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Modeling Of An Stand Alone Photovoltaic Solar Power Plant 120kw, Case Of Mahavelona (Rural Area)

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Abstract—Madagascar's economic situation is linked to the productivity of the rural population, which constitutes 80% of the population. One of the obstacles that hinders their growth is the lack of a sustainable source of energy. The exploitation of solar energy that Madagascar has enormously more than 2800h / year of sunshine will certainly contribute to the socio-economic development of the population. Our study area is located in the rural commune of Mahavelona, district Soavinandriana. This work aims to have an optimized model of an autonomous power plant by photovoltaic solar system. The results obtained with this first will be duplicated at the four other sites which are still in the same district. Its concretization requires passing through holistic studies in a photovoltaic production plant and heuristic studies on the modeling of the inclination and its effect on electricity production. Precised and repeated measurements on the installation site were done for the development of the database necessary for this research. Measurements at four angles of inclination 15°, 20°, 25° and 30° using a pyranometer were carried out. The datas obtained were analyzed and simulated using MATLAB and Excel. The results showed that: first, the inclination and orientation of the solar panel must be precise and vary according to the season for optimal electricity production. The following inclinations must be respected: 15° for the month of September until the end of March and 30° from the month of April until the end of August. Compared to fixed tilt, this change in tilt angle will save 128 MWh during the contract period.

Keywords – Photovoltaic solar, autonomous system, Matlab, socio-economic development, Mahavelona.

I. INTRODUCTION

To have a sustainable development in Madagascar, it is judicious to see in all sides how to deal with the problem of the peasants and to increase their standard of living, because the economy of a country, the basic needs, the raw materials used for the production industry come from there [1]. One of these key points is to give them access to a source of electrical energy. Indeed, this has an impact on their productivity and obviously on their well-being. Compared to other energy resources, the exploitation of solar energy is very advantageous if we take into account the preliminary study which does not require much time compared to the case of hydroelectricity which requires three to five years. [2], Solar system is easy to install in a fixed duration with less maintenance and less risk to the infrastructure. In addition, Madagascar has enormous potential as a source of solar energy with more than 2800 hours/year [3], everywhere on the island [4], but the problem lies in the sustainability and promotion of this sector. autonomous photovoltaic solar energy for rural areas in Madagascar.

The study was focused on a pilot site in the rural commune of Mahavelona located in the district of Soavinandriana, in the Itasy region of Madagascar. From the design of the project to its completion, the data used were obtained from the reality experienced in situ. The study lasted two years from June 2020 to September 2022. The project is currently in the operational phase. Several literatures have shown the advantage and efficiency of lithium batteries compared to gel and liquid [5][6]. Thus, to justify the choice of a technology opted to perpetuate a power plant by autonomous photovoltaic system, we bet on the points which have a more important factor in the production of which the orientation, the choice of the quality and the panel technology, the choice of battery charger-inverter system and finally battery technology. The present manuscript aims to model an autonomous electricity production plant by photovoltaic solar panels through the results of this research work and while subsequently modeling the optimal inclination according to the season.

II. MATERIALS AND METHODS

2.1. Presentation of the study area

The application site and the database used for this study were obtained within the rural commune of Mahavelona located in the district of Soavinandriana, Itasy Region, country Madagascar. Located in the western part of the Itasy region, the municipality of Mahavelona is bounded: to the east by the municipalities of Mananasy and Amberomanga; to the south by Ankisabe; to the west, by the municipality of Ambatoasana center. Geographically, Mahavelona is located at the coordinates:

Latitude: 19°10'14.15" South, Longitude: 46°31'20.81" East.

