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PRESENT STATUS AND PROSPECTS FOR DIGITAL CONTROL TECHNOLOGY

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1. FOREWORD

The insatiable pursuit of man for things that are better, things that are easier to use, things which can be made with more confidence, etc. and the cycle of efforts to meet this are continuing without limit. Electric power field control technology, which is a full-grown technical field, is no exception. In past, the function of individual control devices responsible for each function part of each machine system were expanded by riding on the wave of such a cycle. As a result, the development of information processing technology also participated and this trend is advnacing steadily. On the other hand, from the standpoint of the appearance of demands which cannot be realized without a wide range of unification, a state in which more satisfying control is realized by this has started to appear.

From the standpoints of cost and reliability also, the fact that higher performance was made possible by parallel processing techniques in application digital hardware processing by the advance of semiconductor technology. However, when viewed by those responsible for control, the rational direction must be aimed based on the simple mental attitude "use with greater confidence". This paper describes the status of digital control technology at Fuji Electric and introduces the direction of research and development with while adding the prospects.

2. ENVIRONMENT OF CONTROL SYSTEM

2.1 Historical background

Looking back on the technical development process from mechanization to automation of the industrial world in the past,

(1) The 75 years between 1801 and 1875 were the age of energy engineering in which so-called mechanization progressed and the use of prime movers and other energy, etc. became the mainstream of the point at issue.

(2) The 75 years between 1876 and 1950 were the age of organization in enterprises and various work machines were introduced and the use of time was mainly discussed. Company strategy of the latter half was based on simple forecasting.

(3) The years after 1950 were the age of automation. Information systems were introduced and it became the age of information engineering in which the use of knowledge appeared at the surface. Company strategy also advanced to the age which was built from entire systems unified around computer aided plan models.

The present status and trend of electric power field control technology in the facing of this industrial world infrastructural environment toward unification are searched for.

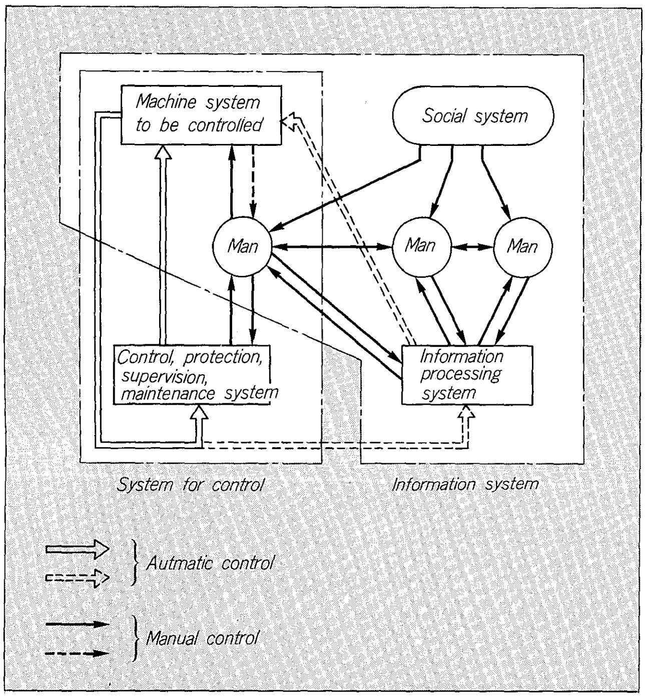
2.2 Composition of systems for control

Formerly, most devices for electric power substations and devices for transmission and distribution systems which make up a power system were controlled by devices with discrete functions, such as regulating control, sequence control, supervision, and protection. Of course, there were also systems which coupled devices in a certain function range as a system and were controlled harmoniously. However, they were not things which spanned a wide maintenance range of each device as described below. In contrast to an information system, a system with the functions of these devices is called a system for control.

As shown in *Fig. 1*, the feature of the information system of this system is that, directly speaking, the objective machine is operated directly. Therefore, special attention was given to the device itself and its operation contents. For this reason, the ideal "Simple is best" became the center. However, since the semiconductor has come into use in control devices and information processing system, they have become systems for control which can perform complex processing sequentially by the achievements and technical progress of 30 years.

