# Electrical Equipment - Course 230.2

## SWITCHGEAR: PART 1

## BUSBARS AND CABLES

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1. OBJECTIVE

The student must be able to:

1.1 (a) State the purpose of an isolated phase bus.

(b) Given a diagram of an outdoor bus, state the principal components and describe their purpose.

(c) State the purpose of an indoor bus.

(d) State the purpose of cables.

1.2 (a) State the consequences of overloading busbars from the following points of view:

(i) thermal,
(ii) magnetic,

(b) State the checks that should be done to ensure a busbar is operating correctly.

1.3 State and briefly explain the six precautions that must be taken with cables.

2.0 INTRODUCTION

2.1 Definition

A **bus** is a conductor or group of conductors that serve as a common connection for two or more circuits. The term **busbar** commonly replaces the term "bus" on heavy current circuits. In generating stations, busbars are used as distribution points for electrical power.

## 2.2 Lesson Content

This lesson briefly examines the three types of busbar and cables that are used in a nuclear generating station, ie:

(a) the isolated phase bus (IPB) which conveys power from the main generators to the main and unit services transformers.

(b) the outdoor busbar system which conveys power from the main transformers to the Ontario Hydro Grid. The outdoor busbar system also conveys power from the grid to the system services transformers.

(c) the indoor busbars, housed in metalclad cubicles which distribute power within the station.

(d) the cables which convey power from the switchgear to the loads.

## 2.3 Problems Common to all Types of Busbars

There are two problems which are common to all types of busbar - thermal and magnetic.

(a) Thermal. As ambient temperature and load current varies, a busbar will heat up or cool down. This will cause considerable expansion and contraction. Expansion joints must be installed to ensure that the busbar is allowed to freely expand and contact. If this is not done, the bus will distort. Sufficient stress may be placed on the support insulators to cause them to break. Any joints in a busbar system, which become loose, will give rise to localized heating. In extreme cases, this heating can result in arcing and cause the busbar to fail.

While overheat busbars are on load, tests are done with infra-red TV cameras to ensure that no joint is overheating.

