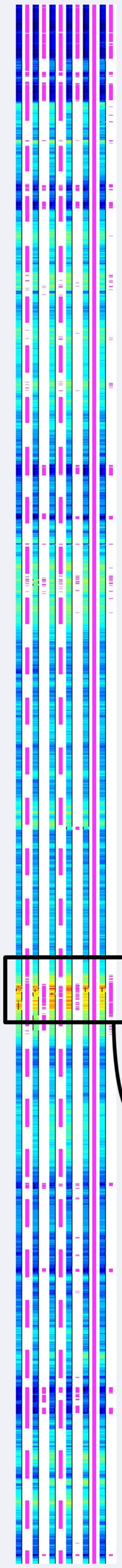
PO076

Graphical Analysis of Wind Turbine Dynamics through SCADA Data Mining

Ludovico Terzi[1], Francesco Castellani[2], Davide Astolfi[2], Emanuele Piccioni[2]
1 Renvico srl, Via San Gregorio 34, 20124, Milan, Italy www.renvicoenergy.com
2 University of Perugia, Department of Engineering, Via Duranti, 06125, Perugia, Italy



Abstract

The widespread diffusion of SCADA control systems in modern wind turbine technology has revolutionized the management of machine portfolios. Potentially, every wind farm owner can develop its own tools for performance evaluation, fault diagnosis and prevention, optimization [1, 2]. Wind technology in the age of information therefore faces the challenge of elaborating vast amounts of data, processing them into knowledge, visualizing them intuitively [3]. Due to the stochastic nature of the source, this ambition lies at the crossroad of engineering, physics, statistics and computer science and has therefore stimulated considerable debate in the scientific literature and fruitful collaborations between academia and industry. In this study, a mathematical and graphical method is proposed for elaborating turbine state dynamics and SCADA measurements in a combined way. Its strength lies in intuitiveness and versatility: it can be be used for a bird's eye view on a portfolio of machines, for inquiring whether maintenance programs are been planned judiciously, for a first investigation on the reasons of faults, especially for SCADA systems which are poor in providing information to the farm owner. Further, the graphical output does not depend on the input language of the single SCADA supplier and is potentially universal. Actually, this method is tested on some wind farms owned by Renvico srl having different SCADA systems suppliers.

Objectives

The main objective of the study is the formulation of a post-processing method for treating simultaneously:

•*SCADA measurements*

•*Wind turbine state dynamics*

These two sources have *different* nature and *time scale* [4]: *10 minute* time basis the *former, continuous dynamics* the *latter*. Actually, a wind turbine might stay in the same operative state for days (as it should in the case of production) or for few seconds.

In this work a *mathematical method* is proposed and an *innovative graphical* output is produced. It is tested *on two wind farms (WF1* and *WF2*, Figures 1 to 4*)*, one in southern Italy and one in France, having very different SCADA languages and operative features.

Actually the strength of the method lies in its universality and versatility. It might be used for:

•*Performance visualization*

•*Bird's eye view* on the *efficiency* of *maintenance programs*

•First *investigation* of the causes of *downtime*.

Figure 1: WF1

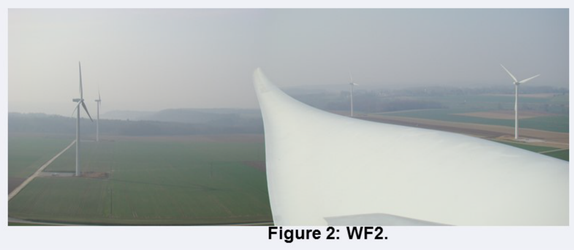


Figure 2: WF2.

Figure 3: WF1

Figure 4: WF2

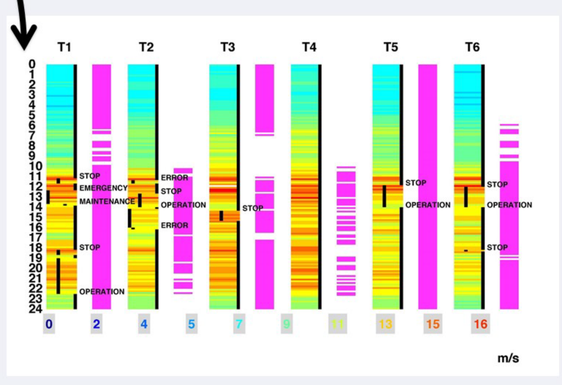
Methods

The method is based on associating *2 numbers to each 10 minute interval for each turbine*:

- The *first number* codifies the *state activated mostly during the interval*: it describes *what the turbine has done*..
- The *second number* is a *meaningful SCADA measurement*. The *choice* of the channel is *customizable*.

