Substations - Volume I: Design Parameters

An Online Continuing Education Course for Engineers

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Substations – Volume I: Design Parameters

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Preface

This course is one of a series of thirteen courses on the design of electrical substations. The courses do not necessarily have to be taken in order and, for the most part, are stand-alone courses. The following is a brief description of each course.

Volume I, Design Parameters. Covers the general design considerations, documents and drawings related to designing a substation.

Volume II, Physical Layout. Covers the layout considerations, bus configurations, and electrical clearances.

Volume III, Conductors and Bus Design. Covers bare conductors, rigid and strain bus design.

Volume IV, Power Transformers. Covers the application and relevant specifications related to power transformers and mobile transformers.

Volume V, Circuit Interrupting Devices. Covers the specifications and application of power circuit breakers, metal-clad switchgear and electronic reclosers.

Volume VI, Voltage Regulators and Capacitors. Covers the general operation and specification of voltage regulators and capacitors.

Volume VII, Other Major Equipment. Covers switch, arrestor, and instrument transformer specification and application.

Volume VIII, Site and Foundation Design. Covers general issues related to site design, foundation design and control house design.

Volume IX, Substation Structures. Covers the design of bus support structures and connectors.

Volume X, Grounding. Covers the design of the ground grid for safety and proper operation.

Volume XI, Protective Relaying. Covers relay types, schemes, and instrumentation.

Volume XII, Auxiliary Systems. Covers AC & DC systems, automation, and communications.

Volume XIII, Insulated Cable and Raceways. Covers the specifications and application of electrical cable.

Introduction

This is volume I of a multi-volume set of courses on the design of rural electric substations. The "rural" distinction implies that only open-air substation designs are covered though many of the concepts and ideas presented herein are applicable to urban substations. It covers rural transmission and distribution with air-insulated, outdoor substations up to 345 kV.

This volume is a broad overview of the design factors and data needed to design a substation. Subsequent volumes will explore equipment, foundations, structures, grounding, relaying and other items necessary to design an electrical substation.

Substations should be designed, constructed, and operated to meet customers' needs at the lowest possible cost commensurate with the quality of service desired. The typical system may include substations for voltage transformation, sectionalizing, distribution, and metering a number of times between generation and utilization.

Reliability Concerns

An example of an outage consideration for a substation would include a transmission switching station that operates with a simple main bus. An outage of the bus results in a complete interruption of power through the substation. The engineer will need to consider other equipment in the substation, such as a transfer bus or different multi-bus arrangement. The engineer should also evaluate the adjacent system to determine if the load can be diverted around the substation for outages to minimize the equipment that is installed in a substation.

Possible design responsibilities of the engineer are covered in this course, including preparation of construction drawings, material, equipment and labor specifications, and any other engineering design services that may be required.

A substation is part of a system and not an entity to itself. Normally, a power system is designed so that the effects of an outage (caused by the failure of a single component such as a transformer, transmission line, or distribution line) will result in minimal interruption of service and affect the fewest customers possible. Failure of one component in a system often forces a greater than normal load to be carried by other components of the system. Such contingencies are normally planned for and incorporated into design criteria.

When evaluating the switching arrangement for a substation, an engineer needs to be aware of the system configuration of which the substation will be a part. System contingency arrangements need to permit the outage of components in a substation for maintenance and unscheduled outages.

Most substations are designed to operate unattended. Remote indication, control, metering, and methods of communication are often provided so that systems and portions of systems can be monitored from a central point.

Substation planning considers the location, size, voltage, sources, loads, and ultimate function of a substation. If adequate planning is not followed, a substation may require unnecessary and costly modification.

Adequate engineering design provides direction for construction, procurement of material and equipment, and future maintenance requirements while taking into account environmental, safety, and reliability considerations.

Types of Substations

Substations may be categorized as distribution substations, transmission substations, switching substations, or any combination thereof.

One design tendency is to reduce costs by reducing the number of substations and taking advantage of economies of scale. Conversely, practical system design and reliability considerations tend to include many substations. One function of system studies is to balance these two viewpoints.

Distribution Substations

A distribution substation is a combination of switching, controlling, and voltage step-down equipment arranged to reduce sub-transmission voltage to primary distribution voltage for residential, commercial, and industrial loads.

Rural distribution substation capacities vary from maybe 1.5 MVA up to perhaps 35 MVA. These substations may be supplied radially, tapped from a sub-transmission line, or may have two sources of supply.

A special class of distribution substation would include a dedicated customer substation. This substation would be similar to a distribution substation except that all of its capacity would be reserved for the service of one customer. The secondary voltages of a dedicated substation would also be modified to match special requirements of the customer. Coordination with the customer

is of primary importance in determining the technical requirements. Confirmation of the technical terms being used is likely to be required since electrical engineers in differing industries may use the same terms to describe similar, yet technically different, criteria.

Transmission Substations

A transmission substation is a combination of switching, controlling, and voltage step-down equipment arranged to reduce transmission voltage to sub t on voltage for distribution of electrical energy to distribution subst ons frequently have two or more large transfor

Transmission substa nd their importance in the system often justifies ore elaborate than distribution substatio

Switching Substations

A switching substatio ipment arranged to provide circuit protecti hing arrangements in a transmission network c abnormal or maintenance conditions

Next we will look at the tation.