PERFORMANCE EVALUATION OF DIGITAL GOVERNOR FOR IMPROVING OPERATIONAL EFFICIENCY AND RELIABILITY OF POWER PLANT

Muddasar Nawaz (Student), CES-NUST University, Islamabad Pakistan
Email: engrmnqureshi@hotmail.com
Farhan Zulfiqar, Lecturer, CES-NUST Islamabad
Email: farhan.zulfiqar@gmail.com
Mohammad Bilal, Principal, CES-NUST Islamabad
Email: principal.ces@nust.edu.pk
Eng. Akif Zia Khan, Lecturer, CES-NUST Islamabad
Email: akifziakhan@ces.nust.edu.pk

ABSTRACT

In this paper, response of newly installed digital governor of Tarbela Power Station has been checked. During testing different parameter like speed of the hydro generator after load rejection, step response of MW, relief valve timing were checked and comparison of previous installed electromechanical governor is also illustrated. Previously in Tarbela, Electromechanical Governor was installed which was replaced with digital governor in 2014. This newly installed Governor has Mark VIe Control System which is designed by G.E (USA) for retrofitting the turbine control system at Tarbela. The Mark VIe software is easy-to-use for configuration and diagnostic tools aid in the startup and maintenance of the system. Digital governors are more cost-effective in the long haul as compared to the electromechanical governor as they are maintenance free. In case of failure of any electronic component, the replacement process is very simple. Testing of all field devices of the digital governor is very easy to use and can be easily maintain over the years. The accuracy of the digital devices is very high and also plays a pivotal role. It is true that mechanical devices can be reliable and accurate, but the digital ones are definitely superior in terms of accuracy.

Key words Digital governor; load rejection; retrofitting.

Introduction

The objective of this research is to discuss the technology of new digital governor for maximizing the performance and reliability of the power plants [1]. Governor system controls the turbine servomotor, which in response control the turbine speed and power by regulating the flow of water.

Background

Tarbela Power Station is the largest Hydro power plant in Pakistan. Units No. 1~4, 5~8 and 09~10 of Tarbela Power Station were commissioned in 1977, 1982 and 1985 respectively. Presently the installed capacity of Tarbela Power Station is 3478MW. Previously in Tarbela, Electromechanical governing system was installed. Due to mechanical wear and tear, prolong maintenance and obsolesce of spares, electromechanical governor was replaced with digital governor [2]. This project was not a complete replacement rather was a retrofitting. This allows the plant to use the reliable existing equipment e.g. pumps, oil pressure lines etc. In the upgradation/replacement of electromechanical governor process was installation of a controller, speed sensor and to remove the mechanical linkages, PMG and dashpot etc.

Main Components of Governor

Governor system consists of different field devices for continuously monitoring the deviation of speed of turbine and converts the speed deviation into change of gate position through the gate servomotor. All devices used in the governor system for controlling of gates and the relevant feedbacks are known as Governing system. For the movement of wicket Servomotor, a pressurized oil system is installed. This system contains pumps, oil tanks, sump tank and piping system for providing the pressurized oil to servomotor for the mechanical movement of the gates.