As the components of such systems for control, individual devices with various functions and the objective machine system of the devices for electric power substation and devices for transmission and distribution system which attempts to described the trend below are first. In addition, the system also includes the human system which fills the function gap that exists between the objective mechanical system and the function of each device and performs setting and maintenance for each device.

Fig. 1 System for control and information system



These devices data process arithmetic, logical, and symbolic expressions. The properties of variables may also mostly belong to the decision logic range.

Moreover, the output from devices is also converted to a form suitable for the machine system. A man-machine interface, which is the contact point with man, sufficient to test the machine system to be controlled and each device was good enough. However, recently, an intelligent interface that performs initial pattern information processing, for example, has appeared and has blurred the boundary between control system and information system.

Conversely, when information systems are viewed from the standpoint of control, they are used to assist man to fill the function gap between the functions of each device and the functions between devices of the control system. Therefore, the processing objectives of an information system has expanded up to pattern information and text and knowledge itself, besides the same objectives as a control system. Naturally, since man is the output objective, total energy is being put into conversion to a form which can be most easily understood by man.

3. CONTROL SYSTEM TRENDS

The machine system which is the objective of the devices in the control system may be independent or may make up a system. *Figure 2* arranges their operation in a form in which can be recognized as a control system. Even in such a form, the control system was corresponded by discrete device as shown in *Fig. 3*.

For instance, for control devices, most regulating control was centered about the running condition. Even for sequence control, starting and stopping and shutdown by signal from protection devices in the running condition

Fig. 2 Control system status transition

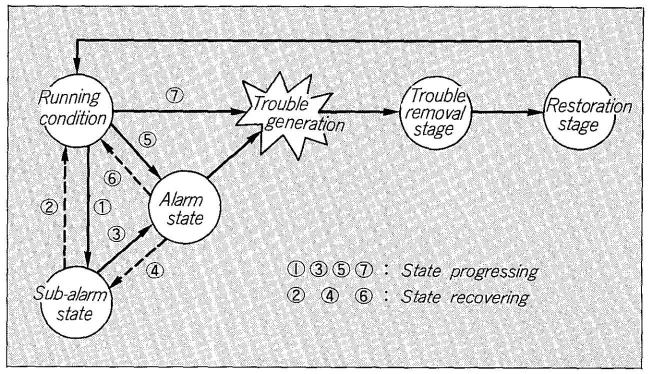
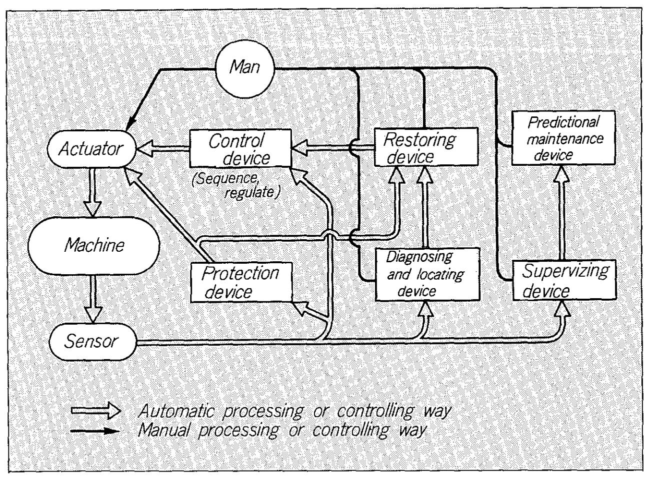


Fig. 3 Relationship between corresponding device and man at each state of a control system



were the objective. As the final target of control, setting of the controlled variables to the target value as positive and fast as possible is given as number one.

