UDC 621.311.21-523+621.316.925

RECENT CONTROL AND PROTECTION TECHNIQUES FOR HYDRAULIC POWER PLANT

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1 FOREWORD

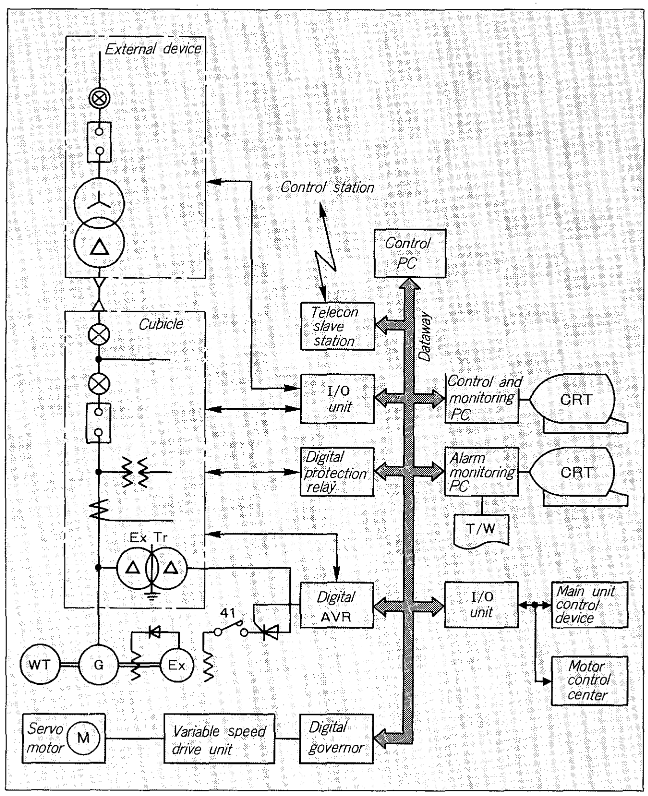
Programmable controllers (PC), which are digital control devices that use a microprocessor, were practicalized from the last half of 1965 and are now widely used instead of the conventional magnetic relay controller as a means of improving the reliability and simplifying the maintenance of hydraulic power plants. Recent rapid technical developments in the PC field have made sophisticated processing, high speed operation, and high speed transmission of voluminous data by dataway possible. CRT displays and other peripheral devices are also equipped. As a result, the construction of a total digital control system for hydraulic power plant encompassing not only the control field practicalized in the past, but also hydraulic turbine governor (called governor hereinafter), automatic voltage regulator (AVR), and monitoring and protection functions has become possible. This system at Fuji Electric is introduced here.

2 COMPOSITION OF TOTAL DIGITAL CONTROL SYSTEM

The composition of the total digital control system is shown in *Fig. 1*. The PC comprising each part can be dispersed or centralized according to the scale and mode of the plant and are connected through a dataway. Data can also be collected over the shortest data route by distributing the I/O units where data is concentrated. The size of the control panel can also be reduced by intensifying the functions of the digital controller previously mentioned.

System redundancy should be established according to the plant scale, topography, etc. For a medium and small hydraulic power plant, the parts comprising the control and monitoring function are based on single system use.

Fig. 1 Block diagram of total digital control system



3 MAIN FEATURES OF TOTAL DIGITAL CONTROL SYSTEM

3.1 Monitoring and control system

In the past, power plants were monitored and controlled with control switches signal lamps, indicators, etc. installed on the generator control panel. However, since the equipment installation space is limited relative to the amount of data of the entire power plant, the individual data was distributed to the local site and the minimum data necessary for operation was selected at the generator control panel.

With a total digital system, since the data from the PC and I/O units installed at each place are connected by a dataway, they can be used organically by using a CRT screen. The use of a CRT screen has the following features:

(1) Erroneous operation is prevented and the operating procedure of the central controller that has become popular in control rooms recently is standardized by

Fig. 2 Power plant control screen (example)

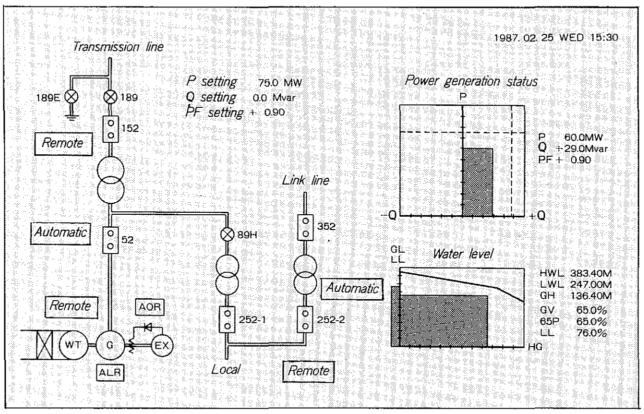
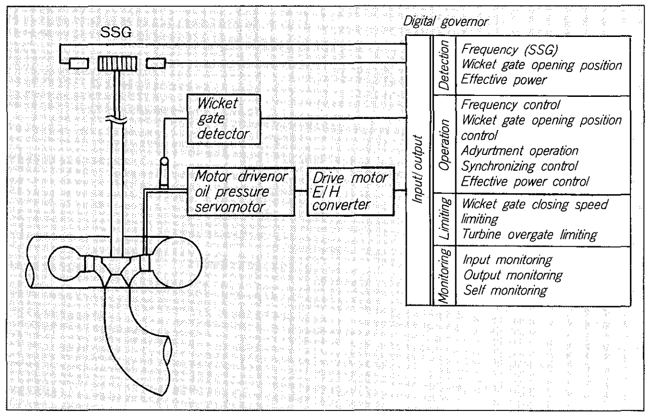


