INTELLIGENT SELF-DESCRIBING POWER GRIDS

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

Thomas DREYER
AUCOTEC AG – Germany
thd@aucotec.com

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

Web-based services are appreciated to be a enabling technology for implementing the vision of future smart energy networks and their correspondent enhanced customer services. Meanwhile, in the development of the Web, semantics are seen as a central key to enable and to support smarter forms of collaboration and process control. In this context, semantics may be essential to manage future power systems with significant share of power generated by distributed energy resources in an intelligent way – as required in the framework of smart grid designs. The EU funded project S-TEN (Intelligent Self-Describing Technical and Environmental Networks) lays foundations for advanced monitoring systems and sensors by applying Semantic Web [1] technologies, Web Services and rules to potentially constantly changing networks composed of network components ranging from simple sensors to complex plants such as combined heat and power plants. This paper will present the work being done to develop and use technologies designed to provide functionalities required by future power grids.

INTRODUCTION

The Vision paper of the European Technology Platform SmartGrids [2] has clearly identified the changing generation landscape of future power networks and the subsequent urgent need for new network design and control strategies enabling customers to become interactive with the network components – taking into account an enhanced concept of customers as new business models comprising generation unit operators, grid operators, consumers, traders or investors are getting into the markets. Flexibility and accessibility of future energy networks are therefore recognised as key elements. Accordingly information and communication technologies (ICT) play a predominant role – as displayed in the Platform’s Strategic Research Agenda [3] – to ensure enhanced business models, to provide standardised interfaces to network equipment, hence enabling plug&play features, interoperability or remote control, and to facilitate an internet-like architecture of energy networks with web-based customer services and a high degree of automation including self-healing properties. Within the context of an environment of constantly changing networks of data sources and devices the S-TEN project (FP6-IST-2005-027683; duration: 01.04.2006 - 30.09.2008) aims to give these individual objects an individual presence on the Web or intranet with the capability to describe themselves and to publish their data in a semantically interpretable form. This includes technical and administrative data, e.g. information about available data and also access paths to offered services and their specifications. Because of a potentially large structural complexity of the data sources in question – like having a complete plant being encapsulated in such an object – this may require to access rather voluminous engineering information. To enable this in a semantically interpretable way, the creation of a ‘bridge’ between two worlds apart up to now, OWL (Web Ontology Language) [4] and STEP (STandard for the Exchange of Product data, ISO-10303) [5], is part of the project, too. By applying formal rules and process knowledge to the semantic data published, decision support and “best practise support” may be offered without recourse to central, proprietary databases. By offering these technologies, S-TEN lays foundations for technical and environmental applications, suitable to overcome those restrictions and limitations stated above.

S-TEN TECHNOLOGY

Registry

Within a grid with lots of distributed resources each resource has its own intelligence, is able to register in the network autonomously and publishes information about its position, services and data. This is done by giving sensors/plants a semantically interpretable self-description which is uploaded into the S-TEN registry. The S-TEN registry is also based on semantically annotated Web Services complemented by a semantically annotated registry schema describing the semantics of data stored in the registry. Authorised control systems can access the registry and query for a particular service (Figure 1) like looking up for installed PV plants with a specified grid area. The registry response contains relevant information to access the Web services offered by the individual sensor/plant, e.g. monitor actual data, browse data for a specific instance in time or a period of time, control capabilities, subscribe to event notification such as alarms and warnings etc..

