Smart Middleware Device for Smart Grid Integration

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Abstract—**Although the concept of Smart Grid is not so new, it has aroused the interest of electric companies only in recent years and some countries still suffer from major studies on methods, techniques and rules. There are many devices that work with legacy or proprietary protocols within the grid that can not be replaced, making it difficult and endearing unification for proper implementation of an intelligent network. We, therefore, propose an open, simplified, modular and well-documented Smart Middleware Device(DMI as in Portuguese acronym) integration gateway for automated protocols conversion and insertion of any existing electrical device into central infrastructure and management system, enabling the implementation of a real smart grid.**

I. Introduction

Smart Grid is the application of smart distributed electrical network concepts that can monitor their own electrical flow and adjust itself to adverse conditions, reconfiguring the devices that compose itself [1] through automation and integration of all network elements. To do this, there is a need of communication among elements composing the network. Among the communication protocols in use, stand out from the IEEE 1815 Distributed Network Protocol or DNP3 (Distributed Network Protocol version 3) [2], which was developed between 1992 and 1994, with the goal of being the first open protocol, supplied to providers (not necessarily of electricity) and industries to provide more scalability, reliability, interoperability and maintenance in relation to previously existing proprietary protocols[3]. And the MODBUS developed by Modicon in 1979, later open source, and the standard, in fact, for industrial networks. However, many proprietary protocols and new open standards, such as IEC 61850, are operating, which requires a system where different protocols can be understood for the proper functioning of the network. In this scenario, the use of a gateway protocol becomes a simple and inexpensive solution to provide interoperability and control between the various network entities.

The integration of data from multiple devices provides, also, a unique network status real-time analysis, enabling issue alarms or control commands, ensuring its operation for a longer period.

Legacy equipment belonging to the operation infrastructure and power grid distribution network supervision, no just use protocols that are often owners, but have limited communication interfaces and are not suited dynamically to available remote links. With the advent of mobile data communications, high-speed optical fiber networks and even wireless technologies in metropolitan networks (e.g. WiMAX), it is necessary that the communication modules could be adaptable and allow legacy equipment and different devices to integrate power grid.

In this context, this article proposes the creation of a Smart Middleware Device(DMI) protocol gateway, providing interoperability between the various members of the power grid devices and create intelligent data analysis mechanisms, documenting all steps to facilitate the addition of new protocols, devices and applications by third parties and allowing further growth, adoption and integration of Smart Grid by the electric utility.

A. *Theoretical Revision*

The existing devices in the electrical distribution network has intrinsically heterogeneous characteristics. The various manufacturers and solutions result in a mix of proprietary interfaces and software tools that require diverse training and vendor dependency. In addition, the safety factor is decentralized, which causes the need for individual passwords for each device.

All these factors prevent the optimization of the structured management of this equipments. Although the market has proposed solutions that enable the inclusion of certain devices to legacy protocols (Modbus, CAN, etc.), there is a need to acquire specific gateways and not always available for all existing and/or proprietary interfaces. In this context, there is a strong demand for a solution that allows quick insertion of devices into a Smart Grid structure with the integration of sensors and actuators as managed objects from the operations center.

With this topology, the integration of devices that are not compatible with the current standards related to Smart Grid structures is made with a lower cost and is scalable. Additionally, manageable elements inherent in the devices are listed in a tree of objects allowing read access and / or writing through the operation center. This is of fundamental importance in the current structure of energy supply. Putting network operation with high levels of responsiveness and performance generating better satisfaction in service.

B. *Functional Description of the Gateway*

The construction of the DMI is designed to be highly modular. The reason is to make it a very flexible and highly scalable device. This allows, among other things, to adapt more easily to the data communication technologies and devices with non-standard interfaces. Monolithic structures tend to become closed and difficult system integration in heterogeneous structures.

The DMI is mounted on a stable model, running as a service on a POSIX operating systems (Linux, BSD), providing protocol libraries related to the Smart Grid (IEC61850, DNP3, Modbus ...) and a DBMS (Database Management System data) that will offer all the support for the various modules, these, defined in a client / server architecture of the TCP / IP stack and WebServices to ease the extension of the architecture. An API is provided for easily add protocols and direct communication between new devices.

1) Internals: To explain the functionality of the application, we present in Figure 1 the system topology which consists of the substation side equipment and controls. In the substation control center, all the control and supervision data are available and carried by a SCADA(supervisory control and data acquisition) software, which performs readings such as voltage, current, circuit status, and switch positions as writings, activating and deactivating elements of network. The SCADA

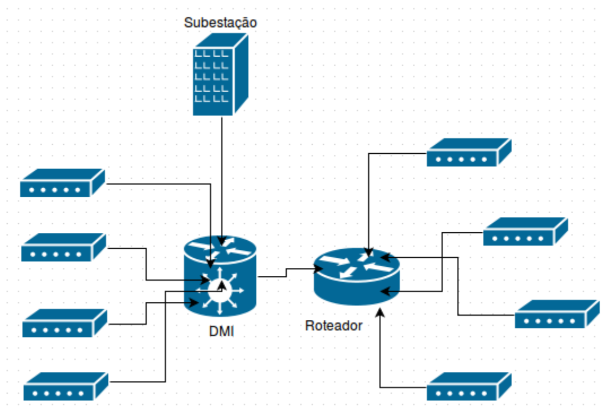

Fig. 1. System topology

communicates with the DMI integrator gateway using standard protocols, such as DNP3, IEC-61850 or MODBUS.

