ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 4 - AUTOMOTIVE ACTUATORS

4.4 Single Phase alternating current machines – Duty-type ratings for electrical machines

- Single-phase AC machines are widely used in domestic and light industrial applications due to their simplicity and ease of operation. Unlike their three-phase counterparts, they operate on a single-phase AC power supply.

4.4.1 Types of Single-Phase AC Machines:

1. **Single-Phase Induction Motors:**

   - **Shaded Pole Motors:** These motors have a shaded pole winding that creates a phase shift in the magnetic field, allowing the motor to start and run. They are used in small appliances like fans and clocks.
   - **Split-Phase Motors:** These motors use two windings, a main winding and a starting winding, to create a phase difference. They are commonly used in household appliances like refrigerators and air conditioners.
   - **Capacitor-Start Motors:** Similar to split-phase motors, these motors use a capacitor to create a phase shift. The capacitor is disconnected once the motor reaches a certain speed.
   - **Capacitor-Start Capacitor-Run Motors:** These motors use two capacitors, one for starting and one for running, to improve efficiency and performance. They are used in high-power applications like pumps and compressors.

2. **Single-Phase Synchronous Motors:**
   - These motors have a rotor with permanent magnets or field windings. They are used in applications that require precise speed control, such as clocks and turntables.

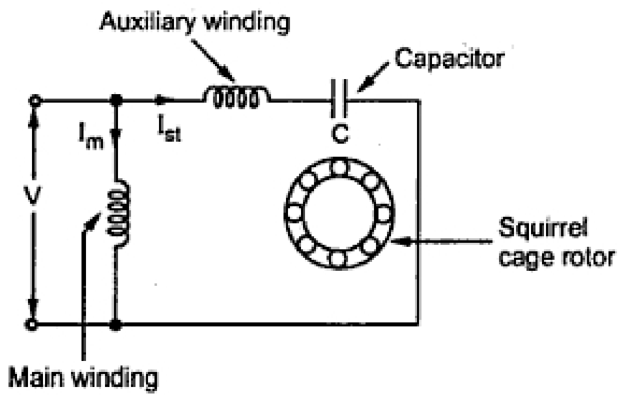
4.4.2 Construction and working of single- phase Induction Motor:

- Similar to a d.c. motor, single phase induction motor has basically two main parts, one rotating and other stationary.
- The stationary part in single phase induction motors is called stator while the rotating part is called rotor.
- The stator has laminated construction, made up of stampings. The stampings are slotted on its periphery to carry the winding called stator winding or main winding.
- This is excited by a single phase a.c. supply.
- The laminated construction keeps iron losses to minimum. The stampings arc made up of material like silicon steel which minimises the hysteresis loss.
- The stator winding is wound for certain definite number of poles means when excited by single phase a.c. supply, stator produces the magnetic field which creates the effect of certain definite number of poles.
- The number of poles for which stator winding is wound, decides the synchronous speed of the motor.
- The synchronous speed is denoted as Ns and it has a fixed relation with supply frequency f and number of poles P.
- The relation is given by,

$$N_s = \frac{120f}{P}\ r.p.m$$

- The induction motor never rotates with the synchronous speed but rotates at a speed which is slightly less than the synchronous speed.
- In the single phase induction motor, single phase a.c. supply is given to the stator winding. The stator winding carries an alternating current which produces the flux which is also alternating in nature.
- This flux is called main flux. This flux links with the rotor conductors and due to transformer action e.m.f. gets induced in the rotor.

- The induced e.m.f. drives current through the rotor as rotor circuit is closed circuit. This rotor current produces another flux called rotor flux required for the motoring action- Thus second flux is produced according to induction principle due to induced e.m.f. hence the motor is called induction motor.
- As against this in d.c. motor a separate supply is required to armature to produce armature flux. This is an important difference between d.c. motor and an induction motor.



The diagram shows a **Single-Phase Capacitor-Start Induction Motor**.

The components and their functions:

- **Main Winding:** This is the primary winding of the motor, connected directly to the power supply. It carries the main current required for motor operation.
- **Auxiliary Winding:** This winding is used for starting the motor. It is connected in series with a capacitor, which creates a phase shift in the current flowing through the auxiliary winding. This phase shift helps in producing a rotating magnetic field, essential for starting the motor.
- **Capacitor:** The capacitor is a key component for starting the motor. It creates a phase shift in the current flowing through the auxiliary winding, as mentioned above. This phase shift helps in producing a rotating magnetic field, essential for starting the motor.
- **Centrifugal Switch:** This switch is mechanically connected to the motor shaft. When the motor reaches a certain speed, the centrifugal force causes the switch to open. This disconnects the auxiliary winding and capacitor from the circuit, as they are no longer needed for continued operation.

