AUTOMATION OF SMALL HYDROPOWER PLANT “RASKA”

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Abstract: Small hydropower (SHP) is one of the most appropriate options to meet increasing energy demand especially in a country like Serbia, where a significant power potential in this sector is available. It is clean and renewable in contrast to fossil fuel based generation which pollute the environment and whose resources are depleting fast. However, high cost per unit generation is a constraint in case of SHP development. So, revitalization and optimization of usage of existing SHP, like it is the case with HPP “Raska”, is of great interest.

Control and operation system for SHP should be simple, reliable, cheap and with minimum interference of operating personal. Control system should be such that remote operation can be performed easily. The main functions of the controller for SHP automation is to execute starting and the shut down sequences under normal and emergency conditions. In addition to these operating sequences, certain control actions like speed control for synchronization and speed control when the machine is put on the grid are also to be performed for frequency control and load sharing. The excitation system should respond with respect to the system requirement that is either to control the voltage or to share the reactive power with the other units operating in parallel. Functions other than control, like continuous monitoring, data recording, instrumentation and protections should also be performed.

Key words: *green energy, small hydropower plant, control system, smart grid, hardware-in-loop*

АУТОМАТИЗАЦИЈА МАЛЕ ХИДРОЕЛЕКТРАНЕ „РАШКА“

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Кратак садржај: Мале хидроелектране (МХЕ) представљају једну од најповољнијих опција за повећање производних капацитета електричне енергије, а како би се изашло у сусрет нарастајућој потрошњи, посебно у земљама као што је Србија. Енергија произведна на такав начин је чиста и обновљива, што је веома значајно, имајући у виду да алтернативна производња на бази фослних горива чије се резерве брзо троше, битно утиче на загађење околине. Међутим, висока цена изградње МХЕ представља ограничавајући фактор у градњи нових постројења. Управо из тог разлога, улагање у ревитализацију и оптимизацију коришћења постојећих електрана је од великог интереса.

У раду је описан контролни део јединственог управљачко/регулационог система МХЕ „Рашка“. Генерално говорећи, управљачки систем МХЕ треба да буде једноставан, поуздан, јефтин и треба да обезбеди минимално учешће посаде електране. Управљачки систем, такође, треба да обезбеди једноставно управљање са удаљеног места. Главне функције контролног система МХЕ су покретање и заустављање агрегата у нормалним и хаваријским режимима. Додатно, потребно је да контролни систем обезбеди контролу времена синхронизације, контролу брзине покретања агрегата до његовог прикључења на мрежу, као и додатне функције као што су контрола учестаности или дељење терета. Систем побуде треба да омогући одговарајући одзив било да се ради у режиму контроле напона, било да се ради о дељењу реактивне снаге агрегата који раде у паралели. Поред контролних функција, управљачки систем треба да омогући континуални надзор карактеристичних величина, приказ и памћење података, контролу заштитних функција и сигурносних система.

Кључне речи: *зелена енергија, мале хидроелектране, управљачки систем, паметне мреже, хардвер-ин-луп*

1. INTRODUCTION

In this age, increasing demand of energy has forced us to look at the other options different from the most usual means of exploiting energy from fossil fuels as those sources of energy are exhaustible. In recent years, all over the world, ther is a trend of investemnts in renewable sources of energy. The beauty of these renewable energy systems is that they are non-exhaustible. Of all the non-conventional renewable energy sources, hydro represents the ‘highest density’ resource and stands in the first place in generation of electricity from such sources throughout the world. Hydropower is one of the most promising available energy sources in the world. It accounts for almost

16 percent of global electricity consumption. It is clean and renewable energy source as compared to fossil fuel based generation which pollute environment.

Before the existence of the automation, qualified personnel operated the equipment manually. This was called Manual System. By incorporatng automation in hydro power plant, it reduces the manual labour as well as increases the efficiency of the operaions performed like providing more flexibility of changing the mode of operation, for example, Power Control, Level Control. It also enables to control the plant from a remote area [1].

In this paper we are going to present realization of the modern control system applied in SHP “Raska” (Fig. 1). Automation of the SHP “Raska” required introduction of the modern SCADA, control system [2-4], turbine governer and synchonization unit. The main goal of the development of such equipment (readily available at world market) is to support a strong trend in Serbia to direct the investments in energy (specially in green energy) towards local firms. The basic idea is to use imported hardware only in the case when the cost of the development of domestic equipment is much higher. Complete software and specially dedicated hardware, which has the larger share of costs, is develloped by domestic companies. From the maintenance point of view, it is important to have local maintenance staff available.