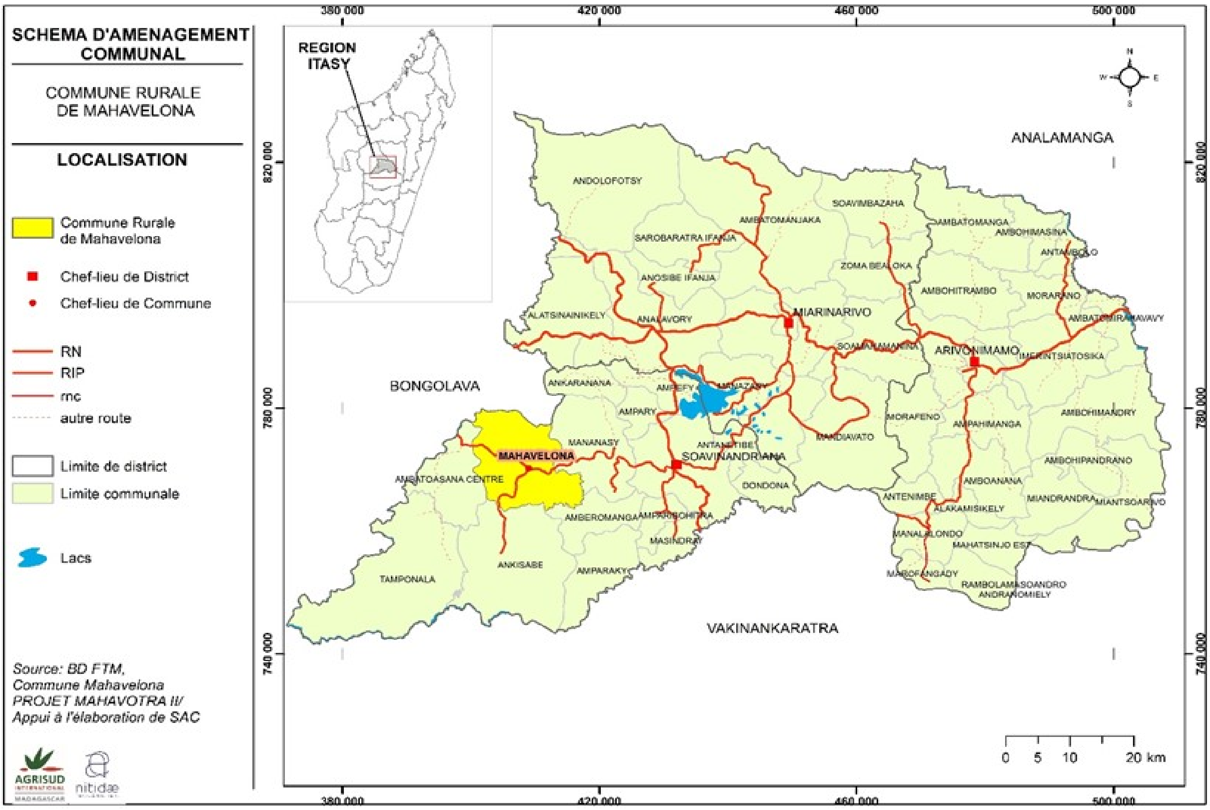

Fig. 1. Geographical position of municipality of Mahavelona [7]

2.2. Datas collection

We used a digital tool to do the surveys, it is the KoBoCollect smartphone application which is an open source collect application from getODK and is used for the collection of primary data according to the information in a pre-established form on an account. of Kobotoolbox which is the tool for compiling all the data collected via the application. The interest of this application is the possibility of quickly acquiring the overview and summary of the main lines of the established survey, the classification curves and also of identifying the position of the customers surveyed that can be exported to map such as google maps and google earth [8]. It is important to frame the different investigative activities for data collection. The data obtained were processed in Microsoft Excel. Then, these processed data were transferred to Matlab for the database, particularly the load curve used, which is the pricing basis to be paid for future electricity users. For the radiation measurement, we used the TES 132 pyrometer which measures and records the solar radiation on the installation site.

Models have been made for each stage of a production plant installation simultaneously with the essential components and materials. We also modeled subscribers with different types of capacitive, resistive and inductive (RLC) loads. We validated one by one all the influential parameters in each process and component of a solar power plant, from installation to consumption within households. Figure 2 below shows the block diagram adopted for this work.

