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Infrastructure development for implementation control-as - A service in substations (Conference Paper)

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Abstract

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The control of the electric power system faces various challenges caused by the introduction of renewable energy sources and rapidly changing loads and the goal is to be ensured reliable, sustainable and safe operation along with a permanent energy efficiency increase. The growth of the information and communication technologies and their integration in the energy systems control leads to Smart grids development. The main goal of the paper is adaptation of cloud technologies for the design and realization of industrial information systems in the electric power system. The research is based on the flexibility and the universality of PLCs which make them suitable and useful tools for application in control systems including SCADA in the electrical power system. An industrial network has been developed comprising smart power transducers, sensors and PLCs in order to control the processes in a substation. This becomes possible with the growth of Ethernet-based industrial networks such as Profinet and Ethercat and allows control the field devices directly from the network. The considerations in the network organization and the choice of PLCs are discussed. The main options of the proposed software solution are explained. © 2016 IEEE.

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Infrastructure Development for Implementation Control-as-a Service in Substations

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***Abstract* - The control of the electric power system faces various challenges caused by the introduction of renewable energy sources and rapidly changing loads and the goal is to be ensured reliable, sustainable and safe operation along with a permanent energy efficiency increase. The growth of the information and communication technologies and their integration in the energy systems control leads to Smart grids development. The main goal of the paper is adaptation of cloud technologies for the design and realization of industrial information systems in the electric power system. The research is based on the flexibility and the universality of PLCs which make them suitable and useful tools for application in control systems including SCADA in the electrical power system. An industrial network has been developed comprising smart power transducers, sensors and PLCs in order to control the processes in a substation. This becomes possible with the growth of Ethernet-based industrial networks such as Profinet and Ethercat and allows control the field devices directly from the network. The considerations in the network organization and the choice of PLCs are discussed. The main options of the proposed software solution are explained.**

I. INTRODUCTION

The electric power system (EPS) is very complex and comprises of generation, transmission, distribution and consumption.

In a traditional power grid, the generation sub-system relies on a small number of large power plants using conventional (coal, oil, natural gas, and nuclear) resources to produce electricity. Then, high-voltage transmission lines, which form the transmission network, are used to transfer electricity across long distances from power plants to electric substations. A substation includes transformers to change voltage levels from high transmission voltages to lower distribution voltages. Furthermore, substations perform several other important functions, such as grid protection and power control. Substations, medium- and low-voltage power lines, and electric meters form the distribution network [1].

Nowadays the power grids have changed significantly their character. This is a result of the introduction of renewable energy sources and rapidly changing loads. Typical representatives of the sources are wind and solar power plants, and of the loads – the electric vehicles recharging stations. They both have an unpredictable character. The quantity of power which is generated by the renewable sources strongly depends on the parameters of the environment. In the same time the simultaneous charging of several electric vehicles in a small location will determine rapid increase of the power demands. The regulation of the power grid is obliged to compensate the increased power demands by increase of the generation. In order to take the right decisions for control the power network an enormous volume of information has to be collected, processed and analyzed. To ensure a permanent energy efficiency increase and a full usage of the renewable energy the traditional generation has to be switched off in when the renewable sources work on full power. Also the power flows have to be redirected in cases of peak loads. In addition to the information collected by the metering infrastructure the reliable and sustainable control needs information from the energy markets, weather forecast and etc.

II. APPLICATION OF SCADA SYSTEMS IN SMART GRIDS CONTROL

The definition of smart grid has variations but the common aspect is the bi-directional or two way communication along with power flow between the two concerned entities i.e. consumer and grid. The key features of smart or intelligent grid involve monitoring, protection, automation, optimization, integration and security of the power flow from utility generators to the end user appliances. In Fig. 1 is shown the architecture of smart grid including the traditional sub-systems through which the electric energy flows and the communication interfaces between all participants in the grid [2]. Advanced monitoring, intelligence, and automation are being added at substations.

