# An analysis of Large RES Penetration Impact on Traditional System Operation at the Canary Islands Isolated Power Systems

## Future trends and contingency measures

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***Abstract*— The Spanish archipelago of the Canary Islands is leading an energy transition towards a decarbonized future, by means of installing a huge amount of renewable power plants, mainly wind and photovoltaics.**

**This trend is heavily supported by the government, both at regional and national level, as RES generation in the context of isolated power systems is, in this case, both cheaper and cleaner than providing power by means of fuel based units as it have been done so far.**

**In this transitioning scenario, which already started a few years ago, the power system dynamics are subject to change, a change driven by two main factors: on one hand the fact that new RES generation is connected to the network through power electronics, and therefore not adding natural inertia to the system. On the other hand, the uncertainty and variability introduced by the primary renewable resource itself, which lead to new operating scenarios from the TSO point of view.**

**In order to maximize RES generation above a certain limit while keeping the power system within security margins, the current system operation criteria must be revisited, and properly adapted.**

**This paper describe in a comprehensive way a set of studies carried out by, Red Eléctrica de España (REE), the Spanish TSO in order to design the abovementioned adaptations of the operation criteria.**

**As a result, a set of conclusions and contingency measures are presented. Those actions, together with the addition of new flexibility solutions to the power systems, i.e, energy storage, will allow further RES integration in the islands during the coming years.**

***Isolated systems; TSO; frequency; stability; PV; wind; RES; storage; balancing; network; congestion***

## I. INTRODUCTION

The Canary Islands, located at the Atlantic Ocean, off the west coast of Africa, are part of Spain and one of the outermost regions of the EU. The archipelago, which comprises six isolated power systems distributed over seven islands, are energized mainly from thermal power plants that include combined cycles, diesel, gas and steam generators, all of them using oil based fuels as the primary energy source, thus making the power production efficiently poor and quite polluting. Until year 2017 there was a rather small number of renewable production plants, mainly wind and photovoltaics (PV), whose year production covered around a 7-8 % of the total annual demand of the islands.

In order to reduce pollution and minimize dependency of imported fuel for electricity generation, there is a strong commitment of national, regional and local authorities in supporting the development of new renewable energy generation facilities.

With a really challenging scenario depicted by year 2025, when renewable installed capacity in the islands is expected to reach 1,3 GW (Figure 1), the installation on new renewable power has already started, and wind power installed capacity has nearly triplicated by December 2018, reaching almost 300 MW in Tenerife island, where demand is between 260-560 MW. A similar situation occurs in Gran Canaria Island.

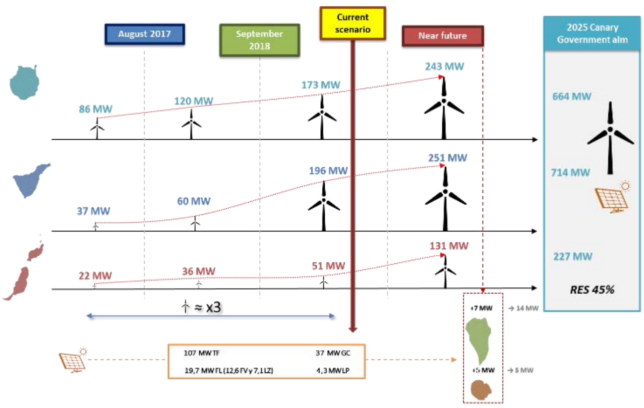


*Figure 1RES installed capacity trend*

This paper describes a set of studies accomplished by the TSO throughout year 2018, where historical data analysis have been carried out, together with the breakdown of power systems' behavior in an increasingly demanding scenario, in terms of combining large non-controllable RES production within small, weak, non-interconnected electrical power systems. The aim of the analysis is to identify the necessary factors and measures that the system operator must take into account to maximize renewable integration while keeping system security, creating a methodology to address the issue in any electric system.