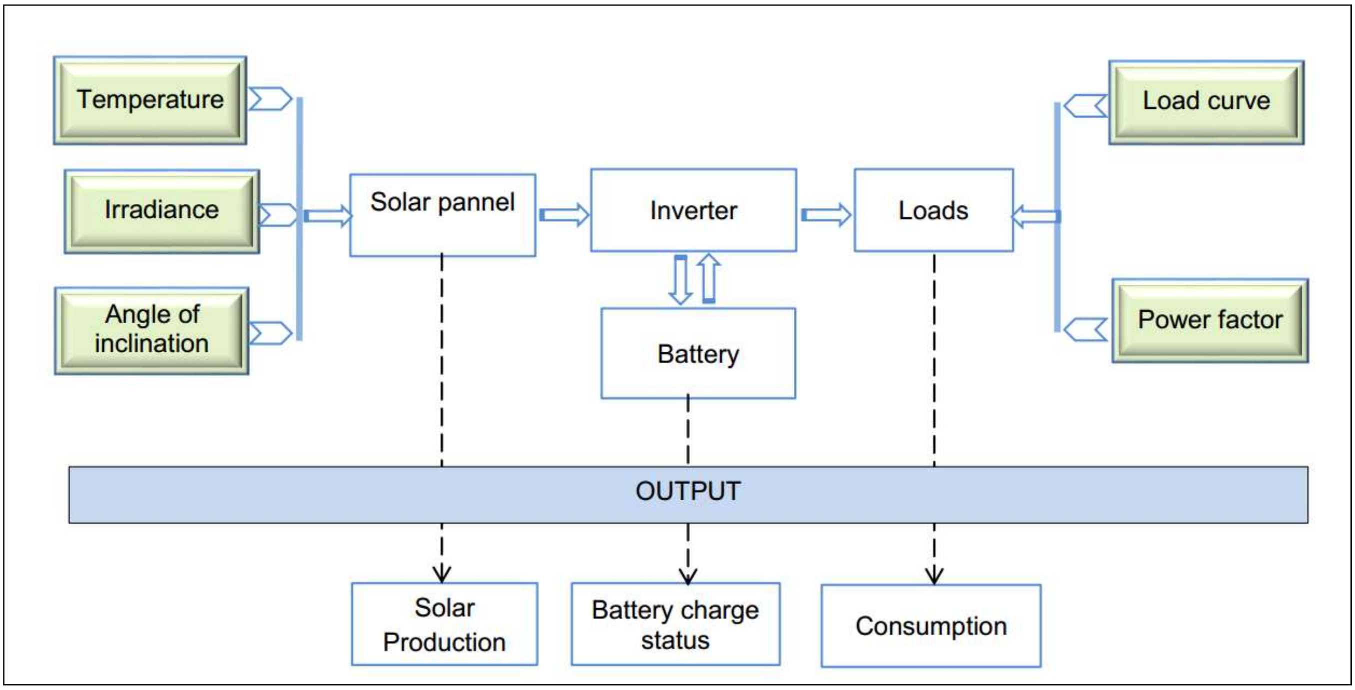

Fig. 2. Block diagram adopted for the modeling of an autonomous photovoltaic solar power plant

In order to see the real behavior of the decorticator machines which are the major consumers, we chose two among the existing eleven. In addition to households, public and private institutions, there are three metalwork workshops considered in the simulation. Its hourly consumption is entered as input data in Simulink. The overview of this need is shown in Figure 3 below.

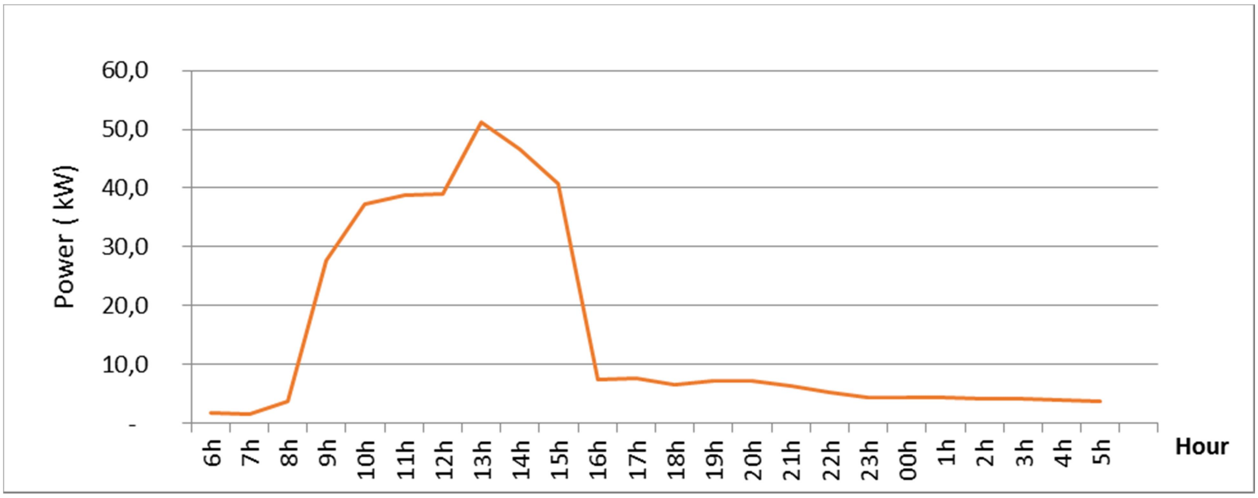

Fig. 3. Load curve used for the simulation

Then this load curve was integrated into simulink in Matlab as load. First, we modeled the inclination of the solar collectors and the solar radiation using the r.sun model [9]. This sub-block is then used as input in the 120 kWp solar panel block. A boost converter is installed to connect the output of the latter with the battery and the inverter. Then, the inverter takes over and transmits it to the user. This modeling is represented in figure 4 below.

