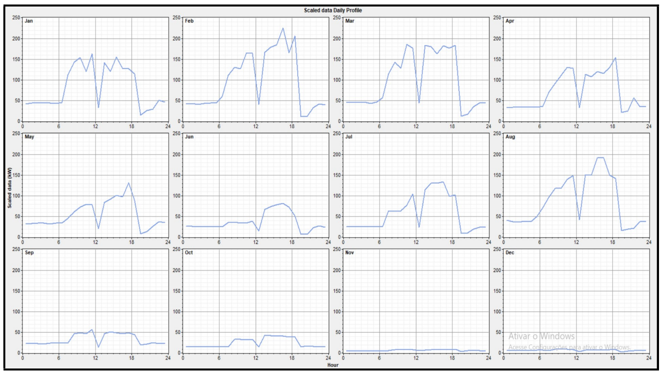

Fig. 1. Monthly load curve of rural property

For simulation levels in the HOMER software it is necessary to indicate the parameters to be analyzed and validated. For this purpose, a 20-year horizon study with an interest rate of 8% per year is used to approximate to the maximum the current reality of the installation of systems with distributed generation in the Rio Grande do Sul.

Based on this information, the forecast of this study was already unfavorable initially for presenting this tariff advantage, but the simulation was done to make this project viable. According to Fig. 2, the simulated values were from the prospecting period, noting that currently this figure is 22% higher, due to a current adjustment carried out by power utility Rio Grande Energia Sul (RGE Sul). The type of tariff is rural green and rural green for irrigation , but both have the same tariffs, with contracting fixed demand and peak hours (18 hours at 21:00 hours) and hourly out-of-point values, other hours of the day, where energy consumption is lower.

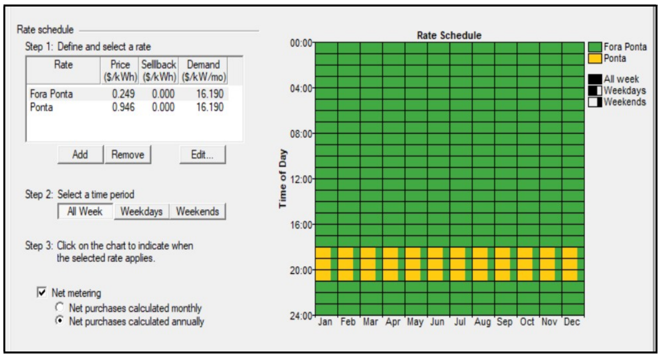

Fig. 2. Tariff values presented in the electricity bill

B. Implementation of DG

For modeling the solar simulation it is necessary to indicate with precision the place to be analyzed, for solar radiation levels and local temperatures, as they are crucial factors in the design of photovoltaic systems, the main source of generation studied. A simulation with biogas generators was also realized at the end of this case study, to cover all the possibilities of sustainable distributed generations in this property.

First, it is necessary to survey the exact coordinates of the property, which is then inserted in the HOMER for simulation. The irradiation values are downloaded and actualized via internet, according to the software database. These values are presented in Fig. 3 in graphical form, where it is easy to understand the variations due to the seasons of the year for central-western region of the Rio Grande do Sul.

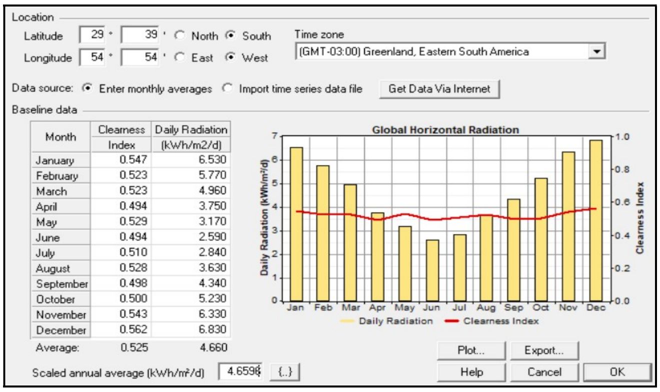

Fig. 3. Solar irradiation data

Another factor of great impact in generation systems by photovoltaic modules is the local temperature where such systems must be installed. For this, the database of the Rio Grandense Rice Institute (IRGA) was used as reference, because it is through this data that many farmers decide their harvest period and off-season [16].

With all parameters defined and inserted correctly in the HOMER software, it is possible to calculate the photovoltaic system, considering the modules are fixed, that is, its power to be installed and its final NPV for each study. The simulation allows us to find the best possible scenario in terms of future investments or if the best option is to continue to be fed by RGE Sul's electricity grid.

For simulation level, it is necessary to stipulate the power of the solar modules and frequency inverters to be designed, according to the power of the system measured by the analysis of the electric bills. For this project the software rated a peak power average of the system of 350kW. Based on this power, it is possible to calculate the number of modules, power of frequency inverters, due to several tests that arrive in this value.

The equipment and materials of the photovoltaic modules are manufactured by Canadian Solar and are guaranteed against manufacturing defects for ten years. The life of the modules is at least 25 years. During the first 20 years of operation, the power generated will not be less than 80% of its rated power, having as Life Time Value (LTV), over 30 years. Parameters of the subtilized photovoltaic modules are shown in Fig. 4.

