INDUSTRIAL PROCESS MEASUREMENT – Industrial Transducer Systems.

The aim of this unit is to introduce the learner to principles and techniques related to the Performance, Operation and Application of a range of Industrial Transducer Systems.

APPLICATION, SELECTION AND OPERATION OF TRANSDUCER TYPES.

Nucleonic analysers – *alpha, beta, gamma, neutron;*
Speed – *tachogenerator, radar;*
Position – *linear/rotary potentiometer, absolute/incremental digital encoder, Linear Variable Differential Transducer (LVDT), resolver*

Nucleonic analysers

Ionizing radiation is energetic particles or waves that have the potential to ionize an atom or molecule. It is a function of the energy of the individual particles or waves, and not a function of the number of particles or waves present. A large flood of particles or waves will not cause ionization if the individual particles or waves are not energetic enough. These ionizations, if enough occur, can be destructive to biological organisms, and can cause DNA damage in individual cells. Extensive doses of ionizing radiation have been shown to have a mutating effect to future generations of the individual receiving the dose. Examples of ionizing radiation are energetic Beta particles, neutrons, alpha particles and energetic photons (UV and above).

The energy required to ionize an atom or molecule may widely vary. X-rays and gamma rays will ionize almost any molecule or atom; Far ultraviolet, near ultraviolet and visible light are ionizing to very few molecules; microwaves and radio waves are non-ionizing radiation.

Ionizing radiation has many practical uses in medicine, research, construction, etc. It also presents a health hazard to humans if used improperly.

Ionizing radiation is produced by radioactive decay, nuclear fission and nuclear fusion, by extremely hot objects (the hot sun, e.g., produces ultraviolet), and by particle accelerators that may produce, e.g., fast electrons.

In order for radiation to be ionizing, the particles must both have a high enough energy and interact with the atom. Photons interact strongly with charged particles, so photons of sufficiently high energy are ionizing. The energy at which this begins to happen is in the ultraviolet region; sunburn is one of the effects of this ionization. Charged particles such as electrons, positrons, and alpha particles also interact strongly with electrons. Neutrons, on the other hand, do not interact strongly with electrons, and so they cannot directly ionize atoms by this mechanism. However, fast neutrons will interact with the protons in hydrogen (in the manner of a billiard ball hitting another, sending it away with all of the first ball's energy of motion), and this mechanism produces proton radiation (fast protons). These are ionizing because of the strong interaction of the charged proton with the electrons in matter. Neutrons can also interact with atomic nuclei, depending on the nucleus and their velocity; these reactions happen with fast neutrons and slow neutrons, depending on the situation. Neutron interaction with nuclei in this manner often produces radioactive nuclei, which produce ionizing radiation when they decay.

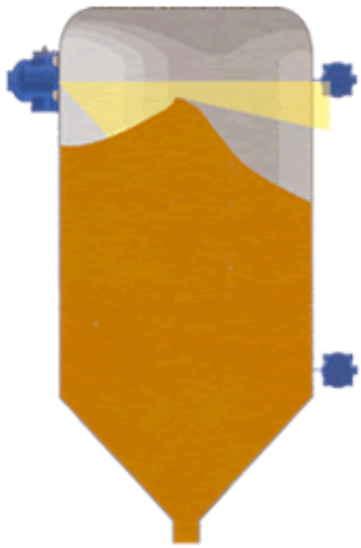
Technical uses of Ionising Radiation.

Since they are able to penetrate matter, ionizing radiations are used for a variety of measuring methods.

Radiography by means of gamma or x rays

This is a method used in industrial production. The piece to be radiographed is placed between the source and a photographic film in a cassette. After a certain exposition time, the film is developed and it shows internal defects of the material if there are any.

Gauges.



- Level indicators: Source and detector are placed at opposite sides of a container, indicating the presence or absence of material in the horizontal radiation path. Beta or gamma sources are used, depending on the thickness and the density of the material to be measured. The method is used for containers of liquids or of grainy substances.