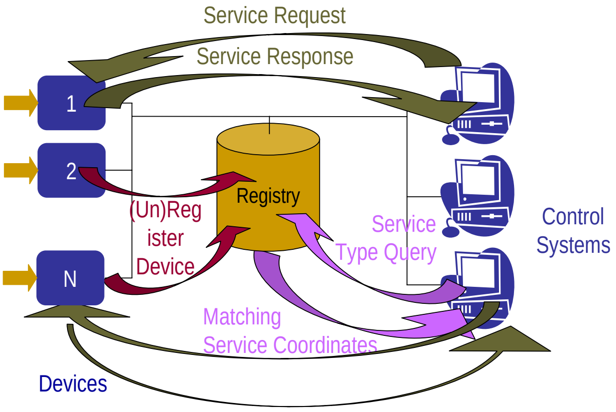

Figure 1 : Overview of the S-TEN system

Web Services

S-TEN data access is based on semantically annotated Web Services or on agent based systems using semantically annotated Web Services. This approach was chosen, as standard Web Services take into account only the functional or syntactical aspects of a service. This means semantic information is either not available or offered only in an informal and human-interpretable way. It's therefore not possible to derive the intended semantics of input, output and function or the meaning of parameters of a Web service from its WSDL description only. In that way, two Web services may have the same syntactical definition and, yet, implement different functionality. In this situation, Semantic Web services constitute a promising research direction to automate the tasks of Web service discovery, composition and invocation and to improve the integration of applications within and across enterprise boundaries. At present, there are three main approaches to enable Semantic Web services: SAWSDL [4], OWL-S [7] and WSMO [8], ranging from pragmatic to more comprehending extensions of standard Web services. Within S-TEN, SAWSDL, as the most pragmatic approach was selected as the only one suitable for implementation. The basic idea behind SAWSDL - which since 28 August 2007 is a W3C recommendation - is to enhance the WSDL specification with the aim to go beyond a mere syntactical description of a Web service by adding semantics to the functions and the data delivered by a service. In this approach SAWSDL model references provide the link to the semantics defined in the S-TEN top-level ontology.

Ontologies

The S-TEN ontology [9] describes all S-TEN system components in a computer understandable way and provides the semantics necessary for exchanging messages between the different components of the S-TEN system including those coming from external users and the ones used internally by the system. A top level ontology for sensor related information and Web Services has been developed. Taking into account existing standards such as ISO 15926, IEEE SUMO, IEC 61850 and ISO 10303 (Figure 2). With respect to IEC 61850 (Communication systems and networks in substations) the parts 7-4 (Basic communication structure for substation and feeder equipement – Compatible logical node classes and data classes) and 7-420 (Communication Systems for Distributed Energy Resources (DER) – Logical Nodes) have been considered in terms of disconnectors and circuit breakers and DERs and their assets such as batteries, inverters, etc., repectively. For wind power plants IEC 61400-25-2 (Communications for monitoring and control of wind power plants – Information models) has been taken into consideration.

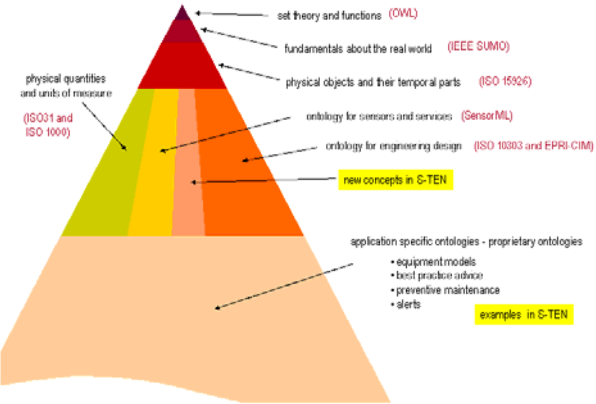

Figure 2 : S-TEN ontology

Currently application specific ontologies referencing concepts of the S-TEN top level ontology are defined for the prototype applications.

Rules

The major advantage of having such an ontology is that automated reasoning can be applied to the data of the network components. Hence, rules supporting system operations are developed within S-TEN and applied to information available in the Web, e.g. measurements. These rules may trigger corresponding alarms in the case of failures, generate Best Practice Advice for the system operator or even induce appropriate control measures based on the currently valid state of the network. Different organisations may have different views on the same data. Therefore each organisation may have their own rule-bases to generate appropriate Best Practice Advice according to the nature of the system status enabling decision-makers to react more precise and faster to unusual situations and unbalanced systems. Therefore, S-TEN provides a flexible instrument for the control of changing networks with a variety of network components of different types.

S-TEN PROTOTYPES

Within the S-TEN project four prototypes are developed to show and evaluate the S-TEN technology Two of them will be described in more detail.

Prototype 1: Control of Distributed Resources in

Electrical Power Networks

Introduction

Smart Grid concepts deal with the massive integration of distributed energy resources on the distribution level causing serious challenges to the power systems that have historically not been designed for this operation. The prototype application "Control of Distributed Resources in Electrical Power Networks" will enable the monitoring of these distributed generators with the aim to improve the management of the distribution network by monitoring and control in terms of economic, technical and environmental measures..

