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Energías Renovables y Eficiencia Energética
Desarrollo Sostenible de África Occidental e Islas de la Macaronesia

Gorona del Viento Wind-Hydro Power Plant

Results, Improvement Actuations and Next Steps

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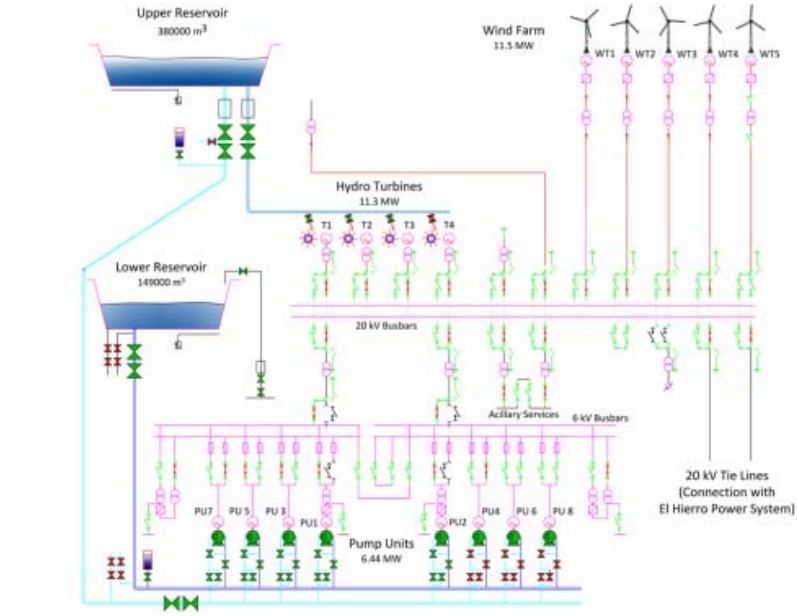

Gorona del Viento Wind Hydro Power Plant

- **Wind Farm; 5 Enercon 2.3 MW turbines.**
- **Water reservoirs.**
  - **Lined with high density polyethylene membrane**
  - **Higher reservoir 380.000 m³**
  - **Lower reservoir 149.000 m³**
- **Penstocks.**
  - **Turbine pipe of 2.3 km and 1 m of diameter**
  - **Pump pipe of 3 km and 0.8 m of diameter.**

- **Hydro turbine station. 4 Andritz Pelton turbines of 2.83 MW (flow 0.5 m³/s).**
- **Pump Station.**
  - **2 pump units of 1.6 MW (0.178 m³/s), controlled by frequency converters.**
  - **6 pump units of 0.54 MW (0.058 m³/s), started by 2 frequency converters**

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Overall results

- **8 consecutive days covering 100 % of the Island demand in June 2017.**
- **79 % of renewable integration into power system in July 2017.**
- **18 consecutive days covering 100 % of the Island demand in January-February 2018.**

- **Continuous improvement process.**
- **Stakeholders sharing information**
- **Gorona --> Plant improvements**
- **REE –> Operational changes**
- **ITC, Endesa, Enercon, Andritz.**

Year	Saved Diesel (tons)	CO_2 reduction (tons)	Integration into power system (%)
2015 (From July up to the end of the year)	2099	4352.57	19.4
2016	5366	11629.56	40.7
2017	6070	13150.87	46.4

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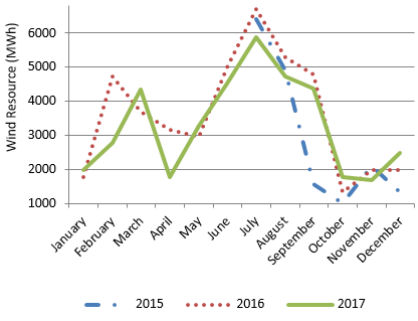
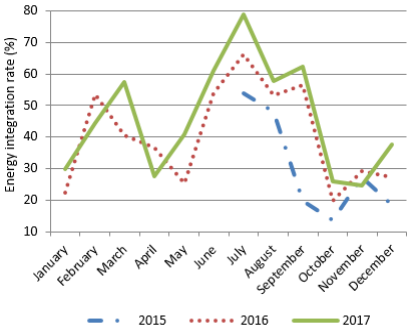
Overall results



