Improvement of thermal performance on PV inverter rooms under high solar irradiation desert conditions

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Abstract

The harsh conditions of the Atacama Desert have been shown to affect both PV performance and lifetime of mechanical and electronic systems. In this sense, inverters inside containers have been the configuration that has presented the highest number of failures by excess temperature. In order to analyze this problem, a simulation of a real PV plant installed in the Atacama Desert and the specific modelling of the inverter rooms inside containers were done. Five cases were evaluated to study and mitigate the excess temperature inside the inverters room. An adequate combination of ventilation and cooling proved to be the best solution in a condition of high irradiation. On the contrary, in a range of medium-low irradiation, ventilation of the inverter rooms is enough to reach the maximum production of the PV plant.

Keywords: PV inverter rooms, ventilation, Atacama Desert, TRNSYS.

1. Introduction

Chile had an exponential growth in solar energy uses in recent years, particularly photovoltaic (PV) technologies. The PV capacity increased from 2 MW operating at the end of 2012, to 2,306 MW operating in February 2019 (CNE, 2019). Favorable market conditions for new investors and the exceptional solar resource are two of the key points to understand this development. The most favorable location for the development of solar energy is the Atacama Desert, where a yearly total over 2,500 kWh/m2 of Global Horizontal Irradiation (GHI) can be reached, according to that, in central and northern Chile there is a great potential for the utilization of solar energy technologies (Escobar et al., 2015). Nevertheless, the performance of PV technologies is affected by desert conditions like high temperatures and ultraviolet (UV) irradiation, deposition of dust, etc. (Zurita et al., 2018). These conditions also affect the operation and reduce the lifetime of mechanical and electronic systems. A main component of solar PV plants is the inverter, which has already shown failures by being exposed to Atacama Desert conditions (Encare & Energia 360, 2017).

Inverters are considered one of the most critical components at PV plants. There are many factors that could affect its performance, such as wrong placing of the inverters into the plant, internal failures or operating with high temperature, which implies low efficiency operation or having to turn off the systems (Gallardo-Saavedra et al., 2019).

Inverters inside containers has been demonstrated to be the configuration with most failures by excess temperature. Each failure means a partial operation of the inverter and therefore less electricity generation from the PV plant. This configuration is designed to protect the inverters from humidity due to rainfall or other environmental factors, it is not appropriated for Atacama Desert conditions, due to the scare rainfall at this location the water protection is not needed, and the inverters room is heated by the high solar irradiation. In this study, several options are evaluated in order to reduce and control the temperature inside each inverters room.

Considering the fast PV growth in the Atacama Desert, it is useful to know the best way to mitigate the high temperature troubles in inverters inside containers. This work studies the most effective solutions to control the temperature inside the inverters room, using active or passive systems, comparing it and finding the optimum combination that allows avoiding the problems in electricity generation for the inverters due to overheating in terms of operating with derating power or turning off the inverters. Moreover, the results of this work can become

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a guideline when the use of batteries increases, if they are placed inside containers.

2. Methodology

The PV plant selected for this study is Finis Terrae Plant, property of Enel Green Power, which uses inverter rooms from the Italian company FIMER. This PV plant is composed of 516,135 PV modules of 310 Wp each one, with an one axis tracking system with east-west orientation, and 220 inverters R7500TL from FIMER. The total installed power of the plant is 160 MWp. The effective power of the plant, according to its ambient impact declaration, is 145 MW due to energetic losses of approximately 10%, which are produced during the process of conversion from solar irradiation to electricity. These losses mainly correspond to DC transmission, diodes and connections, PV modules maladjustment, PV modules temperature, inverters efficiency and AC transmission.

In order to realize performance improvements in inverter rooms, different scenarios are studied. The methodology used in this study considers a characterization of the operational conditions for PV inverter rooms at Atacama Desert. The operational conditions consider the ambient temperature profile during the year at the location of the PV plant, the relative humidity, and mainly the solar irradiation profile. Also, is considered in the physical modeling of the system, the sizing and material of the components inside the room, the material of the walls and the air inside the room. These values are important to characterize and model properly the situation and develop computational simulations in TRNSYS software to evaluate the base case scenario and a series of potential solutions proposed.

First, the Finis Terrae plant was modelled. For its modeling and simulation the following values were considered: energetic loss of 8% at the DC line, an inverter efficiency of 98.62% and 1% of energetic losses at AC line. This values are typically used in PV plants simulation software such as SAM and PVSyst. Energetic losses due to soiling at the PV modules and shading between modules were not considered.