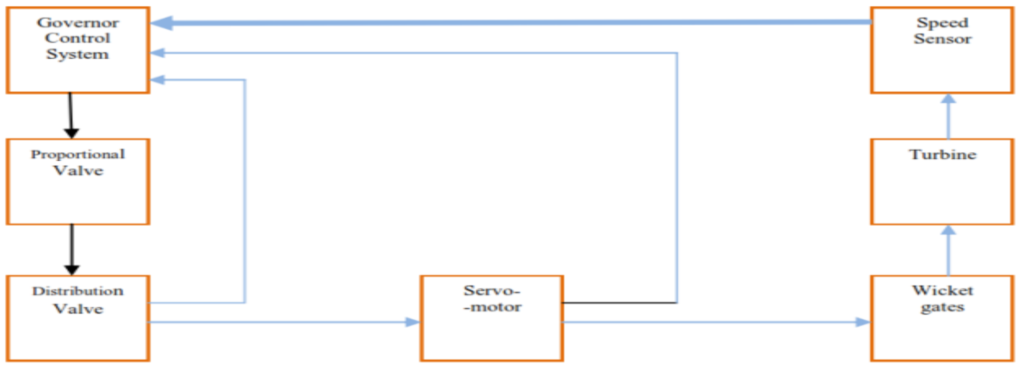

Figure1: Block diagram of Digital Governor

Working of Digital Governor

Governor controller is the brain of the governor system. All the instructions and feedback are sent and received from the controller. Controller gives the electrical signal to proportional valve for opening or closing of the wicket gates. Proportional valve gives a small force oil input to distribution valve which in turns amplifies this small force to large force movement of the servomotor. Distribution valve feedback is also connected to the controller as shown in the fig 01. Servomotor is mechanically connected with the wicket gate which controls the flow of the input water.

For measuring the position of the wicket gate a feedback sensor is installed on the servomotor which continuously monitor and gives signals to the controller. In response controller check the difference between the gate set point and the actual position and give the next instruction. Speed sensors are installed on the top of the turbine shaft for monitoring of the actual speed of the turbine. In previously installed mechanical governor a permanent magnet generator was installed which coupled with the turbine shaft for measuring the speed of the turbine. Digital governor uses zero velocity pickup (ZVPU) which is basically a speed signal generator and provides frequency signal proportional to the unit speed. ZVPU's are also connected with the shaft.

These speed sensors are also used for the creep detection. Creep is the slow rotation of turbine due to water leakage from the wicket gates when the generating unit is in shutdown mode. When this movement is detected by the controller of governor system, it turns on the oil injection pumps for preventing damage of thrust bearing pads.

Performance Evaluation of Digital Governor

Governor system performance can affect the generation of the power plant directly or indirectly. Regular periodic testing is required for the analysis of governor performance [3]. New Digital governor of Tarbela Power station is manufactured by G.E (USA).

1. Start up of generating unit

Starting of the generating Unit of 175MW capability is presented with a digital governor in the Fig 02. Proper tuning in the governor control software has reduced the overshoot speed which is now less than 1 percent. After giving the start command to the governors, the Unit achieved the rated speed in 70 sec approx and was ready/available for synchronization. Gate position is varying continuously for the keeping the speed of the generating unit in the safe range. The detail of inputs and outputs variables selected is as under:

Input/ Output	Variable Name	Description
Input	Auto_Start	Start command for Governor
Input	Speed_SP_PERCENT	Set point of speed
Output	Servo_fdbk	Actual Gate Position
Output	Speed_PCT	Actual response/feedback of speed

In the fig 02 X-axis shows the time and Y-axis shows the magnitude of speed and wicket gate position in %.

