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Unit-5

Industrial Sector

- ❑ Energy efficiency in industrial sector
- ❑ Main challenges to improve energy efficiency in industry
- ❑ Energy Efficient Technologies
- ❑ Industrial Automation
- ❑ Industrial Sensors

Energy efficiency in industrial sector

Energy efficiency in the industrial sector is a critical aspect of sustainable development, as industries are among the largest consumers of energy globally. Improving energy efficiency not only reduces operational costs but also minimizes environmental impact.

Importance of Energy Efficiency in Industry

- **High Energy Consumption:** Industries account for a significant portion of global energy use, especially in energy-intensive sectors like manufacturing, cement, steel, and chemicals.
- **Cost Savings:** Efficient energy use reduces production costs, enhancing profitability and competitiveness.
- **Environmental Benefits:** Lower energy consumption leads to reduced greenhouse gas emissions, contributing to climate change mitigation.

Key Strategies for Energy Efficiency

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(a) Energy Audits: Energy audits are systematic assessments of energy consumption within an organization, facility, or industrial process. They help identify inefficiencies, potential savings, and areas for improvement. By conducting regular energy audits, industries can optimize their energy use, reduce costs, and improve sustainability.

(b) Process Optimization: Process optimization refers to the practice of analyzing, refining, and upgrading industrial operations to achieve maximum efficiency with minimal resource consumption. It helps industries eliminate inefficiencies and improve production processes while lowering energy costs.

Ex-

- 1. Using **Variable Frequency Drives (VFDs)** to optimize motor performance and reduce power use.
- 2. Capturing and reusing waste heat from industrial processes improves energy efficiency including air preheater, superheater etc.

(c) Upgrading Equipment: Upgrading industrial equipment is a key strategy in improving energy efficiency. By replacing outdated machinery with high-efficiency alternatives, industries can significantly reduce energy consumption, operational costs, and environmental impact.

- Ex-
- (1) Retrofitting fluorescent lamps with LEDs in warehouses can reduce electricity costs by 50%.

- **(2)** Energy-efficient welding machines reduce electricity demand.
- **(3)** HVAC systems with VFDs improve energy efficiency by 20-50%.

(d) Waste Heat Recovery: Waste heat recovery is a crucial energy-efficient strategy in industries that helps capture excess heat generated during industrial processes and reuse it, minimizing energy waste and lowering operational costs.

- Waste heat refers to unused thermal energy released during various industrial operations, such as combustion, chemical reactions, and material processing. Waste heat recovery involves harnessing this excess heat and repurposing it for other applications, reducing overall energy demand.
- Ex- Shell-and-tube heat exchangers in chemical plants improve thermal efficiency.
- Turbo chargers uses the exhaust gas from the IC engine to drive the compressor for drawing in fresh air. And in turn improves the efficiency by 20-40%.

(e) Automation and Control Systems: Automation and control systems play a vital role in improving energy efficiency across industries, commercial spaces, and smart grids. These systems monitor, regulate, and optimize energy consumption using real-time data, reducing waste and ensuring smooth operations.

Key Components of Automation and Control Systems

Sensors: Detect temperature, pressure, occupancy, and power consumption.

Controllers (PLCs, Microcontrollers): Process data and issue commands for optimization.

Actuators: Execute commands by adjusting motors, HVAC systems, and lighting.

SCADA (Supervisory Control and Data Acquisition): Provides real-time monitoring and control.

Main challenges to improve energy efficiency in industry

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Improving energy efficiency in the industrial sector is essential but comes with several challenges.

Here are the main obstacles:

1. High Initial Investment Costs

Challenge: High initial investment costs pose a major challenge for businesses, especially small and medium-sized enterprises (SMEs), when adopting energy-efficient technologies. These upgrades—like advanced machinery, automation systems, or renewable energy solutions—typically require a substantial upfront financial commitment.

