A set of study cases for the massive integration of solar renewables in non-interconnected areas

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Abstract

The massive integration of solar renewable energies is challenging in non-interconnected areas such as remote islands or isolated regions. Indeed, their power grid, which cannot rely on the support of larger electricity networks, is more vulnerable to the inherent variability of the solar resource and grid failures, such as sudden breakdown of production units or transmission lines. The TwInSolar project, funded by the European Commission, aims to provide support and solutions to overcome the problems faced by island territories not connected to continental electricity grids. As a part of this project, four study cases are presented to the scientific community, each highlighting specific issues observed at different scales on the island of La Reunion. This article aims to provide a detailed description of the four selected systems, the corresponding challenges, and the data available.

Keywords: Solar energy, non-interconnected area, standalone microgrid, grid-connected microgrid, utility scale PV, insular power grid

1. Introduction

Non-interconnected areas encompass all the power grids that are non-connected to the continental grids, like remote rural communities, entire regions of developing countries or islands. The island of La Reunion, situated in the south-west part of the Indian Ocean, is a good example of a non-interconnected area. Decarbonization and energy self-sufficiency of the non-interconnected energy systems require the use of locally available renewable resources (Erdinc et al., 2015). In many cases, such as island territories in the tropical zone, the sun is the most abundant resource. Moreover, solar systems, like photovoltaic (PV) or domestic solar hot water (DSHW) are mature technologies that produce the cheapest energy in the world (IRENA, 2022). The massive integration of solar energy is, therefore one of the possible ways to achieve the objectives of decarbonization and energy autonomy of these regions.

However, the electricity networks of remote areas are more sensitive than continental grids, and new challenges arise from the massive integration of solar energy. Indeed, due to their small size (thereby impacting power system strength typically represented by system inertia and short circuit power) and limited capacity of power reserves, non-interconnected grids are more vulnerable to unexpected events such as generation ramps, forecast uncertainties commonly observed with variable renewables (i.e., solar and wind) or system failures (e.g., power plant breakdown). Moreover, these isolated grids cannot rely on a larger interconnected grid to balance their lack or excess of generation. On the other hand, solar renewables like PV systems are connected to the grid through power electronics that must comply with the appropriate standards. For instance, in La Reunion, PV inverters must comply with the DIN VDE 0126-1-1 (VDE, 2013), which defines frequency and voltage bands for normal operation. Out of these ranges, the inverter must automatically shut down the power generation. For an isolated electricity network, it is more challenging to maintain the frequency and the voltage within these ranges in case of severe failure. In such conditions, PV systems could likely stop their production and increase the risk of a grid blackout. Consequently, the massive integration of solar energy in these specific grids presents new challenges that are likely to be faced by continental grids in the future.

The goal of this paper is to highlight the challenges currently experienced by non-interconnected areas, which already have a high share of solar production, through the description of four study cases selected within the framework of the European project TwInSolar ("Twinsolar," 2023). The study cases, located in La Reunion and illustrated in Fig. 1, are representatives of issues observed at different scales. In addition, data related to each study-case are made available to the scientific community.

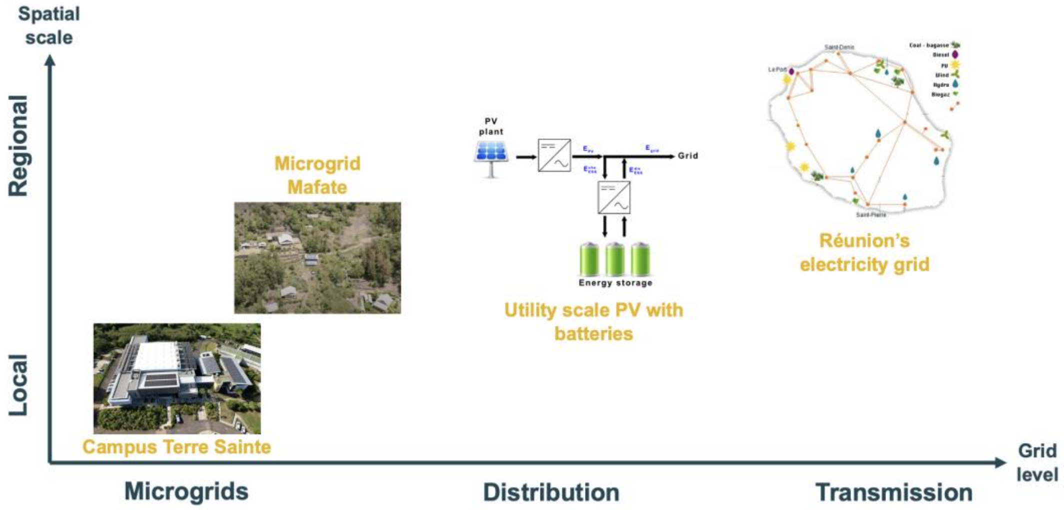

Fig. 1: Positioning of the four study cases selected to highlight the challenges that face non-interconnected island of La Reunion with the massive integration of solar energy.

