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Automatic Voltage Regulation Model of One Unit at Vau Dejes HPP

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***Abstract* - For planning of a safe and reliable operation of the Albanian electrical grid it is very important to have a static and dynamic model of this grid. The model could be used for analyzing the system, identifying the changes to be done in case of problems i.e. to make investigations concerning the restoration process after a black-out. This paper represents the contribution of modeling the voltage regulator of one unit at Vau Dejes Hydro Power Plant, that can be used later on for modeling the entire unit generator.**

Keywords—Voltage regulator, Dynamic modeling, Hydro Power Plants, Simulation.

I. INTRODUCTION

Power system networks are subject to various forms of transients. Various studies have shown that 70 – 90 % of the faults occurred in overhead lines are transient. When a fault occurs in the network, turbine-generators experience a step change in torque. During the rehabilitation Project of Vau i Dejes HPP, a major intervention was done to the hydromechanical and electrical part of the unit generator. Excitation System and Voltage Automatic Regulator have been replaced. This experience has renewed our interest in investigation of the static and the transient behavior of the power plant. The aim was to identify the most important parameters of the mathematical model needed for such investigations. At "Vau I Dejes" HPP measurements were performed to obtain step response time signals of all important functional parts of the plant. For the measurements the set point for active power and the set point for reactive power were changed stepwise during the commercial operation of the unit. The unit was synchronized with grid and was operated in interconnected mode. In this way the static and the transient behavior of the power plant was measured. These measurements were recorded by a PC-based LabVIEW system. On the basis of the available technical documentation and commissioning reports the voltage regulator model of the power plant were developed. With the software Matlab/Simulink, the needed parameters of the voltage regulator were identified. To verify the accuracy of the mathematical model of the voltage regulator, the simulations were compared with the measured values.

Fig. 1 Map of Albania showing HPP Vau Dejes

II. HYDRO POWER PLANT VAU DEJES

About 95 % of the generated power in Albania is produced from 11 main Hydro Power Plants in Albania. These HPP have an overall Capacity of 1466 MW. The three most important HPP (Vau Dejes 250 MW, Komani 600 MW and Fierza 500 MW) form the Drin cascades. Vau Dejes and Fierza HPPs have been recently completely rehabilitated under DRCRP Project (Drin River cascade Rehabilitation Project). The Project was cofinanced by different donors and lenders i.e EBRD, JBIC, SECO, ADA etc. The Project in the electrical part included rehabilitation and or replacement of equipment: New transformers, upgrading and testing of transformers, replacement of the excitation systems of generators, automatic voltage control, new generator protections, rewinding of generators, auxiliary equipment, provision of emergency diesel generators, rehabilitation and upgrading of switchyard facilities, as well as installation of new control and monitoring system.Vau i Dejes HPP is the third Plant in the Drin Cascade cascade in a decending order Vau I Dejes hydropower plant consisting of three embankment dams with heights of 18 m to 59 m was completed in 1971 and has an active storage of about 250 million m3, and five units with total plant power of 250 MW. The plant is owned by the state-owned Albanian Power Corporation (KESH).
The five identical vertical Francis units, 50 MW each, are located in the power house at the foot of the main dam. The nominal head of the turbines is 52 m and average annual energy production is 878 GWh.

A. Technical data of Vau i Dejes HPP

Vau i Dejes reservoir is formed by three dams, i.e. Qyrsaq rockfill dam with clay core and integrated concrete spillway and intake structure (Table 1), Zadeje rockfill dam with clay core, and Ragam embankment dam with clay core.

