The Anemos Wind Power Forecasting Platform Technology - Techniques and Experiences

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Abstract

In the framework of the Anemos project we developed a professional, flexible platform for operating wind power prediction models, laying the main focus on state-of-the-art IT techniques, inter-platform operability, availability and safety of operation. Currently, 7 plug-in prediction models from all over Europe are able to work on this platform.
Keywords: wind energy, wind power prediction, scheduling, power trading, software development, system integration.

1 Motivation

For integrating the fluctuating output from wind farms into power plant dispatching and energy trading, wind power predictions are a crucial tool to support operators, traders and decision makers. The basic idea of the Anemos project was to implement a flexible prediction platform which brings together the knowledge from 11 prediction products used all over Europe; most of them operationally and commercially even before the start of the project.

In practice, the set-up costs and efforts of implementing a prediction system for an specific end-user are quite high. So customers are bound to the system once bought.

On the other hand, due to the high importance of wind power predictions in practice, the permanent improvement of predictions and prediction models is crucial.

2 Goals

The common prediction platform should use state-of-the-art techniques to implement all basic features like data handling, data transport, graphical user interfaces, evaluation, security and quality management issues. On this platform, a big variety of specialized prediction models is run as plug-ins. By this approach, we want to achieve better predictions at decreasing operational costs.

The specific goals of this development approach are:

Include state-of-the-art prediction models

Of course, the overall goal is to provide the best possible operational wind power predictions to utilities and other end-users. So, the main task must be to include as many valuable high-end prediction models as possible in the platform. See chapter 1 for details.

High availability

Wind power predictions are mission-critical as part of power plant scheduling and trading, at least in high-penetration countries. Consequently, an availability of almost 100 % has to be achieved.

High QM standard/High security standards

Both for availability and to ensure correct predictions, a high quality management standard is essential. Running on-site at end-users, the according security standards are to be fulfilled. Even if running at a server which is not installed at an end-user, the prediction result itself consist a critical information which must be secured against unauthorized access.

Well-defined and documented interfaces

To integrate several prediction models as software modules means bringing together software and software techniques from a number of developers. This only can be successful if interfaces are well-defined and well documented.

OS-Platform independent

To be able to adjust to different environments, the product should be independent of the OS platform. At the moment, Windows and Linux are well tested. As databases (DB), MySQL and Oracle can be used. Most features are implemented using Java or other highly portable software techniques.

On-line uncertainty evaluation and other added-value modules

To be used operationally for decisions, for the end user it is not only important to receive predictions, but also added value information like uncertainties and other services.

3 The Platform

3.1 Structure

The basic ideas for the software structure were:
solving all common tasks once

- interfacing to data sources like numerical weather predictions, SCADA, output of prediction results
- handling of static data like power curves etc.
- handling of time series data
- user interfaces for configuration, administration and showing prediction results

encapsulating implementation details like database structures by a software interface layer
common scheduling of all tasks related to prediction generation

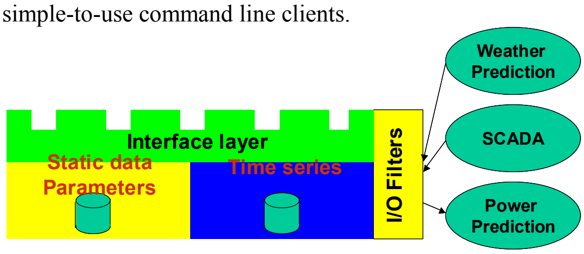
The figures below give an overview of the chosen structure: the prediction modules ("Pred I" etc.) just plug-in in a unified environment. The rest of the system is standardized.

3.2 Features

The Anemos prediction platform implementation leads to the following main features:

Static data
All static data and parameters (wind farm descriptions, power curves, terrain, ...) are handled centrally in a so called static data repository. This repository consists of a SQL DB structure hidden by an interface layer through which the other platform parts can access the corresponding information. The access is granted via direct Java library calls, as a SOAP web service via https or by retrieving the information as an XML file from a command line client.

