Monitoring Systems for Wind Generators Maintenance

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***Abstract*- Wind energy is the renewable energy source with a higher growing rate in the last decades and can be considered a hope in future as a clean and sustainable energy. With the huge proliferation of wind farms, as an alternative to the traditional fossil power generation, the economic issues dictate the necessity of monitoring systems to optimize the availability and profits. Tools to detect the onset of mechanical faults in wind turbines at a sufficiently early stage are very important for planned maintenance actions, because these actions can reduce the outage time and can prevent bigger faults that may lead to machine to stop.**

***Index Terms*—Condition monitoring, neural networks, maintenance, wind energy.**

I. INTRODUCTION

Wind energy had in the past years a fastest growing, becoming, at the present, an important renewable energy source in terms of installed power. Wind had overtaken all other sources of power and become Europe's number one in terms of new installed capacity, 39% of all new power capacity in 2009 [1]. From a worldwide view, installed capacity reached in 2009, 159213 MW, out of which 38312 MW were added in that year, showing a growth rate of 31,7%, the highest since 2001 [2].

Analyzing the Portuguese situation, in 2009 wind energy was responsible for the supply of 15% of consumption, being installed 3535MW, in which 683 MW were added during 2009 [3].

Traditionally wind energy is not dispatched. When wind is available the turbines must work and power produced must be connected to the grid. However due to the growing of power installed in this technology, grid integration must be more controlled and motive of special care by the system operator.

One important issue of wind energy is the competitiveness when compared with other power plants, problem exacerbated by the relatively high cost of operation and maintenance. Normally wind turbines are installed in remote areas with hard to access structures.

As a way to solve this problem in the near future, enhancements of availability, reliability and life time of the turbines will be required [4]. Good predictive maintenance strategies are needed and can't be based only on periodical or preventive maintenance actions recommended by the manufacturers. In spite of being good guidelines for the maintenance of aerogenerators, they do not focus on the specific characteristics of the real and local life of them [5].

There is a lot of investigation in the area of condition monitoring, failure detection as a way for improving performance of wind turbines. This paper will present the use of neural networks to the detection of anomalies in some components of the wind turbine, more specifically in the gear box. In the section 2 will be presented the most common failures of the wind park which is the base of this study. Section 3 will focus on the selection of important measurements to be used as inputs on the neural network and section 4 will present some results of the application of neural networks to the detection of failures in the wind turbine gearbox.

II. IMPORTANT FAULTS

An efficient maintenance of wind generators is very important to minimize the operational costs of a modern wind farm. Normally the maintenance is made by the wind turbine producer, in the wind farms covered by the warranty. The maintenance is preventive and made in pre-defined periods of time. When major problems occur maintenance teams are urgently called to solve it. When the problem is easy to solve, like for instance to reset the turbine, or making some adjustments in the parameters of the turbine or also substituting some electronic devices, the time associated to the repair is not to long. But if the problem is bigger and requires the substitution of heavy dimension the outage time is longer which implicates a reduction in the profits. In addition, if the repair need to use cranes and lifting equipment, that can be a bigger problem because of the unavailability of this kind of machines and his high cost. For these reasons, fault detection techniques are becoming indispensable in modern wind parks.

Faults that can occur in a wind farm can be grouped in three categories, electronic, electrical and mechanical faults.

Electronic faults have a high occurrence frequency; these kinds of problems occur frequently in sensors and in electronic cards and normally after storm phenomena. The anemometer is one example of a component that has a very high fault frequency, but is usual too have problems in the electronic components like sensors or communication cards. The solution for solve this kind of problems is the substitution of the broken component and typically the down time associated to this kind problem is 1 day or less.

Electrical faults are not so common and are associated to the generator or to the transformer. Sometimes short-circuit of the generators winding, or in the transformers windings can occur. When these problems occur, the solution is the substitution of the equipment which leads to large downtime

and create a highly capital-intensive operation. Another electrical problem that had a high rate of occurrence in the wind park under this study was the insulation damage of the cable connecting the rotor to the slip ring. The solution was the replacement of the cable by one with better insulation characteristics. Normally the outage time associated to electrical faults can vary between 3 and 8 days.

