FOSS
Research Centre for Sustainable Energy

DIEGO
Development of quality system through EnerGy Efficiency cOurses

Co-funded by the Erasmus+ Programme of the European Union

University of Cyprus
PV Technology

Introduction to PV power generation forecasting

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- Forecasting Models
- Background and Objectives
- General Methodology
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- Day-ahead Forecasting Tool of UCY
- Forecasting Platform
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Introduction

What is a forecast? Why do we need to forecast the PV generation?

Introduction

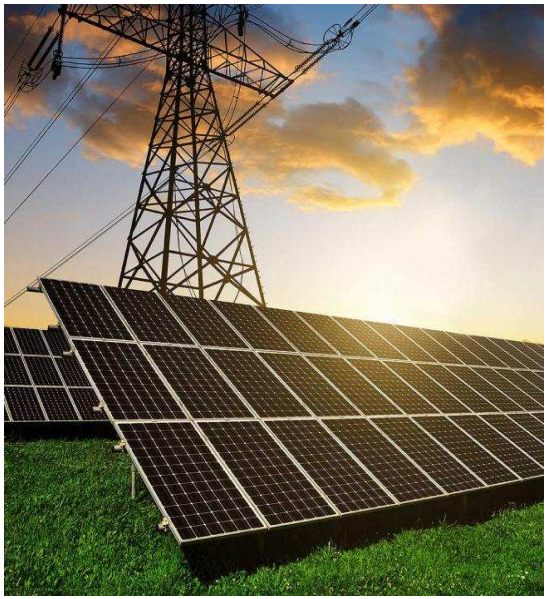
What is a forecast?

A forecast is an estimate of uncertain future events (literally, to "cast forward" by extrapolating from past and current data).

Introduction

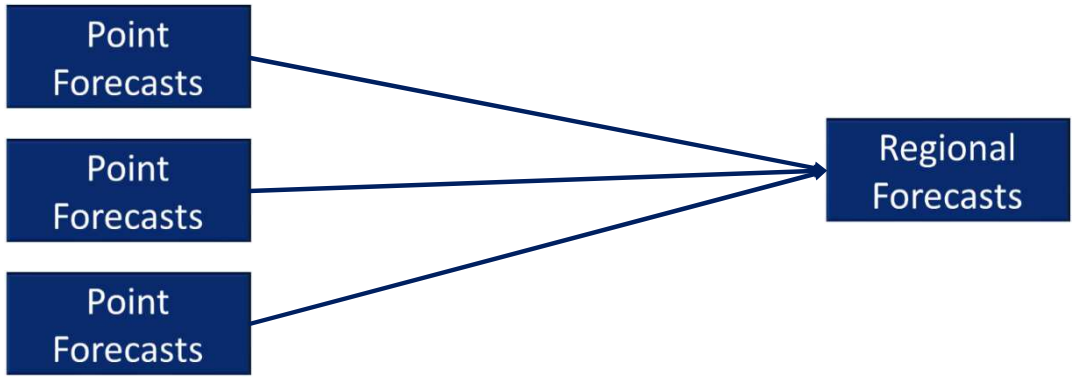
Why do we need to forecast the PV generation?

- PV production forecasting is essential because of the increasing number of grid-connected PV systems generation.
- Important for both grid and plant operators:
  - Ensures grid stability and dispatchability of the electric system (energy management and grid flexibility).
  - Advancement of commercialization for selling to the next day market.

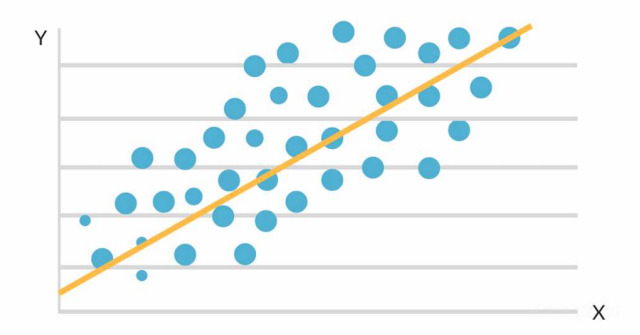


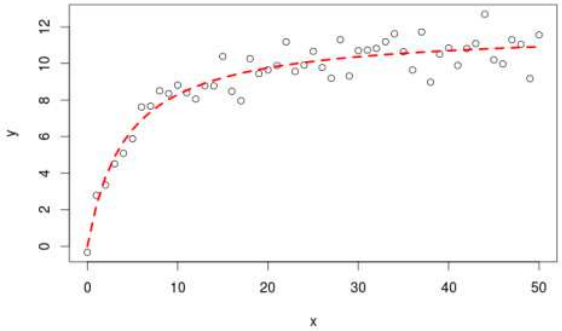
Introduction

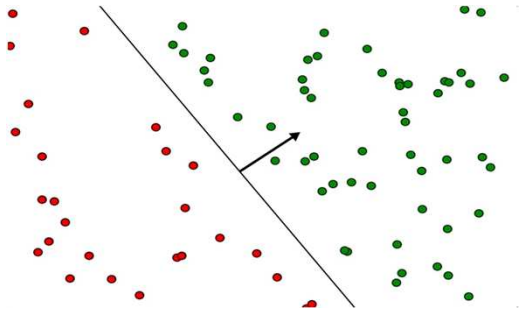
- Forecasts may apply to a single PV system (point forecasts), or refer to the aggregation of large numbers of systems spread over an extended geographic area (aggregated forecasts).