The R7500TL FIMER inverters are installed inside the MS3000 FIMER inverter room, which are shown at Fig. 1. This model of inverter has a control system, which protects the inverters from overheating. The control system can apply power derating or turning off the inverters if it is needed. The control scheme was taken from a technical visit to the PV plant. The control depends on the air temperature inside the inverters room. If it is below 50 °C the inverters work at full capacity. When the temperature rises to a level between 50 and 55 °C the control system applies a linear power derating, going from 100% to 60% of the inverter capacities. Finally, when the air temperature exceeds 55 °C the inverters are turned off. Using this control scheme, the energy losses in the main components of the PV plant, and an input of solar resource data, is calculated the electricity production of the plant. The Fig. 2 shows the control logic described for the operation of the inverters, relating the maximum power capacity of the system with the air temperature inside the room.

Fig. 1: FIMER MS3000 Inverters room, inside it contains four FIMER R7500TL inverters.

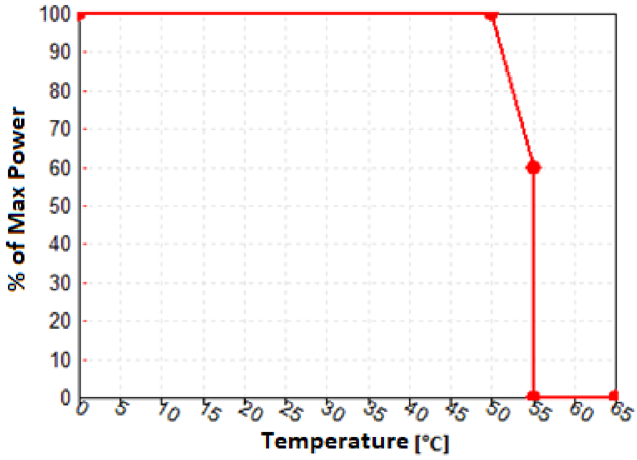

Fig. 2: Derating of the inverters due to air temperature inside the inverters room.

The location selected to perform the simulations is Crucero in northern Chile (Crucero, Lat 22.20 °S and Lon 69.29 °W, Global Horizontal Irradiation (GHI) 2,595 kWh/m2-yr) with an elevation of 1,146 meters above mean sea level (MAMSL). The selection of this site is due to it is located nearby to Finis Terrae plant, about 30km of distance, and for its similar solar irradiation and climatic conditions, furthermore its solar resource data in a TMY3 was validated with a solarimetric station. It is worth to mention, that at these conditions, there is no derating power at the inverters due to elevation above mean sea level. Monthly GHI values of this location are shown at the Fig. 3.

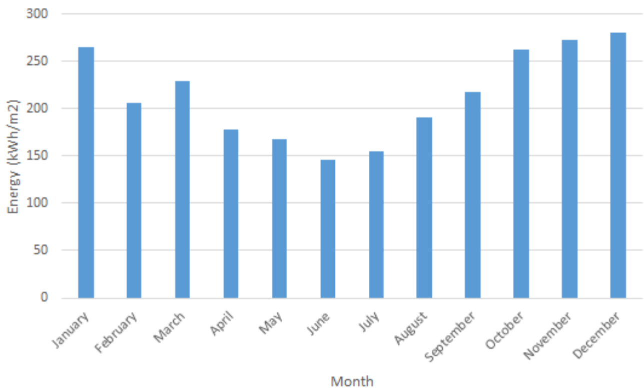

Fig. 3: Monthly GHI at Crucero.

Five cases were defined to be modelled and simulated, these cases represent different scenarios for the inverters room, presenting the base case scenario and possible solutions to the overheating inside the room, avoiding the power derating from the inverters. The cases are listed below:

- Case 1, Base case scenario: This case corresponds to the base case, which models the PV plant considering only energetic losses due to the inverter efficiency, without considering any kind of derating power due to temperature. This case represents the theoretical maximum electricity generation of the plant.
- Case 2, Inverters room without ventilation: This case models a theoretical scenario where the inverters room is sealed without ventilation, to obtain the theoretical maximum temperature inside the room due to the thermal power from the inverters and the solar irradiation.
- Case 3, Thermal case: This scenario evaluates the first proposed solution to the overheating problem inside the room, this solution consists in a thermal case installed inside the room, in its walls, composed by a phase change material (PCM) as a possible solution to avoid high temperatures inside the inverters room.
- Case 4, Room with ventilation: This scenario is other proposed solution to solve the overheating problem. This model considers the incorporation of different filtered air mass flow rates, to extract part of the heat inside the room.

