Introduction

The primary system is the part of the electric system that is between the distribution substation and the distribution transformer and is made of circuits called the primary (or main) feeders. Various interrelated factors affect the selection of a primary feeder ratings, such as:

- The nature of the loads connected;
- The load density of the served area;
- The growth rate of the load;
- The need for providing spare capacity for emergency operations;
- The type and cost of circuit construction;
- The design and capacity of the substation;
- The type of regulating equipment used;
- The required quality of service;
- The required continuity of service.
Renewable energy

The energy of many types, including wind, solar, hydro, geothermal, and biomass (waste material) is known as **renewable energy**.

All renewable energy except for tidal and geothermal, and even the energy of fossil fuels ultimately comes from the sun. Approximately 1-2% of sun energy is converted to wind.

About 174 PW is received from the sun, 30% is reflected back.

Renewable sources can generate both electricity and heat; the term green power indicates electric products that are generated from renewable sources that are environmentally and socially acceptable. Most renewable energy forms can be converted to electricity, while solar energy, geothermal energy, and biomass can also be used to supply heat.

Renewable energy is also a naturally distributed resource: it can provide energy to remote areas without the need for transportation. However, there are situations when renewable energy does not need to be converted to electricity: solar water heaters and wind-powered water pumps are some examples.

Presently, the largest renewable energy technology (except for hydro) is wind power, with 95 GW worldwide by the end of 2007. The capacity of world hydro plants is over 800 GW.

The world primary energy demand almost doubled between 1971 and 2003 and is projected to grow.
Integrating renewables into power systems

- **Grid** is the totality of the electric power network.
  In general, the integration of generators powered by the renewable sources is the same as for fossil-fueled generators and is based on the same methodology. However, renewable energy sources are often variable and geographically dispersed.
- A stand-alone renewable energy generator provides for the greater part of the demand with or without other generators or storage.
- A grid-connected renewable energy generator supplies power to a large interconnected network that is also supplied by other generators. The power supplied by the renewable energy generator is only a small portion of the power supplied to the grid. The connection point is referred to as the point of common coupling.

Distributed generation

It is commonly assumed that by the end of 21st century, the most of electric energy will be provided by renewable energy sources.
Small generators cannot be connected to the transmission system because of high cost of high-voltage transformers. Therefore, small generators must be connected to the distribution system network. Such generation is know as distributed (or dispersed) generation (DG). It is also called the embedded generation since it is embedded in the distribution network.
Power in such power systems may flow from point to point within the distribution network. As a result, such unusual flow patterns may create additional challenges in the effective operation and production of the distribution network. The distribution network becomes active with the integration of DG, therefore, it is called an active distribution network.
Distributed generation

The properties of DG:
1. Normally less than 50 MW;
2. Neither centrally dispatched nor centrally planned by the power utility;
3. The distributed generators or power sources are generally connected to the distribution systems, which typically have voltages from 240 V to 34.5 kV.

The development and integration of the DG are based on the technical, economical, and environmental benefits that are:
1. Reduction of pollution;
2. Rapid load growth rapidly depletes the fossil-fuel resources;
3. Distributed energy resources (DER) are modular units of small capacity;
4. The overall power quality and reliability improves;
5. The overall plant energy efficiency increases;
6. DER can be connected to the network separately or as a microgrid.

Renewable energy penetration

The proportion of electric energy supplied from renewable energy sources is called the penetration. The average penetration is

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\text{Average penetration} = \frac{\text{Annual energy from renewable generators (kWh)}}{\text{Total annual energy delivered to loads (kWh)}} \quad (4.8.1)
\]

On the other hand, the instantaneous penetration, commonly used in system control applications, is

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\text{Instantaneous penetration} = \frac{\text{Power from renewable generators (kW)}}{\text{Total power delivered to loads (kW)}} \quad (4.8.2)
\]
Active distribution network

Active distribution network is also called a generation embedded distribution network. In the past, distribution networks had a unidirectional power transportation and were stable passive networks. Now, the distribution networks are becoming active by inclusion of DG that cause bidirectional power flows in the networks. To have a good active distribution networks with flexible and intelligent operation and control, the following must be provided:

1. Adaptive protection and control;
2. Wide-area active control;
3. Advanced sensors and measurements;
4. Network management apparatus;
5. Real-time network simulation;
6. Distributive penetrating communication network;
7. Knowledge and data extraction by intelligent methods;
8. New modern design of transmission and distribution systems.