Impact: While these investments often lead to lower operational costs and energy savings over time, SMEs may find it difficult to allocate the necessary funds. Limited access to financing, cash flow constraints, or uncertainty about the return on investment can make businesses hesitant to take the leap, even if the long-term benefits outweigh the costs.

2. Lack of Awareness and Expertise

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Challenge: Lack of awareness and expertise presents a significant barrier to adopting energy-efficient technologies across industries. Many businesses, especially small and medium-sized enterprises (SMEs), may not be fully informed about the latest advancements in energy efficiency or the long-term benefits they offer. This knowledge gap can stem from limited access to educational resources, insufficient training programs, or a lack of emphasis on sustainability within certain sectors.

Impact: Without proper awareness, industries may continue using outdated systems that consume excess energy, leading to higher operational costs and environmental consequences. Businesses that fail to upgrade may also miss out on government incentives, tax benefits, or competitive advantages that energy-efficient practices can provide.

3. Resistance to Change

Challenge: Resistance to change is a major obstacle in the adoption of energy-efficient technologies across industries. Many businesses hesitate to upgrade due to fears that new systems might disrupt existing workflows, reduce productivity during the transition, or fail to deliver the promised return on investment.

Impact: This reluctance slows down the shift to more sustainable practices, leaving industries stuck with outdated, energy-intensive technologies. Even when long-term cost savings and efficiency improvements are clear, uncertainty can prevent companies from making necessary changes.

4. Limited Access to Financing

Challenge: Access to financing is a major roadblock for industries looking to invest in energy-efficient technologies. Even when businesses recognize the benefits and are willing to make upgrades, they may struggle to secure loans or incentives due to strict eligibility criteria, complex application processes, or limited availability of financial programs tailored for sustainability efforts.

Impact: Without adequate funding, industries may delay or abandon plans for energy-efficient upgrades, preventing them from improving operational efficiency and reducing costs in the long run. This challenge is particularly significant for small and medium-sized enterprises (SMEs), which often lack the financial flexibility to absorb high upfront costs without external support.

5. Technological Barriers

Challenge: Technological barriers can significantly hinder the adoption of energy-efficient solutions in certain industries. Some sectors rely on highly specialized equipment or processes that may not yet have viable energy-efficient alternatives. For example, heavy industries such as steel production, cement manufacturing, and chemical processing often depend on high-temperature operations that require substantial energy input, with limited scope for immediate efficiency improvements.

Impact:

Slow Adoption – Industries with complex requirements may struggle to transition to energy-saving technologies.

Limited Innovation – Certain processes may not yet have energy-efficient substitutes due to technological constraints.

High Costs for Alternatives – The development and implementation of custom energy-efficient solutions can be expensive.

Environmental Concerns – Continued reliance on traditional, energy-intensive technologies can increase carbon emissions.

6. Policy and Regulatory Gaps

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Challenge: Policy and Regulatory Gaps can be a significant hurdle for industries seeking to implement energy-efficient solutions. When government policies, incentives, or regulations are unclear, inconsistent, or insufficient, businesses may struggle to justify the investment in sustainable practices.

Impact:

Lack of Incentives – Without tax benefits, subsidies, or financial support, industries may find energy-efficient upgrades too costly.

Unclear Regulations – Companies may hesitate to act if legal requirements are vague or frequently change.

Slow Adoption – Industries may delay energy efficiency projects due to uncertainty about compliance or future regulations.

7. Energy Data and Monitoring Issues

Challenge: **Energy Data and Monitoring Issues** can create significant obstacles for industries aiming to improve energy efficiency. Many **businesses** lack **advanced monitoring systems**, real-time **data analytics**, or the necessary expertise to track their energy consumption effectively.

Impact:

Hidden Inefficiencies – Without proper tracking, businesses may unknowingly waste energy in outdated processes.

Inaccurate Decision-Making – Lack of precise data prevents industries from identifying and prioritizing efficiency improvements.

