1

Introduction

Energy turnaround, smart grid, smart meters, smart buildings, smart homes, smart cities, renewable energies (RE), digitization, data protection, data security, efficient use of energy, control and regulation with digital technologies, industry 4.0, decentralized energy supply, demand side management (DSM), electric filling stations, and new business models for the electricity market are the new topics, tasks, and challenges we will deal with in the coming years. Figure 1.1 shows the path of electrical energy from the power plant to the consumers.

Electrical networks and switchgear and their planning and project planning are very much affected by this. They must perform various tasks relating to the transmission and distribution of electrical energy safely and economically. Transmission networks are highly meshed. They are used for large-scale energy transmission, and ensure mutual grid support. Thermal power plants and onshore and offshore wind farms feed into the high-voltage grids. Only a few major customers are connected to the grid. The distribution networks are meshed. These networks are fed by smaller thermal and industrial power plants and wind farms. Typical followers are customers from the big industry.

The high-voltage networks are subordinated to the medium-voltage and low-voltage networks. Smaller decentralized systems feed into the medium-voltage and low-voltage networks. Energy generation plants are based on fossil or renewable fuels such as fuel oil, natural gas, vegetable oil, biodiesel or biogas as well as wind energy plants, photovoltaic (PV) systems, or combined heat and power (CHP) plants. Medium-voltage networks supply industrial, commercial, offices, and department stores, while low-voltage networks supply households, agriculture, and small businesses. The legal, political, and social requirements for electrical energy supply are laid down in the Energy Industry Act (EIA). The EIA requires the planning of safe, reliable, inexpensive, and reliable environmentally compatible networks. In addition, the Renewable Energies Act and the Combined Heat and Power Act promote the expansion of renewable energies and combined heat and power generation. Further advances in heat coupling.

In the distribution grids, the increase in regenerative feeds from wind and sun also lead to variable load flows. The wind and solar energy completely covers local consumption at times, so that the grids can be fed back into the grid by means of regenerative braking, thus endangering network security. Today's networks are not

Analysis and Design of Electrical Power Systems: A Practical Guide and Commentary on NEC and IEC 60364, First Edition. Ismail Kasikci.

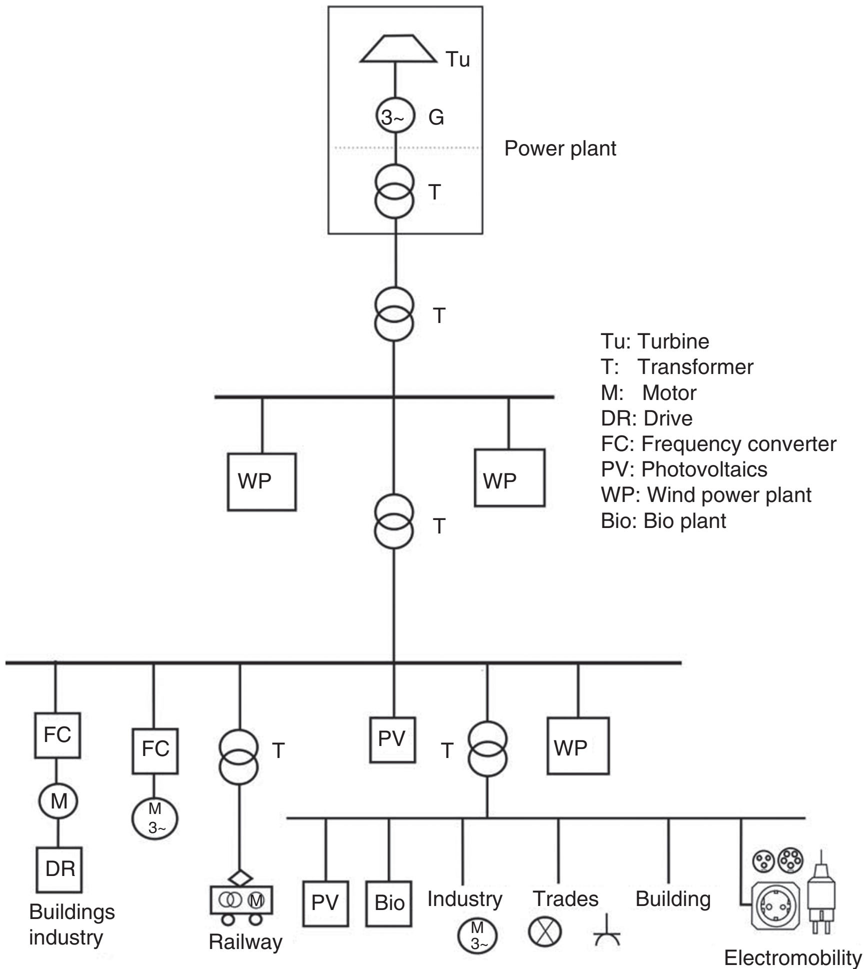

Figure 1.1 Generation, transmission, and distribution of electric power.

