

# Chapter 15

## SCADA Applications for Electric Power System

Florentina Magda Enescu and Nicu Bizon

**Abstract** Main objective of this chapter is to present the Supervisory Control and Data Acquisition (SCADA) technology applied in the energy sector which requires distributed control and monitoring at different levels. If the process is distributed, then the advantages of SCADA system will be seen through low costs related to movements of the equipment to improve the performance tracking. Processes that need to be monitored on a large area, and request frequent and immediate interventions, can be solved more efficiently through a SCADA system. For this, the connection between the master station and remote units must be done via a communication system which can use different communication technologies such as cable, radio, mobile phones, and even satellites. The optimum data transfer may be obtained by using a specific communication protocol. It is worth to mention that such SCADA-based communications are developed using the optical fiber communications technology via the Internet. The information flow between remote and central SCADA units could be designed to be bidirectional for high performance and reliability of the distributed control system, but note that both digital and analog signals are involved in such systems. Besides, an important issue is the information security related to such systems. It is known that the automation and real-time control are used via the Internet and wireless technology, but these technologies have also brought some security problems, having a strong impact both in the business and to the users. The SCADA applications analyzed in this chapter is focused on Electrical Power Systems (EPS). The stepwise design is shown using the programming environment named VIJEO CITECT SURVEILLANCE SOFTWARES—version 7.40<sup>®</sup>. The main objective is to show how can be optimized the real-time control to obtain affordable solutions for the EPS based on Renewable Energy

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Sources (RESs). The both current and optimized solutions are presented, and the role of the reactive power is highlighted in the comparative solutions shown, which are implemented in practice as well. This was achieved by optimizing the SCADA solution of the operation, transmission and overseeing the execution of programs for the operation of power plant trough: (1) the description of the existing solution; (2) the description of the proposed solution with redundant SCADA servers; (3) the disadvantages of the proposed solution with Remote Terminal Unit 32 (RTU32). The optimization of the applications has been carried out because the graphical interface is poor, as long as the only information displayed is from the distribution stations, the states of the switches in medium-voltage lines and of the equipment in the stations. Therefore the dispatcher has not displayed the graphical information about the status of the line equipment, and does not have a quick overview to state of the medium-voltage line as well. Thus, the dispatcher must consult the printed diagrams, which means time consumed and such complicated maneuvers will occupy the most time their activity during a day. Thus, here it will be shown the steps to optimize the graphical interface in order to quickly see the status of the EPS. Furthermore, by improving the graphic interface, the efficiency in carrying out the appropriate maneuvers will increase, as well as the degree of safety. The applications have been designed with high flexibility and can be used either for small applications, either for large size systems. Also, the graphic interface was designed to display online the page's status and the trends in state variables.

## 15.1 Introduction

In last decades the automation devices have evolved from simple electronics circuits used to monitor and control the parameters of the industrial processes [1], to smart devices that communicate with each other in automation networks [2]. The evolution of the automation devices has led to the development of technique for visualization of control parameters and state variables from the automation process [3]. The companies producing automation equipment are those that have achieved the first visualization systems. In time, they have developed the generic software named Viewer, which is adaptable to various situations possible in distributed processes [4, 5].

The Supervisory Control and Data Acquisition (SCADA) system collects data from the distributed processes through sensors. The central computer will store this big data after a preliminary processing. The system can receive commands automatically or manual commands based on the processed data by the human operator [6].

The first SCADA systems, which allowed acquisition and real-time data analysis, have appeared in the 1960s, but then were rarely used in installations. The term SCADA was referred to a comprehensive system of measurement and control. The Programmable Logic Controllers (PLCs), which were designed and built by Gould Modicon in 1971, have changed the philosophy to use the SCADA. The PLCs in EPS have been introduced in 1977 by Allen-Bradley, and this was easily

accepted by electricians. The term of SCADA has been used for the first time in the late 1980s. This term was not widely used until the 1990s when the technology evolved. In 1998, most of the PLC manufacturers integrate the Human Machine Interface (HMI) in/SCADA systems using communication systems and open protocols, nonproprietary. The HMI/SCADA systems offer total compatibility with PLC-s by including the following components [7]: the HMI, the controllers, the input-output devices, the networks, the appropriate software etc.

A generic SCADA system must to implement a distributed database that contains elements called endpoints, which can be either hardware or software. Thus, the distributed database is composed by hardware and software items. The system SCADA controls and monitors the input or output endpoints. The record of each endpoint, including its dynamic, is stored in the database to have the history of all endpoints. This will help in predictive maintenance and the security of the EPS as well [8, 9].

So, the SCADA system has a multi-layered structure composed from basic functions and graphical user interfaces which are hardware and software supervised in real-time [10, 11]. From the point of view of the design environment, a SCADA system contains some specific instruments such as: text editing applications, graphics editors, tools to import/export from/to SCADA libraries to achieve configuration parameters, drivers & tools with advanced features for HMI interfaces, etc. [12].

The carrying-out of a project in the SCADA system, the following aspects must be taken into consideration [10, 11]:

- the needed components to be easily accessible from the point of view of visibility and how these are collaborating;
- timing sequence;
- scalability;
- flexibility to extend the system by the addition of new subsystems;
- redundancy;
- the initial statuses that should be determined;
- the operation diagram of the system.

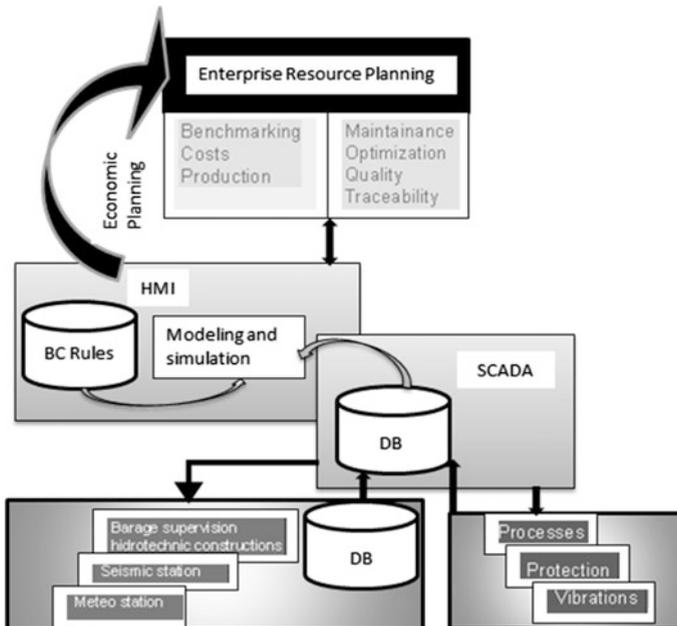
The functions of the SCADA system are the following [1, 2, 8]:

- acquires data collected from the process;
- manages alarms;
- allows the needed actions for automation:
  - a technological preset action;
  - an initiating action of the events;
  - a monitoring of the pre-defined sequences.
- stores and archived data;

- generates and pursues reports:
  - a default graphics;
  - a multiple graphics scaling;
  - a history of graphs.
- allows the dispatcher to control the process via the HMI;
- allows the communication with user interface via the HMI using:
  - a libraries with symbols;
  - a connection between process and graphic elements;
  - a link between screens;
  - a collection of command's operators;
  - an animation based on multimedia features;
  - a possibility of connection with other platforms [5].

SCADA systems may be extended to Large Scale System by architecture, maintenance, post-processing, decision support systems, and economic planning [4, 7].

The architecture of hydro energy system is proposed in [12] and extended here to the architecture shown in Fig. 15.1.



**Fig. 15.1** Extended SCADA architecture with application in hydro-energetics

A number of recent studies in the scientific literature have highlighted the importance of the SCADA systems for RES hybrid EPS [1, 13–15], and in particular, their use for hydropower plants as below:

- the SCADA system applied for hydropower plants connected to national EPS;
- the use of metering systems for the electric power and water from hydropower plants;
- monitoring and control of the hydro power plants;
- monitoring and control of the hydropower plants and RESs used for hybrid EPS.

The SCADA architecture for a hydropower plant is presented in this chapter at level of hardware and software. Five levels of SCADA hierarchy are essentially in complex system [1, 9–11]:

- the devices level for instrumentation and control operations;
- the Remote Terminal Unit (RTU) terminals level;
- the communications system level;
- the master station level;
- the data processing level.

The evolution of SCADA systems is also shown as system generations for cyber security. The cyber security risk assessment for SCADA includes:

- Causes which can lead to catastrophic situations from common technical incidents;
- Cyber Security concepts;
- How incidents are treated;
- The tolerance which is acceptable;

A survey is conducted for a specific hydropower plant from Romania based on SCADA system. Also, an overview of the programming in VIJEO CITECT SURVEILLANCE SOFTWARES 7.40<sup>®</sup> is shown, and the projects to monitor the medium power subsystem of the EPS based on RESs is described step-by-step [10, 16–19].

SCADA system allows the command, control and operation of installations both from the control room of the station and from the center point. The main operative functions of the management system are as follows:

- acquisition, processing and exchange of data;
- instant recording of data;
- transmission by the higher command center (subsequently implemented);
- remote control (control room) and the local branch of the circuit breakers, traps, etc.;
- indication of the position of switching equipment;
- measurement of analog quantities;
- metering;
- sequential recording of data;
- the processing and management of alarms;

- voltage control circuits and plots;
- remote control and adjustment in plants;
- marking;
- long-term information archiving;
- registration of damage;
- interlock of primary equipment;
- switching sequences with checking of signals' timing;
- surveillance system.

All these features are available in new SCADA user interface with VIJEO CITECT SURVEILLANCE SOFTWARES.

Today, a SCADA system operates on large distances, up to the level of a country or continent, if we consider that the national EPSs will be integrated based on smart grids and these technologies. Examples of such processes are given below [20–24]:

- the groups of small hydro stations that are switched on and off in response to energy demand of customers and which are located, in general, in remote places. These systems can be controlled by opening or closing the turbine valves, but must be pursued continuously in order to quickly respond to the dispatcher's energy demands;
- the electrical transmission systems, which cover thousands of km<sup>2</sup>, can be controlled by closing or opening the grid breakers, but these must respond almost instantly to the load demand on the line;
- the areas of oil and gas extraction, including sensors, collection systems, measurement equipment and pumps. These systems are generally distributed over wide areas, require relatively simple controls, such as starting or stopping motors, and metrological information on a regular basis, but must quickly respond to the exploitation conditions;
- the distribution network of gas, petroleum, chemicals, water, which have elements that are located at different distances from a central point of control. These can be controlled by closing or opening valves or starting and stopping the pumps, but must rapidly respond to market conditions and alarms due to the losses from toxic or dangerous materials;
- irrigation systems covering hundreds of km<sup>2</sup> can be controlled by closing or opening of simple valves, but also require a relative complex measurement of water supplied to consumers based on centralized system.

In conclusion, the SCADA system is useful because it helps to [7, 10]:

- optimize the process;
- take a decision objectively;
- increase the efficiency of use for the exploitation equipment;
- decrease energy costs;
- reduce the capital in the future;
- improve the services for the future;
- obtain competitive advantages on the market;

- decrease the number of staff;
- solve the problems of the environment;
- use of a new system instead of the old ones which are exceeded.

### 15.2 Research Extracts from Literature

The study shown in this section is linked to:

- The Electric Power Systems (EPS) as a critical infrastructure;
- Advanced SCADA architectures;
- SCADA system for optimal energy management;
- Cyber security risk assessment for SCADA;
- New SCADA applications.

#### A. SCADA system for driving the stock records from the hydropower plants developed in Valcea region

The SCADA system presented in this section is used in Valcea region, Romania, for driving the hydropower plants from the dispatcher station. The driving system from the Hydro-energetic Dispatcher (HD) contains (Fig. 15.2):

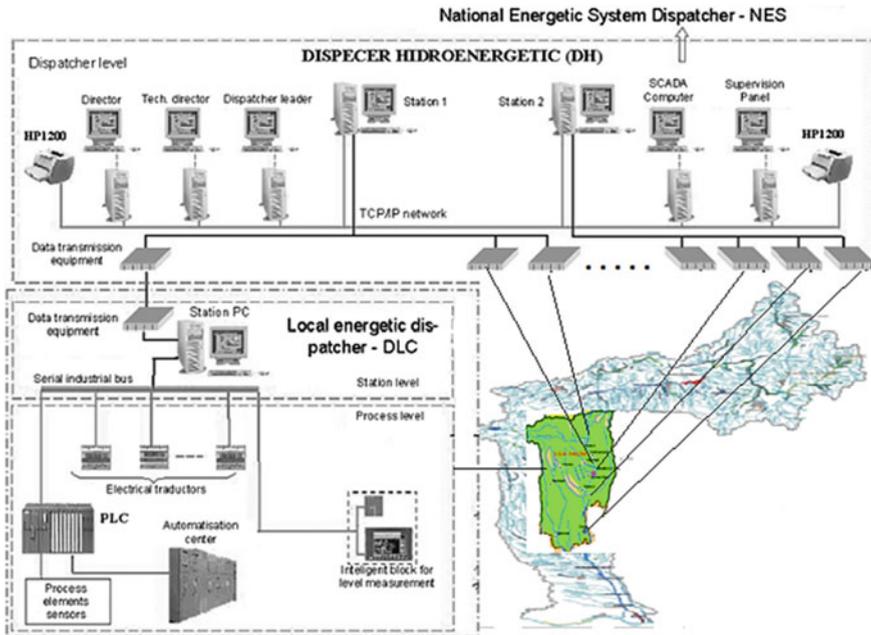


Fig. 15.2 Research extracts from literature

- SCADA systems in central dispatcher;
- SCADA systems in local dispatcher.