First of all, the future scenario will be depicted, focusing on the present and future situation at the two biggest islands, Gran Canaria and Tenerife, as they are the ones with largest new RES developments. The description will cover, among other aspects, the amount on new installed capacity and the relative sizes with respect to island's demand, together with an explanation of the most common issues that are expected to occur, which are actually in place to a certain extent. Those issues include the effect of RES variability on system frequency and balancing among others.

Secondly, a detailed description of the studies that have been carried out is presented, covering different aspects of system operation and leading to a set of potential contingency measures.

The paper concludes with a description of key operation aspects as well as the identification of specific future needs that, as a result of the studies carried out, have revealed as mandatory in order to further push RES integration limits. Those extra measures, covering a wide range of actors across the power system, are considered key in order to add to the system the necessary flexibility to safely manage, not only the extremely challenging RES scenario depicted in a 5 to 6 year timeframe, but the current situation which is already demanding.

## II. CURRENT VS NEAR FUTURE SCENARIO

Traditionally, RES contribution to the Canary Islands energy mix have been rather small. This situation started to change by the end of year 2018, when the first group of a set of new planned RES facilities entered into service. The late commissioning of this new installed capacity have led to a modest contribution in the overall 2018 figures (Figure 2), a contribution that is expected to be more significant in year 2019.

Figure 2 depicts total RES contribution to electricity generation classified by electrical system during 2018.

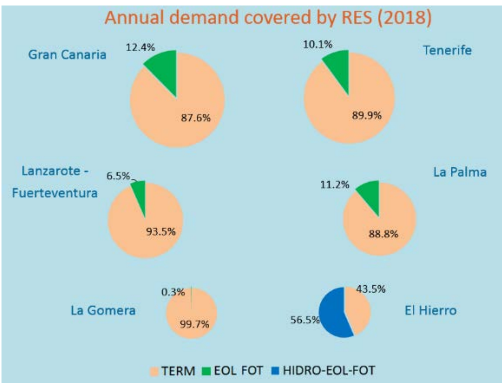


*Figure 2 RES contribution to total demand per system in year 2018*

As shown, the overall RES contribution was mainly between 6% and 12%, with the exception of La Gomera and El Hierro Island, a special case where the flexibility introduced by a reversible hydro power plant has led to RES record integration figures [1] [2] [3]. The newly installed capacity, located in the systems of Gran Canaria, Tenerife and Lanzarote-Fuerteventura, has raised RES integration figures between 2 and 4 percentage points, despite being in operation only for a few months.

It is important to notice that, prior to those new developments, the already installed wind capacity was commissioned before year 2004. As a matter of fact there is currently a big technology gap between old and new wind farms which will imply different behaviors and limitations in terms of how the generation units respond to severe incidents on the network. This fact needs to be properly taken into account at the control room.

This depicted RES capacity installation trend is expected to continue in the coming years. There is already a new tender in place for an additional 180 MW of wind power, and another one is expected to be announced by the end of the year, this time targeting PV plants.

Plans from the regional government estimates that, by horizon 2025 [4], a further amount of RES generation facilities will be installed all over the Canary Islands.

Figure 3 shows actual and expected RES installed capacity in the Canary Islands, both by the end of 2018 and by year 2025, compared to the average range of variation of the daily demand curve.

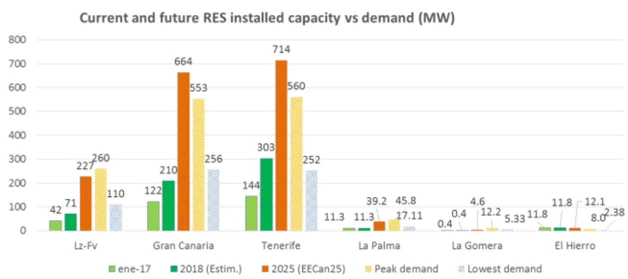


*Figure 3 RES installed capacity vs demand figures*

There is a set of special characteristics that result from this RES capacity development, which will have an effect in how the isolated electrical systems of the islands behave:

- Nature of the primary resource: the vast majority of the planned facilities are wind and PV power plants.
- Size: the total amount of installed power will be, in general, close to or even greater than the maximum power demand of each of the systems.
- Location: RES generation plants are geographically concentrated, as territory is limited and the best performing zones, in terms of capacity factor, are in certain specific areas, mainly located at the south-east shore of the islands.

