Excel Journal of Engineering Technology and Management Science
(An International Multidisciplinary Journal)
Vol. I No. 4 January - June 2013-14 (Online) ISSN 2277-3339

IMPORTANCE OF FEEDBACK CONTROL SYSTEM

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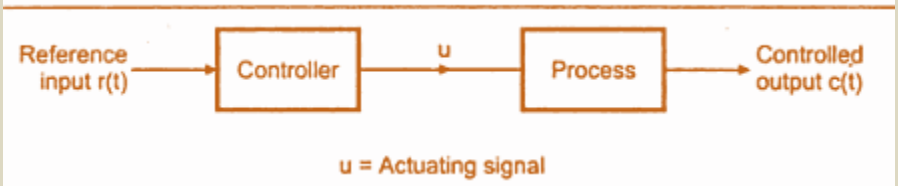
INTRODUCTION

The control system is a field of study in which the system is to be controlled. The system has been given different names like Process, Plant. Basically it came into existence from 1900-1940 eras. During Second World War, the need of radar system, airplane pilots led to the theory of servomechanism. It means slave to command. Today every system we see has some type of control system. For example a ceiling fan is an on/off controller, an air conditioner with smart cooling which adjusts its cooling by taking feedback from room temperature. Even our human brain is also a control system. It follows command given by brain.

SYSTEM WITHOUT FEEDBACK

Let's take a system where we give an input to a controller. The controller is intelligent. It reacts to command input or reference input r (t) and generate a manipulated variable or actuating signal u. The manipulated variable forces the system response or controlled output c(t) to follow the manipulated variable. For this, it has to be passed through the process or plant. The disturbance signal acts on plant. It is an uncontrolled parameter. The disturbance may be acting externally that is due to change in environmental conditions or internally that is within a system. The controller is designed for a specific disturbance signal and if anyhow, disturbance changes due to internal or external conditions then the controller which is designed for a particular disturbance may not be as effective as for this disturbance. This way we will not get the desired result. In literature, we call this system an open-loop system because loop has not been closed to give information of current status of controlled output. It is shown in figure below.



SYSTEM WITH FEEDBACK

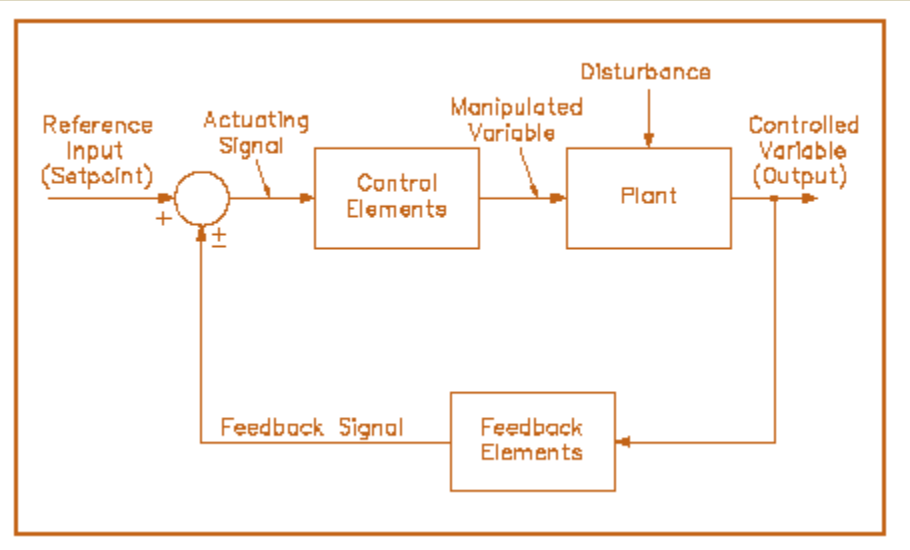
In open loop system, our requirement was not fulfilled. For this reason, another system came into account known as system with feedback or error self-nullifying process.

The Key feature of this system is:

A. The controller is more intelligent enough to work effectively when disturbance changes. It now knows the information of disturbance signal and controlled output.

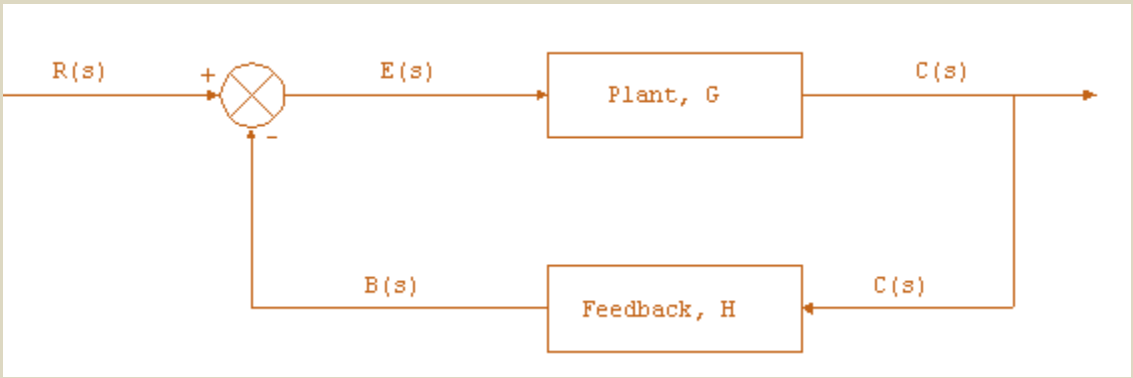
B. Sensor is attached to the system as a feedback element which senses the change in response and controller is informed.