The HD is connected with the Dispatcher in Local Center (DLC) by modems on wire or using the Global System for Mobile communications (GSM), in last case a large communication network dedicated to this process is obtained [12, 25, 26]. This system allows the control of the operative functions, the automatic acquisition of data, and generation of the databases needed. All these actions and data records are necessary for rational utilization of RESs. Note that this SCADA architecture is of open system type, which ensures integration of the regional power plants into national system and flexibility to further develop this system.

The SCADA system from HD station provides information for water flow planning in relation with energy demand from dispatcher, which is of following type [12]:

- for monitoring and ensuring the service continuity for power stations and power substations subordinated to them.
- for implementation of the governmental program to monitor the operation of the main power stations;
- for energy management and operative management in each power stations;
- for operative exploitation of water accumulations and optimal distribution of the water flow to power stations;
- for operation in normal and hazard situations based on the remote control units, switching equipment and primary outlet installations (Fig. 15.2).

The SCADA system from DLC provides information for:

- primary processing of data;
  - storage of data during a limited period;
  - increasing the reliability and the maintenance capacity of system.
- Because this architecture is of distributed type, the functions of the system must to show in real time:
- the retrieval numeric signals for the status of switches and splitters, the operational equipment, the power cells, the protection loops, and timing cells;
  - the acquired and processed signals (of analogue and digital type) from the hydroelectric power stations monitored;
  - the commands to hydroelectric power plants, both in the local and central interfaces of the dispatcher from each hydropower plants;
  - the alarm signals from the dispatchers in the event of the appearance of some defects;
  - the record of the number of operations for each equipment, which is used in the management of revisions;
  - the schematic diagrams of the hydropower plants monitored, the status of state variables from these diagrams, the wiring diagrams and the synoptic chart of the installations used [13];

- the stored records using the graphical or tabular configurations, features which are selectable by the operator [17].

#### B. Metering systems of electricity and water for a residential house

The metering of electricity and water flow requested by a residential house is also a usual application of SCADA system. The SCADA system are responsible for automatic reading of the meters installed and storing the data in SQL database as a record which contains the index of consumption, the location, the time, the state of protection circuits etc. These data generate some alarms and reports related to monthly consumptions, which are used for the allocation of costs facilities for each location and meter. Data are provided directly in Comma Separated Values (CSV) format to be imported directly into the billing software.

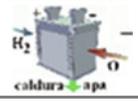
The network architecture is standard [10, 27, 28], and contains the following levels:

- monitoring software: it is composed from separate applications, which are running on different servers; it can be accessed directly on the web through monitoring portal, which displays graphical reports in real-time based on the data received;
- data concentrators, which are used to link the software that is run on the server and the meters installed in each home;
- metering level, which provides support for remote transmission of the index of consuming or other monitored parameters.
- Such metering systems allow the following automatic operations [29–33]:
- reading the consumption and other parameters in the days and at the times programmed by the user; note that data supplied by the meters installed can also be read out manually, at the request of a user, in order to determine current consumption or to verify the proper operation of equipment;
- disconnection of the consumers can be remote controlled using the SCADA software and flow's distributors installed in the network;
- graphical analysis of the daily profile for the load demand or the carbon footprint reported to a day, week, or month, or other parameters available directly in web portal;
- detection and location of the faults arising in operation of the equipment (meters, concentrators, etc.) or the software modules, and generation of alarms via email to the authorized users;
- computing of daily consumption and monthly consumption (which is used for the forecast of the energy sources) by using the software management based on the difference between the automatic readings;
- exporting of the various query reports generated from the database to Excel or other formats.

#### C. Monitoring and control of the renewable energy sources

The RESs (solar energy and wind power especially) are used in hybrid power systems based on distributed generation because:

**Table 15.1** The evolution of energy systems

Year	Energy based on	
The future	Hydrogen—combustion chef	
2010	Solar	
2003	Wind	
1969	Electric Power Plant	
1948	Petroleum	
1900	Steam	

- the actual consumption increased and the trend for the energy; price is to rise even higher in years to come;
- the classical resources begin to run out;
- the importance of RESs in climate change [13–15].

The evolution of energy systems can be monitored in the Table 15.1.

Two examples of RES hybrid power systems are given below:

1. Diesel-wind turbine hybrid EPS to supply the industrial consumers (Fig. 15.3).  
The application is submitted in under (Fig. 15.3) Sect. 15.7.2
2. Home applications based on solar power (Fig. 15.4)

*Supervision and monitoring of the small photovoltaic parks*

The dispatchers of small photovoltaic parks make the surveillance with dedicated appliances that enable measurements to be processed via Bluetooth from inverters. Supervision and monitoring in parks large photovoltaic

*Supervision and monitoring of the large photovoltaic parks*

The dispatchers of large photovoltaic parks use SCADA systems to monitoring the energy generated based on compact reconfigurable items which may avoid the fall

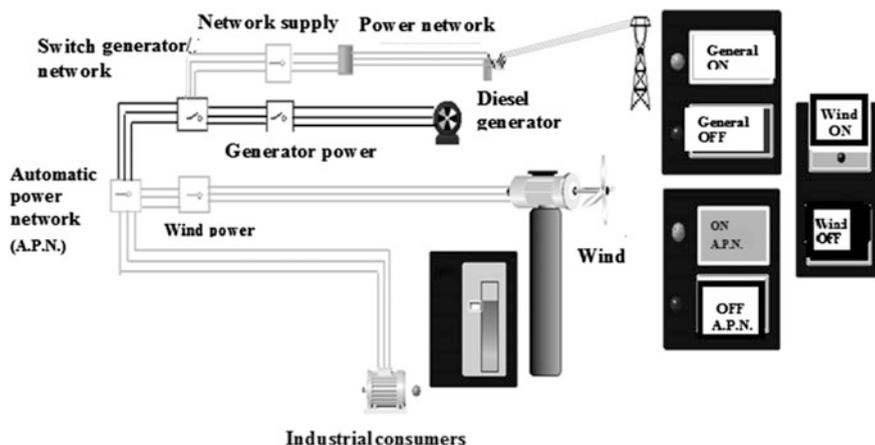


Fig. 15.3 SCADA system for hybrid EPS based on RESs

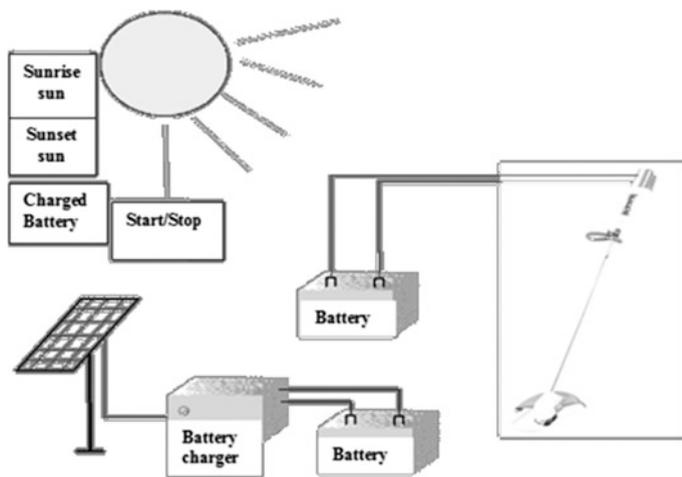


Fig. 15.4 Exploiting the RESs for usual home applications

of some subsystems. These items can be easily changed, reconfigured and maintained [10].

The optimal energy management strategies may be the following [20]:

- to control the balance between supply and demand with a lesser impact on carbon emissions and high profitability in maintaining the business;
- to distribute the energy generated for different energy sources (in particular from RESs);
- to offer clean energy at reasonable costs and under a control of the impact to the ambient.

## 15.3 Hardware and Software for SCADA Systems

As it is known, the SCADA systems are able to measure and monitor different parameters and variables, such as: the level of liquids, the volume of the gases, the volumetric flow rate, the mass of liquids and gases, the pressure, the temperature, the humidity, the viscosity, the position and the moving, etc. For this, some signals must be acquired based on the appropriate sensors and transducers from different electrical and electronic devices, before to be processed and analyzed by SCADA system. These data can be used for supervision of remote processes. For this, the data are processed and analyzed to generate reports which will be transmitted to control the processes parameters within certain limits. The SCADA applications have two basic levels:

- the customer level, which will be performed the human-machine interaction;
- the data server level which will control the entire process.

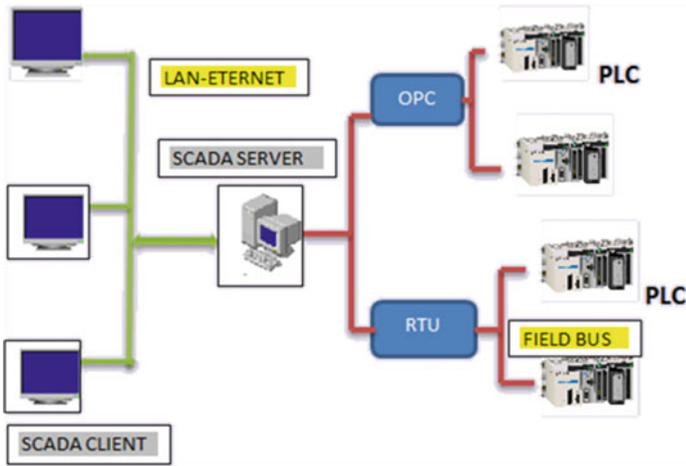
Thus, the data server sends these data to the customer level via remote equipment such as PLCs (connected to the database server either directly or via a communications network, using various communication protocols). The developed protocols can be property of a company (e.g. Siemens H1) or of open type (Modbus, Profibus etc.). Database servers can be fully connected to each other and also to the customer stations through Local Area Network (LAN) networks based on Ethernet technology [21–23]. The SCADA systems may be relatively simple or very complex, depending of the dimension and complexity of the process monitored. These systems operate in real-time using a database system named Real Time Data Base (RTDB), which can be found on one of servers [3].

### 15.3.1 Hardware Architectures

The servers are responsible for the acquisition and management of data for a set of parameters. Is it possible to have dedicated servers for certain tasks (for example, if the objective is to develop the process servers), servers dealing with the handling of alarms, or file servers [23].

A SCADA server will be connected directly to the PLC via an Open Platform Communications (OPC) or a RTU, which both collects and consolidates data from and from PLC-uri (Fig. 15.5). The SCADA takes on request the data from indicator reading appliances and equipment condition.

The OPC and RTU work as a data concentrator. The data is structured using a man-machine interface (HMI) in a convenient format for the operator in order to be able to take any decisions that would optimize the communication between the equipment.



**Fig. 15.5** SCADA hardware

RTU performs:

- the connection with supervised equipment;
- reading of equipment status (such as open/closed position of the valve or relay);
- acquisition of measured signals, such as the pressure, flow, voltage or current;
- the control of equipment by sending command signals, such as the closing of a valve or relay or setting the speed of a pump;
- reading the digital or analog signals, and sending the commands using both digital or analog signals.

The PLC contains a microprocessor used for the automatization of processes. A PLC is provided with input/output sensors and relays. PLC is less expensive alter to old systems which used tens or hundreds of relays and timers. The PLC is programmed using the structured programming languages and elementary logic operations.

The term “Supervisory Station” refers to the servers and software responsible for the communication with the equipment (RTUs, PLCs, etc.) and HMI software which run on master-station in the control room or elsewhere. The master station may be composed of one PC in small SCADA system. In large SCADA systems, the master station may include multiple servers, distributed software applications, and disaster recovery strategies. To increase the integrity of the system, the multiple servers will be often configured in a dual-redundant or hot-standby topology, providing control and monitoring even in the event of a server failure [9].

### 15.3.2 Generations of SCADA Systems

In this section will be presented briefly the well-known generations of SCADA systems.

- First generation is of “monolithic” type based on mainframe computers. The SCADA system was developed under conditions in which there were no computer networks. So, the SCADA systems were dependent designed to number of remote terminal units because the RTU was developed later (Fig. 15.6). An additional mainframe computer is added in the event of failure of the master system.
- Second generation is of “distributed” type because the information is shared in real time in the LAN. The data processing is done on several stations connected to the LAN (Fig. 15.7). Responsibilities are divided to each station, which enables high speed data processing at reduced cost in comparison with first generation.
- Third generation is of “network” type because the SCADA system uses the open system architecture, where can be easily connected peripherals such as printers, hard drives etc. The communication between the SCADA master and networked remote terminal unit is based on Wide Area Network (WAN) protocols such Internet Protocol (IP) address (Fig. 15.8). But the use of IP address standard via Internet makes the SCADA systems vulnerable to cyber-attacks. Consequently, new network protocols are developed by companies, but still remain important security issues to be solved.