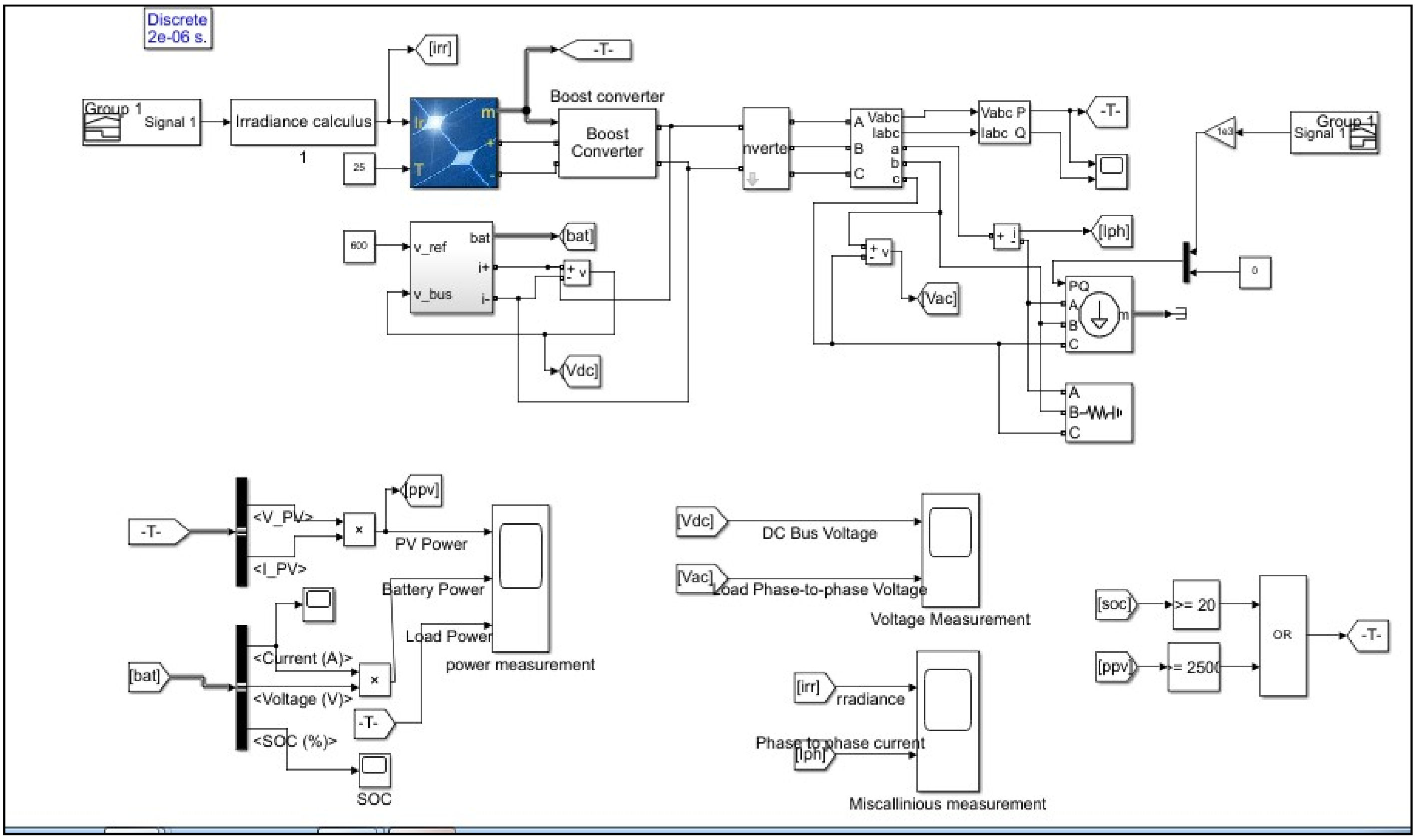

Fig. 4. Modeling diagram of an autonomous photovoltaic production plant 120kWp- under Simulink Matlab

III. RESULTS AND DISCUSSION

For this research work, which will be the basis for export to the other four sites, we have determined and analyzed the parameters for maximum electrical energy production by using modeling of the production system and solar radiation.