- Case 5, Room with ventilation and cooling: This scenario consists into a solution utilizing the same design from the model of the Case 4, but adding a pre-chamber to cool the inlet air.

For the Cases 4 and 5, which considers ventilation as part of the solution, a parametric analysis was performed, considering it with different air mass flow rates through the room. The minimum ventilation conditions that allow to avoid the power derating problems due to temperature were searched. The same parametric analysis was performed to evaluate different air cooling temperatures in the pre-chamber that enters to the room.

All the models evaluate an inverters room composed by 4 inverters with dimensions of 0.82 m long, 2.23 m tall and 1.99 m width each one. The dimensions of the room are 2.47 m long, 2.59 m tall and 9 m width. The models consider a balance of mass and energy to evaluate the thermodynamic behavior inside the room. These balances consider the heat provided by the inverters inside the room, the heat from the solar irradiation in the outside walls of the room, and the heat from convection processes at the internal and external walls of the room. In addition, the models that utilized ventilation consider the effect of the mass flow rate in both balances impacting the temperature of the air inside the room and the balance of mass for the system.

When a PCM case inside the inverter rooms is considered, the heat transfer process changes for the internal wall of the room. In this model, the rise of the wall temperature considers a phase change process, starting with solid material, then at 25 °C this material begins to melt and when it is totally melted the liquid material begins to rise its temperature.

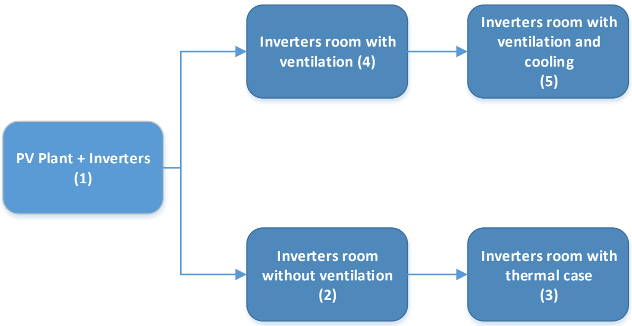

Fig. 4: Five cases defined to be modelled and simulated.

The detailed methodology applied in each case is explained below, considering the development of each mathematical model, and diagrams of each scenario.

2.1 Case 1: Base Case Scenario, PV Plant and Inverters

As mentioned before this case considers the electricity production of the plant only considering the efficiency of the inverters, without taking in account the overheating problems that cause derating in the inverters. This case defines the maximum theoretical electricity production that can achieve the PV plant. In this simulation, the plant is modelled and simulated in TRNSYS software to obtain the annual electricity production, comparing its value to the design conditions, and to the value reported to the National Electricity Coordinator (CEN).

2.2 Case 2: Inverters room without ventilation

In this case, the model developed considers an energy balance over a control volume of air with the inverters room inside dimensions, and another energy balance regarding the walls of the room to consider internal and external convection, and its effect above the internal air temperature. The equations that represent this balance are presented below.

$$c_{air} \cdot \frac{\partial T_{air}}{\partial t} = \dot{Q_{Inv}} - \dot{Q_{ConvIN}} \qquad \text{(eq. 1)}$$

$$c_{wall} \cdot \frac{\partial T_{wall}}{\partial t} = \dot{Q_{Sun}} + \dot{Q_{ConvIN}} - \dot{Q_{ConvEX}} \qquad \text{(eq. 2)}$$

C_{air} corresponds to the thermal capacitance of the air, this value is calculated in the next equation.

$$c_{air} = m_{air}\, cp_{air} \qquad \text{(eq. 3)}$$

m_{air} corresponds to the mass of air inside the room, cp_{air} is its specific heat. On the other hand, $\dot{Q_{inv}}$ is the heat transfer from the four inverters inside the room and it is calculated according to the inverters efficiency as follow:

$$\dot{Q_{Inv}} = \sum_{i=1}^{4} \dot{Q_{Inverter_i}} \quad \text{(eq. 4)}$$

Regarding $\dot{Q_{sun}}$, this value corresponds to the heat transferred from the solar irradiation to the room, and it is calculated as the sum of the solar irradiation received in each external wall of the room, multiplied for its respective area and for an absorptance coefficient which is defined with a value of 0.3.

$$\dot{Q_{Sun}} = \sum_{i=1}^{4} \dot{Q_{Solar_i}} \quad \text{(eq. 5)}$$

Only four external walls of the inverters room are affected by the solar irradiation, because there is an auxiliary services room at one of the sides of the inverters room, for this reason this side is not exposed directly to the sun. It is assumed that there is not a thermal resistance due to the wall thickness, because the metal is an excellent thermal conductor. Additionally, it is considered the thermal capacitance of the wall, which is calculated with the equation presented below.

