Crete Power System

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Abstract— **this paper presents the current state of the electrical system of Crete operating with high penetration of Wind Farms and PV Parks. During the last 25 years a significant number of Wind Farms and PV Parks were installed on the island. The System Operator confronted lots of experiences and new lessons were learned on controlling islanded system with high RES penetration.**

Keywords-RES; Islanded Power System; Wind Farms; PV Parks; Power System Operation

I. Introduction

Last December (2018), the EU reached a political agreement on the new Electricity Regulation and Electricity Directive. EU updates its energy policy in order to facilitate the clean energy transition. The new agreement will empower European consumers to become fully active players in the energy transition and fixes new targets for the EU for 2030:

32% Renewable energy target
32,5% Energy efficiency target
15% Interconnection target of the electricity market
45% Emission reductions relative to 1990

The drivers for implementing renewable energy transition are the increase of the renewable resource potential, new technologies and the policy support. As it is written in [1] “The road to a climate neutral economy would require joint action in seven strategic areas: energy efficiency; deployment of renewables; clean, safe and connected mobility; competitive industry and circular economy; infrastructure and interconnections; bio-economy and natural carbon sinks; carbon capture and storage to address remaining emissions”.

Crete has an electrical isolated power system. Although Crete has begun the transition to clean energy, petroleum is still imported to be burnt in conventional power plants. A percentage of 85% of electricity on the island is produced from conventional steam turbines, internal combustion units, gas turbines and one combined circle power plant. Heavy oil and Diesel oil is the fuel to be burnt.

The wind and solar potential in Crete is among the largest in Europe [2].After the liberalization of the RES electricity market and the subsidy from the EU and National Funds, many companies proceeded with the installation of Wind Farms. During the last 25 years, 202 MW of Wind Farms were installed in Crete. Wind Farms contribute up to 17% of the annual energy production until now. Remote real time monitoring systems have helped the rise of the Wind Power penetration and the secure operation of the System.
Real time reliable communication helps operators trust the computer applications to automatic curtail the surplus power. Continuous monitoring, protection tuning and WF’s operational improvements contributed to a greater utilization of the wind potential and a more economical operation. The annual capacity factor of the Wind Farms reaches an average of 30%. Some WFs in good positions reach an average of 40%.
The first Greek legislation for PV was introduced in 2006 offering generous feed-in-tariffs (a premium for selling green electricity to the grid) and setting the details for legalization and authorization of PV systems. The Regulatory Authority for Energy (RAE) in Greece set a limit of 100 MW of PV parks to be installed in the fields of Crete in the countryside. The reason was the week islanded system, the Technical minimum of the conventional Units and the high Wind installed power. Until now, 97 MW of PV Parks are installed in the fields and on the roofs in Crete Island. The annual capacity factor of the PV Parks reaches 20%.

The energy of all the PV parks covers much of the morning every day peak throughout the year, and has stabilized the voltage in the villages in the countryside. PV production covers 13% of the Daylight consumption of the island and 4,5-5,5% of the annual consumption. Annual RES electricity energy penetration reaches 25% [3].

I. Wind Farms

Since 1993 when the first Wind Farm (WF) was installed by PPC SA (Greek Public Power Utility) in Sitia, 202 MW of WFs are installed in Crete. This is equivalent with the 20% of the total installed power capacity (Figure 1, 2).

