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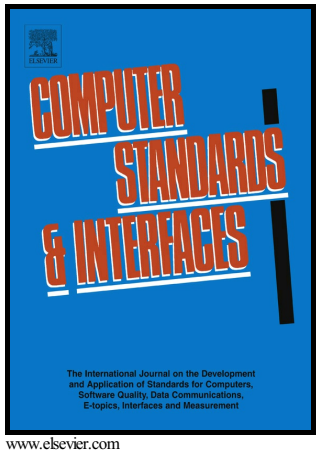


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# Towards an Evolvable Data Management System for Wind Turbines

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**Abstract**

There is a trend towards large wind farms clustering a significant amount of turbines, aiming at continuously optimizing design and maintenance costs and thus reducing the overall cost of energy. Advanced control algorithms and maintenance optimizations may affect the lifetime of the turbines. Therefore it is necessary to actively monitor turbine behavior and condition. In order to fulfill this requirement, clean and accurate data sets need to be available. This data can be diverse in type and might evolve in a progressive innovative environment. In this paper, we present a system which can store and manage such data. Because of non-functional requirements as evolvability, maintainability, scalability and diversity, the Normalized Systems Theory was taken as theoretical foundation for the development of this system. Since the theorems of this theory are not always easy to grasp for practitioners, we combined our development with the derivation of a set of rules tailored to the application domain of our technology stack.

*Keywords:* Wind Turbines, Monitoring, Evolvability, Data Management, Normalized Systems

## 1. Introduction

The wind turbine industry is continuously improving turbine designs to reduce the overall cost of energy. At the same time turbine reliability needs to be guarded in order to guarantee a lifetime of 20 years [1]. During the last decades, there has been a high increase in the number of turbines in operation [2]. There is a trend towards large wind farms clustering a significant amount of turbines. In particular, offshore wind turbines typically make part of large wind farms with a single or small amount of high voltage substations. Consequently, these farms can be managed as one electrical power plant.

Advanced control algorithms will be soon available to control the individual wind turbine power production in order to optimize the overall wind farm performance [3]. This can include derating selected turbines to minimize wake effects or active and reactive control for the optimization of electricity grid behavior.

Such control may affect the lifetime of the turbines. Therefore it is necessary to actively monitor turbine behavior and condition and take the real occurring loads into account for the turbine life assessment. The trend for prognostics based maintenance of wind farms is in line with these considerations. Structural health monitoring is considered of primary importance because it is the structure that provides the integrity of the system [4].

This evolution thrives the need for advanced health monitoring systems in combination with tailored maintenance schemes aiming for minimal downtime during peak energy and bad weather periods. Optimized maintenance actions will not only significantly affect the business case of the wind farm owner operator. Also the grid operator benefits from the availability of the complete wind farm at critical moments of peak use [5].

All these goals have a similar requirement: the availability of clean and accurate data sets, which are diverse in type and might continuously evolve in a progressing innovative environment. Consequently, the data management system need to support the properties of evolvability and support for diversity. Besides, maintainability is in general considered an important design parameter [6]. With these requirements in mind, we wanted to