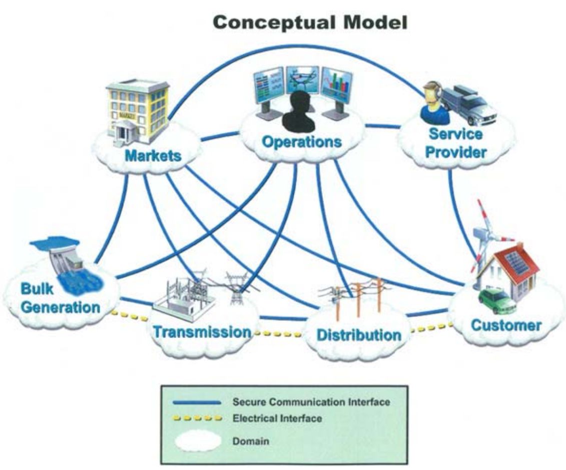

Fig. 1. Smart grid architecture proposed to NIST [3]

This allows local system conditions to be monitored and managed more effectively. In addition, when problems are detected, local control can be deployed to mitigate their propagation and impact on the rest of the grid. Substation analytics also provide real-time monitoring of dynamic line ratings, so operational limits on lines and transformers can adapt in real time to safely ensure maximum utilization of existing grid assets. Intelligent data filtering and validation occurs at the substation, which provides the control centers with more clean, coherent, correlated, and validated data [4].

To improve the reliability of electricity provision and to support distribution automation Supervisory Control And Data Acquisition (SCADA) systems are integrated in the power networks. They usually consist of the following components as it is depicted in Fig. 2:

• Remote telemetry units (RTUs): microprocessor-controlled devices responsible for: (i) interacting with sensors, (ii) converting sensor readings to standard data formats, and (iii) delivering sensed data to monitoring stations;

• Programmable logic controller (PLCs): minicomputers that are used as field devices for process control and machine automation (e.g., to open or close circuit breakers at substations);

• A supervisory computer-based system that is composed of several remote units and a master station, and it is used to collect the data from RTUs, perform data analysis and send commands to PLCs;

• Databases for storing historical data, measuring trends and deriving forecasts;

• Human–Machine Interfaces (HMIs) to present a simplified representation of the system and its status to a human operator, who can make supervisory decisions;

• A communication infrastructure connecting the supervisory system to the other SCADA components [1].

Meanwhile the SCADA centralized architecture has also evolved over time, allowing more distributed processing and control, and the interconnection of different SCADA systems through wide-area networks.

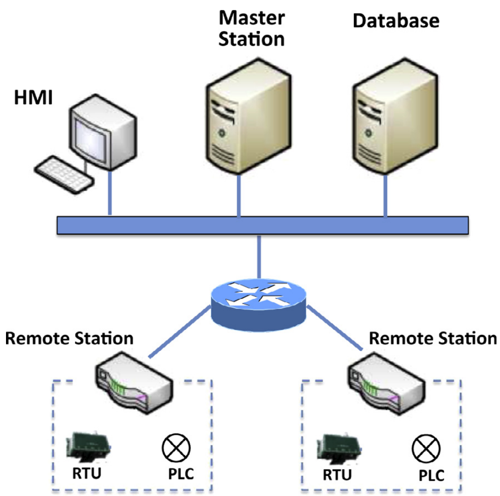

Fig. 2. SCADA-based control system [1]

III. APPLICATION OF CLOUD COMPUTING IN SCADA SYSTEMS

Although cloud computing is becoming more common, it is relatively new for SCADA applications. Cloud computing provides convenient, on-demand network access to a shared pool of configurable computing resources including networks, servers, storage, applications, and services. These resources can be rapidly provisioned and released with minimal management effort or service provider interaction. The benefits of cloud computing for SCADA can be considered as follows:

• Add new resources on demand when and if needed;

• No need to purchase redundant hardware and software licenses, or set up disaster recovery sites that may not be used;

• Provides huge amounts of storage capacity that can be purchased incrementally;

• Provides improved reliability and redundancy via multiple Internet connections and more backup servers;

• New infrastructure can be running in a few minutes;

• Makes real-time and historical information available on any type of Internet-connected device, including laptops and Smartphone;

• Easier to manage updates and patches;

• Provides testing advantages through the ability to clone machines [5].

