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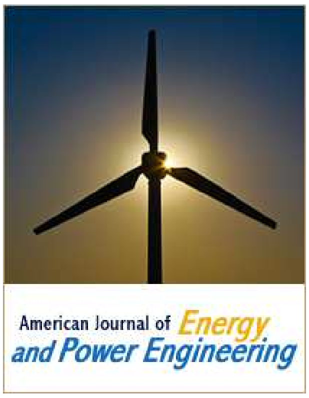

A study on optimum regional power grid in feed estimation of renewable energy

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Abstract
Renewable Energy Resources (RES) are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies which are most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, Since most of the renewable energy sources are intermittent in nature therefore it becomes a challenging task to integrate RES into the power grid infrastructure. In this paper we'll discuss on work flows of power forecast for renewable energy.

1. Introduction

For maintaining a reliable and cost effective supply, new efforts have to be undertaken for the management of energy networks, integration and also forecasting of renewable energies in the networks, for generation and load management and for a range of other technical and socio economic aspects of decentralized energy markets. The renewable power forecasting is very crucial for large-scale renewable energy integration to the electric grid. The increasing penetration level of PV and wind systems is raising the concerns of some utilities due to the possible negative impacts of the power fluctuations generated from these systems on the network operation. Also, the fluctuation in the power of these systems can lead to unstable operation of the electric network prior to the fault conditions, high power swings in the feeders and unacceptable voltage fluctuations at certain nodes in the electric network. Moreover, the random fluctuations of the power output generated these systems does not allow for considering them in the scheduling process of electricity generation. Accurate forecasting will reduce its uncertainty and lead to the better electric grid integration. Statistical power forecasting for electric farms: The system usually build the statistical relation between the historical farm power and weather data, and then predict the farm power for the future by the Numerical Weather Prediction (NWP) input [1]. According to the range of power forecasting, it can be roughly divided into 2 categories: very short-term forecasting (for next 4 hours), short-term forecasting (for next 24~72 hours).

2. Present Situation of Renewable Energy Sources

The development of renewable energy in Germany has been a great success. They are the world leader in terms of installed wind capacity (nearly 40 % of the global capacity), one of the largest installed photovoltaic capacity in the world. Since 1991, with the coming into force of the first German feed-in law, the Act on Supplying Electricity from Renewable, fixed remuneration has been paid to electricity based on renewable energy sources (RES), leading to the market breakthrough in wind energy.

Its successor, the Renewable Energy Sources Act in April 2000, improved the regulations in many respects and made market entry possible for other renewable.

Table I. *Wind energy Statistics (Europe) [2][3]*

Countries	Installed Capacity in 2012 (MW)
Belgium	1,375
Netherlands	2,391
Germany	31,308
Austria	1,378
Slovakia	3
Czech Republic	260
Poland	2,497
Denmark	4,162
Finland	288
Sweden	3,745
Norway	703

Table II. *Solar Energy Statistics (Europe) [4][5]*

Countries	Installed Capacity in 2012 (MW)
Belgium	2650
Netherlands	266
Germany	32,411
Austria	418
Slovakia	523
Czech Republic	2072
Poland	7
Denmark	394
Finland	11
Sweden	19

3. Power Forecasting for Res

Rapid growth of renewable power (such as wind, solar) has led to the urgent need of advanced renewable power forecasting methods. Accurate forecasting will reduce its uncertainty and lead to the better electric grid integration. Most of state-of-art systems contain two stages:

1) Numerical weather prediction (NWP) for one or two locations of the farm (usually the locations of the wind towers or other meteorological monitoring devices): This forecasting is usually acquired from the meteorological agency. Because its space resolution is usually from 5 kilometers to tens of kilometers, so only one or two location points can be forecasted for a farm.