TABLE 1 QYRSAQ ROCKFILL DAM WITH CLAY CORE

Construction period	1967-71
Dam height (m)	46
Crest length (m)	375
Dam volume (million m^3)	1.2
Annual Inflow (million m^3)	9460
Active Storage (million m^3)	250
Discharge Capacity (m^3/s)	4200
Installed power	5 x 100 MW

III. MEASURMENTS

The measurements were performed by engineers from the University of Rostock with assistance of the HPP engineers. The measurements were conducted on one generator-turbine Unit. The other units are expected to be identical in its dynamic behavior. There was no possibility to run the investigated unit in island operation. The signals were measured and recorded by a PC-based LabVIEW system with 16 channels. The sampling rate was 50 ms. The measurements have to be performed during the transition from one stationary working point to another. These transitions can be initiated by manually changing the setpoint for active power (turbine controller determined) and reactive power (voltage controller determined). Table.1 gives a list of all the measured signals.

TABLE 2 MEASURED SIGNALS

Chanel No.		Signal
1	n	Speed
2	Gv	Turbine opening
3	P	Active power
4	SP	Spiral pressure
5	h	Turbine head
6	Ug	Generator voltage
7	ie	Excitation current
8	ue	Excitation voltage
9	ig	Generator current
10	Qg	Reactive power
11	P	Active power

The active power was measured from two different panels so we can choose the better signal for our purpose.

IV. MODELLING AND IDENTIFICATION OF THE VOLTAGE REGULATOR

Using all available information about the power plant like technical documentation, commissioning and test data a block-scheme of the Voltage regulator model could be generated. The model was developed in Simulink.

The parameters of the components, excitation system, are identified using least square method starting from the orienting typical values for such systems and some of the parameters are taken from the technical documentation.

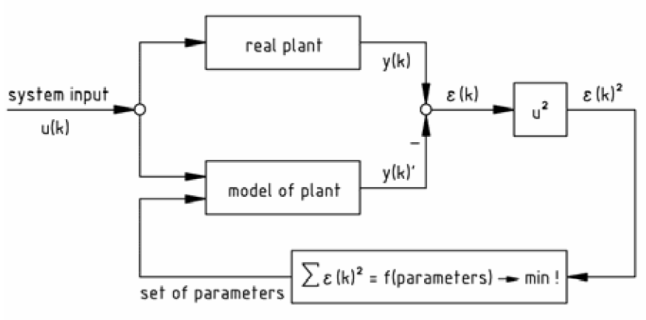

Fig. 2 Least square method

A. Voltage Regulator model

The voltage regulator is manufactured from ABB and is a ES202 system. From functional point of view, the system can be divided in two main parts, power supply(exciting field power) and regulating the output voltage of the generator. The regulator contains an atomatic digital regulator and one independent manual regulator. The excitation system has to provide the following functions:

- Regulating the machine terminal voltage, and if supplying to a grid regulating the reactive power contribution.

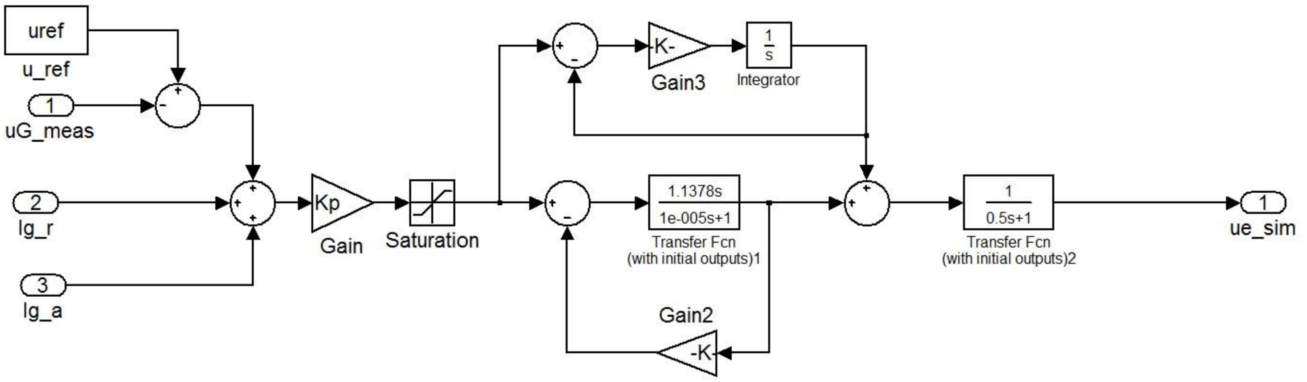

Fig. 4 Voltage regulator model

- Ensuring that the best conditions (stability) of energy supply to the network are maintaned.
- Bringining the machine back to normal operating conditions as fast as possible after a disturbance has occurred.
- Having the capability of bringing the alternator back to the foreseen operating field.
- Ensuring the machine and system inegrity under extreme conditions (shutdown or stop sequence).