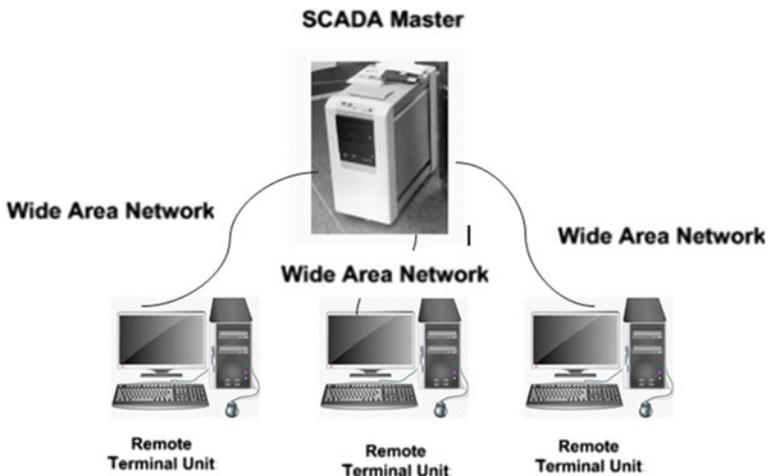


Fig. 15.6 First generation of SCADA systems

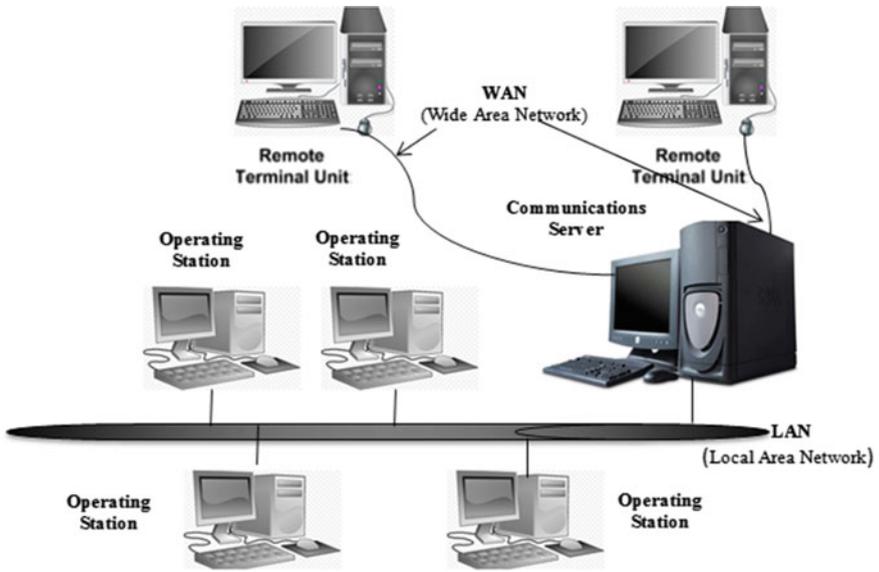


Fig. 15.7 Second generation of SCADA systems

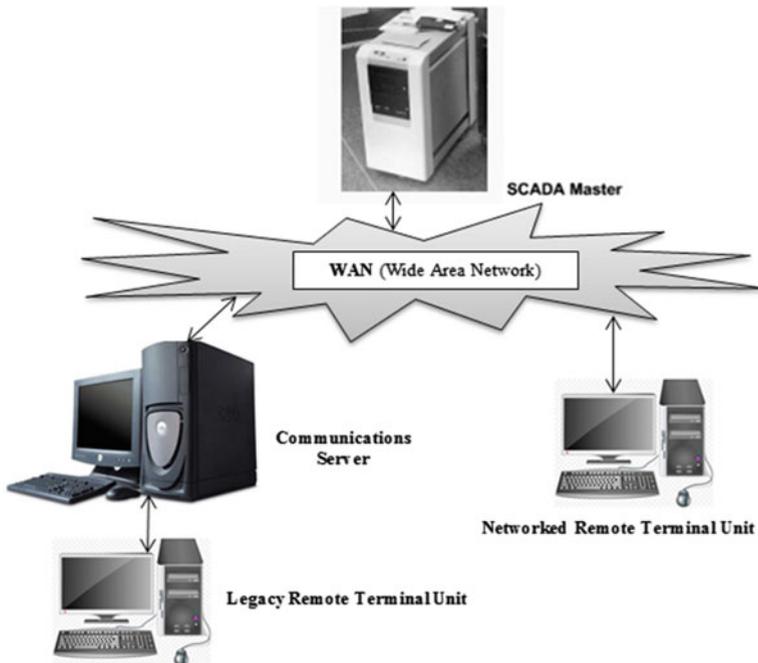


Fig. 15.8 Third Generation of SCADA systems

### 15.3.3 Software Architectures

The SCADA applications are implemented based on the software architecture (Fig. 15.9).

SCADA software architecture has at least two components:

- the SCADA server application;
- the SCADA client application;

The SCADA server application; is multi-tasking being responsible for storing the SCADA client applications in a database. The SCADA client application receives data via serial port using RS232 and MODBUS RTU protocols.

In many cases the SCADA applications shall be addressed to and remove the users who have not an Internet connection. In this case it is necessary a new software component on a Web server. A Web server is used for generating dynamic Web pages, which are supplied to customers decrease. The Web SCADA clients can benefit to real-time access (in a manner similar to regular SCADA clients) to the lists of parameters, the lists of events and the list of alarms via a simple browser. But, the Web SCADA clients do not receive the same level of graphical user interfaces and have the same HMI features as the regular SCADA clients. The regular SCADA clients are accustomed to running specific applications as opposed to The Web SCADA clients who view the Web pages provided by Web SCADA server. In order to reduce as much difference between the regular SCADA clients

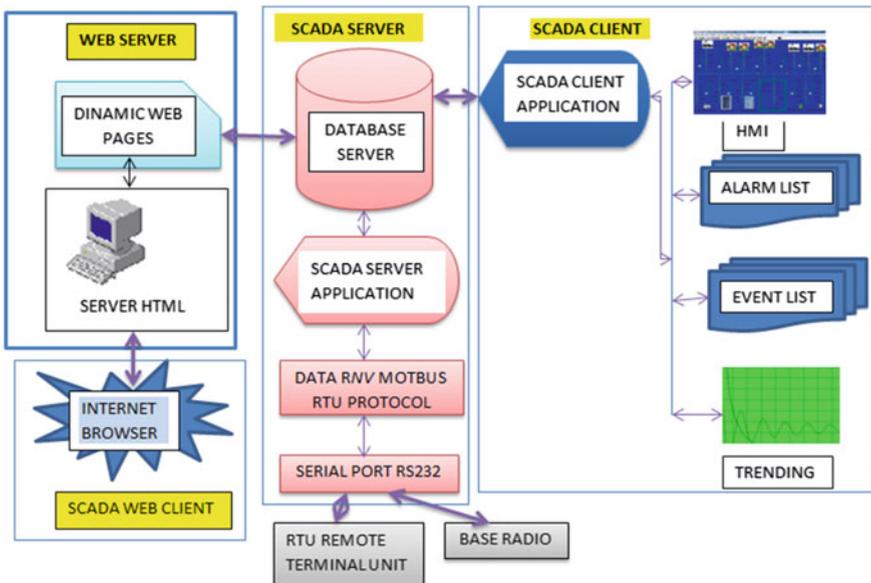
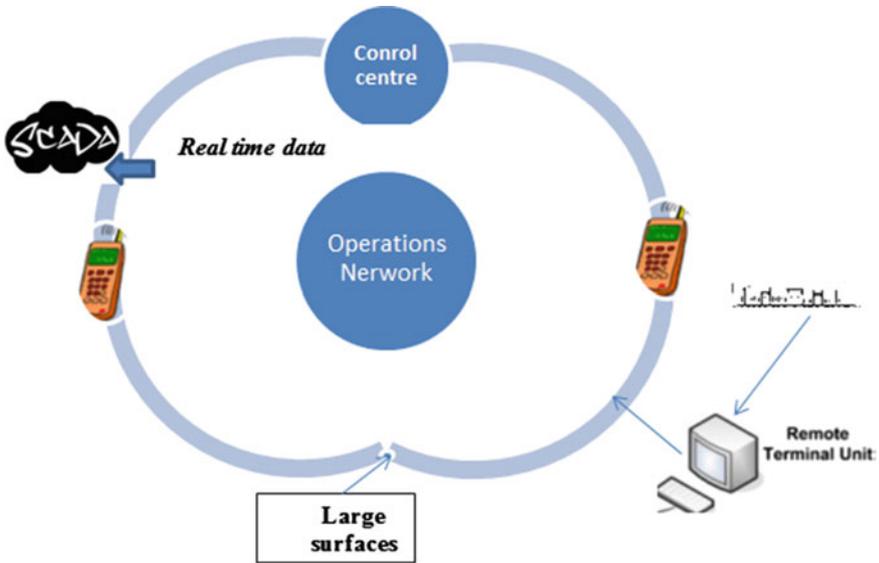


Fig. 15.9 SCADA software architecture



**Fig. 15.10** SCADA systems

and Web SCADA clients some drives, services and virtual instruments are implemented in HMI. Visualization software used for monitoring and control of industrial process is called “software” HMI or “SCADA software”. HMI as it is called generically, means any switch, interface through which you can control a device. The term “automation” refers to the graphical interfaces implemented through interaction with the mouse and/or the keyboard or by touch.

HMI/SCADA appeared as a terminal dedicated for users from the system implemented with PLC units. A PLC is programmed to automatically control a process. Because the PLC units are distributed in a large system, the data from PLC are stored and then transmitted. HMI/SCADA has the role to gather and combine the data from the PLC using a specific protocol. HMI software can be connected to a database in order:

- to fulfill the charts and diagrams in real time;
- to analyze the PLC data;
- to treat the planned maintenance;
- to drill the schemes for a particular sensor or machine;
- to apply the troubleshooting methods of the system.

The basic SCADA protocol is MODBUS, which is designed to send data to the master station even when the master interrogates the RTU station. MODBUS is based on a master-slave architecture known also as client-server architecture. The protocol is designed to be used by Modicon in own PLCs. Now, it became a standard of communication for the industry and is currently the most widely used to

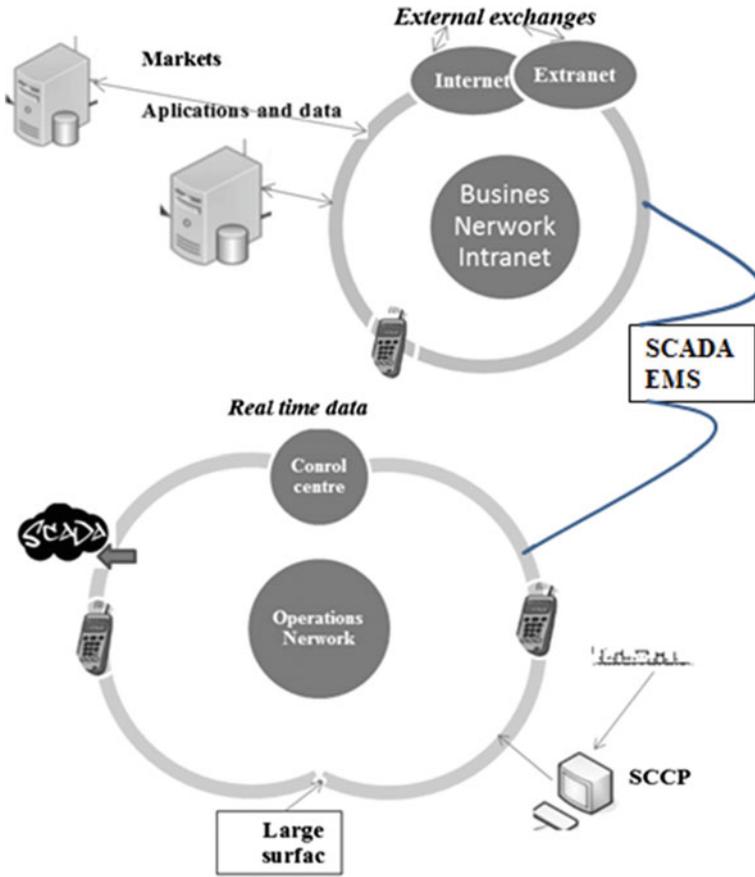


Fig. 15.11 SCADA energy management system

connect all the industrial devices. The protocols contain extensions to operate over Transmission Control Protocol (TCP/IP). In practice, it is suggested to avoid the security of Internet connection in order to reduce risks of cyber-attacks.

This protocol has the following features:

1. it is an open protocol with available documentation;
2. it can be quickly implemented (in few days, not months);
3. it works with bits and bytes, so no particular requirements on implementation.

MODBUS allows the management of the network devices, which gives new features to the SCADA system related to flexibility, reliability and safety in operation at high performance.

## 15.4 Assessment of Cyber Security Risk for SCADA

The developments in Information Technology (IT) systems regarding the safety of SCADA systems are shown in Table 15.2 [9–11].

Catastrophic situations which may occur due to incidental technical at level of the automation systems, Energy Management System (EMS), SCADA system, communications system, and support infrastructure. Besides these, other causes may be the incidents of cyber security and problems in the management of emergency situations.

### *New risks which occurred*

“The Stuxnet incident has underlined what many ICS security experts had assumed for a long time: A sophisticated cyber-induced attack against an industrial facility would try to attack control systems rather than IT systems”—CIGRE WG B5-D2.46

- June 2010, Stuxnet was discovered;
- September 1, 2011, Duqu was discovered;
- May 2012, Flame Retardants was discovered;
- June 2012, Gauss was discovered;
- etc.

### *What is the concept of Cyber Security?*

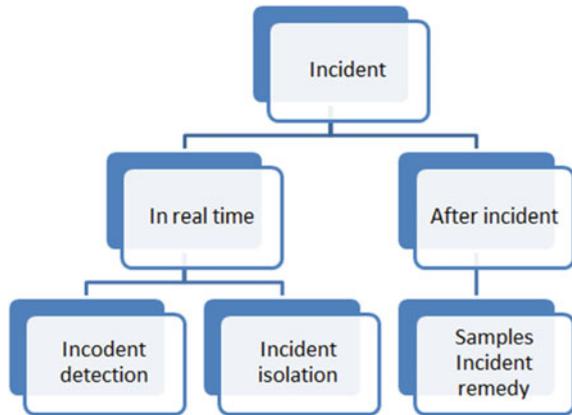
Security of those systems cannot be treated as a whole, and nobody can guarantee perfect security, because there is any system of defense perfect. Measures to protect and prevention are not enough, because emergencies and viruses could act in time using hidden forms or different rules. It is important as process to be defined from the point of view of management and responses to the incidents [8]. Incidents may be treated as shown in Fig. 15.12.