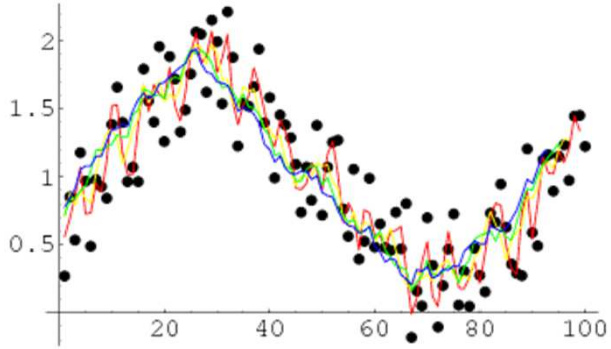


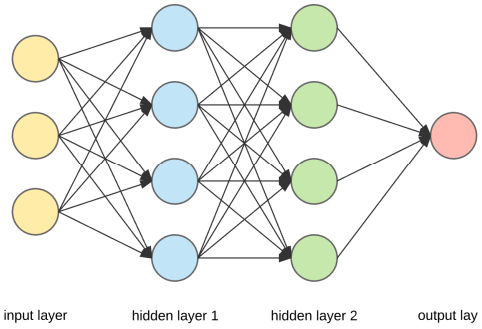
Introduction

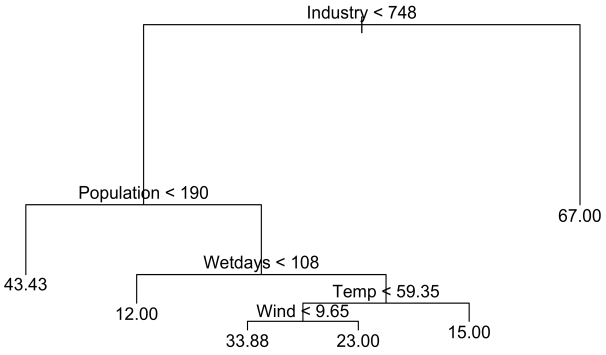






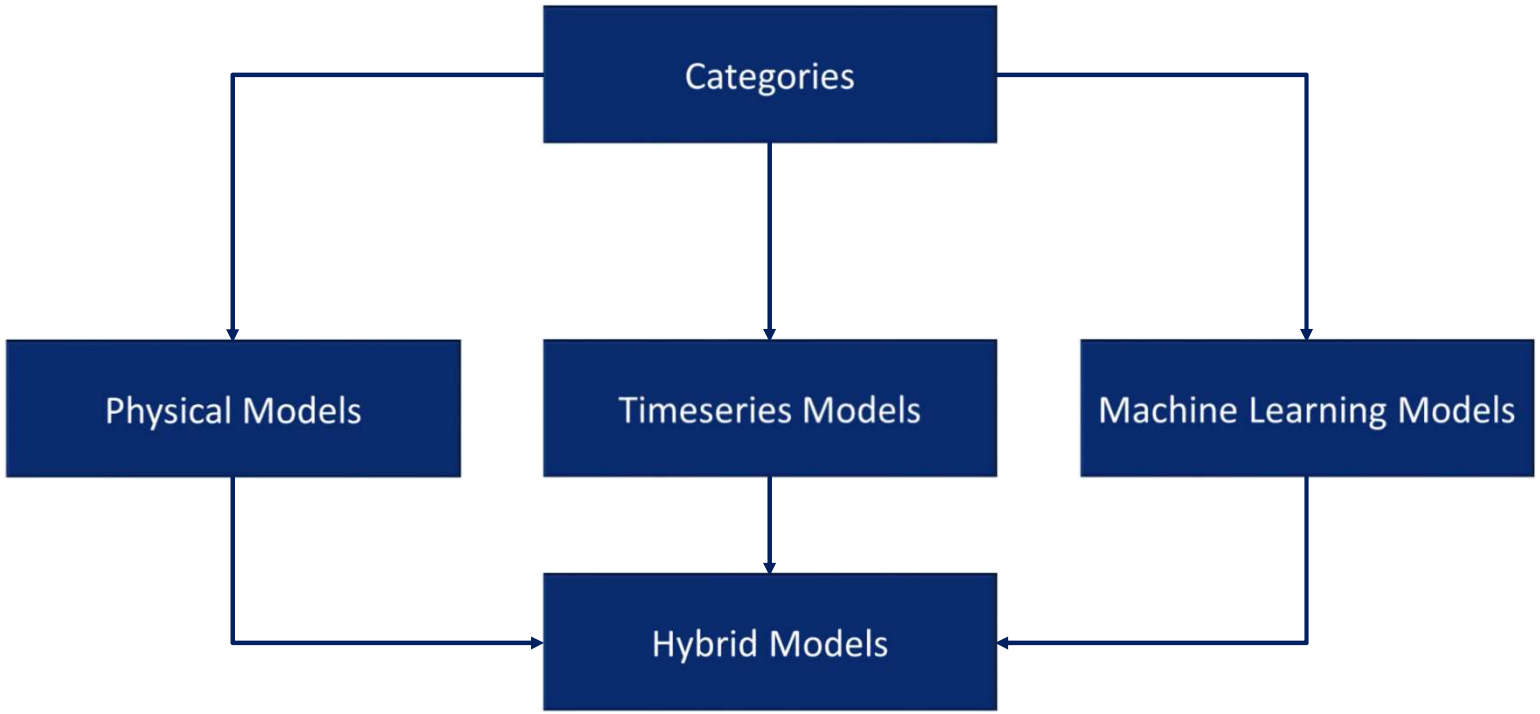






Risks of Bad PV Forecasting

Forecasting Models



Forecasting Models

Physical Models:

- PVWatts
- PV-GIS
- PV-USA
- System Advisor Model (SAM)

Forecasting Models

Timeseries Models:

- Autoregressive Moving Average Model (ARIMA)
- Spectral Analysis
- Wavelet Analysis
- Curve Fitting
- Nonlinear Exogenous Models
- Hidden Markov Models (HMM)

Forecasting Models

Machine Learning Models:

- Artificial Neural Networks (ANN)
- Support Vector Machines (SVM)
- Regression Trees (RT)
