

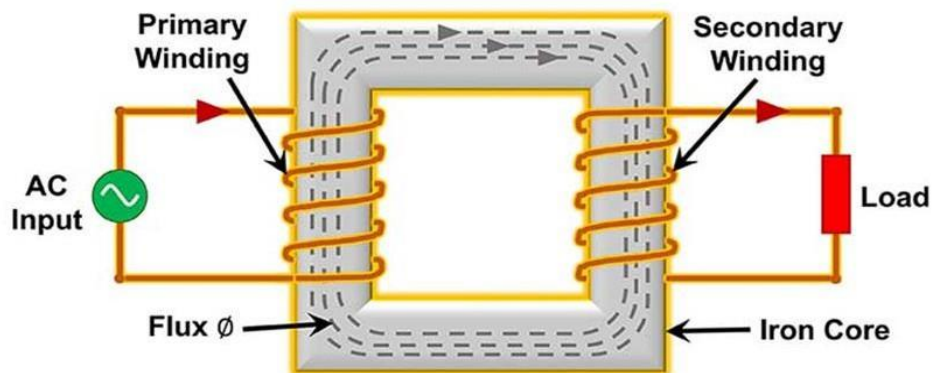


EE3035 GRID INTEGRATING TECHNIQUES AND CHALLENGES

UNIT-II

Transformers in Electric Power Grids

A power transformer is a static device that transfers electrical energy from one circuit to another without changing the frequency. It works on the principle of electromagnetic induction and can step up or step down the voltage level of an alternating current (AC) supply. Power transformers are essential for the transmission, distribution, and utilization of electrical power in various sectors.



Basic Construction of Transformer

Power transformers can operate with high efficiency and reliability for long periods of time.

Power transformers are used for several reasons in the electrical power system. Some of them are:

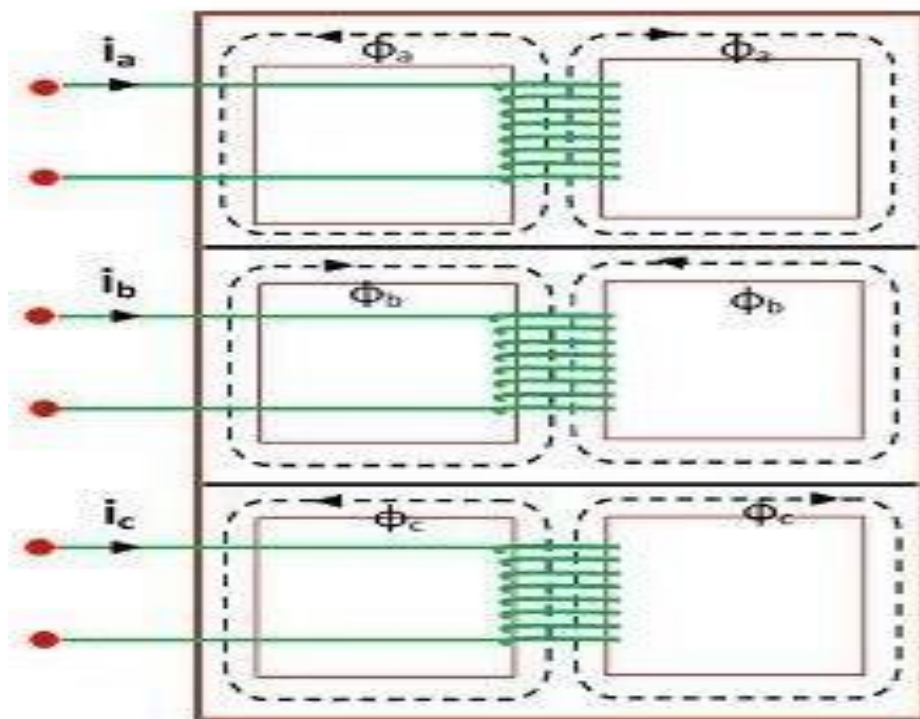
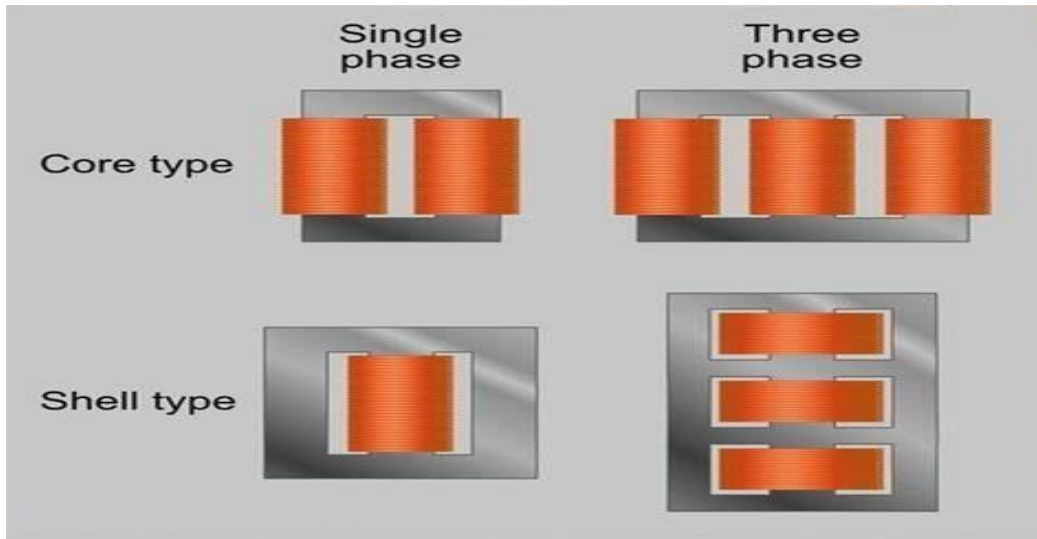
- To reduce power loss in transmission lines: Electrical power is generated at low voltage levels, which results in high current and high line losses due to ohmic heating. By using a step-up transformer at the generating station, the voltage level can be increased, and the current can be reduced, which reduces the line losses and improves the power factor. Similarly, at the receiving end, a step-down transformer can be used to lower the voltage level to a suitable value for distribution and consumption.
- Galvanic Isolation Provided: Power transformers ensure electrical isolation between circuits with different potentials or frequencies. This protection prevents short circuits, ground faults, and equipment damage due to electrical interference.
- Impedance Matching: By adjusting voltage and current levels, power transformers match the load impedance with the source impedance, enhancing power transfer and circuit efficiency.