Higher Operational Costs – Undetected energy wastage leads to unnecessary expenses over time.

8. Integration with Renewable Energy

Renewable energy sources like solar, wind, and hydro can significantly boost efficiency and sustainability, but incorporating them requires **additional infrastructure**—such as energy storage solutions, smart grids, and specialized equipment. **Expertise** is also crucial for designing, installing, and maintaining these systems, which may not be readily available in every industry.

Impact:

For industries unfamiliar with renewable energy, these requirements can act as a **barrier** to adoption. Businesses may struggle with the **high upfront costs**, the complexity of system integration, and the need for specialized knowledge. This can slow down the transition to cleaner energy, despite the long-term financial and environmental benefits.

To overcome these barriers, industries can:

- Leverage government incentives and subsidies for energy efficiency projects.
- Invest in training programs to build awareness and expertise.
- Collaborate with energy service companies (ESCOs) for financing and implementation.
- Adopt digital tools for energy monitoring and management.

Impact:

Industries may struggle to ensure **long-term performance and reliability** of energy-efficient systems. Without proper maintenance and skilled professionals, operational issues can arise, reducing the expected efficiency gains. Additionally, businesses may face **higher costs** for hiring specialized technicians or training staff, making adoption less attractive. If not handled properly, these challenges could **offset the intended benefits** of energy-efficient technologies.

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Energy Efficient Technologies

Energy-efficient technologies are innovations designed to perform tasks using less energy while maintaining or improving performance. These technologies help industries, businesses, and households optimize energy use.

Some of the major energy efficient technologies are

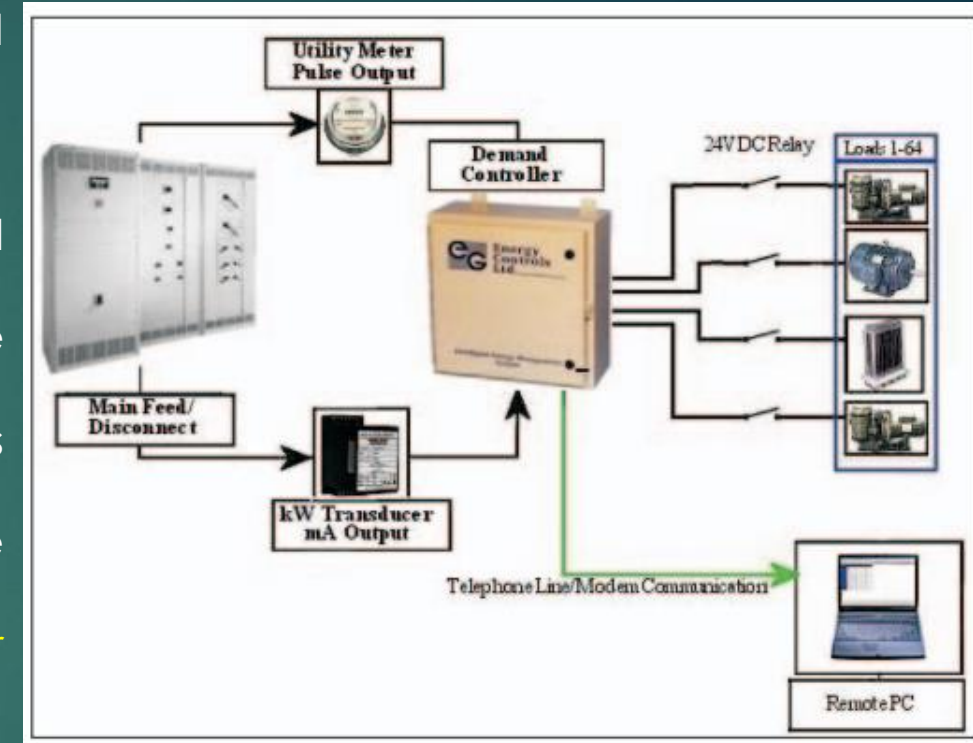
1. Maximum Demand Controller
2. Soft starters
3. Energy efficient transformer
4. Electronic ballast

Maximum Demand Controller

A **Maximum Demand Controller (MDC)** is an electrical power management device designed to monitor and control the maximum demand for electricity in industrial, commercial, and residential settings. Its primary function is to prevent demand from exceeding a predetermined level, thereby avoiding peak demand charges and optimizing energy use.