- Gradient Boosting Machines (GBM)

Hybrid Models:

- A combination of various models to provide optimal forecasts.

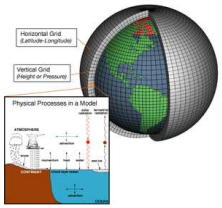
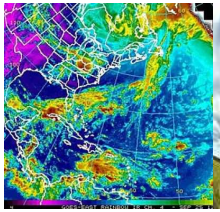
Background & Objectives

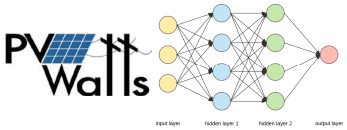
- **The focus is to provide accurate PV production forecasts for point sites in the range of 5 % (nRMSE).**

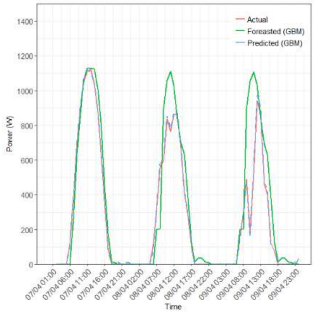
Specific Objectives

- Develop approaches to yield accurate forecasts.
- Prove whether the forecasting accuracy can reach state-of-the art levels
- Establish a PV power forecasting tool that will also act as a multi-agent system for active grid management.