3.1. Most profitable tilt angle

The parameters most influencing in the production are the inclination of the solar pannel, the technology of the solar panels, the technology and the quality of the batteries. Production also varies according to the season which is not controllable, but production can be optimized. The curve mentioned in figure 5 shows the monthly production according to the season and according to the different angles chosen, which varies from 15° to 30°.

Because the position of the sun changes during the year depending on the season. The result obtained shows us an increase in production by changing the orientation twice a year by 15° for the month of September until the end of March and 30° from the month of April until the end of August. For a fixed installation, we can choose between 20° and 25°. Therefore 20° is more profitable than 25° throughout the season, because between January and March there is a high demand for electricity in the area, hence the choice of the 20° inclination for this installation. In the future after demand saturation (in 5 years) it makes sense to apply this change in inclination twice a year. The system of metal fixings of the installed solar panels already allows this modification. The structure of the panels has holes to choose from (16 choices), to adjust the desired inclination according to the season. With this optimization, there is an overproduction of 128 MWh during the duration of the contract which is 25 years or equivalent to 217,000,000 Ariary compared to the fixed system.

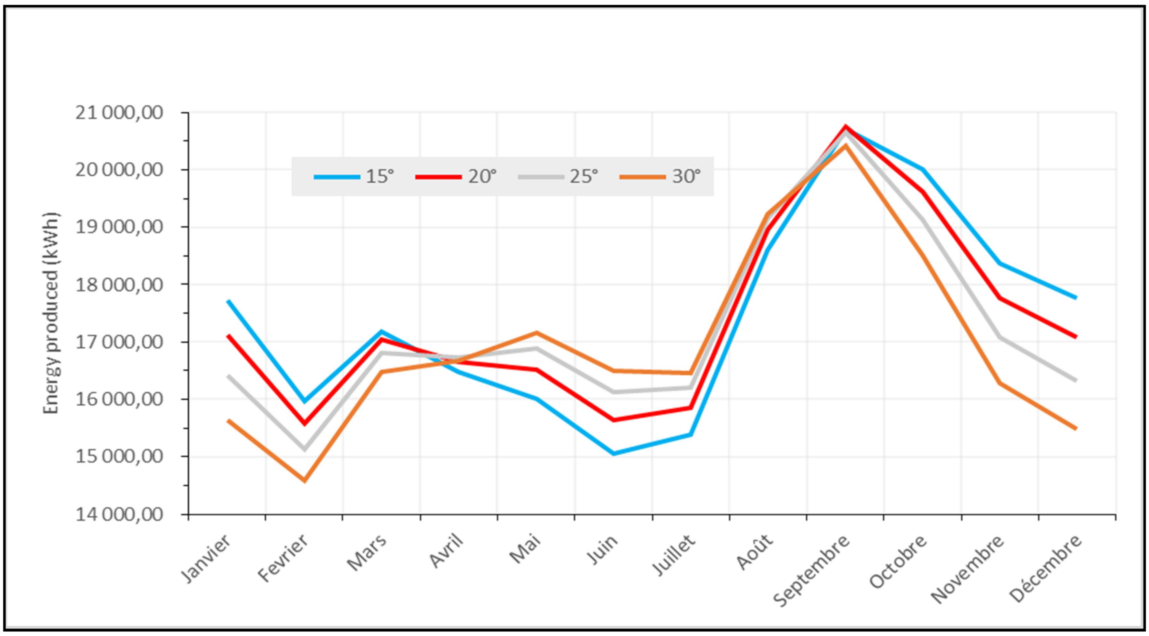

Fig. 5. Monthly production on different tilt angle

3.2. Measurement of solar radiation according to tilt angle

To compare the theoretical results with reality, we took solar radiation measurements in February, June and September 2022, which are the key months for the study area. The results obtained are shown in Figure 6 below.

These measurements showed that the optimal inclination of the months of September and February is 15° and 30° for the month of June. A particularity for the case of 15° in February and September, it is a little exceeded in the afternoon, but in total for the day it is advantageous.