Working

- The MDC continuously tracks electrical power consumption in real time. It records power utilization data for analysis and reporting.
- When power usage approaches the specified demand limit, the MDC automatically sheds or shuts off non-essential loads.
- It prioritizes critical loads while temporarily disconnecting less important ones.
- The MDC provides alerts when power consumption nears the maximum demand threshold.
- Operators can take preventive actions to avoid unnecessary power surges.



Benefits

- **Cost Savings:** Prevents penalties by optimizing power usage and reducing peak demand charges.
- **Energy Efficiency:** Reduces wastage by scheduling operations during off-peak hours.

Maximum Demand Controller

Soft starters

Soft starters are devices used to control the voltage and current supplied to motors during startup, ensuring a smooth acceleration rather than an abrupt application of full voltage. This helps reduce mechanical stress, electrical surges, and energy consumption.

Working

- Soft starters use **Silicon Controlled Rectifiers (SCRs)** arranged in pairs for each phase.
- These **SCRs** gradually increase the voltage supplied to the motor by controlling the firing angle of the AC waveform.
- Initially, only a fraction of the total voltage is applied, reducing the **inrush current**.
- As the **motor begins to rotate**, the control system decreases the **firing angle**, allowing more voltage to pass through.
- This **progressive increase** ensures a **steady acceleration** while preventing sudden torque shocks.
- By **controlling the voltage**, soft starters limit the startup current, typically **reducing it to 2-3 times the motor's rated current** instead of the usual 6-8 times seen in direct-on-line (DOL) starters.
- This **prevents excessive torque and stress** on motor components.

Benefits

Reduced Mechanical Wear – Prevents abrupt torque spikes that cause stress on gears, couplings, and bearings.

Lower Power Consumption – Limits peak current draw, leading to energy savings.



Soft starters

Electronic Ballast

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Electronic ballasts use semiconductor components to convert AC power into a high-frequency AC signal, typically ranging from **20 kHz to 60 kHz**, rather than the traditional **50 Hz or 60 Hz** power supply. This high-frequency operation **reduces flickering, enhances brightness**, and extends the life of the lamp.

Working

- The ballast first converts the **incoming AC power** into **DC power** using a **bridge rectifier and capacitor**.
- A **DC-to-AC inverter** inside the ballast generates high-frequency AC.
- Before igniting the lamp (for fluorescent lamps), the ballast sends a small current to preheat the **lamp electrodes**.
- The ballast applies a **high voltage pulse** across the lamp to **ignite the gas inside**.
- Once the lamp is lit, the ballast **maintains a steady current flow** to ensure efficient operation.

Benefits

- **Energy Efficiency:** Uses less power than magnetic ballasts.
- **Flicker-Free Operation:** Produces a constant and stable light output.
- **Compact & Lightweight:** Smaller in size compared to magnetic ballasts.



Electronic Ballast

Energy Efficient transformer

An **energy-efficient transformer** operates on the same fundamental principles as a **conventional transformer** but is designed to **minimize energy losses** and improve efficiency.

Working

- Like all transformers, it relies on **Faraday's Law of Electromagnetic Induction** to **transfer electrical energy** between **primary and secondary windings** without direct electrical connection.
- Instead of **standard iron cores**, energy-efficient transformers use **amorphous metal cores** or **high-permeability silicon steel** to reduce **hysteresis losses** (energy lost due to repeated magnetization and demagnetization).
- The **windings** are made from **low-resistance copper** or **aluminum** to **reduce I^2R losses** (heat generated due to electrical resistance). Some designs use **foil or continuously transposed conductors (CTC)** to improve efficiency.
- Energy-efficient transformers integrate **smart sensors** and **load management systems** to optimize power distribution and reduce unnecessary energy consumption.