$$c_{wall} = m_{wall}\, cp_{steel} \quad \text{(eq. 6)}$$

Where m_{wall} is the mass for the walls of the inverters room, and cp_{steel} corresponds to the specific heat for the steel. Regarding the external convection, $\dot{Q_{convEX}}$ corresponds to the heat transferred to the ambient from the room. It is assumed that there are 5 walls with external convection, due to is assumed that the auxiliary services room is at ambient temperature, for that reason there is thermal transference between the rooms. In addition, in all cases is considered that there is not heat transference with the floor. The external convection is calculated by the next equation.

$$\dot{Q_{ConvEX}} = \sum_{i=1}^{5} \dot{Q_{ConvetionEX_i}} \quad \text{(eq. 7)}$$

$\dot{Q_{convectionEx_i}}$ is the heat dissipated for each wall, and is calculated with the following equation.

$$\dot{Q_{ConvectionEX_i}} = h_2 A (T_{air} - T_{amb}) \quad \text{(eq. 8)}$$

T_{amb} corresponds to the ambient temperature, A represents the area of each specific wall and h_2 corresponds to the external convection coefficient for each face, which depends of its geometric specifications. h_2 is calculated in the following equation.

$$h_2 = \frac{Nu\, k}{L} \quad \text{(eq. 9)}$$

Where Nu corresponds to the Nusselt number, which is obtained from correlations, k is the air conductivity at film temperature, which is the mean temperature between the ambient temperature and the temperature inside the room, and L is a characteristic longitude. There are two configurations to model the walls, one corresponds to a flat plate vertically oriented with uniform temperature, which applies to the vertical walls of the room, and the other one corresponds to a flat plate horizontally oriented with uniform temperature, which corresponds to the roof of the room.

The correlation utilized for the flat plate vertically oriented with uniform temperature, assuming natural convection, and uses as characteristic longitude the height of the wall, is presented below.

$$Nu = \begin{cases} 0{,}59 (R_a)^{\frac{1}{4}} & 10^4 < R_a < 10^9 \\ 0{,}1 (R_a)^{\frac{1}{3}} & 10^9 < R_a < 10^{13} \end{cases} \quad \text{(eq. 10)}$$

In that correlation R_a corresponds to the dimensionless Rayleigh number. On the other hand, the correlation utilized for the flat plate horizontally oriented with uniform temperature, assuming natural convection, which uses as characteristic longitude the value $\frac{Area}{Perimeter}$, is presented below.

$$Nu = \begin{cases} 0{,}54(R_a)^{\frac{1}{4}} & 10^4 < R_a < 10^7 \\ 0{,}15(R_a)^{\frac{1}{3}} & 10^7 < R_a < 10^{11} \end{cases} \quad \text{(eq. 11)}$$

When the wind velocity is above 0 m/s, it is considered forced convection externally. In this case two correlations are utilized to obtain the Nusselt number, which depend on the dimensionless Reynolds number (R_e), which determinates if the wind flow must be considered laminar or turbulent. Also, is included in both correlations the dimensionless Prandtl number (P_r). These correlations are presented below, defining the Polhausen correlation for laminar flow at Equation 12, and the Colburn correlation for turbulent flow at Equation 13.

$$Nu = 2\ (0{,}332\ Pr^{1/3} Re^{1/2}) \quad \text{(eq. 12)}$$
$$Nu = (0{,}037 Re^{4/5} - 871)\ Pr^{1/3} \quad \text{(eq. 13)}$$

The characteristic longitude in this case corresponds to the distance traveled for the wind in each wall. As the wind can flows from different directions, this affects in how the wind faces the room, therefore, it has been pondered the effect that the wind flows in east-west direction and it flows in north-south direction.