The control of local processes at the level of primary equipment is realized in the framework of distributed devices (or intelligent electronic devices – IED). These devices, at hardware and software level are fully product of Serbian experts. So, not only that the investment funds remain in Serbia, but professionals are educated and became experienced in working with modern equipment.

The control system is equipped with modern devices for on-line monitoring and diagnostics of synchronous machines and network conditions. Consequently, the synthesis of the respective control actions can be performed in an attemt to integrate these SHP in incoming smart grid network. Smart power generation is a concept of matching electricity production with demand using multiple generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peaking power generation. Matching supply and demand, called load balancing, is essential for a stable and reliable supply of electricity. The load balancing task has become much more challenging as increasingly intermittent and variable generators such as wind turbines and solar cells are added to the grid, forcing other producers to adapt their output much more frequently than has been required in the past.

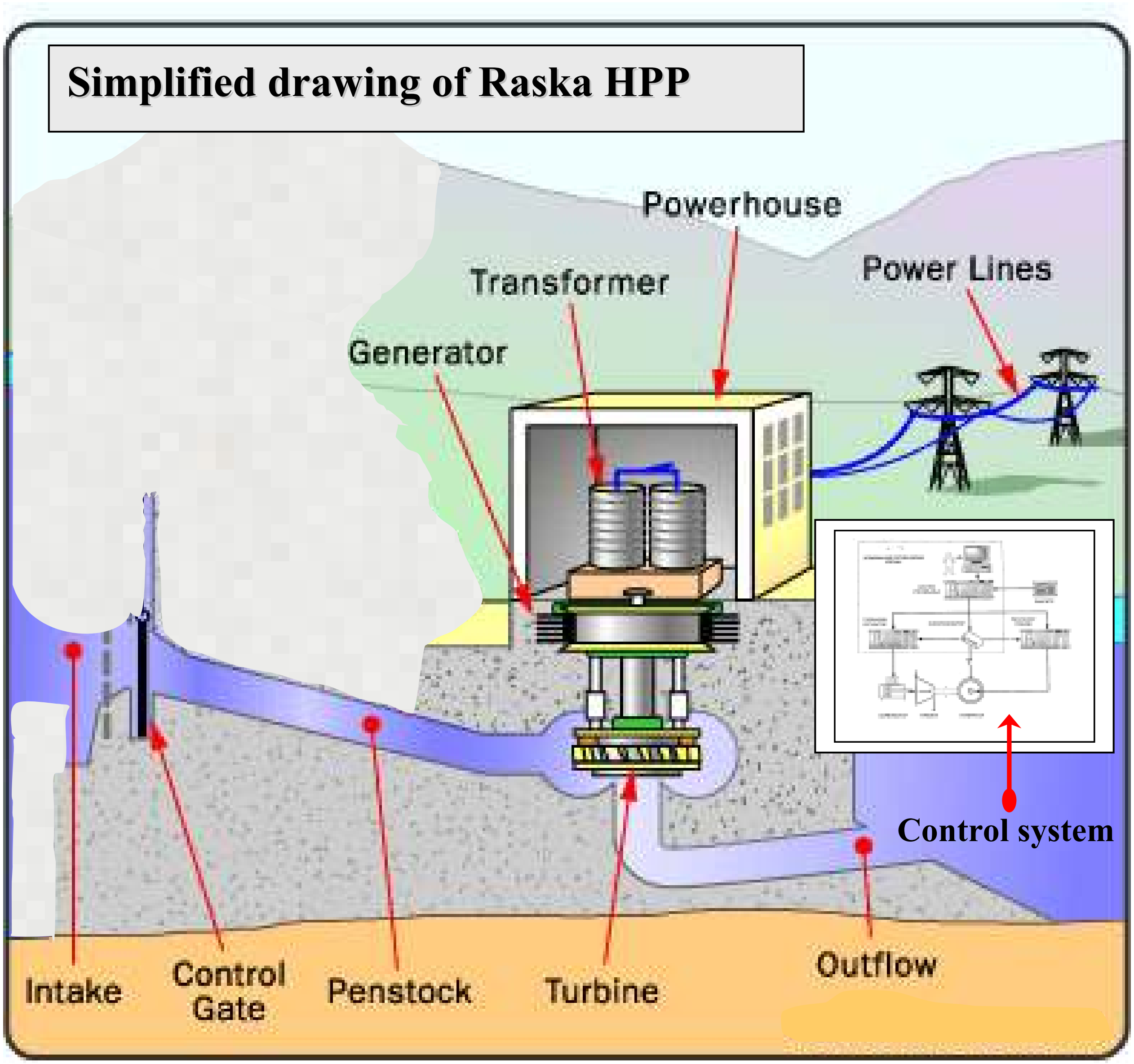

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Figure 1. Simplified drawing of HPP "Raska"

2. OVERVIEW OF THE CONTROL SYSTEM

Control, automation and monitoring system in a hydroelectric power plant is associated with start and stop sequence for the unit and optimum running control of power (real and reactive), voltage and frequency. Data acquisition and retrieval is used to cover such operations as relaying plant operating status, instantaneous system efficiency, or monthly plant factor, to the operators and managers. The control equipment for a hydro power plant include control circuits/logic, control devices, indication, instrumentation, protection and annunciation at the main control board and at the unit control board for generation, conversion and transmission operation including grid interconnected operation of small hydro stations. These features are necessary to provide operators with the facilities required for the control and supervision of the station's major and auxiliary equipment. The control system of a power station plays an important role in the station's rendering reliable service.

The infrastructure of hydro power plants demands greate flexibility when setting up the process architectures. Because of the sheer quantity and variety of equipment involved connection to the central processing unit has to be simple. Distributed architectures are the perfect choice for large installations, particularly when the plant comprises several turbine-generator units (in our case two units). Each unit