Benefits

Lower Energy Losses – Reduces power wastage, leading to cost savings.

Improved Lifespan – Less heat generation means longer operational life.

Environmental Benefits – Lower carbon footprint due to reduced energy consumption.



1 600 kVA amorphous core transformer

Industrial Automation

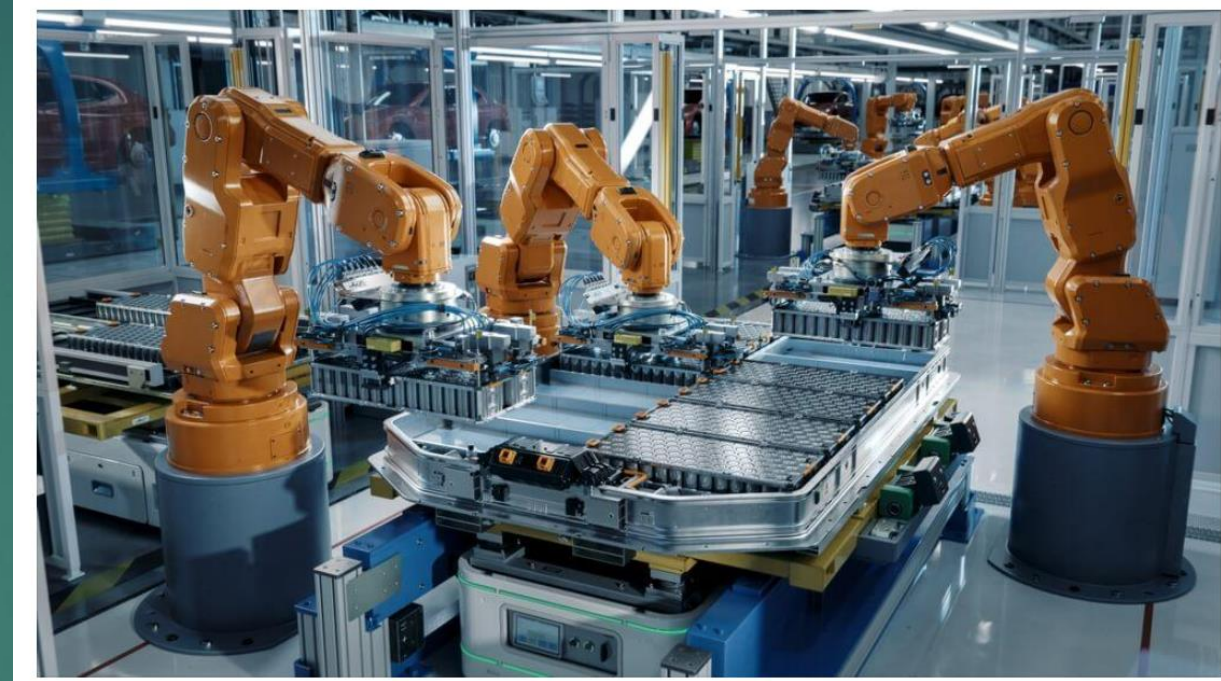
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Industrial automation refers to the use of **control systems, robotics, and computer technology** to enhance manufacturing processes, reduce human intervention, and improve efficiency, productivity, and safety. Automation plays a crucial role in modern industries by minimizing errors, optimizing production rates, and lowering operational costs.

Industrial automation relies on several hardware and software components, including:

1. **Sensors and Actuators**

- Sensors collect data such as temperature, pressure, speed, proximity, and more.
- Actuators convert electrical signals into physical action (e.g., motors and valves).
- A proximity sensor detects someone approaching (sensor function).The actuator (electric motor) receives the signal and opens the door (actuator function).