- **Voltage Level Adjustment:** Power transformers supply various voltage levels suited for diverse applications—lighting, heating, and communication. For instance, a three-phase transformer can deliver both three-phase power for industry and single-phase for home use.

Types of Power Transformers

Power transformers can be categorized based on different criteria, such as their construction, function, application, etc. Some of the common types of power transformers are:

- **Step-up and step-down transformers:** These transformers are used to increase or decrease the voltage level of an AC supply. A step-up transformer has more turns in the secondary winding than in the primary winding, while a step-down transformer has fewer turns in the secondary winding than in the primary winding.
- **Single-phase and three-phase transformers:** These transformers are used to handle single-phase or three-phase AC supplies. A single-phase transformer has one primary winding and one secondary winding, while a three-phase transformer has three primary windings and three secondary windings that are connected in star or delta configuration.
- **Two-winding and autotransformers:** These transformers have either two separate windings or one common winding for both primary and secondary circuits. A two-winding transformer is used when the voltage ratio is greater than 2, while an autotransformer is used when the voltage ratio is less than 2.
- **Distribution and power transformers:** These transformers are used for different purposes in the power system network. A distribution transformer is used to step down the voltage for distribution to domestic or commercial users. It has good voltage regulation and operates at full load or near full load most of the time. A power transformer is used to step up or step down the voltage for transmission between generating stations and substations. It has poor voltage regulation and operates at variable loads depending on the demand.
- **Instrument transformers:** These transformers are used to measure high voltages and currents in a circuit by stepping them down to lower values that can be measured by conventional instruments. They include current transformers (CT) and potential transformers (PT).
- **Oil-cooled and dry-type transformers:** These transformers differ in their cooling methods. Oil-cooled transformers use mineral oil as a cooling medium that circulates through radiators or heat exchangers. Dry-type transformers use air as a cooling medium that flows through vents or fans.
- **Core type and shell type transformers:** These transformers differ in their core shapes and winding arrangements. A core-type transformer has a rectangular core with two vertical limbs and a horizontal yoke. The windings are cylindrical and concentric and are placed on both limbs. A shell-type transformer has a central limb and two outer limbs that form a shell around the windings. The windings are sandwiched between the limbs and have multiple layers.



3-Phase Shell Type Transformer

Circuit Globe

- Outdoor vs. Indoor Transformers: Outdoor transformers, designed for harsh conditions, are oil-cooled and housed in metal tanks. In contrast, indoor transformers operate in controlled environments and are typically dry-type, enclosed in metal cabinets.