Concept of microgrid

A microgrid is an active distribution network and is made up of collection of DG systems and various loads at distribution voltage levels. They are generally small low-voltage loads of a small community. The examples are university campuses, commercial areas, an industrial site, a housing estate...

The generators (micro sources) used in a microgrid are generally based on renewable/nonconventional distribution energy resources. They are integrated together to provide power at distribution voltage level. To introduce a microgrid to the utility power system as a single unit meeting local energy requirements, the micro sources must have power electronic interfaces (PEIs) and controls to provide the necessary flexibility so to maintain the power quality and energy output.

However, before microgrids can be established, a number of technical, regulatory, and environmental issues must be addressed. They include the establishment of standards and regulations for operating the microgrids together with the power utility, low energy content of the fuels involved, and the climate-dependent nature of production of the DERs.
Concept of microgrid

A microgrid differs from conventional power plants:
1. Power is generated at distribution voltage level and can be directly provided to the utility distribution system;
2. Capacity of generators is much smaller than in conventional plants;
3. They are usually installed closer to the customers so that electric/heat loads can be efficiently served with proper voltage and frequency and negligible losses;
4. They are ideal for providing electric power to remote locations;
5. They can be treated as a controlled entity within the power system;
6. They meet the electrical/heat requirements locally: consumers can receive uninterruptable power, reduced feeder losses, improved local reliability, and local voltage support;
7. They reduce environmental pollution by utilizing low-carbon technologies.

Concept of microgrid

A microgrid connection scheme. Microgrids are connected to the medium voltage (MV) utility “main grid” through the point of common coupling (PCC) circuit breaker. Micro source and storage devices are connected to the feeders through micro source controllers (MSCs).
Concept of microgrid

Some loads on feeders B and C may be the priority loads (those needing uninterruptable power supply) while the rest are non-priority loads. The microgrid has two modes of operation:

1) Grid-connected;
2) Stand-alone.

In the first mode, the microgrid imports or exports power from or to the main grid. In the event of any disturbance in the main grid, the microgrid switches to the stand-alone mode but still supplying power to the priority loads. This may be achieved by opening corresponding circuit breakers. Considering the example above, the feeder A may be left with no power…

The central controller (CC) include energy management module (EMM) and protection coordination module (PCM). The EMM supplies the set points for active and reactive power output, voltage, and frequency to each microgrid controller (MC). Advanced communication and artificial intelligent techniques may be used for this purpose…

Concept of microgrid

The PCM is responsible for microgrid and main grid faults so that proper protection coordination of the microgrid is achieved. The functions of the central controller (CC) in the grid-connected mode include:

1) Monitoring system diagnostics by gathering information from the micro sources and loads;
2) Performing state estimation security assessment evaluation, economic generation scheduling and active and reactive power control of the micro sources by using the collected information;
3) Ensuring a synchronized operation with the main grid maintaining the power exchange at specific points.
Concept of microgrid

The functions of the central controller (CC) in the stand-alone mode include:
1) Performing active and reactive power control of the micro sources to keep stable voltage and frequency at load ends;
2) Adapting load interruption/load-shedding strategies using demand side management with storage device support for maintaining power balance and bus voltage;
3) Beginning a local "cold start" to ensure improved reliability and continuity of service;
4) Switching over the microgrid to grid-connected mode after main grid supply is restored without impeding the stability of either grid.

Concept of microgrid

Technical and economic advantages of microgrids for the electric power industry are:
1) Reducing the impact to the environment;
2) Reducing some operational and investment issues;
3) Improving power utility and reliability;
4) Increasing cost savings;
5) Solving market issues.
Concept of microgrid

Despite the potential benefits, the development of microgrids suffers from several challenges and potential drawbacks, such as:
1) High cost of DERs;
2) Technical difficulties;
3) Absence of standards;
4) Administrative and legal obstacles;
5) Market monopoly (microgrids might retail energy at a very high price exploiting market monopoly during the periods of the need).