The abovementioned aspects, in this large RES penetration context, triggers a set of new arising issues that have already being identified, and are briefly described hereafter.

The main challenges that will need to be faced by the TSO are:

- System stability in low inertia scenarios
- Uncertainty and variability of RES generation
- Network congestion
- Synchronous generation requirements due to balancing

*A. System stability in low inertia scenarios*

It is a fact that the increase of new wind and solar power in the generation mix of the islands will reduce de total synchronous inertia available in the system, as those power plants connect to the system by means of power electronics.

A lack of natural inertia in the system effectively reduces its strength, in terms of its capability to instantaneously react to sudden generation-demand imbalances. Beyond certain limits, an extremely weak system could not be able to cope with such an imbalance, namely the loss of the biggest generation unit or the most probable renewable ramp rate, and therefore, the probability of having a system wide blackout or severe incidents increases.

In this scenario, a set of transient stability studies must be accomplished, and tools have been developed [5], in order to determine the set of synchronous units that must conform the so called “must run”, and its plausible alternatives from the available thermal generation units.

Further investigations on the contribution of converter connected generators to the overall system inertia, by means of inertia emulation implemented through power electronics programming, should be investigated, especially when exploring extremely high RES penetration scenarios.

*B. Uncertainty and variability of RES generation*

The nature of the primary resource used by the newly installed RES plants, wind and solar radiation, is subject to two special behaviors: uncertainty and variability.

Uncertainty refers to the difficulty to accurately predict the generation output of those power plants, at different time horizons. The grade of accuracy in the prediction of RES generation have a direct impact in the thermal generation requirements, in terms of designing the generation dispatch and determining the optimum operational reserves that guarantee the energy supply to the load.

Variability refers to the rate of variation in which RES generation can change at different time frames, especially in the very short term. Wind power is subject to sudden variations as a result of wind gusts, while PV generation is sensible to clouds passing over the panels. Both meteorological phenomena are common in the islands, and their effects in power output of RES plants increases by the fact that generation plants are geographically concentrated, as best performing areas are located in certain specific spots. Even without uncertainty in this case, the issue of variability, when it becomes extremely high, it is not easy to solve with no limitations or storage facilities.

Furthermore, the mix of RES technologies introduces a combined behavior during the daytime hours, which could differ from the expected when there is only wind or solar present.

In order to securely operate the power system, an analysis of the RES generation have been carried out by the TSO, whose results characterize the general behavior of RES and the operational needs in terms of reserves, flexibility and requirements to the conventional generation units.

*C. Network congestion*

A raise in RES installed capacity leads to a new distribution of generation along the power systems that could imply changes in how the energy flows through the current transmission network infrastructure, changes that could lead to congestion in certain situations.

Over the last years the TSO have been working on the necessary transmission network developments (mainly new substations) that were identified as needed, in order to make it possible for the new RES plants to evacuate their energy production.

Nonetheless, once recent RES plants have entered into operation, and with new developments being announced, a set of future possible congestion scenarios needs to be assessed, identifying the needs for new transmission network development as well as the actions needed in terms of thermal generation or RES curtailment requirements to solve N-1 contingencies, and therefore, comply with the current grid codes.

*D. Synchronous generation requirements due to balancing*

In order to reach a high RES penetration scenario a key enabling factor is the flexibility of the power system itself. This flexibility can be provided by different services and/or technologies, such as energy storage, demand side management schemes, EV integration and flexible thermal generation units.

Despite there are several major energy storage initiatives in progress in the Canary Islands (i.e. Pumped storage hydro plants), they are not in operation so far. This fact, together with the lack of extensive demand side management services, and the very low penetration of EV infrastructure, makes the flexibility requirements rely on the thermal generation plants.

Those thermal plants were designed some decades ago, in a totally different context, and therefore their technologies, sizes and related characteristics do not necessarily cover the flexibility needs of a high RES penetration system.

