Implementation of a Test System based on OPC Server for Development of Electronic Speed Governor in Gezende HEPP

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Abstract

Speed governors (SG) are auxiliary devices to measure and regulate the turbine speed where the turbine is coupled to a synchronous generator. A rehabilitation project for Gezende HEPP has been signed at the end of 2010 covering renewing of SG and excitation system of the plant. SG could be divided into two subparts; hydraulic speed governor and electronic speed governor (ESG). In order to develop ESG in factory within the conditions close to the field, a test system based on Matlab/Simulink and intelligent I/Os will be designed and implemented. Before production of ESG cubicles and execution of tests with real signals, it is possible to develop and test ESG in a setup using OPC Server. In this paper, the test system designed and implemented based on OPC Server for the development of ESG will be explained.

Index Terms—Hydropower Generation, Electronic Speed Governor, Test System, OPC Server

1. Introduction

Gezende HEPP is a 20 year-old hydropower plant which is situated in the southern part of Turkey on Göksu Stream with 3x52 MVA of generation capacity. Turkish Electric Power Generation Incorporated Company (EUAS) and Scientific and Technological Research Council of Turkey (TUBITAK) have signed a rehabilitation project to renew the SG and excitation system of the plant in order to successfully satisfy the ancillary services requirements of Turkish TSO. The basic function of a SG is to control speed and/or load [1]. SG brings the turbine speed to the nominal speed before synchronization to the network and after synchronization is completed, SG is used to control the active power output of the unit in one of the operation modes among speed control, opening control and active power control.

There are many studies concerning speed governors and test systems in general. In [2], relevant features and conditions are defined for a test system to be used during the design and test process of ESG. Signals of simulation model of a turbocharged diesel engine in Matlab/Simulink are sent or received via Matlab/xPC target toolbox through I/O interface circuit test system in [3]. Test system with different communication connections such as RS-485 and CanBus for a diesel engine is told in [4].

By the usage of the test system with OPC Server, critical points listed below are checked:

- Logic diagrams used for ESG
- Wrong alarm, trip and threshold values
- Logic diagrams of ESG against fault conditions formed by the test system
- Buttons, trends and lists in HMI screens

Following Section I, hardware, software and communication components of the test system will be explained in Section II. Design and models of the test system will be told in Section III. The concluding remarks are given in Section IV.

2. Features of Test System

SG is composed of hydraulic and electronic parts. Hydraulic Speed Governor (HSG) includes high pressurized oil system, various valves and servo cylinders. This equipment are used to provide sufficient oil pressure, to manipulate pressurized oil to the servo cylinder or to the oil tank and to make wicket gates to move in desired range. ESG sends the desired operation point to the driver of the servo cylinder. Also, ESG is a signal interface between the SCADA system of the plant and HSG. Relevant measures and status signals reach the SCADA system via ESG and set points given by the operator of the plants is realized through ESG.

Using test system with OPC Server, all signals coming from control room and the SCADA system of the plant to the current ESG will be created in the memory area of programmable logical controllers (PLC). Similarly, all the signals from ESG to SCADA system of the power plant and control room will be formed and all related parts and equipment of the plans will be modeled. A critical point in this rehabilitation projects is that existing SCADA system is not being rehabilitated and this requires that the new ESG signals should be compatible with the remaining ESG.

2.1. Hardware

Hardware of the test system consists of simulation computer, network switch, PLC and Human-Machine Interface (HMI) screen.

Simulation computer has two important features in the test system: Simulation software and OPC Server are installed in this computer and communication of OPC Server with PLC is achieved via this computer's network interface.

ESG is developed in PLC platform. The logic diagrams for SG are run on PLC. Although in real ESG signal transfer is done via I/O modules, in test system based on OPC Server, signal transfer is done on PLC's memory area.

In Table 1, the test system signal numbers are given. Among the signals classified below, there exist status signals which are received by ESG coming from both the SCADA system of the power plant and HSG. Normally, speed information is obtained from inductive sensors and pulse counter modules in real system. Since it is not possible to generate pulses in this test system, speed signal is generated in the model and written on the memory area via OPC Server. Moreover, level, pressure and temperature measurements signals are formed in the model and written on the PLC memory area.