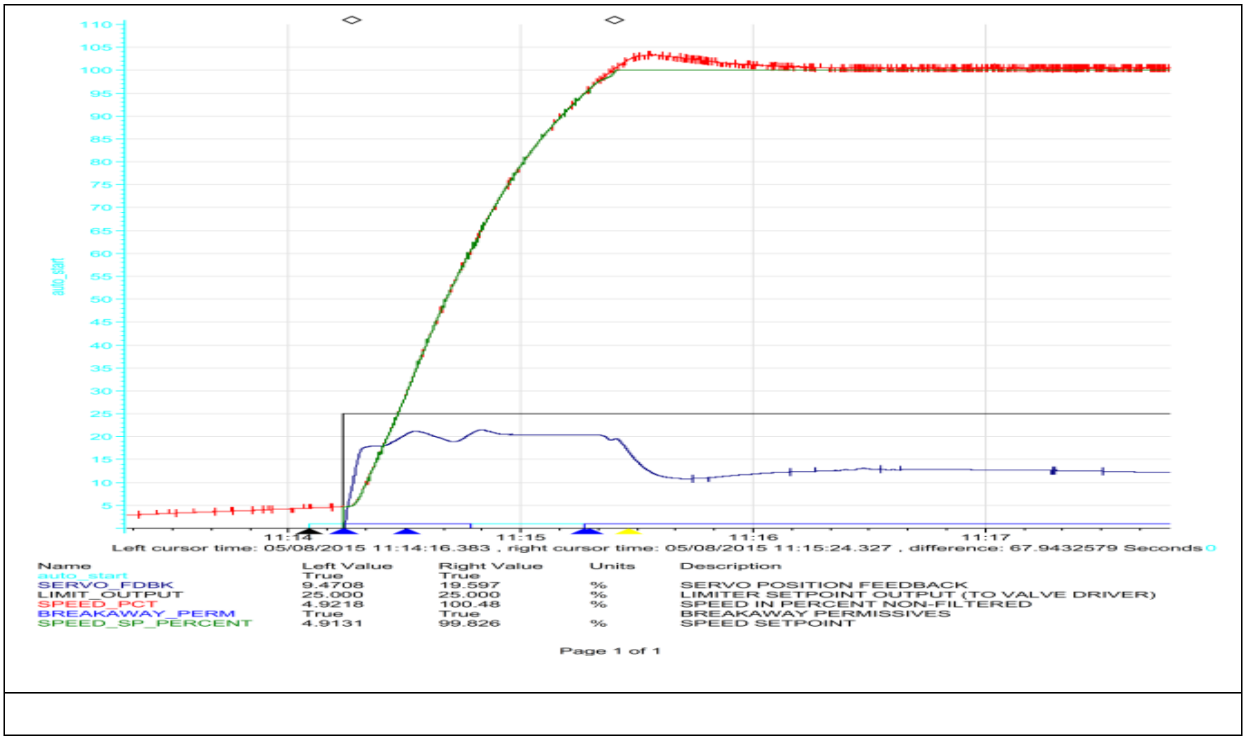

Figure 2: Start up of Generating Unit

2. Load rejection test of generating unit

Load rejection test is carried out for verifying the response of governor for sustaining the load rejection in order to prevent the over speeding and with no adverse effect on turbine and penstock.

For this test first Generating Unit was started and synchronized with the system. When the Unit was operating at full load, the breakers of the Unit was opened thus making it at no load with 100% wicket gate in opening position.

Speed Response of the unit was checked with new governor and found satisfactory. Relief valve was also operated in time to divert the water flow and relieves the pressure from the gates and penstock. The detail of input and output variables are as under:

Table 1 *Input/Output Description*

Input/ Output	**Variable Name**	**Description**
Input:	MW_FDBK	Feedback of load/megawatt from full load to no load.
Output:	Servo_fdbk_1	Feedback of gate position before and after the operation.
Output:	Speed_PCT	Feedback of machine speed after opening of the main breakers.
Output:	Bypass_fdbk_1	Response of relief valve after the load rejection.

Where in the figure 3 X-axis shows the time and Y-axis shows the magnitude of the above all four variables.

