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Validation of Reality Oriented Model of Hydropower Plant

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Abstract

This contribution presents the most important steps for creation of a reality oriented model of the “Chibru” Hydropower Plant, Uttarakhand, India. In the hydro power plant measurements were performed to obtain step response time signals of all important functional parts. The transient behavior of the power plant was taken from the previous data available. On the basis of available technical documentations, a general model including different sub models of the power plant was developed. All the parameters of the mathematical model were identified using Matlab software. The entire model of the hydro power plant consists of separate models of hydraulic part (water tunnel, surge chamber, penstock), turbine regulator, Francis turbine, voltage regulator with power system stabilizer, network model and generator. The simulation results show a good correspondence between measured and simulated values.

Index terms: hydro power plant, modeling, identification, simulation, power system, Dynamic behavior, dynamic modeling.

Introduction

Modern hydropower has to face new challenges related to completely different exploitation strategies leading to an increase of the solicitation of the entire machine. Consequently, manufacturers, consultants and electric utilities of hydropower plants need to integrate new technologies and methodologies for improving dynamic performances, ensuring the safety and increasing the competitiveness of hydroelectric power plants. This requires developing appropriate experimental and numerical tools and methods for a better understanding and thus for planning of a safe and reliable operation.

Investigated Hydropower Plant

The Hydropower Plant Chibru lies in Uttrakhand, India, about 35 km from Dehradun,(U.K),India. It is situated on the river Tones. Main data of the "Chibru" Hydropower Plant are:

- Type of turbines : Vertical Shaft Francis, 4000MHP
- Number of units : 4
- Rated power (unit) : 60 MW
- Rated voltage : 12 kV
- Rated speed : 250/493 rpm
- Rated flow : 62.5 m³/s
- Net height : 25 m

The hydropower plant at " Chibru" is a derivational, storage type of hydro power plant as shown in Fig.1.

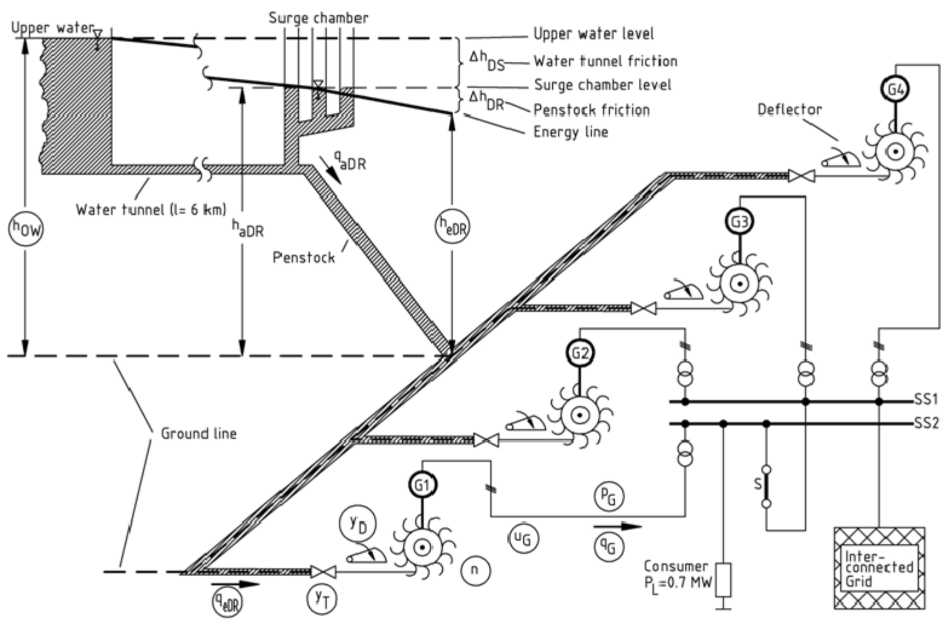

Figure 1: Scheme of the hydro power plant "Chibru" at Uttarakhand, India.

Measurements

The measurements are conducted at only one generator-turbine system in each of the power plants. The other systems are treated as similar. As step input for the measurements there has been selected an immediate reduction of the active and reactive power, because this guarantees that all the concerned frequencies of the unit's time response can be identified. As depicted in Fig. 1 the investigated machine delivers energy to the interconnected network via busbar 2 and a bus coupler circuitbreaker. For the case, that there is no isolated operation possible, as occurred in "Chibru" Hydropower Plant. The measurements must take place in normal operation during:

- starting of the unit,
- stopping of the unit,
- changing step by step the set point for active power or speed,
- changing step by step the set point for reactive power or generator voltage.

As depicted in Fig. 1 and Fig. 2 the circled signals are measured ones. All measured signals of the "Chibru" Hydropower Plant are:

- active power p_G
- reactive power q_G
- generator voltage u_G
- excitation voltage u_e
- excitation current i_e
- frequency f
- speed n turbine gate position y_T
- deflector/bypass position y_D
- water pressure at the storage lake h_{OW}
- water pressure at turbine input h_{eDr}
- water flow at the turbine input q_{eDr}.