2. Programmable Logic Controllers (PLCs)

A **Programmable Logic Controller (PLC)** is an industrial digital computer used for automation of electromechanical processes. It is widely used in manufacturing, assembly lines, and robotic systems.

Working Principle of PLC

Input Processing – PLC receives signals from sensors, switches, or other input devices.

CPU Processing – The central processing unit (CPU) executes the programmed logic based on input conditions.

Memory Storage – Stores the program and operational data for execution.

Output Control – Sends signals to actuators, motors, or other output devices to perform actions.

Communication Interface – Connects with other systems for monitoring and control.

Consider an **automatic conveyor belt system**:

Sensors detect an object on the belt.

PLC processes the signal and determines the next action.

Actuators adjust the belt speed or sort the object accordingly.

3. Supervisory Control and Data Acquisition (SCADA) Systems

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- SCADA (Supervisory Control and Data Acquisition) systems function by gathering data from field devices, transmitting it to a central control system, processing the information, and enabling operators to monitor and control processes in real-time.

• Working of SCADA

▪ Data Collection:

- SCADA systems rely on **sensors and field devices** (such as PLCs) to collect data from machines, equipment, and industrial processes.
- These devices measure parameters like temperature, pressure, flow rate, voltage, and other critical variables.

▪ Data Transmission:

- The collected data is **transmitted via communication networks** to a central SCADA system.
- Communication can occur through wired (Ethernet, fiber optics) or wireless (radio signals, satellite, cellular) networks.

▪ Data Processing & Visualization:

- The SCADA system **processes** the incoming data and presents it via **Human-Machine Interfaces (HMIs)**.
- Operators can monitor real-time information displayed through graphical dashboards, alarms, charts, and trend analyses.

▪ Control & Decision Making:

- Operators can **adjust system settings** based on the processed data.
- Automated responses can be programmed—e.g., shutting down a system when an **anomaly is detected**.

- **Example: Manufacturing:** Tracks assembly lines, detects defects, and optimizes production.

4. Industrial Robots

Industrial robots are automated machines designed to perform repetitive tasks with precision, speed, and efficiency. They are widely used in manufacturing, logistics, healthcare, and other industries.

Working:

- 1. Sensors & Input:** Robots use sensors (vision, proximity, force) to detect objects and surroundings.
- 2. Processing & Decision Making:** AI and control systems analyze data and determine actions.
- 3. Actuation & Movement:** Motors and actuators enable robots to move, grip, weld, or assemble parts.
- 4. Feedback & Adjustment:** Robots continuously adjust their actions based on real-time data.

Examples of Industrial Robots in Action

Assembly Robots: Used in automotive and electronics industries to assemble parts with high precision.

Welding Robots: Automate welding processes in car manufacturing, ensuring consistency and safety.

5. Human-Machine Interfaces (HMI)

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Human-Machine Interfaces (HMI) are systems that allow humans to interact with machines, providing control, monitoring, and data visualization. They are widely used in industrial automation, healthcare, transportation, and consumer electronics.

Working

- Data Collection:** Sensors and controllers gather real-time data from machines.
- Processing & Display:** The HMI processes the data and presents it visually through screens, dashboards, or control panels.
- User Interaction:** Operators can input commands via touchscreens, buttons, or keyboards.
- Control & Feedback:** The system executes commands and provides feedback, ensuring smooth operation.
- Alarm & Alerts:** HMIs notify users of system errors or critical conditions.

Examples

- Healthcare:** Medical monitoring systems showing patient vitals and enabling doctors to modify treatment parameters.
- Automotive:** Car infotainment systems with touchscreens for navigation, climate control, and entertainment.

Types of Industrial Automation

Industrial automation is classified into different levels:

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1. Fixed Automation (Hard Automation)

- Used for mass production with **highly repetitive** processes.
- Best suited for large-volume manufacturing (e.g., automotive assembly lines).