Wind Resource



Energy integration into El Hierro power system

2018 integration			
Jan.	Feb.	March	April
66 %	57 %	49 %	71 %

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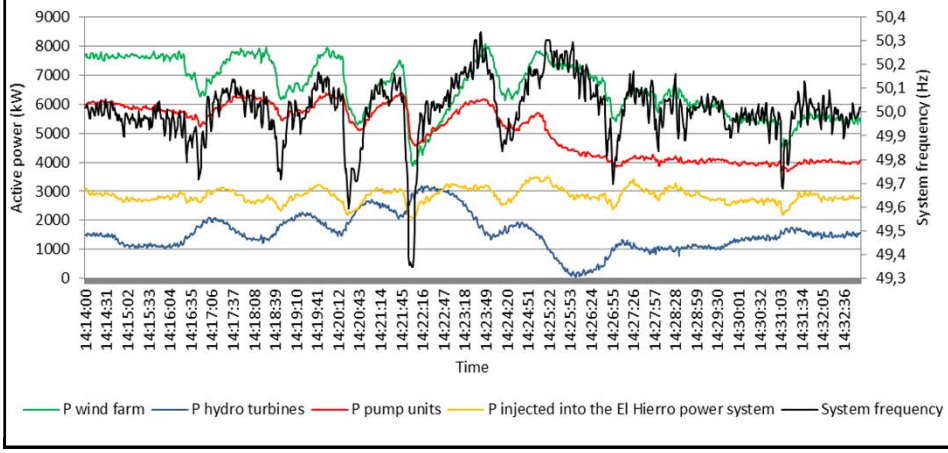
Wind ramps - Frequency Control

- **11.5 MW Wind Farm > 7 MW of El Hierro Peak load → The wind ramps have a big impact on the system**
- Tertiary regulation, the TSO, REE provides a weekly/daily/hourly power dispatch
  - System Security and Stability
  - Economic criteria.
  - Modified with the real time wind resource.
- Secondary regulation – Response time → seconds to minutes.
  - REE sends an active power setting for wind farm, that is given to the Farm Control Unit.
  - Hydro and pump units receive active power setting in their speed governors and frequency converters according to the dispatch and an automatic generation control device corrections.
- Primary regulation – Response time → few seconds.
  - Hydro turbines and diesel generators, through speed governors.
  - Pumps, through frequency converters (case of pump units driven by converters)
  - Wind farm primary regulation is, nowadays deactivated
- Pump shedding – Response time → 100 ms.
  - Underfrequency
  - ROCOF; df/dt

Pump Shedding

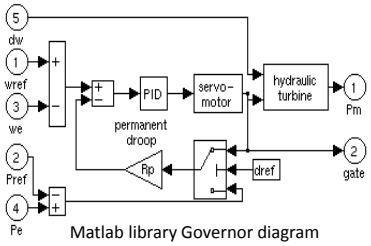
Primary regulation in Hydro turbines <u>was</u> not enough

- Pump shedding necessary to ensure the security of the system
- Impact to system performance (50%)
- Pumps life -- More than 700 trips due to underfrequency in 2017!!



Actuations - Improvements

- Speed Governor Logic
- Wind farm Active Power setting treatment



Matlab library Governor diagram

Speed governor logic

- Primary regulation limit

  Load/generation unbalance → Frequency deviation→ Speed governor action –> needle actuation –>
  –> traveling pressure wave (water hammer) → Pressure oscillations–>
  –> Mechanical power oscillations–> frequency oscillations

  Speed governor action is limited by pipe pressure oscillations.

- New Logic and retuning
  - DAMPER: Design and implementation of a damper to mitigate the pressure waves in the turbines penstock.
  - PID: Retuning of the PID gains of the hydro turbine speed governor, that allows a better hydro turbine response when a wind ramp or outage of others generators occur.
  - DEFLECTOR: New setting of the hydro turbine deflector in order to improve the hydro generator response during an over frequency event as well as the performance of the damper.

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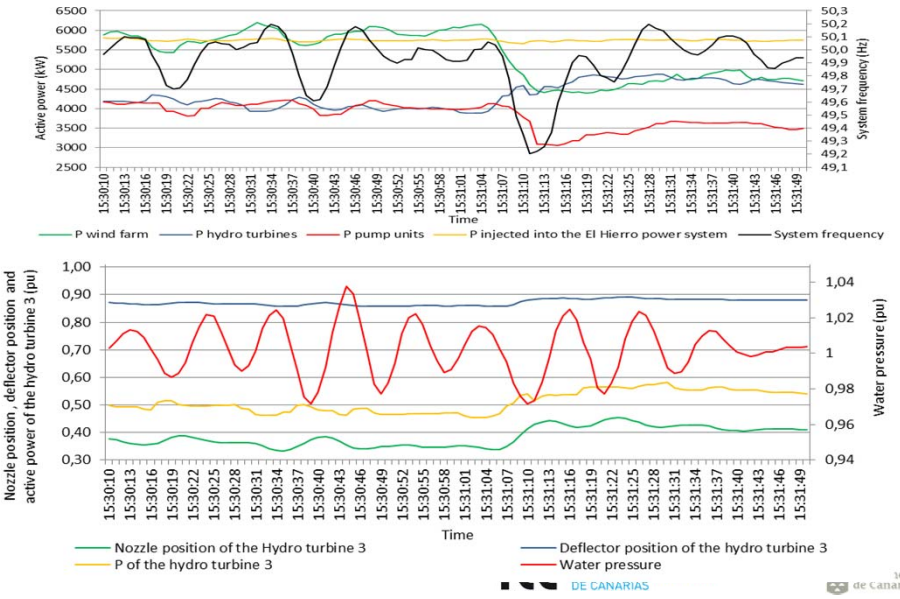
Speed governor logic