Modeling and Identification of parameters

Using the schemes of the hydro power plants, as for instance depicted in Fig. 2 and all available technical documentations, the models of the different part systems shown in Fig. 3 were developed using the Matlab/Simulink software. The created overall model for each of the plants consists of 14 state variables and 32 unknown parameters which have to be identified. As example the developed model of the hydraulic part for the "Chibru" Hydropower Plant is shown in Fig. 3. The circled signals are again measured ones.

The identification is conducted in Matlab using the Least-Square-Method, the principle is shown in Fig.4. In the first step only the hydraulic part, together with the mechanical part, is identified using the turbine gate position as input and the water pressure and the speed of the turbine as outputs. In the second step, the parameters of the turbine and deflector/bypass controllers are identified using the hydraulic and mechanical system as identified before [1], [2]. In this case the active power is the input and the positions of turbine gate and the deflector are the outputs. In a third step, the electrical part of the generator and the excitation system are identified using the active and reactive power as inputs and the generator voltage, the excitation voltage and the excitation current as outputs.

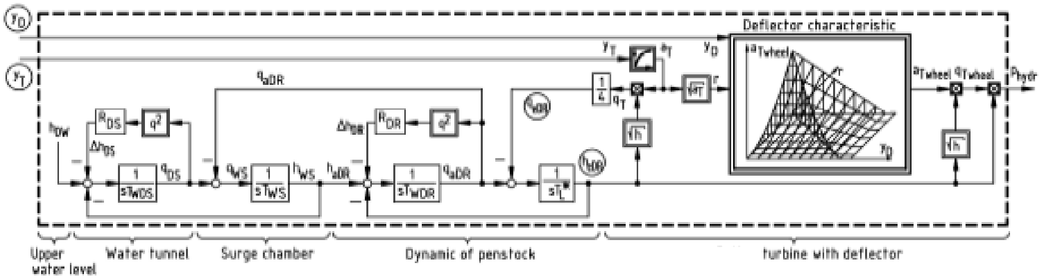

Figure 2: General block diagram of a hydro power plant.

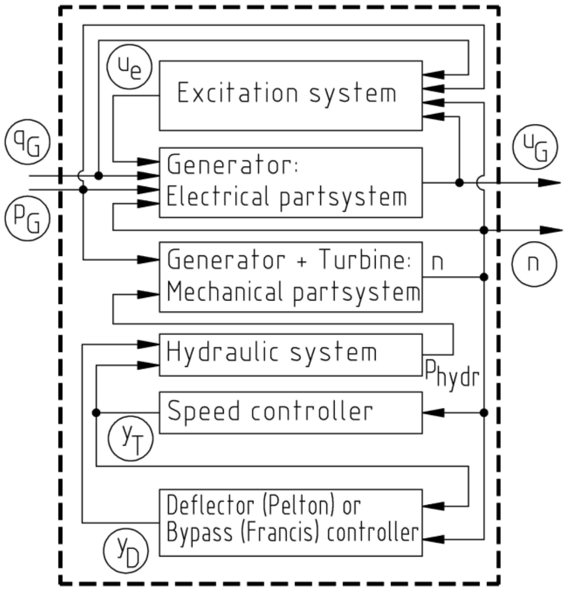

Figure 3: Hydraulic system of "Chibru" Hydropower Plant.

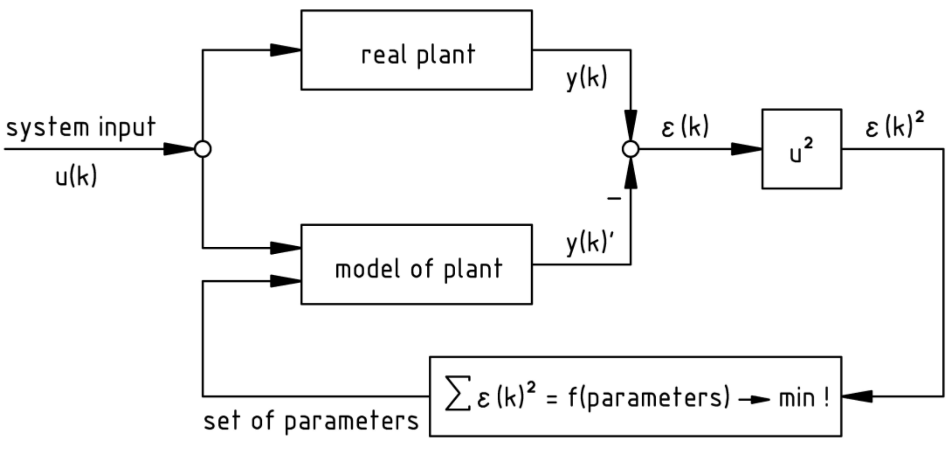

Figure 4: Least-Square identification method.