Mechanical faults are related with gearboxes, blades or mechanical break. With the increase of size of wind towers, the rotors velocity must be slowed. So, the gearbox must reduce the velocity applied to the rotor. Because of that, forces applied to the cog-wheel of the gearboxes are very high which can lead to the tooth break. Sometimes gear box structure has small cracks that lead out oil. These problems are solved with the substitution of the gearbox. Rotor blades are another component susceptible of fault, normally when it is struck by lightning. The blade has a thin metallic layer connected to the mass copper conductor, when a lightning hits the blade, the metallic layer or the copper conductor can be destroyed or the tip of the blade can be damaged. Some of these problems can be solved with no necessity of bring down the blade but sometimes that is necessary. Mechanical break can have troubles too because with the increase of size of the towers and blades, turbines are exposed to strong winds. The continuous vibrations and the extremely forces involved make these components one of the weakest point of the system. The downtime associated to a mechanical fault varies between 4 and 7 days and normally costs involved are very high. Fig.1 presents the usual outage time per failure in wind turbines components.

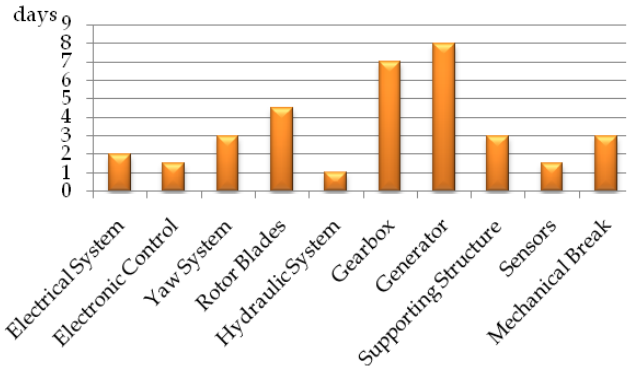

Fig. 1. Typical downtime per failure

If the responsible for the maintenance or the wind parks owners had informatics tools to predict faults in the equipments that could send alerts in case of detection, this could be very useful and certainly operation and maintenance cost would be lower. Neural Networks (NN) can be an useful help to reach that objective.

III. Measurement Selection

Wind turbines have a lot of sensors measuring important information of its behaviour. Depending on the turbine kind and producer, several measurements are made and saved in the park central computer or in the control centre, if it exists. Measurements are normally 10 minutes average values and can hide important information. In this particularly Portuguese wind park equipped with 13 machines of 2 MW, measurements saved are:

Time and date;
Wind speed;
Pitch angle;
Generator rpm;
Power;
Frequency;
Currents and voltages;
16 temperatures.

Application of neural networks is dependent of the number of measurements and on the quality of them. The more quality of the data set will be translated on more quality of the results. If is used one year of measurements the data set is very large and can be used for learning, test and validation of the NN. The main goal is to understand which measurements are important to use as input of the NN, because some measurements can have a weak influence on the process and is only contributing for waste computational time.

All measurements with a strong correlation are important and for that reason correlation analysis of the measurements will be used as a factor of choice. Sometimes beyond this analysis is necessary to have some care with the choice of the measurements, for instance power produced has a weak correlation with gear oil temperature but from the experience point of view is clear that if power varies, gear oil temperature must also vary, fig. 2 gives an example of that.

