INTELLIGENT SELF-DESCRIBING POWER GRIDS

Andrea SCHRÖDER
FGH e.V. – Germany
andrea.schroeder@fgh-ma.de

Inaki LARESGOITI
Fundación LABEIN – Spain
lares@labein.es

Karl WERLEN
CYGNUS Engineering AG - Switzerland
karl.werlen@cygnus.ch

Bernhard SCHOWE-VON DER BRELIE
FGH e.V. – Germany
bernhard.schowe@fgh-ma.de

Armin SCHNETTLER
FGH e.V. – Germany
armin.schnettler@fgh-ma.de

ABSTRACT

Requirements by international electricity markets and increasing dispersed generation add to the complexity of power grid operation. Automated network management systems based on massively distributed information help to maintain the expected quality performance, manageability and reliability.

Within the research project S-TEN such automated network management systems are developed including one demonstrator for the control of distributed resources in electrical power network and another for distributed secondary control of microgrids. The paper will introduce the S-TEN technology and describe the mentioned applications.

INTRODUCTION

The aim of the S-TEN project is to exploit the "Semantic Web" [1] for scientific and engineering applications and to provide an automated network management in a massively distributed and continuously changing network of intelligent self-describing devices.

The S-TEN approach provides support for decision makers in such a complex and continuously changing environment. This support is based upon the application of process knowledge bases to measurements, human observations and design information published on the Web.

Major industrial enterprises that perform network management activities, like electricity transmission grids, petrochemical plants, and water supplies rely for their operation on the existence of a static network configuration in which components are added/removed from the network after lengthy planning processes and on safety critical applications where a guaranteed short response time and a high level of whole system reliability are required. Such requirements cannot be met by software running over the Internet and using non real-time operating systems.

Nonetheless for emerging applications, it is the dynamicity of the composition of the network and low cost that makes a system based on S-TEN technology practical. Therefore the first take up of the S-TEN technology will be for new applications where a traditional system is not suitable, because of expense, complexity and rigidity for the addition/removal of components.

The paper introduces the main aspects of the S-TEN approach and describes two possible applications in the field of power systems.

THE S-TEN PROJECT

Overview

W3C[1] envisages the future of the Web to be a "Semantic Web" extended by machine-understandable information and automated services that go far beyond current capabilities.

The objective of the S-TEN (Intelligent Self-describing Technical and Environmental Networks) project is to tap these new possibilities for applications in the technical domain. This support is based on applying rules and process knowledge on available data published to the web. The data comprises measurements, human observations and design information. Data acquisition and process control is assisted by self-describing devices, e.g. measurement sensors or intelligent sub-systems, installed in the considered technical systems.

Innovations provided by the S-TEN project will comprise an ontology that enables a device to announce its existence, position in a network, and the services it provides. Also, the capturing of human qualitative observations and their publication on the web with respect to a formal ontology, as well as the development of rules that can be applied to any kind of technical data available on the web are key innovations.

The S-TEN project, coordinated by FGH e.V., started in April 2006 and will last till October 2008. It will provide prototype software, implementation examples and will contribute to Semantic Web standards. The S-TEN approach is validated and demonstrated by application examples including the control of distributed resources in electrical power networks and distributed secondary control of microgrids.

The following subsections provide more details about the Semantic Web, the Ontology Web Language, decision support and the S-TEN approach.

1 world wide web consortium (see http://www.w3.org)

The Semantic Web

The Semantic Web is an enhancement of the World Wide Web (WWW) and is based on the ideas of WWW-founder Tim Berners-Lee. It supports cooperation between human beings and machines in the Web [2]. Information published on the Web is enriched with an additional formal description. Applications are able to process this semantically enriched information and to understand the meaning of it. The Semantic Web needs to deliver the right information to the right person at the right time in the right place. Many of today's web applications, such as flight booking systems and search engines can be considered as implementations of the ideas of the semantic web. However, few of them yet fully exploit proposed standards such as OWL (Ontology Web Language) [3] and related software tools.

Ontology Web Language (OWL)

For the representation of complex knowledge relationships the expression "ontology" became naturalized in computer science in connection with the Semantic Web. Ontologies exist of components like concepts, instances and relations. An ontology implies both the definition of properties for classes (semantically related elements) and the description of logic relations. OWL is the standard language for ontologies in the Semantic Web.

Decision Support

One objective relevant to power system operation is to provide support for operators working on complicated and continuously changing networks [4].
Most current decision support systems use ad hoc algorithms. S-TEN will develop non-proprietary decision support systems based upon formal rule bases.
Within the S-TEN project rules will be applied to OWL defined data published on the Web, e.g. measurement data, human observations and design information. Inference engines apply rule-bases upon monitoring data, trigger appropriate alerts and generate appropriate advice documents. Preventive maintenance is supported by triggering maintenance requests appropriate to equipment state and generating appropriate maintenance documentation. Rule-based filters applied to historic data, can help to analyze fault situations with a potential to enhance an ever growing knowledge base for a specific class of equipment. A rule base operating on process monitoring data provides an operator with Best Practice Advice appropriate to the current network state.