2. A standalone microgrid

The first case study is a standalone microgrid located in the isolated Mafate cirque, in the heart of a UNESCO World Heritage national park. This micro-region of Reunion has neither roads nor power lines. The small villages in that area are only accessible on foot or by helicopter and must produce their energy locally. Since the 2000s, buildings in Mafate have been mainly powered by standalone PV systems with lead-acid batteries. The first installed photovoltaic systems have recently reached the end of their life. In this context, local authorities have decided to develop isolated microgrids to reduce their replacement costs, facilitate maintenance, and develop a new economic model. These new microgrids connect several houses to a single PV plant equipped with batteries.

Fig. 2: Aerial view (Francou 2022) and repartition of electric load of the remote microgrid located in the Mafate cirque, La Reunion

The proposed study case, illustrated in Fig. 1, has three rural accommodations, a single PV plant of 7kWp, and lead-acid batteries with a capacity of 140kWh (Calogine et al., 2019; Francou et al., 2019). The houses have no heating or cooling. The residents use wood-fire and gas cylinders for cooking and thermal solar panels provide domestic hot water. Thus, the electrical microgrid powers fridges, freezers, multimedia devices (TV, mobile phone, computers), lighting and DIY tools. As presented in Table 1, the fridges and freezers are the main loads of the microgrid. The washing machines also account for a significant share of the load with approximately half of their consumption occurring outside the sunshine hours.

Table 1: Main operation indicators of the remote microgrid of Mafate derived from 1-min records between May 2020 and May 2021

Operation indicators	Average	Min	Max
Power demand (kW)	0.29	0.001	3.28
Daily load (kWh)	5.73	2.57	10.24
Daily plan of array irradiance (kWh/m^2)	5.26	1.29	7.54
Estimated daily PV production (kWh)	29.44	7.25	42.25
Actual daily PV production (kWh)	12.25	7.94	19.96
System daily efficiency (%)	46.7	21.0	83.5
Estimated storage state of charge – SOC (%)	98.1	92.3	100

The system design, based on current practices in design offices, minimizes the risks of electricity shortages and does not consider the possibility of involving users in the operation of the microgrid. Consequently, the battery and power converters are strongly oversized, and the resulting Levelized Cost of Energy (LCOE) is exceptionally high. As shown in Table 1, from May 2020 to May 2021 and considering the average daily energy demand, the capacity of the storage correspond to more than 20 days of electricity supply without sun. One can also observed that the estimated state of charge (SOC) of the storage never fall below 92%. The strong overestimation of the sizes of the components (i.e. ESS and power converters) results in a very low energy storage and distribution efficiency ranging between 21.0% and 83.5% on a daily scale.

The main challenge is to achieve a cost-effective design and to engage the users in the management of the microgrid. Indeed, optimal sizing of the PV plant and the ESS (Energy Storage Systems) leads to a more reasonable investment cost (Francou et al., 2022). Moreover, efficient demand-side management could be achieved with a better involvement of the users. For this study case, a human interface fed by an Energy Management System (EMS) has been tested to improve the simultaneity between the PV generation and the load (Abbezzot et al., 2022).

The microgrid has been fully instrumented and monitored with a sample time step of 1 minute from 2019 to 2022, the duration of the project “Microréseau Mafate” granted by the European Regional Development Funds and the Région Réunion (Francou et al., 2019). First, a weather station installed on the PV plant shelter recorded the main weather parameters (i.e., global horizontal and plan of array solar irradiance, temperature, humidity, wind, and rain). Second, a data acquisition system associated with the PV plant measured the PV production, the total power demand, and the battery state (current, voltage, and state of charge). Finally, five energy meters per house monitored the main types of loads (fridge, washing machine, lights, etc.). One year of anonymized data, from May 2020 to May 2021, are freely accessible on zenodo (Calogine et al., 2023).

3. A grid-connected microgrid

The second system is the university Campus of Terre Sainte, which can be considered a grid-connected microgrid. The campus is located in Saint-Pierre, on the southern coastal part of the island. The climate is hot and humid during the wet season (Nov. to Apr.) and cooler with trade winds during the dry season (Apr. to Nov.). The annual solar potential of the site reaches 2000 kWh.m^{-2} on a horizontal surface, making it an ideal location for using solar renewables. The campus hosts approximately 12,500 m^2 of floor area for the university building, a student residence with 244 rooms, and a restaurant. Fig. 3 gives an overview of the campus and installed PV capacity. The Faculty of medicine, which was commissioned in September 2023, is not currently included in the scope of the microgrid for the moment because we do not have any data.