- **Rotor:** The rotor is the rotating part of the motor. It is made of laminated iron core with slots that carry the rotor conductors. The rotating magnetic field produced by the stator winding induces currents in the rotor conductors, which in turn produce a magnetic field. The interaction between the stator and rotor magnetic fields causes the rotor to rotate.

Working:

1. **Starting:** When the motor is initially connected to the power supply, the capacitor creates a phase shift in the current flowing through the auxiliary winding. This creates a rotating magnetic field, which induces currents in the rotor conductors. These currents produce a magnetic field in the rotor, which interacts with the stator magnetic field, causing the rotor to start rotating.
2. **Running:** As the motor accelerates, the centrifugal switch opens, disconnecting the auxiliary winding and capacitor from the circuit. The motor continues to run on the main winding alone.

4.4.3 Applications of Single-phase Induction Motor:

- **Household appliances**: Fans, refrigerators, washing machines, blowers, mixers, and grinders
- **Commercial appliances**: Air conditioners, water pumps, and compressors
- **Industrial tools**: Light industrial tools for woodworking and metalworking, CNC machines, lathe machines, and drilling machines
- **Agricultural appliances**: Water pumps and threshing machines
- **Toys and hair dryers**: 1/400 kW to 1/25 kW motors are used in toys and hair dryers
- **Vending machines**: Single-phase induction motors are used in vending machines

4.4.4. Duty-type ratings for electrical machines:

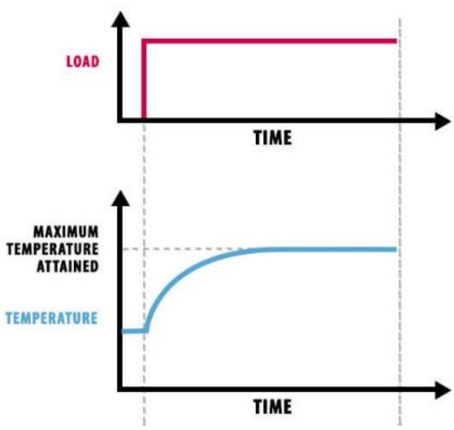
What is a duty Cycle for a Motor?

- The International Electrotechnical Commission (IEC) defines eight classifications for a duty cycle, grouped by continuous, short-term, or periodic cycles. Duty cycles encompass the frequency and duration of typical operations. These include starting, running with no or full load, electric braking, and resting
- Duty-type ratings for electrical machines define the specific operational cycle, including load, speed, and rest periods, that a machine can endure without exceeding its thermal limits. This rating is crucial for selecting the right machine for a particular application, as it ensures optimal performance and longevity.

Common Duty-Type Ratings:

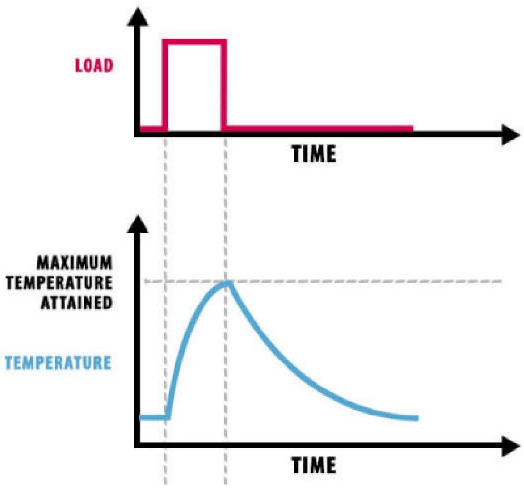
The International Electrotechnical Commission (IEC) has standardized a classification system for duty-type ratings. Some of the most common types are:

1. **S1: Continuous Duty**
   - The machine operates continuously under constant load for a time long enough to reach thermal equilibrium.
   - Example: Fans, pumps, conveyors.

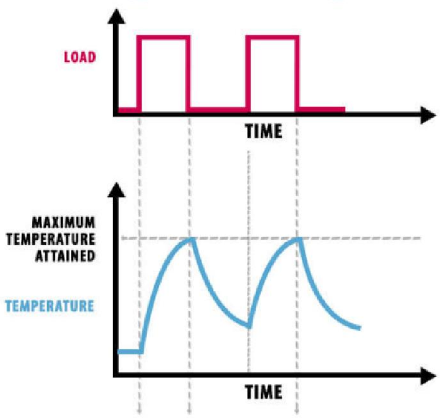


2. **S2: Short-Time Duty**
   - The machine operates at a constant load for a specified short period (less than the time required to reach thermal equilibrium) followed by a rest period to allow cooling.