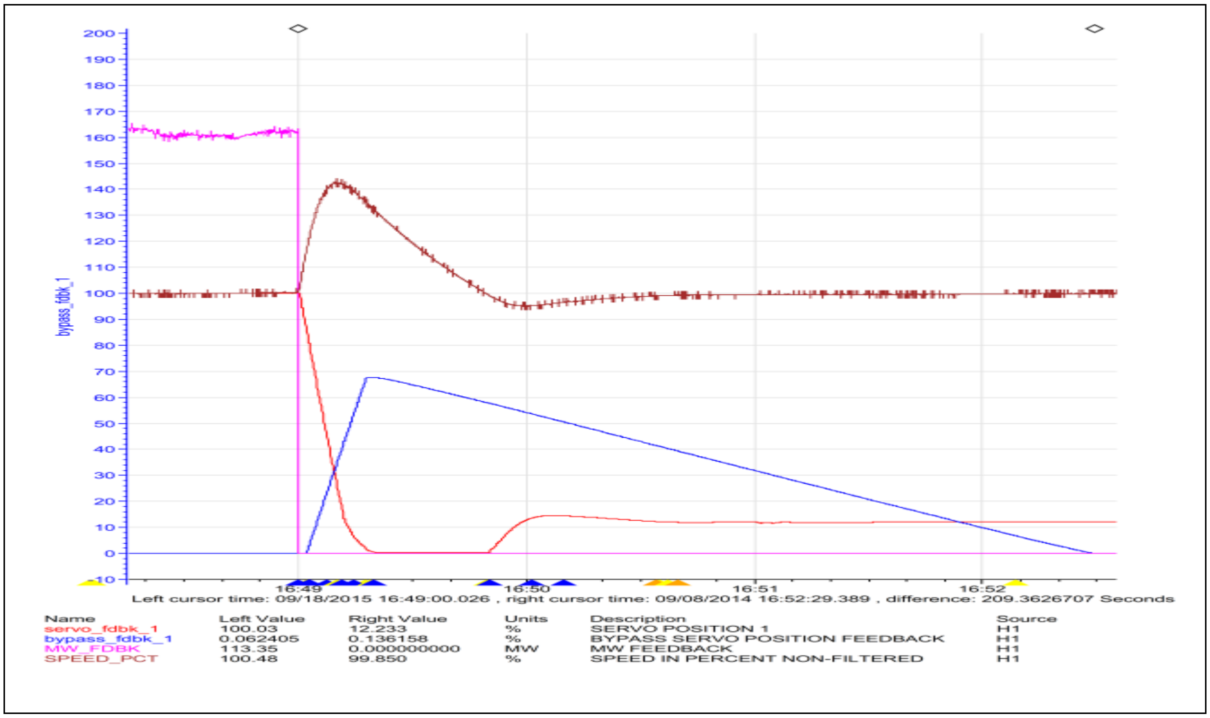

Figure 3: Load Rejection Test

3. Wicket gate opening/closing response

The moving speed of wicket gate has a certain effect on the generator stability. The wicket gate actual opening and closing timing should match the design timing in order to prevent unnecessary wear and tear [4]. In previous governor there was not proper way to evaluate the timing test of the governor. Now through this digital governor the timing test can be performed easily through Mark Vie software.

For checking the response of the gates, Generating unit have to be in maintenance mode. i.e. inlet valve fully closed. Now the wicket gates set point is changed from zero to 100%. Wicket gate started to move towards at 100% position. Then the set point is changed from 100% to 0 for checking the response of closing of wicket gate.

The timing of opening and closing can be easily analyzed from the trend stored in the governor software. The opening and closing time can be adjusted mechanically from the distribution valve. The result of this test is shown in the Fig 04:

The detail of input and output variables are as under:

Input/Output	**VARIABLE NAME**	**DESCRIPTION**
Input:	LSS_Output	Wicket gates opening/closing set point.
Output:	Servo_fdbk	Wicket gates opening/closing position feedback.

Where in Figure 4 X-axis shows the time and Y-axis shows the magnitude of the wicket gate position.