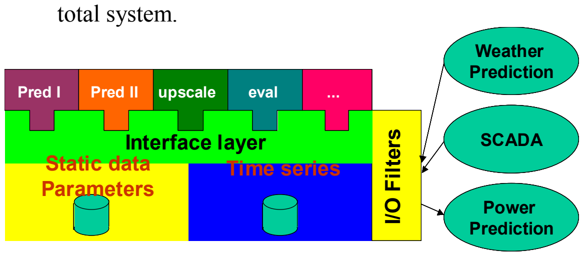
Time series data
As the static data, the time series data are stored via an SQL DB scheme and an abstracting interface layer. The modules implementing the prediction functionality interact via SOAP calls, retrieving from and pushing data to the repository. As an intermediate format, a standardised character file for time series data ("DEPRI") is used. For simplifying the migration of existing models, they can just implement interfaces to this file format and data retrieval is handled by simple-to-use command line clients.



All data is stored centrally in two data bases: static data and parameters (bottom, yellow), and time series data (bottom, blue). The implementation and the data bases itself are hidden by an interface layer which provides standardised SOAP web services to store and access data (light green layer). These data management structures communicate with the outside world via I/O filters yellow, right. Data can be transported via email, sftp or SOAP/https interfaces (all these techniques are used already in existing installations to meet the requirements and IT possibilities of our customers).

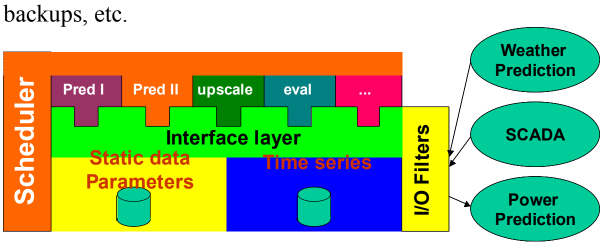
Information and data transport
As mentioned, as well static as time series data is transported via SOAP/https web services. So several goals can be reached by this approach implicitly:

- standard security techniques can be used without additional implementation effort (as ssh encryption, password protection, …)
- the system can be run in a distributed way; there can be different servers in a network environment without additional effort. E.g., one central server can retrieve and store numerical weather prediction data and distribute this to several end-user servers producing specific predictions.
- With the possibility of having distributed servers on the Internet, it was easy to implement mirroring and backup services to guarantee a high availability of the total system.



On top of the interface layer, the prediction modules ("Pred I" etc.) just plug-in in a unified environment. All data flows are transacted via this standardized interface. Data can be handled by interface calls or as standardised files. So existing and future prediction and added-value tools don't have to care about data storage, security issues, etc. at all.

Scheduling
The scheduling of a prediction system consisting of numerous data sources and tasks is not an easy thing. Generalised calling procedures for a big variant of software modules must be developed, including model chains, backups, etc.

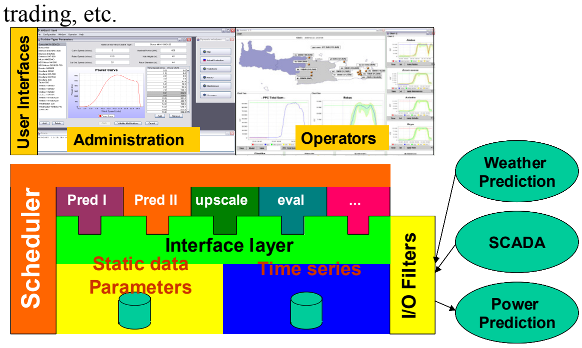


The system operation is controlled by a scheduler task (left) which is configured via the user interfaces.

