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HS5.2 – Innovation in Hydropower Operations and Planning to Integrate Renewable Energy Sources and Optimize the Water-Energy Nexus

Towards energy autonomy of small Mediterranean islands: Challenges, perspectives and solutions

Athanasios Zisos, Maria-Eleni Pantazi, Marianna Diamanta, Ifigeneia Koutsouradi, Anna Kontaxopoulou, Ioannis Tsoukalas, Georgia-Konstantina Sakki, and Andreas Efstratiadis

Department of Water Resources & Environmental Engineering
National Technical University of Athens, Greece

Motivation: Ensuring energy autonomy for Sifnos island

Source: Wikipedia

General characteristics:

- Located in the western Cyclades complex
- Area: 74 km^2
- Permanent population: 3 203 inhabitants
- Up to 100 000 tourists during summer
- Major geological formation: Dolomitic marble

Source: Google Earth

Profile of current energy supply system:

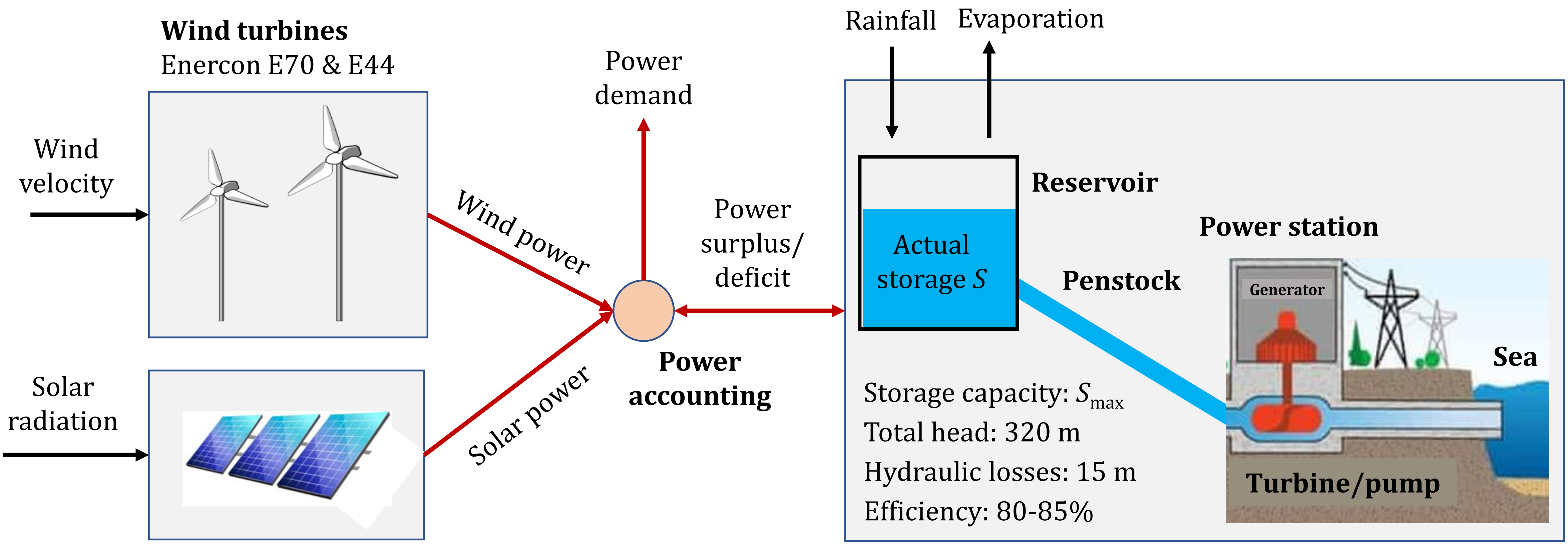
- Non-interconnected island
- Energy production from a 9.0 MW oil power station
- Small share from renewables (1.2 MW wind, 0.2 MW PV)
- Total annual energy demand (2021): **17.3 GWh**
- Peak energy demand (summer period): **5.4 MW**
- Projected peak demand: **8.0 MW**