Controllers play an important role in automation systems. In distributed automation systems, each individual controller or PLC device provides independent control functions for each separate module of devices. These devices are needed to be connected to the PLC by means of electrical signals and I/O devices conventionally. With growth of Ethernet-based industrial networks such as Profinet and Ethercat, it is possible to control the field devices directly from the network. This shapes the main idea of delivering control functions as services to the field floor [6]. These trends might require the definition of new automation architectures differing from the current hierarchical automation pyramid [7].

Service Oriented Architecture (SOA) is seen as a promising candidate to support cross-layer integration to make distributed systems more interoperable. Such technology shift has been in progress at the enterprise system level for many years. Legacy systems typically have proprietary protocols and interfaces resulting in vendor lock-ins and possibly site specific solutions; however with SOA these systems can be wrapped and integrated in a modern infrastructure. Interfacing and integrating legacy and SOA components of a DCS/SCADA system will require some, for the purpose developed and/or adapted, technology. Such integration may be based on some kind of integration component like Gateway or Mediator. Such Gateway or Mediator have the task to bridge the communication from major standardized protocols used close to field applications today: HART communication supported by HCF, Profibus PA in combination with Profibus DP, Foundation Fieldbus, etc.

These protocols follow specific characteristics. The use of Gateways or Mediators is a well proven concept for integrating/connecting and migrating devices, attached to different networks. It is used to transform protocols as well as syntax of data [8].

IV. Implementation of the Proposed Infrastructure

The presented proposal is based on the block diagram from Fig. 2. The field level and the control level of the well-known automation pyramid [6] are realized physically using measuring and automation apparatus.

The system, shown in Fig.3, uses two gateways which connect the field devices to the cloud. There is developed a smart energy transducers network using a PLC as a gateway. The PLC is intended to read the states of relay inputs and to control relay outputs in the substation – for example circuit breakers. Also it monitors analog signals which are attached to its analog inputs – e.g. analog outputs of voltage and frequency measuring transducers, and the temperature of the transformers. In addition to these basic functions of the PLC, it is responsible to maintain the communication with the smart transducers using a serial interface RS-485. Thus it bridges the transducers network and the Profibus DP. The second gateway transfers the information from the substation to the cloud using Profinet. The higher levels – HMI, databases, master stations and etc. are migrated to the cloud.

The PLC of Siemens Simatic S7-200 CPU 226 is chosen as a first gateway. Its possibilities are enough to maintain the smart transducers network and to control digital inputs and outputs. The communications resources include two ports realizing RS-485 serial interface. Port 0 of Simatic S7-200 CPU 226 is chosen to operate with the transducers network. For communication port 0 uses Freeport protocol and 9.6 kbaud data rate is chosen to correspond to the same value that is used by the transducers. The number of transducers Nmax in the transducers network is defined as the maximum number is 32. Port 1 of Simatic S7-200 CPU 226 using MPI protocol realizes the connection to the personal computer.