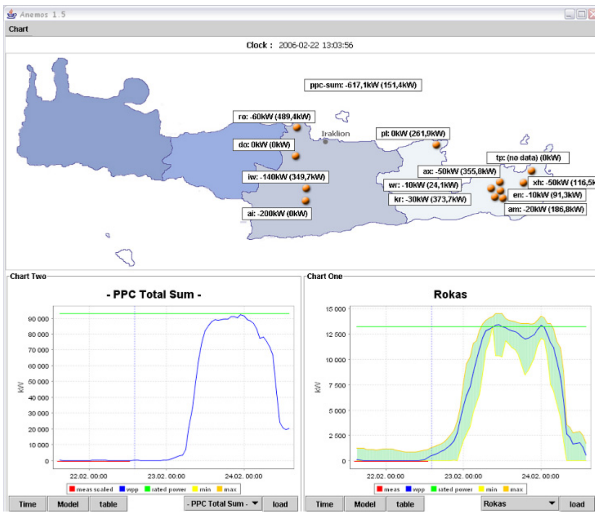
Operating system
By choosing carefully the applied software tools, we did reach a high level of platform independency. At the moment the system is running on all Windows flavours and Linux systems. It is likely that other platforms are possible without bigger adjustments. Beside using Java as the main implementation language, an important point for this feature is the encapsulation of implementation details by interface layers. So, e.g. the data base structures for storing the time series data are totally hidden to the prediction modules. This makes it easy to adjust the system to different SQL engines

and gives space for optimisation of the DB structures without affecting the prediction modules at all.

Graphical user interfaces
For different purposes, there are specialized user interfaces. *Anemos Setup* handles the system set-up, e.g. setting up power curves, wind farm descriptions, prediction model parameters and scheduler configuration.
AnemosLive gives the end-user access to the prediction data as time series charts or as tables and also on a geographical map.
Anemos Analysis and *Anemos Value* access modules which give added value like the tracking the system performance, calculating benefits from applying prediction results for trading, etc.



End-users, operators or power brokers have two possibilities to access the prediction results: via the graphical user interfaces or via additional implemented I/O filters pushing the data into existing systems like EMS.



Section of the operator user interface "AnemosLive".

4 Prediction modules

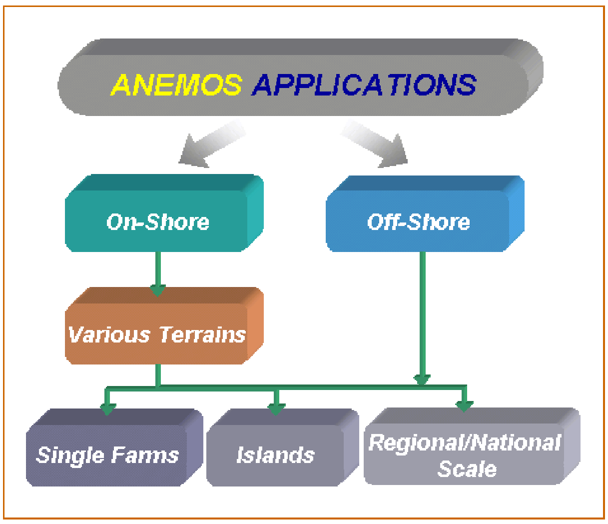
4.1 Wind power prediction modules

The majority of Anemos partners are research institutions and developers of advanced prediction models. Most of these models were commercially operational before the project started. The basic ideas behind the modelling contain physical and purely statistical approaches. On the new Anemos platform, the following models were implemented until today:

Model name	*Modeller*	*Type*
PC model, AWPPS	Armies, FR	physical/ statistical
Aria Wind	Aria, FR	physical
IBV	RAL, UK	statistical
LocalPred	Cener, ES	physical/ statistical
Prediktor	Risø, DK	physical
Previento	energy & meteo systems, DE	physical
Sipreolico	UC3M, ES	statistical
WPPT	DTU, DK	statistical
NTUA	NTUA, GR	statistical

4.2 Added value modules

Model name	*Modeller*
Online uncertainty assessment	Armines, FR
Prediction risk	Armines, FR
Upscaling	Uni Oldenburg, DE
Automatic combination of models	UC3M, ES
Benefit and performance monitoring	UC3M, ES
Security checks, operation surveillance	Overspeed, DE
Scheduled maintenance	Armines, FR



Specialized prediction modules are available for variant applications.