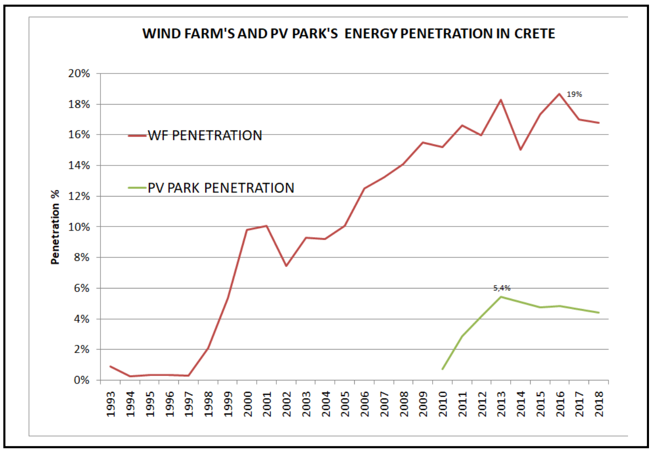


Figure 1. Installation of Wind Farms during the last 25 years

As soon as the first WF was installed, a tailor-made digital communication protocol was developed in order to get 'live' data in the Dispatching Center SCADA system and send upper limit set-points to the WFs. Since 1992 a SCADA and LFC (Load Frequency Control) system is under operation in the Dispatching center of Crete. The WF management system was embodied in the existing SCADA system.

Control applications for the WFs send set-points every 2 minutes and determine the maximum output of each WF. The applications take into consideration the Technical Minimum of the power units in operation, and the maximum allowed penetration of the WFs which is ranged around 30-40% depending on the weather conditions or other distractions of the grid.

The algorithm works like a decision tree: The Actual set-point to the WFs is the Minimum of:

- System Load- Sum of the Technical Minimum of the conventional Units
- System Load* C% (allowed penetration) = System Load* 30-40%
- Installed WF capacity

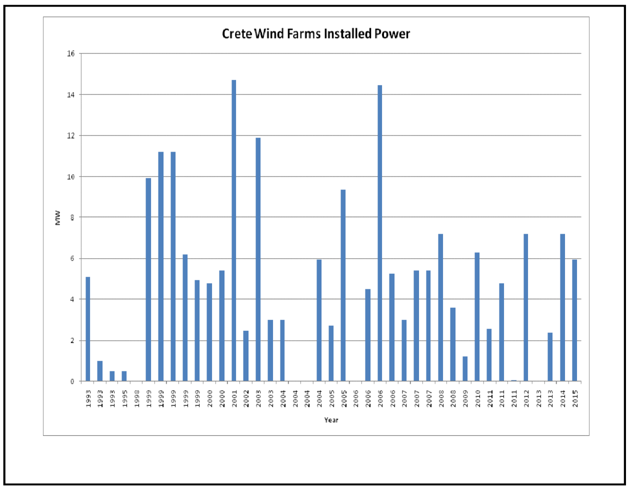


Figure 2. Installation of Wind Farms during the last 25 years

Depending on the technology, the output power of the WF is restricted in various ways:

- By stopping some Wind Turbines,
- By adjusting the pitch control Wind Turbines
- By means of power electronics

The instantaneous penetration percentage can be reduced down to 10 % or less, if weather conditions or other system security reasons are required. After many years of tuning of the protection settings, upgrade and maintenance of the interconnection lines of the WFs with the substations, and better specifications of new WFs, a impressive improvement of the System Operation was observed. The new WFs are equipped with 'Fault Ride Through' protection, and may withstand the sudden voltage deeps during grid faults and prevent the frequency from collapsing.

II. PHOTOVOLTAIC PARKS

The massive installation of the Photovoltaic Parks in Crete began during 2009. The most PV Parks were installed during 2010. Now the installed power of the PV Parks verges on 97 MW. The most of them are distributed in the fields with max power 80 kW each, and around 17 MW are installed on 1500 roofs.

It was a big necessity to install a system in order to monitor all this power. Thirty (30) PV Parks were chosen to be monitored. The PV Parks were chosen in order to satisfy the need to have a good representation of the type (fix or rotating trackers) and of the region where PV Parks are installed. A device collects data from one PV Park's active and reactive power output every 20 sec using the pulses of the electricity meter and sends it via mobile phone GPRS with GPS coordinators to a main server. The server collects all data and a moving average is used to smooth out short-term fluctuations and highlight longer-term trends. The voltage quality throughout the countryside has been improved during the last years due to the PV parks.