Fig. 3 Digital governor block diagram



selecting the equipment to be operated with special keys on a keyboard (or light pen, etc.) and sending out a command by operating a control pushbutton separate from the CRT after confirmation at the screen.

(2) Circuit breaker, etc. operation lamps also allow judgement of the charging place by equipment symbol and bus light emitting color change and can clearly display the status.

(3) Since sequence lamps can display characters near the related equipment and can show the sequence transition by making the hydraulic power plant a graphic, the status can be grasped more directly.

(4) The display contents of the measured signals can be switched according to the operating state. For example, at the main unit starting process, main attention can be focused on the wicket gate opening position, rotating speed, and primary controller set position measurement and during parallel in, the generator output, wicket gate opening position, and head can be superimposed on the plant status and measured. The optimum data at each time can be displayed in an easy to read form by using the advantages of the CRT screen in this way.

(5) Failure display can display generated failures only. Not only single items, but also the failure zone, generation and reset times, generation location, set value, and other detailed related items can be displayed and effective data presentation for positive phenomena judgement and resetting is possible. An example of a power plant control screen is shown in *Fig. 2*.

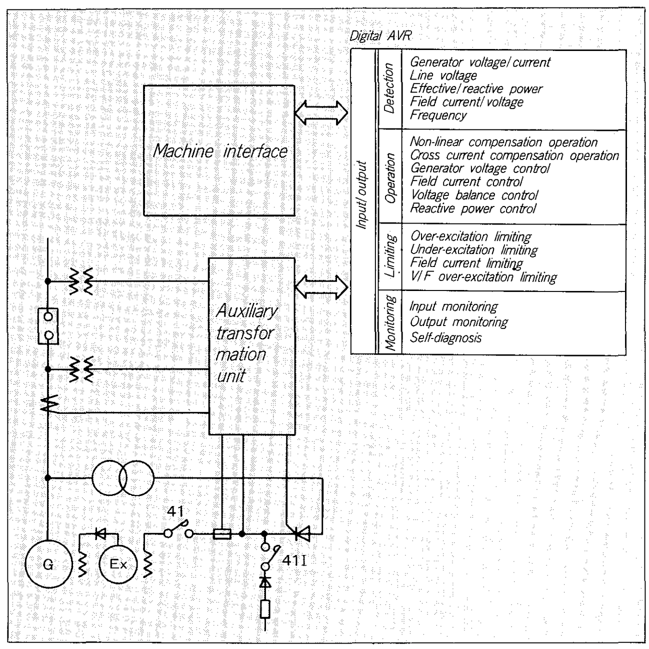
3.2 Digital governor and digital AVR

The digital governor and digital AVR use the functional processing and fast operation functions of the PC and have the following features:

(1) Operation is mainly PID, but controlability can be improved by incorporating the hydraulic power plant characteristics into this and performing nonlinear compensation.

(2) Converters can be eliminated by calculating the electricity amount from the voltage and current instantaneous value.

Fig. 4 Digital AVR block diagram



(3) The limiting function can perform limiting from conventional limiting by single setting to limiting by nonlinear operation and limiting according to external factors (voltage, frequency, etc.) and effective operation within the limits of the equipment is possible.

(4) Sequence control and other secondary control functions can be added, as required.

(5) Since monitoring of the entire system, including sensors and output, and processing when a failure occurs are easy, if failure at a PC or other important part is recovered, operation of the main unit based on the prescribed policy can be continued.

The digital governor block diagram is shown in *Fig. 3* and the digital AVR block diagram is shown in *Fig. 4*.

3.3 Failure monitoring system

Central control and unmanning of hydraulic power plants for operation rationalization is progressing, but inspection of power plants is entrusted to routine patrol by maintenance personnel, as in the past. The failure monitoring system uses current sensor technology and the information processing function of the PC as a means of maintaining and improving plant operation reliability, preventing of failures, and making patrol inspection more efficient and automatic by early detection of failures.