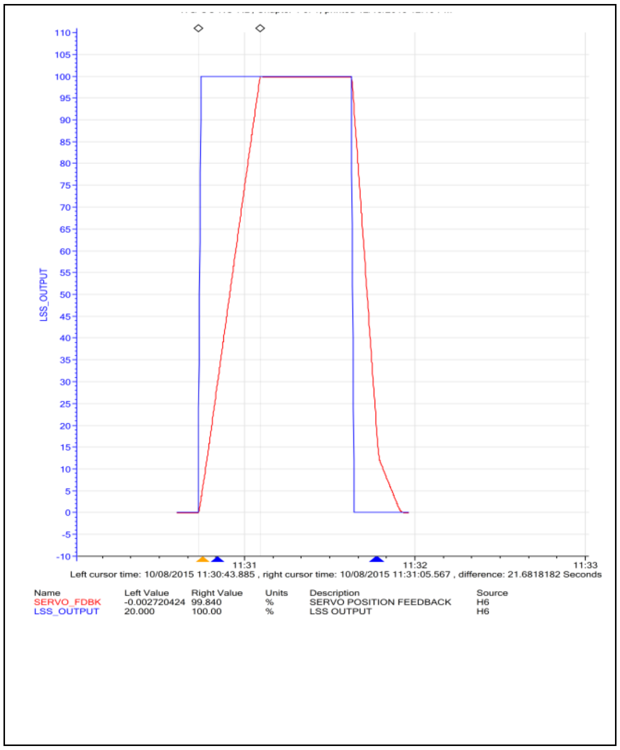

Figure 4: Response of Wicket Gates

UNIT NO.	Opening Time (Design)	Actual Opening time	Closing Time (Design)	Actual Closing time
Unit 06	20 sec	21.68 sec	15 sec	15.5 sec

4. Relief valve opening/closing response

Relief valve is the protection of penstock against the water hammering caused by sudden load rejection or any failure. The opening timing of relief valve should match approx the closing time of wicket gate for relieving the back pressure of water.

For checking the response of the relief valve, Generating unit have to be in maintenance mode. i.e. inlet valve fully closed. Now the relief valve set point is changed from zero to 100%. Relief valve started to move towards at 100% position. Then the set point is changed from 100% to 0 for checking the response of closing of relief valve.

The timing of opening and closing can be easily interpreted from the trend. The opening and closing time can also be easily adjusted from the distribution valve of relief valve.

In figure 5 the response of relief valve is presented below.

Unit No	Opening Time (Design)	Actual Opening time	Closing Time (Design)	Actual Closing time
Unit 01:	15 sec	15 sec	180 sec	181.5 sec

The detail of input and output variables are as under:

Input/ Output	Variable Name	Description
Input:	BYPS_CTRL_OUTPUT	Relief valve opening and closing set point
Output:	Bypass_fdbk_1	Relief valve actual position feedback

Where in Figure 5 X-axis shows the time and Y-axis shows the magnitude of the relief valve position.