- Thickness gauges: if the material is of constant density, the signal measured by the radiation detector depends on the thickness of the material. This is useful for continuous production, like of paper, rubber, etc.

Applications using ionization of gases by radiation

- To avoid the build-up of static electricity in production of paper, plastics, synthetic textiles, etc., a ribbon-shaped source of the alpha emitter ^{241}Am can be placed close to the material at the end of the production line. The source ionises the air to remove electric charges on the material.

- Smoke detector: Two ionisation chambers are placed next to each other. Both contain a small source of ^{241}Am that gives rise to a small constant current. One is closed and serves for comparison, the other is open to ambient air; it has a gridded electrode. When smoke enters the open chamber, the current is disrupted as the smoke particles attach to the charged ions and restore them to a neutral electrical state. This reduces the current in the open chamber. When the current drops below a certain threshold, the alarm is triggered.

- Radioactive tracers for industry: Since radioactive isotopes behave, chemically, mostly like the inactive element, the behavior of a certain chemical substance can be followed by *tracing* the radioactivity. Examples:

Adding a gamma tracer to a gas or liquid in a closed system makes it possible to find a hole in a tube. Useful in checking to completeness of pipe welds.

Adding a tracer to the surface of the component of a motor makes it possible to measure wear by measuring the activity of the lubricating oil.

MEASUREMENT OF SPEED

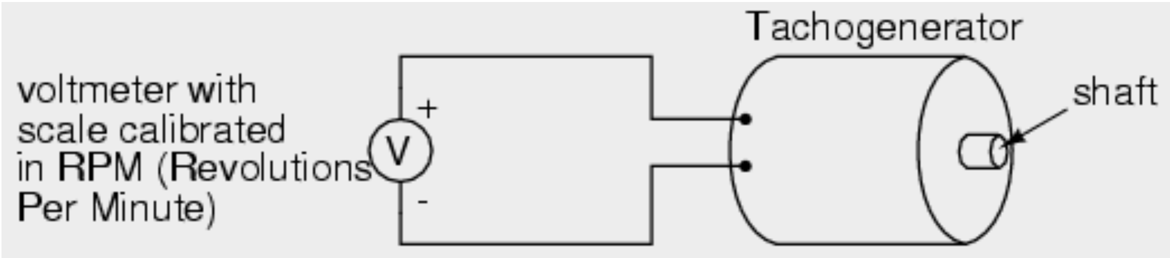
Speed is the rate of motion, or equivalently the rate of change in position, often expressed as distance d traveled per unit of time t.

Speed is a scalar quantity with dimensions distance/time; the equivalent vector quantity to speed is known as velocity. Speed is measured in the same physical units of measurement as velocity, but does not contain the element of direction that velocity has. Speed is thus the magnitude component of velocity.

The DC Tachogenerator is a speed transducer, which develops DC voltage proportional to speed of the motor connected to it.

Tachogenerators

An electromechanical generator is a device capable of producing electrical power from mechanical energy, usually the turning of a shaft. When not connected to a load resistance, generators will generate voltage roughly proportional to shaft speed. With precise construction and design, generators can be built to produce very precise voltages for certain ranges of shaft speeds, thus making them well-suited as measurement devices for shaft speed in mechanical equipment. A generator specially designed and constructed for this use is called a *tachometer* or *tachogenerator*.



By measuring the voltage produced by a tachogenerator, you can easily determine the rotational speed of whatever it's mechanically attached to. One of the more common voltage signal ranges used with tachogenerators is 0 to 10 volts. Obviously, since a tachogenerator cannot produce voltage when it's not turning, the zero cannot be "live" in this signal standard. Tachogenerators can be purchased with different "full-scale" (10 volt) speeds for different applications. Although a voltage divider could theoretically be used with a tachogenerator to extend the measurable speed range in the 0-10 volt scale, it is not advisable to significantly over speed a precision instrument like this, or its life will be shortened.

Tachogenerators can also indicate the direction of rotation by the polarity of the output voltage. When a permanent-magnet style DC generator's rotational direction is reversed, the polarity of its output voltage will switch. In measurement and control systems where directional indication is needed, tachogenerators provide an easy way to determine that.

