ROLE OF HUMAN OPERATOR IN CLOSED LOOP CONTROL SYSTEMS

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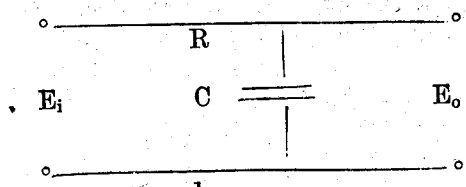
ABSTRACT

This article gives a brief account of a particular aspect of human engineering which aims at improving the efficiency of working of a complicated machine, not by improving upon the machine itself, but by simplifying the operating procedures for the operator who has to run the machine. A human operator has been treated like a servocontrolled machine. It has been stressed also that probably a man and a machine are basically different; the former often acts in peculiar ways whereas, the latter generally behaves in a manner bound by its design which is extremely flexible in the case of a man.

To a layman this title might sound a bit queer or sophisticated but generally speaking even to a man of science the subject is highly complicated. A system in which control is error-actuated, i.e. control is guided by the deviation of the actual quantity from the required quantity is called a closed loop control system. The technical name of such a control is servo-mechanism examples of which are numerous in this age of everything automatic. At a moment's thought one can visualise that all human activities are also servo-controlled operations. Take the case of any sensory organ, as for instance, ear, eye, etc., these supply the stimulii for doing a certain work and the motor nerves actuate the muscles depending on the impression of the particular sensory organ for the object position. Automatic machines and apparatus are, however not exact replica of the human machine. On the basis of different classifications of automatic machine or servo systems it can be presumed that human servo-systems are almost exclusively non-linear or discontinuous. This means that the transfer function (as explained below) between the input and out-put quantities are not well defined and hence the frequency response, stability and transient response of such a servo system are difficult to estimate. Advancement in the handling of non-linear servo systems and determination of basic servo equations, if any, of human systems are sure to throw light on the subject.

Transfer Function.

Consider a simple electrical network as below



In this circuit $E_o/E_i = \frac{1}{1+TD} = f(D)$, where $T=RC=$time

constant of the network and D=d/dt while f(D) is called the transfer function of the circuit. Knowing this function it is possible to find out the transient and steady-state behaviours on the frequency response with the help of conventional mathematical analysis.

Attempts have been made to find out human servo equations by using different working models by Tustin and others. Interesting observations have been made but no definite conclusion could yet be reached. Tustin postulated a linear law for a human operator on the basis of the results of his investigations on the response of human operator to controls.

Tustin's linear law for human operator

$$PH=K(1+T_1P)\exp(-T_2P)\,E$$

where H=displacement of a handle operated by the human operator

E=displayed error

T_1=exponentical time constant of the human operator

T_2=the dead time of the human operator

P=d/dt

and K=constant.

This is an empirical law and Tustin himself had reported cases which had marked deviations from this. However, further research under more complicated situations than those in Tustin's experiments as for example, on the response under various types of controls, such as, position, velocity or acceleration along with the effects of resistance and inertia in the controls may give valuable results.

The basic difference between a man and a machine is that the former is liable to act in very many ways, whereas the latter can do in one and possibly only one way under identical circumstances. This comes from the power of judgement which a man possesses but a machine does not. Thus it is possible to devise and design a machine that will faithfully give certain definite performances in an already chalked out manner within a certain period of time but it is almost impossible to say whether a man having such previous knowledge of the work can give exactly similar demonstrations. In practice, we find, man cannot for he has one outstanding distinction from the machine "in "time-lag" better known as "reaction time", between thought and physical action. This reaction time is different for different sense organs and further perception and reaction time interval for a particular organ also vary with the character and frequency of the stimulus, environment and psychological factors. It is therefore quite evident that it is difficult to generalise about the behaviour of human machine although there is no denying the fact that even a near approach towards a correct formulation of human servo machines or human controlled mechanism will solve many problems of closed loop systems where the role of a human operator is still indispensable, as for instance in very vital defence problems like anti-aircraft gunnery or piloting on aircraft.

References

1. A. Tustin, J. I. E.E., Part IIA, 1947 (May)

2. A. Porter, An Introduction to Servo-Mechanism (Book).