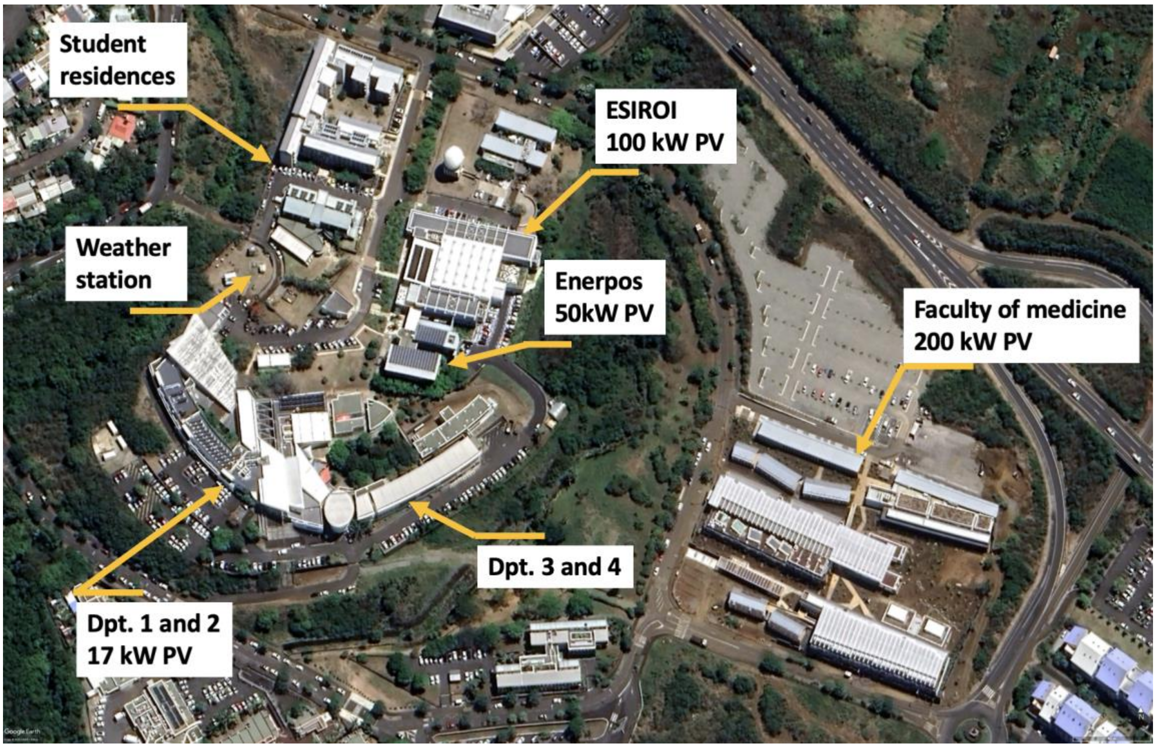

Fig. 3: Overview of the university campus of Terre Sainte, La Reunion

Table 2 below gives more details on the existing buildings. The student residences are already equipped with solar hot water (DWH) that supplies more than 80% of the energy needed for showers and cooking. The university buildings currently host 165,8 kWp of PV on their roofs (the additional 200 kWp of the faculty of medicine will come soon) and the microgrid has an electrical self-sufficiency of nearly 16%. The last generation of university buildings built on the campus (Enerpos and ESIROI) are NetZero Energy Buildings (Lenoir and Garde, 2012). Their annual electricity demand is balanced by the Building Integrated PV installed on their roofs. For instance, the ENERPOS building produces approximately five times its electricity consumption on a yearly basis. With approximately 50% of the area being air-conditioned, cooling is the main load of the microgrid. With the building plans and the online software Helioscope, we estimated the additional PV capacity that could be installed on the available roofs (last column of Table 2). Considering existing systems and the potential for new systems, we could install more than 1 MWp of photovoltaics on the campus and produce more than 1.5 times the annual electricity consumption.

Table 2: Key figures of the university campus of Terre Sainte, La Reunion

Building name	Commissioning Year	Floor area (m^2)	Energy demand 2021 (kWh)	Installed PV (kWp)	Potential additional PV (kWp)
Dpt. 1 and 2	1998	5,006	273,432	17	373.4
Dpt. 3 and 4	2006	2,171	228,309	-	223.0
Enerpos	2008	979	15,710	48.8	46.9
SEAS-OI	2012	597	34,178	-	72,0
ESIROI	2020	3,885	260,160	100	127,9
Student residences	2008 and 2019	6,110	373,060	-	173,0
	Total	**18,748**	**1,184,759**	**165.8**	**1,016.2**

Fig. 4 gives a detailed view of the current load profile of the ESIROI building, where each type of load is monitored. The main load, even if that building is very well designed, is the cooling (purple and orange areas). With a significant difference in the cooling demand, the building load profile differs strongly between summer and winter. The increase of electric vehicles (EV) results in a significant share of the load coming from EV charging (dark green area). The overall shape of the load profile, also representative of the total campus load, shows that energy demand occurs primarily during daylight hours. Therefore, powering the microgrid with solar energy seems to be a good solution to increase its self-sufficiency. However, with a relatively important share of demand occurring at night, a solution based solely on solar energy will have its limitations.