General Methodology





Weather Forecasts

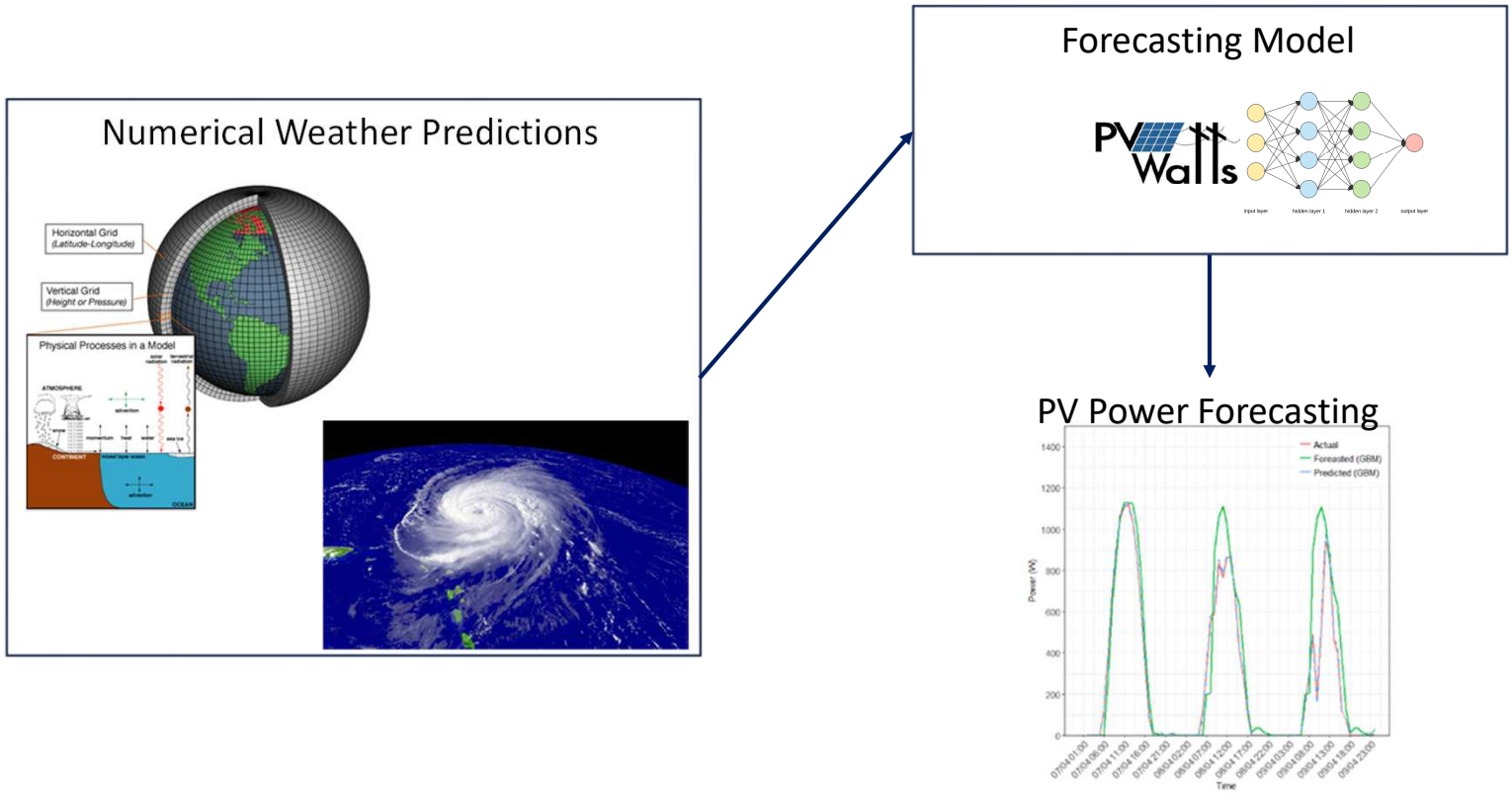
PV System Characteristics and Measurements

Forecasting Model

Forecasted PV Power

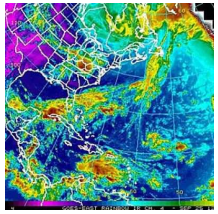
Input **Processing** **Output**

Mid-term Forecasting (1 to 4 Days Ahead)



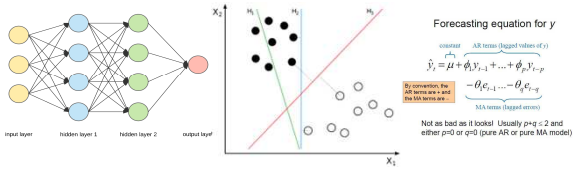
Short-term Forecasting (1 to 10 Hours Ahead)

