# POWER SYSTEMS EMULATOR BASED ON DCS

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**Abstract:** *Research, optimization and practical implementation of optimization processes in power subsystems of power plants, heating plants and industrial plants present a relatively complex task that is nowadays unimaginable without powerful specialized tools of computer support. The paper presents a power systems emulator concept (a tool for the design and application processes involving power systems) that is based on decentralized control systems (DCS) standardly used today. Basic principles of modular design of the emulator along with an example of its implementation based on the Siemens SIMATIC-S7 DCS system are presented.*

**Keywords**: ENERGY PROCESSES, MODELLING, DECENTRALIZED CONTROL SYSTEMS, EMULATOR

## *1. Introduction*

Hydropower has now become the best source of electricity on earth and plays an important role in the safe, stable and efficient operation of the electric power system. It is produced due to the energy provided by moving or falling water. The most important advantage of hydropower is that it is green energy, which mean that no air or water pollutants are produced, also no greenhouse gases like carbon dioxide are produced which makes this source of energy environment-friendly. It prevents us from the danger of global warming. Because of the many advantages, most of the countries now have hydropower as the source of major electricity producer. The size of hydro power plants (HPPs) and the structure complexity of the hydraulic-mechanical-electrical system have been increasing. The proportion of electricity generated by intermittent renewable energy sources have also been growing. Therefore, the research on control strategy and transient process of HPPs is of great importance.

At present, the control of power generation and distribution in power generation plants (power plants, heating plants and power systems in large industrial plants) is largely based on concrete design solutions and on improvements to existing algorithms based on ongoing practical experience. Large multinational companies have their own research teams, techniques and "know-how" that is, however, mostly inaccessible to smaller companies due to the financial costs involved. The aim of this paper is the conceptual design of a "universal power simulator" that would correspond as much as possible to a concrete real power system. It is a tool that would allow, as closely as possible in accordance with the real system, model-based investigation and design of specific subsystems of power plants, heating plants and other production processes. The gained knowledge could be further used directly in the practical implementation of a particular control system, especially in the control of such systems [1-4], in their visualization [5-6] and also in the training of operating staff (operators of turbines, boilers, small hydropower plants, etc.).

The emulator based on the concept presented in the paper has been built in the laboratories of fy Energo Control s.r.o. Kosice in cooperation with the Department of Electrical Engineering and Mechatronics of Faculty of Electrical Engineering and Informatics Technical University of Kosice, Slovakia.

## *2. Power Systems Emulator Concept*

The emulator concept is based on the requirements for its application in the technological practice of companies and plants that deal with the deployment of control systems in power and heating processes [7-8]. The general situation that needs to be emulated is illustrated in Fig. 1.

The power system has two main parts: the technological and the control part. Because it is virtually impossible to emulate the DCS system with another (simpler, cheaper, etc.) computer system, it is optimal and most convenient to base the technical means of the proposed emulator on a standardized DCS system.

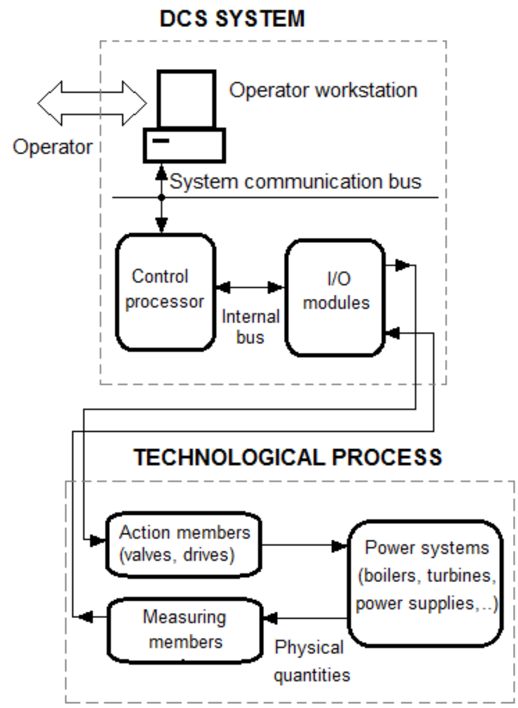


***Fig. 1*** *Illustrative scheme of the controlled energy process*

One part of the emulator will simulate the DSC subsystem itself and the second part the power process with its subsystems. This solution further enables emulator-designed control and visualization blocks to be directly applied and deployed to control the particular power facilities being investigated. This concept also enables training of operators practically on a real HMI (Human Machine Interface), which significantly improves the quality of their acquired knowledge and experience. Another advantage of this solution is the possibility of testing the concrete connection of the particular measuring and action members of the proposed system directly in the emulator, prior to their project design, which reduces the number of required modifications to the project during implementation and also greatly accelerates the execution time on site.