# MAIN OUTPUT SYSTEM

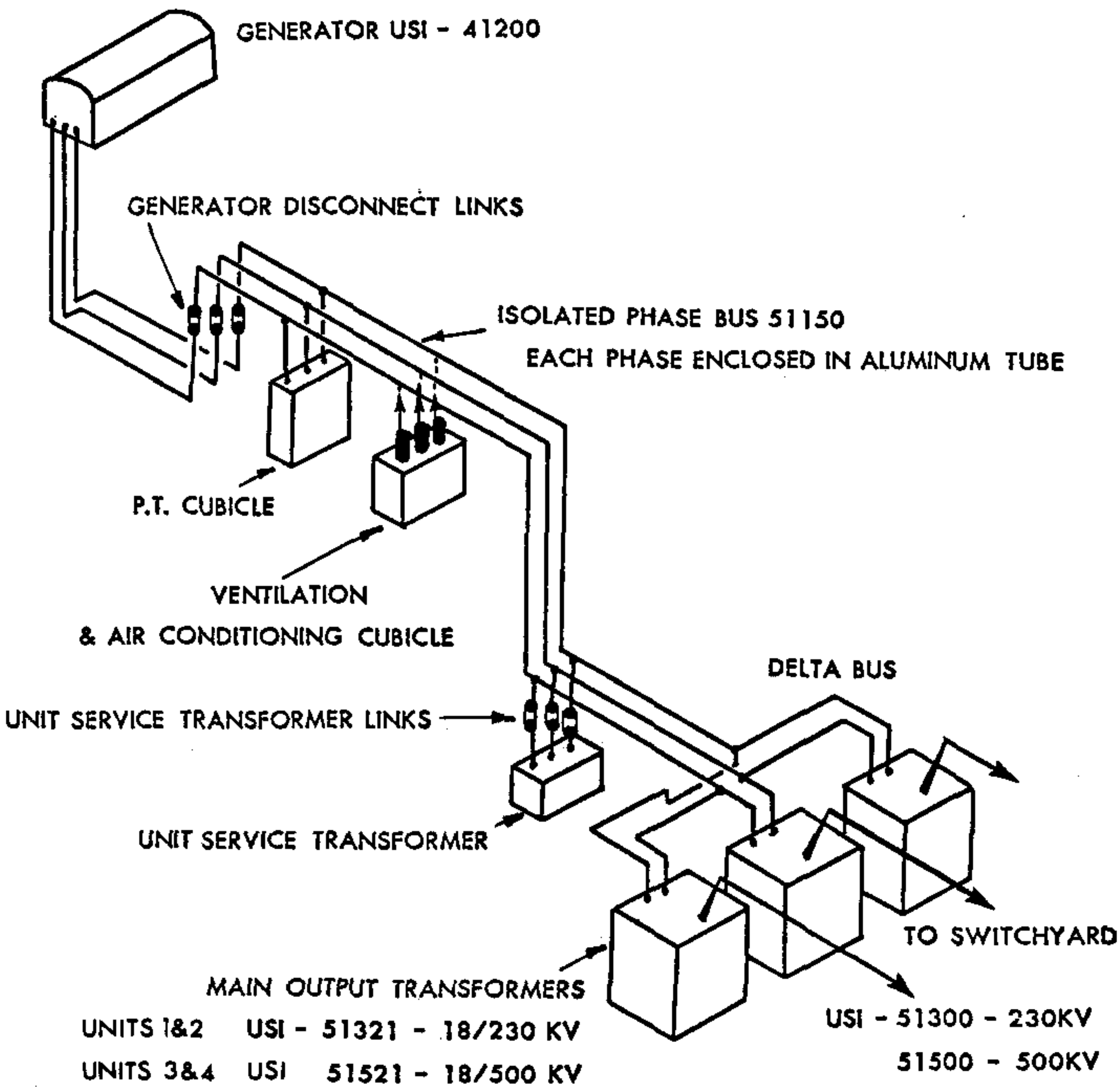



Figure 1: Diagram Showing the Main Output Isolated Phase Bus, (IPB), at Bruce "A" NGS.

(b) Magnetic. When current flows in a conductor, a magnetic flux is produced around the conductor. When current flows in two adjacent conductors the magnetic fluxes interact and produce attractive or repulsive forces, (dependent upon the direction of curent flow). With normal load currents, these forces are small but under short-circuit conditions the forces can be very high and reach tonnes per metre length. Clearly, forces of this magnitude can distort conductors and break insulators.

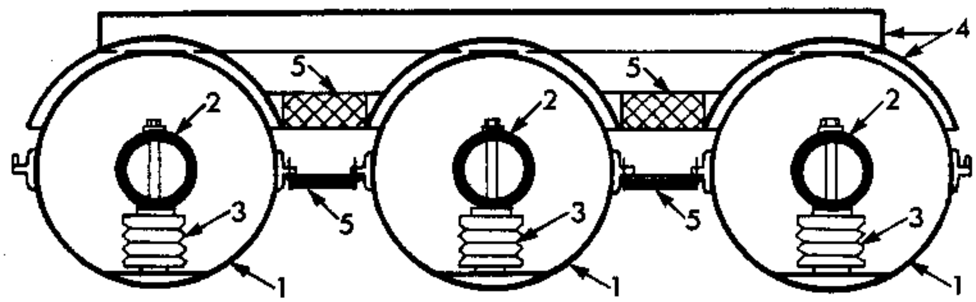
## 3.0 BUSBARS AND CABLES

### 3.1 The Isolated Phase Bus

3.1.1 Construction. Figure 1 shows the Isolated Phase Bus (IPB) at Bruce 'A' NGS. The IPB conveys power from the generator to the main transformer. Because the IPB has to convey very large currents, (up to 16 500 A at Pickering and 30 000 A at Bruce 'A'), it has to have a large cross sectional area. Bearing in mind, that as a rule of thumb, 6.45 $cm^2$ (1 square inch) of copper is required to convey 1000 A, the Pickering generator will require a copper conductor section of 106 $cm^2$ (16.5 square inches) and the Bruce 'A' generator would require 193 $cm^2$ (30 square inches) cross section. Clearly, copper conductors of this size would be very expensive so aluminum is used. To allow for the lower conductivity of aluminum, the cross section has to be increased by a factor of 1.64.

