SHORT TERM WIND ENERGY PREDICTION SYSTEM (SWEPS)

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Abstract

According to World Wind Energy Association, installed global wind power capacity has increased 10 times within the last decade. In EU, wind power installed capacity at the end of 2009 has reached to 9739 MW. In Turkey, installed wind power capacity is currently around 2000 MW and it is expected to reach 10 000 MW within the next five years. During last two years, the number of wind energy plants license applications to Turkish Energy Market Regulatory Authority was extremely increased. This project aims to develop a short-range wind energy prediction system in Turkey based on the meso-scale numerical weather prediction models, diagnostic wind model and/or Computational Fluid Dynamics (CFD) model and adaptive statistical models.

Keywords: wind energy, mesoscale meteorological model, diagnostic models, CFD, wind power prediction system, Turkey

1. Introduction

The increasing use of wind power will contribute to the reduction of CO_2 emissions and this will help to combat the climate change. Recently, wind energy has been the fastest growing energy technology in the world. In some European countries wind power has already been widely used, as an example the wind power share of gross electricity consumption in Germany reached to 6.4%. Turkey is the 6th largest electricity market in Europe and there is significant growth potential for wind power in the country. Currently, there is around 801MW of wind power installed in Turkey. The General Directorate of Electrical Power Resources Survey and Development Administration, EIE, [2009] estimates that current wind energy potential of Turkey is around 10,000 MW or higher in operation. It is expected that it will be around 11,193 MW in 2013 and 20,000 MW in 2023. Although, wind energy has significant contribution to the energy system, there are some uncertainties due to discontinuous nature of the wind field. Therefore, wind energy farms cannot supply continuous energy to the grid. For effective energy planning in the grid, it is necessary to be able to predict wind energy production as accurately as possible up to 48 hours. In order to improve the short term wind predictions over wind farms, there is a need to built an accurate wind energy forecasting system which captures the dynamical and statistical nature of the wind field in different spatial and time scales (Enomoto et al., 2001; Joensen, 1997 ;Joensen, 2002; Madsen, 1996 ; Nielsen and Madsen, 1996 ; Sanchez, 2006 ; Waldi and Kariniotakis, 2006).

To integrate wind energy into the electricity system, it is necessary to be able to predict wind energy production as accurately as possible up to 48 hours. In a liberalized electricity market, such prediction ability will optimize the contribution of wind energy to the energy system.

The aim of this project is to develop short-range wind energy prediction system based on the combination of the models: meso-scale numerical weather prediction; diagnostic wind /or Computational Fluid Dynamics (CFD) and adaptive statistical models. The prediction system will be developed within two year timeframe.

2. The Approach of SWEPS

Short term wind energy prediction for wind turbines in the wind farms is important for the planning of electricity production with precisely and energy planning in the grid system. The SWEPS project is structured into seven work-packages, which address the following technical objectives:

- Data collection and evaluation of needs.
- Off-line and on-line evaluation of prediction techniques (MM5, WRF, WAsP and WindPRO, CFD, WindSim)
- Development of statistical models.
- Verification of the predictions of dynamical and statistical models with the observations.
- SWEPS prediction system development.
- Evaluation of on-line operation.
- Overall assessment

The short term wind energy prediction system consists of four modules to predict wind energy for two days ahead. The system is shown in Fig.1 First, global weather forecast model outputs are downscaled for the region by using one of the meso-scale numerical weather prediction models such as MM5 and WRF.

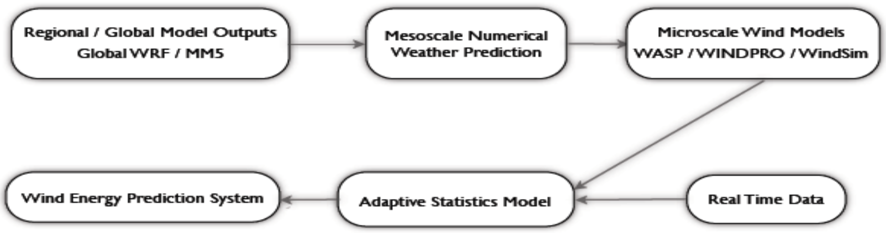

Fig.1. Wind energy prediction system

These models are non-hydrostatic atmospheric models so that nesting structure of these models lets the user increase the spatial resolution of the interested region up to a few km (Fig.2).