On the other hand, regarding the internal convection $\dot{Q}_{convIN}$, this value corresponds to the heat dissipated from the air inside the room to the walls, represented with the following equation.

$$\dot{Q}_{ConvIN} = \sum_{i=!}^{5} \dot{Q}_{ConvectionIN_i} \quad \text{(eq. 14)}$$

Where $\dot{Q}_{convectionIN_i}$ corresponds to the heat dissipated for each wall and it is calculated with the following equation.

$$\dot{Q}_{ConvectionIN_i} = h_1 A (T_{air} - T_{wall}) \quad \text{(eq. 15)}$$

A represents the area of each specific wall, h_1 corresponds to the internal convection coefficient for each face, which depends of its geometric specifications, h_1 is calculated using the same equations used to calculate h_2. To model the walls of the room was utilized the same focus, analyzing two options, a flat plate vertically oriented with uniform temperature, and a flat plate horizontally oriented with uniform temperature. There is one correlation different between the calculations of h_1 and h_2, and it is the one for the flat plat horizontally oriented with uniform temperature, in this case must be considered that the plate is hot in the upper side, and its equation is presented below.

$$Nu = 0{,}27(R_a)^{\frac{1}{4}} \qquad 10^5 < R_a < 10^{11} \quad \text{(eq. 16)}$$

Is assumed that there is only natural convection inside the room. The equations regarding external convection are presented below.

$$\dot{Q}_{ConvectionEX_i} = h_2 A (T_{wall} - T_{amb}) \quad \text{(eq. 17)}$$

It is considered that the wall transferred heat with the ambient.

2.3 Case 3: Inverters room with Thermal Case

In this case, the model developed considers an energy balance similar to the Case 2 considering a wall, nevertheless, a thermal case filled with a phase change material (PCM) is added to the wall, this implies three different situations. First, when the wall temperature is lower than the phase change temperature, the PCM inside the thermal case keeps in solid phase, and the energy balance is represented by the following equation.

$$c_{PCM\ solid} \cdot \frac{\partial T_{wall}}{\partial t} = \dot{Q_{Sun}} + \dot{Q_{ConvIN}} - \dot{Q_{ConvEX}} \qquad \text{(eq. 18)}$$

Where $C_{PCMsolid}$ corresponds to the thermal capacitance of the wall, when the PCM inside of it resides in solid phase, this is calculated with the following situation.

$$c_{PCM\ solid} = m_{PCM}\ cp_{PCMsolid} \qquad \text{(eq. 19)}$$

m_{PCM} corresponds to the mass of the PCM used in the thermal case, and $cp_{PCMsolid}$ corresponds to the specific heat for the PCM at solid phase.

The second situation occurs when the wall temperature is equal to the phase change temperature; in this case the energy balance is represented by the following equation.

$$\frac{m_{PCM} \cdot \Delta h}{\Delta t} = \dot{Q_{Sun}} + \dot{Q_{ConvIN}} - \dot{Q_{ConvEX}} \qquad \text{(eq. 20)}$$

Where Δh represents the change of enthalpy and Δt represents the time step considered. In this situation the wall temperature remains constant.

The third situation occurs when the enthalpy is equal to the latent heat of the PCM, in this case the PCM changes to liquid phase and the energy balance is represented with the following equation.

$$c_{PCM\ liquid} \cdot \frac{\partial T_{wall}}{\partial t} = \dot{Q_{Sun}} + \dot{Q_{ConvIN}} - \dot{Q_{ConvEX}} \qquad \text{(eq. 21)}$$

$C_{PCMliquid}$ corresponds to the thermal capacitance of the wall, when the PCM inside of it is in liquid phase, this value is calculated with the following equation.

$$c_{PCM\ liquid} = m_{PCM}\ cp_{PCMliquid} \qquad \text{(eq. 22)}$$

In the last equation, m_{PCM} corresponds to the mass of PCM inside the thermal case and $cp_{PCMliquid}$ corresponds to the specific heat of the PCM in liquid phase. Regarding the equation that represents the energy balance of the air inside the room, is similar to the equation in the Case 2, and is presented following.

$$c_{air} \cdot \frac{\partial T_{air}}{\partial t} = \dot{Q_{Inv}} - \dot{Q_{ConvIN}} \qquad \text{(eq. 23)}$$

The PCM material selected is called Bio PCM®, from the company Phase Change Energy Solutions. This material was selected due to its operating temperatures, mainly to its phase change temperature around 25 °C, which is useful for the temperature requirements inside the room. In addition, this material is commercially available and it is commonly used for similar applications at datacenter rooms. Some properties for this material are listed below (Phase Change Energy Solutions, 2015).

- Melting point temperature: 25 °C
- Latent heat: 230 kJ/kg
- Specific heat in solid phase: 2.2 kJ/(kgK)
- Specific heat in liquid phase: 4.5 kJ/(kgK)
- Approximate price: $35 USD/kg (Beltrán et al., 2017).