Since this system monitors the facility continuously while performing suitable input processing and judgement for data detected directly and indirectly, failures can be detected early and when a failure is detected, the relevant data before and after it can be displayed and printed and effective data for failure cause search and processing can be supplied. The data which is obtained continuously is gathered in report (daily report, monthly report) data, failure data, instantaneous value data, and other block units and stored in an external storage unit and past and current data can be printed arbitrarily and long-term changes of devices by comparison, etc. can be judged.

A system which constantly monitors the state of the power plant even at a control station can be built by adding a transmission unit to the system and displaying the necessary data at the control station and power plant. As a result of an overall study of the degree of affect at failure generation, number of failures generated, and other past data, the following items are monitored: Bearing temperature and oil surface, vibration, hydraulic system oil leakage, water supply amount, air leakage, sequence operation, auxiliary equipment operation.

3.4 Digital protective relay

3.4.1 System composition

The digital relay unit using a microprocessor and is the basic hardware unit of the digital protective relay. The protective relay for hydraulic power station has the system composition shown below from the standpoints of reliability and economy.

(1) The generator and transformer protective relays consist of one digital relay unit.

(2) Normal dupleted series, independent operation when a failure occurs is possible by using two digital relay units.

The system block diagram is shown in *Fig. 5* and description of protective relay is shown in *Table 1*.

3.4.2 Characteristic of protective relay

A generator protective relay demands high accuracy over a wide frequency band from low frequency at generator starting to the frequency rise region at tripping of the load. Since the objective of the arithmetical algorithm of the distribution substation digital protective relay is the power system rated frequency, it cannot be used directly for this purpose. Therefore, a wide frequency regulating algorithm which adds correction by using the number of sampling data of one cycle of the power system input is used for generator protection.

The frequency characteristic of a generator protective overcurrent relay algorithm is shown in *Fig. 6*.

Fig. 5 System block diagram

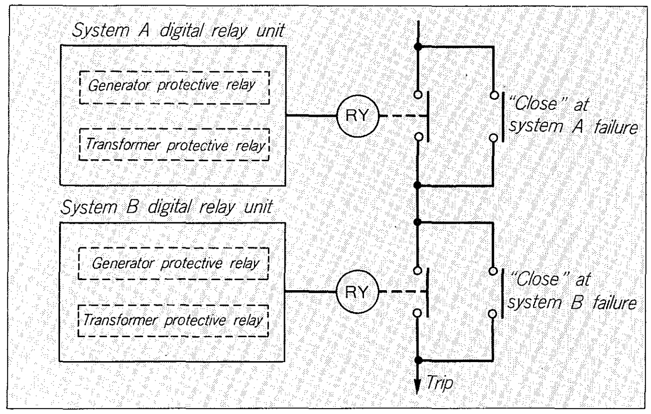
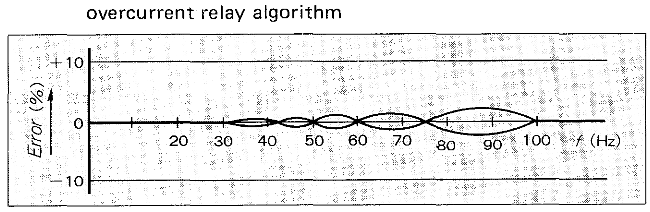


Table 1 Discription of protective relay

Application	Device number	Protective relay name	Purpose of protection
Generator	87	Percentage differential relay	Internal short circuit
	87G	Percentage differential relay	Internal short circuit
	59	Overvoltage relay	Overvoltage
	40	Loss of field relay	Loss of field
	51	Overcurrent relay	Overcurrent
	64N	Grounding overcurrent relay	Grounding overcurrent
Transformer	87T	Percentage differential relay	Internal short circuit
	64T	Grounding overcurrent relay	Grounding overcurrent
	51T	Overcurrent relay	Overcurrent

Fig. 6 Frequency characteristic of generator protective overcurrent relay algorithm



3.4.3 Automatic supervising

When a failure occurs at a device, it is detected by an automatic supervising system consisting of an automatic checking system and continuous monitoring system, and operation reliability is improved by automatically switching to independent operation of the healthy system of a normal duplexed series system.

For quick repair of failures, a failure indication function is provided for each hardware block.

3.4.4 Construction of equipment

The protective relay equipment consists of a power source unit, digital relay unit, checking unit, auxiliary relay unit, and input converting unit and is housed in a 700 mm wide standard control panel.

The digital relay unit is shown in *Fig. 7*.