In [1] also the regulation functions are included:

- Feedback, compound and voltage regulation.
- Over-excitation limit.
- Under-excitation limit.
- Volt/Herz limit.
- Power system stabilizer
- Manual current regulation
- Current feedback

The simulation with power system stabilizer could not authenticate the model for the most measurements, so at least in interconnected operation mode the power system stabilzer was taken out to fullfill an accurate model. In island operating mode no meassuremnts were made and therefore no prediction about this model can be made.

The system input is voltage reference uref, measured generator voltage Ug_meas and reactive generator current Ig_r. The output of the system is the excitation voltage ue. The model of the voltage regulator was developed based on the documentation of the plant. This regulation amplifies the difference between voltage reference and the transduced value of the system terminal voltage to which the contribution of limitation and compounding system are added. The PID regulator and the excitation machine can be seen at the model of the voltage regulator Fig. 4.

The identified parameters for the voltage regulator are shown below:

- Dynamic amplification of generator *Kp=10*
- Time constant *T5=1.13775*
- Positive saturation bias *up_limit=5.654*
- negative saturation bias *lw_limit=-4.25*
- Direct gain voltage regulator *Kd=50.729*

V. SIMULATIONS

The simulation results of the voltage regulator model are shown in Fig. 6-9. The upper signal of the simulation is the measured Generator voltage in per units. The middle signal is the measured reactive power and the lower plot shows the comparison between measured excitation voltage (blue) and simulated excitation voltage (red).

The simulations shows so far a good behavior with respect to the measured values.