2.4 Case 4: Inverters room with ventilation

In this case, the model developed considers an energy balance similar to the Case 2, which considers the inverters room without ventilation, nevertheless, an additional component must be considered in this energy balances, corresponding to the mass air flow rate which ventilates the room. The energy balance is represented by the following equations.

$$c_{air} \cdot \frac{\partial T_{air}}{\partial t} = \dot{Q}_{Inv} - \dot{Q}_{ConvIN} - \dot{Q}_{Vent} \quad \text{(eq. 24)}$$

$$c_{wall} \cdot \frac{\partial T_{wall}}{\partial t} = \dot{Q}_{Sun} + \dot{Q}_{ConvIN} - \dot{Q}_{ConvEX} \quad \text{(eq. 25)}$$

Where $\dot{Q}_{Vent}$ corresponds to the effect of the room ventilation, which is calculated with the following equation.

$$\dot{Q}_{Vent} = \dot{m}_{air} \cdot cp_{air} \cdot (T_{air} - T_{amb}) \quad \text{(eq. 26)}$$

2.4 Case 5: Inverters room with ventilation and cooling

In this case, the model developed is the same from the Case 4, the only difference will be the air temperature that ventilates the room, but the mathematical model implies the same equations.

Fig. 5 shows the scheme that models all the cases presented, considering the energy balance specified in each case.

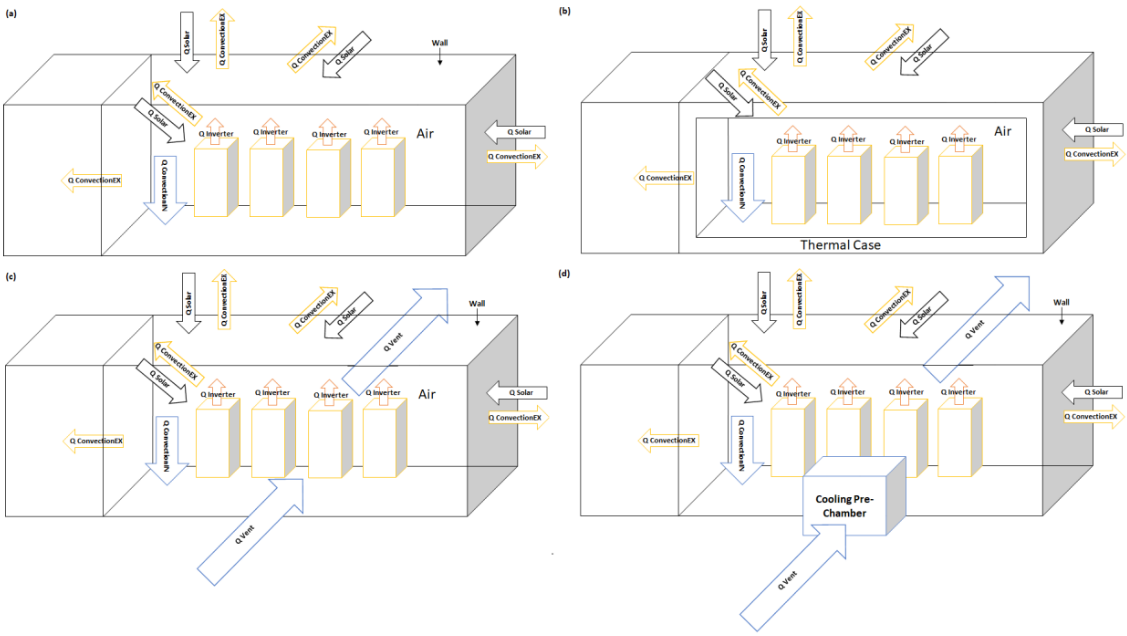

Fig. 5: Scheme of the model for each Case. (a) Scheme of the Case 2, inverters room without ventilation; (b) Scheme of the Case 3, inverters room with thermal case; (c) Scheme of the Case 4, inverters room with ventilation; (d) Scheme of the Case 5, inverters room with ventilation and cooling.

3. Results

The results conducted by the methodology used in this study, for each case, are presented in terms of total annual energy produced by the PV plant. In the first case, the maximum theoretical annual energy production is reached, due to this case does not consider the energetic losses due to the overheating temperature problems inside the inverters room.

To evaluate the thermal performance of the plant in the base case, and the Cases 2 and Case 3 which do not consider ventilation, it was simulated a typical clear sky day for the location, which corresponds to December 16.

Regarding the Case 1, was simulated the output power of the plant without considering energetic losses, for the typical day selected, this result is shown in Fig. 6. The energetic losses related to DC line are 8% approximately, this value is important due to this power is distributed between the 220 inverters and let us calculate the thermal losses associated to each inverter.