Input Parameters

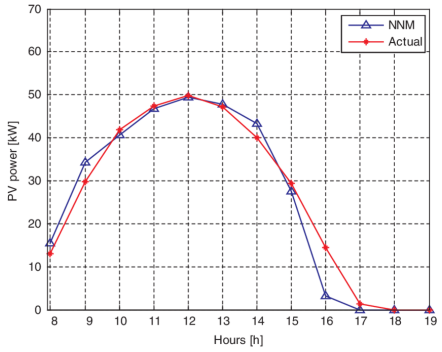


$$P_{DC}(t+n) = G_I(t) + T_{amp}(t) + \ldots$$

Forecasting Model



PV Power Forecasting



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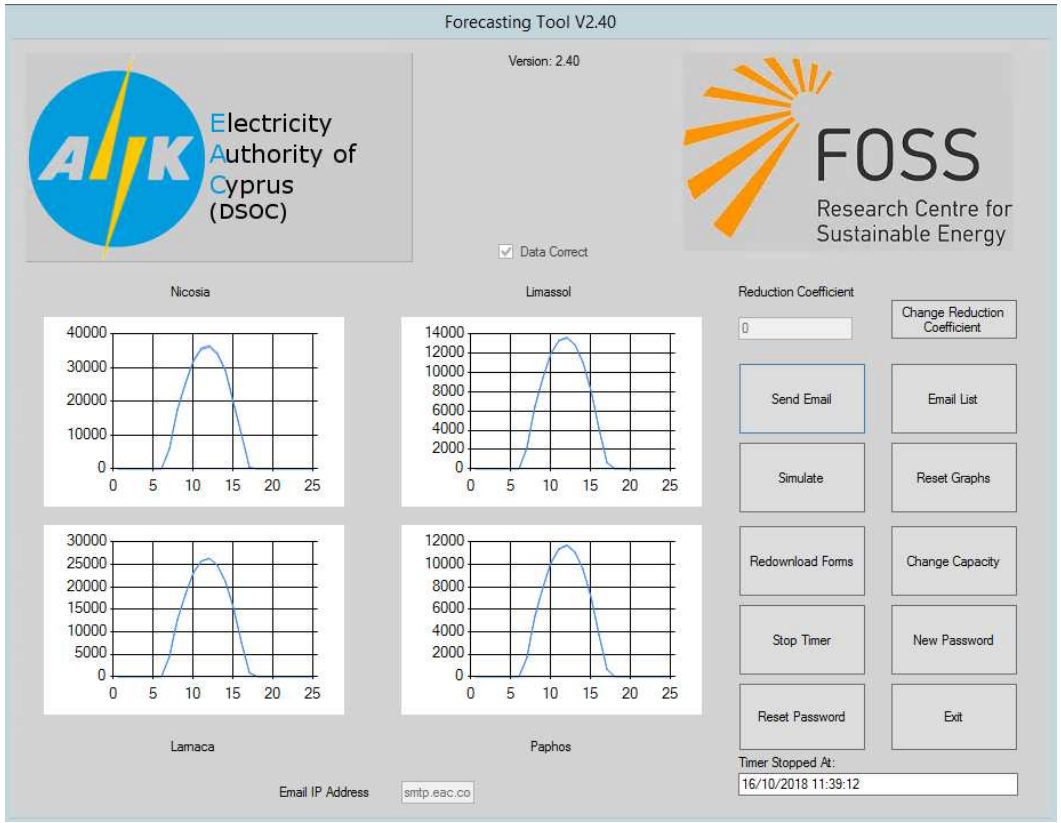
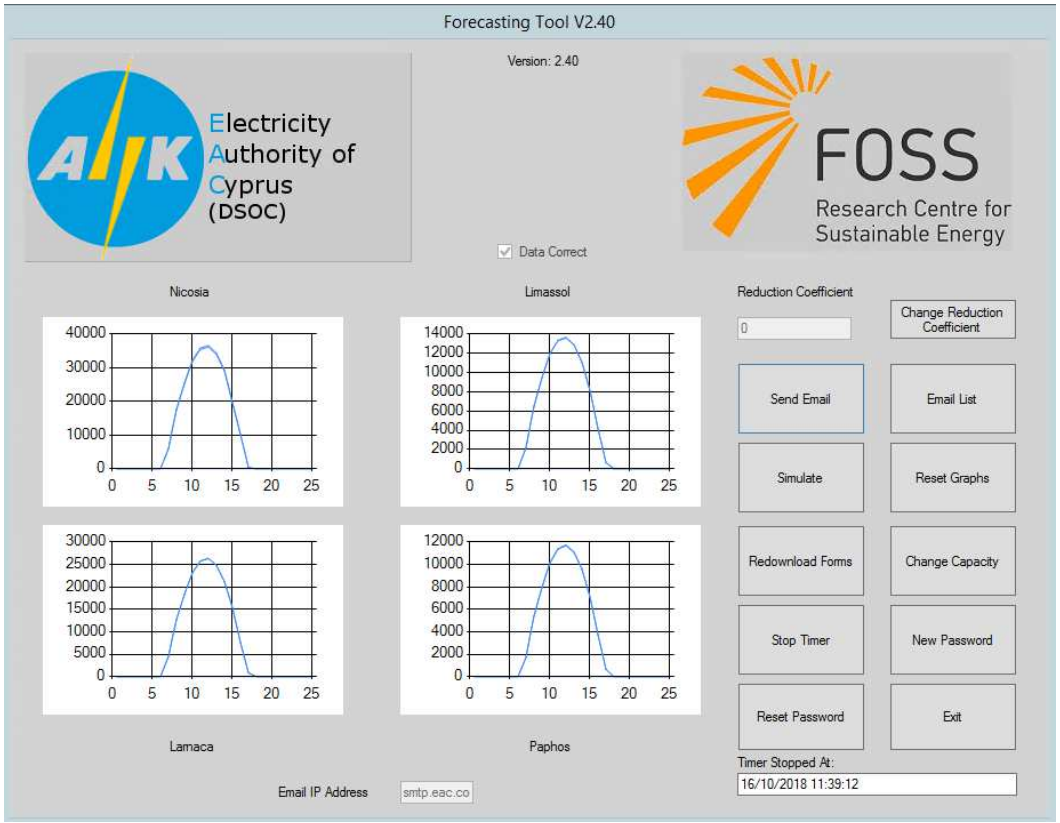
Day-ahead Forecasting Tool of UCY