Figure 2 shows how the hollow tubular conductors are supported by insulators and encased in an aluminum tube which provides environmental protection. Three separate aluminum tubes are used to ensure that a short-circuit cannot occur between phases. With this arrangement, a short-circuit can only occur between a phase and ground. (A phase-ground short-circuit produces a low value of current, typically 300 A whereas a phase-phase short-circuit produces a very large value of current, typically 30 000 A plus.)

Note how insulation is placed between the outer tubes. This prevents stray circulating currents.




1. Aluminum Outer Tube.
2. Conductor.
3. Support Insulator.
4. Support Beam.
5. Insulated Supports.

Figure 2: Cross Sectional View of an Isolated Phase Bus.

3.1.2 Operation. Fans circulate cooling air through the tubes and over the conductors. The air is in-turn cooled by an air/water heat exchanger. An air dryer is included in the air circuit. This ensures that no condensation can form in the tubes and on the insulators. Because the IPB is enclosed, it is impossible to visibly check the bus whilst it is on load. It is advisable to do regular checks to ensure the ventilation and dryer systems are operating correctly.

3.2 The Outdoor Busbar System

3.2.1 Construction. Figure 3 shows part of a typical outdoor busbar system comprising of:

(a) Flexible high level overhead busbars suspended from strain insulators and high level support structures. The overhead busbar, in older installations, is made from stranded copper conductors. In newer installations, stranded aluminum conductors are used. Where large spans have to be covered, the stranded Aluminum Conductor has a central Steel Reinforcement, (ACSR for short). There is no need for flexible joints with overhead conductors, thermal expansion is taken up by the conductor flexing and sagging.

(b) Tubular lower level busbars are supported by pillars and pedestal insulators. These busbars are made tubular for four reasons:

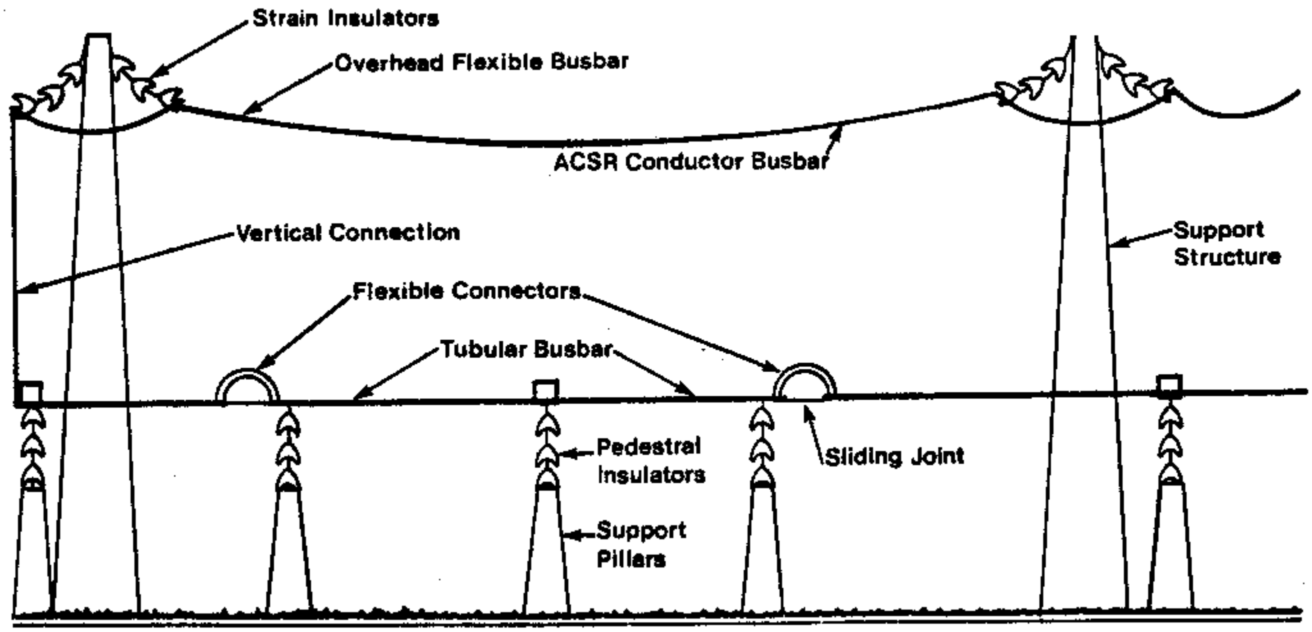



Figure 3: Outdoor Busbar System: Flexible and Tubular Busbars.

(i) there is a greater surface area for cooling (compared with a solid conductor having the same cross-sectional area).

(ii) a tubular conductor will have slightly less apparent resistance than a solid conductor having the same cross sectional area. This is because of magnetic effects: current tends to flow on the surface of conductors.

(iii) a tubular conductor is more rigid than a solid conductor, having the same cross sectional area.

(iv) with large diameter conductors, less corona (and less radio interference) is produced, than with smaller diameter solid conductors.

However, tubular conductors require flexible connectors to take up thermal expansion. These connectors are a potential source of failure and require frequent examination to ensure they do not overheat and fail.

## 3.3 Indoor Busbars

3.3.1 Construction. Indoor busbars which operate at 13.8 kV, 4160 V, 2400 V and 600 V are housed in metalclad cubicles. The busbars are insulated along their length. They have additional insulation at all support points.

3.3.2 Operation. This type of busbar is very reliable and unless problems are suspected, only requires inspection when the unit is shut down for overhaul. Occassionally, with this type of busbar, electrical discharges occur in and on the insulation. When the discharges are minor, they can be heard as a fizzing sound. When the discharges are reaching a dangerous level a glow can be seen (with covers removed). Any discharges, which can be seen or heard, are a sign that serious insulation deterioration is taking place and remedial work is urgently required.

## 3.4 Cables

In power plants, cables are used to convey power to electrical equipment at 13.8 kV, 4.16 kV, 600 V and lower voltages. Control cables are used at 250 V, 120 V and lower voltages. The cross sectional area of each conductor depends upon the current being carried. Once again, as rule of thumb, 6.4 $cm^2$ (1 square inch) of copper is required to carry 1000 A.

3.4.1 Construction. Modern cables, rated at 600 V and below are plastic insulated. At 4160 V the insulation can either be plastic, or paper and oil. Above 4160 V paper and oil is usually used. Figure 4 shows a section of a single phase HV cable, Figure 5 shows a cross section of a three phase HV cable.

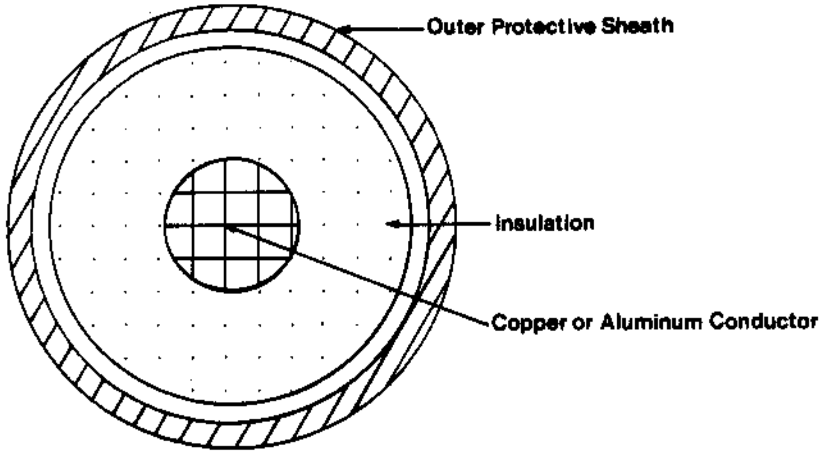



Figure 4: Section of a Single Phase HV Cable.