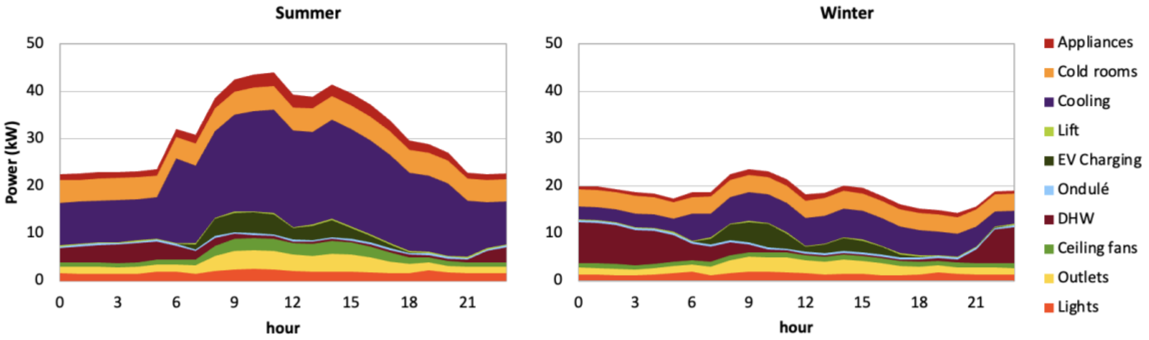

Fig. 4: Average daily profile of electricity demand by type of use of the ESIROI building for summer (Nov. to Apr.) and winter (Apr. to Nov.)

Fig. 5 presents the results of a simplified model of the current microgrid, considering a PV production based on the observed performance ratio of existing systems and actual electricity demand. The model computes the self-sufficiency of the microgrid for an increasing installed PV capacity. As expected, without flexibility means, like ESS or demand side management, the self-sufficiency hardly overtake a limit of 50%. The dotted lines highlight the current situation (blue line), a virtual NetZEB microgrid (green line) and a PV system covering all the available roofs (red line).

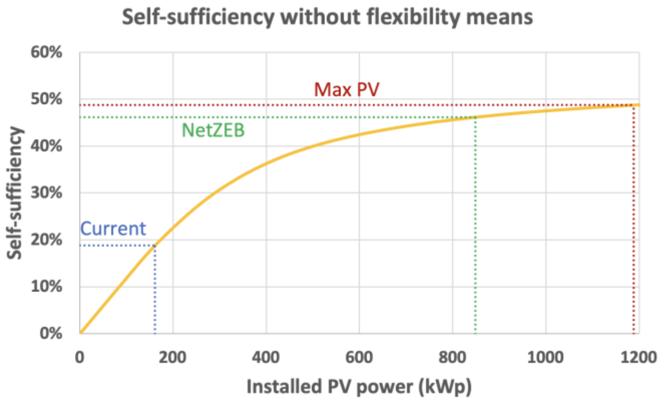

Fig. 5: Simulated self-sufficiency for an increasing installed PV capacity and no flexibility means

Therefore, reducing operation costs and carbon emissions of the whole microgrid requires optimizing the operation and size of a system, which integrates flexibility means like an ESS, to enable increasing the self-sufficiency from solar generation beyond 50%. More precisely, the TwInSolar project aims for 80% self-sufficiency from solar. The main issue is not to install new PV capacity but to achieve a techno-economic optimum to reduce the operation cost of the microgrid. Complementary approaches have already been tested to reach this goal: a combination of PV with compressed air energy storage (Castaing-Lasvignottes et al., 2016; Simpore et al., 2019) and a predictive Energy Management System (EMS) fed by probabilistic solar forecasts and load forecasts (Ramahatana et al., 2022). But these works were restricted to the Enerpos building. The next step is to extend the approach to the whole microgrid.

The campus is fully instrumented to monitor weather and electrical parameters with at least a 10-min time step. First, the university maintains its own complete weather station equipped with advanced solar irradiation sensors (global, diffuse, and direct irradiance on a solar tracker). Second, the electricity demand is recorded for each building separately and for the most recent constructions, the main types of loads (i.e., cooling, lights, ceiling fans, etc.) are also monitored. Finally, the production of the different PV plants is also recorded. A set of consolidated data with a 10-min granularity for two consecutive years, 2021 and 2022, is publicly available on the TwInSolar website in the deliverables section (“Twinsolar,” 2023).

4. Utility scale PV systems with energy storage

In order to reduce the uncertainty associated with their production and consequently improve the stability of the main grid, the latest generation of large-scale photovoltaic farms installed in La Reunion must be coupled with an energy storage system (ESS). In 2021, 19 utility-scale PV plants, for a total of 30 MWp, were operated jointly with energy storage (Reunion Island Energy Observatory (OER), 2022). Tab. 2 gives three examples of these atypical systems installed in La Reunion, with their main characteristics. These PV farms comply with the technical specifications required by a series of calls for tenders launched by the government starting from 2011 for the non-interconnected French areas. The operators of these solar power plants must provide a production schedule one day in advance and risk penalties if they do not respect it. Two different ways of planning the production have been proposed:

- the generation of a trapezium-shaped power profile during the daytime (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, 2011),
- a free power profile during the daytime and the possibility of producing a constant power during peak hours (i.e., 7:00 p.m. to 9:00 p.m.) with a better selling price (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, 2015).