Safety in the field of energy must be monitored on the basis of production, transport and distribution, until to the end-consumer. In general, the current

**Table 15.2** Systems developments in IT and SCADA security

Past	Present and future
SCADA (Fig. 15.10)	SCADA + Energy management system (EMS) + protection to electromagnetic pulse (EMP) (Fig. 15.11)
Closed systems	Partially open systems
Push-to-talk communications and cyber safe	Bi-directional communication and high cyber security (CIGRE—WG D2.34)
Few information	More information
Dedicated operating system (OS)	Standard OS + commercial OS
Few security requirements	Consistent data requirements

**Fig. 15.12** Procedure for treating the incidents



problems are treated without taking into account new risks which can appear and could make huge damage, if will not be considered.

Risk assessment management involves the following stages:

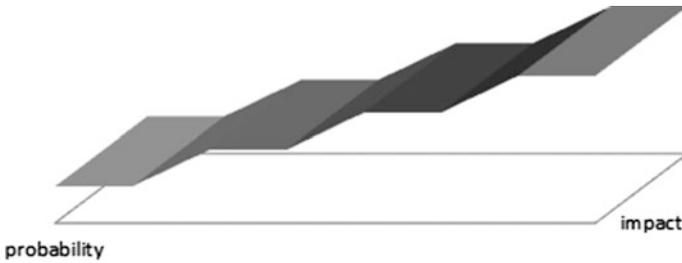
- the analysis by which risks are identified in order to be assessed;
- the risks assessment from the point of view of the impact and likelihood of occurrence within tolerance imposed;
- the future decision by identifying and understanding risk [24].

Risk assessment can be done using several tools, one of the most popular being the probability-impact matrix which encompasses:

- the assessment of the probability that a risk to materialize and measured the degree of certainty;
- the assessment of the impact as the consequence or effect, where the risk would materialize. In the impact assessment, account shall be taken of the fact that the risks that have a strong impact on acute misconduct, while those which manifests itself frequently and have a low impact signals a chronic problem;
- the evaluation of risk exposure as a combination of probability and impact can be felt where the risk would be materialize. In case of the materialization, the risk exposure is, in fact, an impact [24].

As a result of completing the stages of identifying and assessing of possible risk, finally, a synthetic and clear representation of the risks must be drawn, mentioning their ranking in accordance with the level of exposure. The prioritization of risks is a very important tool in risk management. Tolerance is estimated by determining the level of risk accepted. The level of risk accepted is established after the adoption of the response. The following should be taken into account:

- inherent risks;
- residual risks.



**Fig. 15.13** Assessment of exposure to risks

Risk tolerance involves some subjectivity because it depends to a large extent by the way in which this is perceived as risk. Risks which have a high level of the exposure is located on top of the tolerance and should be dealt with by means of measures by which exposure to residual risks must be made under this tolerance [24] (Fig. 15.13).

## 15.5 SCADA Applications

The HMI/SCADA software can be installed on personal computers or embedded computers with touch-screen, distributed through the house or into the industrial process. It runs a real time operating systems because it must respond in the shortest time to changes in the parameters of the process monitored. Consequently, the HMI/SCADA software must meet the following requirements:

- to be easy to use;
- to have an intuitive interface;
- to provide increased security;
- to enable the remote access (if it is the case);
- to be easily to access and use the information;
- to be flexible in use;
- to have the possibility of communication through the various services (sms, e-mail, fax).

The HMI/SCADA software must be capable of performing certain functions, such as:

- control and supervision of process;
- alarming the user;
- acquisition of the data needed;
- storing of the events;
- keeping the databases updated;
- developing of graphical evolution of the process;
- coupling with Enterprise Resource Planning (ERP) software.

The most important element of an integrated HMI/SCADA is the interface that connects the command and the system that is monitored. This interface is used by the human operator to access:

- the graphic elements that symbolize the automated technological process in a systemic, appropriate and intuitive manner;
- the most important functions in order to enable all functionalities;
- the state of alarm variables and the alarms history;
- and many other information displayed in a form easy to be followed by the human operator to see the evolution over time of the process monitored.

### ***Optimization through SCADA solutions***

Currently, in the world and in our country, the energy industry is characterized by profound structural transformations. Besides these requests for structural changes, the function in a competitive market leads to the amplification of the current efforts made by the power companies to increase efficiency and quality of their service. One of the ways of achieving this aim is the orientation towards the smart grids based on a new strategy for energy management. Thus, information of the EP system is one of the basic prerequisites for increasing the effectiveness and safety of the operation of the national energy system. An example of optimization of the electric power stations along a river is shown in next section.

#### ***15.5.1 SCADA System Existing in a Hydropower Plant***

The existing SCADA system (Fig. 15.14) consists of:

- the SCADA systems associated with each Hydro Electric central Computer (HEC) (HEC1, HEC2, HECi);
- the SCADA System for the Hydro Energy Dispatching (HED) from based Hydroelectric Station (HS).
- At the level of the HECs arrangement, the SCADA system is composed of:
- Distributed Antenna System (DAS) which represents the equipment for the data transmitted between the SCADA processes in HEDs from the Hydroelectric Station (HS).

The DAS has available four RS232 I ports and an Ethernet port. The communication protocols supported are: (1) the DAS Serial, (2) the Modbus RTU, (3) the International Electrotechnical Commission (IEC) 1107 Mode C for serial ports, (4) the DAS TCP/IP, and (5) the Modbus TCP for the Ethernet port. Note that the communication with HEDs is made through the DAS serial ports on two redundant paths: (1) using the telephone line and the communication protocol; (2) using the radio communication protocol.

- Functional Assemblies (FAs 1–4) may represent Hydro-aggregate automation systems, automation systems, General Services (GS), and HEC barrage.

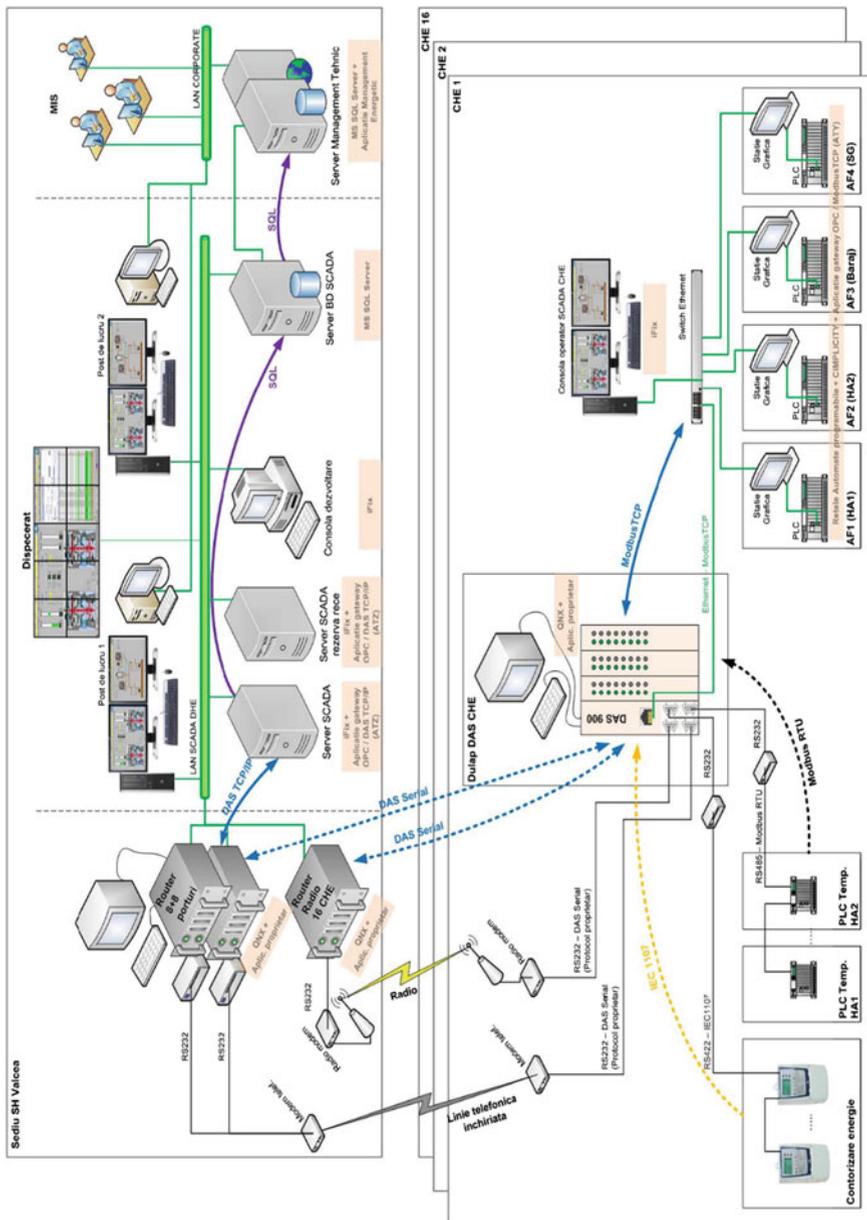


Fig. 15.14 Architecture of the existing SCADA System

The communication protocols implemented in the FA are the OPC industrial communication protocol (available in Wincc, Cimplicity). Communication with DAS is via Ethernet using the Modbus TCP protocol, which has the role of protocol gateway between OPC industrial communication protocol (available in Wincc, Cimplicity) and Modbus TCP protocol (available in DAS-900).

- The operating Console of the SCADA HEC is based on the OPC industrial communication protocol available in SCADA iFix (Intellution).

Programmable thermometry in Hydro-agregate Automation (HA1, HA2) systems is made based on (1) Modbus RTU communication protocols, which assure the communication with DAS via RS485 (or RS232) with the energy meters.

CewePrometer is a family of high-precision four-quadrant energy meters which has the following communication protocols available: (1) Digital Library Management System (DLMS) (used by the energy metering application) and (2) IEC 1107 serial C Mode. Communication with DAS is via RS-422 (or RS232) using the communication protocol IEC 1107.

The HED of the SCADA system is composed of:

- The Serial Router (8 + 8 ports) is composed by two industrial computers with QNX operating system. Communication protocols supported by the application are the DAS Serial and DAS TCP/IP Ethernet. Communication with DAS HECs is done in two paths as well.
- The radio Router System assures the communications with 16 hydroelectric power plants through radio-relay, using the same communication protocols as the Serial Router.
- The SCADA application is installed on the SCADA iFix (Intellution) server and the OPC/DAS TCP/IP gateway. The second SCADA server will operate as the main SCADA server if will be the case.
- The Data Base (DB) SCADA server use the iFix application based on the Microsoft SQL Server (MS SQL). MS SQL server is the data source for the “Technical Management” application.
- Technical Management server is a computer on which is installed and runs the “Technical Management” application based on the installed MS SQL server and WEB server.

### ***Information flow diagram***

From the point of view of information flow, the existing SCADA is presented in Figs. 15.15 and 15.16. Thus, at the level of DAS-900, the HEC data concentrator acquires specific data for HECs SCADA from the FAs. FA1 and FA2 read the data from the automation systems HA1 and HA2. The General Services (GS) and the Barrage application use the OPC protocol (existing graphic stations as base driver) via the Modbus-TCP from the DAS-900. This conversion from OPC to Modbus-TCP has the following disadvantages:

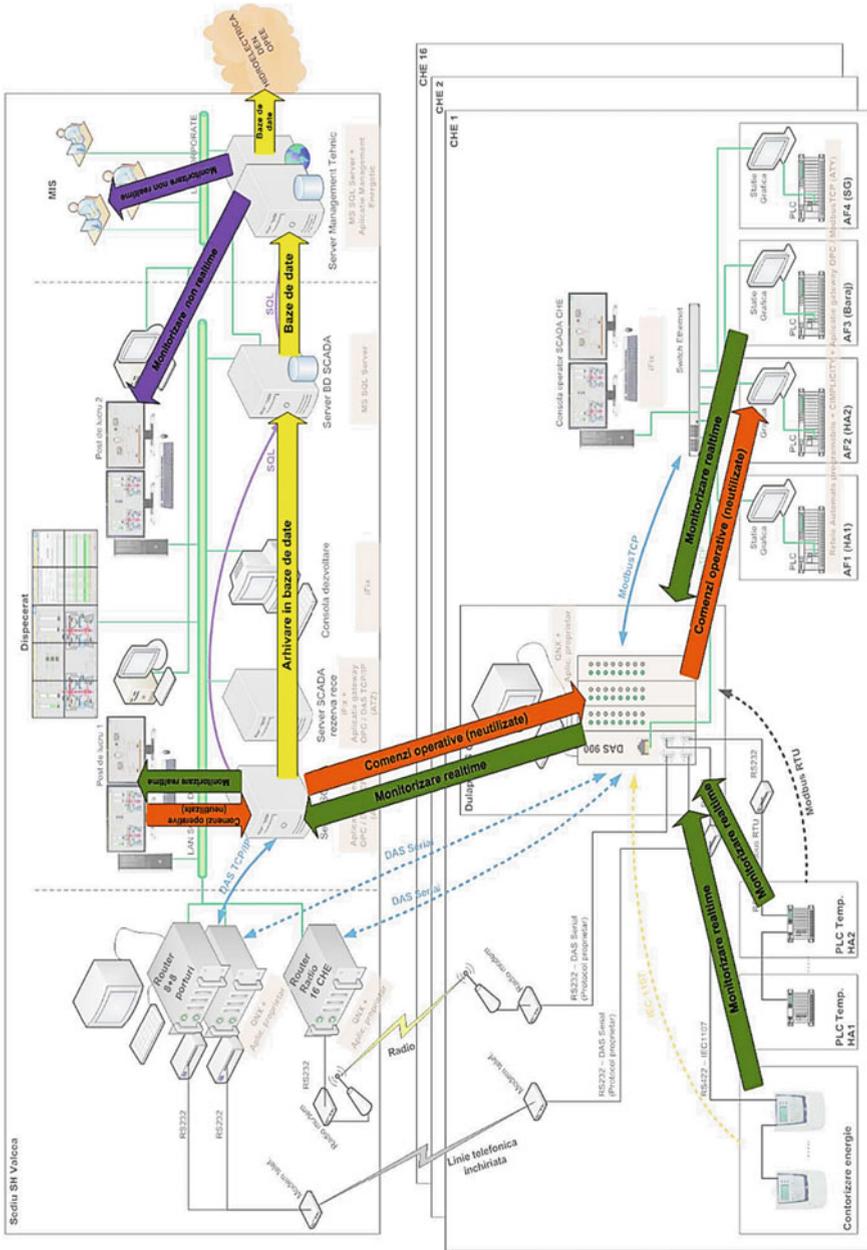


Fig. 15.15 SCADA system information feeds

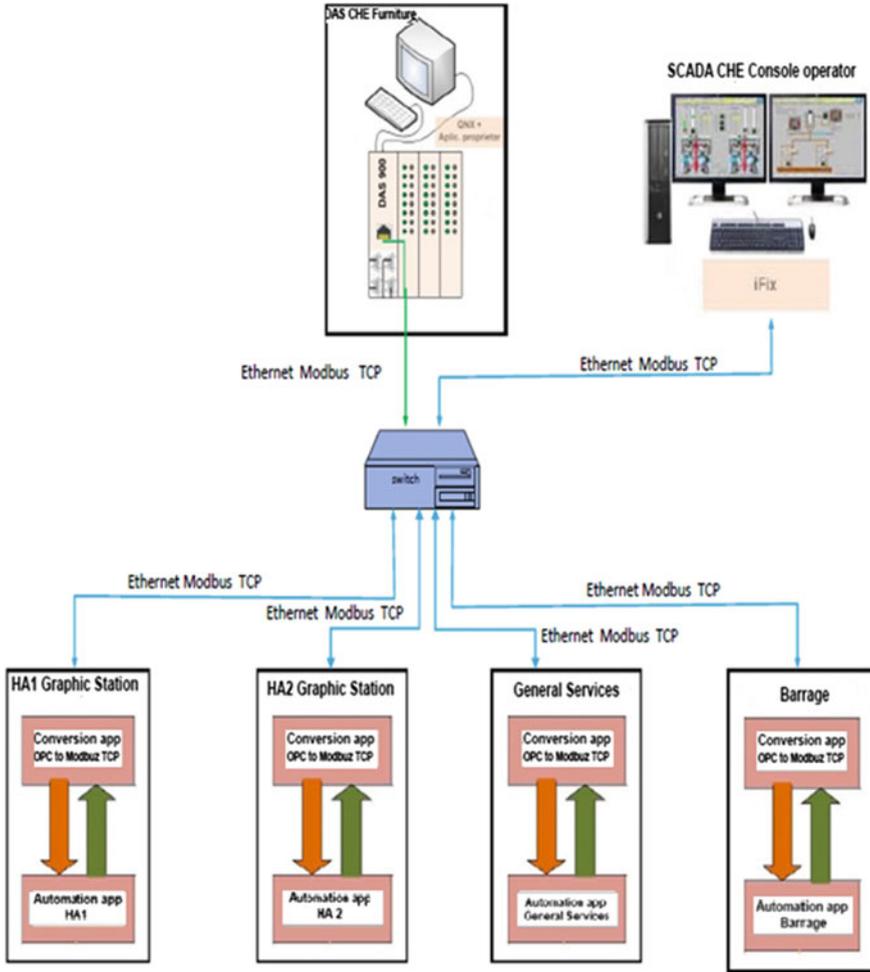


Fig. 15.16 Streams and SCADA system architecture for the river hydro-arrangement

- the software application is not documented and it is very hard to be interfaced based on standard protocols with existing SCADA architectures. It appeared as a necessity to interface DAS-900, which doesn't support for the OPC protocol, with the process charts from the HEC stations, which have locally implemented the OPC protocol;
- it requires automatic start and stop upon launching the application of monitoring and control on each processor of the workstation graphics or restarting the operating system. So, it must be individually monitored for any restart in the event of a communication blockage;

- as was seen in operation, there were frequent blockages of this application, which means that data and commands are not passed to and from the hierarchical level;
- the application for operation relies on two text files with strict rules of editing (spaces, TABs, bookmarks, etc.), which must be configured identically for each workstation graphics (HA1, HA2, General Services, and Barrage) and DAS-900. Note that the existing SCADA system has the possibility of transmission the commands, but at the present time these are not used.

Thermometry system for the HA1 and HA2 will read the temperatures monitored and the CewePrometer meters will give the main electric values: active power, reactive power, voltage, current etc. The data concentrated in DAS900 are transmitted by the SCADA system to the HED through the two redundant paths mentioned above. DAS900 system has the option of receiving SCADA commands and records from HED, but at the present time these are not used.

The SCADA data acquired and processed by the HED are stored in the MS SQL database in order to be used by the “Technical Management” application.

### ***15.5.2 SCADA System Proposed at the River Hydro-Arrangement***

The proposed architecture (Figs. 15.17 and 15.18) was chosen to obtain an increased security by physical separation of the LANs HEC, SCADA LAN, LAN DSZ, and LAN CORPORATE using Router/Firewall equipment.

The implementation of a fiber optic network (of redundant ring type) will facilitate the communication between the HEDs related to East River and HEC. The IEC 60870-5-104 communication protocol is proposed, which is an industrial protocol suitable for communication between servers and optimized SCADA network of HED and HEC WAN.

Note that the existing radio network will remain functional as a backup plan for fiber-optic (FO) network. Thus, the IEC 60870-5-101 radio protocol will be used as a hot backup (with automatic switching) for the IEC 60870-5-104 main protocol based on FO network. Consequently, the HED communication with other HECs will not be affected.

The managers of the Hydro-electrica (HE) Company aim to implement a central SCADA system data of “real time” type on all hydro-stations. For reasons of security and reliability, it is not recommended to send the data directly from HE SCADA LAN (which is a closed and secure network), but it is possible to transmit data from the isolated nodes. The Technical Management server has all the necessary facilities for data transmission to HE Company.

The proposal to modernize the HEC architecture by replacing the existing equipment with new DAS-900 equipment and two SCADA redundant servers (with

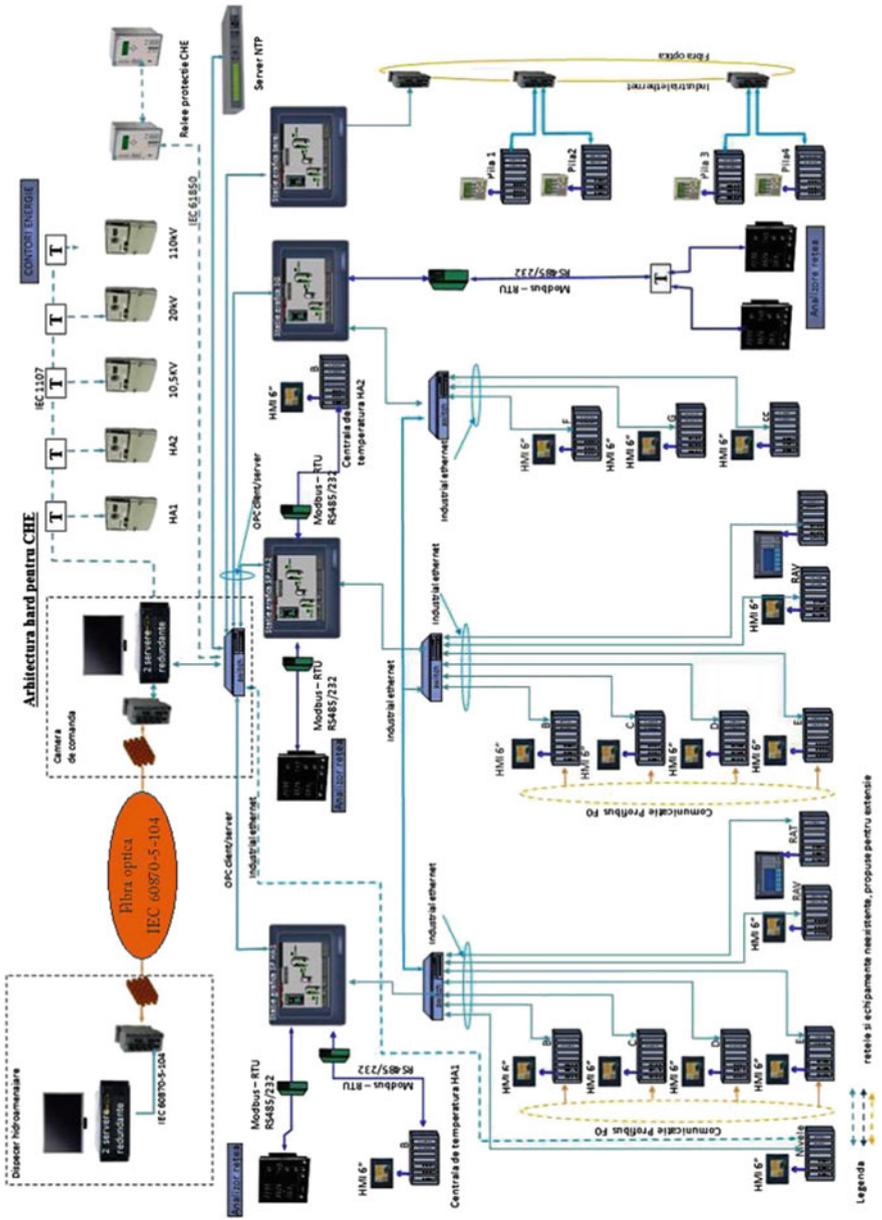


Fig. 15.17 Architecture of the proposed SCADA system

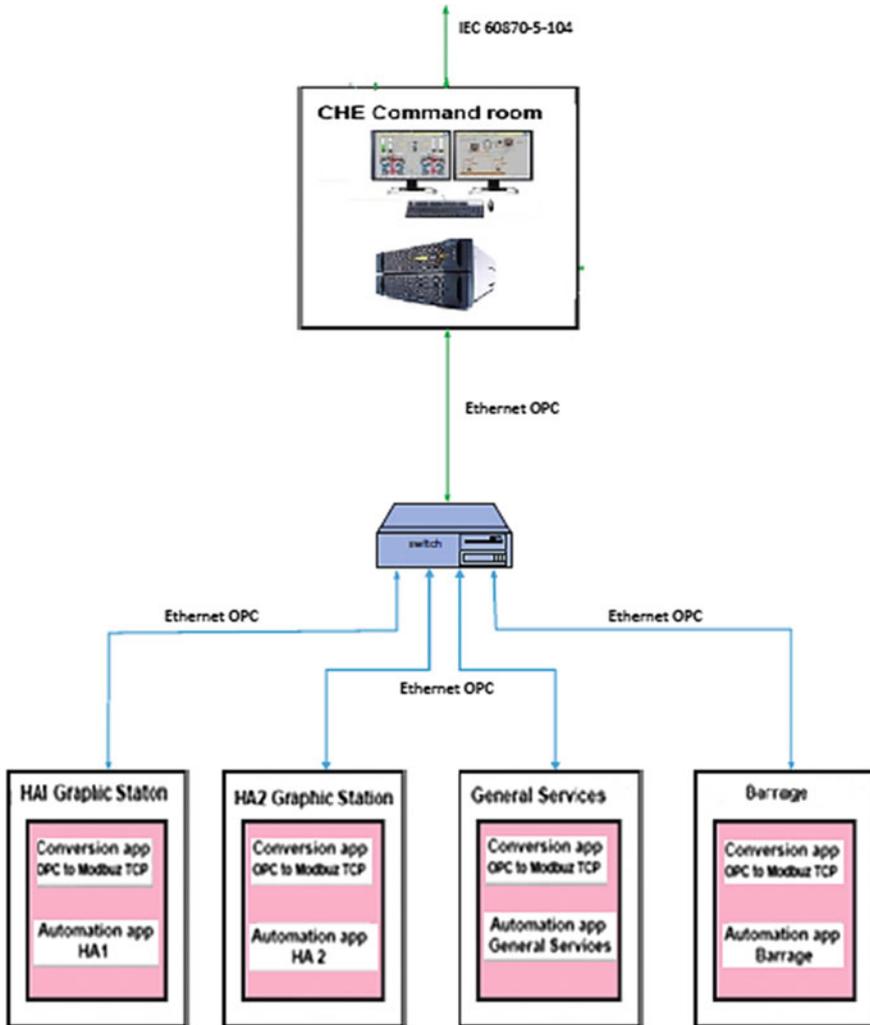


Fig. 15.18 Streams and SCADA system architecture proposed for river hydro-arrangement

hot redundancy) to eliminate the existing malfunctions and in addition to implement new communication functions needed for operation in HED such as

- Bidirectional communication between the automation systems (HA1, HA2, Barrage, GS) using the OPC industrial protocol, without the need of other applications for data conversion;
- Communication (in terms of realtime monitoring of the main electrical variables) with existing CewePrometer meters using the IEC1107 and Ethernet TCP-IP communication protocols;

- Bidirectional communication (in terms of data monitoring and transmission of commands) of HED SCADA system using two paths communication: IEC 60870-5-104 communication protocol (primary path) and IEC 60870-5-101 (backup path).