A touch panel is used as HMI in ESG. This HMI is also connected to the network and all of the screens needed by the power plant operator to control SG are found on this HMI.

Since the communication between simulation computer and intelligent I/O devices are Ethernet based, a network switch is utilized in the hardware.

Table 1. Number of signals in test system

Type	From	To	Number
Memory-Status Info	Test System	ESG	28
Memory-Status Info	ESG	Test System	16
Memory-Alarm	Test System	ESG	20
Memory-Alarm	ESG	Test System	9
Memory-Measurement	Test System	ESG	9
Memory-Measurement	ESG	Test System	6

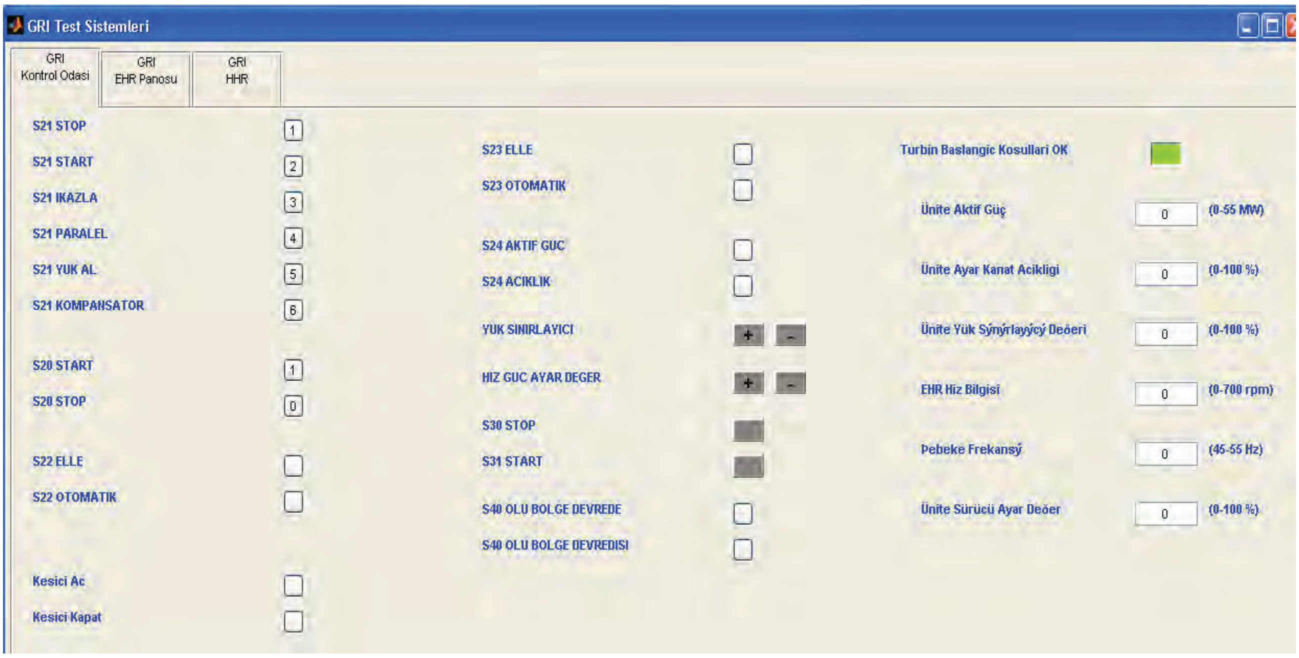


Fig. 1. GUI of the test system prepared in Matlab

2.2. Software

Matlab/Simulink is installed in the simulation computer. Modeling of the power plant with various equipment and Turkish grid and communication with OPC Server are achieved by using Matlab/Simulink. Matlab's powerful calculation and communication skills and Simulink's visual modeling blocks are key features of this software for being chosen for the test system. In addition to transferred signals in the test system, there are many internal signals. In order to visualize these signals, a graphical user interface (GUI) has been designed in Matlab. It is possible to change status and measurement values of the signals manually by using prepared GUI as seen in Fig. 1.

