A Smart Turbine Speed Regulator Design for Hydroelectrıc Plants

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***Abstract*—The flow rate of dam water in hydroelectric plants varies depending on time. The change in flow rate causes alterations in rotation speeds of turbines. Since the change in rotation speed of tribunes alters the frequency and amplitude of the produced electrical energy, the obtained electrical energy does not conform with UCTE (Union for the Co-ordination of Transmission of Electricity) standards in terms of quality. The system to be designed consists of a control unit which evaluates parameters such as blades that control the flow rate of water to turbine, motors, sensors, speed information with tacometer, amplitude and frequency information of produced electricity; and adjusts the blade position according to reference inlets. In the system to be designed in scope of the project, as different from current systems, the system check shall be carried out by Profibus (Process Field Bus)-DP (Decentral periphery) network based, which is a different approach to be presented for data communication infrastructure and its control. Therefore, higher performance shall be obtained compared to current systems in topics such as reliability, remote control, data transmission speed, real time transmission, system stability. In this method, it shall be possible to decrease the negative effects of factors which influence the quality of energy (i.e. precise control of turbine wicket gates, turbine speed and power measurement) Moreover, data transmission among hardwares shall be carried out by Fiber Optic, thus increasing data speed as well as data security and reducing network delay. As a result of the project, by the utilization of this new technology in Turkey's hydroelectric plants, foreign dependency shall disappear, new employment environments shall be created, production potential of hydroelectric energy shall be utilized more efficiently and big economic benefit shall be provided.**

***Index Terms*—hydroelectric plant, turbine, turbine speed regulator, profibus control**

I. INTRODUCTION

Turkey is a quite rich country in terms of its diversity and potential of its sustainable energy resources. It's quite important in terms of economic and strategic benefits of our country that hydroelectric plants; one of the most important sustainable energy reources; should be established and set into operation at first since they have positive and efficient aspects i.e. they have no fuel expenses, can easily conform to load demand and frequency adjustment of the system, have less environmentally hazardous effects. Determination of river resources which are suitable for hydroelectric plant establishment and starting to build them at once shall provide very significant contributions to our country's energy production. The priority policy on energy field in our country is to project construction of large capacity dams and hydroelectric plants [1].

The aim of this study is to present a new model on speed regulators algorithm, which is one of the crucial elements in hydroelectric plants that have an important position among renewable energy resources.

The reduction in dependency to foreign countries for hydroelectric plants forms the most important aim of the project.

The current electronically controlled functional speed regulators in hydroelectric plants are imported from other countries.

With its new model design, the regulator shall have an efficient operation performance remotely and in fast control features by having Profibus network base. Boundary diagram of Speed Regulation System is shown in Picture 1. Also in this study, a new Speed Regulation model that is different from traditional design and control strategies and has a lot of superiority is recommended Communication and system check between systems units shall be performed by a Profibus-DP network based model. In this method, it shall be possible to decrease the negative effects of factors which influence the quality of energy (precise control of turbine wicket gates, turbine speed and power measurement).

Because Profibus-DP network structure has a high speed of 12 Mbit/s in data transmission; and in communication between hardwares; data transmission shall be performed by Fiber Optic Cable and with that,

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advantages such as data security and reduction in network delay shall be obtained as well as data speed. It is an inevitable truth that in hydroelectric plants in which electric energy is produced by utilizing water power, the electric energy obtained from generator should be in desired frequency and power rating. The control for frequency and power ratings of the energy obtained in consequence of the control for water inlet amount to turbine is performed by the help of governor mechanisms.

The duty of governor system is to provide control of the turbine speed and power by regulating the water amount access to turbine. If more power is required, more water is provided to the turbine inlet by the help of wicket gates. Likewise, if less power is required, wicket gates are closed at a certain degree and thus less amount of water is allowed to access the turbine. In this way, frequency is obtained in desired value [2].