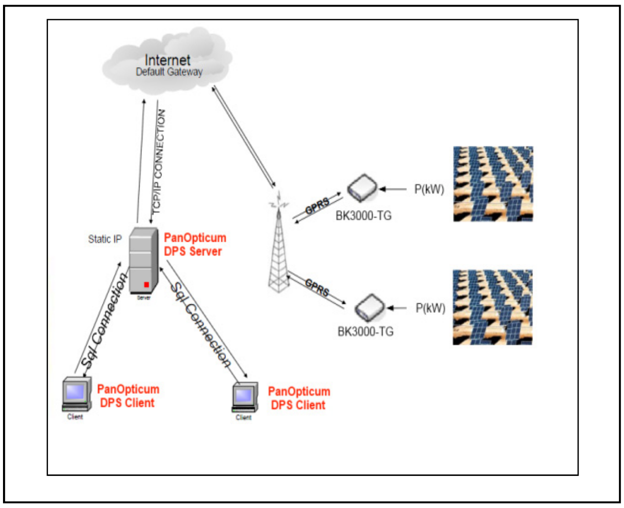
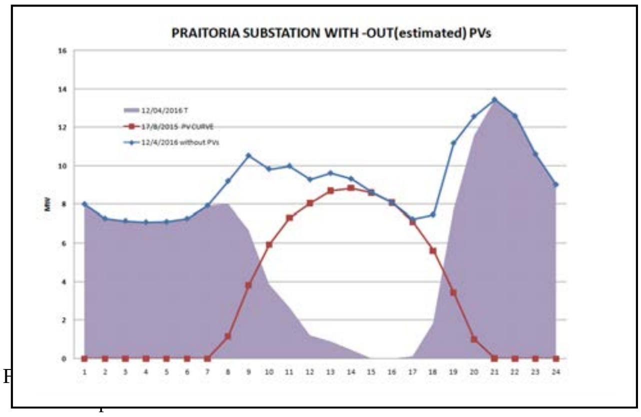


Figure 3. PV Monitoring system Architecture



The PV monitor system architecture consists of the following sections: Telematic devices which are installed in representative Photovoltaic Parks and collect measurements, a server with the appropriate software which is responsible for storing the data from all photovoltaic power plants, and the interface for the control and supervision of power plants in the local control centers (Figure 3).

The software features are: Vector Map display from PV Power Plants, display power output PV station in real time (active power last minute), power summations effect of different PV station in real-time, power curve last hour for each PV station.

The server Up-scales the data, taking into account the type and the place of the telemeter PV Parks. The final estimated value is accumulated to the power system load, and this is the load value used in the Dispatching Center of Crete. A similar installation is developed in the island of Rhodes where 17 MW of PV Parks are installed.

There are big fluctuations due to clouds in each PV Park during winter period. But the high dispersion combined with the low installed power in each PV Park contribute that the total production has no effect on the system frequency, and the total production appears smooth without sharp fluctuations (Figure 4).

The total estimated energy by the installed system has an accuracy 3-4% comparing with the real production measured by the energy meters.

III. Operational Difficulties

High RES, low Loads

After the economic crisis, the electricity demand in Crete the last ten years stopped increasing with the rate of 5% used to be the last 20 years. Demand remained stable or decreased. There were years when the peak load was decreased by 3.5%! The operation of the conventional units during the fall and especially during winter 2012-2014 was difficult: Low loads, high wind production, high Photovoltaic Production and high Technical Minimum of the conventional units were a production and demand mixture difficult to manage without energy storage (Figure 6, 7).

