Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

# Unit 16: Instrumentation and Control Systems

# Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

# Control Concepts

# Contents

# INTRODUCTION

**Analyse the control concepts used within a process**

- Recognise system terminology and concepts, including distance velocity lags, capacity, resistance, static and dynamic gain, stability, feedback types, open and closed loop, feed forward control and control algorithms.
- Investigate system tuning techniques, including Zeigler-Nichols, continuous cycling, reaction curves, decay methods and overshoot tuning.

# GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

**Purpose**

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

**Theory**

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

**Example**

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

**Question**

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

**Challenge**

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

**Video**

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

# 3.1 System Concepts

It's important that engineers are aware of some of the concepts involved in real-world control, digital simulations require a lot of assumptions for effective computation.

## 3.1.1 Distance/Velocity Lag

Distance/velocity lag is the delay involved between the input and the output. For example, the boiler in a house may be switched on, with the thermostat regulated to a given value, however, the boiler is not switched on and the temperature of the house and the water immediately turns to the temperature set by the thermostat, it needs to warm up. Fig.3.1 shows the temperature reading of the temperature compared to the value set by the thermostat and demonstrating the distance/velocity lag.

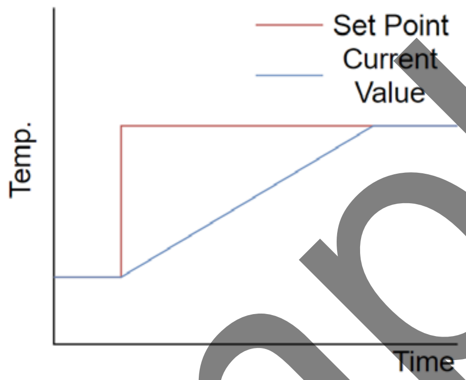


*Fig.3.1: Distance/velocity lag example*

## 3.1.2 Capacity

Capacity can be considered the limit of a system, or how much of a physical quantity the system can hold. Such as the amount of fluid a container can hold, how much weight a machine can operate with, or the amount of charge a capacitor can hold. Adding to a system already at capacity can cause several problems, whether it is mechanical failure, electronic failure, loss of product, hazardous spillage, or, in the case of pressurised systems, explosions.

## 3.1.3 Resistance

Resistance occurs in all forms of motion. No system is 100% efficient, and we must consider any and all resistances that will limit the output of the system. By not accounting for resistance in calculations, accuracy is lost. Sometimes it is too difficult to account for all resistive forces, and sometimes it is possible to overlook small resistances, but these small resistances add up. Most engineering systems will incorporate a "safety factor" a multiplier employed to ensure that any small resistances overlooked are more than compensated for.

## 3.1.4 Gain

The gain is given as the ratio of the input to the output, when considering the gain of the system it is important to consider both the static and dynamic gain.

**Static Gain –** The static gain is the gain of the system when it is stable. If the input remains constant, and the system is stable, then the output will begin to revert to its steady state.

**Dynamic Gain –** Dynamic gain is the gain of the system as it is adapting to a variation in the input. Unlike the static gain, the dynamic gain will not be a constant value and will be a function dependent on time. The dynamic gain is not solely restricted to stable systems, but also unstable systems.

### 3.1.5 Stability

Stability is whether or not the system can be controlled by the control system in place. Let's consider a power plant, a schematic of a typical power plant system is shown in Fig.3.2.

- Pipe pressure at every stage
- Temperatures at every stage
- Air flow into the combustion chamber of the boiler
- Rotational speed of the turbine shaft
- Pressures at every stage of the pipe