Power Transformer Specifications

Power transformers have various specifications that describe their characteristics and performance. Some of the common specifications are:

- Rated voltage: This is the nominal voltage that the transformer is designed to operate at. It is usually expressed in kilovolts (kV) or volts (V).

- **Rated power:** This is the maximum apparent power that the transformer can deliver at its rated voltage and frequency. It is usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA).
- **Rated current:** This is the maximum current that the transformer can carry at its rated voltage and frequency. It is usually expressed in amperes (A) or kiloamperes (kA).
- **Voltage ratio:** This is the ratio of the secondary voltage to the primary voltage of the transformer. It indicates how much the transformer steps up or steps down the voltage.
- **Turns ratio:** This is the ratio of the number of turns in the secondary winding to the number of turns in the primary winding of the transformer. It is related to the voltage ratio by the equation:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

where V_s and V_p are the secondary and primary voltages, and N_s and N_p are the secondary and primary turns.

- **Impedance:** This is the opposition to the flow of current in the transformer. It is usually expressed as a percentage of the rated voltage divided by the rated current, or as an ohmic value.
- **Efficiency:** This is the ratio of the output power to the input power of the transformer. It indicates how well the transformer converts electrical energy from one circuit to another.
- **Regulation:** This is the change in secondary voltage when the load changes from full load to no load, expressed as a percentage of the no-load voltage. It indicates how well the transformer maintains a constant output voltage.

Power Transformer Applications

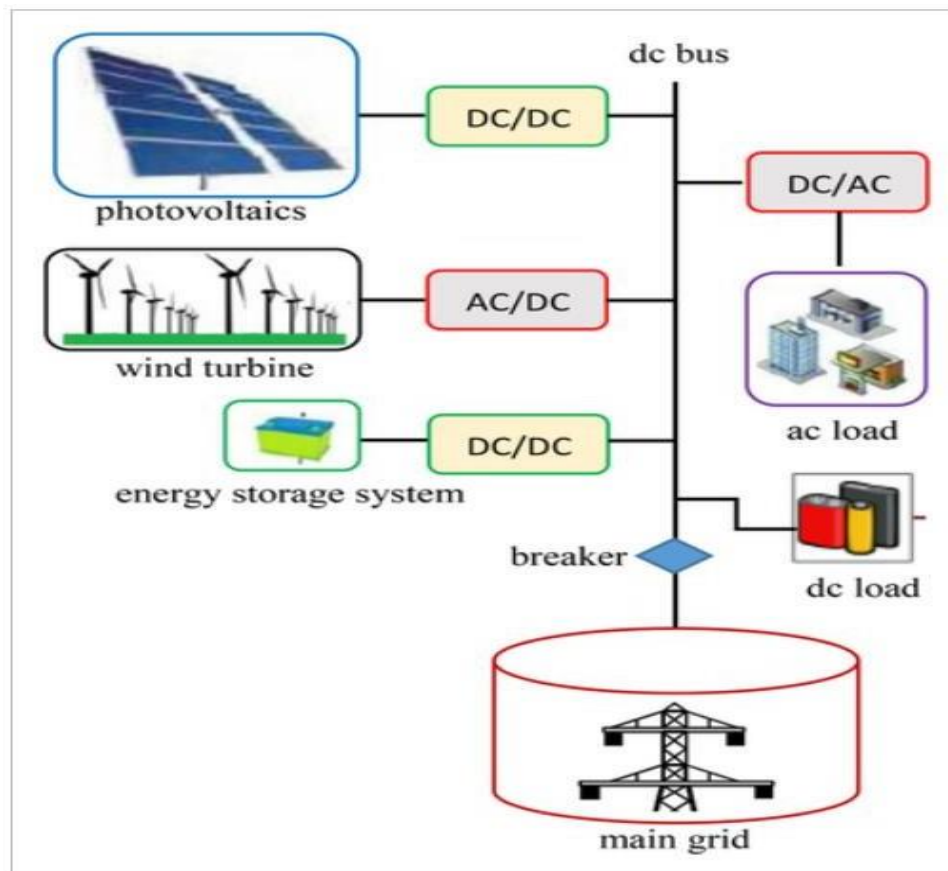
Power transformers are widely used in various sectors, such as:

- **Power generation:** Power transformers are used to step up the voltage generated by power plants for transmission to substations.
- **Power transmission:** Power transformers are used to step up or step down the voltage at different points of the transmission network for efficient power delivery.
- **Power distribution:** Power transformers are used to step down the voltage for distribution to domestic or commercial users. It operates at variable loads depending on the demand and has good voltage regulation.
- **Power generation:** Power transformers are used to step up the voltage of the electricity generated by power plants before it is sent to the grid. This reduces the current and the line losses during transmission.
- **Power transmission:** Power transformers are used to step up or step down the voltage at different points of the transmission network for efficient power delivery. They also provide galvanic isolation and impedance matching between different circuits.