With this *two-dimensional map*, a *graphical representation* is built:

- Each *turbine* during a period is represented by *a bar*
- The *bar is filled with color and a black line*
- The *bar* is actually the *juxtaposition* of *horizontal slices* made of a *black dot* and a *color background*.
- The *dot* represents the *state*. Moving *from right to left: production, start-up, run-up, manual stop, emergency, errors*.
- The *background color* is built by *mapping the interval of SCADA values into a color interval*. *Blue* is the *lower* limit, *red* is the *upper* limit.
- Meaningful examples of *SCADA* measurements in *background* are *wind speed or direction, turbulence intensity, power, temperatures* (Figures 4, 5, 6).



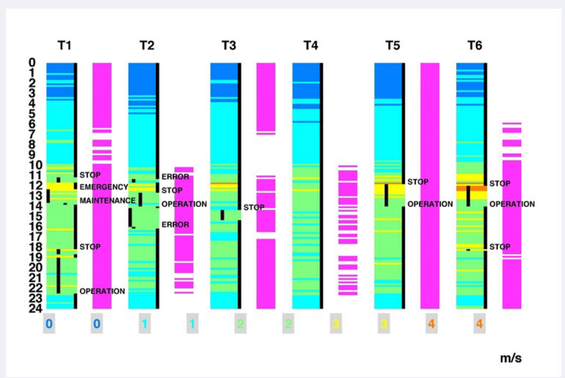
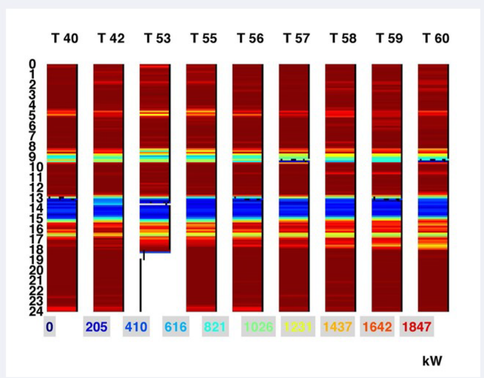


Figure 4: WF2. Incoming fault. Wind Speed standard deviation (left), Wind Speed (right) in background. The magenta bar represents alarm activation.



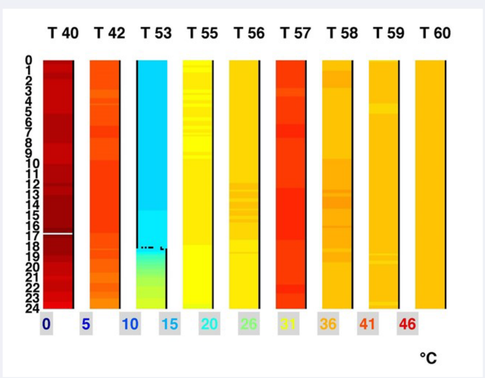


Figure 5: WF1. Fault incoming, Active Power in background (left), Rotor Bearing Temperature in background (right).

Figure 6: WF2. Monthly view. Wind speed in background. The magenta bar represents activation of an alarm.

Conclusions

- The proposed *graphical analysis* conjugates *versatility* to *exportability* to different SCADA languages.
- For *exhaustive SCADA systems*, the method provides *an aggregate performance visualization*, useful for a *bird's eye view* on wind farm behavior. Further, when *information* is *superabundant* and can not shed light on wind farm dynamics, the aggregate visualization of states, alarms and SCADA provides *powerful insight*.
- For *more basic SCADA systems*, the method helps in *reconstructing the dynamics*: *extracting sense from scarcity*.
- For the testing ground of WF2, a possible case of *too conservative wind farm management* is highlighted. The method is precious as *intermediation between ownership and management and for improving management.*

References

1. Kusiak A, Zhang Z, Verma A. ``Prediction, operations, and condition monitoring in wind energy''. *Energy*, 2013;60:1 -- 12.
2 Amirat Y, Benbouzid MEH, Al-Ahmar E, Ben- saker B, Turri S. ``A brief status on condition monitoring and fault diagnosis in wind energy conversion systems''. *Renewable and sustain- able energy reviews*, 2009;13:2629--2636.
3. Astolfi D, Castellani F, Garinei A, Terzi L. ``Data mining techniques for performance analysis of onshore wind farms''. *Applied Energy*, 2015; 148:220--233.
4. Castellani F, Astolfi D, Terzi L. ``Analyzing state dynamics of wind turbines through scada data mining''. In ``Advances in Condition Monitoring of Machinery in Non-Stationary Operations'', pages 213--223. Springer, 2016;