OPC Server is the key software of the test system since it operates as an interface between Matlab/Simulink by which the power plant is modeled and the PLC on which the logic diagrams are run and HMI screens get data from. OPC Servers could communicate with many PLCs of different trades and models [5]. It operates as an application programming interface and protocol converter. OPC Server is based on Server/Client architecture and uses OPC standard which defines methods and structures for transferring real-time data between automation devices and clients with Microsoft operating systems [6]. Signal transfer between Matlab/Simulink and OPC Server is achieved through OPC Server Toolbox [7].

2.3. Communication

Communication structure and main components of the test system is shown in Fig. **2**. Simulation computer, PLC and HMI are connected through a Local Area Network (LAN) based on Ethernet. OPC Server supports communication with Siemens controllers via network protocols such as Siemens TCP/IP, PPM, and PPI & AS511. Data exchange between HMI and PLCs are done through Siemens TCP/IP protocol.

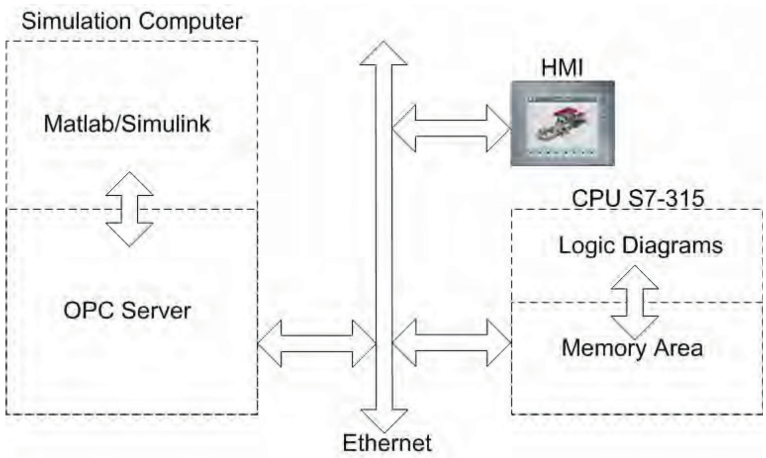


Fig. 2. Communication structure and interaction between test system components

3. Design and Operation Philosophy

The motivation for the test system is to facilitate the target system with the field conditions. Therefore, field signals with similar behavior as in the plant are supplied by the test system.

In Fig. 2, interaction between the test system and target system, ESG could be seen. Both the OPC Server and PLC use the same memory addresses for the same signals, therefore, the only way of interaction of ESG and the test system is writing signal values on the related memory area.

All equipment in the plant which affects operation of ESG is modeled in the simulation computer on Matlab/Simulink software.

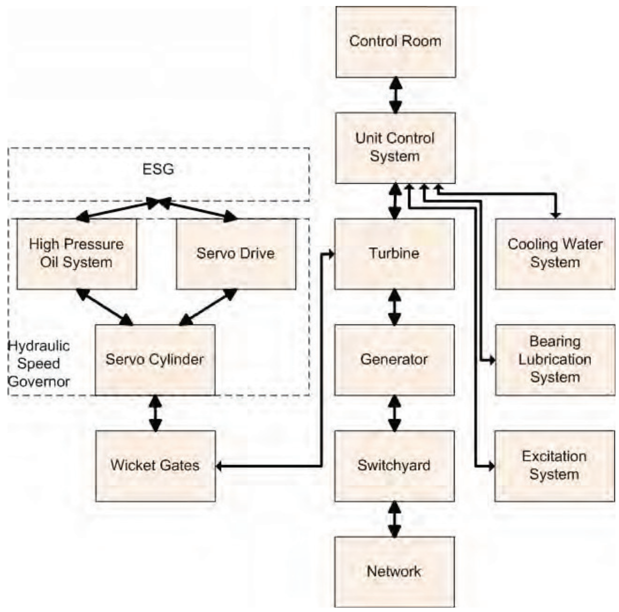


Fig. 3. General model blocks in Matlab/Simulink

The behavior of the SCADA system of the plant, buttons and switches of control room are modeled according to logic diagrams of the plant. Considering logic diagrams of the SCADA system of the power plant, start and stop process including quick and emergency stop processes take place in simulation model, as well.

