Substations - Volume III: Conductors and Bus

An Online Continuing Education Course for Engineers

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Substations – Volume III: Conductors and Bus

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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.

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Chapter 1: Bare Conductors

This chapter covers bare conductors and includes material types, ampacities, and connectors.

Conductor Materials

Copper and aluminum are the two major conductor materials used for substation buses and equipment connections. Both materials can be fabricated into various types of flexible or rigid conductors. The trend in substation construction is toward use of mostly aluminum conductors. Copper conductors are used principally for expansion of similar systems in existing substations.

The conductivity of aluminum is from 50 to 60 percent that of copper, depending on the aluminum alloy. Consequently, larger aluminum conductors are required to carry the same currents as copper conductors. The larger aluminum conductor diameters result in greater wind and ice loads but tend to minimize corona, which is more of a problem at higher voltages.

For the same ampacity, copper conductors weigh approximately twice as much as aluminum conductors. The higher copper conductor weights can result in more sag as compared with aluminum conductors for equal spans. To reduce the sag, it is usually necessary to increase the number of supports for rigid conductors or, in the case of flexible conductors, increase the tensions.

Rigid Conductors

Rigid electrical conductors are available in a variety of shapes and sizes to suit individual requirements. Some of the more commonly used shapes include flat bars, structural shapes, and tubes. Specific physical and electrical properties and application data can be obtained from the conductor manufacturers.

Flat bars can be utilized for outdoor substation buses and are particularly suitable since they can be easily bent and joined. For high-current applications, a number of flat bars can be grouped together, leaving a small space between the bars to facilitate heat dissipation. The ampacity of a group of flat bars depends on whether the bars are arranged vertically or horizontally. The number of bars that can be grouped together is limited because of skin and proximity effects. Flat bars are usually limited to use at lower voltages because of corona.

Because of their inherent lack of rigidity, supports for flat bar buses are usually closely spaced to minimize the effects of meteorological loads and short-circuit forces.

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The *structural shape* conductors that have been used in outdoor substation construction consist primarily of angle and channel types. The flat surfaces permit bolting directly to support insulators and provide convenient connection points. To increase ampacity, two angles or channels can be used. Special fittings are usually required for these configurations. The positioning and grouping of structural shapes have limitations similar to those of flat bars. The rigidity of both angle and channel shapes is somewhat higher than for flat bars of the same ampacity. Consequently, support spacing can usually be increased.

Square and round tubular shapes are considerably more rigid than either flat bars or structural shapes of the same ampacity and permit longer spans. The flat surfaces of square tubes provide convenient connection and support points. To facilitate heat dissipation, ventilation holes are sometimes provided in the square tubes. Round tubular conductors are the most popular shape used in outdoor substation construction. The round shape is very efficient structurally and electrically and minimizes corona at higher voltages. The special fittings required for connecting, terminating, and supporting round tubular conductors are widely available.

Special shapes combining the advantages of several of the standard shapes are also available. Integral web channel buses, uniform thickness angles, and other special configurations can be furnished.

Aluminum conductors are available in a variety of alloys and tempers with different conductor conductivities and strengths. Round tubular conductors are usually specified as either 6061-T6 or 6063-T6 alloy. The 6063-T6 alloy has a conductivity approximately 23 percent higher and a minimum yield strength approximately 29 percent lower than the 6061-T6 alloy. Consequently, the 6063-T6 alloy can carry higher currents but may require shorter support intervals. Both Schedule 40 and 80 pipe are available in either alloy. The Schedule 80 sizes have wall thicknesses approximately 40 percent thicker than the Schedule 40 sizes, resulting in lower deflections for equal span lengths.

Alloy 6106-T61 is frequently utilized for flat bars, structural shapes, and square tubes. Other alloys and tempers are available for special applications.

Flexible Conductors

Flexible electrical conductors can be used as substation buses and equipment taps. The conductors are normally cables fabricated by stranding a number of small conductors into one larger conductor. Stranding provides the required

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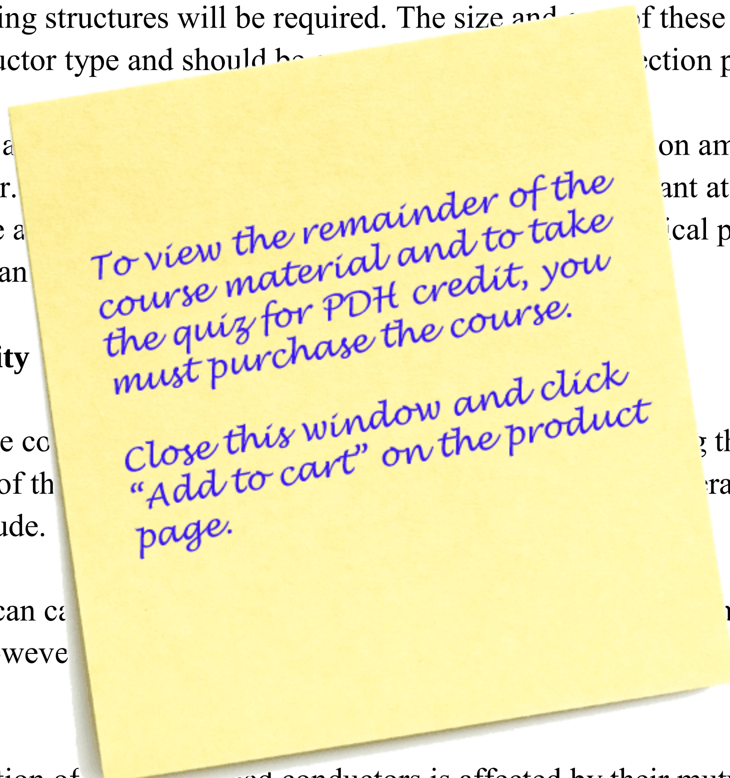
conductor flexibility while maintaining strength. The flexibility can be increased by reducing the diameter and increasing the quantity of individual conductors. Bare electrical cables for substation construction are usually concentric lay stranded with Class A or AA stranding in accordance with ASTM Std. B231.

Most flexible conductors used in substation construction consist of all copper, all aluminum, or aluminum with steel reinforcing (ACSR). The conductor type selected for a particular application is usually based on the span length, tension and tolerable sag, and cost. For long spans, large supporting structures will be required. The size and ... f these structures may depend on the conductor type and should be ... ction process.



Flexible conductors a ... on ampacity, strength, weight, and diameter. ... ant at higher voltages where corona can be a ... ical properties of the various wire types can ...

Conductor Ampacity

The ampacity of bare co ... the conductor material, proximity of th ... rature rise, emissivity, and altitude.

Copper conductors can ca ... minum conductors of the same size. Howeve ... is required for the same ampacity.

The current distribution of ... spaced conductors is affected by their mutual inductance in accordance with the proximity effect. The additional losses attributed to this effect can usually be neglected if conductor spacing is 18 inches or greater.

Climatic conditions have a great effect on conductor ampacity. Ampacities are usually determined based on ambient temperatures of 40C. For prolonged ambient temperatures above this value, ampacities are usually reduced. Wind tends to reduce the temperature of outdoor bare conductors. An assumed steady wind may be reasonable in many areas. The sun's radiation can cause the temperature of bare conductors to increase, which results in lower ampacities and should be considered in predominately sunny locations.

Conductor temperature rise is the temperature increase above ambient at which the conductor is operating. To prevent excessive surface oxidation and possible damage from annealing, the temperature rise is usually limited to 30C for a total maximum conductor temperature of 70C

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