The S-TEN approach

The S-TEN approach is based upon off-the-shelf Semantic Web software, plus:

- standard ontologies for publishing measurements on the Web;
- standard ontologies for publishing network design data on the Web
- rule bases to provide notification and operator support, which are configured for each application

Therefore the S-TEN approach is different from traditional network management systems because Semantic Web technology is used as a single platform, as follows:

- the Internet provides the communications infra-structure;
- the publishing of measurements on the Web using standard ontologies replaces the SCADA system;
- the publishing of design data on the Web using standard ontologies provides communication with network design systems;
- the Semantic Web itself becomes the centralised data base;
- rule bases acting on the Web-published information will provide notification and operator support.

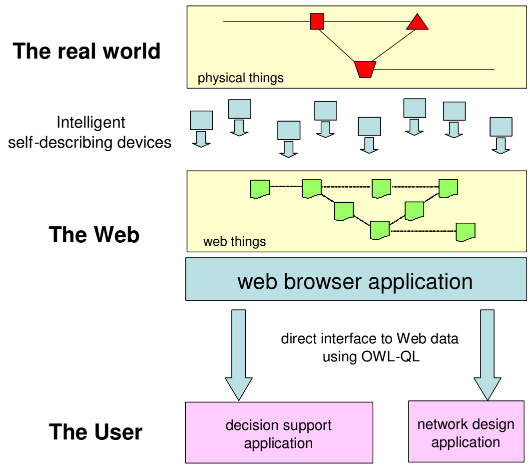

Figure 1: Diagrammatic representation of the S-TEN approach

Figure 1 shows a diagrammatic representation of the S-TEN approach. Data acquisition and process control is assisted by self-describing devices, e.g. measurement sensors or intelligent sub-systems, installed in the considered technical systems (physical things).
Information about design and state of the considered system is not held within a centralized database but each node has its own intelligence, is able to register in the network autonomously and publishes information about its position, services and data (web things).
A monitor operation analyses the current status of the network and determines which objects are part of it, how they are connected and what they are currently doing.

THE S-TEN APPLICATIONS

Introduction

The emergence of more and more distributed energy resources (DERs) will have crucial impact on the structure of tomorrow's power grid. Power generation will not only take place in a few central power plants of some 100 MW up to 1 GW per unit but also in the increasing number of dispersed power generation units located in the medium voltage level (e.g. wind power plants) as well as in the low voltage level (e.g. residental Combined Heat and Power (CHP) and solar power plants).

According to a study of VDE (Association for Electrical, Electronic and Information Technologies) in 2006 [5], the distribution systems are said to change significantly in the coming years. Power flows from the transmission system to the distribution system will partly reverse as more and more small generators based on renewable energies feed in the distribution system. As a consequence reserves managed by the transmission system operator will have to be composed of traditional power plants and virtual power plants, which may be a combination of many small distributed enery resources. By this process of clustering, these virtual power plants can offer network services, e.g. in the energy control market. Such clusters must be able to optimize and control themselves to a large extend according to a prognosticated schedule.

A main requirement for the integration of dispersed power generation units and the realisation of virtual power plants is the controllability of DERs. A prerequisite for controllability, though, is the existence of communication links between distributed resources and control centers. Up to now, communications links between DERs and control centers do not exist at all in the low voltage system - apart from a few exceptions. In medium voltage systems the number of DERs with communication links is higher but there are nevertheless many DERs lacking them. This problematic situation is worsened by the fact that no continuous monitoring of the system voltage exists in the low voltage system. In the medium voltage system more information is available but also here it is not complete. In brief, system wide measurements are missing in order to determine the impact of DERs such as changes in voltage and power.

The application "Control of distributed resources in electrical power systems"

The prototype application "Control of distributed resources in electrical power networks" will provide monitoring facilities for DERs, such as wind turbines and CHP units, to improve the distribution system management in terms of remote control capabilities. Apt target functions and restrictions of a multi-criteria optimization of decentralised energy systems will be developed for different operation strategies and necessary control parameters for the operation of a DER interconnected with other DERs will be derived taking into account both ecological and economical constraints such as emissions of DERs and power generation costs. Moreover, strategies for providing Best Practise Advise will be developed. Except for DERs, the following assets will be monitored and controlled: Short-circuit indicators, disconnectors, transformers and circuit breakers.

In the medium voltage level short-circuit displays within substations will be considered as they can give valuable hints after a short-circuit in terms of where the failure location is. The aim is shortening of supply interruptions after fault clearing from about 1 hour (in the average) to some minutes by remote reading of short circuit indicators and remote switching of disconnectors. As hardly no communication lines exist from distribution substations to a control center up to now, different ways of communication will be analysed. As one possibility, it is suggested to implement a PC with UMTS modem and VPN access to a PC within the control center. Whenever a short-circuit occurs the substation provides this information to the control room. The faulty section can then rapidly be switched off. This could be done manually or automatically (in the latter case by defining a rule).

