NOTES & REFERENCES

Module 1

UNIT SERVICE POWER

OBJECTIVES:

After completing this module you will be able to:

Page 2 ⇔ 1.1 Explain what is meant by the term "odd/even power supplies".

Pages 3–4 ⇔ 1.2 For a Class IV power, describe:
- a) Its normal source of supply,
- b) Reliability requirements,
- c) Generic loads.

Pages 4–5 ⇔ 1.3 For a Class III power, describe:
- a) Its normal source of supply,
- b) Its source of backup supply,
- c) Reliability requirements,
- d) Generic loads.

Page 5 ⇔ 1.4 For a Class II power, describe:
- a) Its normal source of supply,
- b) Its source of backup supply,
- c) Reliability requirements,
- d) Generic loads.

Page 6 ⇔ 1.5 For a Class I power, describe:
- a) Its normal source of supply,
- b) Its source of backup supply,
- c) Reliability requirements,
- d) Generic loads.

Page 5 ⇔ 1.6 Explain the role of the standby generators (SGs) in a nuclear generating station.

Page 6 ⇔ 1.7 Explain the role of the emergency power supply (EPS) in a nuclear generating station.

Pages 7–8 ⇔ 1.8 Explain load transferring by parallel, fast and slow transfer schemes.

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NOTES & REFERENCES

INSTRUCTIONAL TEXT

INTRODUCTION

The following section will deal with the Classes of power, normal and backup supplies, reliability requirements and their applications within the station.

The station's electrical system buses are classified in four levels of reliability. Reliability refers to the probability that the power supply will be able to energize its loads when called upon to do so. The higher the number, the lower the reliability of the power supply. For example, Class IV power is the least reliable power in the station, and Class I power is the most reliable power in the station. Each of these classes of power will be explained below.

Odd/Even power supplies, standby generators and emergency power supplies will also be discussed.

Obj. 1.1 ⇔

ODD/EVEN POWER SUPPLIES

All electrical systems are divided into two systems, odd and even. For example, pump 1, inverter 3, compressor 1 are **odd numbered components**, and **would be supplied by an odd bus** (Bus A or C for example). **Evenly numbered components**, such as shutoff rod 2, rectifier 2, transformer 2 will be **fed from an even supply** (Bus B or D for example). Supplies for an odd bus will come from an odd winding (A winding) of a transformer. Similarly, even bus supplies will come from an even winding (B winding) of a transformer.

By splitting the electrical system in this fashion, as the old saying goes, you are not putting all of your eggs in the same basket. Loads are connected such that **half of the process is connected to an even supply, and the other half is connected to an odd supply** (refer to Figure 1.1 on page 3). In the event of a **fault on one of the buses, the other bus is unaffected**, and still can provide power to the system. In this way, the system will still have components that are able to run, and may even be able to maintain full capability (depending on the redundancy and capacity of the remaining components). This **improves the reliability** of the operation of our systems.

NOTES & REFERENCES

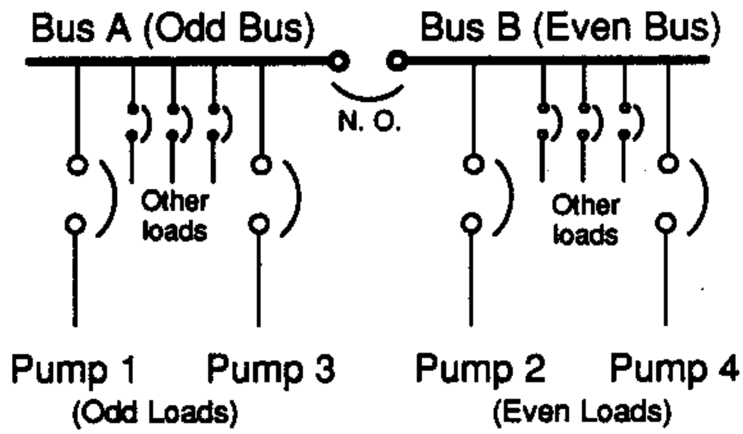

Figure 1.1 – Odd/Even Designations

Obj. 1.2 ⇔

CLASS IV POWER

The Class IV power system is the **least reliable** source of power in the station. The loads normally supplied by the Class IV power system are systems which can tolerate long term power outages without affecting personnel or equipment safety. These loads are **not essential to satisfy fuel cooling requirements following a reactor or turbine trip, but are essential for operation of heat sinks above a couple of percent of reactor full power**. The loss of Class IV power means that high power operation cannot be sustained, and reactor power must be quickly reduced to decay power levels.

For example, some of the **major typical loads** on the Class IV power system are main boiler feed pumps, main heat transport circulating pumps, condenser cooling water pumps, moderator circulating pumps, generator excitation (in some stations), and some of the service water pumps. Most heating and ventilation equipment, miscellaneous motors and normal lighting systems are also other examples of systems that are supplied by the Class IV power system.

Now, it does sound a little strange that systems like our main heat transport circulation pumps or boiler feed pumps fall within this category, but it really does make sense. You see, if we lose these systems, we still have the ability to control the reactor, cool the fuel and contain radioactivity with other systems (more will be discussed about this in your reactor safety course). In this case, we have only lost the ability to produce power. Although producing power is our business, it would not be wise to maintain operation when our power supplies are in jeopardy (remember, safety first!).

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The Class IV power can be supplied from two sources. During **normal operation*, power is tapped from the isolated phase bus through the unit service transformer (UST)****. This improves the reliability of the Class IV power by preventing upsets in the bulk electrical system from causing a total loss of Class IV power (ie. you will still supply power to your own unit, even if you lose your ability to transmit the power. The unit will be ready to transmit power once the grid has stabilized).