5 Operational use

5.1 End users

Anemos is running operationally for 7 end-users in total. For Denmark (ELSAM), France (EDF) and Spain (EHN, IDAE), predictions are delivered for single wind farms. For Greece (PPC), Ireland (ESB), UK/Northern Ireland (SONI) and North-West Germany (EWE), all wind farms in the corresponding grid areas are part of the forecasts. Three installations are run from remote, while four are run in-house at the customer.

5.2 Experiences

In addition to the experience of all project partners who are operating wind power predictions operationally for years, with the new platform we now have gained operational experience for more than one year. In the recent 18 months, by mirroring the prediction system on independent systems, we reached a 100 % availability.

It turned out that after being familiar with the interface and system structures, the implementation of new models and modules on base of the unified platform is quite simple and fast. Furthermore, it is also possible to make fast ad-hoc implementation of new features requested by clients.

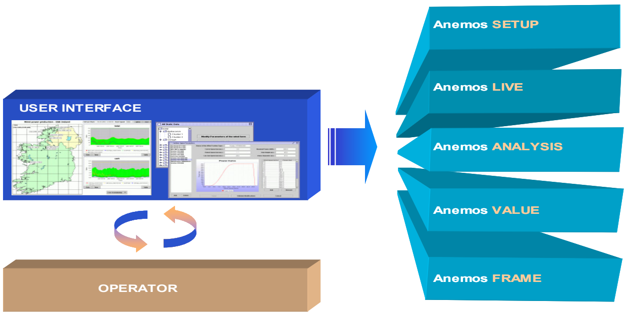
6 Challenges and implementation experiences

Although the current results and experiences are quite promising, it was a long way to go to reach this stage of cooperation, standardization and integration.

The first challenge is to learn about the different ways to tackle the prediction tasks. We had to integrate the views, data handling and parameter requirements from 9 modelers having totally different experiences and backgrounds. Also, making wind power predictions with statistical or physical models are two very different ways to look to the problem. This directly reflects in data and parameters needed and structures to map the reality. For instance, a physical model is in general based on a physical description of the world, making up a hierarchy starting with the single site, having roughness and orography, the turbines power curve, etc. A statistical model could work in a totally different way: e.g. if using multi-parametric regression, all power outputs of all turbines could interact in principal with each other. Theoretically, the physical relations between the different sites could be totally neglected. These different approaches lead to very different kinds, numbers and structures of parameters.

Though two partners with dedicated commercial IT experiences were part of the proposal group, the implementation effort for the platform as well as for the model integration proved to be dramatically higher than initially foreseen.

Another lesson learned: whatever electronic media are available for communication, basic problems about ideas of structures and standardization could be solved only by real-world workshops. Direct informal communication and mutual commitment by sitting physically at one table can not be replaced by electronic communication means.



Different user interface options for operation and analysis.

7 Conclusions and outlook

In the framework of the Anemos project we succeeded in implementing a common, highly standardized wind power prediction platform. On the platform, currently there are 8 prediction and 5 service modules running from leading European wind power prediction developers. Predictions can be made for single farms as well as for pools of wind-farms, e.g. in a TSO area. Special end-user requests about additional services can be handled by an experienced consortium

We are testing under commercial conditions at 7 end-users. In general, the chosen techniques and standardizations proofed to be feasible to reach high availability, proper predictions results and a high level of security and QM.

Due to its standardization and high quality, Anemos is a good value for the investment of end-users in a prediction platform. One future development will be to implement a simplified platform variant with lower set-up and operational costs. With this approach, we also want to tackle the market of single site predictions, especially markets with an obligation to provide predictions from each wind farm operator (*Anemos to-go*).

Acknowledgments

This work was performed in the frame of the ANEMOS Project (ENK5-CT-2002-00665) funded in part by the European Commission under the 5th Framework Program.

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