Research objective: Design of a hybrid power system based on **seawater pumped-storage** and two **renewables** (solar, wind)

Sharing is encouraged

Further info: Katsaprakakis & Voumvoulakis (2018)

Conceptual scheme of proposed hybrid power system



Photovoltaic park
Number of panels: N_P
Nominal power: 340 kW
Panel area: 1.94 m^2

Setup of design optimization: Estimation of reservoir capacity and PV park size (number of panels) in order to maximize the anticipated net profit and system's reliability

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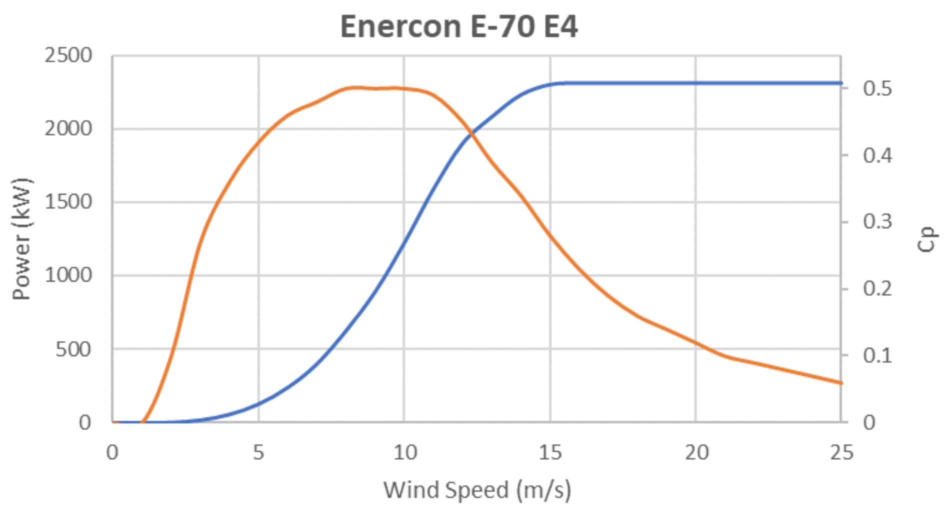
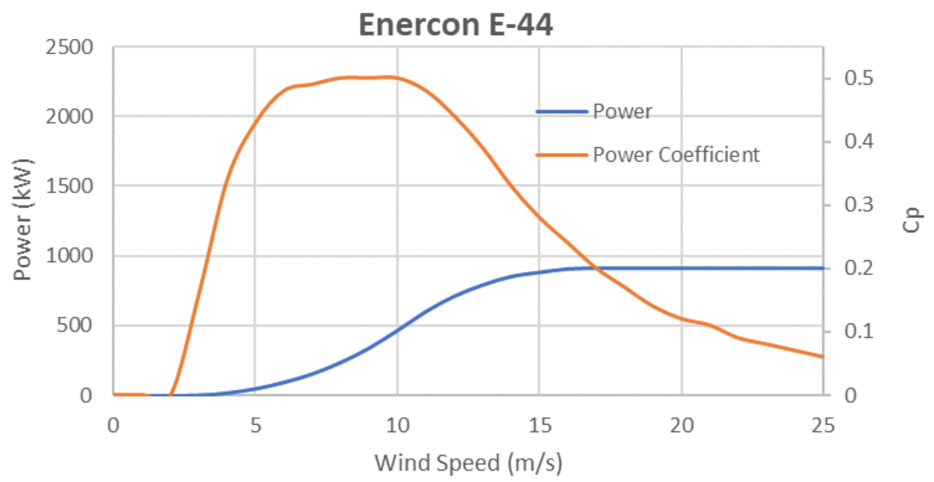
Stochastic simulation-optimization approach

- System driven by inherently uncertain processes, i.e., **meteorological** and **socioeconomic**.
- Stochastic simulation-optimization approach (Sakki *et al.*, 2022), by using the **anySim model** (Tsoukalas *et al.*, 2020) to provide **synthetically generated hourly data** for:
  - Wind velocity
  - Power demand (socioeconomic process)
- Application of a **typical annual profile** for other meteo-rological processes (solar radiation, rainfall, evaporation).
- System design optimization under **multiple input data scenarios of 10 years length**.
- Preliminary investigations impose the use of a suitable **turbine mix** to maximize the available wind potential (key challenge: avoid energy losses due to often **cut-offs**).