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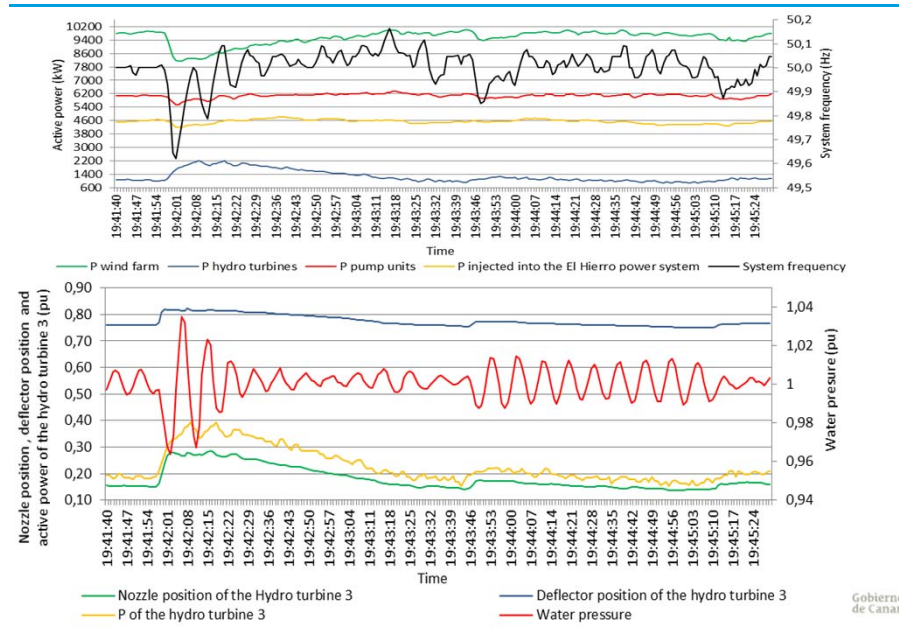
Speed governor logic



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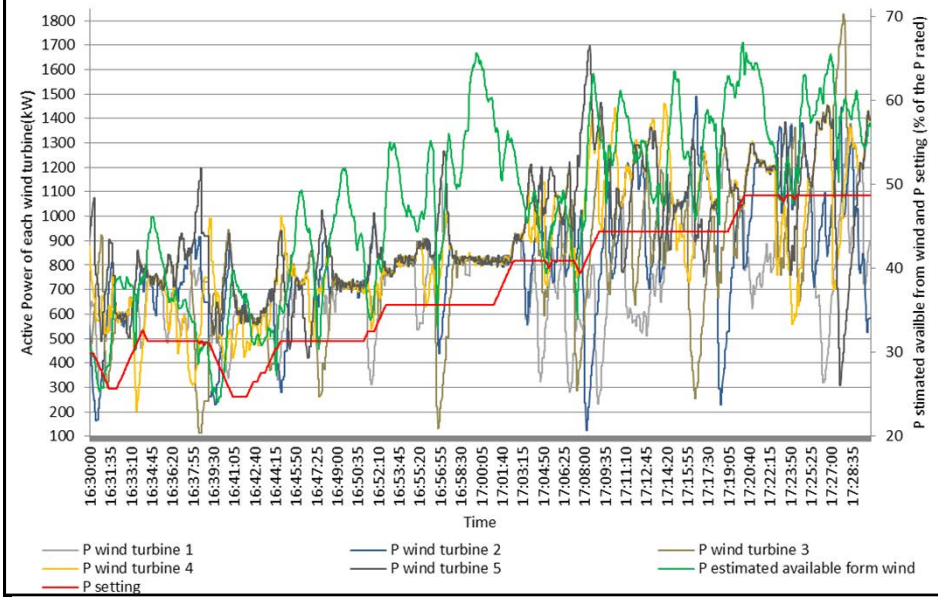
Wind farm active power setting



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Conclusions and next steps

- Continuous analysis of the system. Collaboration between REE and Gorona is better for the system, because it is easy for the actors to detect, analyze and solve problems.
- More confidence in the plant frequency regulation.
  - 80 % of pump shedding reduction (more reduction with more than 2 Pelton Turbines dispatched)
  - Performance increases →Same system security with less pumps
  - It seems production increases
- Next steps
  - Synchronous compensator
    - Response improvement (damper)
    - Diminish water consumption
  - Wind farm;
    - FCU enhance
    - Primary regulation
  - Short term forecasting; Machine learning.

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