There is actually a rather strict RES integration limitation due to high technical minimum of thermal units and long start-up, stop required times that prevent some specific units to be disconnected, as demand coverage in the morning hours could be compromised.

An overall analysis of the different thermal dispatch scenarios needs to be performed, in order to identify those that allow for larger RES penetration keeping the system safe at the time generation costs are optimized.

Those four challenges make up the basis of a set of coordinated studies that will be presented in the following sections, and whose final objective is to determine generation dispatching and real time operation criteria in order to maximize RES integration while assuring supply and keeping the system parameters within security margins.

## III. SYSTEM-WIDE STUDIES

REE, in its role as the TSO responsible of security and guarantee of supply in the power systems of the Canary Islands, performed a coordinated set of studies in order to face the abovementioned challenges. The results showed that a set of requirements need to be covered in order to maximize renewable generation while keeping the power systems running within security margins.

Figure 4 shows a schematic view of the performed studies and how the different analysis link to each other.

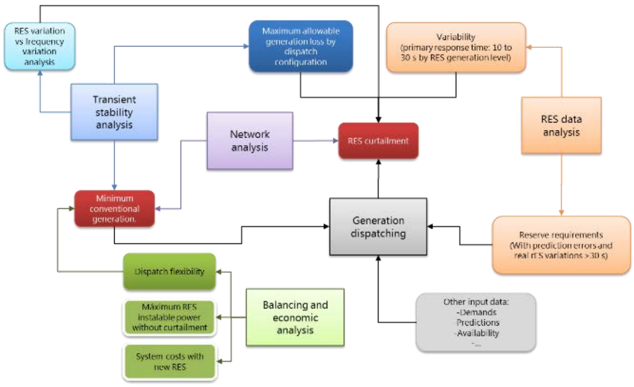


*Figure 4 Studies and their interrelation*

A description of the methodology is detailed in the following sections.

### *A. Transient stability analysis*

In an electrical system, the power demanded and the renewable generation vary, being it necessary to have regulation mechanisms in order to maintain real time balance between generation and demand. These regulation mechanisms are also necessary to deal with sudden imbalances between generation (renewable and conventional) and demand. In the first seconds or milliseconds, the additional energy will be extracted from the kinetic energy stored in the rotating masses of the system, whose speed of rotation will experience a variation that is reflected in the same proportion in the frequency of the system. All of this occurs as long as the power supplied by the turbine in each generating unit is not modified.

The power generated in the power plants is controlled in three levels. In each generating unit the speed of the group is controlled by the turbine speed governor; this constitutes what is called primary regulation, whose response, together with the inertial response, will be evaluated in the transient stability period.

To avoid reaching the boundaries of system stability, a load shedding plan could be implemented to return the system to a stable balance point after a significant impact on generation.

The new renewable scenario in the Canary Islands could cause significant imbalance. This means that determining the minimum conventional synchronous generation is necessary to ensure that, in case of the event of disconnection or sudden variation of the renewable generation, the frequency does not reach values that cause load shedding.

This will allow to define the minimum number of running thermal units to comply with the inertia and with the primary regulation requirements. This must-run is a minimum to ensure system stability. However this must-run by itself cannot determine the renewable gap due to the fact that other aspects have their influence in the minimum generation profile.

Several levels of demand have been evaluated based on the most common configurations, taking into account the power units flexibility and the hypothesis of the sufficient availability of spinning reserve.

Furthermore, it is necessary to postulate the contingencies to consider in the analysis, which are:

- Generation loss is simulated without electrical short circuit. The value of this loss is according to the maximum production associated to thermal unit disconnection or the maximum variation of renewable energy.
- In addition, simulated ramps of maximum wind and photovoltaic production obtained in the renewable variation studies:
    - Maximum negative ramp.
    - Maximum positive ramp.

The results have been evaluated by establishing the acceptance criteria through the definition of frequency boundaries admissible by the electric system.

Additionally, the physical model has been tested with real data obtained from historical events of sudden imbalance of real generation-demand situations.