The SCADA applications dedicated servers hold a large number of standardized protocols for direct communication with automation devices used in monitoring and management of industrial processes. The advantages for data acquisition and remote management of the hydropower plants retrofitted with redundant SCADA servers are:

- Simplification of the structure by removing the SCADA DAS-900 equipment (or other similar equipment) and use of the redundant servers for sending commands and data from the central dispatcher and vice versa; this allows easy capacity expansion and further development of software, no constraints;
- The use of a SCADA software installed on the server, ensuring direct connection via OPC industrial communication protocol to the existing equipment for the management and supervision of the processes, without intermediate software; servers will provide the following functions: acquisition, operation of data, storage and archiving, printing and reporting to the higher and lower levels of communication, supervision of automated processes.

This will also assure: (1) communication with existing equipment installed (meters, protection relays etc.), (2) high speed communication through the FO network of the each HEC and HED, (3) improved security provided by the two levels SCADA servers (two network cards and firewalls on the routers), (4) local drivers and OPC connectivity with inferior equipment levels, (5) storage and upgrade of existing licenses for iFix and SQL Server, (6) uninterrupted operation through hot-plug functions of the redundant servers, both in terms of data (change of the HDD without stopping the server) and to server maintenance (change of the power supply without stopping the server), and (7) easy interfacing with HED Technical Management server.

### ***15.5.3 Issues Related to Data Acquisition and Remote Management***

Issues related to data acquisition and remote management applications of the power plants, which running on hydropower facilities with RTU, are the following:

- RTU32 in the proposed SCADA architecture is not hot redundant at equipment level;
- Unable to communicate with graphic stations of the RTU process and SCADA servers via the OPC industry standard protocol;

- The need to create a new application (named “Date Gateway”) at the level of SCADA servers, as well as the “Technical Management” server, for bidirectional communication between the servers;
- Managing under Windows XP of the Setup software in RTU with Straton;
- Bringing of electrical signals directly through wires to the level 1 (RTU 32 level) is not indicated, but the solution to bring them to level 0 (PLC and RTU) it is recommended.

## **15.6 Overview of the Programming Environment VIJEO CITECT 7.40**

CitectSCADA system is considered one of the most complex and complete products for the SCADA systems [34, 35], being part of the VIJEO CITECT SURVEILLANCE SOFTWARES 7.40<sup>®</sup> of to the Schneider company. This software product includes over 150 drivers for communication with the input-output devices and over 350 models for PLCs, RTUs, controllers and regulators, barcode readers etc.

For any type of SCADA application, this system offers the needed flexibility in implementation and execution of the project, in terms of speed, efficiency and accessibility. More detailed, the CitectSCADA system offers the following opportunities to user:

- Use of the HMI graphic pages for central or local control stations;
- Realization of operation stages by creating the graphical control buttons;
- Display the status of the actuators via graphical charts;
- Display the alarm messages and their evolution;
- Language selectable to display the messages;
- Achieving of universal commands through the keystrokes;
- Controlling, storing, monitoring and displaying of the alarms;
- View the graphs in real time or in “history record”;
- Efficient and effective monitoring of the system;
- Creating of reports;
- Supervision of product quality by Statistical Process Control (SPC);
- Acceptance of transferring data with other applications;
- Security system can be configured on the priority levels.

VIJEO CITECT SURVEILLANCE SOFTWARES has the following modules:

- Citect Explorer;
- Project Editor;
- Graphics Builder;
- Cicode Editor.

### ***Citect Explorer***

The Citect Explorer module is used to create and manage a CitectSCADA project. This controls the configuration permitting enforcement of project in the rest of modules. Citect Explorer screen is shown in Fig. 15.19a:

The launch of the Citect Explorer module will automatically run the Project Editor and Graphics Builder modules, but these are minimized in Fig. 15.19a. The close of Citect Explorer module will close all CitectSCADA applications.

### ***Project Editor***

The Project Editor module is used to create and manage the configuration information of CitectSCADA project. The Project Editor window can be viewed by all projects. Special commands are accessible from the buttons or submenus (Fig. 15.19b).

### ***Citect Graphics Builder***

The Graphics Builder module is used to achieve pages and editing graphical objects used on other new graphics (Fig. 15.19c). Graphics Builder editor is activated by a double click on a graphic object in Citect Explorer.

### ***Cicode Editor***

The programs are edited in the window of Cicode Editor. The Cicode Editor menu contains a list of functions. The support information for functions is obtained by a right click on the name of the function (Fig. 15.19d).

### ***Configuring CitectSCADA Projects***

The schematic of a CitectSCADA project looks like in Fig. 15.19e.

As can be seen in Fig. 15.19e, the CitectSCADA project includes the following items:

- Graphics;
- Databases;
- Cicode programs.

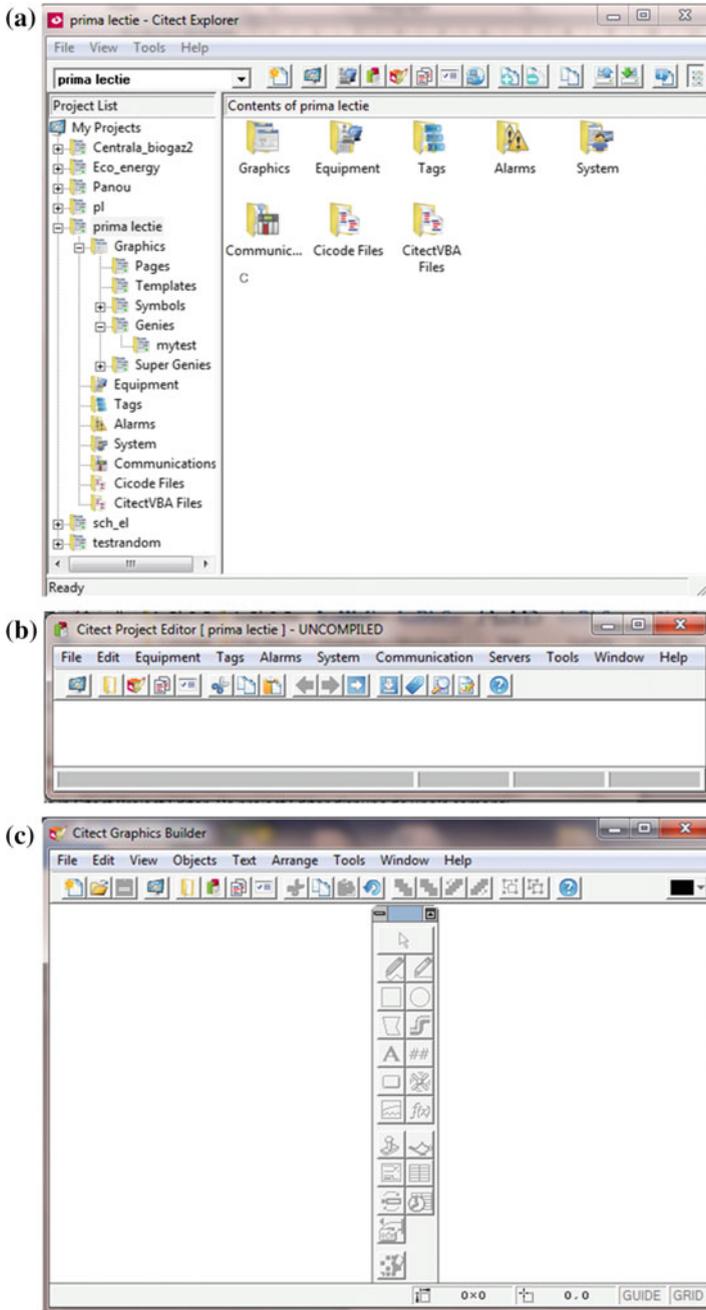
*Graphics* mean a graphic page which allows the monitor to display the graphical interface with control buttons.

*Databases* allow the storage of process information collected for monitoring and controlling the system. These may be linked to the graphics page if desired.

*Cicode programs* allow functionality and contain a number of useful functions stored.

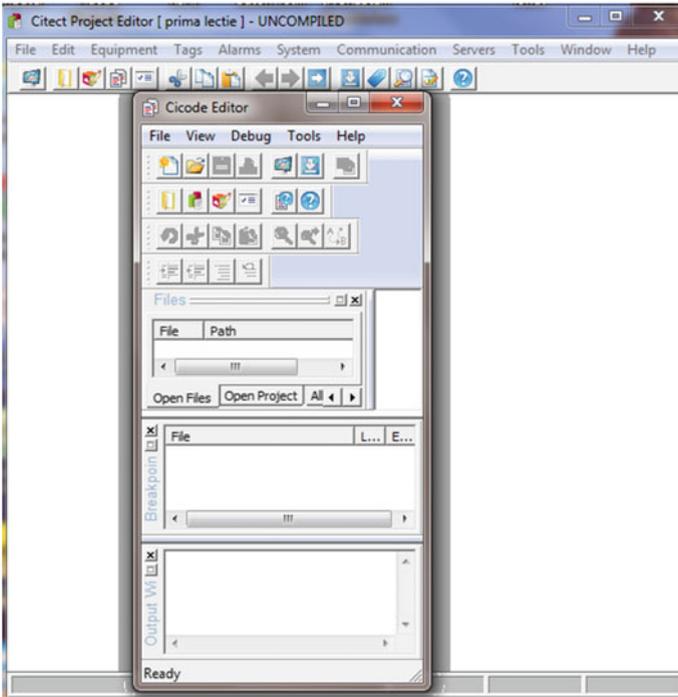
In all projects carried out, the user can:

- Create;
- Select;
- Open;
- Shut down;
- Delete;
- Etc.



**Fig. 15.19** a Screen of citect explorer. b Screen of project editor. c Screen of graphics builder d Screen of cicode editor. e Scheme of the CitectSCADA project

(d)



(e)

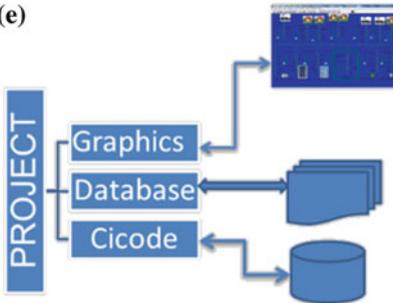


Fig. 15.19 (continued)

## 15.7 Developing Step by Step a SCADA Application for Electric Power System

### *Application 1*

#### *15.7.1 Implementing a Medium Voltage EPS Based on RESs*

The CitectSCADA environment is used here to develop step by step a SCADA application for the Electric Power System based on RESs. The both interfaces will be shown in this section in order to shown the advantages of the new SCADA interface, which is a friendly and intuitive interface, with a high degree of integration schemes, facilitating for more dispatchers to work simultaneously.

##### *The old interface*

As can be seen in Fig. 15.20, the old interface used is poor. In case of maneuvers in power installations, the dispatcher has a limited overview on the system.

##### *The new interface*

A SCADA application is developed step-by-step starting with the identification of needed elements and objects, which then will be set for data acquisition, command and control equipment etc. The software structure will be identified correspondingly in the hardware structure.

A new project must be opened and created, and finally must be saved. The project will define the appropriate hardware to achieve a simulation structure using the graphical page. For the simulation process, the structure must be monitored to be identified and set properly in the graphic pages as associations of hardware items

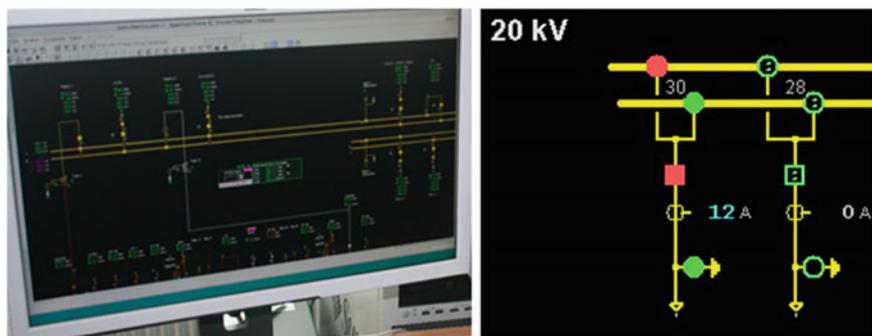


Fig. 15.20 Medium-voltage EPS based on RESs represented in the existing SCADA system

and their appropriate functions. An important step will be dedicated to security, namely:

- setting application users;
- setting their rights.

After implementation of the simulation structure, each item must be checked using the software to test all functional features (Fig. 15.21a).

The steps for creating a new project are:

- From the Citect Explorer → File → New Project, a new project called “Micro\_energy” is open (see Fig. 15.21b);
- From the Citect Explorer → gen → Communications → Clusters, define a cluster of communication called “sch\_el\_cluster” (Fig. 15.21c);
- From the Citect Project Editor → Servers → Network Address, define the TCP/IP address 127.0.0.1 called “sch\_el\_adr”;

Address “sch\_el\_adr” is the TCP/IT data acquisition system which are allocated to the system (Fig. 15.21d).

- Then, the further facilities will be configured as below:
  1. “Alarm”: From the Citect Project Editor → Servers → Alarm Server (Fig. 15.21e).
  2. “Trending”: From the Citect Project Editor → Servers → Server Report (Fig. 15.21f).
  3. “Report”: From the Citect Project Editor → Servers → Server Trend (Fig. 15.21g).
  4. “I/O Server”: From the Citect Project Editor → Servers → I/O Server (Fig. 15.21h).
  5. “Express Communications Wizard”: From the Citect Explorer → gen → Communications → Express I/O Device Setup → Next → Use an existing I/O → Disk I/O Device → Citect generic Protocol → Automatic refresh of tags → Finish (Fig. 15.21i).