Since the power drawn by the user from turbine plant varies at times, it leads to a change in turbine speed, thus in its output voltage and frequency. When the power drawn from the system increases, turbine speed decreases depending on the strain of the alternator, thus voltage and frequency falls under the desired value. In order to bring turbine to its normal speed, more water is required to be taken into system. Similarly, when the power drawn from the system diminishes, turbine speed goes up depending on discharge in the alternator, thus voltage and frequency rises above the desired value. In order to bring them to their normal values, the amount of water access into the system should be lowered. For that, automatic control system is utilized. This system consists of a sensor measuring the turbine speed and a mechanism which regulates the amount of accessed water into the system by opening-closing the wicket gate according to information from sensor, in order to keep the speed constant. Regulators are used to control the turbine speed. Until recent years, all regulators used in hydrolic systems were providing power change by regulating the water to the turbine. A regulator's duty is, whether it is mechanical or electrical, to regulate the speed on turbine shaft. If more power is required, more water is provided to the turbine inlet and likewise if less power is needed, turbine inlet is narrowed thus less amount of water can be taken into turbine [3].

II. Speed Regulation in Hydroelectric Plants

Regulation and command are auxiliary actions which are used for automatizing a main operation. Duty of regulation technique is to control and regulate the physical magnitudes such as amount, pressure, number of revolutions or voltage on technical devices or of a material or energy in facilities, according to a plan given and designed in advance. In regulation operation, a previously given value of a magnitude is checked by a relevant unit of the regulator by being measured continuously. If any change occurs in the previoously given value - the desired value, this change is automatically adjusted by the regulator [2].

For the regulation of the speed of water turbines which are used in hydroelectric plants, generally the number of revolutions of turbine-generator shaft or an electrical magnitude suitable for this number of revolutions, is considered to be the input magnitude signal of turbine speed regulator. But in some circumstances, frequency or voltage of synchronous generator which the water turbine drives, can be selected as the input magnitude signal of speed regulator. A speed regulator used in hydroelectric plants drives the control mechanism of the turbine via special servo motors, and leads to a change in turbine's wicket gates or in spacings of its deflector by the turbine's nozzle needle, and thus effects a change in power of the turbine. However, during the change in the power, turbine's revolutions per minute remain constant. No matter how much the power of turbine changes, it is the main duty of the speed regulator to keep the revolutions per minute constant in desired levels. The different effects of electrical network on turbine's speed regulation varies according to operating conditions of turbine generator unit, whether in an isolated network or in the national electricity system or with other energy production facilities. Another point which should not be out of consideration for speed regulation is the voltage regulation circuit of the generator driven by the turbine.

Particularly, adjustment issue of voltage regulation circuit of a hydroelectric plant generator operating in an ohmic charged isolated network is very important for speed regulation. Because any change to occur in number of revolutions for the turbine and generator also leads to a temporary change in generator's voltage, and a change to occur in generator's active charge considerably affects the number of revolutions regulation circuit according to system status [4].

The regulation event performed by a regulator is generally caused by different events recorded below which occur automatically and in order.

A. Measurement (Control)

Identification of current value of a regulated magnitude, namely, of a magnitude desired to be adjusted by being subject to regulation.

B. Comparison (Comparing)

Comparing the current and desired values of any magnitude, it is desired to be by being subject to regulation.

C. Reinforcement and Establishment of Temporal Motion Rate

In other words, producing any value as control and adjustment magnitude.

D. Control (Adjustment)

Changing the energy current or mass movement until the desired value of any magnitude that is subjec to regulation is obtained [5].

Governor mechanisms are used in order to regulate turbine generator speeds in power systems. The idea of Governor was first studied by Clark Maxwell in an

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analytic way in the 19th Century. Governor system has gone through thre phases during its development. These phases are mechanic hydrolic speed regulator, analog electro-hydrolic speed regulator and digital electro-hydraulic speed regulator Digital electro-hydraulic governor system is divided into two types; one of them has full digital control, the other has analog control in hydrolic part and digital control in electrical part [6].