Fig. 7 Digital relay unit

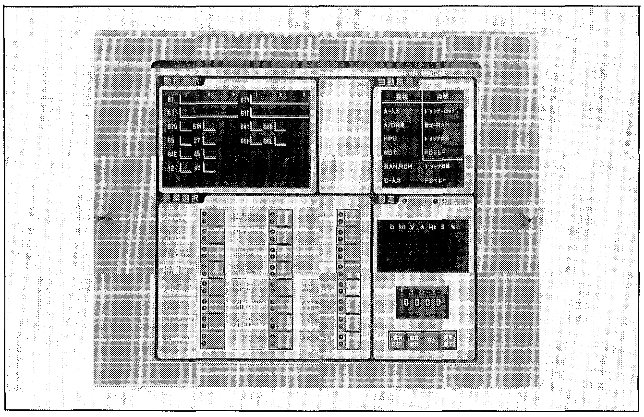


Fig. 8 Block diagram of brushless servomotor controller

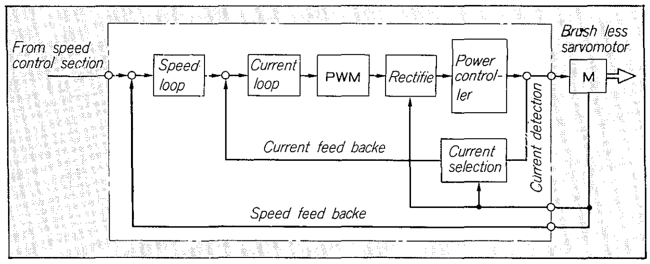
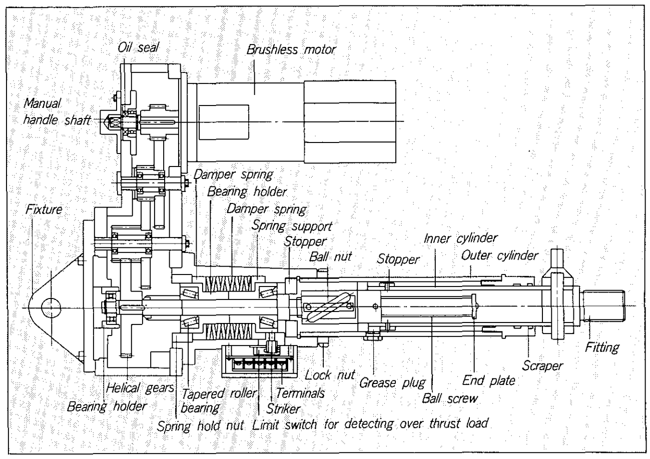


Fig. 9 Motor-operated actuator



4 MOTOR OPERATED HYDRAULIC TURBINE DIGITAL GOVERNOR

This section introduces the motor operated hydraulic turbine digital governor recently used frequently with small hydraulic turbines. It incorporates the newest electronic technology and mechatronics technology and has excellent stability and quick response for improved functions and has the following features:

(1) Same performance as the conventional electro-hydraulic governor.
(2) Since pressure oil equipment is unnecessary, the turbine facilities can be simplified considerably.
(3) Compact size so that installation space can be used effectively.

As shown in the digital governor block diagram of *Fig. 3*, besides a digital governor by PC, it consists of a frequency-detecting toothed disk, proximity switch, wicket gate opening position detector, brushless motor controller, motor operated actuator which converts rotation into linear position etc.

4.1 Speed detecting unit

Rotating speed detection uses a digital rotating detection system by toothed disk and proximity switch and can detect rotating speed from near zero speed up to overspeed. The wicket gate opening position is detected electrically by electrostatic capacitance change and is input to the digital governor.

4.2 Brushless servomotor controller

This unit controls a brushless servomotor with the output signal from the digital governor. It detects the rotor position and passes a current through the stator winding in accordance with this signal and drives the brushless servomotor by controlling the value of this current. Therefore, response is extremely quick and stable operation down to very slow speeds is possible.

The block diagram of the brushless servomotor controller is shown in *Fig. 8*. The following features are obtained by using a brushless servomotor:

(1) Since there are no brushes, maintenance is reduced considerably.
(2) The wicket gate can be held at a fixed position by the motor torque while the turbine is operating and a brake for position keeping is unnecessary.
(3) Quick response and good speed control operation for torque changes requested from the wicket gate is possible.

4.3 Motor-operated actuator (motor-operated servomotor)

The motor-operated actuator is a so-called mechatronics product which converts the rotation of a motor to linear operation. A ballscrew and nut are used at the actuator. It has high transmission efficiency, low friction and long life, simple lubrication, and other advantages.

The construction of the motor-operated actuator is shown in *Fig. 9*.

5 CONCLUSION

Recent control and protection techniques for hydraulic power plants were described above. In the future, development of suitable interfaces by digital control will advance with the advance of application of microprocessor-applied technology and total digitalization in the broad sense will advance.

Development of larger capacity motor-operated servomotor technology is urgent business to meet the strong demand for an oiless power plant.

Efforts in improving plant operation reliability and unmanned maintenance by introducing these new techniques will be made in the future. The guidance and support of users is requested.