Tab. 2: Examples of utility scale PV systems with energy storage installed in La Reunion

Name (commissioning year)	Operator	PV capacity	ESS capacity	Operation type	Source
Stade de l'Est (2020)	Albioma	1.25 MWp	1,33 MWh	Free daily profile and evening peak	(Albioma, 2023)
Aéroport Saint-Pierre Pierrefonds (2023)	TotalEnergies	7,7 MWp	10 MWh	Free daily profile and evening peak	(TotalEnergies, 2023)
Les Cèdres (2015)	Akuo	9 MWp	9 MWh	Trapezium-shape daily profile	(Akuo, 2023)

We will focus in this work only on the second type of injection profile, which favors the injection of power at peak hours. The left side of Fig. 6 illustrates the profile shape the operator must deliver to the Distribution System Operator (DSO) one day in advance. This profile and delivery times must respect a series of complex rules. Here, we will give a brief overview of the main requirements. The reader can access the detailed technical specifications here (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, 2015). The plant operator must transmit the generation profile of the next day to the DSO at 4:00 PM the day before. 4 redeclarations are possible at 4:00 AM, 10:00AM and 2:00 PM on the day of production. To avoid severe ramps during the daytime, the slope of the announced profile must be less than 0.6% per minute of peak power. Deviations ($Deviation{=}Actual\ injeted\ power - Announced\ power\ profile$

(eq. 1) from the announced profile, which exceed a power tolerance of $\pm 5\%$ of the installed peak power, lead to penalties calculated as follows: a positive deviation (i.e., overproduction) is not purchased and a negative deviation (i.e., underproduction) results in a penalty given by $Penalty{=}Feed\ in\ tariff \times \left[\frac{Deviation^2}{Peak\ power} - 0.1 \times Deviation - 0.0075 \times Peak\ power\right]$ (eq. 2. The right side of Fig. 6 illustrates the value of the penalties for deviations ranging from -500 kW to 500 kW for a PV farm of 1 MWp and a feed-in tariff of 215 €/MWh, which corresponds to the average feed-in tariff of the installations awarded by the call of tender launched in 2015 (CRE, 2015). To encourage production during the peak hours, the feed-in tariff was raised by 200 €/MWh.

$$Deviation = Actual\ injeted\ power - Announced\ power\ profile \qquad \text{(eq. 1)}$$

$$Penalty = Feed\ in\ tariff \times \left[\frac{Deviation^2}{Peak\ power} - 0.1 \times Deviation - 0.0075 \times Peak\ power\right] \qquad \text{(eq. 2)}$$

The rules for the penalties are surprising. Indeed, for a simular absolute value of the deviation, you lose more money when you overproduce (positive deviation) than when you underproduce (negative deviation). No penatly jump appears when leaving the 5% tolerance band for negative deviations, as defined by equation 2. For positive deviation, the penalty corresponds to a shortfall because the DSO will not buy your excess of production. The slope is the feed-in tariff and a jump appears because you are not penalized within the 5% tolerance band.

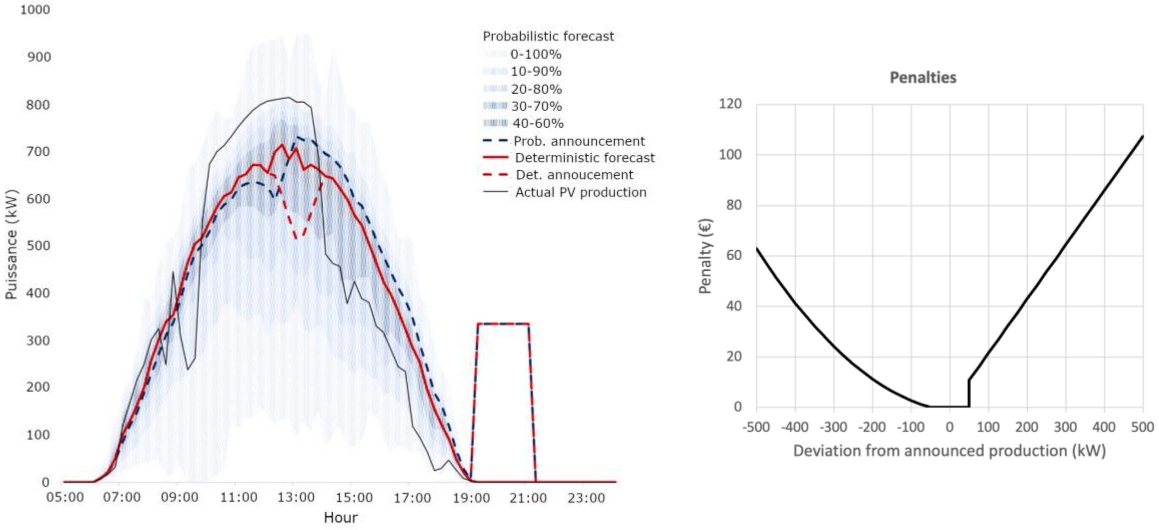

Fig. 6: At the left, one day of deterministic (red line) and probabilistic (grey intervals) forecast, the corresponding announced injection profiles (dashed lines) and the actual PV output power (black line) of 1 MWp PV plant situated in the coastal part of La Reunion. At the right, the penalties resulting from deviation from the announced production profile for a feed-in tariff of 215 €/MWh.