- Power distribution: Power transformers are used to step down the voltage for distribution to various consumers. They also provide multiple voltage levels for different applications, such as lighting, heating, cooling, communication, etc.
- Lighting: Power transformers are used to provide low voltage and high currents for lighting systems, such as fluorescent lamps, neon signs, etc.
- Audio systems: Power transformers are used to isolate and amplify audio signals in speakers, amplifiers, microphones, etc.
- Electronic equipment: Power transformers are used to provide low voltage and regulated power supply for electronic devices, such as computers, televisions, radios, etc.

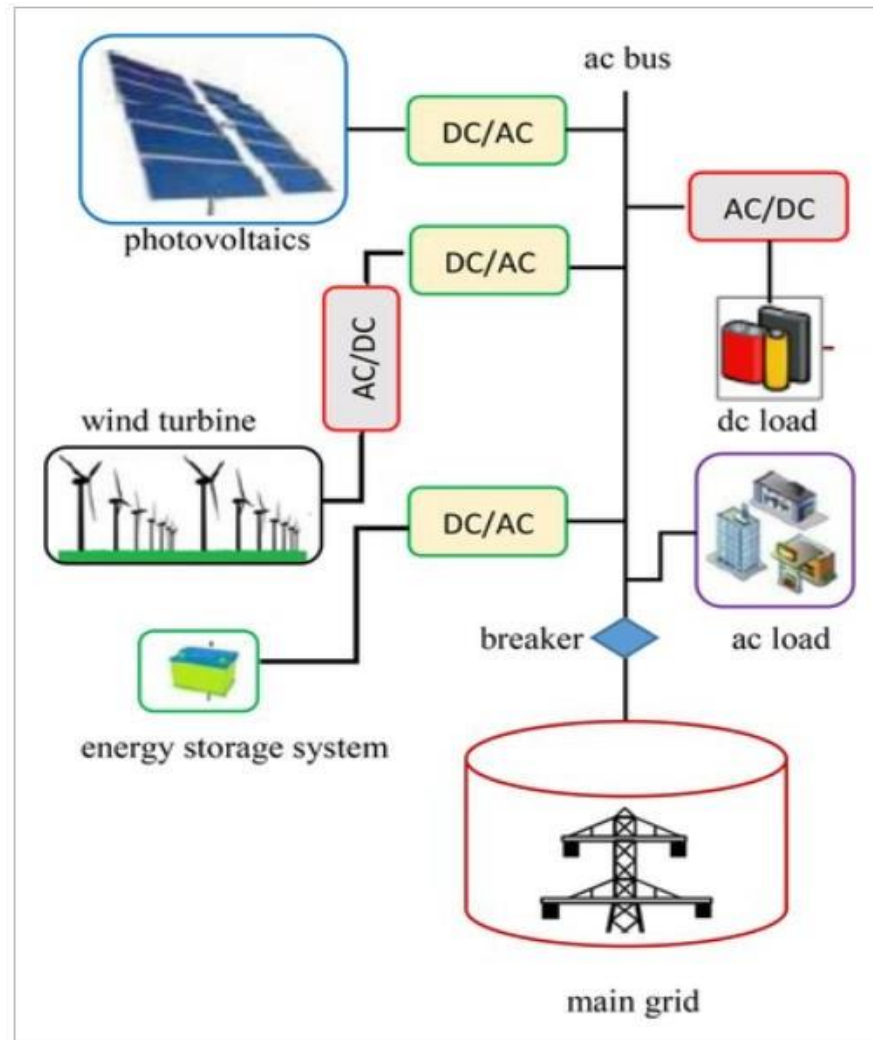
Modeling of Micro Grid

The microgrid is classified as an AC power system, a DC power system, or a hybrid system, which when applied, reveal their advantages and disadvantages. There exist many studies on the advantages and disadvantages of both AC and DC microgrids. The DC microgrid can be applied in grid-connected mode or in autonomous mode. A typical structure of AC microgrid is schemed in Figure.