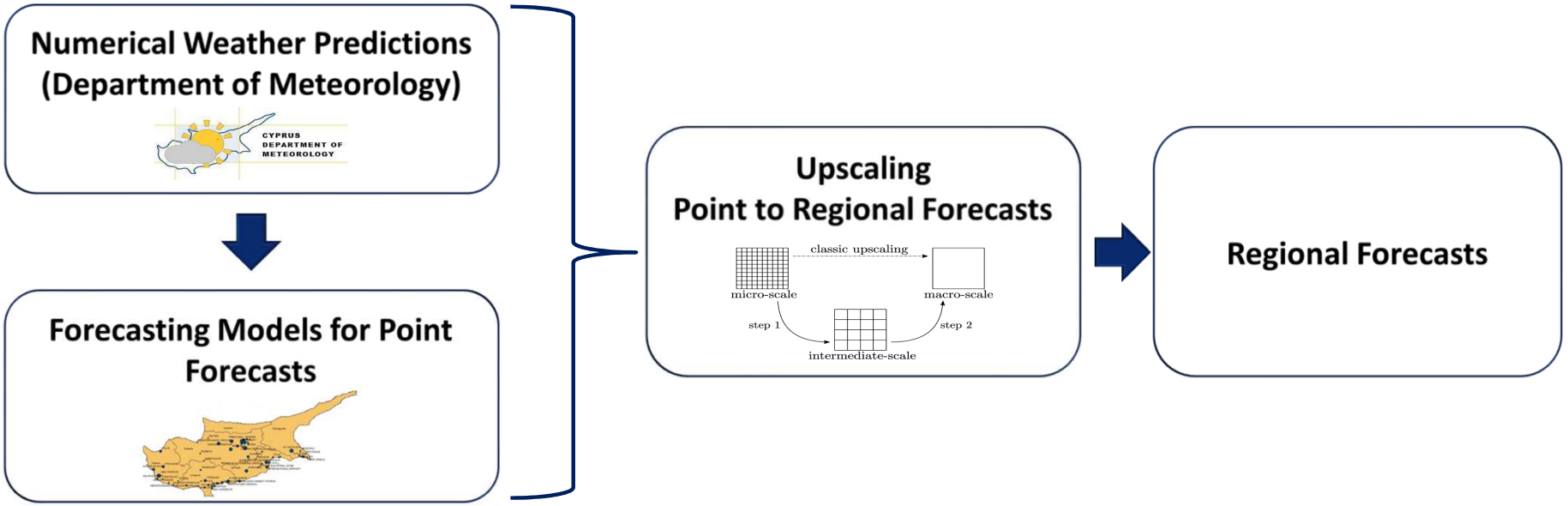


Day-ahead Forecasting Tool of UCY

- Operating since December 2015 in collaboration with Electricity Authority of Cyprus.
- Fully automated tool.
- The most recent update on the tool provides 4 days-ahead PV power production forecasts to the Transmission System Operator.