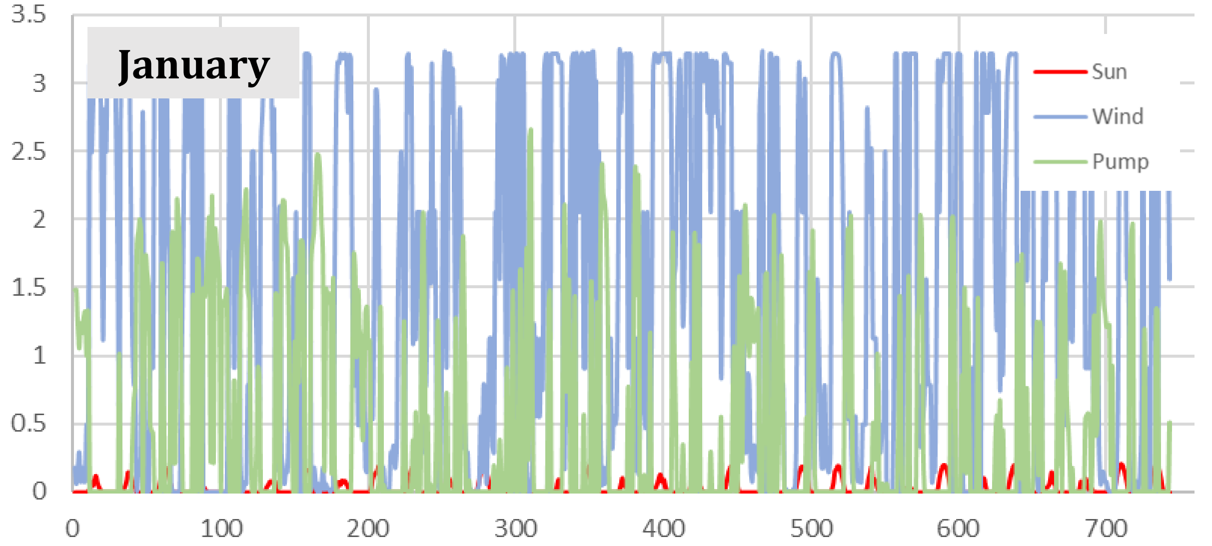


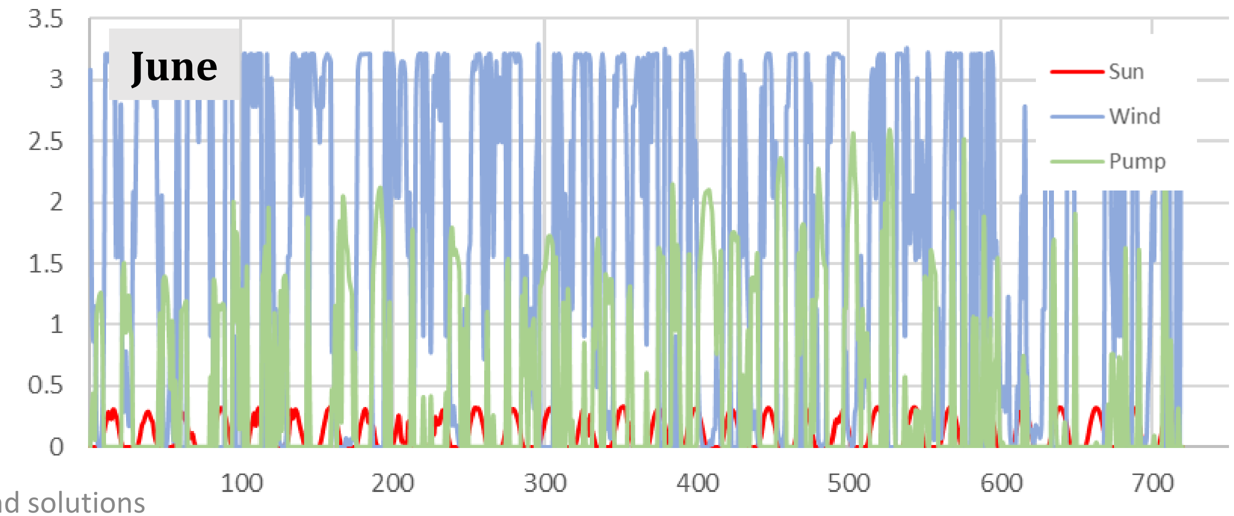
Outcomes of simulation procedure

System outputs:

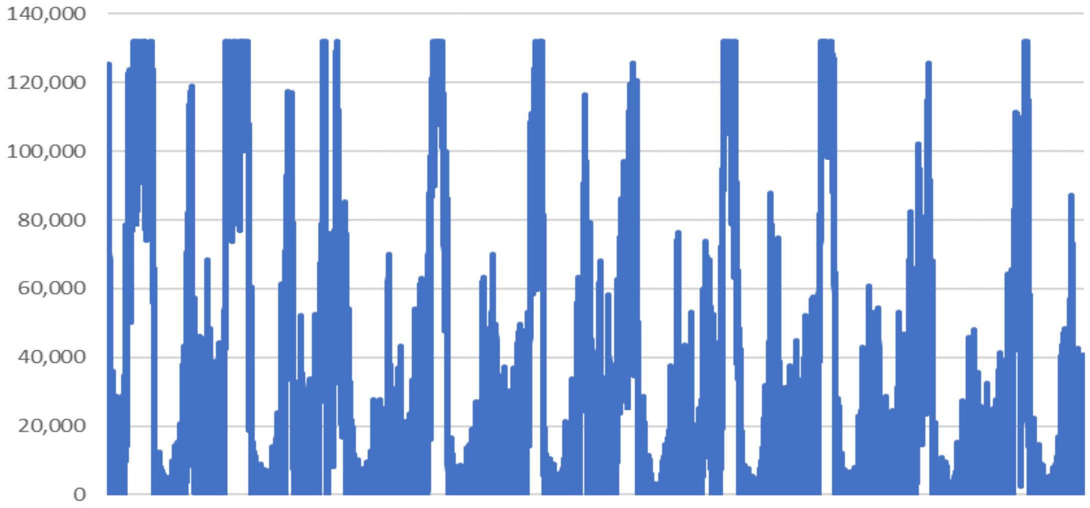
- Energy fluxes (power generation per source, power consumption due to pumping)
- Water fluxes (reservoir storage, penstock flow)
- Financial fluxes (depreciated construction costs, maintenance costs, energy production revenues)

Sharing of energy production (MWh)





Reservoir storage (m^3)