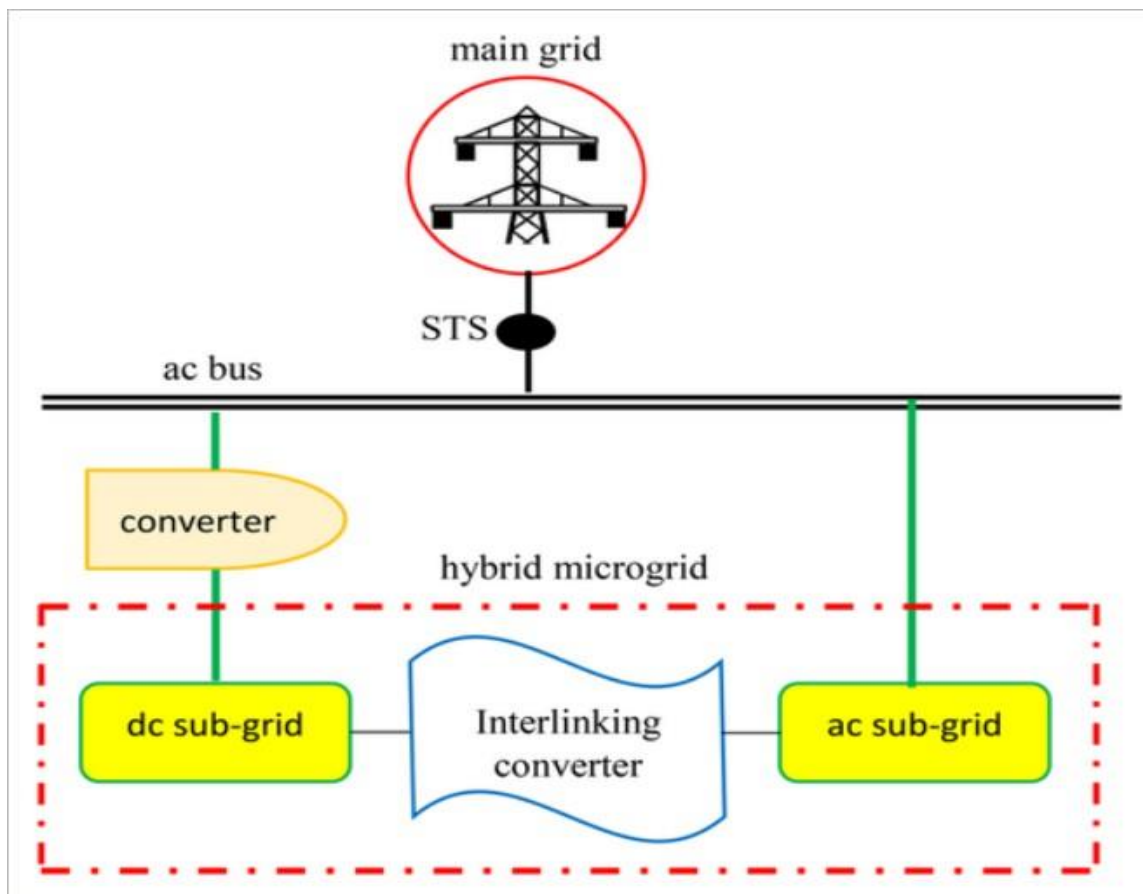


The distribution network of a DC microgrid can be one of three types: monopolar, bipolar and homopolar.

In an AC microgrid, all renewable energy sources and loads are connected to a common AC bus. The main disadvantage of the AC microgrids is the difficulty in the control and operation. A typical structure of AC microgrid is schemed in Figure. Microgrid AC can be classified into three types according to the distribution system: single-phase, three-phase without neutral-point lines, and three-phase with neutral-point lines.



The structure of a hybrid microgrid is schemed in Figure, where, it is connected to the main grid through a static transfer switch (STS). The power flow between the networks and the utility grid are controlled through the power electronic converter interface. The power direction is subject to the balance between load and generation. The aim of constructing hybrid microgrids is improving the overall efficiency of the network, that they include minimize conversion stages, increase reliability, reduce interfacing devices, and reduce energy costs. Much research on the application, protection, and stability of DC, AC, and hybrid microgrids has been reported in the various literature.



MICROGRID INTEGRATION CHALLENGES

The performance of the renewable energy sources depends on many factors which they are not remaining constant for all the time. Thus, the performance of microgrid, which depends on the function of these resources, is also changed. Microgrid can improve the stability, reliability, quality, and security of the conventional distribution systems, that it is the reliable and more useful technique to produce electric power and reduce the use of the nonrenewable energy source.^{98, 99} Nevertheless, the integration/connotation of microgrids in to main grid presents different types of technical and economic challenges may arise when integrating microgrids into the main network. Voltage collapse, large investment, low-power quality, and huge transmission loss are the drawbacks of the grid-connected microgrid.