Ontology

Based on the S-TEN top-level ontology an application specific ontology is defined featuring CHP, PV, wind power devices and additional network devices such as circuit-breakers, disconnectors, inverters, batteries, etc..

The Web Services the network resources offer are semantically annotated that is they link to the application ontology and the S-TEN top-level ontology. The following XML document shows an example of a browse request and the browse response written according to the S-TEN ontology:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<BrowseRequest>
   <SessionID>012154782</SessionID>
   <ObservedBy>http://www.fgh.de/sten/DER.xml#MDevice_CHP_1
   </ObservedBy>
   <Observes>http://www.fgh.de/sten/DER.xml#CHP_1</Observes>
    <PhysicalProperty>http://www.fgh.de/sten/CHP.xml#ActivePower
   </PhysicalProperty>
   <After>1201508970325</ After>
   <Before>1201512570325</Before>
</BrowseRequest>
```

Figure 3: Browse request example

```xml
<?xml version="1.0" encoding="UTF-8"?>
<BrowseResponse>
  <ObservedBy>http://www.fgh.de/sten/DER.xml#MDevice_CHP_1
  </ObservedBy>
  <Observes>http://www.fgh.de/sten/DER.xml#CHP_1</Observes>
  <PhysicalProperty>http://www.labein.es/sten/CHP.xml#Active_Power
  </PhysicalProperty>
    <Scale>http://www.fgh.de/sten/SIUnits.xml#Watts</Scale>
    <DataTimeValue>
       <TimeSpec>1201508970325</TimeSpec>
       <DecimalValue>25400</DecimalValue>
    </DataTimeValue>
    <DataTimeValue>
       <TimeSpec>1201508932630325</TimeSpec>
       <DecimalValue>30000</DecimalValue>
    </DataTimeValue>
    <DataTimeValue>
       <TimeSpec>1201508932690325</TimeSpec>
       <DecimalValue>31200</DecimalValue>
    </DataTimeValue>
    <BrowseResponseMessage>
       < SuccessIndicator>Browse succeeded</ SuccessIndicator>
    </BrowseResponseMessage>
</BrowseResponse>
```

Figure 4: Browse response example

Also, rules definition uses concepts from the S-TEN top-level ontology and the application specific ontology.

Architecture and functionality

Each resource within the network (e.g. CHP plant, PV plant, etc.) is connected to an S-TEN server. The S-TEN server registers its monitored resource in the S-TEN Registry as soon as it is in operation. The registration file contains both the URL of the resource and the services it offers.

Each resource sends its data via a communication interface to the S-TEN server where the data is stored in a database. After successfully logging in the client application that is after authorisation and authentication, the user can query the registry for its registered resources having the possibility to ask for all, a type of resource or a resource belonging to a certain network area. As result of this query a list of all registered network resources matching the searching criteria is sent back. When selecting a resource the service description of this resource is demanded from the S-TEN server and sent to the client application. The user is then presented with all available services of this resource from which he can choose the one(s) he is interested in. Once a service is selected (e.g. data browsing) a SOAP query is launched in which the interesting data that shall be retrieved from the resource, e.g. the actual power of a CHP, can be entered. The SOAP query is sent to the S-TEN server of the resource of interest - the URL of which is known from the registration file held in the S-TEN registry - which retrieves the data of interest (real power of the CHP) and sends it back to the client. If a control operation is performed (e.g. drive up a CHP), the way of interaction is the same as described for the monitoring data service only that the client gets a status information of the executed service.

Based on semantically interpretable information rules can be defined enabling automatically derivations and subsequent actions, e.g. switching on or off a disconnector within a ring where a short-circuit occured. Besides, observations and data derived from network resources can be linked together and activated with formal rules in order to provide best practise support for the user.

Initial Operation and Preventive Maintenance in Electrical Systems

Introduction

An integration of engineering, initial operation and maintenance in electrical systems is the aim of the "intelligent Service Assistance System" (iSAS) demonstrator: At present, the fields of application of engineering, initial operation and maintenance in the domain of electrical systems are dominated by a lack of information integration: Especially, for initial operation and maintenance, not only this information integration is missing, but most actual experiences are lost or are at least inadequately integrated into the overall system documentation, and are, at least, not easily accessible in their context in comparable situations. Based on high quality engineering data, iSAS is intended to support initial operation and maintenance through integrated access to design information, product data, instruction manuals, maintenance guidelines, and actual and historic system states. This approach taken in iSAS contrasts with the present situation dominated by a lack of information integration within and, especially, in between engineering, initial operation and maintenance. A traditional separation of these domains can still be observed today, to such a degree, even, to rightly speak of ‘worlds apart’. In particular, for initial operation and maintenance it can be stated that current experience is often lost or only insufficiently documented or is, at least, not easily accessible in its context in comparable situations.