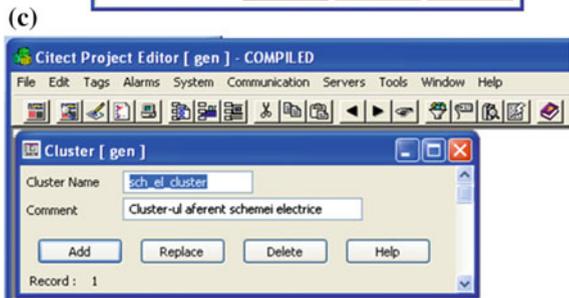
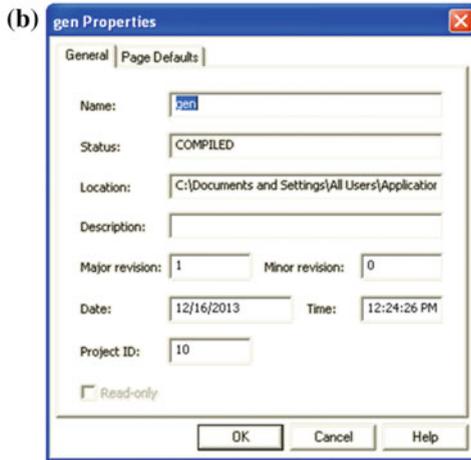
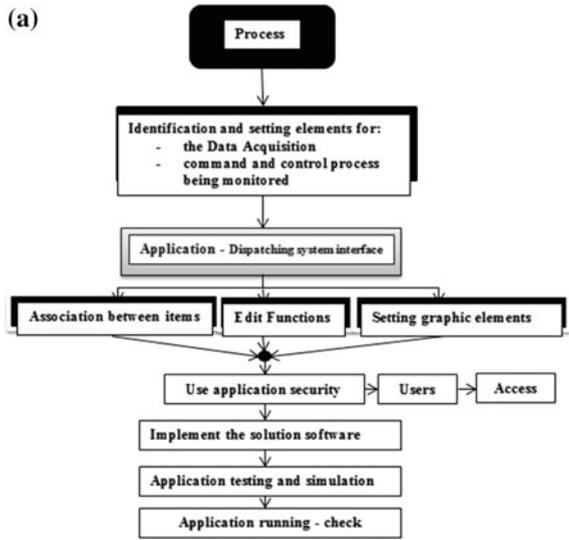
### 15.7.1.1 Making the Graphic Page

To this end, in this section the libraries of the associated elements, which are required or which must be designed or imported if there are no such elements, are shown below (Fig. 15.21j).

The following symbols and window is used for the transformer and to set the voltage ratio, and to obtain the animation symbol in order to switch the power on or off the power for transformer (Fig. 15.21k).

Each of the symbols used in application are briefly shown for further identification. Also a suggestive name, a label and a serial number will be associated to

**Fig. 15.21 a** Concept diagram of the SCADA application. **b** Window “New Project”. **c** Window “Cluster”. **d** Window “Network Address”. **e** Window “Alarm Server”. **f** Window “Report Server”. **g** Window “Trend Server”. **h** Window “I/O Server”. **i** Window “Express communications wizard”. **j** Imported images. **k** “Transformer” symbol and window “Symbol Set Properties”. **l** “Electrical splitter” symbol and window “Symbol Set Properties”. **m** “Switch” symbol and window “Symbol Set Properties”. **n** Animated symbols. **o** Window “Variable Tags”. **p** Window “Symbol Set Properties”. **q** Window for proposed process. **r** Graphic window of the active process. **s** The sequence of code in the graphical user interface (GUI)



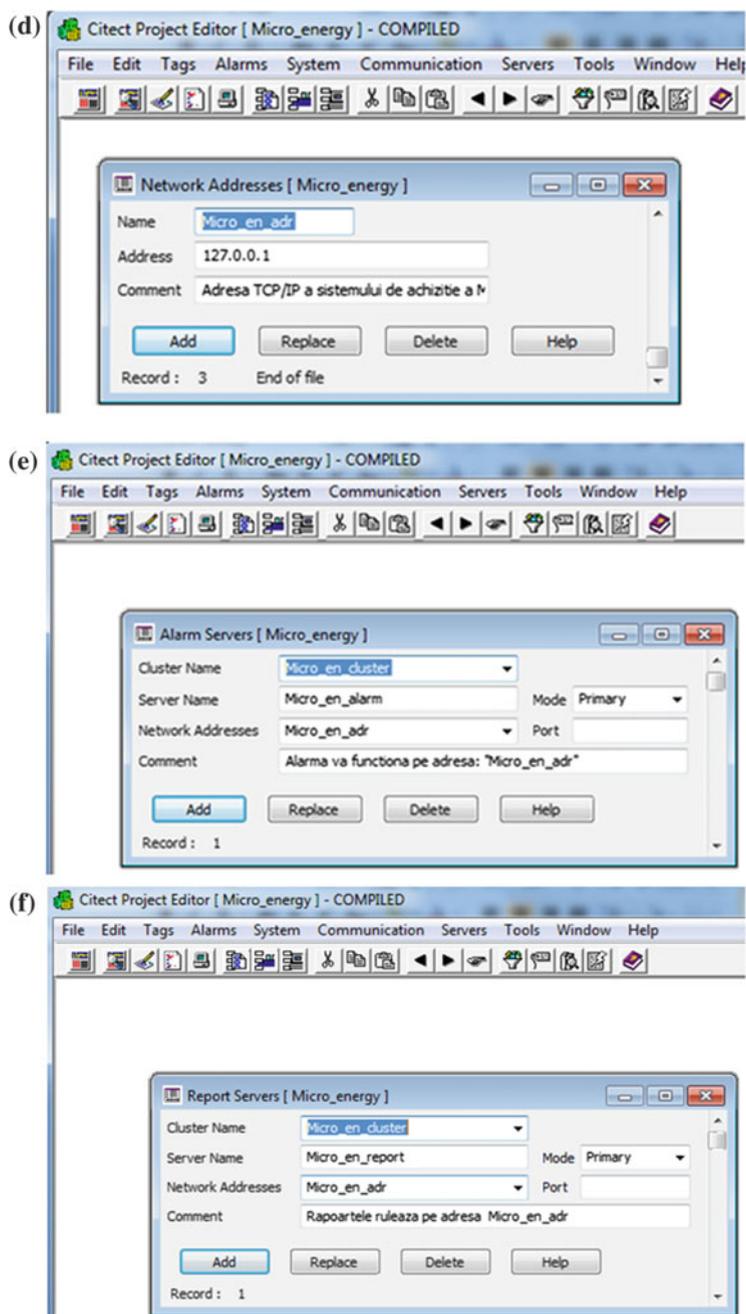


Fig. 15.21 (continued)

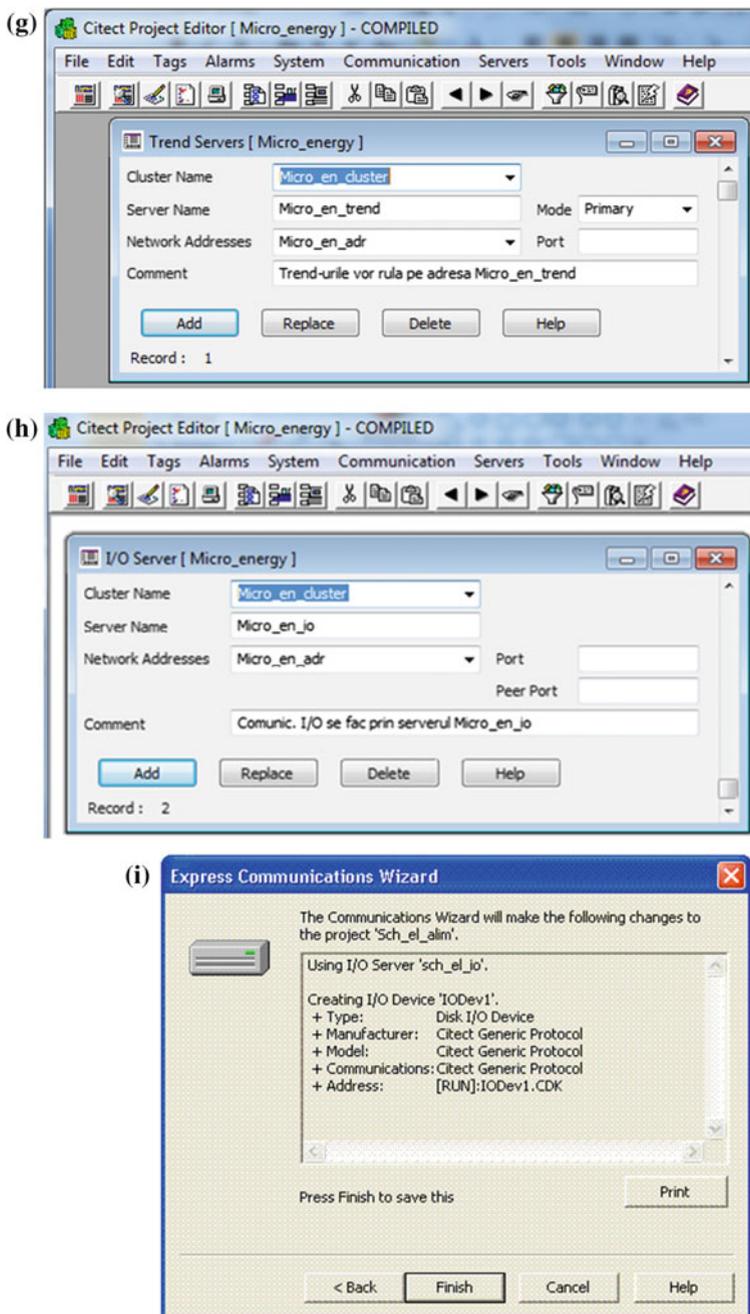


Fig. 15.21 (continued)

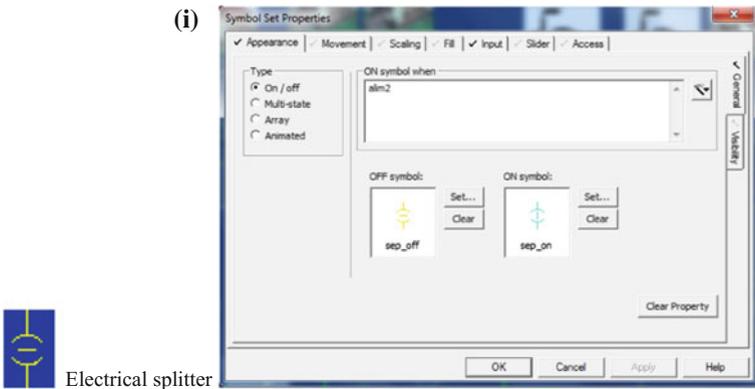
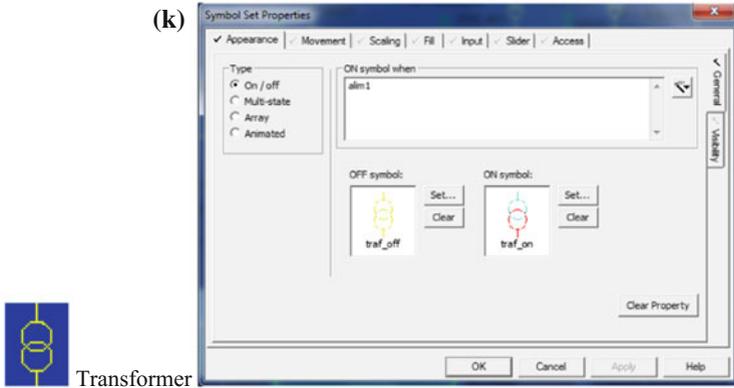
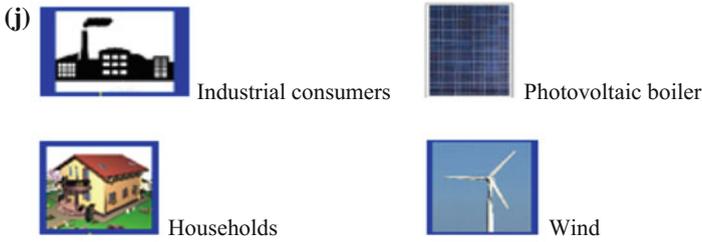


Fig. 15.21 (continued)

each symbol (Fig. 15.21i). See below the symbols for the electrical splitter (Fig. 15.21i) and the switch (Fig. 15.21m).

In the same manner are designed the next symbols used in application (Fig. 15.21n).