In addition, parts of the new HSG are modeled including high pressure oil system pumps, electric motors, directional valves and accumulators. ESG controls the electric motors in order to keep oil pressure in allowable limits, model of high pressure equipment is to be established in simulator model but control of these motors is achieved by the logic diagrams running in the ESG PLC. Signals of level and pressure transmitters, status of filters, level switches could be changed in GUI of simulation software. Through this GUI, it is possible to test failure signals and threshold values for analog values. In Fig. 3, simulation model structure of Matlab/Simulink is given. Network block models the transmission lines and load to which the generator is connected. The model is able to reflect island mode conditions as well as interconnected operation. The tuning of the ESG is done via unifying the models of the ESG, HSG, turbine and the network model. The following details the models of ESG and network blocks of the Figure 3.

Fig 4 a) and b) depict the MATLAB/Simulink model formed to develop and test the PID controller of the ESG in the speed regulation mode. The PID Controller box is implemented in the PLC while the remaining parts of the model are implemented in the simulation computer on Matlab/Simulink software to reflect the HSG equipment and speed behavior.

Fig. 5 depicts the simulation results of the scenario in which the generator is running in the island-mode and a load step of -0.3 p.u. is applied. It could be seen from Fig. 5 a) that the ESG successfully regulates the unit speed consistent with the droop curve.

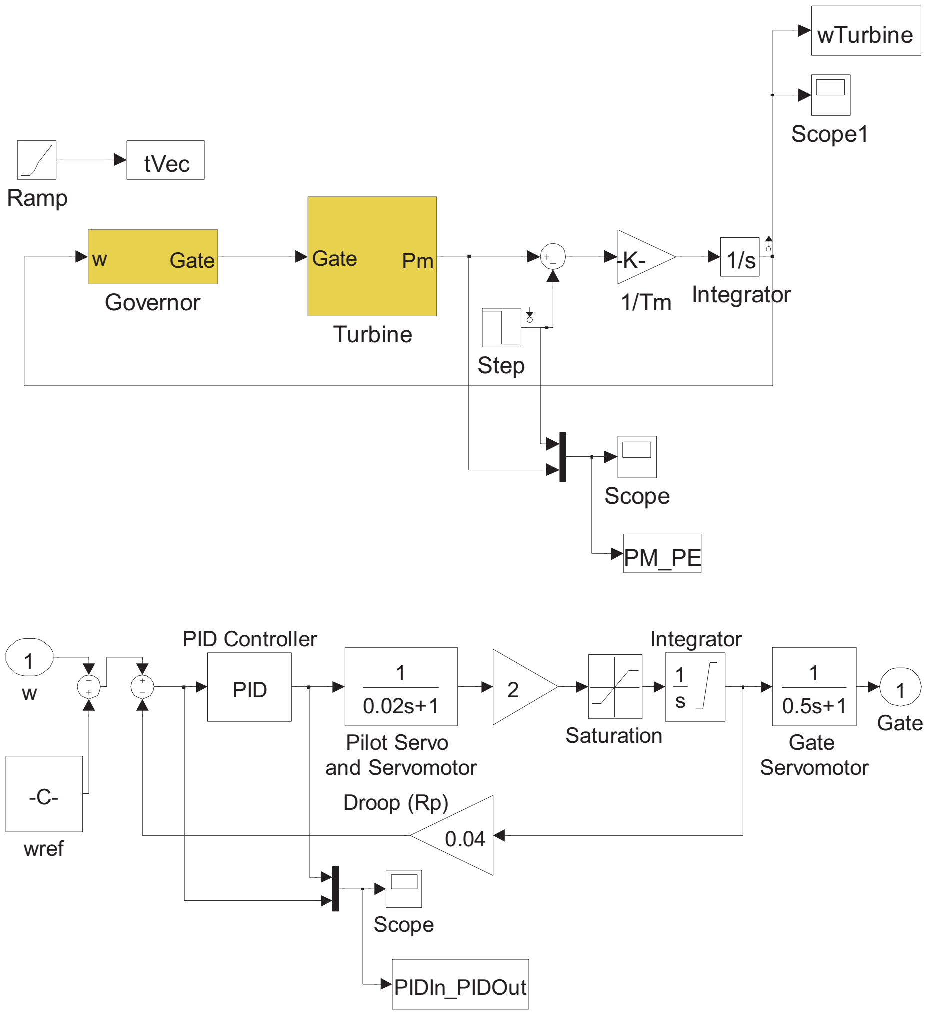
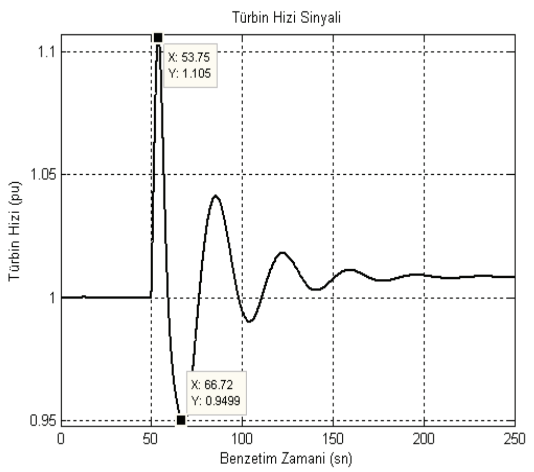
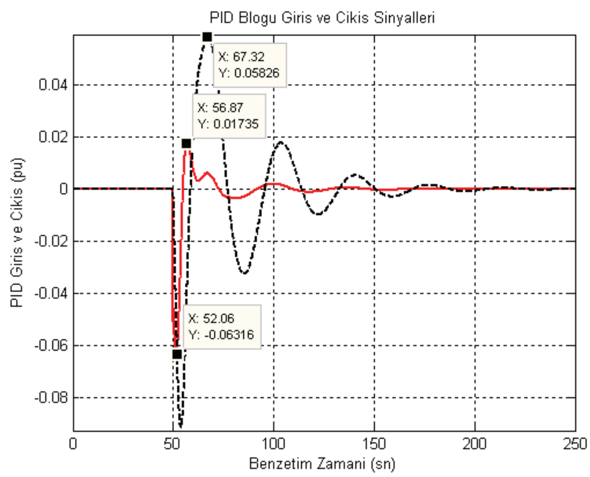