Due to the requirement for versatility of the proposed emulator, its software needs to be built hierarchically and strictly modularly. This involves three basic types of modules:

1. *Control modules*. The most widely used types of such modules are today a standard part of every DCS system. These are classic PID controllers, binary controllers of drives and valves of various types, sequential controllers, etc. In case other, less standard controllers are required (fuzzy controllers, neural

networks, reference model controllers, adaptive controllers, etc.), a new library module needs to be developed in the DCS system according to the standards of the system used.

2. *Interface modules*. This type of module is currently also a standard part of every DCS system and is designed to interconnect the system with the relevant technology. Since these modules will mainly serve for internal interfacing with the technological modules in the proposed emulator, they need to be modified, especially in terms of simple redirecting of their input and output signals.
3. *Technological modules*. These modules are the core of the emulator and need to be developed, verified and implemented for every single subsystem of the energy system in the most general form. A simplified example of a power system is a small hydropower plant, the block diagram of which is in Fig. 2.

In this case, for example, the turbine module could be built on the following assumptions [9-13]:

– The turbine mechanical power output *P*m on the shaft is directly proportional to the flowrate *Q* through the turbine body and the height *H* of the water column on the turbine.

– The turbine flowrate change d*Q*/d*t* is proportional to the difference between the actual height *H* and the size of $H_0$ when the turbine is unloaded.

– The height of the water column *H* on the turbine is directly proportional to the opening speed of the servo-valve *G* at the turbine inlet and it is inversely proportional to the actual flowrate *q*(t). This dependency is non-linear, it is often considered as a quadratic function.

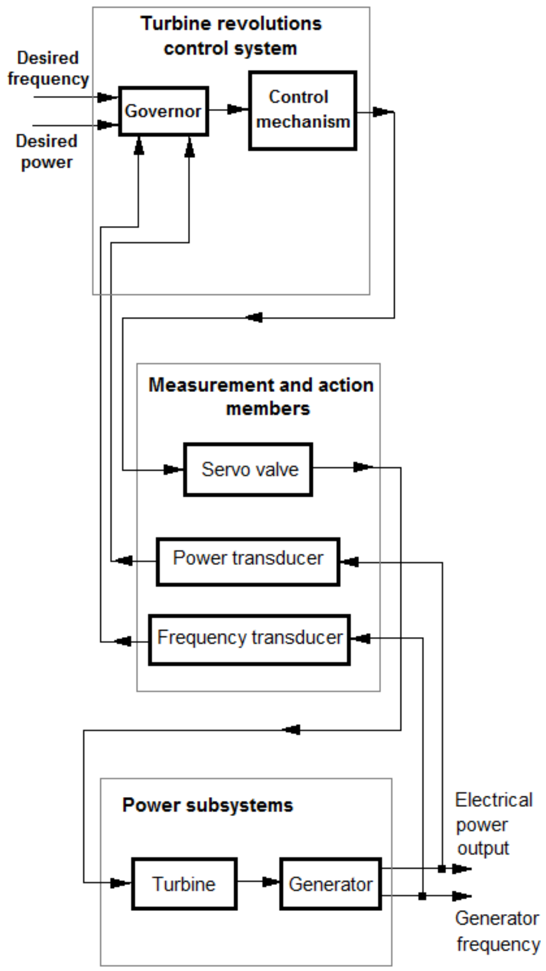


***Fig. 2*** *Block diagram of small hydropower plant*

The internal structure of the turbine module built under these assumptions is shown in Fig 3. It is clear that each module must be a program block that has defined inputs, outputs (red fields), parameters (yellow fields) and internal structure (blue fields). The internal structure of a block can be defined explicitly analytically (see Fig. 3), or implicitly by means of dependencies between block inputs and outputs (by fuzzy rules, neural network, etc., which is suitable for nonlinear systems with indefinitely defined parameters for a particular technology).

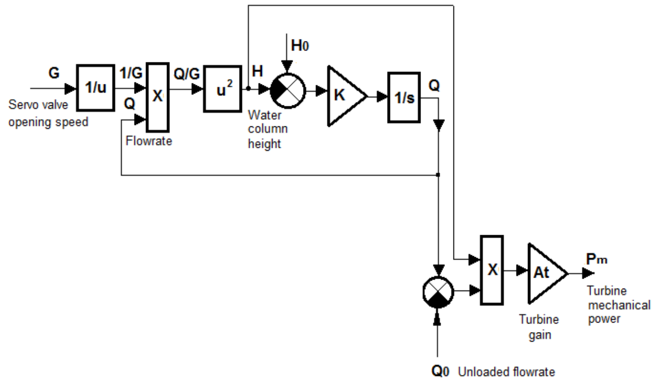


***Fig. 3*** *Internal structure of turbine module for emulator*

## 3. *Implementation of Power Systems Emulator Based on Siemens DCS System*

Based on the concept described in the previous chapter, emulator HW was designed and implemented on basis of the Siemens SIMATIC-S7 system, as shown in Fig. 4.