As a result, the study provides a set of valid thermal units' configurations which have to be confronted with other restrictions and conditions. These other conditions reduce the amount of possibilities to a few feasible cases according to other requirements related to power balance and network constraints.

### *B. RES generation variability analysis*

The vast majority of renewable power in the Canary Islands is based on wind and photovoltaic generation. The nature of the primary resource implies an inherent degree of uncertainty and variability in this sort of RES generation that has a direct impact in how the power system is operated. This impact is especially significant in the context of isolated power systems that are generally weak and prone to incidents.

It is therefore necessary to study RES generation variability at different timeframes, in order to quantify the expected impact in the primary and secondary reserve requirements, and determine, in case they are needed, the necessary curtailments defined by the maximum allowed generation loss that the system is able to cope with.

Several methods are available in order to quantify the RES ramp rate and variability that need to be addressed by the thermal generation units. Figure 5 shows 4 different alternatives taken into account.

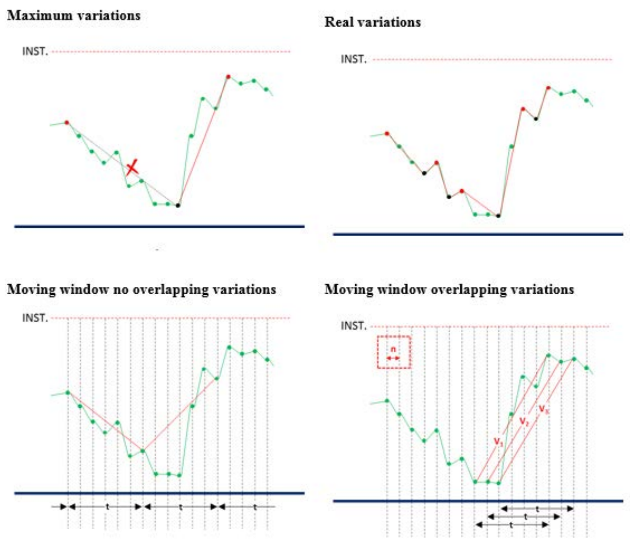


*Figure 5 Four different alternatives to quantify RES variations*

The "real variations" method has been selected in this study, assuming that "noise" in the data series has minimum impact in variations with great ramp rates, and it actually do not duplicate or omit values.

The "maximum and minimum" values have been matched with forecast values to identify secondary reserve values.

And finally, the "moving window variations" help to determine the primary and tertiary reserve requirement.

A special role on this analysis is the one played by the wind power prediction tools, whose error magnitude is critical in order to guarantee the amount of reserve established by the grid codes. The first set of studies carried out analyzed renewable historical variability, scaled up to the expected installed capacity, together with the error from wind power predictors.

*1) Renewable variability and wind power prediction: secondary reserve requirements*

This study cover variations longer than 1 minute along a renewable data series and the hourly forecast data almost 2.5 years long.

Those combined studies led to a set of curves from which, based on the predicted wind generation, it is possible to identify the secondary reserve requirements. As a result, it has been concluded that, for RES generation below a certain value of installed capacity, the reserve requirement needs to be equal to the current production. For higher production rates a more relaxed reserve requirement it is found to be enough. The inverse requirement is identified in the case of down spinning reserve.

*2) Secondary reserve "quality": ramp rates*

In terms of the ramp rate requirements (in MW/min) for the available reserves, an analysis of wind power variations from historical data have been performed. The probability density function and distribution of the data analyzed show that most of the ramps are below the thermal units' capability threshold.

Ramps rate relation to RES generation levels have also been studied, revealing that higher variation rates are not frequent.

This expected ramp rates could lead to extra conventional generation requirements, depending on the current RES generation level, needed in order to keep system's frequency deviations within the margins specified in the applicable grid codes.

For lower RES generation levels, despite thermal generation could be not fast enough to follow extreme RES variations, severe frequency deviations are not expected.

*3) Renewable variability: primary reserve requirements*

From the point of view of the system requirements in terms of primary reserve, an analysis of RES historical data have been performed, focusing in short term variations, that is, within 10, 20 and 30 seconds interval. In this occasion the "moving windows overlapping variation" method from Figure 5 was found to be more suitable for the purpose of the analysis.

