1.1 OVERVIEW OF POWER SYSTEM OPERATION

The main objectives of power system operation are safety, reliability, and efficiency. System operation has always been regarded as a critical function in utilities around the world because it can significantly change the utility’s bottom line. System operation affects people’s safety, impacts system reliability, and influences operational costs associated with the deployment of transmission and generation resources.

The electricity deregulation in the last decade created a new landscape for the energy industry. This change coupled with the potential for increasing penetration of large amounts of integrated and variable generation and the move toward smart grid, including advancing generation, transmission, and distribution technologies as well as customer enablement technologies continue to increase the complexity of power system operation.

In power system operation, there are three main actors:

- **Operator**, who is responsible to execute different functions
- **Process**, which provides a detailed description of how a function should be executed and
- **Technology**, which enables and facilitates the process

In simple terms, power system operation involves establishing a picture of the prevailing system operating condition by measuring different system signals such as flows and voltages. Using this picture, the operator executes different operation functions resorting to two means of

- The process book or the operating order book which serves as the reference book detailing the actions that operators need to take under different conditions
- The technology or decision support tools which enable and facilitate the operating orders

This exercise will eventually result in some automated control actions directly taken by the system or manual control actions taken by the system operator as shown in Figure 1.1. A good metaphor for this is operating or driving a car. The operator examines the driving condition by watching the surroundings of the car. He compliments this information with the information from the car dashboard, which provides the
prevailing operating condition of the vehicle such as speed, engine’s temperature, and gas content. The operator then responds to the prevailing condition based on the rules specified in the driving rule book using the technologies enabling the rule book actions such as the steering and brake systems. Under some conditions, the car can take an automated control action directly such as triggering airbags under emergencies using the prevailing condition without operators’ interaction.

1.2 OPERATOR

Operators are responsible to manage system operation with the objectives of safety, reliability, and operational efficiency. To achieve these objectives, they need to perform a number of functions and their associated tasks. Some of the major functions that operators need to execute include

- Transmission monitoring
- Transmission limit assessment
- Transmission voltage management
• Transmission congestion management
• Transmission outage management
• Load shedding management
• Generation load balance
• Generation operation
• Generation reserve management
• Generation outage management
• Interchange communication
• Interchange monitoring
• Interchange congestion management
• Interchange operation
• Emergency generation capacity management
• Emergency load shedding management
• Emergency transmission management
• Restoration

North American Electric Reliability Council (NERC) has published a generic task list [1] detailing all the functions that system operators need to execute to manage system operation. The task list includes about 400 tasks divided under the following broad categories:

• General control center operations
• Transmission
• Generation
• Interchange
• Restoration

1.3 PROCESS

To fulfill their functions, operators need to develop business processes for each function. A business process is a structured set of linked activities designed to produce a product or service. One of the most significant people in the eighteenth century to describe processes was Adam Smith [2], who described the production of a pin in the following way:

One man draws out the wire, another straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head: to make the head requires two or three distinct operations: to put it on is a particular business, to whiten the pins is another... and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which in some manufactories are all performed by distinct hands, though in others the same man will sometime perform two or three of them.
Starting from Chapter 2, the process corresponding to each operator critical function will be examined.

1.4 TECHNOLOGY

To enable and facilitate business processes, technology solutions are required. For example, to achieve the process of pin production with minimum manual work, a number of technology solutions need to be deployed. Similarly, for power system operation, each process may need one or a number of technology solutions for process enablement.

1.5 POWER SYSTEM OPERATION CRITERIA

NERC was established following the blackout of Northeast USA with the mandate of developing operation and planning reliability standards. These standards are the planning and operating rules that electric utilities follow to ensure an acceptable level of reliability. While NERC’s standards were historically voluntary, in 2007, the Federal Energy Regulatory Commission (FERC) made them mandatory. This gave NERC another mandate to enforce compliance with NERC Reliability Standards, which it achieves through a rigorous program of monitoring, audits, and investigations and the imposition of financial penalties and other enforcement actions for noncompliance. NERC also manages the program that certifies system operators, ensuring they have the required knowledge and skills to perform their functions.

NERC defines reliability as the combination of transmission adequacy and transmission security where:

- Transmission adequacy is defined as “The ability of the electric system to supply the aggregate demand and energy requirements of their customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements/components.”
- Transmission security is defined as “The ability of the bulk electric system to withstand sudden disturbances such as electric short circuits, unanticipated loss of system components or switching operations.”

For reliable power system operation, a power system must remain intact and be capable of withstanding a variety of disturbances. Since it is impractical to consider all contingencies, instead only a set of probable contingencies are considered. These contingencies, which are called $(N - 1)$, are the ones that consider the loss of only one element of an $N$-component grid. It is recognized that more severe contingencies than $(N - 1)$ can occur for which a reliable power system operation may not be achieved. For these conditions, measures should be taken to minimize the impact.

NERC standards [3] define the system performance requirement for the normal system when the system has not suffered any contingencies and the conditions after the contingencies. Performance requirement could include voltage profiles, allowed voltage dip after a contingency, system frequency damping, etc. An example of
voltage profile performance requirement after a contingency is given in Figure 1.2. This figure shows the limits imposed on the maximum transient voltage dip, the time duration of voltage dip exceeding the imposed limit (e.g., 20%), and the post-transient voltage deviation.

Figure 1.2 NERC voltage performance requirement following a contingency.

1.6 OUTLINE OF THE BOOK

The book is composed of 12 chapters and one appendix. It describes power system operation from the viewpoint of an operator’s functions and needs. This practical approach provides the readers with a deep appreciation for power system operation objectives, processes established to achieve those objectives, and the technology needed to enable the processes.

The first eight chapters of the book cover an operator’s functions and his needs to fulfill his functions. This is followed by providing the established process details to perform the functions as well as the required technology solutions enabling the processes. Starting from Chapter 2, each chapter is dedicated to one operator’s critical function, its process, and the enabling technology. Chapter 9 discusses modern power system operation control centers’ requirements and design features. Chapters 10 and 11 provide complete descriptions of energy management systems and distribution management systems. Each chapter provides an ensemble of technology solutions playing together for transmission and distribution operation respectively. Chapter 12 deals with evolving technology solutions for system operation. Finally, Appendix A deals with fundamental theoretical concepts to reinforce the understanding of the chapters.