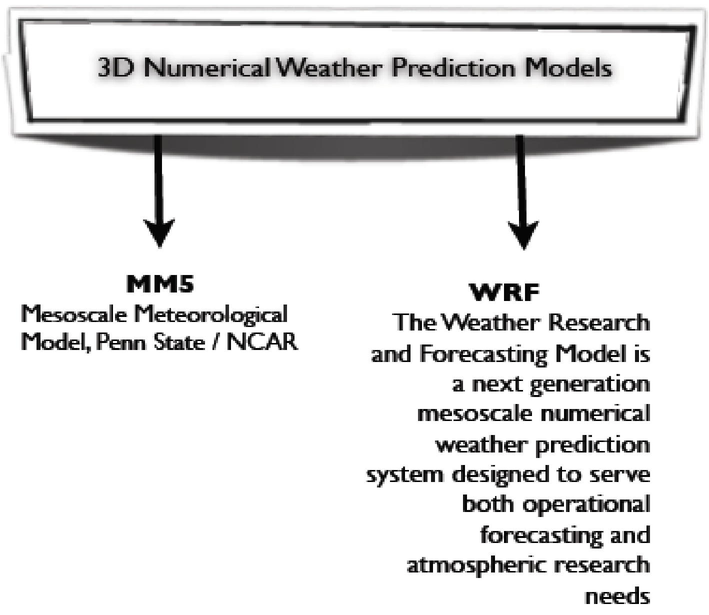

Fig.2 Mesoscale meteorological models used in the project

2.2.1. MM5

The PSU/NCAR mesoscale model (known as MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. The model is supported by several pre- and post-processing programs, which are referred to collectively as the MM5 modeling system.

2.2.2. WRF

It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to kilometers.

2.3. WAsP and WindPRO

The accuracy of the model's surface representation depends mostly on the horizontal resolution of numerical weather prediction model. The improvement of the forecasts due to the higher spatial resolution is even more significant over a complex terrain. Therefore next stage of the modeling system is diagnostic wind model and/or CFD simulations. Diagnostic wind model (WAsP and WindPRO) uses wind speed and direction as well as pressure and temperature obtained on the previous phase of the forecast system. The model characteristics were shown in Fig.3. It better represents the effects of topography, roughness and obstacles with up to a few hundred meters, and transforms wind speed forecast to wind power forecast.

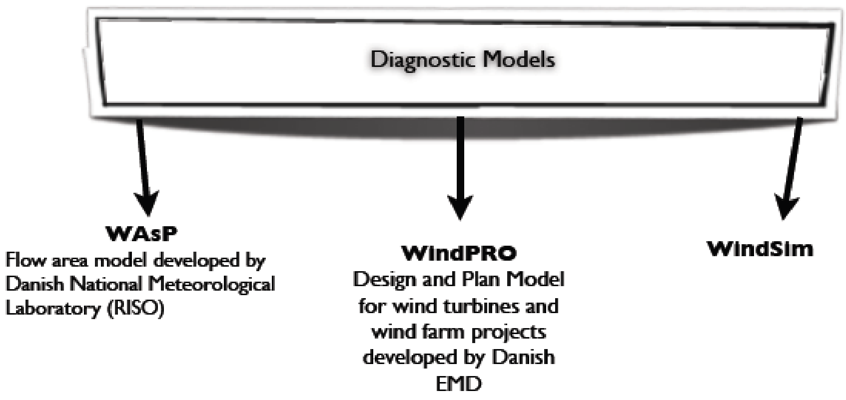

Fig.3. Diagnostic models

Additionally, WindSim model which based on CFD that combines advanced processing with 3-D visualization will be used in the project. As a general point of view, CFD is a method to analyze every kind of fluid flow under different conditions. Three main equations governing the fluid flow (continuity, momentum and energy) are computationally solved in this method to obtain flow data like pressure, velocity and temperature distributions. A wind map with a lower resolution than 100 meters can be achieved with the CFD simulations. Finally, adaptive statistical module covers any systematic mismatch of the model forecast and the turbine measurements. A statistical model will be developed by analyzing wind power forecast and observational data for the last ten days to reduce the forecast error. Different methods such as multiple linear regression, artificial neural networks, and time series analysis can be evaluated during the diagnostic phase of the module. A benchmarking process will be set-up to evaluate the performance of the developed models and to compare them with a number of cases. The general performance of model predictions will be evaluated over one year using forecast evaluation measures such as the root mean square error, the absolute error etc. in the last module of the forecasting system. Then, appropriate physical and statistical prediction models are chosen for selected three wind farms for this project.

The outcome of the project

The outcome of this project will help consistently the increase of wind integration in two levels; in an operational level due to better management of wind farms, but also, it will contribute to increasing the installed capacity of wind farms. This is because accurate prediction of the resource reduces the risk of wind farm developers, who are then more willing to undertake new wind farm installations especially in a liberalized electricity market environment. In the case of the realization of the project, short term and small-scale wind estimation will contribute to energy planning, and control of forest fires, sport activities and determination of small-scale distribution of air pollution.

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