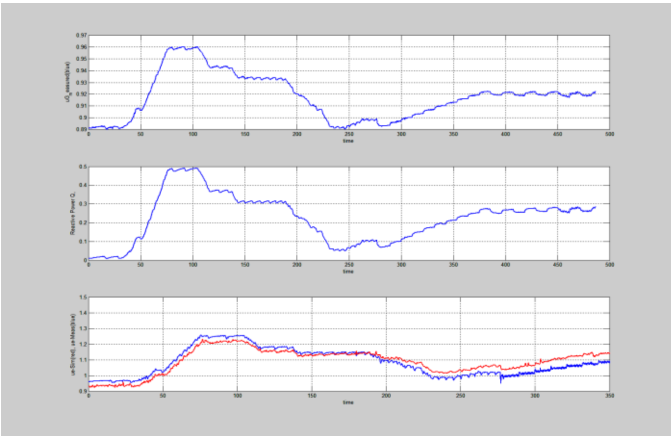

Fig. 3 Simulation of VR measurement 4

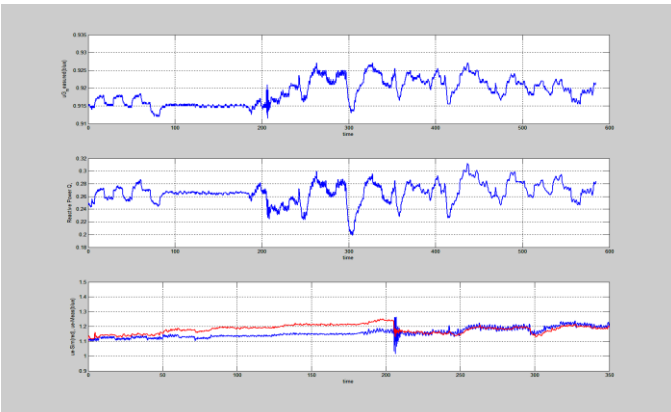

Fig. 5 Simulation of VR measurement 6

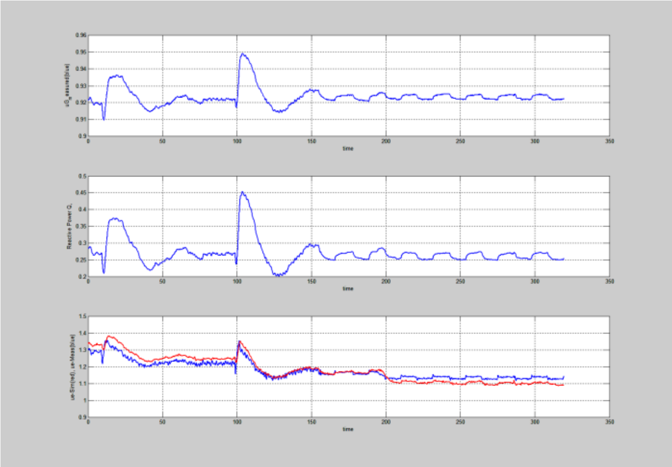

Fig. 6 Simulation of VR measurement 7

VI. CONCLUSIONS

The simulated model of the voltage regulator has a correct behavior compared to the real voltage regulator of the HPP

- The experiments and measurements were made in interconnection operation mode.
- In order to judge the handling of the regulators as accurate as possible, it would be necessary to experiment and measure in island operation mode, but it was not possible to perform this experiment.
- The model parameters could be identified with the least square method and some of them were taken from the technical documentation of the plant. It was concluded that the model has a similar behavior with real plant due to the accuracy of the parameters.
- As a next step, we will continue with mathematical model of generator and hydraulic equipment, i.e governor in order to complete the entire unit generator model.

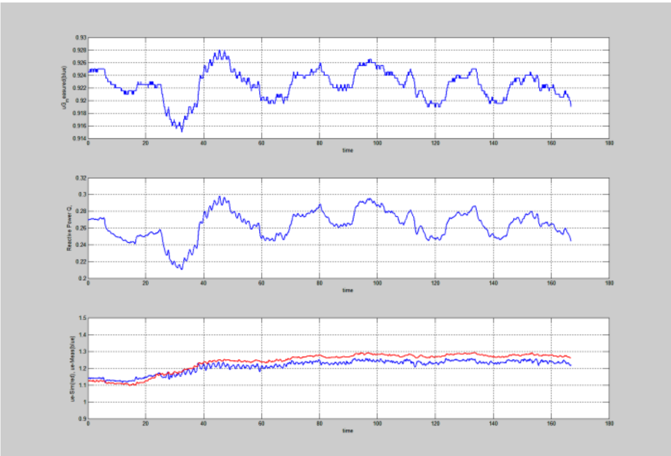

Fig. 7 Simulation of VR measurement 8

- Operation in island mode is also a target for evaluating the right behavior of the Hydro power plant. So the capability of the Automatic speed and voltage regulation in island mode can be inspected. This is very important for investigating the behavior of the power plant also in emergency situations, i.e. restoring the power system after a black out.

REFERENCES

[1] A. A. B. Boveri, "Sytem Description, Power Plant Documentation".

[2] E. Saqe, T. Haase, F. Prillwitz and S. E. Al-Ali, "Simulation model of the hydro power plant Vau i Dejes with software matlab/simulink," *Medpower*, 2008.

[3] P. Weber, D. F.Prillwitz and D. T.Haase, "Messung, Modellierung und Identifikation des Wasserkraftwerks Innertkirchen II," Universität Rostock, Rostock, 2000.

[4] P. S. Kundur, Power system stability and control, Palo Alto,California: McGraw-Hill,Inc..

[5] H. W. Dissertacion, "Dynamische Netzreduktion zu Modalanalyse von Frequenz und Leistungspendelungen in Ausgedehnten elektrischen Energieübertragungsnetzen," Universität Stuttgart, 1990.