Tachogenerators are frequently used to measure the speeds of electric motors, engines, and the equipment they power: conveyor belts, machine tools, mixers, fans, etc.

The accuracy of the tachogenerator decides the maximum accuracy of speed of the controlled machine.

Tachogenerators have been employed in industry for many years and enable the control of machinery, where precise rotation speeds are desired. In appearance a tachogenerator takes the form of a small electric motor, but with a much higher specification. The device can be directly coupled, in-line, via a flexible coupling to a driven spindle or belt driven by means of a timing belt and pulley arrangement. Usually, it is coupled to the main drive motor for which control is required.

A tachogenerator operates using the process of inducing emfs by a permanent magnetic circuit into the windings of an iron cored rotor whilst this is revolving. An output at the terminals of the tachogenerator is an analogue DC voltage which is a precise function of rotation speed and is a constant for that model of tachogenerator. There are many different models available, from the RE.O 110, which develops a voltage of 0.007v/rev or 7v/1000rpm, to the RE.O 588 which can develop 200v/1000rpm. This voltage is used to provide a speed feedback signal for the DC Power Drive or AC Inverter powering the main motor. In this way the motor speed can be very accurately maintained.

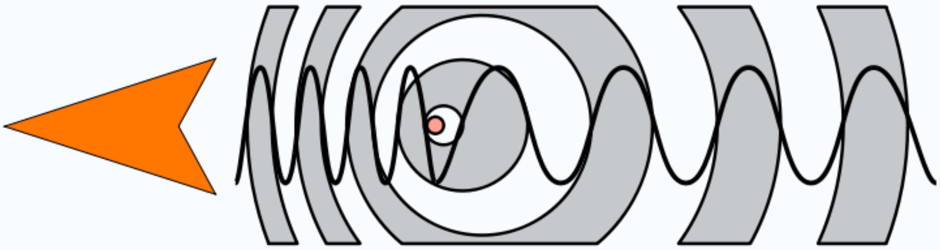
There are a number of methods of electrically varying the speed of the driven load and driving motor. These are:
D.C. Motor
Universal Motor
Schrage motor
High Slip Motor (Fan Motor)
Slip Ring Motor
Variable Frequency Drive and Induction Motor

Radar is a system that uses electromagnetic waves to identify the range, altitude, direction, or speed of both moving and fixed objects such as aircraft, ships, motor vehicles, weather formations, and terrain.

Speed is the change in distance to an object with respect to time. Thus the existing system for measuring distance, combined with a memory capacity to see where the target last was, is enough to measure speed. Modern radar systems perform the equivalent operation faster and more accurately using computers.

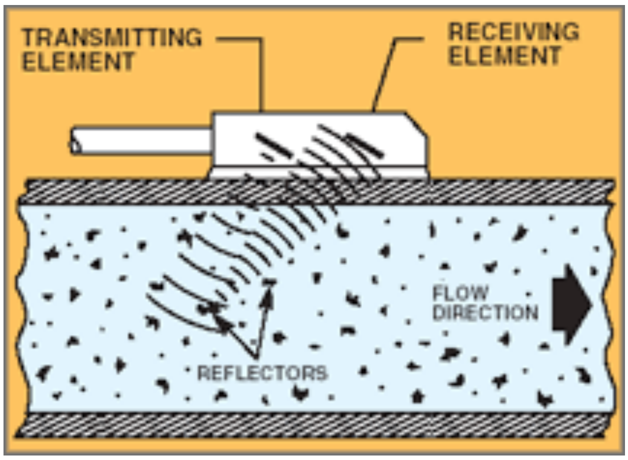
However, if the transmitter's output is coherent (phase synchronized), there is another effect that can be used to make almost instant speed measurements, known as the Doppler effect. Most modern radar systems use this principle in the pulse-doppler radar system. Return signals from targets are shifted away from this base frequency via the Doppler effect enabling the calculation of the speed of the object relative to the radar. The Doppler effect is only able to determine the relative speed of the target along the line of sight from the radar to the target.