Prototype description

The prototype presented in this paper is meant to enable an initial operation or maintenance engineer or technician to get, independent of his location, integrated access to design information, product data, instruction manuals, maintenance guidelines, and actual and historic system states. Designed to improve on initial operation and ‘up-time’, it attempts, not the least by recognition of comparable situations of the past, to offer best practise advice founded on semantically interpretable information. From a technological point of view, ‘iSAS’ comprises three main components:

- Client application: The client application is based on an Eclipse rich client and comprises, in form of plug-ins, all components necessary to access the Registry, to browse its content, and, finally, to interpret the selected content in a correct way, to access the server installation and all its modules, to interpret the accessed data correctly, and, where necessary, to present them, and to combine information drawn in a foreseen way to support the user.
- Server installation: The different modules of the server installation are partly accessed, like the Data Source services, via semantically annotated standard Web Services based on SOAP and SAWSDL (http://www.w3.org/TR/2007/REC-sawsdl-20070828/), partly via standard HTTP. The standard HTTP channels serve to transfer STEP data, SVG files (schematics) and product and maintenance information laid down in diverse standard formats like pdf, if they are not stored in the STEP data-base. Axis is used as ‘middle-ware’ for standard Web Services. Security is based on WS-Security as implemented in Axis2.
- Registry application: The Registry application uses semantically annotated standard Web Services, too. The data model for S-TEN System data stored in the Registry is based on an XML schema that is semantically annotated; offering the advantage to combine semantics with conformity check and flexibility in a simple way. As ‘middle-ware’ for Standard-Web-Services Axis2 is used. In the same way, the security concept used, is based on WS-Security. All data-bases supporting XML data types can be used.

OUTLOOK

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 status monitoring, collaboration and process control as requested in the framework of future smart energy network designs.
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 and it is therefore expected that the S-TEN approach has considerable impact. The key innovations of this approach are as follows:

- Intelligent self-describing networks
- Recording human observations and making them public via formal ontologies in the Web.
- Developing rules for supporting system operations and their application to arbitrary technical data on the Web.

Implementing S-TEN technology within networks with a constantly rising number of decentralised generators as private and commercial combined heat and power plants and photovoltaic plants and a higher degree of flexible operation would result in a crucial and low-cost contribution to an efficient network management including maintenance.

ACKNOWLEDGMENTS

The research described in the paper has been carried out within the S-TEN project (‘Intelligent Self-describing Technical and Environmental Networks’, www.s-ten.eu, FP6-IST-2005-027683) co-funded by the European Community in the Information Society Technologies programme.

REFERENCES

[1] T. Berners-Lee, J. Handler, O. Lassila, 2001, "The Semantic Web", *Scientific American Magazine*
[2] Vision and Strategy for Europe’s Electricity Networks of the Future; http://ec.europa.eu/research/energy/pdf/smartgrids_en.pdf
[3] Strategic Research Agenda for Europe’s Electricity Networks of the Future; http://www.smartgrids.eu/documents/sra/sra_finalversion.pdf
[4] OWL “Web Ontology Language”, http://www.w3.org/2004/owl#specs
[5] ISO 10303-1:1994 Industrial automation systems and integration Product data representation and exchange - Overview and Fundamental Principles, International Standard, ISO TC184/SC4, 1994.
[6] http://www.w3.org/2002/ws/sawsdl/
[7] http://www.w3.org/Submission/OWL-S/
[8] http://www.w3.org/Submission/WSMO/
[9] S-TEN consortium, 2007, "Ontology for self-describing networks (D2.1)", http://www.s-ten.eu