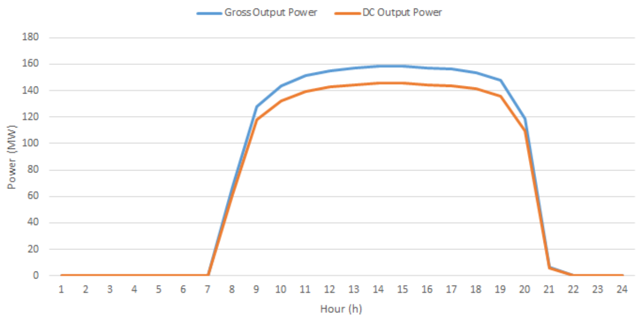

Fig. 6: Output power of the PV plant, without considering energetic losses related with the overheating problem at the inverters.

The Case 2 considers the simulation of the inverters room with no ventilation. In this case, the energetic losses due to increment of the temperature inside the inverters room are noticeable, in terms of monthly operating hours with derating power into the inverters, and the time when the inverters are turned off due to the high temperatures inside the inverters room, according to the control scheme. Fig. 7 shows the results of the simulation considering the control scheme, the temperature inside the inverters room is higher than 55 °C for many hours, this implies that the annual quantity of hours when the system is turned off is higher than the hours when the system is operative, even considering its operation with derating power. This situation presents the worst case scenario, without taking measures to improve the thermal performance of the room.

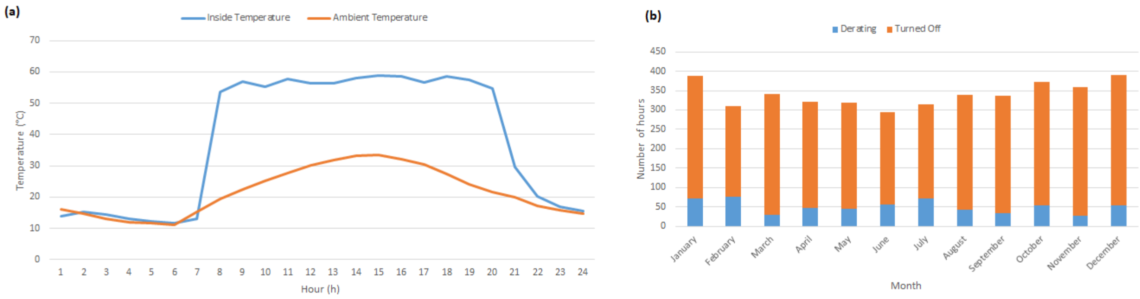

Fig. 7: Results for Case 2. (a) Temperature of the air inside the inverters room and ambient temperature; (b) Monthly hours when the inverters are turned off or operating with derating power due to the high temperatures inside the room.

The Case 3 adds a thermal case to the inverters room, filled with phase change material. The mass required of this material is estimated on its thermal properties and considering the dimensions inside the room, and is equivalent to 3,000 kg of mass, which represents adding 6 cm of thickness to the wall. The cost associated to this quantity of phase change material is $105,000 USD approximately. The results of the simulation are shown in Fig.8 in terms of temperatures and monthly hours with the system turned off and with the system operating with derating power. It is noticeable that the hours with the system turned off are lower than the Case 2, but the problems with derating power are persistent and the problem of operating with high temperatures inside the inverters room are not solved with this solution, only decreasing the quantity of turned off hours.

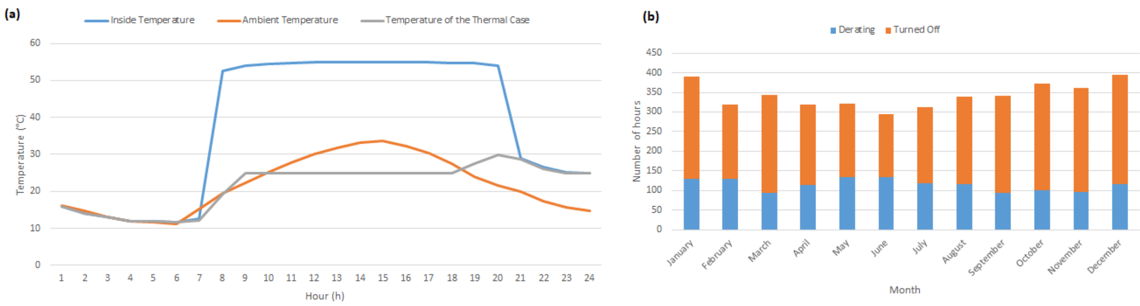

Fig. 8: Results for Case 3. (a) Temperature of the air inside the inverters room, temperature of the thermal case and ambient temperature; (b) Monthly hours when the inverters are turned off or operating with derating power due to the high temperatures inside the room.