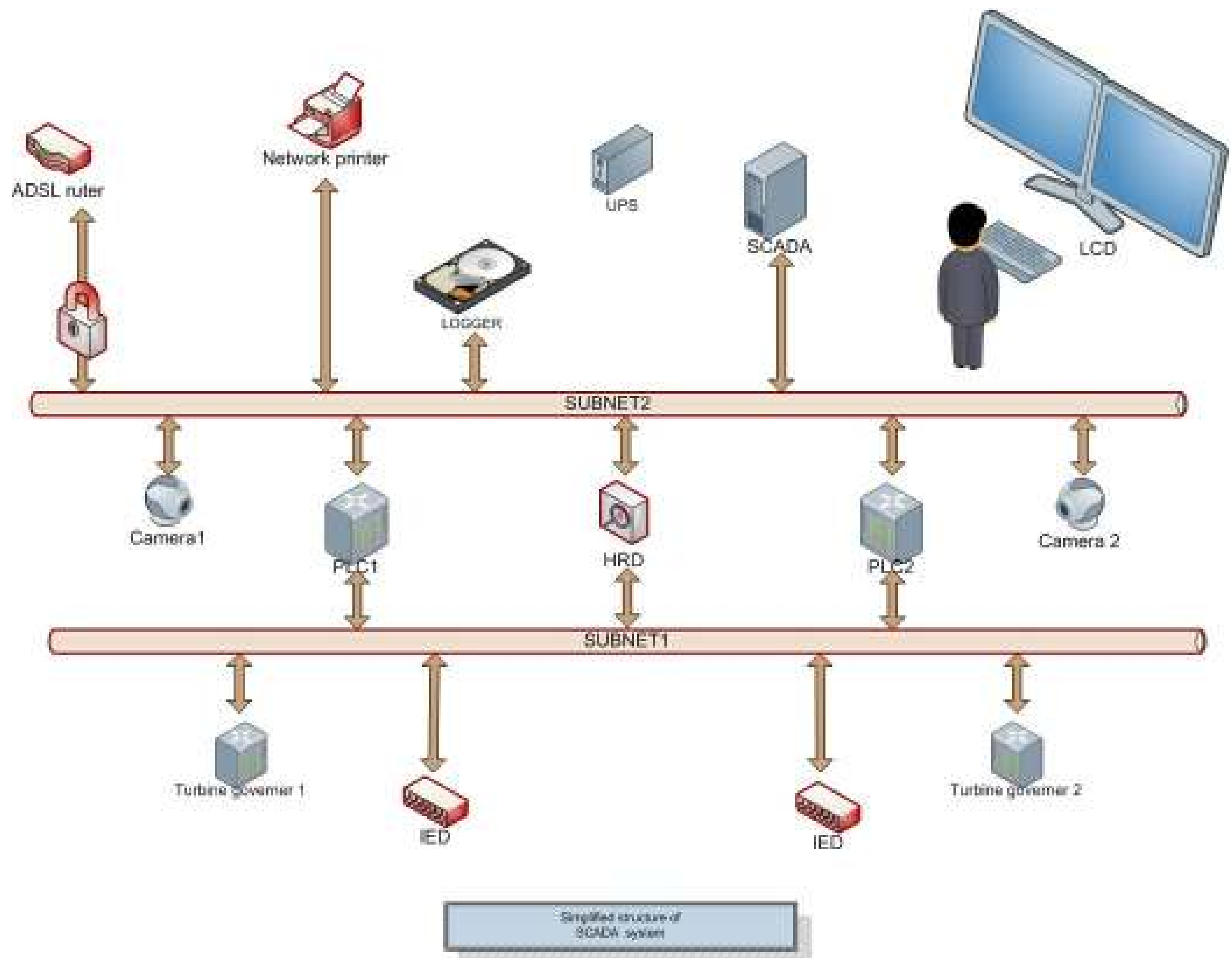

Figure 2. Simplified structure of SCADA system

is independent and controlled by a PLC and each sub-unit is connected to the SCADA system (Fig. 2) via an industrial network. This system allows the creation of reliable, flexible solutions which can be adapted to any scenario depending on the number of units or devices to be connected. Communication between the PLCs and the SCADA system is based on standard EtherNet/IP protocol for data exchange and synchronisation. Our architectures are built around reliable industrial products which have been adapted for use in harsh environments. The modular nature of our solutions and architectures facilitates expansion and modernisation of both the hardware and software alike.

As it was said, plant control deals with the operation of plant. It includes sequential operation like startup, excitation control, synchronization, loading unit under specified conditions, normal shutdown, emergency shutdown etc. The mode of control may be manual or automatic and may be controlled locally or from remote location. Plant control usually include monitoring and display of plant conditions. Different plant controls are given in Fig 3.