A total of more than 3 million variations along wind and PV time series were analyzed, classifying them both by magnitude and by level of RES generation when de variation itself appeared. The analysis was performed individually for wind, individually for PV, and for the combination of wind and PV.

It has been found that observed increases and decreases in 30 seconds intervals are always below the response capacity of the thermal units.

As a conclusion, with the RES capacity in service at the end of 2018 this should not be a problem in terms of primary reserve. Having said that, continuous analysis is being performed and, with the expected future capacity increase, this statement must be re-evaluated.

*4) Renewable variability: tertiary reserve requirements*

The forecast data analysis as well as the renewable variation for over 30 minutes reveal the low firmness of renewable energy (Figure 6) and the difficulty of forecasting due to two special characteristics: the high concentration of renewable plants; and the special geography of Canary Island and the very specific weather conditions in the archipelago.

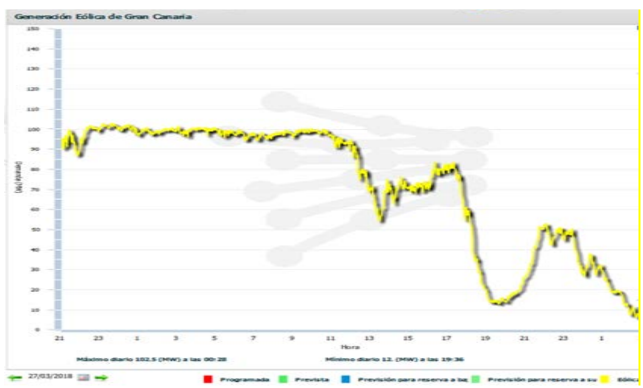

*Figure 6 Wind power variation along a day*

There is no guaranty of power, so the system need to have enough generation to reach the peak, and therefore enough tertiary reserve is needed to face this variability.

### C. Network limitations studies

During recent years, and in accordance to the planned electricity infrastructure, the transmission network of the isolated systems at the Canary Islands have been reinforced, in order to make the evacuation of new RES generation possible.

In that sense, the TSO has built several new substations close to the zones where the wind and solar resource is more abundant, and therefore enabling new RES developments in those areas.

In both grids, the main thermal generation plants (Tirajana in Gran Canaria and Granadilla in Tenerife) are located in the south east coast of the islands, the same spot where RES development is more intense. This leads to a situation in which almost all generation is at the same location within each of the power grids.

Despite this transmission grid update [6], which is still ongoing, the recent commissioning of new RES plants along year 2018 together with the announcement of new RES tenders in the short term have triggered the analysis of new future scenarios, in order to properly identify possible issues at the most affected power systems, that is, Gran Canaria and Tenerife.

The identified issues, all of them raised in the so-called N-1 situations, have been assessed. As a result, several situations and their associated contingency measures have been identified for each of the specific power systems:

The assessments performed in those specific studies, evaluated at different possible demand and generation scenarios, have concluded t the capability of the transmission network for the short term, as main issues are expected to arise in very specific situations, and contingency measures are available.

It must be noticed that the performed studies targeted years 2018 and 2019, where planned RES penetration is still rather moderate. A different situation is expected in the 2025 year scenario, much more extreme in terms of planned RES development, and therefore subject to future analysis in the matter.

### D. Minimum synchronous generation due to balancing restrictions

This study contemplates the impact on the definition of the minimum generation due to the power balance motivated by the increase of the renewable generation in the electrical systems of Gran Canaria and Tenerife.

The aim is to determine the minimum generation, considering all the aspects related to the technical conditions of power units, as well as the systems security constraints, which are considered essential in order to not leave the electric system in a risky situation.

Conditions for the coverage balance, such as starting, stopping and running times, as well as other factors related to the reliability of certain aspects of the generation (such as the coupling of conventional groups), impose minimum generation requirements that can be translated into limitations of renewable production.

This minimum generation may rise limitations based on the necessary reserve resulting from the dispatch that is determined, once the rest of the requirements and restrictions described in the previous sections have been considered.