In mechanic-hydrolic speed regulators which were used until the mid 20th century, speed detection used to be made by the help of a mechanical mechanism in pendulum style.

Control mechanisms of mechanic-hydrolic governors are complex, maintenence-required systems that have high opening costs. Speed detection and speed-output settings in electro-hydrolic governor systems are electrically controlled and utilization of mechanical components are minimized. In this way; total efficiency of the system, hardware life and system's reliability shows increase. Since the costs of protection and speed detection units of such type of governor systems are high, they are more suitable to be used in large capacity hydroelectric plants [7].

Digital governor systems are the most used governor mechanisms today. The superiority of those systems are; they are able to react quickly for temporary states, can be remotely controlled, system can be launched and deactivated by one command and output power can be controlled according to network frequency [8].

III. The Developed Speed Regulator System

Boundary diagram of Speed Regulation System is shown in Fig. 1. Also in this study, a new Speed Regulation model that is different from traditional design and control strategies and has a lot of superiority is recommended. Communication and system check between systems units shall be performed by a Profibus-DP network based model. In this method, it shall be possible to decrease the negative effects of factors which influence the quality of energy (precise control of turbine wicket gates, turbine speed and power measurement). Because Profibus-DP network structure has a high speed of 12 Mbit/s in data transmission; and in communication between hardwares; data transmission shall be performed by Fiber Optic and advantages such as data security and reduction in network delay shall be obtained as well as data speed [9].

It enables the following activities only to be made by the program: checking of the designed system with Provirus-DP based control network, regulation of the system operation independently from hardware, easy renewal of the system, activating or deactivating input-output units. The characteristic of this study is an important superiority in this presented design as well as in automation systems.