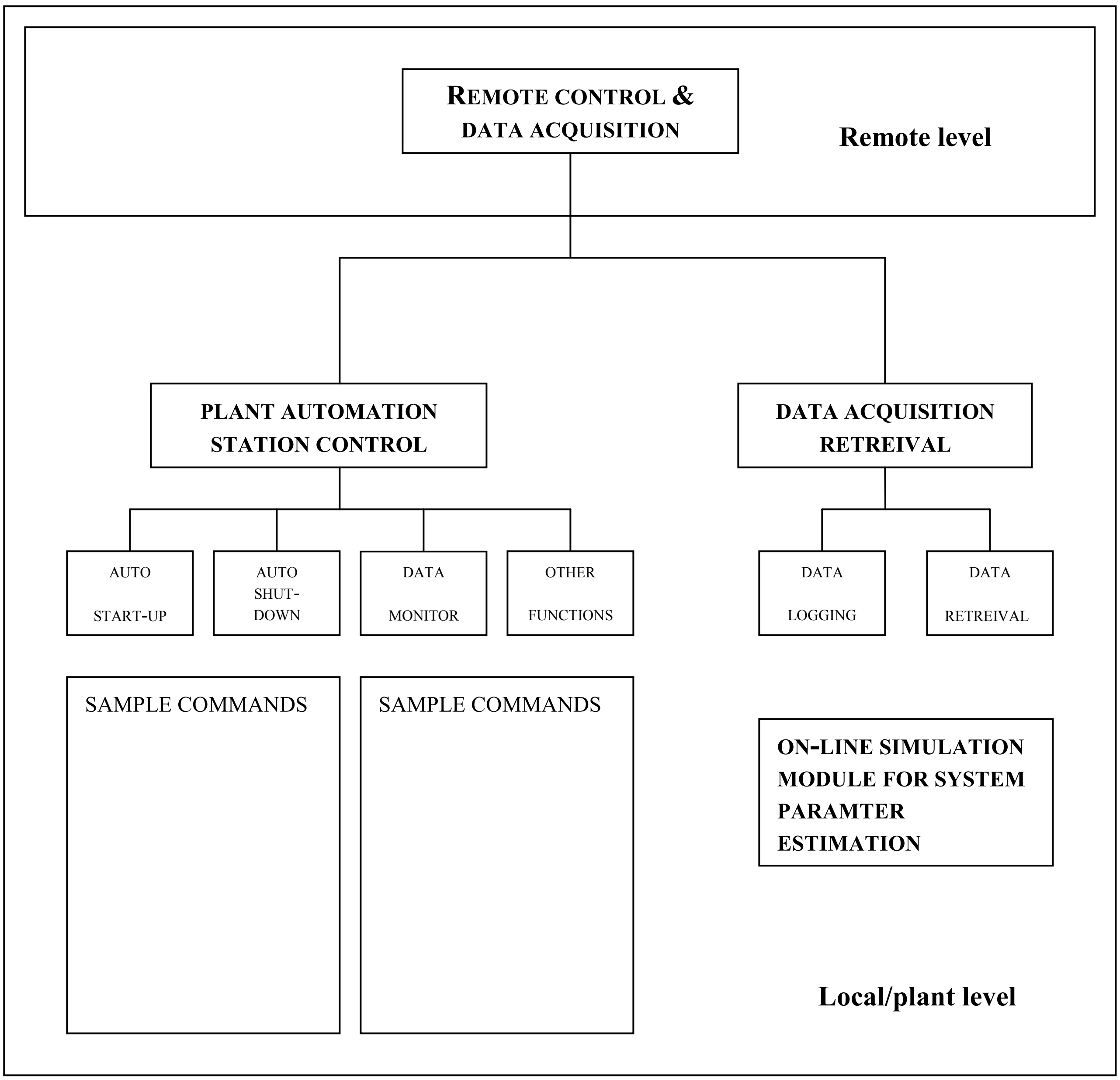

Figure 3. Simplified overview of plant automatic control

We can see that, comparing to the standard solutions, a part of the system is also dedicated module for on-line system parameter estimation and simulation of the part of the system.

Visualization of plant status and condition, logging of events and metering, and annunciation of alarm conditions are generally managed by the SCADA HMI (human-machine inteface) station (Fig. 2). It serves as the local operator's portal into the process. SCADA is used to log regulatory, alarm, and performance information. This data is stored in an SQL data-base. Data may then be pulled from the archive for reporting to meet regulatory obligations, to monitor performance, and to provide insight into plant operations.

The 24 hours, 7 days a week nature of the power generation business requires a constant watchful eye on hydro generating facilities. But profitability requirements often don't allow for full-time, onsite staff. The solution is telemetry, which allows remote monitoring and control. Smart phones have become a mobile telemetry platform, allowing operators to remain informed of plant status and alarm conditions, and even providing access for remote control. This is accomplished using a mixture of technologies including SMS text messaging of alarm conditions generated by the station SCADA, automated status and production reporting via e-mail, and even remote access and control through Web-enabled smart phones.

In the particular case, on-line 24 hours, 7 days a week video monitoring of the system is integral part of the system. It create oportunity to the stuff to stay inside control room and still have video contact with the individual control units, or plant parts. This is enabled by instalation of the security cameras (Fig. 2) that can be controlled from the HMI station (they can be oriented toward specific location and then image can be zoomed).

The unit control system should be designed to perform following functions:

- Data gathering and monitoring
- Start stop control sequence
- Annunciation & alarm conditions