2) Statistical power forecasting for electric farms: The system will build the statistical relation between the historical farm power and weather data, and then predict the farm power for the future by the NWP input. According to the range of power forecasting, it can be roughly divided into 2 categories: very short-term forecasting (for next 4 hours), short-term forecasting (for next 24~72 hours) [1].

The key to perform single generating equipment-based forecasting is the good performance of NWP for each generating equipment. Different with the meteorological agency, the proposed system make accurate high-resolution numerical weather prediction of each generating equipment by assimilating the real-time weather monitoring data. Based on the result of high-precision numerical weather prediction (NWP), it uses a combination of different statistical models to achieve the short-term and very short-term forecasting of wind turbines and photovoltaic panels, and then lead to the forecasting of wind and solar electric farms.

The Forecast can be developed in four ways-

•A novel framework can be established for very short-term and short-term power forecasting not only for electric fields but also for single generation equipment.

•Improve the resolution and precision of numerical weather prediction for the renewable farms by assimilating the real-time weather data from the wind tower, turbines and other meteorological monitoring devices

•Hybrid power forecasting and probabilistic forecasting models can be introduced to reduce the risk of power integration

•The approach of adaptive model parameter adjustment and error correction for forecasting should be done.

4. Forecasting Challenges

High penetration of solar and wind power in the electricity system provides a number of challenges to the grid such as grid stability and security, system operation, and market economics. Ones of the considerable problems of solar and wind systems, they depend on the weather, as compared to the conventional generation. As we know, the balance in managing load and generated power in energy system is very important. If the power which is supplied from solar and wind perfectly predictable, the extra cost of operating power system with a large penetration of renewable energy will be reduced. Since, the accurate and reliable forecasting system for renewable sources represents an important topic as a major contribution for increasing non-programmable renewable on over the world. The target of this study is to describe the advanced hybrid evolutionary techniques of computational intelligence applied for PV as well as wind power forecast. The rising temperature, climate change and economy issues are changing the face of power system. As a result, the renewable energy in the power network is in strong growth during the last decade. In this case, large rapid changes in non-programmable sources can cause a significant reduction in reliability and economy. Forecasting of solar and wind power, allows planning the connection or disconnection of solar and wind plans or conventional generators, thus achieving a balance in the management load and generated power. Furthermore, when the variable pattern of wind power is not predicted, it is indispensable to use extra reserves which make power system generally expensive, in order to compensate the unbalance. That is reason why we have to analyze solar and wind power prediction system provide the accurate and reliable information how much they can be expected at which point of time.

5. Necessary Equations

Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy that can be supplied, via the grid.

The following table shows the definition of various variables used in this model:

E = Kinetic Energy (J)

ρ = Density (kg/m^3)

m = Mass (kg) A = Swept Area (m^2) $=\pi r^2$

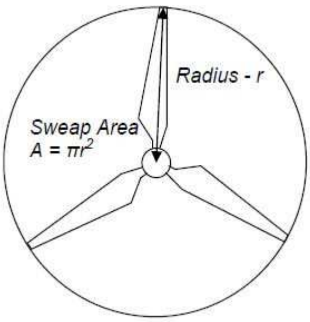


Figure 1. *Swept Area*

V = Wind Speed (m/s)

C_p = Power Coefficient

P = Power (W) r = Radius (m)

dm/dt = Mass flow rate (kg/s)

The power in the wind is given by the rate of change of energy:-

$$dm/_{dt} = \rho \mathrm{AV}$$

A German physicist Albert Betz concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. To this day, this is known as the Betz Limit or Betz' Law. The theoretical maximum power efficiency of any design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "power coefficient" and is defined as [6]:

$$Cp = 0.59$$

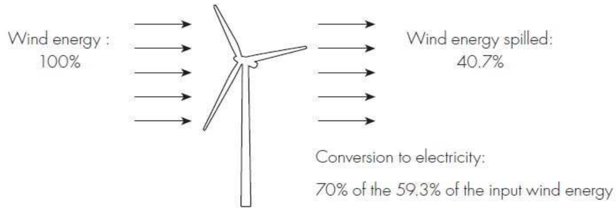


Figure 2. *Real scenario of Power coefficient*

And available extractable power is,

$$Pavail = {}^{1}/_{2}\, \rho A V^3$$

The global formula to estimate the electricity generated in output of a photovoltaic system is-

$$E = A \times r \times H \times Pr$$

Where,

E = Energy (kWh)

