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Plug-in driven architecture for renewable energy generation monitoring

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ABSTRACT

This paper is about the benefits of a plug-in based software architecture, but it is not only intended for programmers. It also stands the fact that monitoring is needed in any renewable energy generation plant and describes a way to fulfill this need.

The fast evolution of renewable energy sources during the last decades resulted in the installation of many power systems all over the world, showing a sharp trend towards Distributed Resources (DR). There are many people related to them (because they use, own, operate, maintain or receive services from DR) who may be interested in knowing things about them for several reasons like production, maintenance, investigation, profitability, etc.; that is why data-acquisition systems are widely used in renewable energy source applications. These systems allow to collect and analyze data regarding the renewable energy installation performance as well as meteorological data.

The basic idea on this paper is to achieve monitoring of different energy generation plants using a plug-in driven design technique, presenting as a result of an extensible software architecture design.

The main difference between this paper and the previous work is that we focus specifically on monitoring as a necessity, proposing a generic and extensible software system, which could be employed to monitor any kind of renewable energy plant and extended to connect to new developed devices by changing small pieces of software.

Contents

1. Introduction

Renewable energy is the name given to the energy obtained from natural sources virtually inexhaustible, either by the vast amount of energy they contain, or because they are able to be regenerated by natural means. We can name, for instance, solar power, wind power, geothermal power, fuel cells, etc. [1].

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For years and years, fossil fuels have been enormously consumed on the Earth [2], so they have been rapidly decreased, making it more difficult and expensive to use them. In addition, the pollution produced by fossil fuels made people realize the importance of renewable energy. During the last years, many people have dedicated to the research, development and utilization of such important energy, causing the need to monitor its generation.

The following Section enumerates some existing technical solution purposes on that matter. Section 3 describes the main characteristics of a plug-in architecture and its benefits, justifying its use.

Section 4 goes on detailing our proposed solution, an architecture which establishes the basis for collecting data from a renewable energy generation plant, visualizing them both in a statistical as a real-time manner and notifying the user about several events and anomalies that may occur.

Finally, Section 5 reveals the conclusions reached and Section 6 points out some ideas that can contribute to future works.

2. State of the art

In this section we present part of the current work on renewable energy generation monitoring. Several authors have been investigating on this subject and achieved different goals.

While some of them focus on monitoring the installation state and controlling involved devices, others prefer to pay attention to data related with the installation performance and meteorological behavior. Among important aspects usually monitored we must mention connection status, real power, reactive power, voltage, frequency and energy (kWh). In some of these articles alarm and notification issues are also treated.

du Boulay et al. [3] show that it is possible not only to monitor but also to control sophisticated instruments remotely. In their article they present the web services based system for collaborative monitoring of remote scientific instruments and sensors.

Kuo-Hua Liu [1] studied the dynamic characteristics of photovoltaic energy generation using a PLC control. The present work includes real-time voltage and current monitoring, event detection, information collection and the set-up of a security system.

There are also various papers which focuses on data collection, Koutroulis et al. [4] as well as N. Forero et al. [5] introduce interesting articles about data acquisition. On the first one, the proposed system consists of a set of sensors for measuring both meteorological and electrical parameters. The collected data is then sent to a LabVIEW program, which is used to further process, display and store it in the PC disk. The second one's aim is to present a system developed for monitoring PV solar plants using a novel procedure based on virtual instrumentation. The measurements and processing of data are made using high precision I/O modular field point devices as hardware, a data acquisition card as software and the package of graphic programming, LabVIEW.

Benghanem and Maafi [6] go beyond, developing an expert system for studying the performance of photovoltaic (PV) systems; in particular the sizing of such systems and their reliability. They show it is possible to exploit the information about the climatic environment of a given site and the parameters related to PV systems. On this work data are treated and decoded in their real physical values (current, voltage, energy, etc.) and used by a PC computer to study the performance of the PV system considered.

On the other hand, papers like [7] emphasize on the analysis of modules performance, degradation or failure under realistic outdoor conditions, showing another important responsibility of monitoring systems: failure detection.

The inclusion of DG (Distributed Generation) systems is changing the paradigm of energy production. Local Grid Codes dictate the behavior of the grids under different faults. However, in grids with high penetration of renewable energy sources, conventional regulations are under revision. The basic element for interconnecting DG to the transmission system is the three phase inverter. In normal grid conditions, three phase DG inverters inject all the generated active power into the grid, but one of the major drawbacks for proper operation of the whole installation occurs when a voltage sag is transmitted through the network. Depending on the depth and duration of the voltage sag, Grid Codes may force even a temporary disconnection of the system.

A flexible voltage support control scheme has been proposed in [8] for three phase DG inverters under grid fault. In grid fault conditions, the controller must react to the perturbation and mitigate the adverse effects on the inverter side. The purposed voltage support strategy can be modified by means of a control parameter according to the type of voltage sag, resulting in a flexible combination of raising and equalizing capabilities. Voltage sags and other significant issues that may occur will be easier to understand as more information we have about the behavior of DG, therefore monitoring is an extremely useful tool as far as research is concerned.

Finally, Li Wang and Kuo-Hua Liu [2] show that it is as important to know the state of the system at a given time as to be notified when something is not going as expected. Their system performs different functions such as power-flow data measurement and collection, realtime load monitoring and load-shedding control, real-time and historical data mapping, timely report and handle of alarms and events.

All of these papers show us how important monitoring is and allow us to identify main parts in any monitoring system, such as: data collection, data processing and visualization and finally, notification and handle of alarms and events.

3. About plug-ins

A plugin is just like a little black box that provides a public interface to the outside, which can be used by other plugins. In plug-ins based software systems the main application logic is reduced to mere plugins hosting and management, as it provides no other functionality to users [9]. The real feature set offered by these applications is defined by different individuals plugins loaded and managed by this base infrastructure. Communication and interaction between plugins is achieved by using its public interfaces.

A plug-in can also provide general functionality allowing other plug-ins to extend or customize portions of it through an Extension Point. The extension point declares a contract that extensions must conform to. Plug-ins with more specific functionality may connect to that extension point by implementing that contract. The key attribute is: the plug-in being extended knows nothing about the plug-in that is connecting to it beyond the scope of that extension point contract. This allows plug-ins built by different individuals or companies to interact seamlessly, even without them knowing much about one another.

By dividing an application into multiple plugins, giving each one a well-defined task, complexity and size of each module is drastically reduced [9]. Also, when compiling a plugin into a well-documented executable unit, the plugin becomes a sealed unit with a clearly defined interface and can be shared between various developers, without having to take a look at the original source code.

A high degree of modularity is an important factor for building software systems of high quality [9]; however, proliferation of the functionality of a plugin-based system could be detrimental to its ease of use and bring to confusion and disorder if users who have