Doppler radar uses the Doppler effect to measure the radial velocity of targets in the antenna's directional beam. The Doppler effect shifts the received frequency up or down based on the radial velocity of target (closing or opening) in the beam, allowing for the direct and highly accurate measurement of target velocity.



The Doppler effect is also used in some forms of radar to measure the velocity of detected objects. A radar beam is fired at a moving target—a car, for example, as radar is often used by police to detect speeding motorists—as it approaches or recedes from the radar source. Each successive wave has to travel further to reach the car, before being reflected and re-detected near the source. As each wave has to move further, the gap between each wave increases, increasing the wavelength. In some situations, the radar beam is fired at the moving car as it approaches, in which case each successive wave travels a lesser distance, decreasing the wavelength.

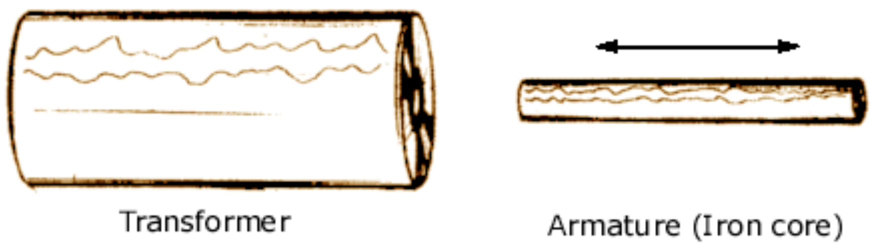
Instruments such as the laser Doppler velocimeter (LDV), and Acoustic Doppler Velocimeter (ADV) have been developed to measure velocities in a fluid flow. The LDV and ADV emit a light or acoustic beam, and measure the Doppler shift in wavelengths of reflections from particles moving with the flow. This technique allows non-intrusive flow measurements, at high precision and high frequency.



POSITION- linear/rotary potentiometer, absolute/incremental digital encoder, Linear Variable Differential Transducer (LVDT), resolver

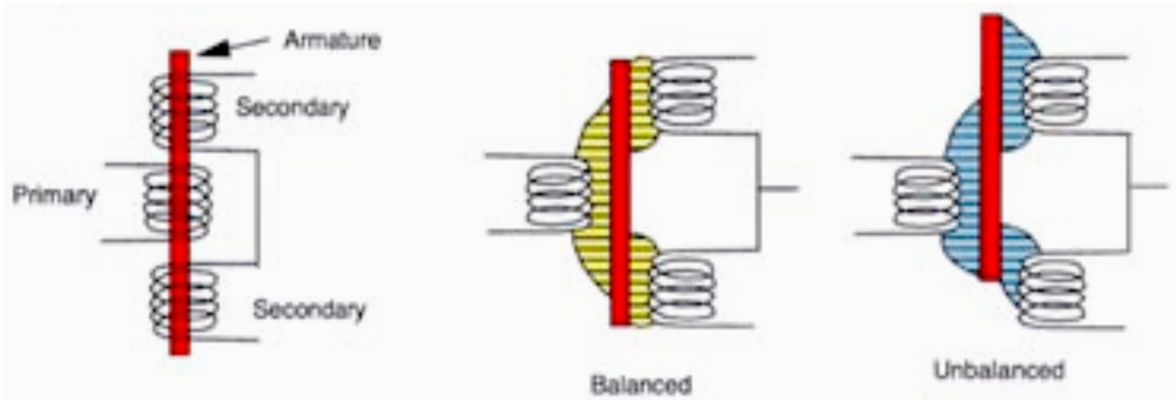
The Linear Variable Differential Transformer (Lvdt)

The Linear Variable Differential Transformer (LVDT) is a displacement measuring instrument and is not a strain-based sensor. It is the most broadly used variable-inductance transducer in industry. It is an electro-mechanical device designed to produce an AC voltage output proportional to the relative displacement of the transformer and the armature, as illustrated in the figure below.



The LVDT is a variable-reluctance device, where a primary center coil establishes a magnetic flux that is coupled through a mobile armature to a symmetrically-wound secondary coil on either side of the primary.