A = Total solar panel Area (m²)

r = solar panel yield (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

The output power equation for solar cell is,

$$P = VaI = IsVa\left(e^{\frac{Va}{Vt}} - 1\right) - IphVa$$

Where,

Is = saturation current of the diode

Iph = photo current (which is assumed to be independent of the applied voltage Va)

And,

$$Vt = \frac{K \times T}{q}$$

Here,

k is Boltzmann constant, T is the temperature of the cell and q is the electron charge.

For evaluation metric, accuracy and accept rate should be adopted-

As for accuracy r1 [7],

$$r1 = \left(1 - \sqrt{\frac{1}{N}\sum_{k=1}^{N}(\frac{Pmk - Ppk}{Cap})^2} \times 100\%\right)$$

Where P_{Mk} is the actual average power at time k, P_{Pk} is the forecasted average power at time k, N is the total number of time slots (e.g. short-term forecasting N=96 where the forecasting interval time is 15 minutes), C_{ap} is the boot capacity of the electric field.

For accept rate r2,

$$r2 = \sqrt{\frac{1}{N}\sum_{k=1}^{N} Bk} \times 100\%$$

Where,

$$\left(1 - \frac{Pmk - Ppk}{Cap}\right) \times 100\% \geq 75\%, Bk = 1$$

$$\left(1 - \frac{Pmk - Ppk}{Cap}\right) \times 100\% \leq 75\%, Bk = 0$$

6. Work Flow of Forecasting System

This section will introduce the workflow, framework and architecture of the proposed system-

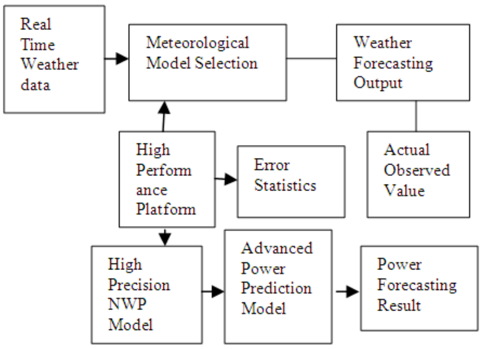


Figure 3. *High-precision Integrated Wind and Solar Power Forecasting System process*

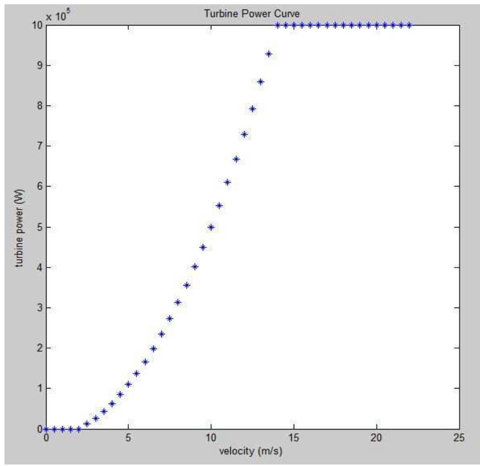
The integrated wind and solar power forecasting system for the demonstration project can provide the very short-term and short-term power forecasting of wind turbines, wind and solar electric fields, and the high-resolution numerical weather prediction for next 0 to 48 hours.

The workflow of the High-precision Integrated Wind and Solar Power Forecasting System is shown in Figure. The system performs high-resolution meso-scale weather forecast based on the initial large scale background circulation released by the World Meteorological Organization. Weather forecast also considers turbulence models and high resolution topographic data of wind-PV fields. Thus, the wind forecast for single turbine and the ground solar radiation flux are obtained. Then, the single wind turbine and solar panels power forecasting is achieved by the use of statistical model calculations, optimization, and adaptive correction. Combined with the downtime plan, it can calculate the total forecasting power of whole electric station.