At this time, engineering wise, they must be handled with confidence. (Related to robustness) The smallest possible number of inputs is desirable from the economical standpoint and the smallest number of manipulated variables is desirable from the standpoint of reliability. However, these and control performance generally have a tradeoff relationship. It is no exaggeration to say that the change of control logic was a war waged against a technical background. Looked at historically, the control method changed from forward control to feedback control and forward functions accompanying prediction were added and a simple mathematical model was base the standard and method and other innovations matched to this model were made. When this is developed further. because of the complexity of the objective system, etc. at the present time, for even parts which depend on manual operation, there is a connection with the appearance of the "in-line-simulation" which simulates the response of the objective system to the pertinent operation before operation and performs the operation after verifying the result, etc. If only an evaluation method is established for the response of the system, the dream of complete automation will be lost.

Moreover, the number of state variables has changed

Moreover, the number of state variables has changed from single variable to multiple variables and the time domain has changed from continuous to sampling and sampled-data control was introduced, which has not become the mainstream. However, recent so-called digitalization is complex, which must be handled by discrete control theory, but it is used on continuous control theory under the condition of sufficient high speed sampling interval. Of course, control methods based on deterministic variables, variables which must be handled stochastically, and sensual information with vague characteristics are being offered for practical use. All of these are the product of digitalization. Furthermore, reduction of the cost of memory provides an opportunity for conception and research of control devices with a simple configuration, etc. as opposed to the supporting movement by study. Protection devices detected fault generation and were the center of the means of preventing the spread of the fault, that is, the fault removal stage. Taking a power transmission system as an example, protection devices with a trouble-shooting function incorporated and which are connected to an advanced man-machine interface have appeared.

The reclosing device for transmission line used from the past are simple restoring device for distribution which receive signals from the protection device and diagnosing·locating device of *Fig. 3* and reclose the circuit breaker tripped by a fault after the predicted arcquenching time. However, there is a chance that the protection device may or not operate erroneously and make the system trouble condition complex. Therefore, most operations at the suitable fault point judgement and fault restoration stage must depend on the hand of a veteran even when the system is not complex. However, it is said that the possibility of automation was seen by expect system application research of the last several years. On the other hand, regarding transmission line protection devices themselves, research on a more direct and more positive fault detection method by using OPGW (optical fiber on guad wire) is progressing. This trend is not limited to power transmission systems, but research and development is also being conducted in the same direction for system components.

The next stage will be the approach to taking preventing action at the stage before fault generation. It is thought to advance in the direction in which the subalarm and alarm state of *Fig 2* can be recognized. This is the part which must be reached to advance reliability one step. Its realization will cause a basic change in the maintenance mode. Presently, it is advancing in the area judged to be where the vanguard phenomena is appearing comparatively noticeably. For example, regarding the self-supervision function of protection devices, technology which measures the degree of fatigue of material in the alarm state and predicts the time for it to reach destruction, etc. are said to be the beginning of recognition for sub-alarm states.

As previsouly discussed, application of AI technology to control is effective as one mode of unification of control system and information system. Regarding this also, development to operation guidance, partial automation via recognition by man and finally to complete automation in the .same order as the process that applied control by computer to machine systems in the industrial field in the past, that is, beginning from trial, is observed.

4. CONCLUSION

Control systems are being unified with information systems, which originally supplements between devices with various functions inside it and the system itself. Control systems are being developed to unified systems which meet more advanced needs by means of this.
However, this does not mean a collection of hardware and "use with confidence" must be made the foundation from the standpoint of control. Hardware-wise, the current trend is toward an internal composition of distributed and individual devices and higher speed, higher performance, and higher reliability by parallelization by making the discrete parts simple and coupling them as tightly as possible. Happily, VLSI (very large scale integrated circuit) which make this possible are appearing. On the other hand, software-wise, making it possible to secure autonomy at each distributed part is a precondition. Development of a practical distributed data base that make coupling and autonomy possible and which withstands control field use is the base. Because a obtaining better results is being attempted based on information from related environments, it is said to be the age of mass data. If the receptacle capable of handling diverse data efficiently is made a data base, it will become the key to unification of a control system that can be sued safely and positively in time.

This special issue concentrates on the generator control system which is the main machine of gigantic electric power system and introduces digital system application examples.