2013 IREP Symposium-Bulk Power System Dynamics and Control –IX (IREP), August 25-30, 2013, Rethymnon, Greece

# Renewable Energy Sources in Crete

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## Abstract

This paper presents a picture of the current state of the electrical system of Crete. During the last 15 years a significant number of Wind Farms and Photovoltaic Parks were installed in the island. The instantaneous and annual penetration of RES soared to heights that rival the levels of Spain and Germany. New experiences gained from managing these energy sources in isolated systems..

## Introduction

Renewable energy supplied last year 16% of the global energy consumption (includes bio fuels and hydroelectricity). Fossil fuels share 81% of the Global Final Energy Consumption, and nuclear 2, 8 %. Wind, solar, bio fuels and geothermal energy account only for 5, 4%. The share of renewable energy in global electricity production reaches 20%; the no-hydro renewable is 3,3% when 67, 6% comes from fossil fuels, and 16, 3 % from Hydro. In the island of Crete the Wind and Solar Energy share of Electricity production climbed to 19,5 % in 2011! And 20,6 % in 2012.

As it is known, the wind and solar potential in Crete is among the largest in Europe. After the liberalization of the RES electricity market and the subsidy from the EU and National Funds, many companies rushed to install Wind Farms. During the last 15 years 184 MW of Wind Farms were installed in Crete. Wind farms after the first difficulties contribute up to 17% to the annual energy. Remote monitoring systems have helped the rise of the Wind Power penetration and the secure operation of the System. With continuous monitoring, protection and operational improvements a greater utilization of the wind potential and a more economic operation can be achieved.

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 authorization of PV systems. The Regulatory Authority for Energy (RAE) in Greece allowed 100 MW of PV parks to be installed in the fields of Crete in the countryside. Up to now, 84 MW of PV Parks are installed.

The energy of all those PV parks covers much of the morning peak every day, throughout the year and has stabilized the voltage in the villages in the countryside.

## Wind Farms

Since 1993 when the first Wind Farm (WF) was installed in Sitia, 184, 5 MW of WF are installed in Crete which is the 20% of the installed power capacity. The island is powered by engines which burn fuel oil and diesel oil. There are no fossil fuels on the island, so around every 40 days ships supply oil to the three power stations. The Power Units are: Steam units, Diesel units, Gas turbines and one Combined Cycle in Chania. From the beginning of the establishment of the WFs, a new communication protocol was developed in order to get 'live' data in the SCADA system and send upper limit set-points to the WFs. In the Dispatching center of Crete a SCADA and LFC (Load Frequency Control) system are in operation since 1992. The new WF management system was embodied in the existing SCADA system.
Management programs for the WF were developed which send set-points every 5 minutes and determine the maximum output of WFs. They take into consideration the technical minimum of the 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.

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

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

The penetration percentage can be reduced down to 10 % if weather conditions or other system security reasons are

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required. After many years of operating improvements of the protection settings, preserving the interconnections of the WF with the substations, and better specifications of new WF a high improvement of the System Operation was observed. For example, the new WFs equipped with Fault Ride through protection, may withstand the sudden voltage deeps during grid faults and thus prevent the frequency from collapsing.

Another big step was the installation of a pilot system in the WF of 'Plastika Kriris ', which releases the Set-point if a frequency drop occurs. This system will assist the Cretan electrical system towards increased stability; while at the same time allow from time to time, the injection of extra power production from the wind farm to the system. More specifically, the newly installed algorithm will constantly monitor the system frequency. In case the frequency drops below a certain limit (due to sudden increase in power demand or decrease in production or other technical issues that may arise), and during a possible curtailment from PPC of the production of the specific wind farm, the system will immediately switch to Frequency Control mode. During this, the wind farm's power output will gradually increase in a linear way until the system has reached required stability. The wind farm will remain at this state of increased production for one hour.

In short, the main characteristics of the new system are:

• Range of operation 48 up to 49, 8 Hertz
• In case of under-frequency, the active power set point issued by PPC is overpasses
• Algorithm will help system stability and increase production
• Algorithm is in test phase and under constant development

It is obvious that the experience of this pilot system may contribute to the adaptation of a kind of frequency-control systems in the Wind Farms. The uncertainty of the Wind Output, the lack of a system to support the frequency deviations and the sensibility to faults are the obstacles to increase the penetration in small islanded systems. The technology gave solutions to repair the voltage sensibility through the FRT protection. Another big step will be a frequency support system during the windy periods.