Day-ahead Forecasting Tool of UCY



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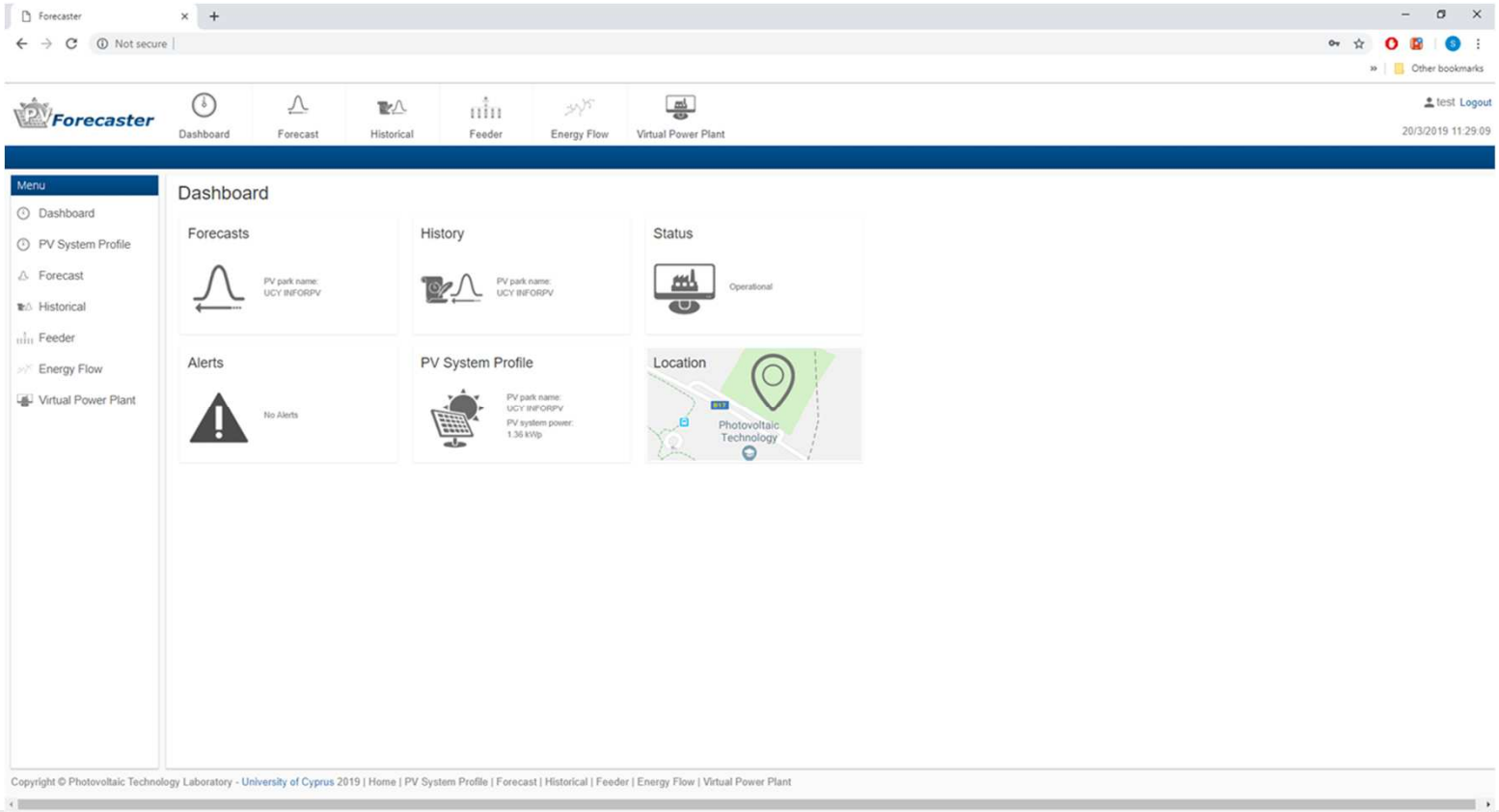
Forecasting Platform



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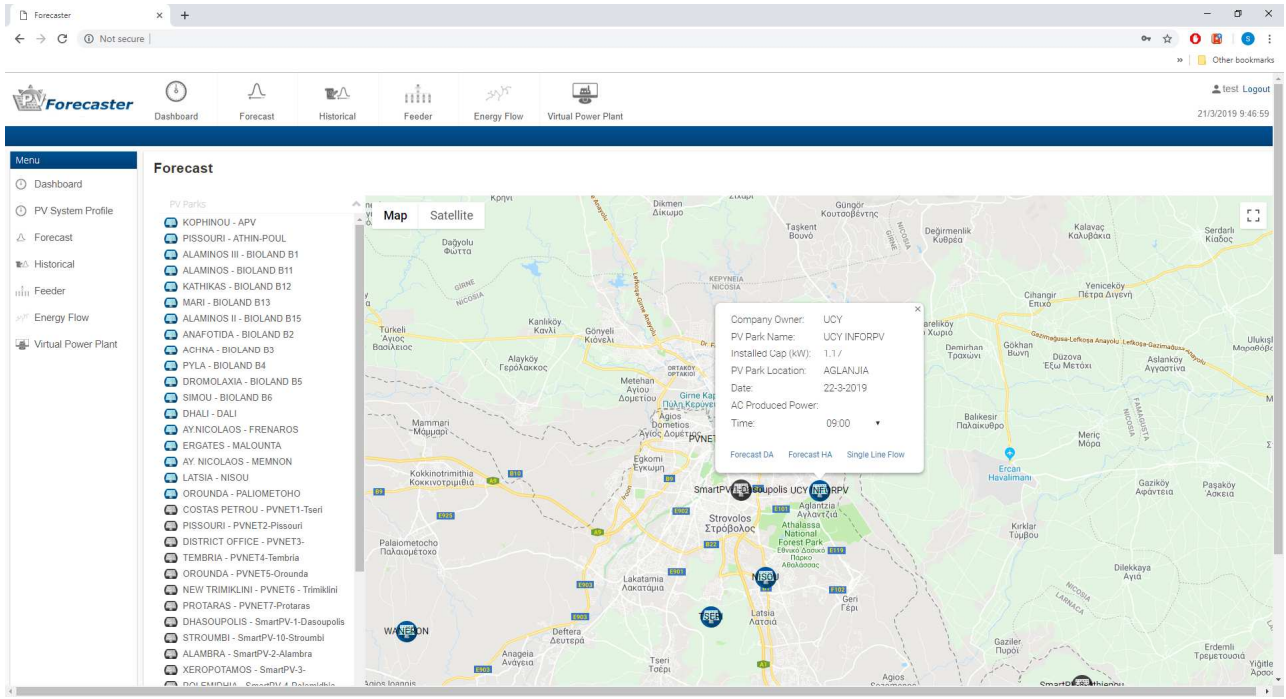
Forecasting Platform