In an electric system with a generation mix such as Tenerife and Gran Canaria, where several technologies coexist, the analysis of the balance plays an important role in the unit commitment determination that guarantees compliance with the balance of coverage in the short and medium term.

In electric systems without energy storage capacity, it is necessary to provide that management capacity through the system spinning reserves. In this sense, primary reserve helps to maintain the transitory stability, secondary reserve to absorb the deviation in short-term and return frequency to nominal values and tertiary reserve to replenish the margin of secondary reserve.

Each type of reserve needs a specific response, so this is the main reason to develop an analysis focused on the thermal units' parameters.

The parameters analyzed are mainly:

#### a) Start-up time

This parameter plays a fundamental role in the management of the power dispatch. It defines the minimum notice time that must be considered in order to dispone a unit participating in the power dispatch. This anticipation, in systems with high renewable integration is essential and decisive to define the power dispatch criteria. In this respect, any advance or delay may represent, respectively, either a limitation on the renewable generation higher than initially envisaged or an up spinning reserve defect.

Units with higher values cannot be considered as tertiary reserve.

#### b) Shutdown time before start-up

This thermal condition is associated to the thermodynamic cycle of this kind of units and it has as a consequence a temporary unavailability along the time specified in this condition since shutdown has occurred.

This parameter has a significant importance in the daily management of the power generation dispatch and also in the determination of the groups that must remain permanently running, due to their cyclical use not being viable in order to achieve the correct levels of security and guaranty of demand coverage.

When these times are excessively high, making a daily management is impossible due to the high daily difference of demand between peak and valley for the electrical systems of Gran Canaria and Tenerife, as well as the high level of renewable penetration.

The uncertainty is not only present in renewable production, but also plays a fundamental role in the power dispatch. Opting for the shutdown of manageable generation can seriously compromise the stability of the system. All of this is controlled through the reserve requirement that came from the renewable variability and forecast error.

#### c) Running time before shutdown

This thermal condition is associated to the thermodynamic cycle of this kind of units and it has as consequence a temporary must-run along the time specified in this condition since start-up has occurred.

*d) Shutdown time*

The shutdown of thermal units cannot be immediate, so it is a constraint to define the minimum time of notice to consider in power dispatch management.

This restriction can produce, in case of supervening increase of renewable generation that is not absorbed by down spinning reserve, the curtailment of renewable energy temporarily until the generation shutdown materializes.

Some technologies are more sensitive to this problem, with longer periods needed to shutdown these units. Others a lower requirement.

Both systems have a similar generation structure. In Gran Canaria and Tenerife, there are four types of technologies with similar installed capacity:

- The steam turbines.
- The gas turbines.
- The diesel engines.
- The combined cycles.

The unit commitment considering all of the aspects above has as a result a combination of units in accordance with security requirements, minimizing the variable costs.

Another necessary step is the validation of the above criteria, introduced all of them as an input to the unit commitment. Consequently, simulation cases are needed in order to consolidate the criteria. Therefore, several monthly scenarios have been analyzed in representative periods of the year, combining profiles of demand and renewable, and different kinds of renewable integration levels.

The results of these monthly scenarios are evaluated considering two situations:

- Planned situation: represents how the following day (D+1) power dispatch faced viewing from the perspective of the current day, using the demand and renewable series expected.
- Real situation: simulates the same scenario by introducing real series for demand and renewable energy considering that those power units with limited flexibility may not be amended, so its state is fixed in this simulation.

If it was not possible to reach a feasible solution in real time, it would be necessary to reevaluate the instrumental margin of reserve and the considered must-run, in order to ensure the system security.

In accordance to the requirements of transient stability and balancing reliability the results are a must-run with steam turbines and combined cycles as a minimum. These results are strongly linked to the system structure of generation, the uncertainty of renewable energy (with very high dependence of the placement of renewable energy –very concentrated in Canary Islands) and the behavior of the consumption (big gap between valley and peak).