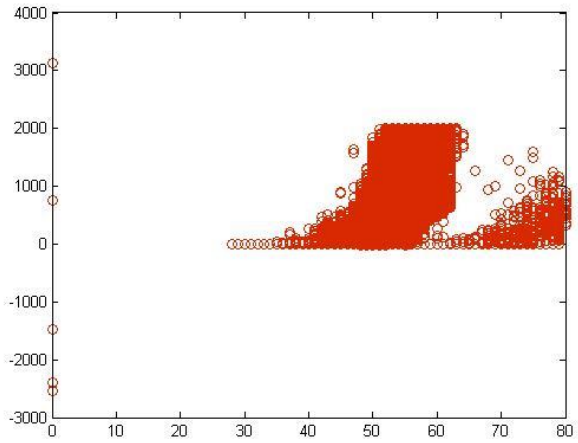

Fig. 2. Correlation between gear oil temperature and power produced.

In this particular example the correlation between these two measurements is inexistent. But as was said before must be a relation between power and gear oil temperature. The reason for this occurrence can be explained by the low system load. As is possible to see in fig.3, most of the time the turbine is working with low wind speed and inherently producing little

power. For this reason power may not influence strongly the temperature of the gear oil.

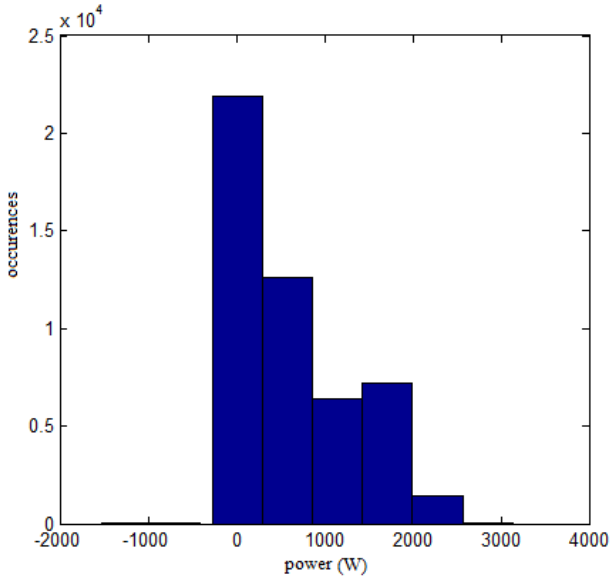

Fig. 3. Histogram of power produced by the wind turbine.

The correlation between measures should not be the only approach to choose the appropriate input measurements, is necessary to have too some sensibility to not leave out of the input set some measurements which can carry important information.

After making the analysis about measures correlated is necessary to analyze the behaviour of each measure. because some of them have a similar behavior and therefore bring no added value, for that reason instead of two or three measurements with the same behavior is possible to use only one of them, reducing this way the number of inputs and the computational time.

Another issue that must be understood is if any of the input measurements has some delay. Sometimes there is an inertial effect in the output in respect to an input and because of that, the influence of a change on a input variable may be felt in the variable output delayed some periods of time. For a good performance of the NN is necessary to ensure that the maximum influence of an input of the model in its output is at the right period of time, including delays if they are needed.

Summarizing, for a good choice of the input set is necessary to find the measurements with more influence in the output variable, then is important to watch if there are measurements with the same behaviour and finally is necessary to inspect if is necessary to introduce delays in some measures.

After doing this study to choose which measurements will be the inputs of the NN, the answer fell on 4 variables, for the detection of faults in the gear box. The variables are presented below.

- Power generated (t-1)
- Environment temperature (t-3)
- Bearing temperature (t)
- Nacelle temperature (t)

IV. NN Application Results

For a good fault detection approach is necessary to develop very accurate models, built based on series of measures that effectively represents the normal operation of wind turbine. In the model implemented the measurement set for training, test and validation of the model had 1 year interval and the model has 4 inputs in the input layer, 1 hidden layer and 1 output.