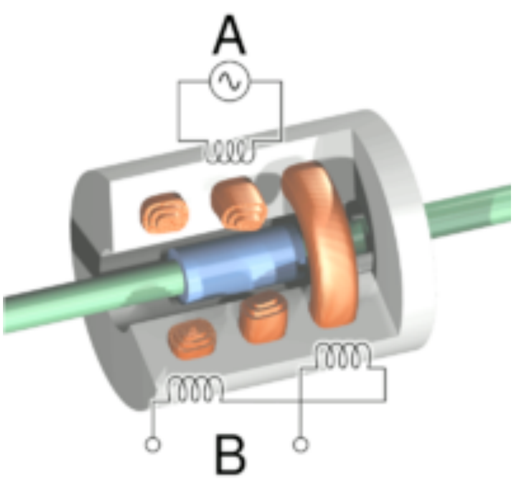
Two components comprise the LVDT: the mobile armature and the outer transformer windings. The secondary coils are series-opposed; wound in series but in opposite directions.



As the core moves, these mutual inductances change, causing the voltages induced in the secondaries to change. The coils are connected in reverse series, so that the output voltage is the difference (hence "differential") between the two secondary voltages. When the core is in its central position, equidistant between the two secondaries, equal but opposite voltages are induced in these two coils, so the output voltage is zero.

When the core is displaced in one direction, the voltage in one coil increases as the other decreases, causing the output voltage to increase from zero to a maximum. This voltage is in phase with the primary voltage. When the core moves in the other direction, the output voltage also increases from zero to a maximum, but its phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core (up to its limit of travel), which is why the device is described as "linear". The phase of the voltage indicates the direction of the displacement.

Because the sliding core does not touch the inside of the tube, it can move without friction, making the LVDT a highly reliable device. The absence of any sliding or rotating contacts allows the LVDT to be completely sealed against the environment.



LVDTs are commonly used for position feedback in servomechanisms, and for automated measurement in machine tools and many other industrial and scientific applications.

The **DC LVDT** is provided with onboard oscillator, carrier amplifier, and demodulator circuitry. The AC LVDT requires these components externally. Due to the presence of internal circuitry, the DC LVDT is temperature limited operating from typically -40 C to +120 C.

The standard LVDT displacement transducer provides an A.C. output and need a supporting electronic unit to energise and condition the signal. Some models are available with internal electronic circuitry to give a DC in – DC out performance. A suitable DC supply is needed and the choice of outputs available are D.C. bipolar, 0-5V, 0-10V and 4-20mA.

RESOLVER

A **resolver** is a type of rotary electrical transformer used for measuring degrees of rotation. It is considered an analog device, and has a digital counterpart, the rotary (or pulse) encoder.

The most common type of resolver is the brushless transmitter resolver (other types are described at the end). On the outside, this type of resolver may look like a small electrical motor having a stator and rotor. On the inside, the configuration of the wire windings makes it different. The stator portion of the resolver houses three windings: an exciter winding and two two-phase windings (usually labeled "x" and "y") (case of a brushless resolver). The exciter winding is located on the top, it is in fact a coil of a turning transformer. This transformer empowers the rotor, thus there is no need for brushes, or no limit to the rotation of the rotor. The two other windings are on the bottom, wound on a lamination. They are configured at 90 degrees from each other. The rotor houses a coil, which is the secondary winding of the turning transformer, and a primary winding in a lamination, exciting the two two-phase windings on the stator.

The primary winding of the transformer, fixed to the stator, is excited by a sinusoidal electric current, which by electromagnetic induction induces current to flow through the secondary windings along the stator. The two two-phase windings, fixed at right (90°) angles to each other on the stator, produce a sine and cosine feedback current by the same induction process. The relative magnitudes of the two-phase voltages are measured and used to determine the angle of the rotor relative to the stator. Upon one full revolution, the feedback signals repeat their waveforms. This device may also appear in non-brushless type, i.e., only consisting in two stacks of sheets, rotor and stator