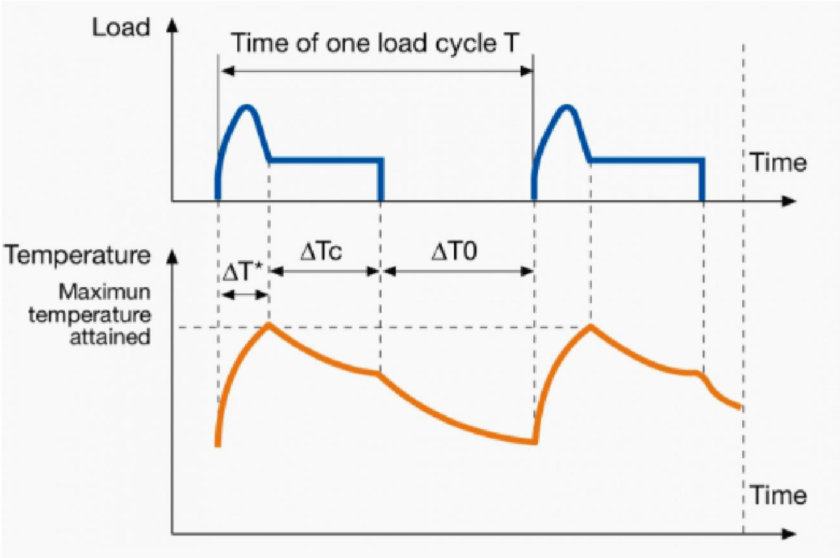
- Example: Hoists, cranes, spot welding machines.



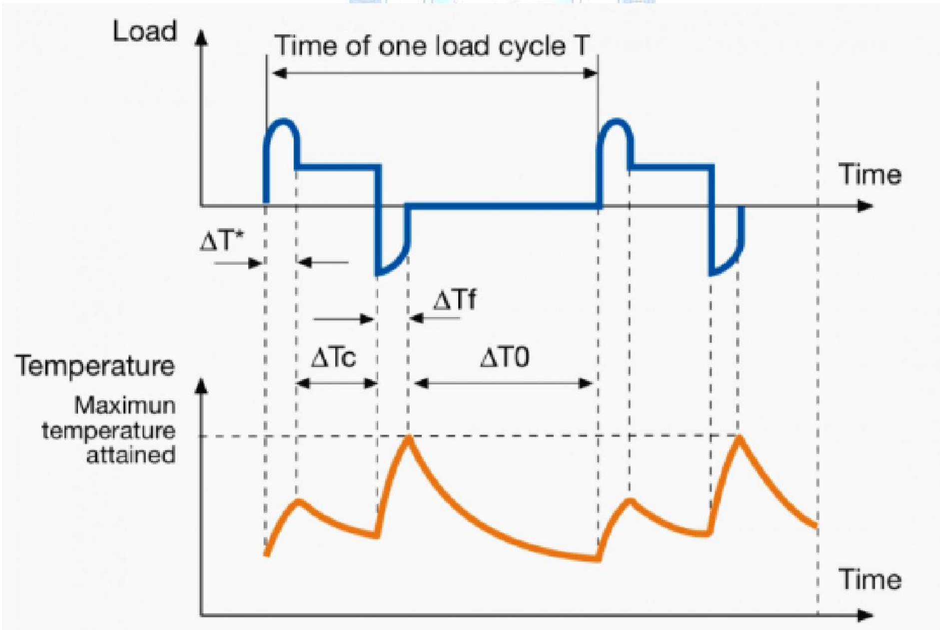
3. **S3: Intermittent Periodic Duty**
   - The machine operates in cycles of identical duration, with periods of operation and rest. The operation period is too short to reach thermal equilibrium, and the rest period is insufficient for full cooling.
   - Example: Compressors, machine tools.