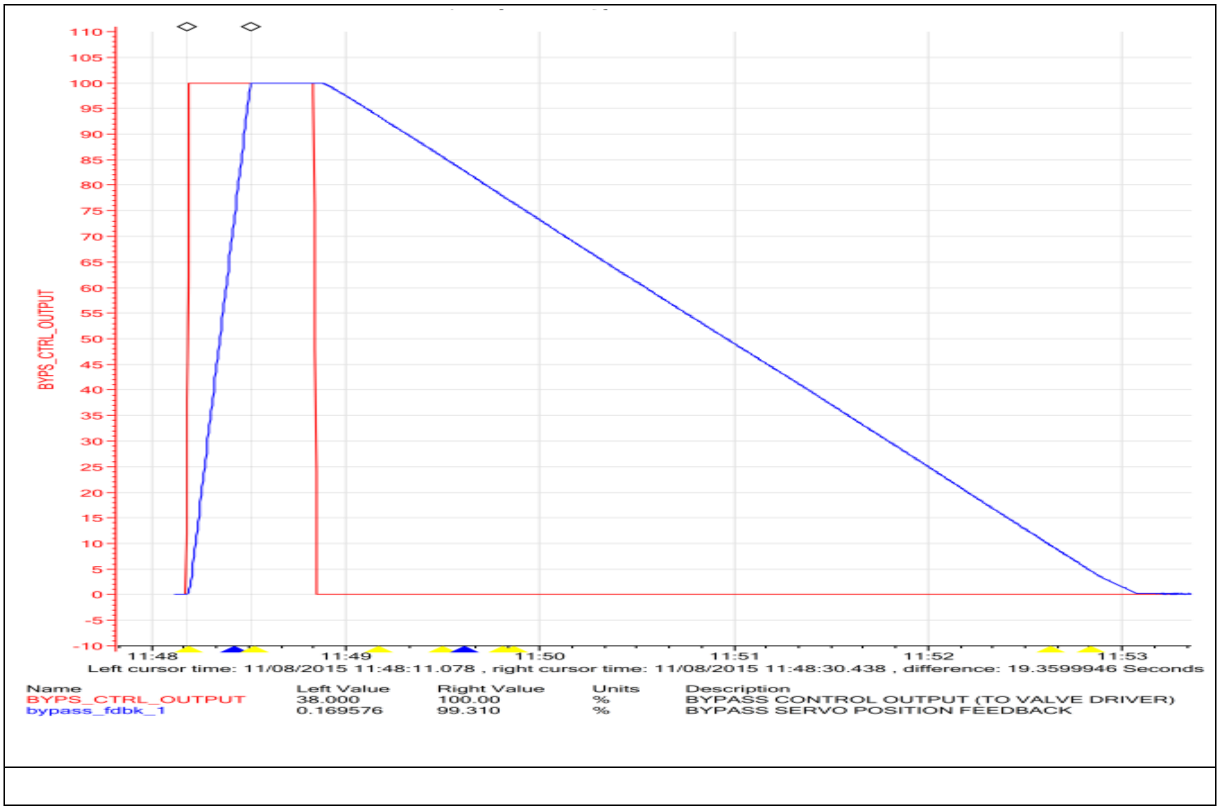

Figure 5 : Response of Relief Bypass Valve

5. Step response of load (megawatt)

This response was checked online i.e. unit was synchronized with the power system. Step response of load can be checked by varying a small load by changing the set-point while generating unit is on bar and its behavior is checked in that short time.

Now Tarbela power plant provides load-frequency regulation in an efficient manner through joint load by controlling the load of all the units simultaneously. Governor control of wicket gate in response to load variations must be checked in detail in order to guarantee the no harmful pressure fluctuations and instabilities.

Step response of load and was checked by changing the respective set-point as shown in the following figure#06 and found satisfactory.

The detail of input and output variables for step response of load are as under:

Input/ Output	**Variable Name**	**Description**
Input:	MW_SP	Minor/Step change in load set point
Output:	MW_fdbk	Actual feedback of the Load

In Fig 06 X-axis shows the time and Y-axis shows the magnitude of load/megawatt.