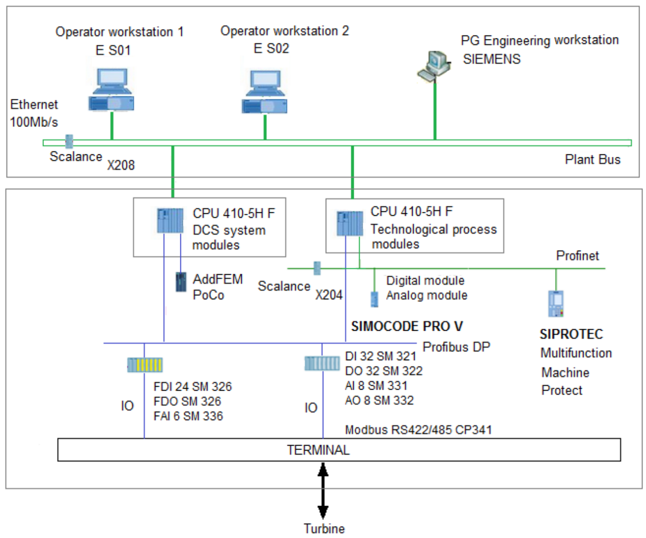


***Fig. 4*** *Block diagram of emulator based on Siemens DCS*

The whole emulator is built on two processors, one of which emulates the control itself and the other the power generation technology. The emulator includes two operator workstations (they can also serve as engineering workstations) for visualization and one portable programming workstation. The processors are interconnected via Profibus DP. During emulation and operator training, all signals between the control and the technological part of the technology being emulated (i.e. between Processor 1 and Processor 2) will be transmitted via this bus. When connected to the real equipment, the signals from the modules will be switched to the real IO cards of the system.

The emulator software is built on program modules corresponding to each subsystem of the power generation technology.

The concrete implementation of the *control modules* as well as their visualization is given by the DCS system used in the implementation of the emulator. An example of a visualization for the SIMATIC-S7 DCS system is shown in Fig. 5.

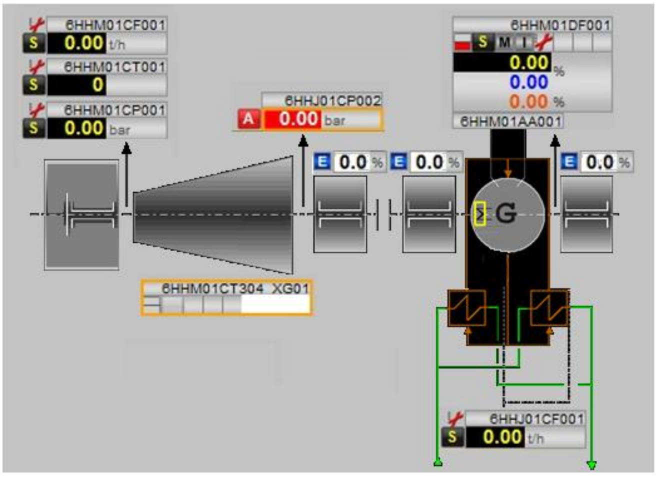


***Fig. 5*** *Visualization of standard DCS modules*

The technological modules are implemented according to the specific technological subsystem. Each such module consists of the following parts:

1. *Module core*. This is the program block in which the functional dependency between the relevant inputs and outputs of the technological subsystem is programmed. This dependency can be modelled explicitly analytically (see Fig. 3), or it can be modelled implicitly (e.g. using fuzzy rules describing relations between inputs and outputs).

2. *Module parameters block*. Considering the required versatility of the emulator, it is obvious that the difference between two power blocks of the same type will be given by the set of their internal parameters, which is why each technological module must have a subsystem for recording its parameters and a method of their setting. This may be a problem especially for non-linear systems because their nonlinearities may not be explicitly mathematically described. For a particular technological element (e.g. a turbine) they can be obtained by measuring, and displayed using a table or a suitable FIS (Fuzzy Inference System) structure.

3. *I/O interface of the module*. This interface links the technological module to other modules or to the DCS system environment. In addition to IO signal processing, it must also include the possibility of redirecting signals from its IO table to the defined HW of the IO card.

4. *Visualization interface of the module.* Unlike control modules that receive signals (commands, mode switching, etc.) from the operator (or the master modules) and also visualize their states, the technological modules only require visualization (very rarely setting a switched state, e.g. "engaged" for a turbine). On the other hand, in a power subsystem there are normally significantly more signals for visualization than in a standard control block. That is the reason this interface mainly includes visualization screens for a given technological element as is shown in Fig.5.

## *4. Conclusion*

The paper presents the concept of a power system emulator designed for research, simulation and verification of specific power systems. The emulator can also serve as a training simulator for training operators of these systems, as their training (especially in the initial stages) on a real system is demanding and often carries the risk of undesirable losses or damage to the technological equipment.

The emulator based on the concept presented in the paper has been built in the laboratories of EnergoControl s.r.o. Košice in cooperation with the Department of Electrical Engineering and Mechatronics of FEI TUKE.

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