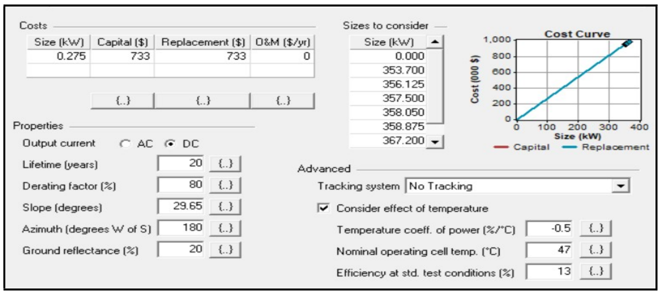

Fig. 4. Parameters of the solar modules

For higher power systems installed in plants, for example, frequency inverters manufactured by Sungrow are used that are guaranteed against manufacturing defects for a period of five years. The lifespan of the inverters is 10 to 12 years. 60kW and 125kW inverters are the highest power units manufactured by Sungrow. These work in overloading up to 35% of their nominal value, because of this, was made this choice for precision simulation of values and equipment that are used worldwide in the largest solar plants and in high power generation systems. Parameters of the frequency inverters used are shown in Fig. 5.

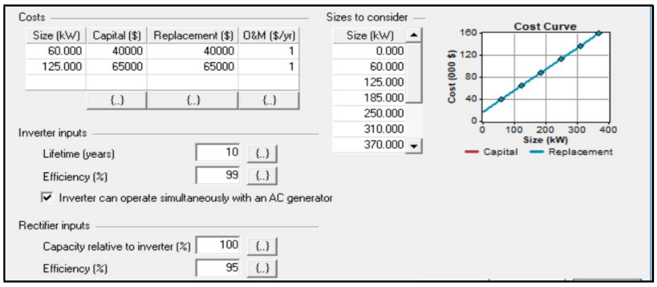

Fig. 5. Parameters of frequency inverters

Therefore, it is also necessary for the simulation level to stipulate the power of the generators, of the biogas generating biomass, however, the parameters of the solar modules and the frequency inverters were taken from the previous study. With an average peak power of the already dimensioned system of 350kW, it is possible to calculate the power and estimate the power of the biogenerator with reference to the portfolio of PROBIOGÁS [17].

The Fig. 6 presents the parameters of the biogas generator for simulation levels, as well as the generation power ranges based on 50kW. The equipment and materials are manufactured by the company CHP Brazil and are guaranteed against manufacturing defects for a period of one year.

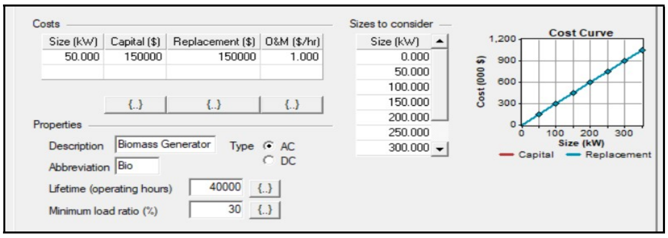

Fig. 6. Parameters of biogenerators

To stipulate the supply of raw materials for biogas generation, together with the owner of the rural property, the amount that could be produced and the structure for production were studied, which left this study only for comparison with the best case only with solar generation, for use this there is a demand of physical and personal structure. With this in view, the parameters measured for daily production, arriving at an estimate of 0.33 tons per day, due to a confinement of livestock existing in the property, however deactivated at the moment.

C. Results

The first analysis of results is measured from the simulation in the HOMER, which brings as final result the economic index NPV with total payment of the system at the moment of installation of the system to the network. But because it is a high value, this study presents a second analysis in Excel, with the system financed 48 times in the most attractive investment banks of the region in (This will be presented in the next topic), with the purpose of analyzing the NPV for this system in two different and more distinct ways and more realistic. Will be considered two scenarios, the first only with PV system the second with PV and biogas, this because of the interest of the owner of the property.

In a first scenario is considered only the DG through photovoltaic. With all parameters inserted in the HOMER, 343 hypotheses were simulated for this case, bringing the best results in terms of NPV of the photovoltaic system and without any connected distributed generation system, only the RGE Sul network currently connected, according to the Fig. 7.

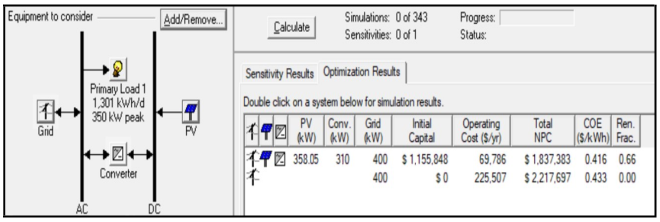

Fig. 7. Simulated result with PV only

Therefore, for this fare modality, the best option is the combination of solar modules with power of 358.05 kW and 310 kW of power of the arrangement of frequency inverters, connected to the electric grid. In Fig. 8 it is possible to visualize the cost summary for this system over the 20 years, resulting in the value of its NPV of R$ 1,837,833.00.