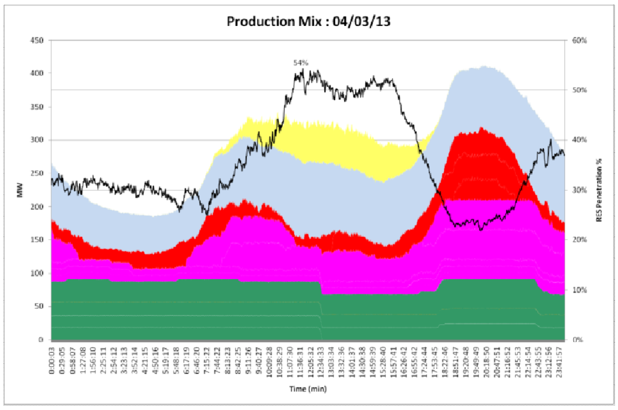


Fig. 1: High RES Penetration in Crete

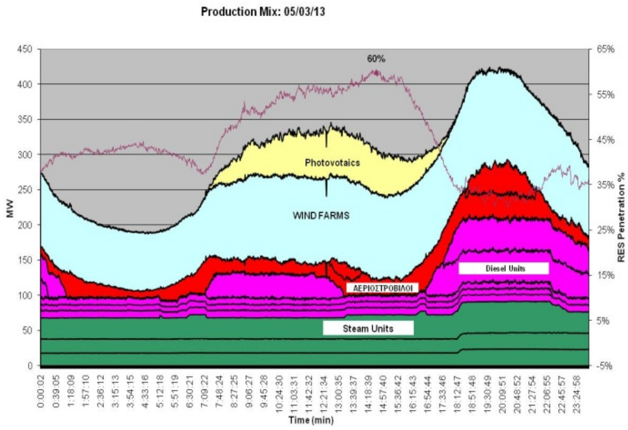


Fig. 2: Very high RES Penetration in Crete.

## Photovoltaic Parks (PV Parks)

The massive installation of the Photovoltaics 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 87 kW each, and around 10 MW are installed on 1000 roofs. In the beginning of the operation of the PV Parks, it was an misimpression that the load was reduced during the sunshine hours and even that a big change of the morning peak time in Crete was occurred which is normally between 12-2 PM depending on the season.
So it was a big necessity to install a system in order to monitor all this power. Twenty (20) 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 of the active and reactive power every 20 sec using the electricity meter and sends it via mobile phone and GPS to a main server. The server collects all this data and a moving

average is used to smooth out short-term fluctuations and highlight longer-term trends. Although the power produced by an individual PV Park imposes fluctuations in the grid during winter, the size and the dispersion of the PV Parks don't influence the total system. In the contrary the voltage throughout the countryside is more stable improving the power quality during the last years.

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 the last months in the 'Rhodes' island where 15 MW of PV Parks are installed.

There are big fluctuations due to clouds in each PV Park during winter period. But the wide dispersion and the low power installed 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. With a larger sample size information will be closer to reality.

The system architecture consists of the following sections: Telematic devices which are installed at some 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.

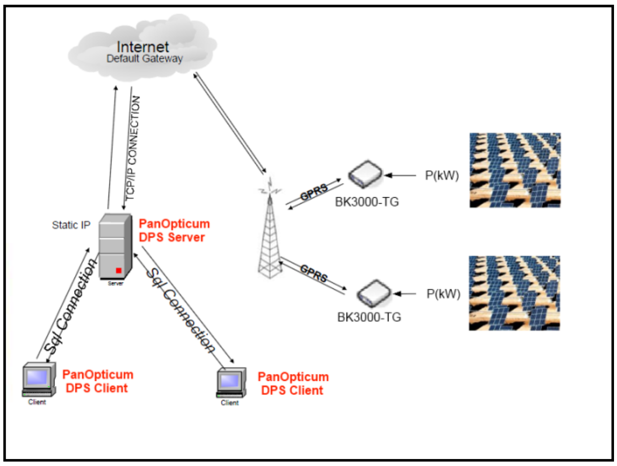


Fig. 3: PV Monitoring system Architecture

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.

## Operational Difficulties

During the last three years Greece confronted the most severe economic crisis during the last 50 years. The prosperous island of Crete wasn't able to resist. The high summer loads were decreased, tourism was diminished, people tried to live using less money. In addition with the above, the weather was changed. No boiled days during the summer and very mild winters.

The electricity demand the last three years stopped increasing with the rate of 5% of the last 20 years, stayed stable and the last year decreased! The peak load was decreased 3,5%! The operation of the conventional units during the fall and especially during winter 2012-2013 was difficult to be settled: Low loads, high wind production, high Photovoltaic Production and high Technical Minimum of the conventional units. During the windy nights although a big effort to improve the communication with the Wind Farms was occurred, the lack of communication of some WF forced the operators to open the circuit breakers of the distribution lines of the big farms. Lack of communication during windy nights means that Set-points for the maximum allowed production aren't able to be transferred to the Wind Farms. That means that uncontrollably production is injected to the system and the frequency arises! The System is in danger! And the operators confront nightmares!

## Conclusion

Crete is a live lab to examine the impacts of high RES penetration. May be it's time to review the way we operate such small islanded systems with low loads and high RES penetration! A solution maybe is to keep less conventional units running, to decrease the spinning reserve, decrease the security but decrease also the cost!

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