Identification Results

The identified parameters of the "Chibru" Hydropower Plant, the hydraulic, mechanical, electrical part and some parameters of the speed controller and the excitation system are shown in Table 1. The identification is divided in a few steps. The basis for the identification is a table with measured stationary state values in different stationary working points. With this it is possible to define time independent characteristics and to detect offsets. The identification has been carried out in the following order:

- Approximation of the function between guide vane position G_V and active power p_G,
- Approximation of the function between runner position R_U and guide vane position G_V,
- Identification of the turbine regulator,
- Identification of the losses characteristic together with generator and network.

For the "Chibru" Hydropower Plant, the simulation results of the identification parameters are shown in Fig. 5. As depicted, a good correspondence between measurement and simulation is achieved. The actual hydropower plant and the developed practical simulation model have shown nearly the same dynamic behavior.

Conclusions

Today the production of electrical energy is too low, while the losses are too high and the facilities are not up to the mark. Therefore a lot of renewing, rehabilitations and enlargements in the electric power system are necessary in the next years. On that account it will be very useful to have an overall dynamic network model based on up to date conditions[5]. Based on the measurements in the "Chibru" hydro power plant and on the provided documentations a dynamic model of the power plant was designed and identified. The model and the real power plant show nearly the same behavior. The created model is only valid for interconnected operation mode. For further investigations it can be recommended to investigate also the isolated operation. The behavior respectively the model of the power plant is different in both operation modes.

Table 1: Calculated and Identified parameters.

Hydraulic Parameters								
R_{DS} 0.08	T_{WDS} 6.7 s	T_{WS} 700 s	R_{DR} 0.02	T_{WDR} 1.46 s	T_L 0.34 s	k_{kV} 0.043	k_{pV} 0.1	k_{qV} 0.054
Generator Parameters								
T_A 6.8 s	x_d 1.5	x_d' 0.4	x_d'' 0.22	x_q 1	x_q'' 0.24	T_d' 1.5 s	T_d'' 0.03 s	T_q'' 003 s
Voltage Regulator Parameters								
σ_p 3.8 %	T_{ip} 1 s	k_p 9.3	k_u 22	k_f 1	T_f 0.54 s			

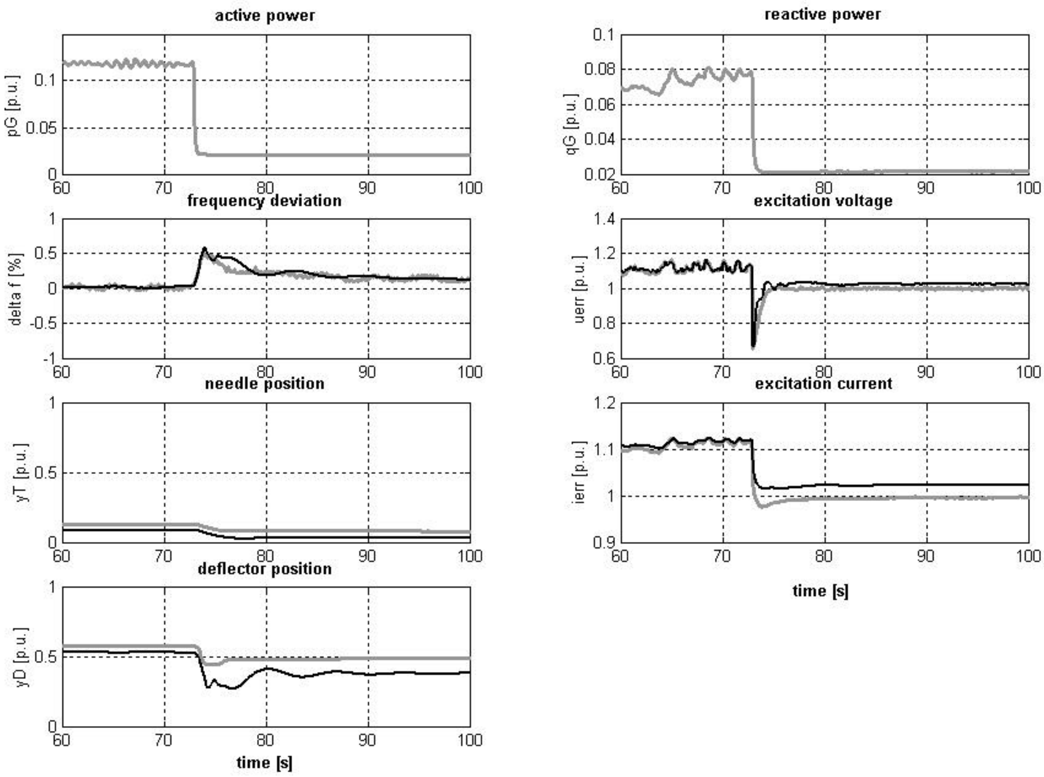

Figure 5: Comparison of measured (grey) and simulated (black) signals.

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