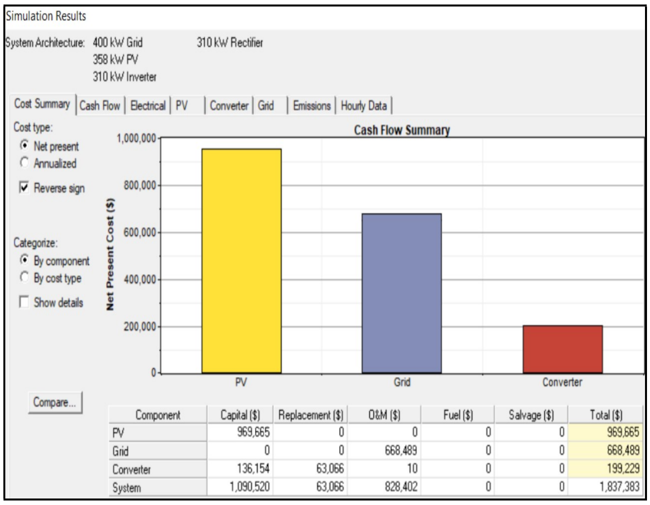

Fig. 8. Stratified costs of the best solution

In a second scenario will be considered the generation of electricity with biogas. With all parameters inserted in the HOMER, 2352 hypotheses were simulated, bringing the best results only with biogenerator, only with photovoltaic system, with both generations in the system and without any distributed generation system connected, only the RGE Sul network currently connected, according to with Fig. 9.

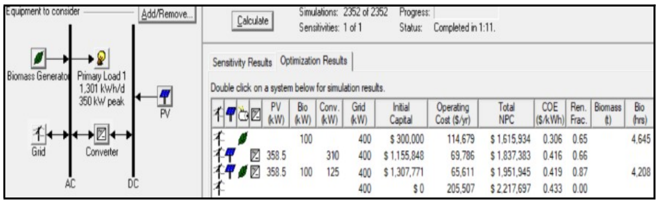

Fig. 9. Results of simuleted case with PV and biogenerator

This modeling was only for the purpose of comparing the NPV with the photovoltaic system financed, because the difficulty of installing and operating a biomass system would require energy and a new logistics in the property not feasible at present, due to the fact that there is no structure and system ready for this generation. Therefore this study was not further developed for these reasons and because it's NPV is higher than the NPV of the photovoltaic system financed.

D. Financing

For purposes of refinement of this study, we searched the best financing rates and banks to make this investment more attractive and improve the NPV for this system. Once the research was realized and verified with the owner of the rural property, the bank chosen for this analysis was SICREDI, since this came at a rate of 1.5% per month along with the bank, but "Banco do Brasil" has agribusiness financing of 8% per year, which would be the best case, however, "SICREDI" opted for the credit facility.

The new NPV was calculated with the parameters presented in the HOMER simulation, that is, with the annual contracted demand of the grid of R $ 69,786.00 and the PV system, with solar modules, frequency inverters and installation, the value of R $ 1,155,848.00 with 100% of the amount of the system to be financed 48 times (4 years), which reduces the NPV economic index, the cash flow is presented in Fig. 10.

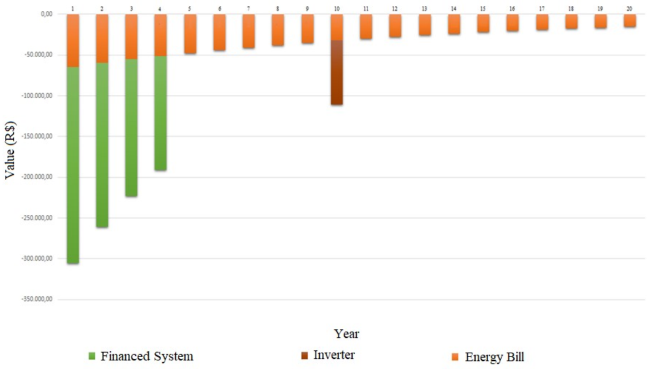

Fig. 10. Cash flow with financing

VIII. CONCLUSIONS

At the end of the simulations and in this study it is possible to reach very satisfactory results for the insertion of distributed generation in the agribusiness, mainly for the photovoltaic energy that is up for its efficiency, easy installation, agile operation and by the increasing reduction of its cost. It was possible to reach a NPV of the electric grid, having as parameter the RGE Sul concessionaire, within the presented scenario of 20 years and with an average inflation of 8% per year in electricity, totaling a NPV of R$ 2,217,697.00.

From the first simulation, with the photovoltaic system paid at the time of installation NPV is R$ 1,837,383.00, which already presents an economic advantage in relation to a system only connected and fed by the concessionaire of R$ 380,314.00 bringing to net present value. However, when analyzed in terms of funding, this same photovoltaic system with a high rate, the NPV reduces further to the value of R$ 1,511,958.06, presenting the best economic advantage of R$ 705,738.94 when compared to the current system. Although, this values shows the feasibility technical and economic of distributed generations in agribusiness.

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