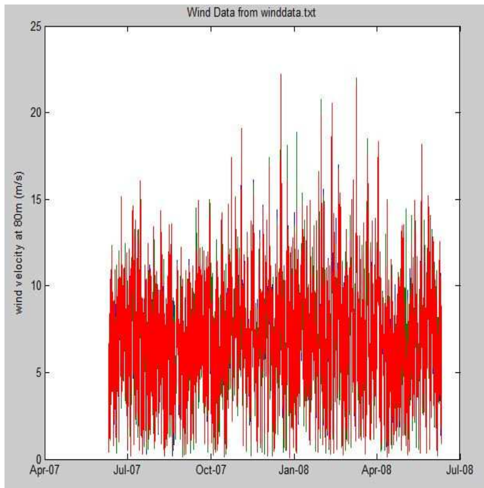
7. Results and Discussion

7.1. Wind Power Forecast

A wind turbine power curve along with wind graph from the text file containing wind speed of different location and the wind tower heighthas been graphically produced by MATLAB.



(a)



(b)

Figure 4. *(a) Turbine Power Curve and (b) Wind data from text file.*

Power increases up to a certain limit, but after that limit, power is in saturation. As we can see from the turbine power curve, power increases up to a certain limit for the wind speed. This is the main concept of a wind turbine modeling and we need to keep it in mind that beyond how much wind speed, the power will be saturated.

7.2. Solar Power Forecast

PV output for each system can be forecasted as follows. First, a clear-sky expectation for the output of each system is obtained. Subsequently, we need to correct for outages, system orientation, and partial shade due to permanent obstacles (not clouds). Finally, deviations from the clear-sky operation of the system are the effect of clouds. Here we can define the clearness index K at every location (x, y) and time (t) as

$$K(x, y, t) = POA(x, y, t)/POAclear(x, y, t)$$

Where, $POA(t)$ indicates the plane of array *(POA)* irradiance at time t and $POA_{Clear}(t)$ indicates the modeled POA irradiance in the absence of clouds. Since the output of any particular PV system normalized by peak power (kW/kWpeak) is approximately proportional to *POA* irradiance, we can write

$$Ki = Pi(t)/Piclear(t)$$

Where pi(t) is the normalized power output (kW/kWpeak) for system i and pi,clear(t) is the normalized power that would be generated under a clear sky. Once K has been determined for every system at the present time t, then it is possible to forecast K at time t + dt, and at location (x, y) using

$$K(x, y, t + dt) = K(x - vxdt, y - vydt, t)$$

Where vx and vy are the x, y components of the cloud velocity. Values of K at locations between the points where PV systems are located are determined by interpolation. For each location *(x, y)*, K is determined for the four closest PV systems *{Ki}*. We then compute *K(x, y) = MEDIAN ({Ki})*

8. Conclusion

The forecasting models must be adaptive (in order to take changes of dust on blades, changes roughness, etc. into account). A reliable estimate of the forecast accuracy is very important. Using more than a single weather forecast provider for delivering the input to the wind power prediction tool will improve the accuracy. It is advantageous if the same tool can be used for forecasting for a single wind farm, a collection of wind farms, a state/region or the entire country. Using statistical methods for phase correction, the phase errors will also improve the accuracy. Estimation of the correlation in forecast errors is very important. Forecasts of cross dependencies' between load, wind and solar power might be of importance. For PV, a significant challenge in forecasts is to determine the cloud edge velocity. Ground-based measurements of wind are not an accurate measure of the velocity of clouds. Although there are lots of limitations and challenges for the forecasting, massive level research is going on now a day and hopefully we'll get something perfect.

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