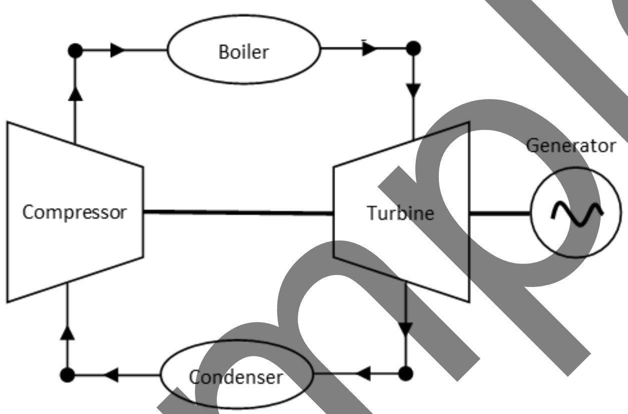


*Fig.3.2: A basic power cycle*

**Theory**

Let's say it's the middle of the night, and everyone has gone to sleep, and electricity demand is incredibly low; this will drop the resisting electromechanical torque produced by the generator, and as a result, the generator will speed up and produce a higher voltage, which lowers the current even more and will become unstable. The increase in voltage will also ripple through to the grid and damage most household electronics.

What if it is the world cup final? During half time electricity consumption is at one of its peaks in the UK, as everyone goes to put the kettle on. The huge demand will increase the electromechanical torque from the generator, slowing it down. This in turn will drop the voltage, which further increases the current demand and slows it down even further.

The stability of this system is related to the mechanical input power, and the electrical power output that can be produced by the generator. The variable $\delta$ is with regards to the asynchronous motor, and it is considered the difference between the electrical stator speed and the rotor's mechanical speed.

**Need AES Notes to finish this**

# 3.2 Feedback Systems

The systems can be considered either open loop or closed loop, which has been discussed in Workbook 2. But engineers also need to consider more about the different type of feedback that a system can have.

## 3.2.1 Positive Feedback

Positive feedback control systems use the set point and current value of the system and add them together since the feedback is "in phase" with the input and compatible. The effect of positive feedback is to increase the system's overall gain as opposed to a system without feedback.

We can use an Operational-Amplifier (Op-Amp) to create a simple positive feedback system, shown in Fig.3.3 below. When the input $V_{in}$ is positive, then the feedback from the Op-Amp will begin to add to $V_{in}$ and the overall gain will increase, as $V_{out}$ will also increase.

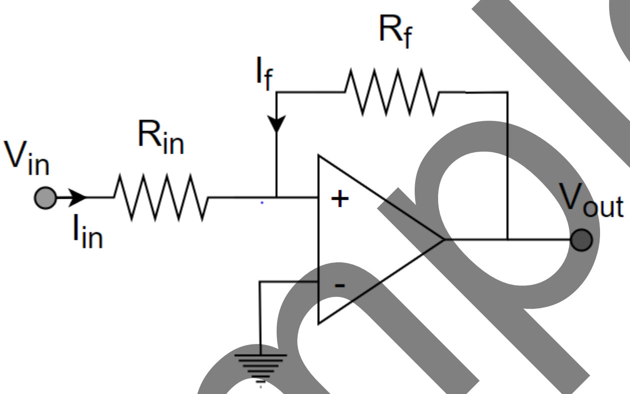


*Fig.3.3: Op-Amp positive feedback system*

Gain will increase as long as $V_{in}$ is positive, when $V_{in}$ becomes negative, the gain will begin to decline. The simplest way to think about a positive feedback system is "less is less, and more is more".

## 3.2.2 Negative Feedback

Negative feedback control is accomplished by feeding some of the output voltage back into the inverting input terminal of the Op-Amp. An Op-Amp negative feedback system is shown below in Fig.3.4, one thing to notice is that the $V_{in}$ is now connected to the inverter of Op-Amp.

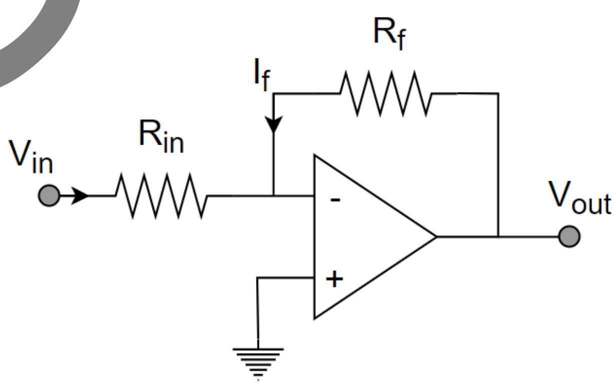


*Fig.3.4: Op-Amp negative feedback system*