Therefore, the predictive schedule of these plants should reduce penalties while increasing the amount of energy injected into the grid. For instance, to maximize the revenue, a possible strategy is to charge the ESS at 100% during the daytime and to discharge it during peak hours. The main challenge for these specific PV farms and their operators is to select sound solar forecasts and integrate them into the system's EMS (David et al., 2021). Indeed, the quality of a forecast can be evaluated by a large set of indicators, such as the Mean Bias Error (MBE), the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE) for the deterministic forecast (Yang et al., 2020) and the Continuous Rank Probability Score (CRPS), or the Ingnorance Score for probabilistic forecast (Lauret et al., 2019). However, improving these evaluation metrics does not mandatorily correspond to better revenue for the user.

For this study case, the operation data, such as the PV production and the ESS state of charge, are not publicly available because they belong to private operators. However, it is easy to find the main technical characteristics of the PV plants and the ESS on the Internet (see Tab. 2: Examples of utility scale PV systems with energy storage installed in La Reunion. Finally, the technical specifications cited above fully describe the technical and financial rules used to run these PV plants and simulate the EMS. Time series of PV production and forecasts can be simulated through CorRES tool (Koivisto et al., 2019).

5. The power grid of the island of La Reunion

With approximately 400,000 electricity consumers and a wide variety of means of production, the electricity network of La Reunion Island is not a small isolated power grid. Moreover, the distance between La Reunion and the nearest continental grids is so long that interconnection is not possible. This intermediate-size electricity grid, often called non-interconnected, faces different issues than stand-alone microgrids. Therefore, it will prefigure the challenges of continental grids with a high share of intermittent renewable energies such as PV and wind power. In 2021, as illustrated in Fig. 7 andFig. 8, the total installed capacity was 931.8 MW and the annual electricity production was close to 3,000 GWh. The same year, with an installed capacity of 223.6 MW (24% of the total installed capacity), the PV produced 8.7% of the electricity mix (Reunion Island Energy Observatory (OER), 2022). With such a high penetration rate of intermittent renewables and to guarantee the grid stability, the French government fixed a regulatory limit of a maximum of 35% of the total produced power coming from variable renewable energies (VRE) such as PV and wind. Beyond this limit, the local DSO considers that the high penetration rate of renewable energy systems connected via power electronics such as inverters results in an unacceptable risk. Indeed, the inverters must operate within the frequency and voltage bands defined by the DIN VDE 0126-1-1 (VDE, 2013) and, in case of severe failure on the grid, they could stop their production if the frequency or the voltage drop suddenly. With the current conversion to biomass of coal and diesel power plants, the electricity generation will be 100% renewable by 2024 (Ministère de la transition écologique, 2022). However, most of the required biomass (i.e., wood pellets and biofuel) will be imported and this conversion will unfortunately perpetuate the high energy dependency of the island.

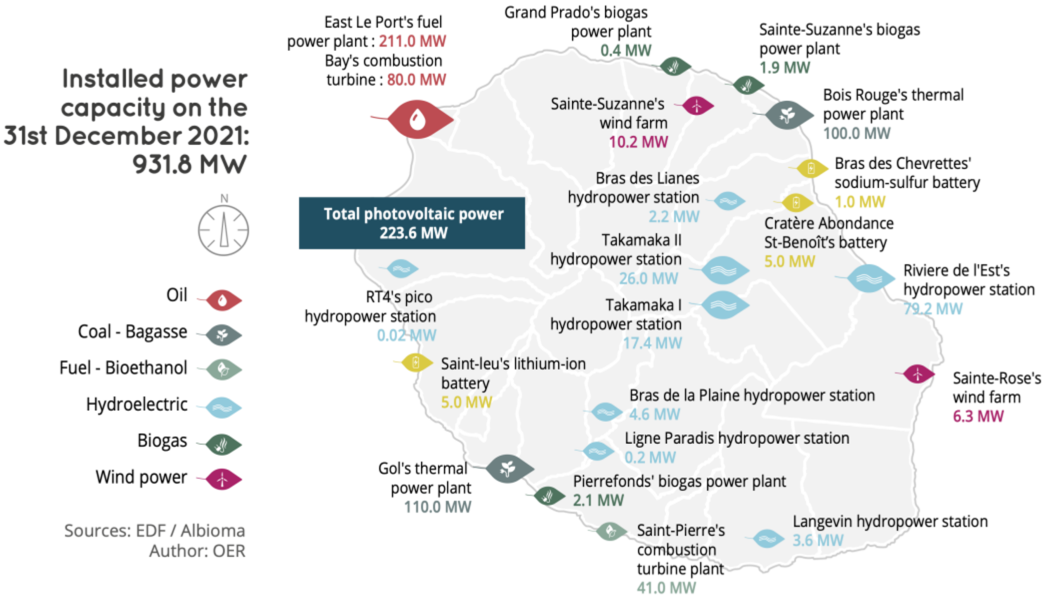

Fig. 7: Schematic diagram of La Reunion's electricity grid in 2021 (Reunion Island Energy Observatory (OER), 2022)