- Temperature monitoring
- Metering & instrumentation
- Event recording
- Synchronizing and connecting the unit to grid
- Control of real & reactive power

The unit control system must be able to provide startup and shutdown sequencing under both normal and abnormal conditions. Under normal conditions, the unit is started and stopped in manner that produces minimal disturbance to the system. For instance of normal stop sequence entails a controlled unloading of machine and when completely unloaded, the generator breakers or contactor is tripped. On the other hand protective relay operation will initiate immediate tripping of the unit and complete shutdown as quickly as possible. For certain mechanical troubles the unit is unloaded as quickly as possible before tripping, in order that the potential damage from over speed is avoided. The unit control system, in order to control and monitor various control sequences, must interface with number of plant systems, including the following:

- Auxiliary system – pumps & valves
- Governor load control rollers – setters, solenoids & brake control
- Excitation – setters, contactors and circuit breakers

PLCs are used to control individual generator units. They are also connected with IED parts via dedicated industrial Ethernet subnet using Modbus/TCP protocol. Network of IED is consisted of several devices that are distributed all over the plant. The examples are turbine control unit based on SIEMENS PLC, generator excitation regulator, synchro unit (based on LPC 2138 controller), RTD measurement unit (based on LPC 1766 controller), analog signal (4-20mA) masurement unit (based on LPC 1766 controller), protection unit, local HMI based on Weintek i8100 series etc. Local HMI is used for the local supervision of the system condition. In order to provide reliable communication PLC communicate with IEDs via multiple ports and uses also BPL (broadband over power line) channels. The control of auxilary systems that are parts of some of the subsystems like the turbine control subsystem, is provided via local IED unit. Control of the time-critical equipment is provided directly from the PLCs.