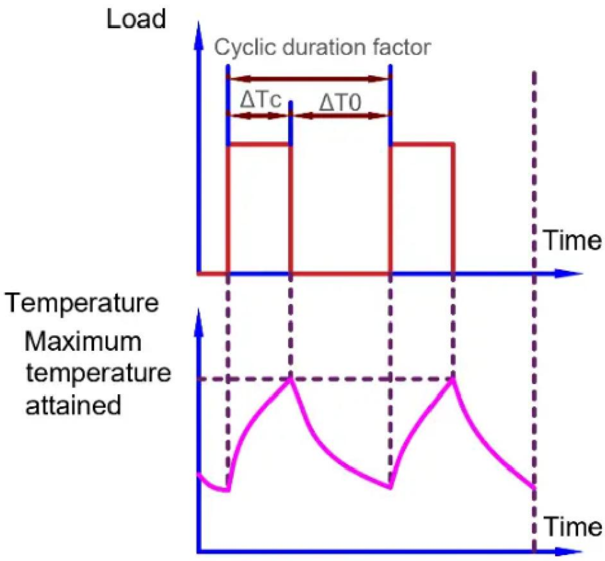
4. **S4: Intermittent Periodic Duty with Starting**
   - Similar to **S3**, but includes significant starting and braking periods that affect the thermal performance.
   - Example: Elevators, industrial presses.



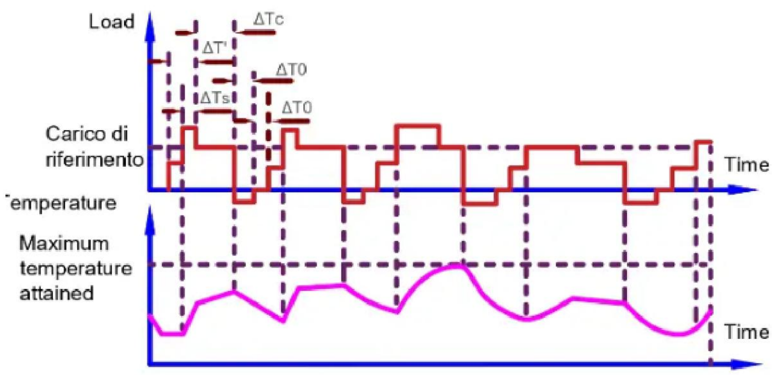
5. **S5: Intermittent Periodic Duty with Starting and Electrical Braking**
   - Similar to **S4**, but with additional braking energy dissipated in the machine during stopping.
   - Example: Rolling mills, material handling systems.



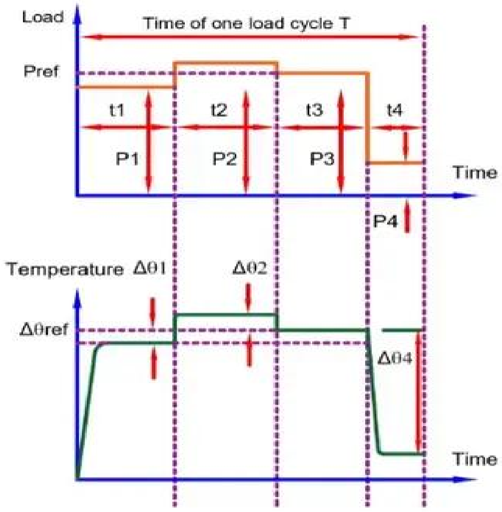
6. **S6: Continuous Operation Periodic Duty**
   - The machine operates for repeated cycles of load and no-load operation, without rest periods.
   - Example: Fans or pumps with variable loads.



7. **S7: Continuous Operation with Starting and Electrical Braking**
   - The machine operates with repeated cycles of starting, operation at constant load, and braking, without rest periods.
   - Example: Rolling mills, reciprocating compressors.
8. **S8: Continuous Operation with Load and Speed Changes**
   - The machine operates with repeated cycles, including speed and load changes, without rest periods.
   - Example: Multispeed drives, industrial conveyors.
9. **S9: Duty with Non-Periodic Load and Speed Variations**
   - The machine operates under varying loads and speeds, with frequent overloads.
   - Example: Electric traction, drives for crushers.



10. **S10: Duty with Discrete Load Variations**
    - ❒ The machine operates with discrete steps of load and speed, with no specific pattern, often including overloads.
    - ❒ Example: Testing machines, special industrial equipment.



Key Considerations for Duty Ratings

- ❒ **Thermal Limitations**: Each duty cycle impacts the temperature rise of the machine.
- ❒ **Starting Conditions**: High starting currents and torques can affect mechanical and thermal stresses.
- ❒ **Load Fluctuations**: Machines with intermittent or variable loads need specific design considerations for durability and efficiency.

Applications of Duty Ratings

Understanding duty ratings ensures proper machine selection and application:

- **Continuous Duty (S1)**: Used where machines run constantly (e.g., pumps, fans).
- **Intermittent Duty (S2, S3)**: Used in operations with breaks, like elevators or machine tools.
- **Variable Duty (S6-S9)**: Used in dynamic systems like rolling mills or variable-speed drives.

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