- Live monitoring of actual PV power.
- Live monitoring of forecasted power.
- Hour-ahead forecasting functionalities



Forecasting Assessment Metrics

$$MAE = \frac{1}{n} \times \sum_{i=1}^{n} \left| y_{\text{actual,i}} - y_{\text{predicted,i}} \right|$$

Measures the average accuracy of forecasts without considering error direction

$$MBE = \frac{1}{n} \times \sum_{i=1}^{n} \frac{y_{\text{actual,i}} - y_{\text{predicted,i}}}{y_{\text{actual,i}}}$$

Indicates over or under estimation of the forecasting

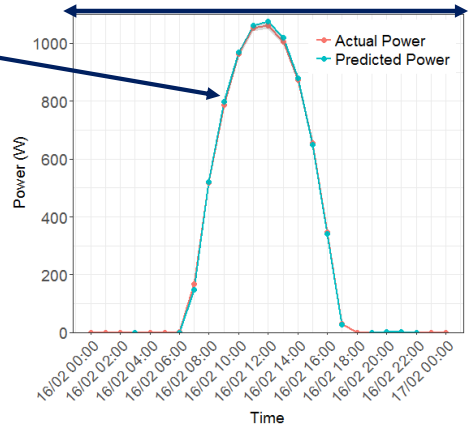
$$RMSE = \sqrt{\frac{1}{n} \times \sum_{i=1}^{n} (y_{\text{actual,i}} - y_{\text{predicted,i}})^2} \quad nRMSE = \frac{100}{P_{\text{nominal}}} \times \sqrt{\frac{1}{n} \times \sum_{i=1}^{n} (y_{\text{actual,i}} - y_{\text{predicted,i}})^2}$$

Measures the average accuracy of forecasts without considering error direction and gives a relatively high weight to large errors

$$SS = 100 \times \left(1 - \frac{RMSE_{\text{predicted}}}{RMSE_{\text{reference}}} \right)$$

MBE / RMSE / nRMSE(%) over a day period

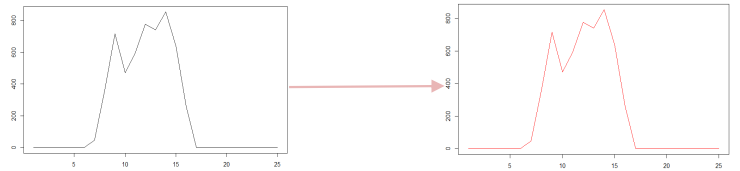
Error / APE for each point



Persistence Model (Reference Model)

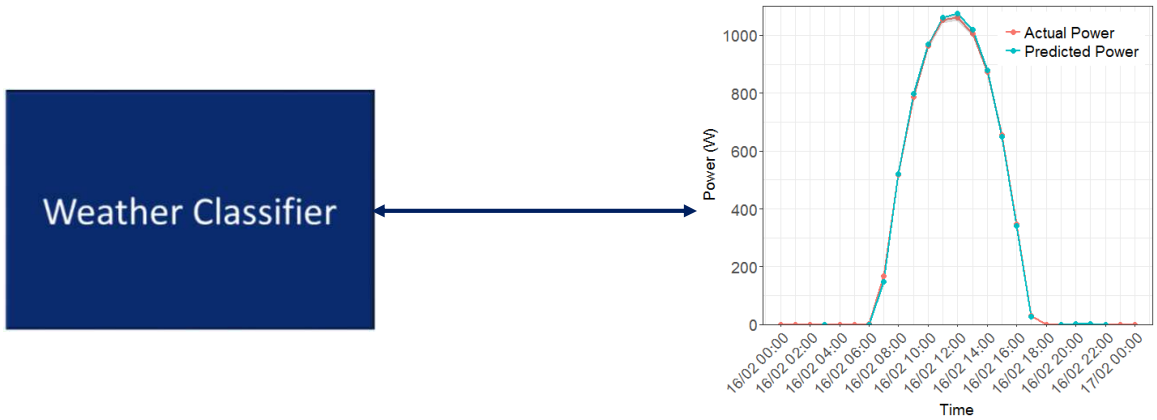
Measurements for Day (D)

Forecast for D + 1



Improvements on Forecasting

- Precautionary Adjustments:
  - Example: Development of different models based on weather classification
- Post-processing techniques:
  - Example: Weather classification combined with simpler model to correct the biases between the forecasted and actual observations



Upcoming Presentations

- A brief introduction to the state-of-the art levels:
  - Techniques
  - Methodologies

- Advance PV production forecasting:
  - Machine Learning Models:
    - Artificial Neural Networks
    - Support Vector Machine
    - Regression Trees
    - Model Selection
- Day-ahead and intra-day forecasting:
  - Methodology to derive accurate day-ahead and intra-day forecasts

Thank you for your attention

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Acknowledgment