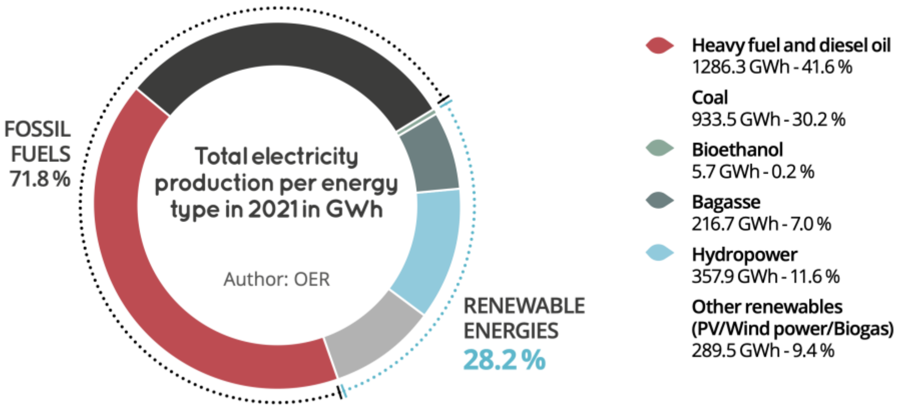

Fig. 8: Electricity production mix of La Reunion in 2021 (Reunion Island Energy Observatory (OER), 2022)

To better understand the current operation of the electricity network, Fig. 9 shows 3 days of hourly electricity production for summer and winter. Coal/bagasse[1] power plants and diesel generators are the historical baseload power plants of La Reunion. Hydropower plants and combustion turbines are the most flexible production means. They are mainly used for peak shaving and power reserve. However, due to the volcanic nature of the soils, large dams are not feasible. As a consequence, hydropower plants have relatively low energy capacity. In summer (left side of Fig. 9), two peaks in electricity consumption appear. The first occurs in the middle of the day due the important cooling demand of the buildings. The second is the classic evening peak caused by residential electricty demand. Solar generation and baseload power plants meet daytime demand. At the same

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[1] Bagasse is the sugar cane straw remaining after juice extraction. It's a residue from sugar factories.

time, hydropower offsets fluctuations in demand and solar production. In the evening, fast and expensive combustion turbines are used in combination with hydropower to meet peak demand. In rare cases, such as February 5, 2021, when there is not enough hydropower available at the end of the day, the DSO increases production from coal/bagasse plants. In winter (right side of Fig. 9), air conditioning demand is low and therefore electricity demand is lower than in summer with the exception of the evening peak which remains similar. The latter is managed as in summer with a combination of hydroelectricity, combustion turbines and baseload power plants. However, during the day in winter, we see that power reductions of coal/bagasse plants, which are the least reactive means, compensate for significant solar production. Thus, rapid means such as hydroelectricity are not the only ones to be used to integrate solar production into the electricity mix of La Reunion. A last important point is highlighted in the bottom part of Fig. 9. In summer as in winter, the power limitation of 35% of the total power coming from VRE is frequently reached in the middle of the day. Above this threshold, the DSO must curtail PV production to avoid important risk for the stability of the electricty network.

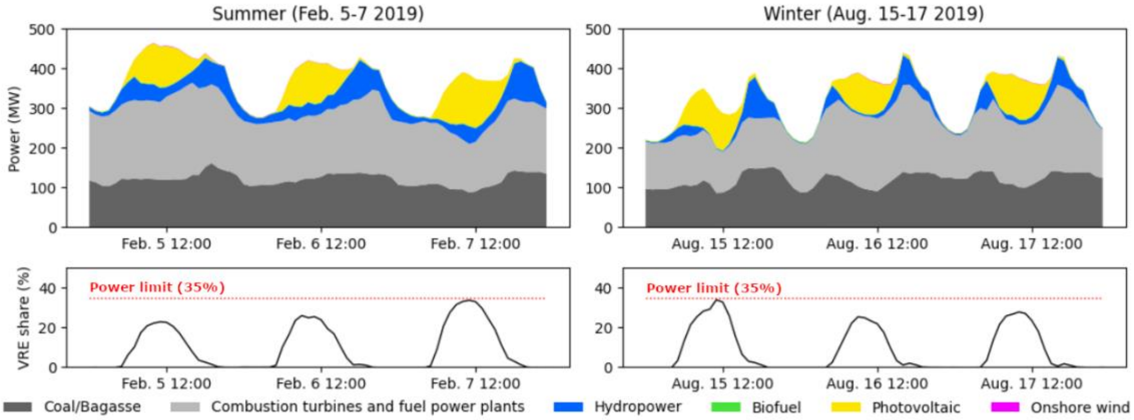

Fig. 9: Hourly profiles of electricity production in La Reunion by type of generation means (top) and associated power fraction from variable renewable energies (bottom) for 3 typical days of summer and winter 2021