Besides, more operational data will be collected for an effective system management, such as data on power system currents and voltages. For both, rules for upper and lower limit violations will be defined leading to automated warnings and alarms.

The application "Secondary control of electrical power systems"

Microgrid definition

A microgrid [6] could be defined as a low voltage distribution network with distributed energy sources (micro turbines, fuel cells, PV, diesel, etc.) altogether with storage devices (flywheel, batteries, etc.) and loads.

These systems could be operated, either interconnected to the main grid or either isolated from it, by means of a local management system with a communication infrastructure allowing control actions to be taken following any given strategy and objective.

At the laboratory micro grid system, each micro grid connected device including generation, storage and loads will have its own local controller with its defined aims. These local controllers incorporate communication protocols, based on Internet standards, acting as gateways to the proprietary device interface.

Management functions

The Micro Grid Management System [7] provides the following functionality:

- SCADA like system; it is able to acquire data from the sources inside the micro grid and send commands.
- Selling bids managing system; the generators can produce selling bids and send them to a central market manager (based on the Spanish electricity market [2]).
- Power schedule tracking system; the generators' local controllers retrieve power scheduling information and send the set points to the generators.

- Secondary regulation system; it is in charge of analyzing planned generation targets and real measurements and performing suitable corrections over generation schedules.
- Load shifting system; the load shifting process consists in delaying the time period when a load is effectively connected in accordance with some optimization criteria.
- Load curtailment system; it decreases the power consumption of the loads.

Secondary regulation

The Secondary Regulation Control System is in charge of adjusting the current power schedules of the generators taking into account real time measured active power generation, initially planned schedules and micro source configuration settings.

The microgrids of the future are seen as highly automated electricity grids composed of generation, storage equipment and that can be dynamically connected and disconnected from the network.

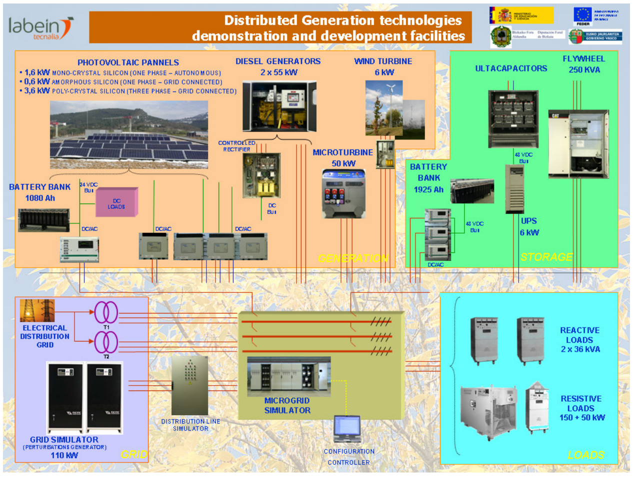

Figure 2: Electrical Schema of the test bed

This connection/disconnection capability of the components of the grid requires plug and play functionality of the devices, as well as, a certain degree of intelligence in each of the devices.

To demonstrate the secondary control regulation in microgrids, we are going to design an architecture that allows each of the devices to:

- Announce their existence to the rest of the devices connected to the network.
- Volunteer its participation in the network management process.
- Describe, semantically, the services that each of the devices provides.
- React to the invocation of services by other devices of the network.
- React to emergency situations, like the failure of other devices and have the ability for taking over others' roles in such situations.
- Perform an automatic configuration of the network based on the self descriptions provided by the different devices.

Laboratory micro grid

The experiments will be performed at LABEIN's laboratory. The diagram of the equipment of the laboratory is shown in Figure .

CONCLUSIONS

The web gives the opportunity to make things readily available, independent of location and at a low price. Semantics are seen as the key to smarter forms of collaboration and process control. In the electricity industry, security reasons and real time requirements have delayed the uptake of this technology. Nevertheless, future power systems with significant share of power generated by DERs have to be managed in an intelligent way.

This paper presents the work that is being done for the use of technologies that have proved successful in other fields and that can provide the functionality required by the grid of the future.

MISCELLANEOUS

Acknowledgments

The S-TEN project is co-funded by the European Community in the Information Society Technologies (IST) FP6-IST-2005-027683.

The financial support is greatly acknowledged.

REFERENCES

[1] Tim Berners-Lee, James Handler and Ora Lassila, May 2001, The Semantic Web, Scientific American Magazine

[2] IEEE Intelligent Systems special issue on the Semantic Web (March-April 2001)

[3] OWL "Web Ontology Language", http://www.w3.org/2004/owl/#specs.

[4] KADSII-Project http://hcs.science.uva.nl/projects/CommonKADS/home.html.

[5] Studie zur Versorgungsqualität, http://www.vde.com/VDE/Fachgesellschaften/ETG/Aktuelles/2006-oeffentlich/2006-23.htm

[6] Integration of Distributed Energy Resources - The CERTS MicroGrid Concept, LBNL-50829, http://certs.lbl.gov/pdf/50829.pdf.

[7] Energy Manager Design for MicroGrids, March 2005, http://certs.lbl.gov/pdf/54447.pdf.