Based on Figure 2, communication between the SCADA and DMI is started by invoking one of the methods GWDNP3(), GWModbus() or GW61850() to use, respectivelly, DNP3, MODBUS and IEC61850 for communication, all belonging to "core" module on DMI gateway. When a request comes from SCADA, the gateway selects the appropriate protocol translator and, from this point on, all data and command are converted for a intermediate internal protocol, through methods "encode()" and "decode()" standardized to, respectively, encode and decode a frame from any protocol. Then, the network element is selected by internal routing, its protocol is selected on translating list and the communication starts. These element can be any hardware, using any protocol that is already implemented, as TCP/IP or RS232 microserverson (on figure2, represented by elem 1, elem 2, ...), which implement basic communication between the element itself and the DMI gateway. This interaction is accomplished, usually, through RPC (remote procedure call) due to the impossibility of having

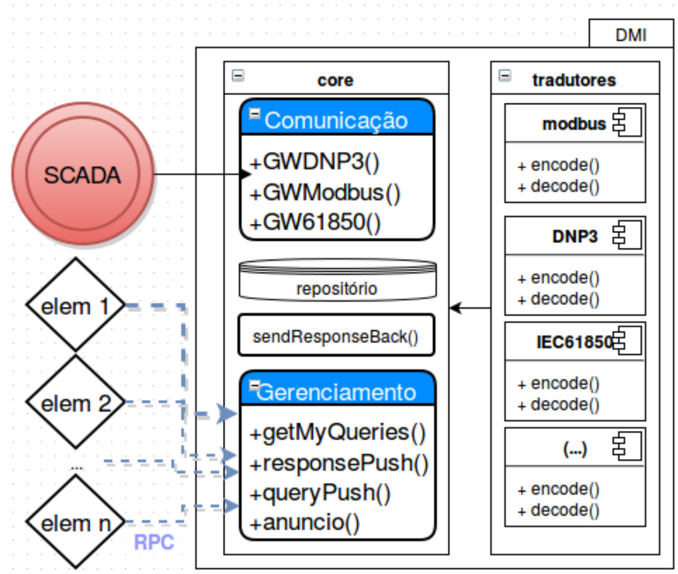

Fig. 2. Smart Middleware Device Integrator Gateway

all modules running on the same server. Remote Procedure Call(RPC)[4] is an interprocess communication that allows a computer program to call or execute the procedure or routine in another address space.

Every new element that connects to its microserver ou direct into gateway, invokes a call to method "anuncio()" from "core" module. There, All communication structre is created, including instantiation of internal protocol so that readings becomes possible. Then, the device will be seen as ACTIVE from SCADA and is already possible to receive commands and to send readings.

Other then "anuncio()" and SCADA communication methods, four control methods are implemented on "core" module on gateway. The first one is the "sendResponseBack()", whose purpose is to collect the answer for the query on the repository, regulate it, normalize it and send it back to the SCADA.

The second one is "getMyQueries()", used by microservers in fixed time cycles to order queries to the elements directly connected to them.

The third method is the "resposePush()", using, too, by microservers to send the answers to queries to be translated, processed and stored.

The fourth and final method is the "queryPush()", invoked by the microserver to force a send to SCADA, in an emergency scenario or, in case of a parameter previously set to inform its modification, be satisfied.

These methods from module "core" are required to create and configure devices and allow a flow of communication and control between the SCADA and any type of device.

2) Case Study: Integration with a Low Voltage Recloser: Low Voltage Reclosers are devices with the capacity to detect faults and disconnect the circuit in low voltage power grid. The detection sensors can also be used to monitor the network status.

This laboratory have developed a low voltage recloser with a GPRS connection and it was installed across the state of Maranho, Brazil. The recloser is in constant communication with the DMI, receiving commands or sending readings.

By integrating the Recloser into power grid through DMI, we had real-time information of transmission network and with the collected data, it was able to create quality of service indicators and predict fluctuations on power grid, issuing an alarm and actuating on recloser, shutting it down, avoiding power outage and damage.

The idea behind this solution focuses on adapting high availability communication for legacy devices. It's not economically feasible to replace all running devices to newer ones. Providing a protocol translator and multilink communication solutions allows us to insert those devices in the operation and control topology.

II. CONCLUSION

This work presented a device that gives us a twofold solution on Smartgrid scenarios: the first one is an extensible protocol translator; the second one is a multilink communication solution. This has been the solution implemented on an electrical company in the state of Maranhão, Brazil. This device (DMI) is part of a bigger solution to integrate legacy devices on the operation center of the company. Many of the features implemented on the DMI can be moved to a higher level in the architecture of the whole solution. However, the communication techniques remain a problem to bypass. Thus, the DMI is always a valuable way to keep legacy devices on the structure. As a future work, it is interesting to integrate a protocol editor based on formal specification methods such as Petri Networks. This allows to adapt promptly legacy protocolos to standard protocols such as DNP3.

ACKNOWLEDGMENT

The authors would like to thanks CEMAR(Maranhão State Electric Company) and CNPq (National Counsel of Technological and Scientific Development).

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