As the sun is the first local renewable resource, the self-sufficiency goal for La Reunion requires continuing the installation of PV systems to achieve massive integration of solar renewable energies. To reach a 100% renewable with local resource, a prospective study done by the French energy agency ADEME highlights that the future energy mix of La Reunion will be higly dominated by solar technologies (BISCAGLIA et al., 2018). Moreover, the French government, in agreement with the local authorities, plans a strong increase of the PV with a doubling of the installed capacity by 2028 (Ministère de la transition écologique, 2022). If 100% PV electric production with a affordable Levelized Cost of Energy (LCOE) is achievable (Perez et al., 2023), a important capacity of ESS is needed. However, these works have not solved the issues related to grid stability when sudden production fluctuations are observed or when a severe failure occurs. Therefore, the main challenges to achieve a massive integration of solar renewable energies into the electricity network are PV generation and demand forecasting, ESS and smart management of the production means.

The local DSO, EDF Réunion, recently created a website bringing together a lot of data concerning the island's electricity network (EDF, 2023). These freely accessible data provide a detailed description of the means of production, transport lines and main transformers. Additionally, the web portal also provides hourly records of electricity production by type of generation means (see Fig. 9) and costs from 2016. This dataset provides a useful tool for studying the massive integration of solar energy into a medium-sized non-interconnected power grid.

6. Conclusion

The decarbonization of electricity production and more broadly the energy autonomy of non-interconnected territories like Reunion Island require the massive integration of solar energy in the near future. While solar technologies, such as PV and solar DHW, are mature, the variable nature of the solar resource and their connection to the electrical grid with power electronics raise new scientific challenges to achieve this goal. This work details 4 study cases that highlight these challenges at different scales: an isolated microgrid, a grid-connected microgrid, utility-scale photovoltaic plants equipped with ESS and the electricity network of the island of La Reunion. All these case studies come with freely accessible data allowing the scientific community to study possible alternative solutions to significantly increase the share of solar power in the production mix.

Concerning the case of the standlone microgrid of Mafate located in the isolated cirque of Mafate, in the heart of a national park classified as a UNESCO world heritage site, the sizing of the components of the system (i.e. PV farm, ESS and power converters) should result from user requirements, the potential of demand management measures and the detailed analysis of simulated production profiles. The current design, carried out according to the usual practices of a design office, did not take such a strategy into account. Therefore, the installed system is highly oversized and the LCOE is exceptionally high. Data collected from the microgrid can be used to refine the design process and achieve an affordable energy price.

The second case study is a university campus, located in Saint-Pierre on the southern coastal part of the island, comprising university buildings, student residences and a restaurant. Approximately 50% of the floor area of university buildings is air-conditioned and the cooling demand is the main load of the microgrid. The most recent campus buildings are bioclimatic, energy efficient, and have rooftop PV systems, aiming for a net zero energy balance between consumption and production on an annual scale. In 2021, the whole campus's electricity self-sufficiency was approximately 16%. The next step is increasing the self-sufficiency of the whole microgrid, with a target of 80%, while reducing operating costs. The data recorded over the last few years allows a detailed analysis of loads and PV productions, necessary to achieve cost-effective integration of solar systems.

Since 2013, large-scale PV systems must include an ESS and their operators have to provide a power supply schedule one day in advance. Penalties are applied for the difference between the actual supply and the delivery schedule provided to the authorities. In 2021, 19 utility-scale PV plants, for a total of 30 MWp, were operated jointly with energy storage. The operation of these hybrid systems requires high-quality forecasts of photovoltaic production and efficient EMS to generate forecast schedules for energy injection into the network. The goal is to maximize the direct injection of solar energy into the grid while minimizing penalties due to deviations from schedule.

The last study case is the La Reunion’s electricity network. With around 400,000 electricity consumers, a wide diversity of production means and no possibility of cable connection with continental networks, this electricity grid is an example of a non-interconnected system. To achieve energy autonomy for the Island, the massive integration of solar energy, already underway, seems to be the most suitable solution. However, due to the high variability of solar production and the current specifications of the power electronics used to convert PV production, the massive integration of solar energy in an non-interconnected system raises new issues to guarantee supply security and grid stability. Highlighted by the data provided by the DSO, the main challenges to achieve the massive integration of solar renewable energies are the demand and PV production forecast, ESS and smart management of production means.

7. Acknowledgements

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