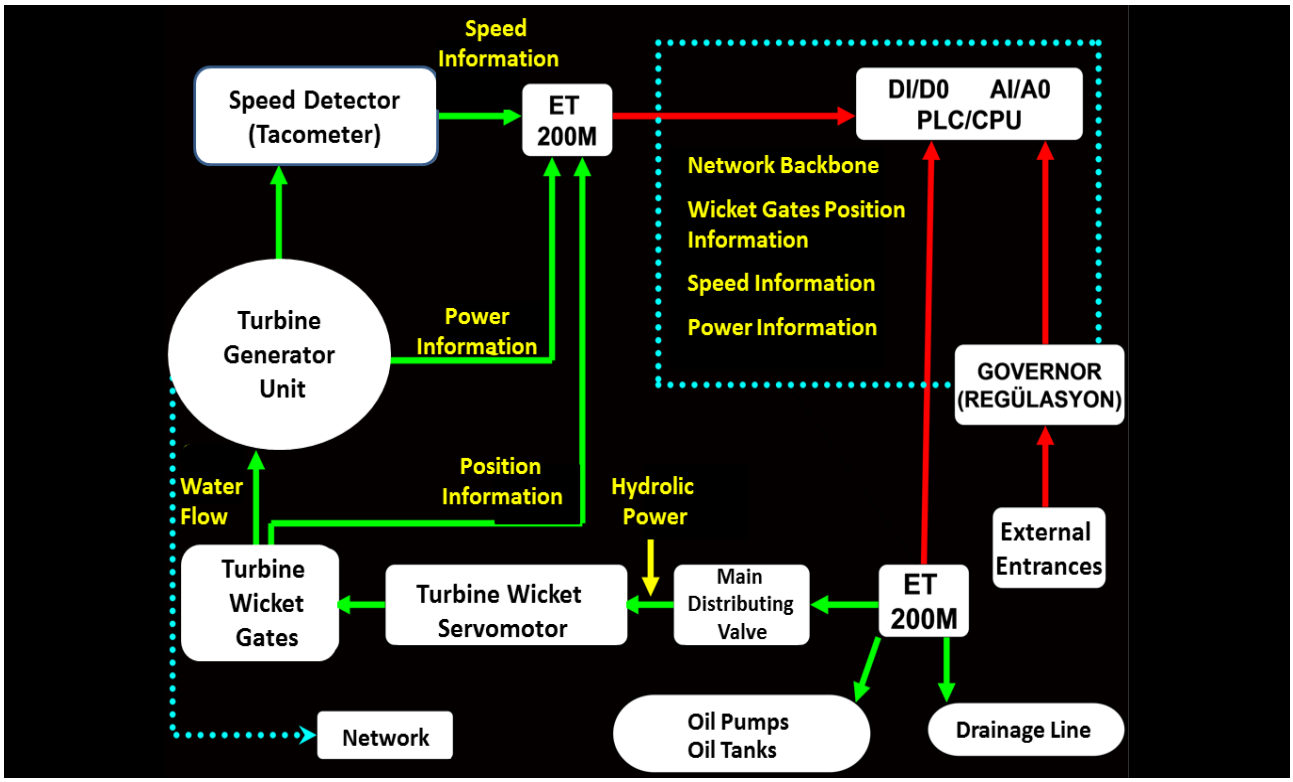

Figure.1. Block diagram of the project to be implemented

IV. Conclusion and Suggestion

The advantages of this system, which is performed as Profibus-DP and Fiber Optic infrastructure based, to other systems are it has higher reliability, design flexibility and option of being able to perform the desired intervention by the software. The developed governor system continuously measures the alternator's frequency

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(in 1 second intervals) and keeps it between 49.8-50.2 bandwith. If the frequency of alternator is between 49.8Hz-50.2Hz bandwidth, no intervention is made. When the alternator loads frequency, it goes down below 50Hz value which is the nominal frequency. In this method which is designed as Profibus-DP network based, it shall be possible to decrease the negative effects of factors which influence the quality of energy (precise control of turbine wicket gates, turbine speed and power measurement). Because Profibus-DP network structure has a high speed of 12 Mbit/s in data transmission, and since data transmission is carried out by Fiber Optic in communication between hardwares, data transfer is fast and advantages such as data security and reduction in network delay is obtained as well. It enables the following activities only to be made by the program: checking of the designed system with Profibus-DP based control network, regulation of the system operation independently from hardware, easy renewal of the system, activating or deactivating input-output units.

The characteristic of this study is an important superiority in this presented design as well as in automation systems.

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References

[1] M. T. Özdemir, M. T. Gençoğlu, and M. Cebeci., "Small hydroelectric hower plants instead of the classic turbine banki turbine michelle-business benefits of using," Fırat University Faculty of Engineering in Electrical and Electronics Engineering, 2002.

[2] A. Dalcalı, E. Çelik, and S. Arslan., "Design of a microprocessor based electronic governor system for micro and mini hydroelectric power plants," *Erciyes Univerrity Journal of the Institute of Science and Technology*, 2012.

[3] Tekno Tasarım A. Ş. And H. Başeşme, *Hydroelectric Power Plants and Hydroelectric Power Plants*, Ankara: EÜAŞ Publications, 2003.

[4] S. Akçay., "Load – frequency control at hydroelectric power plants," Master Thesis, Kahramanmaraş, 2007.

[5] Eker., "Robust governor design for hydro turbines using a multivariable-cascade control approach," *Arabian Journel for Science And Engineering*, vol. 28, no. 2B, Oct. 2003.

[6] J. Codrington, "The hydro turbine governor and why it is important to understand it," in *Proc. Electrical Power And Energy Conference*, Canada, Aug. 2010

[7] Guide For Selection Of Turbine And Governing System For Small Hydropower, Alternate Hydro Energy Centre Indian Institute Of Technology, Roorkee, May 2008.

[8] C. Yılmaz and O. Gürdal., "A comparison between classic with profibus network systems," in *Proc. Symposium on Modern Methods in Scienc*e, Kocaeli, 2005, pp. 557-564.

[9] Yenilenebilir enerji genel müdürlüğü. [Online]. Available: http://www.eie.gov.tr/

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