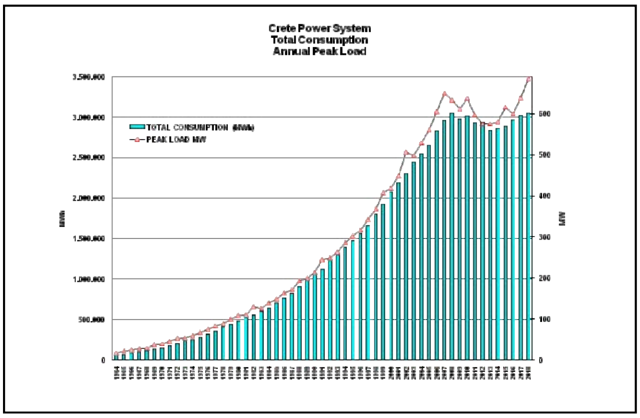


Figure 5. Crete Power Comsumption

Lack of Communication

During the windy nights although a big effort to improve the communication with the Wind Farms was made, lack of communication with WFs forced the operators to open the circuit breakers of the interconnection lines of the big farms. Lack of Digital Communication during windy nights results in lack of upper limit production of the WFs. Uncontrollably production is then injected into the system, the frequency arises, and the System is in danger.

The last two years Internet layer is used for the communication with the Wind Farms. ADSL lines, Satellite Internet for the Wind Farms and Mobile telephony for the PV monitoring.

Solar Production takes part of the WF's energy share

Another difficulty occurs when solar production is very high and the Technical Minimum of the conventional Units is so high that Wind Farms should be curtailed.

Due to the uncontrollable PV Park production there are daylight hours when Wind Power energy cannot be absorbed. This energy is estimated that reaches 2-4% of the WF energy production potential. After the massive installation of the PV Parks the curtailments of the WFs were increased from 8-10% to 10-14% (Figure 7,8,9,10).

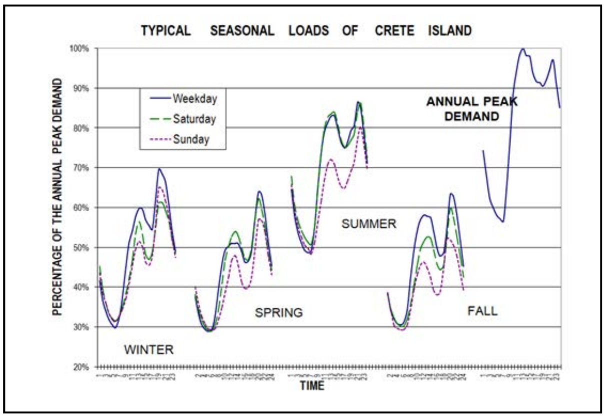


Figure 6. Typical Seasonal Loads of Crete System

IV. CONCLUSION

Crete is a living lab to examine the impacts of high RES penetration on an island. The simultaneous operation of 300 MW RES and 800 MW conventional Units Installed Power in a system of 700 MW Peak Load and 330 MW Mean Load with big differences between night and day Loads is a successful story of a high RES penetration islanded system.

Uninterruptible real time communication with all the power sources is essential for the reliable, safe and stable operation of the system.

The PV up-scaling production simulation system produces satisfying results.