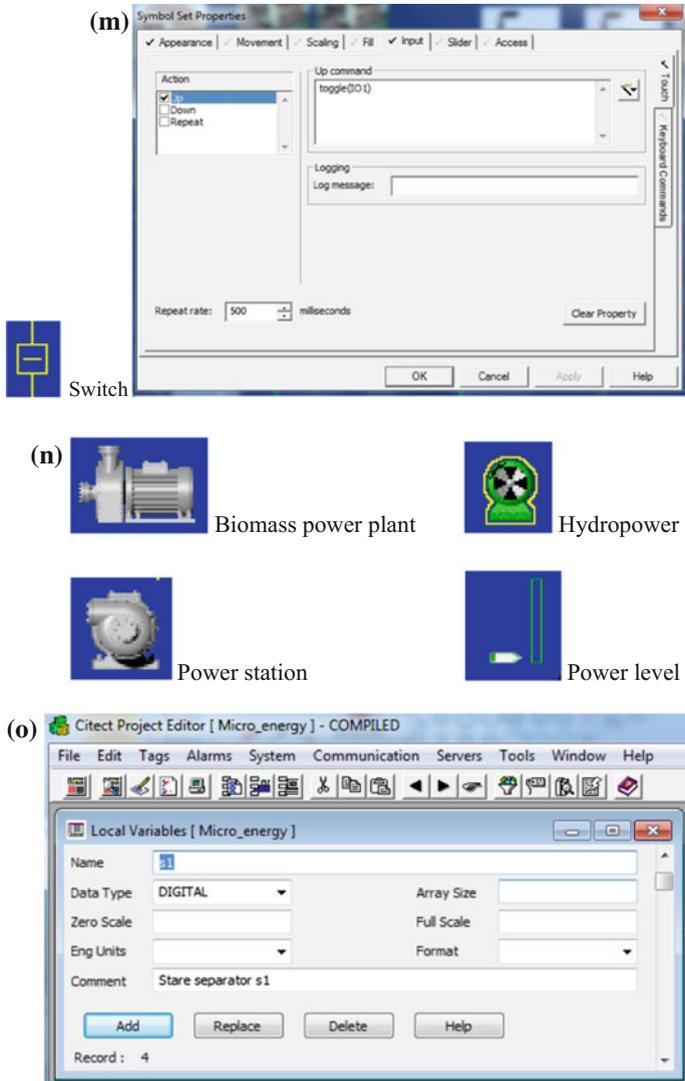


Fig. 15.21 (continued)

### 15.7.1.2 Configuring the Variables

All SCADA application are based on the setting and using of the tag-type variables. Tags are the interface between the user and the monitor. There are several types of tag-type variables:



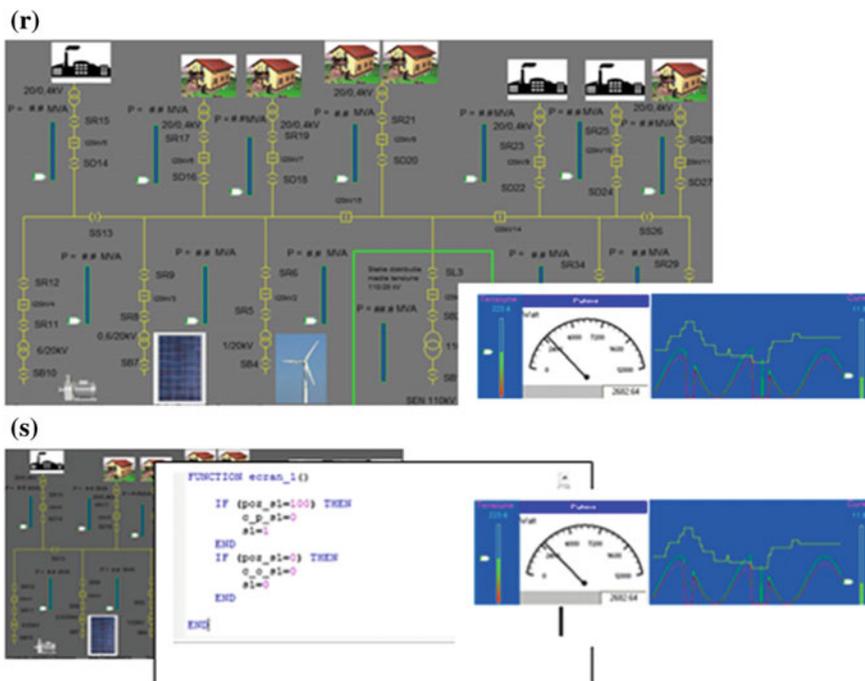


Fig. 15.21 (continued)

As shown, the variable called “s1” will be associated with the separator s1. Similarly, the rest of the variables were introduced and associated with each switching element or existing splitter shown in the diagram from Fig. 15.20

To associate an element to a symbol variable, the Properties window must be open for that element, as shown in the following figure for “Up command”. Here, access the list of variables using the right button. From the list that appears, select the setting required for an ease of identification which containing a serial number associated with its name (Fig. 15.21p).

### 15.7.1.3 Method of Implementation

A new graphic page with the name “L 20 kV SCADA” will be created from the Citect Explorer → gen → Graphics → Pages → Next → Create new page → (Fig. 15.21q). Place the elements in the graphic page using the library and then configure the related functions as indicated above. One can start the graphical page in accordance with the operating mode of each one, and then the variables will be set; or vice versa, the design program being very flexible.

The simulation diagram is tested if running proper. Operation for each item is tested with the left button of the mouse, in different combinations of the tabs. Also,

the operation of the power level indicators is checked. Adjustment is possible through the existing cursor for both consumers and energy producers. If it appears that there are inconsistencies, errors and changes are required. Finally, the application will be saved.

The whole process of the distribution system is monitored and controlled permanently by SCADA. The interface used is improved, showing the new features implemented at level of the dispatcher, which has an overview of the EPS and can perform maneuvers in the system in order to control the process. Besides the information about the state of switches at distribution stations, distribution lines appear illustrated to both household and industrial consumers. Depending on environmental conditions and the load demands are enabled the available energy sources: power plants, small hydro, wind turbines, biomass power plants and photovoltaic plants. These sources have the level indicators for the active power and the reactive power that can be modified and tracked at the consumer and the producer (Fig. 15.21s). The most important resource to increase the energy efficiency is to reduce own energy consumption.

An effective tool for studies and planning of the development of electricity distribution networks, and to reduce the domestic electricity consumption, is the analysis of the load profiles.

This verification process is repeated as many times as necessary, until the application will work correctly and as it is specified (Fig. 15.21r).

The application contains circuit breakers and disconnectors that will act as in the “General Regulation” of the maneuvers in the electrical installations and EPS (Fig. 15.21s).

## ***Application 2***

### ***15.7.2 Diesel—Wind Turbine Hybrid EPS to Supply the Industrial Consumers***

#### **15.7.2.1 Concept Diagram of the Application**

The concept diagram of this application is shown in Fig. 15.22.

#### **15.7.2.2 Description of the Operation Diagram**

The scheme shown in Fig. 15.23 considers the case of an industrial consumer powered from three different energy sources: wind, diesel, national EPS. Energy management strategy implemented is simple: the industrial consumer will be feed from the RES available, but not from two or more sources.

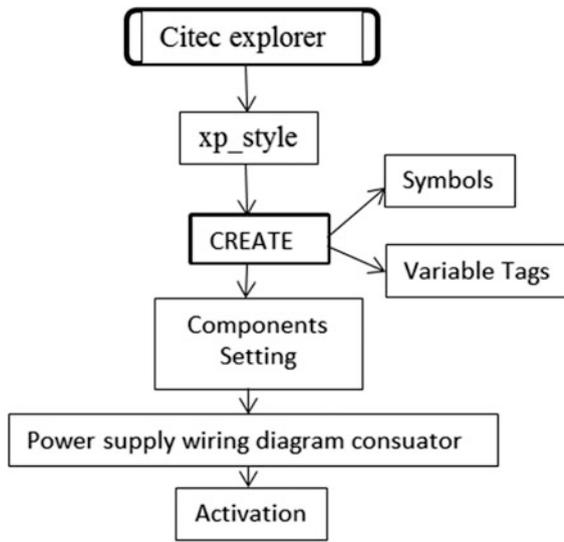


Fig. 15.22 Concept diagram of the application

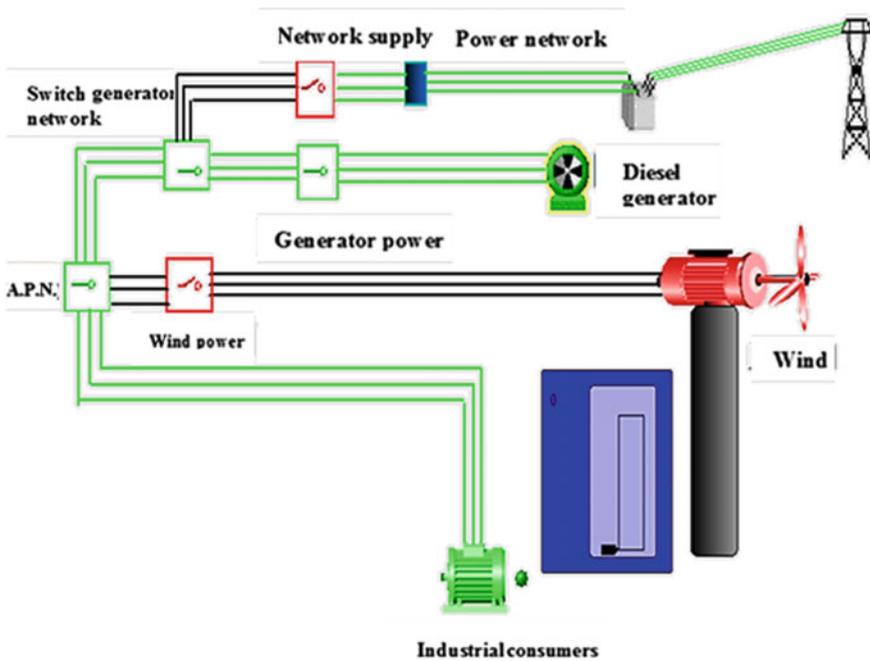


Fig. 15.23 EPS based on RESs

In this conception, the wind system is a priority, following on same level diesel generator and EPS. If the wind starts and can rotate the wind turbine, then the electric consumers will switch to energy produced by the wind turbine. If the wind stops, then the consumer will be automatically feed from the other two sources, whichever is convenient based on the specification: if the chosen second source will be interrupted, then it will automatically switch to the third variant. The energy management strategy will switch the consumer to energy line of the wind turbine if the wind will appear again.

In the scheme shown in Fig. 15.3 were also introduced three buttons as follows:

- “WIND ON” AND “WIND OFF” to start/stop voluntary the wind farm;
- “APN ON” and “APN OFF” to start/stop the industrial consumers;
- “GENERAL\_ON” “GENERAL\_OFF” to start/stop automatically the power flow between the national grid and diesel generator.

If wind turbine works, then the network between “SWITCH GEN/NETWORK” and “APN” switch is not active for reasons related to consumer protection.

The panel with cursor simulates wind speed which is established in a certain margin and which can turn on/off the wind turbine.

## 15.8 Conclusion

The focus on new IT strategies represents one of the basic premises of increasing the efficiency and safety of the national energy system.

Advantages and disadvantages of using a SCADA system were illustrated by applications shown in this chapter.

The first application proposed for River Hydro arrangement presents a complex SCADA architecture. For the existing architecture, it was proposed some improvements in order to increase its performance:

- Implementing a network ring-type redundant with fiber-optic which will facilitate communication between HED and HEC network, instead of the radio communication (which will remain operational as standby solution);
- Replacing of the existing equipment (DAS900 in Figs. 15.14, 15.15, and 15.16) with a new equipment (2 redundant servers), which will eliminate the existing DAS dysfunctions and in addition will implement new functions that are necessary in exploitation of the hydro facilities: (1) a bi-directional communication (for the purpose of monitoring and transmission of commands) with the automation systems (as HA1, HA2, SG, and Barrage) using the Open Platform Communications (OPC) industrial protocol; (2) a dedicated server for SCADA applications which has a very large number of standardized protocols for direct communication with devices of automation used in monitoring and driving of the industrial processes.

- Simplification of the SCADA architecture (Fig. 15.17) by (1) using the DROP software on the servers, (2) ensuring the direct connection between equipment without intermediate software, (3) ensuring a high speed communication with existing equipment based on the standard protocols, and implementing of high security levels for servers;
- Assuring of local drivers and OPC connectivity (Fig. 15.18) will permit (1) the functioning without interruption using the hot-plug redundant servers, (2) a future expansion and easy software development, without constraints, and (3) a simple interfacing of the equipment starting from the top-level to the bottom-level.

The second application proposed in this chapter has shown the stepwise implementation of a medium-voltage EPS based on RESs. The application is implemented using the HMI interfaces of the programming environment VIJEO CITECT®. This application provides an improved and friendly interface, with a high degree of integration of the schemes that facilitates easy operation of the system. Compared to the initial application, this new application enables:

- Monitoring and handling of the active and reactive power level indicators; the power factor is possible to be evaluated and improved in real-time;
- Monitoring is done both for consumers and producers using visualization in both value and graphic representations.
- The application will allow a quick view of the irregularities occurring in the system, so it will be possible to eliminate them (Fig. 15.21q, r, s).

Another application shows a diesel—wind turbine hybrid EPS used to supply the industrial consumers. This system has the advantage that the wind speed is permanently monitored and adjusted if is the case. The advantages of this supply system are the low costs and the flexibility in choosing of best variants to use the RESs in relation with the environment conditions.

Even if the initial costs related to SCADA implementation are relatively high, these will be recovered in short time due to the advantages offered by the SCADA:

- improved operation of the installation and of the process, whence a number of savings will appear as a result of the optimization operation;
- increased productivity;
- full operational control of the process being monitored;
- safety, robustness, minimum expenditure in exploitation;
- improved system safety due to a better information of the dispatchers and improved supervision;
- energy savings due to optimization of the manufacturing processes;
- improving the access to information, and their quality and visualization in real-time;
- extremely easy to extend the system;
- the possibility to be connected with different systems.

## 15.9 Trends in the Evolution of SCADA Systems

The trends in the evolution of SCADA systems refer to communications, RTU and MTU as follow:

- The development of new communication technology to optimize the equipment used as size and energy consumption, making it possible to integrate them even in the RTU;
- The upgrade of the radio equipment with numerical subsystems to perform the auto-calibration, which reduce the starting time of the transmitters up to seconds;
- The use of the geostationary satellites for SCADA systems using portable broadcasting stations which have the price comparable with that of mobile phones;
- The use of communications on fiber-optic, which offers the advantages of high speed transmission, increased safety and confidentiality; this technology is well adapted to the needs of communications in field of energy as well;
- The development in the RTU units based on embedded computers allowed more flexibility related to its functionality as controllers, meters, energy management units etc.

The later developments of the MTU units are focused along three levels: (1) improved operator interface (graphical user interfaces, windows, objects, graphics-oriented etc.), (2) increased autonomy of the intelligent self-trained systems, and (3) improved car-to-car communication based on LAN networks.

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