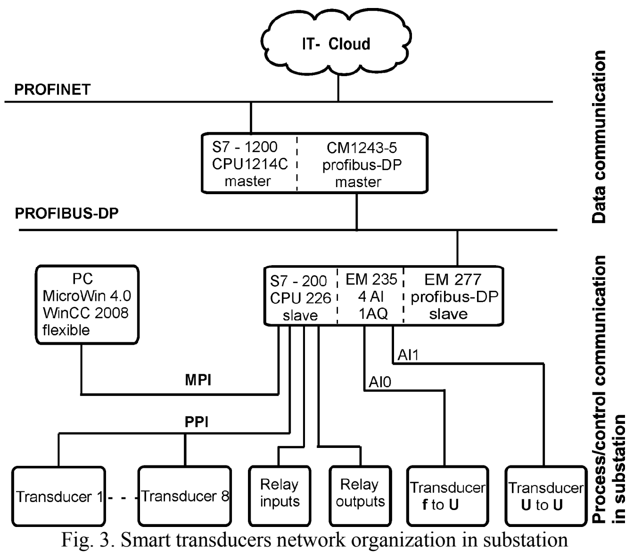

Fig. 3. Smart transducers network organization in substation

A communication processor module CP 5611 is added to the personal computer which enables it to communicate using MPI protocol. The analog module EM235 with four analog inputs and one analog output is added to the processor module. Two of the analog inputs are used to measure output signals of one voltage and one frequency transducers with analog outputs. The analog signals are in the range 0 – 10V. Digital inputs are intended to monitor the state of four relays and four digital outputs are used to control circuit breakers. Profibus DP slave module EM277 is intended for connection to the second gateway of the upper level of the SCADA, in this case PLC of Siemens Simatic S7-1200 CPU 1214C extended with Profibus DP master module CM1243-5. Thus the information from the substation is easily accessible in the IT – cloud.

V. Software Design

During the startup initialization the communication parameters for the Port 1 of Simatic S7-200 CPU 226 are set: Micro/WIN → CP5611 (MPI) interface and 19200 baud rate. This port is provided for programming the controller and receiving the manipulated data from voltage and frequency measuring transducers and the transducers with addresses from 1 to 8.

The SIMATIC WinCC flexible 2008 programming package is used for process visualization in the substation. The communication parameters are defined as follows: personal computer as HMI - address 1, interface MPI/DP, baud rate 19200, network profile MPI and communication station SIMATIC S7 200 as a gateway - address 2. The appropriate tags are developed that give the relationship between the displayed value and the relevant data stored into the buffer for visualization in the PLC memory. Also tags are provided to read relay inputs (Symbolic IO Field, mode - two states) and to control circuit breakers (Switch, type - switch with text).

The project is starting in runtime mode. The buffer for visualization is updated every second. After that starts the information part of the buffer consisting of the values of the quantities of the electric power system. The data is sent by the transducers in two formats. In each of them the value of the bytes is limited to $7F. So they are transmitted as ASCII string and could be recognized by standard processing programs.

The first format is unsigned hexadecimal integer. It has length of two bytes and using it the values of the quantities have the following accuracy: voltage – 0,1V, current – 0,001A, frequency – 0,01Hz, phase angle – 0,1°.

The second format is signed hexadecimal integer. It has length of two bytes and it is used for the values of the active and reactive power which have different signs in the four quadrants of the complex plane. The accuracy is 0,1W or 0,1VAr.

The data of three phase – three elements transducer from the network is shown in Fig. 4. It is connected to the secondary side of measuring voltage and current transformers with rated values: $V_{ph\text{-}N}$ = 57,7V; $V_{ph\text{-}ph}$ = 100V; I = 5A.