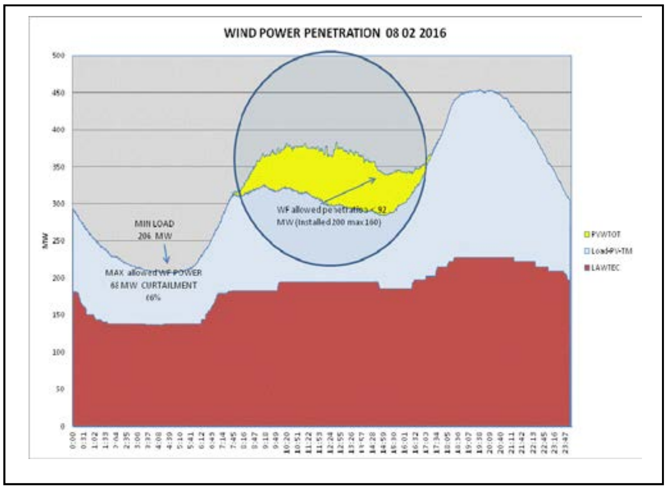


Figure 7. High PV Penetration

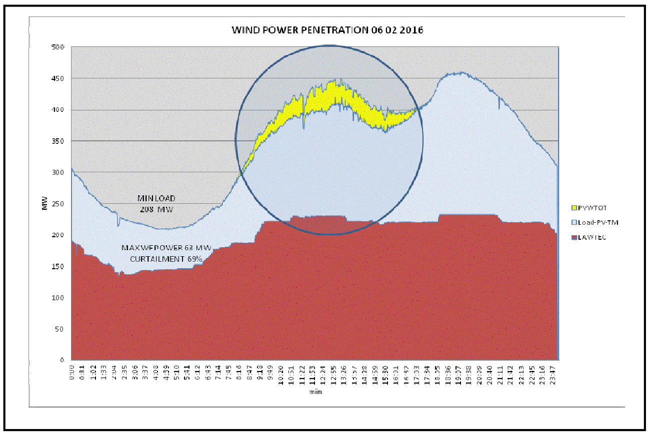


Figure 8. Low PV Penetration

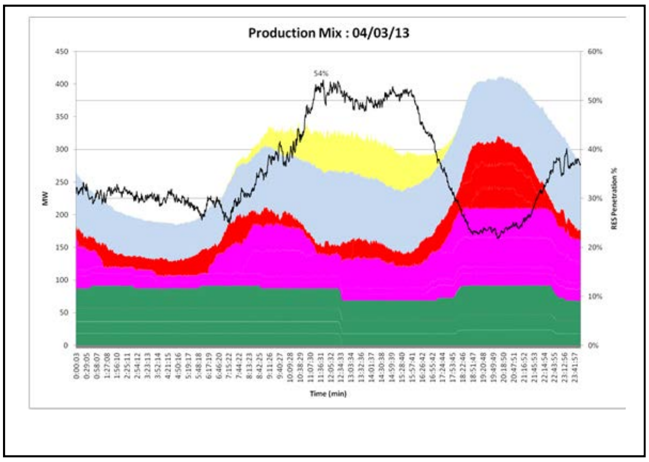


Figure 9. High RES Penetration in Crete.

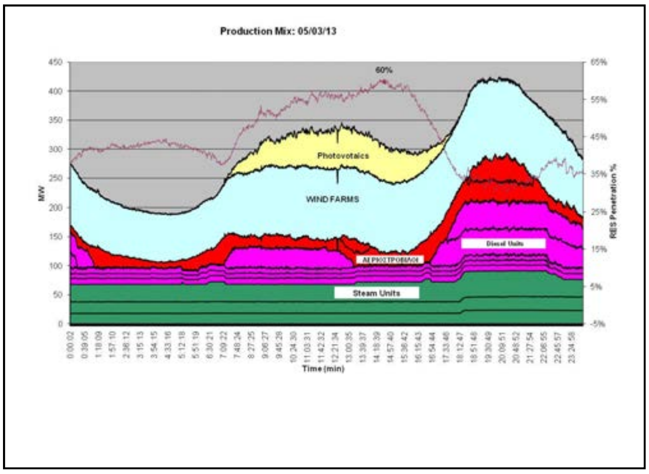


Figure 10. Very high RES Penetration in Crete.

V. ACKNOWLEDGMENT

- HEDNO SA ,

- Crete Dispatching Center Operators.

VI. REFERENCES

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[2] https://www.globalwindatlas.info/

[3] ΕΤΗΣΙΟ ΔΕΛΤΙΟ ΕΚΜΕΤΑΛΛΕΥΣΗΣ ΣΥΣΤΗΜΑΤΟΣ ΚΡΗΤΗΣ 2018/ ΔΕΔΔΗΕ/ΔΔΝ/ΤΑΚΕ