3. SYSTEM FOR ON-LINE MONITORING AND DIAGNOSTICS OF SYNCHRONOUS MACHINES AND NETWORK CONDITIONS

The first power stations were reasonably simple and small, with little or no automation. As the stations grew in size and complexity, more information on the plant status was required for the operator to make the necessary adjustments. Analog governors were introduced to provide speed regulation, with hard-wired protection relays, annunciation circuits and monitors to deal with fault conditions. Generally, there was no communication between the units [1]. Next, digital computers, offering increased functionality and versatility, began to replace many of the analog functions. These enabled more complex control algorithms to be implemented, for instance, multiple control modes covering start-up, shut-down, commissioning, power control and head level regulation. Two digital programming techniques evolved based on Programmable Logic Controllers, with software specific to that application, and on Tailored Software Systems, in which algorithms were pre-coded with a facility for parameter customization. Digital technology also facilitated the use of SCADA (Supervisory Control and Data Acquisition) to provide overall site control and monitoring. Initial SCADAs were hierarchical in nature, with point-to-point communication links with each of the unit controllers. As communications technology advanced, these point-to-point communication links began to be superseded by data bus structures which offered significantly less wiring infrastructure. Data bus structures also facilitated distributed processing using modern low-cost micro-controllers. Single-chip micro-controllers are now commercially available equipped with on-board analog-to-digital converters (ADCs), digital-to-analog converters (DACs), and serial and parallel communication ports.

With distributed processing structures (Figure 2), the site-based functions such as SCADA and water level measurement can be considered as peripheral functions attached to the site data bus. This structure also facilitates more efficient use of data set-up tools, and ably supports computational solutions based on tailored software systems. Data set-up itself becomes another peripheral function on the site data bus. These structures are further complimented by more powerful desktop PCs that are able to readily communicate on the data buses as well as hosting multiple peripheral functions such as Data Set-up and SCADA. Multiple communication buses are also widespread.

Today's development engineers use a very different toolbox compared to their predecessors. Tools which may have been expensive, unaffordable or inflexible, can now be realized for low-budget solutions and can be used to extract optimal control parameters for the equipment installed on the site. Although SCADA systems were originally developed for operational monitoring and control, they offer a powerful tool for verifying distributed processing operation. SCADA systems can be implemented as software packages on a standard office PC with data bus communication via a standard PC serial port. Through exploiting the continual bus traffic monitoring capability of a bus peripheral with SCADA's inherent data recording facilities, SCADA systems can be extended to provide comprehensive event and data recording across a distributed processing structure, and thus aid system development and verification. However, data provided by SCADA ususally does not give enough information for design of the control loops for the processes which have time constans below 1 second. In that case it is necessary to get dedicated hardware which consist of powerfull controller units and that are equipped with I/O boards that enable so-called hardware-in-the-loop simulation for system verification. In the system of interest National Instruments COMPACT-RIO device is used for monitoring and estimation of the turbine, generator and system parameters. Those parameters are used for calculation of optimal control parameters of the particular control loops that enable optimal operation of the whole plant.

4. CONCLUSION

The paper presents particular solution of the control system of the SHP “Raska”. We proposed solution that follows modern trends in the area. Adopted architecture is modular and distributed which reduces cabling. Using multiple communication cahnnels increases availability of the system.

Addition of the on-line monitoring module enables achievemnt of the additional freatures to the system. It actually changes the nature of the system from passive monitoring aned standard control and change it into active system which continuosly “improves” parts of the system (local contol loops) in order to obtain the optimal performance of the whole plant. Consequently, the synthesis of the respective control actions can be performed in an attemt to integrate these SHP in incoming smart grid network. Smart power generation is a concept of matching electricity production with demand using multiple generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peaking power generation.

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