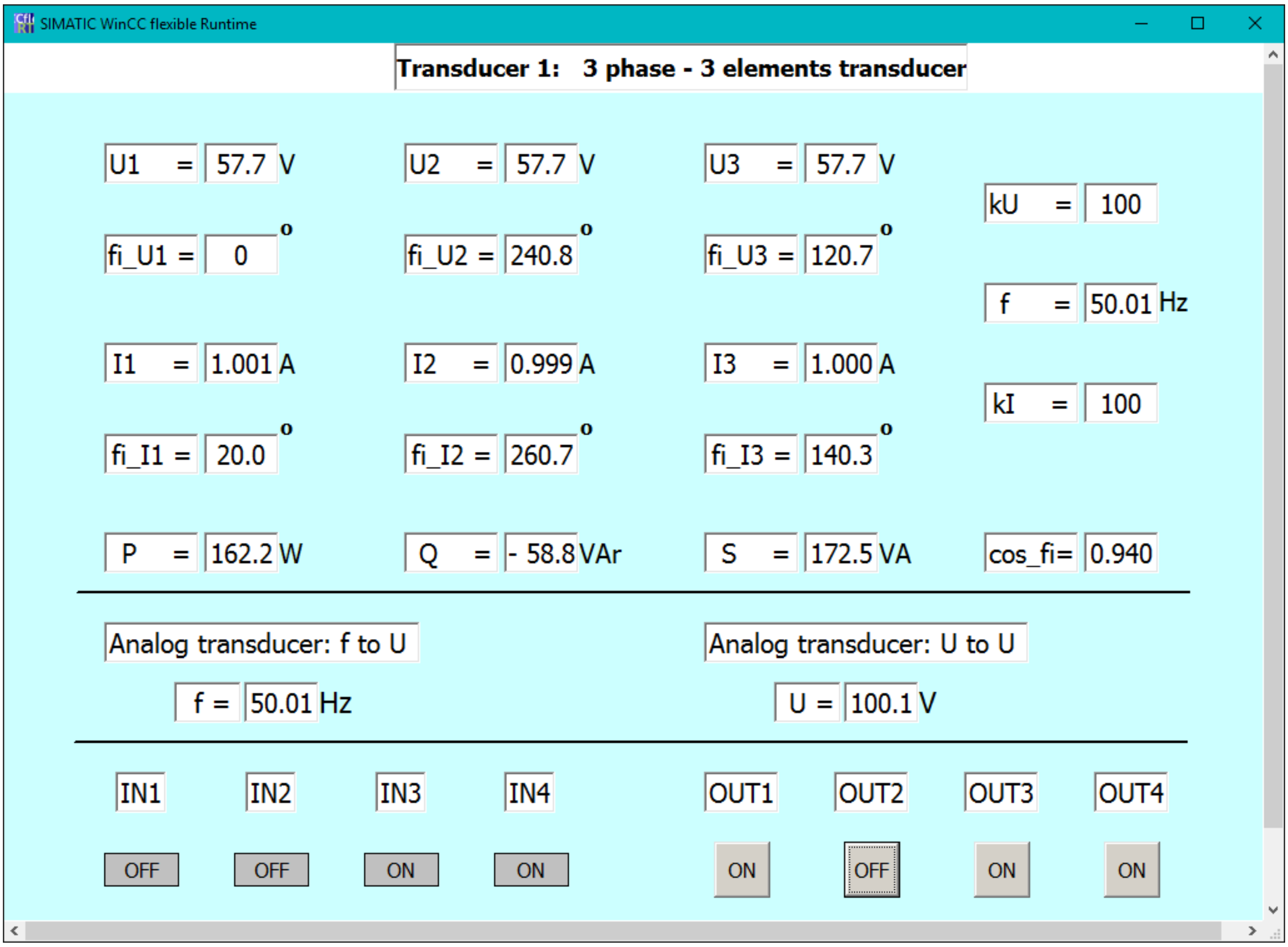

Fig. 4. User's interface

The data from the other transducers are displayed on similar screens. The output values of analog transducers (frequency and phase-to-phase voltage) and states of digital inputs and outputs are shown on every screen.

The appropriate software is developed to transfer all information to master PLC Simatic S7-1200 using Profibus DP interface. The TIA Portal V13 programming package is used to create simple web pages that enables remote reading and archiving the data of the substation.

VI. CONCLUSION

The substation automation approach is very reliable, user friendly using PLC and SCADA. The paper presents a research on the possibilities for implementation monitoring and control of substation from the cloud. An infrastructure with two gateways is developed to connect the field devices to the cloud. The data acquisition is accurate, and the data measurement, storage, parameter adjustment, and various signal alarms of substation can be realized.

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