2. Programmable Automation

- Allows modification of process parameters using **software programming**.
- Ideal for batch production with varying product specifications.

3. Flexible Automation

- Enables **rapid product changes** without significant system modifications.
- Commonly used in **custom manufacturing** or industries with dynamic product demands.

4. Integrated Automation

- Combines **AI, IoT, and advanced robotics** for complete industrial automation.
- Allows autonomous decision-making and process optimization.

Industrial Sensors

Industrial sensors are essential components of modern automation and control systems. They enable machines and systems to **monitor, measure, and respond** to changes in environmental and operational conditions. Sensors help in detecting physical, chemical, and electrical properties, ensuring efficient and precise industrial processes.

Types of Industrial Sensors

Industrial sensors are classified based on the type of measurement they perform. Some of the most commonly used sensors include:

1. Temperature Sensors

- Measure temperature variations in industrial processes.

Types:

- **Thermocouples:** Used for high-temperature applications.
- **RTDs (Resistance Temperature Detectors):** Provide accurate temperature readings.
- **Infrared Sensors:** Non-contact temperature measurement.



Industrial Sensors

2. Pressure Sensors

- Detect pressure levels in fluids and gases.

•Types:

- **Strain Gauge Pressure Sensors:** Use strain gauges for precise pressure measurement.
- **Capacitive Pressure Sensors:** Operate based on capacitance change.
- **Piezoelectric Pressure Sensors:** Convert mechanical stress into electrical signals.
- **Differential Pressure Sensors:** Measure pressure difference between two points.

3. Proximity Sensors

- Detect objects without physical contact.

•Types:

- **Inductive Proximity Sensors:** Used for metallic object detection.
- **Capacitive Proximity Sensors:** Detect non-metallic objects (plastic, liquids).
- **Ultrasonic Sensors:** Measure distance using sound waves.
- **Optical Sensors:** Use light beams to detect objects.

4. Flow Sensors

- Measure the flow rate of liquids and gases.

- Types:

- **Turbine Flow Meters:** Detect fluid movement using rotating blades.
- **Electromagnetic Flow Sensors:** Use magnetic fields to measure flow in conductive fluids.
- **Ultrasonic Flow Meters:** Use sound waves to detect fluid movement.
- **Mass Flow Sensors:** Measure flow rate based on mass transfer.

5. Motion Sensors

- Detect movement in industrial settings.

- Types:

- **Infrared Motion Sensors:** Identify heat signatures.
- **Ultrasonic Motion Sensors:** Detect movement using sound waves.
- **Laser Motion Sensors:** High-precision detection for security and automation.

6. Gas Sensors

- Measure gas concentration and detect leaks.

- Types:

- **Electrochemical Gas Sensors:** Detect oxygen, CO, and toxic gases.
- **Catalytic Bead Sensors:** Used for detecting combustible gases.
- **Infrared Gas Sensors:** Monitor gas emissions in industries.

Applications of Industrial Sensors

Industrial sensors find applications across multiple sectors:

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1. Manufacturing

1. **Quality Control:** Optical sensors inspect defects in production lines.
2. **Process Monitoring:** Temperature sensors regulate furnace temperatures.

2. Automotive Industry

1. **Pressure Sensors:** Monitor fuel and tire pressure.
2. **Proximity Sensors:** Used in vehicle collision avoidance systems.

3. Chemical & Petrochemical Industry

1. **Gas Sensors:** Detect toxic gases and prevent leakage.
2. **Flow Sensors:** Monitor liquid flow rates in chemical plants.

4. Pharmaceutical Industry

1. **Humidity Sensors:** Ensure controlled moisture levels for drug storage.
2. **Optical Sensors:** Used for precision filling in medicine packaging.

5. Aerospace Industry

1. **Vibration Sensors:** Monitor aircraft engine conditions.
2. **Temperature Sensors:** Regulate heat levels in spacecraft

Thank You