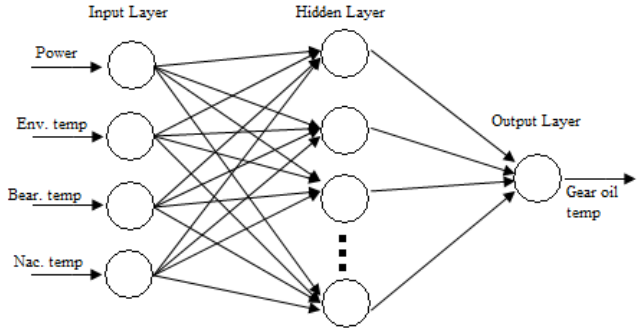

Fig. 4. Schematic of the NN model

The criterion used to evaluate the performance of the model is the reduction of the mean square error (MSE), given by (1). The number of epochs, which indicates the training speed, can be used as criteria too.

$$MSE = \frac{1}{n}\sum_{i=1}^{n} e_i^2 \tag{1}$$

Using the CLEMENTINE software to implement the NN to make the prevision of the gear oil temperature for 1 year data and as input of the NN model the measures described in the previous section, the results are presented in the fig. 6. In fig. 5 is represented the influence of each input on the output.

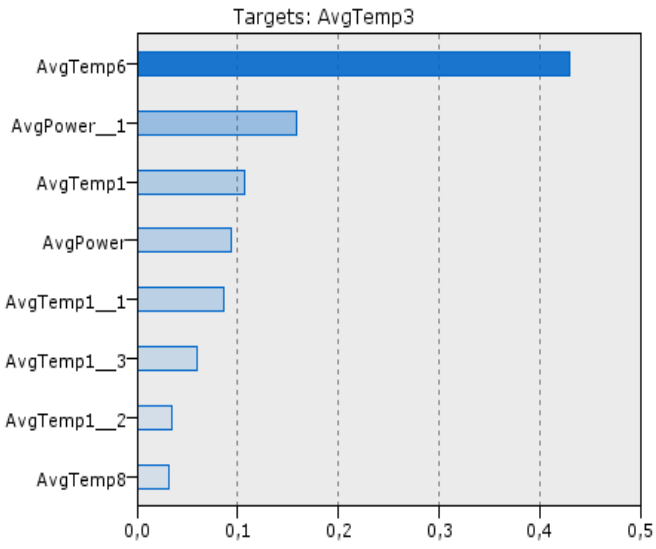

Fig. 5. Variable importance

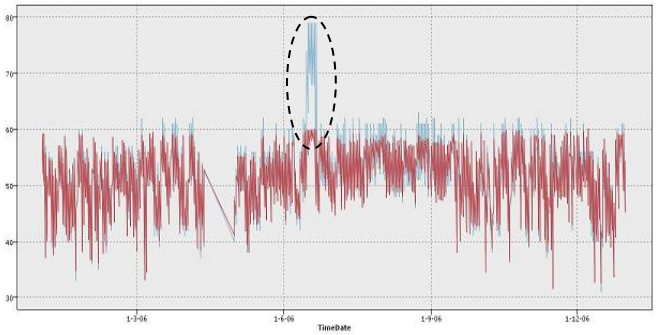

Fig. 6. Comparison between real and estimated values.

The lighter colour represents the real gear oil temperature and the darker colour represents the prevision made by the NN model. As is possible to see during most of the estimated gear oil temperature follows the real temperature, but in a very clear period of time this does not happens (dashed balloon). It's clear that something wrong happened in that period.

Analyzing the period in which the deviation is out of normal was possible to identify that it occurred between 15 and 21 of June. Referring to the unavailability report made by the wind farm owner was possible to check that the machine had some troubles related with gear oil high temperature. Looking to the service reports made by the maintenance team on that wind turbine, is reported that gearbox had serial troubles in some components, in that period, with the maintenance team working on that to troubleshoot a problem in the gear oil system. With these results is possible to conclude that developed NN model of wind turbine is validated.

V. Conclusions

The study presented in this paper shows that neural networks are a valid tool and can be useful to make an early detection of failures in some wind turbines equipments. In spite of results presented are referred to troubles happened in the past, is possible to use the same method with online measurements as a way to warm some future faults in wind turbines components. The results presented here were applied to the gearbox but the model can be used for earlier detection of faults in other components of the wind turbine.

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