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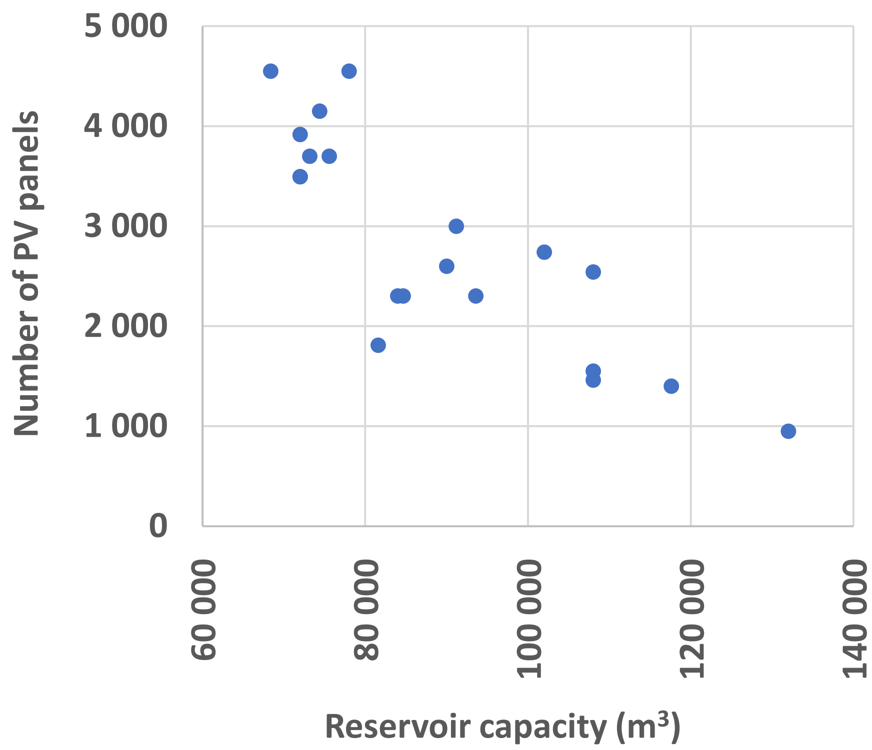
Optimization under uncertainty

- Investigation of two optimization settings:
    - **Setting A**: Minimization of system's failure probability (= frequency of power deficits)
    - **Setting B**: Full depreciation of investment costs for given time horizon
- The two settings provide substantially different results, yet setting B ensures a more economic design (impressive reduction of reservoir size, reduction of PV panels), with minimal decrease of reliability.
- Multiple combinations of optimized design variables, induced by wind and power demand uncertainty.

Summary results of the two stochastic optimization settings (mean values of synthetic scenarios, standard deviations in parentheses)

	Setting A	**Setting B**
Number of solar panels	3 587 (562)	2 825 (1 085)
Reservoir capacity	443 340 (170 019)	89 313 (17 914)
Reliability (%)	82.81 (1.22)	78.58 (1.51)
Investment costs (10^6 €)	30.60	19.60



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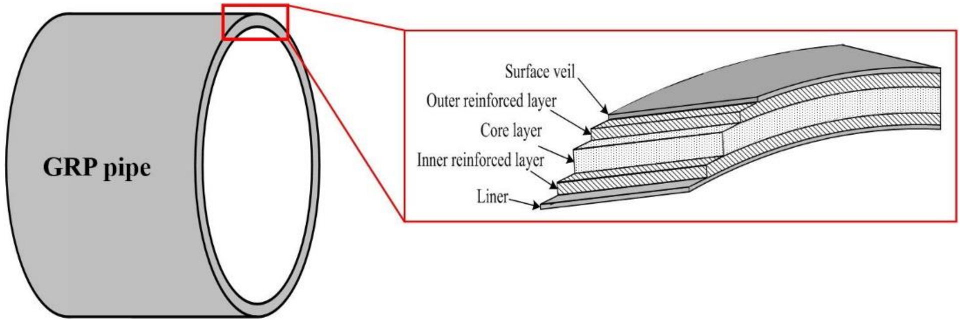
Other engineering challenges & provided solutions

Pipe erosion:

- Pipe material: GRP
- Significant reduction of friction losses
- Increased durability to UV radiation
- Achieving flow velocity within safety limits (0.6 – 6.0 m/s)



Source: Yoon and Oh (2015)

Tank waterproofing:

- Application of HDPE geomembranes
- High resistance in tension, puncture, environmental stress cracking and chemicals

Source: Plastika Kritis S.A.

Erosion of electro-mechanical equipment:

- Stainless steel equipment
- High resistance in seawater erosion

References

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