The Case 4 and Case 5 consider ventilation, and cooling with ventilation as a solution. For this reason, a sensitive analysis was performed in order to obtain the total annual energy production, with different air flow rates and cooling effect. The effect of an adequate ventilation in the inverters room is presented in the Fig. 9, since an increase in the air flow rate per container allows to reach the maximum production of the ideal case. Cooling the inlet air produces a decrease in ventilation requirements. Indeed, an air flow rate of 7,750 m3/h at environment temperature is needed to achieve the maximum production of the model, which decreases to 5,250 m3/h if the cooling air flow rate has 10°C. When the inlet cooling air has 15°C, the air flow rate required is only 4,500 m3/h.

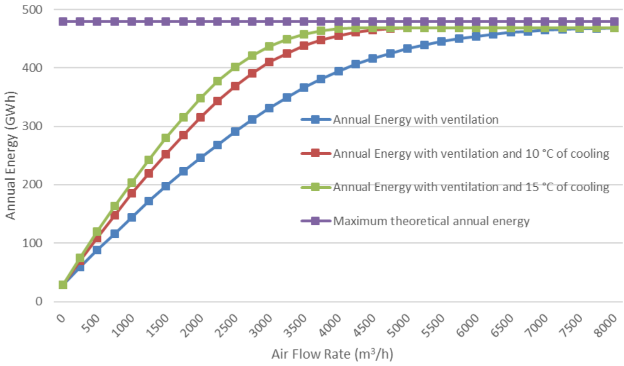

Fig. 9: Annual energy production for different ventilation air flow rate and cooling.

Another relevant parameter is the total daily energy produced by the PV plant connected to the different inverter room models and its relation with the daily irradiation received. Fig. 10 shows that the worst scenario is without ventilation, where the inside temperature of inverter rooms increases above 55 °C even with low GHI and therefore almost all the day the inverters are off. The scenario with thermal case is quite bad, compared to the ventilation scenarios. When ventilation is applied with inlet air at environment temperature (purple points) the production is close to the maximum until 6 kWh/m2 of daily GHI. If the irradiation increases, refrigeration should be added to decrease the ventilation requirements to avoid all the overheating problems in the inverters.

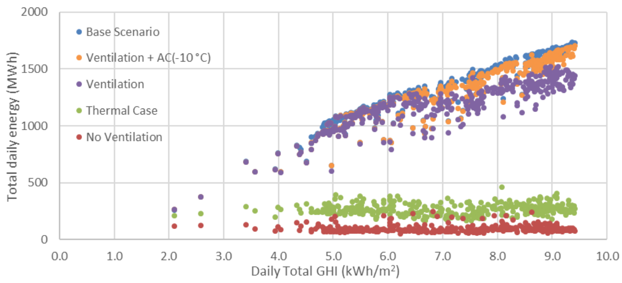

Fig. 10: Total daily energy production vs total daily GHI, for five simulated scenarios.

4. Conclusions

This study allows to evaluate the performance of the different scenarios presented, proposed as solutions to the problems in photovoltaic plants related to the malfunctioning of the inverters room due to high temperatures. It is clear that some scenarios are not a solution to improve the performance of PV plants.

The thermal case scenario is not effective as a solution, mainly because it does not reduce effectively the temperature inside the inverters room. This scenario does not show a significant improvement in the electricity generation compared to the scenario without ventilation presented as Case 2. In economic terms, this scenario presents an investment of 105,000 USD per room, which is economically unfeasible, due to this price per room is higher than the price of invest in new inverters from other companies with better performance.

On the other hand, it is shown that for the cases which consider ventilation as an option, there is an optimal ventilation value to assure an operation without derating power in the inverters. This optimal ventilation value must be calculated, depending on the capacity and efficiency of the inverters, related to its heat dissipation, and to the solar resource in the selected location. For the case of ventilation combined with cooling, the optimal ventilation value also depends on the cooling level applied to the air. Both scenarios are effective as a solution to improve the energy produced by the PV plant, raising the total annual electricity production of the plant with a considerable increment in the thermal performance of the inverters room, reaching lower temperatures and totally avoiding the derating power episodes.

It is worth to mention, that the proposed solutions with ventilation must consider an air filter system, to avoid the incorporation of dust and other elements inside the room, due to this elements could cause other performance problems in the operation of the inverters. These filter systems corresponds with other topic that could be studied in detail in further works.

5. References

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