designed for feed-ins from regenerative feed-ins. The power quality is impaired at the feed-in node. In addition, the changing load flow directions cause voltage fluctuations that cannot be regulated by the transformers. The use of decentralized energy management systems (DEMS) in the distribution networks will become very important in the future. They coordinate the energy use of the decentralized generation plants with the energy consumption of the consumers and control their energy feed or acceptance. In addition to electricity, a communication network is required that enables the exchange of information between producers, consumers, and storage facilities.

In combination with smart metering in buildings (use of intelligent, electric electricity meters), the so-called Smart Grids (intelligent power grids), which provide load management via bidirectional data communication, are already installed in various plants. Every electrical system must not only satisfy the normal operating condition, but also be designed for faults and must be able to handle both faultless and faulty operating conditions. Therefore, electrical systems must be dimensioned in such a way that neither persons nor material assets are endangered.

The dimensioning, efficiency, and safety of the systems are strongly dependent on the control of short-circuit currents. With increasing installed capacity, the calculation of short-circuit currents also gained in importance. A three-phase system can be temporarily or permanently disturbed by faults, especially short-circuits, circuit measures, or by consumers. Calculation models and solution algorithms for power generation, transmission, and distribution systems provide a comprehensive tool as a calculation and dimensioning program for the planning, design, analysis, optimization, and management of any power supply network. Owing to the liberalization of the energy markets and in particular the rapid expansion of renewable energies, the requirements for network planning and operational management processes are becoming increasingly complex.

Transformers (with or without medium voltage), generators, and neutral grid feeds are available. A neutral mains supply can be mapped by specifying the impedances, the loop impedance, or the short-circuit currents. In supply circuits, an individual fuse of parallel cables with several protective devices can optionally be calculated and dimensioned in addition to the fuse protection of parallel cables by a protective device. The selected feeds can be connected to each other via directional or nondirectional couplings. By defining the different operating modes required (e.g. normal operation, emergency operation …), the network supply can be represented in a practical way and included in the calculation.

Sub-distributors, group switches, busbar trunking systems, busbar trunking systems with central supply, or distributors with replacement impedances are available as distributors. When selecting these elements, certain specifications must also be made with regard to the design, e.g. whether the connecting cable is to be designed as a busbar or cable and which and how many switching devices are to be used. If a cable section is selected, the intended type of installation must also be specified so that the values of the current-carrying capacity influenced by this are taken into account in the dimensioning. The distributors are always inserted into the graphic on a busbar. This can be the busbar that symbolizes the feed-in point or the busbar of an already connected distributor or the representation of a busbar string, so that the network can be branched further as a radiation network.

For final circuits, consumers with fixed connections, socket outlet circuits, motors, charging units, capacitors, and equivalent loads are available as elements. These are in turn connected to the busbar of existing sub-distribution boards or the representation of a busbar line or directly to the busbar symbolizing the feed-in point. There are also various options for placing these elements in the mesh graphic. These are offered in the selection window specific to the element. Simultaneity factors or utilization factors can also be specified for the different circuits, which are also then taken into account during dimensioning. Once the network structure is completely constructed in this way, the actual calculation and thus the dimensioning and selection of the elements can be initiated.

The results of this dimensioning can be viewed and documented in the various available view variants of the network graphic. In addition to the possibility of individually configuring the labeling of the network graphic, standardized labeling variants (device parameters, load flow/load distribution, short-circuit load, energy balance) are available, so that all parameters relevant for the network calculation are clearly displayed.

In practice, selectivity verification is often mandatory, e.g. for safety power supply systems. Back-up protection can also be taken into account when selecting switchgear, i.e. the switching capacity of a downstream switch can be increased by the fact that the upstream switch trips simultaneously and thereby limits the current.

Suitable programs can be used for the design and selection of electrical equipment, calculation of mechanical and thermal short-circuit resistance, calculation of short-circuit currents, selectivity and back-up protection for the selection of overcurrent protection devices, and calculation of the temperature increase in control cabinets.