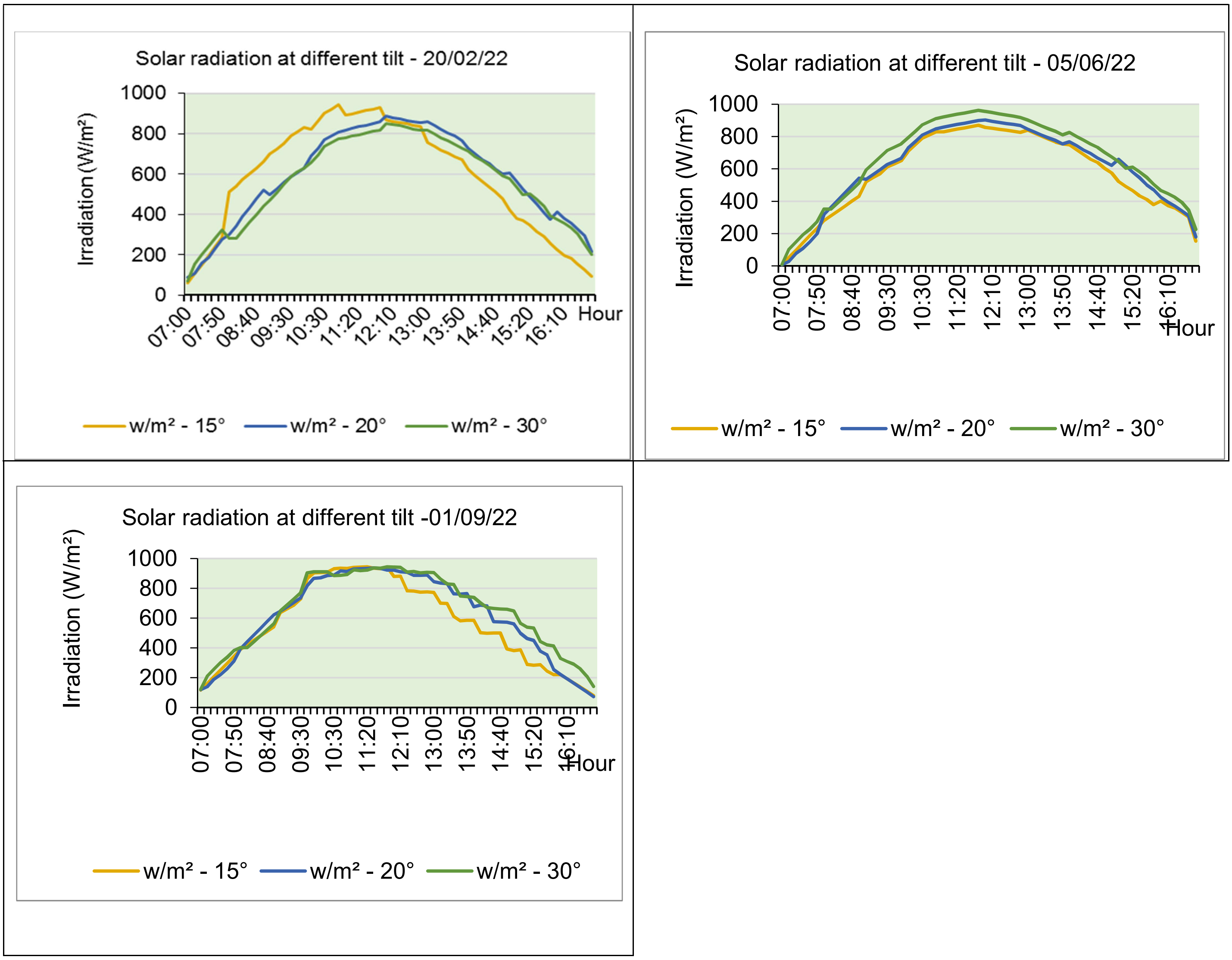

Fig. 6. Solar irradiation of February, June and September according to the tilt angle

IV. Conclusion

The interest of this research lies in the fact that the modeling of a photovoltaic solar power plant allows us to determine the influence of the inclination of solar panels on the production of the power plant. The results of this research will be exported to the four other sites which are currently in the study validation phase. The results from the virtual simulation have been validated and verified experimentally in the field. Indeed, for optimization, we found two optimal inclination angles, 15° from September until the end of March and 30° from April until the end of August. This tilt angle modification option is significant as soon as the load inrush saturation is reached, which will be scheduled for year 5 (i.e. in 2027). This option gives a saving of 128 MWh compared to fixed orientation and tilt. So far, two months into operation, the plant data, particularly for the solar field is working as expected in this study. The use of solar tracker is an interesting option to further optimize this installation, but it requires much more budgets at the start.

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