The basic frame of system with feedback is given below:



The user gives input in the form of command signal or reference signal. The reference input is converted into actuating signal through actuator element. The reference input is fed to control element or controller and produces a manipulated variable. It then flows to plant or process and generates a controlled output. The disturbance acting on plant if somehow changes then the sensor present as a feedback element senses it. The sensor knows the current status of controlled output and it generates a feedback signal. The controller here is more intelligent and it compares the feedback signal and reference input and produces an error signal and forces controlled variable to follow reference input. In this way, we achieve the desired result. In literature, we call it as a closed loop system.

The simplest feedback system was designed by Harold S. Black. He designed a feedback to amplifier.



Where: R(s) =Reference signal

E(s) =Error Signal = R(s) – B(s)

C(s) = controlled output

B(s) =Feedback Signal

He attached an attenuator as a feedback element. He observed that due to feedback, Gain is reduced from A/ (1+AB) to 1/B. The system also becomes less sensitive to disturbances and environmental conditions but instability increases causing oscillations.

REQUIREMENTS OF CONTROLLER

a. Controller should be made **Robust**. The control system works well when output follows the input. For this, the controller should be intelligent enough to compare the reference signal and feedback signal and generates an error signal.
b. **Accuracy** should be maintained in the system. As the time passes, the system loses its accuracy. The controller should be designed in such a way that it gives precise results.
c. Controller should be **less sensitive** to environmental conditions and change in parameters.

DESIGN OF CONTROLLER

The controller should be designed keeping in view the above requirements. There are basically three approaches for its designing .Its overview is given as:

a. Experimental approach

In this approach, the controller is installed based on practical experiment. Its value is changed on line looking into the change in disturbance signal. It is a non-linear model and it completely relies on experimental knowledge. This approach in literature is known as controller tuning.

b. Model Based or Analytical approach

If the system is too complex to be tuned then this approach is used. The dynamics of the model is captured in mathematical form. It may be represented as differential equation, Transfer function and state variable model. It relies on quantitative knowledge. It gives more information about characteristics of controller. This approach can be represented as either by physical laws or experimental laws or system identification. The observation says that controller designed by this approach is far better than previous approach.

c. Knowledge Based approach :

It is on the stage of active development .It is actually an expert control approach. Here an operator is placed in the system. The fuzzy control, neural network are playing role in this approach.

There are two methods of design:

A. Classical methods of design:

It is basically frequency domain design. It started from 1940-1960. The closed loop system or system with feedback is highly accurate but instability arises due to accuracy. There is a trade-off between these two factors. Various stability approaches came into account for this.

i) Harry Nyquist creates Nyquist stability criteria.
ii) Henry Bode came with bode plots
iii) Root locus method was made.

These three methods were designed for achieving stability to feedback system.

B. Modern Methods of design:

It is basically a state-space method of design. It started from1960 onwards. It was designed for tracking space vehicles and scientists assumed that it will replace classical method but ninety percent of industries still prefer classical methods of design.

ADVANTAGES AND DISADVANTAGES OF SYSTEM WITH FEEDBACK

The closed loop system or system with feedback has numerous advantages as follows:

i) The accuracy of this system is very high because the controller manipulates the signal to generate zero error signals.
ii) It becomes less sensitive to non-linearity and environmental changes.
iii) The bandwidth of this system is very high.
iv) Sensor plays a vital role. It senses the response and generates the feedback signal.
v) This type of system is more reliable and faster.
vi) This system is robust as compared to open loop system due to feedback.
vii) It is an automatic adjusting system where an intelligent controller adjusts to reduce error signal and make response follow the input.

In spite of its advantages, it suffers from the following drawbacks:

i) The sensor inside as a feedback element produces unwanted high frequency noise. It can be eliminated by injecting a noise filter in the system.
ii) Instability arises due to accuracy causing oscillations It can be made stable by using many methods like root locus, nyquist stability criteria, bode plot.
iii) Though the system is quite fast but sometimes time lag is introduced due to feedback.
iv) Its design is complicated hence it is costly as compared to open loop system.