Fig 4. a.) ESG + HSG + Turbine model, b.) Inner structure of ESG+HSG





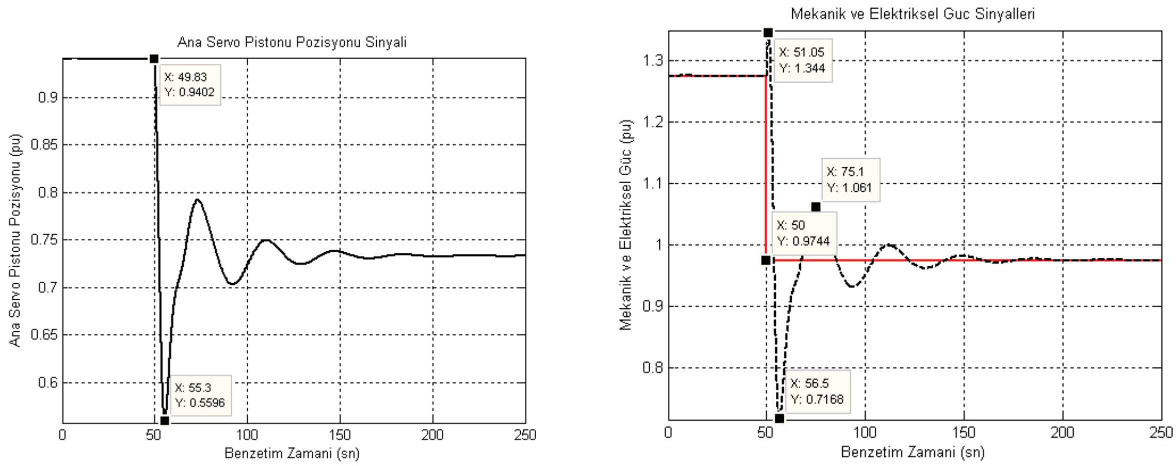


Fig. 5. a.) Turbine speed, b) PID Input (dashed), Output (solid), c) Main Servo Position d.) Mechanical Power (solid), Electrical Power (dashed)

4. Conclusions

In this paper, test system based on modeling and OPC Server which is used to develop a SG system for a rehabilitation project are explained. Hardware, software and communication features of the test system are told in detail. Operation philosophy and modeling structure of the test system are given. During design and implementation of a test system, it is very critical to set up a test system with the field conditions.

5. References

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