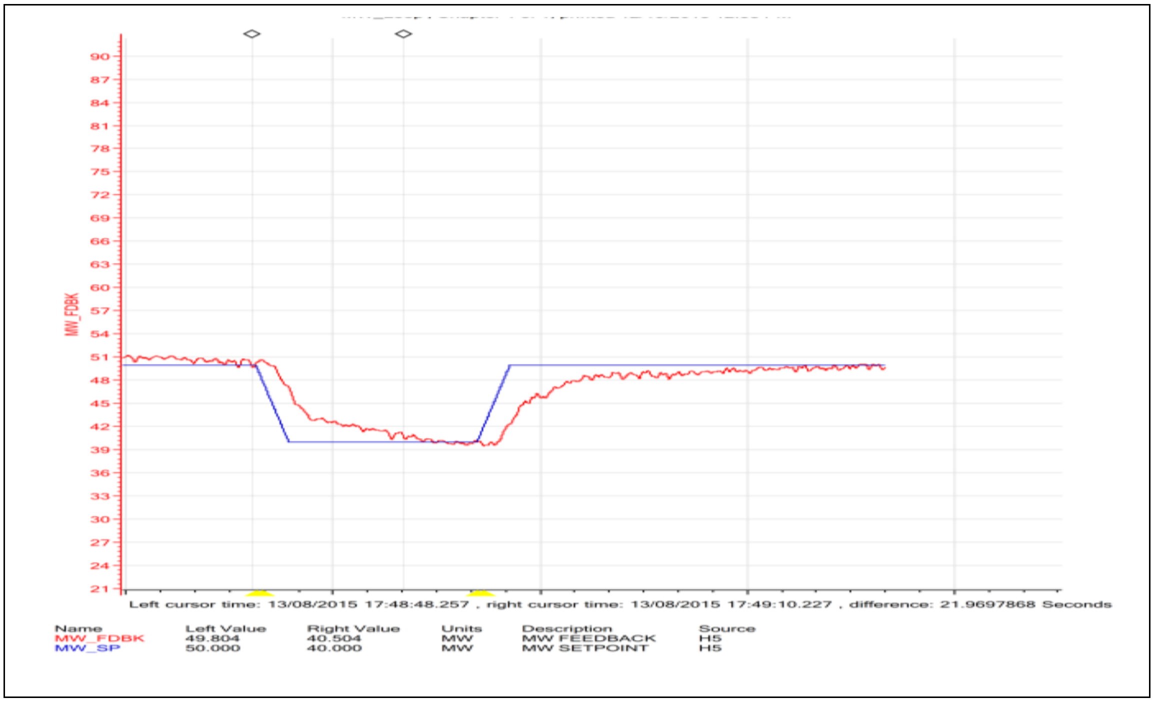

Figure 6: Step response of Megawatt

Conclusion

In Tarbela Power Station, after the replacement of Mechanical Governor with the digital governor, several benefits and advantages were added. In the previous installed governor there were many different mechanical movables parts which were susceptible to collapse, thus resulting the outage of the generating unit and causing a high revenue loss to the Government sector. Moreover, high maintenance costs and longer time periods for major over hauling made the system unreliable and inefficient as compared to the digital governor. Digital governor has no moving parts, so there is no chance of wear and tear that can cause the breakage of any equipment. If the digital governor part breaker/collapse due to any reason it can be replaced easily and effectively. All the governor parts now can easily be maintained over the years. Periodic testing of governor is required for proper checking of the governor performance. These tests may be conducted off-line and online for checking the governor hunting, stable response of frequency [5], feedback sensors of wicket gate and relief valve and test for timing test for synchronization of the generating unit. Good result of these tests can definitely increase the performance of generating unit.

Response of the new governor is also very fast and can be monitored easily through the software. As shown, Software also makes data logging and algorithm development for troubleshooting simple.

References

1. Agee, J.C.; Yu, H.D.; Volk, J., (1999). Installation and testing of a prototype digital governor at Mt. Elbert power plant, in *Power Engineering Society Winter Meeting, IEEE* , 1(3), 102-107.
2. Hovey, L. M. (1962). Optimum adjustment of hydro governors on Manitoba hydro system in *Power Apparatus and Systems, Part III. Transactions of the American Institute of Electrical Engineers* , vol.81, no.3, pp.581-586, April 1962.
3. Bakaric, V.; Miskovic, I.; Horvat, K., "Hydroelectric power unit simulator for turbine governor testing," in *MIPRO, 2012 Proceedings of the 35th International Convention* , vol., no., pp.794-799, 21-25 May 2012.
4. Gencoglu, C.; Tor, O.B.; Cebeci, E.; Yilmaz, O.; Guven, A.N., "Assessment of the effect of hydroelectric power plants' governor settings on low frequency inter area oscillations," in *Power System Technology (POWERCON), 2010 International Conference on* , vol., no., pp.1-8, 24-28 Oct. 2010.
5. Hagihara, S.; Yokota, H.; Goda, K.; Isobe, K., "Stability of a Hydraulic Turbine Generating Unit Controlled by P.I.D. Governor," in *Power Apparatus and Systems, IEEE Transactions on* , vol.PAS-98, no.6, pp.2294-2298, Nov. 1979.