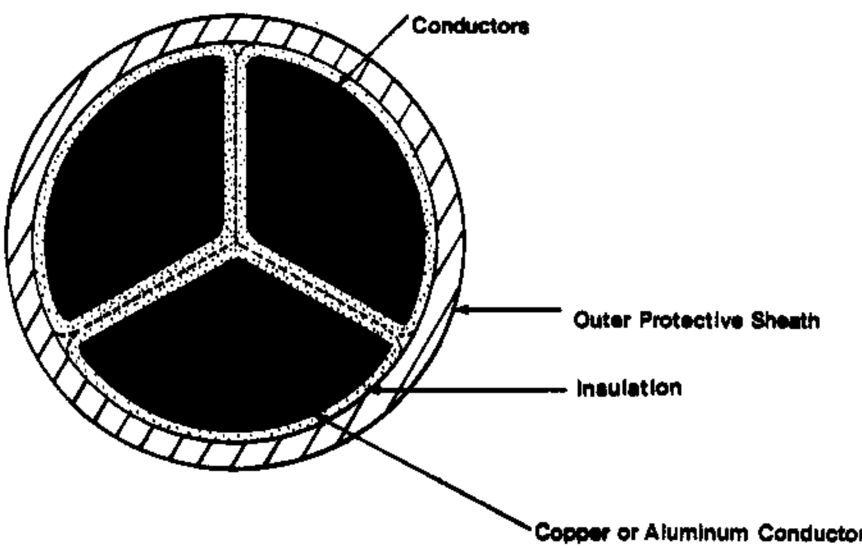



Figure 5: Section of a 3 Phase HV Cable.

3.4.2 Operation. Provided that cables are operated within their voltage and current ratings and receive adequate cooling, they will give trouble-free service for the life of the station. In practice, cable failures are attributable to one of the following:

(a) Heat. Cables, when carrying load, must have adequate ventilation or their temperature will attain a value that will damage the insulation. For example, plastic insulated cables can only withstand a temperature slightly above their normal working value before the insulation starts to "flow" and fail.

(b) Cold. Plastic insulation, when exposed to very low temperatures, will operate satisfactorily until it is moved or flexed when it will crack or break. For this reason, great care should always be taken when handling plastic insulation cables. This precaution is particularly relevant when the temperatures are below -10°C.

(c) Fire. Some types of plastic insulation contain fire retardants but many types do not. There have been many very serious power plant cable fires and for this reason great care should always be taken to keep flammable products well clear of cable areas.

(d) Moisture. The outer sheath on power and control cables is designed to be moisture proof. Any damage to cable sheaths will allow moisture to enter. The moisture may damage the insulation and cause a failure. Paper insulation will fail if contaminated by minute quantities of moisture. The terminal boxes at each end of the cable must be kept dry so no tracking will occur in the insulation.

(e) Physical Damage. Most physical damage to cables is caused by objects hitting or striking the cables. In some areas, rodents have damaged cables and for this reason, precautions should be taken to eliminate rodents in a power plant. Cables also fail because of poor installation. For example, if a cable is installed over a sharp piece of metal, due to pressure, the insulation will "flow" and become thin. This forms a weak point in the insulation and after some years, the insulation will fail and cause a short-circuit.

(f) Oil Leaks. Any oil leaks from an oil filled cable must be reported immediately. Failure to do this can result in the oil draining out of the insulation which will lead to cable failure.

## ASSIGNMENT

1. State the purpose of:

   (a) the isolated phase bus, (Section 3.1)
   (b) the outdoor bus system, (Section 3.2)
   (c) the indoor bus system, (Section 3.3)
   (d) cables, (Section 3.4)

2. A busbar system is subjected to excess currents. Describe how the busbar may be damaged. (Section 2.3)

3. State the checks that should be done to ensure that the following are operating correctly:

   (a) an isolated phase bus, (Section 3.1)
   (b) an outdoor busbar, (Section 2.3, 3.2)
   (c) an indoor busbar, (Section 3.3)

4. State and briefly explain the six precautions that must be taken with cables. (Section 3.4)

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