Figure 7 show some examples of daily planning scenarios:

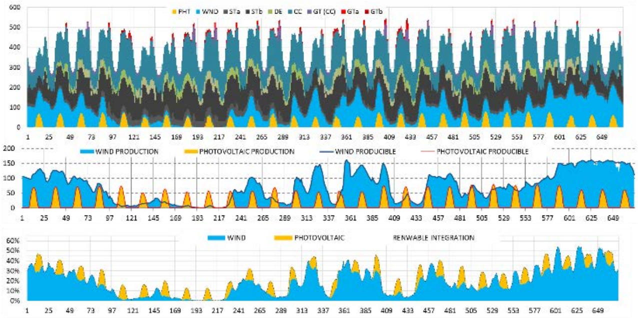


*Figure 7 Examples of daily planned scenarios*

- First figure shows the mix generation dispatch analyzed in a period of four weeks
- Second figure shows the renewable profile not accumulated.
- Third figure shows renewable integration in percentage against demand.

Figure 8 shows an example of daily real scenarios with similar information and for the same period are as follows:

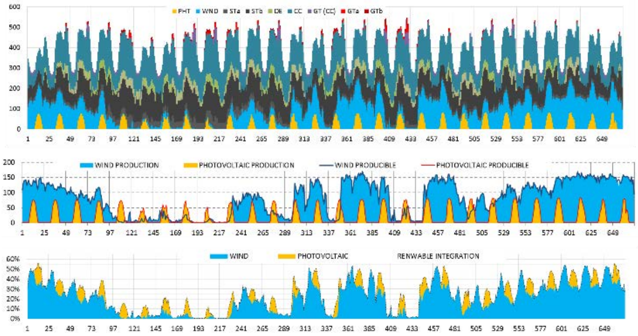


*Figure 8 Example of daily real scenarios*

The empty area in the third figure shows some renewable energy that has to be controlled through the control production tools available. This energy cannot be integrated in the system.

## IV. Conclusions

A large development of new RES facilities is planned in the Canary Islands, in its transition to a decarbonized future. This transition, which started along year 2018, implies a significant increase of installed renewable capacity in the short term, and an extremely challenging scenario in horizon 2025.

In order to guarantee an effective operation of the power system on the near future, and anticipate bigger issues in the longer term, the Spanish TSO has led a set of studies which address four main issues:

- System stability
- Uncertainty and variability of RES generation
- Network congestion
- Balancing requirements

Results showed that certain specific measures need to be taken into account:

- The analyses of RES variability at different timeframes has led to the definition of the new primary, secondary and tertiary reserve requirements, which is now dependent on the RES generation level, and not only tied to the possible loss of the biggest running unit.
- Additional considerations have been introduced, in order to keep the necessary reserves at the time of increasing the room for RES generation, by reducing the technical minimum associated with the must run units. Those actions mainly involve manoeuvers in units with daily flexibility of adaptation to power dispatch necessities.

The decision on steam turbines are conditioned to specific situations associated to the demand, power unit's availability and the long term renewable forecast.

The most flexible units have and specific role linked to tertiary reserve.

- A set of must-run units due to balancing restrictions has also been identified. Those limitations, imposed by the operating limitations of the physical thermal units.
- Requirements of minimum must-run units have been identified by means of transient stability analysis, performed for both, traditional severe contingencies on one side, and the estimated most critical sudden loss of RES generation on the other, for the short term scenarios.
- Several additional countermeasures, mainly the connection of fast units, have also been determined, has they have proved to be a useful resource to reinforce the power system in specific scenarios of high variability of the system's frequency.

On top of the complete catalog of solutions and modifications to the current operation schemes that have been obtained, the work carried out has produced, as an additional result, a complete set of software tools. Those tools will allow both, the continuous monitoring of the efficiency of the defined actions, as well as future analysis as long as the potential envisaged scenarios change.

After implementing into the control room procedures several of the abovementioned measures, the system have reached integration levels over 50% in several hours. This integration level is strongly dependent on the mix generation available in each moment and its flexibility, as well as to the uncertainty and variability of renewable energy, which is connected to the power capacity installed and the physical location of this facilities.

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