PRACTICAL IMPLEMENTATIONS OF CLOSED LOOP SYSTEM IN VARIOUS FIELDS

A. Designing an unmanned aerial vehicle:

A fixed wing aircraft was chosen to simplify some of the characteristics of flight and to avoid some of the challenges found in rotary wing machines. Two aircraft were tested: a large and heavy gasoline powered aircraft and a smaller and lighter electric powered sailplane. An autopilot was implemented into both platforms that would fly the aircraft and allow the measurement of flight vehicle characteristics. A link with the vehicle was created to allow communication between the autopilot and a ground computer. This allows updates to the controllers PID feedback loops to change flight characteristics and made the recording of flight parameters possible. To control the vehicle remotely, a ground computer was used. It also allowed the programming of flight plans to the autopilot. Combining these systems together proved successful and stable flight. Hence feedback system is practically implemented.

B. Bio medical control :

Successful application of control system has emerged in two key application areas: cardiovascular system and endocrinology. Ventricular assist devices (VADs) are exploring feedback and model-based control to compensate for changes in patient needs. A more recent development is the use of magnetic levitation in the World Heart Inc. ventricular assist device called Levacor. World Heart recently received an FDA investigation device exemption (IDE) in preparation for clinical trials. The control system is a hybrid passive/active magnetic bearing where the active magnetic bearing employs a single active feedback loop designed by loop shaping. A key component of the technology is the high-reliability electronic design which transferred from aircraft control systems to this device.

C. Implementation in power system:

i) The Generic Power System Stabilizer (PSS) block can be used to add damping to the rotor oscillations of the synchronous machine by controlling its excitation. The disturbances occurring in a power system induce electromechanical oscillations of the electrical generators. These oscillations, also called power swings, must be effectively damped to maintain the system stability. The output signal of the PSS is used as an additional input (vstab) to the Excitation System block. The PSS input signal can be either the machine speed deviation, dw, or its acceleration power, Pa = Pm - Peo (difference between the mechanical power and the electrical power). The Generic Power System Stabilizer is modeled by the following nonlinear system.

To ensure a robust damping, the PSS should provide a moderate phase advance at frequencies of interest in order to compensate for the inherent lag between the field excitation and the electrical torque induced by the PSS action. The model consists of a low-pass filter, a general gain K, a washout high-pass filter, a phase-compensation system, and an output limiter. The general gain K determines the amount of damping produced by the stabilizer. The washout high-pass filter eliminates low frequencies that are present in the dw signal and allows the PSS to respond only to speed changes. The phase-compensation system is represented by a cascade of two first-order lead-lag transfer functions used to compensate the phase lag between the excitation voltage and the electrical torque of the synchronous machine.

ii) In an interconnected power system, as a power load demand varies randomly, both area frequency and tie-line power interchange also vary. The objectives of load frequency control (LFC) are to minimize the transient deviations in theses variables (area frequency and tie-line power interchange) and to ensure their steady state errors to be zeros. When dealing with the LFC problem of power systems, unexpected external disturbances, parameter uncertainties and the model uncertainties of the power system pose big challenges for controller design. Active disturbance rejection control (ADRC), as an increasingly popular practical control technique, has the advantages of requiring little information from the plant model and being robust against disturbances and uncertainties. The controller is constructed for a three-area power system with different turbine units including non-reheat, reheat and hydraulic units in different areas.

CONCLUSION:

The control system has been widely used in all the sectors. The open loop system suffers from various drawbacks but feedback system has replaced several problems since second world war. The feedback system is used in day to day activities. The aim of using this system is to control the process or plant effectively and error should be reduced to zero. It very well minimizes the error but the main drawback it has suffered from is system instability due to high accuracy. Many scientists worked on its stability and achieved to some extent for example henry bode created bode plot and harry Nyquist made Nyquist plot. Through these methods the problems somehow disappeared. Without feedback ,the system may not work effectively and we will not get desired result. Feedback element and controller is the heart of the system. Through intelligent

controller which compares the actual output from desired output and generates an error signal and sensor as an feedback element, a lot of new areas of study has been appeared. The bio medical field is the recent one. Through control system , we can now measure blood flow in a patient's limbs and determine the level of spinal cord or peripheral nerve stimulation required to improve blood flow, thereby reducing ischemic pain in the limbs. Closed-loop temperature control has been employed in ablation systems (such as the Atakr from Medtronic) with thermocouple feedback for safety. Though the sensor used as a feedback element produces unwanted high frequency signal in the system which creates disturbances. This problem has also been solved by injecting noise filter in the circuit which filters all the noise and disturbances. This system is comparatively faster and very reliable. The sms feedback system was launched in dutch to help the rural community. The same feedback principle was involved. The rural people were sending messages in which they were describing their problems and difficulties and government was helping them through this feedback. So looking at its various advantages and applications, I think that our industrial sector is incomplete without feedback. Though it is also emerging in other fields as well like medical field. In recent years it will be spreading its wings in all the fields of study and research.

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