If generator produced power is unavailable, ie. during a turbine trip, or during an outage, the **power may be taken from the electrical system grid** through the system service transformer (SST)*** (the transfer from the unit service transformer to the system service transformer is performed automatically, and will be discussed later in this module and during your station specific training). In multi–unit stations, it is possible to obtain power from another unit's system service transformer through transfer buses (this will also be discussed during your station specific training). Figure 1.2 at the end if this module can be unfolded and kept in sight for easy reference to see the typical power distribution supplies.

Obj. 1.3 ⇔

CLASS III POWER

The Class III power system is a **more reliable** source of power than the Class IV power system. The loads normally supplied by the Class III power system are systems which can **tolerate only short term power outages** before personnel or equipment safety will be affected. These loads are essential to maintain fuel cooling with the reactor in a low power state when Class IV power is not available+.

The duration that a Class III power outage would be expected to last is only the time that is required to start–up a standby generator and re–load the Class III power system. This would typically be less than 5 minutes.

During normal operation, **Class III power is taken from Class IV power,** through the odd even designation. This improves the reliability of the Class III power by ensuring that partial losses in the Class IV power system will not cause a total loss of Class III power. If all of Class III power is unavailable (due to a complete loss of Class IV power), it is possible, in multi–unit stations, to obtain **power from another unit through transfer buses** (this will be discussed during your station specific training).

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* *In single unit stations and some multi–unit stations, half of the unit load is supplied by the generator, and the other half of the unit load is supplied from the grid.*

** *This is called the generator service transformer (GST) in some stations.*

*** *This is also referred to as the station service transformer.*

\+ *The reactor is automatically shutdown when Class IV power is lost, thus bringing the reactor to a low power state where the Class III loads are sufficient to keep the fuel cool.*

NOTES & REFERENCES

In any case, the **standby generators** (SGs) will start, synchronize and re–load the Class III power system. This will restore power to critical loads to the station.

Some of the **typical loads** on the Class III power system are auxiliary boiler feed pumps, auxiliary condensate extraction pumps, shutdown cooling pumps, turbine turning gear, heat transport feed pump(s)*, Class I power rectifiers, fire water pumps, emergency coolant injection pumps, instrument air compressors, and some of the service water pumps. You will note that these systems include those required to bring the plant to a safe state. If we lose these systems, our options to cool the reactor will be limited.

Obj. 1.6 ⇔

Before we move on to the next class of power, I will mention how **important the SGs really are to the safe operation of the unit.** If all sources of Class IV power are lost, and the SGs are not able to restore the Class III power, **all power in the station will be lost in under one hour** (this will be described in the section on Class I power). With this loss of power, we lose the ability to monitor and control what is happening. Although the power can be interrupted for short periods, it is vital to the safety of the station that this power be restored as soon as possible. The SGs start automatically on the loss of Class IV power, and, at some stations, will also start on a High Pressure Emergency Coolant Injection System initiation signal (to ensure there is reliable power to perform the functions of HPECI during a LOCA).

Obj. 1.4 ⇔

CLASS II POWER

The Class II power system is an **even more reliable source of power** than the Class III power system. The loads normally supplied by the Class II power system are systems which cannot tolerate the power outages that may occur in the Class III system. These loads are considered uninterruptable and are critical for controlling the reactor**.

The duration that a Class II power outage would be expected to last is only the time taken to tie in a back–up power supply (only a few power cycles).

The **normal source of Class II** power is from the Class I dc system, through the inverters. If the inverter is not available to supply a given bus, then the power **can be supplied by a tie into the Class III** power system.

Some **typical loads** on the Class II power system are the digital control computers, shutdown system loads, reactor regulation process instrumentation, boiler feed pump's auxiliary oil pump and emergency lighting.

* *These pumps are also referred to as pressurizing pumps.*

** *The reactor is automatically shutdown when Class II power is lost, since high power operation is not desirable without power to the reactor control systems.*

NOTES & REFERENCES

Obj. 1.5 ⇔

CLASS I POWER

The Class I is a dc power supply, and is the most reliable source of power in the station. Each Class I bus is normally supplied by two rectifiers supplied from the Class III system. A set of **batteries is connected directly to each of the Class I buses, and provides uninterrupted backup power** if the rectifiers fail or lose their power (note that the batteries are constantly being charged). This back–up power is capable of supplying the load on the dc buses for approximately 40 minutes. After this time, all Class I and II power will be lost if Class III power cannot be restored.

The loads normally supplied by the Class I power system are systems which **cannot tolerate any power outage.** Some typical loads on the Class I power system are the Class II inverters, dc seal oil pumps for the generator, dc lube oil pumps for the turbine generator bearings, turbine trip circuits, dc stator cooling pumps and the protection schemes for the station electrical distribution system.

These systems are uninterruptable, since the potential for damage if they fail, is very high.

Obj. 1.7 ⇔

EMERGENCY POWER SUPPLY (EPS)

In most CANDU stations, we have an additional power source to the Class I, II, III and IV, and it is called the "emergency power supply". This power source will supply power to **critical systems to allow for reactor shutdown, monitoring and decay heat removal under conditions where all other power supplies may not be available** (ie. Class III power and/or Class III switchgear are unavailable). Some examples of events that this system is designed to provide power during are earthquakes, harsh environments in the powerhouse (steam line break, turbine missiles) or a fire in the control room *.

The equipment supplied by these emergency power supplies have their normal station electrical supplies, with an **additional tie to the emergency power supplies.** Depending on your station, you may have to switch to the emergency power supply manually or this may occur automatically, (this will be outlined in your station specific training). There will be interlocks in place to prevent the emergency power supply from feeding the failed power systems.

The emergency power generators, just like the SGs, start automatically on the loss of Class IV power, and will also start on a LOCA signal. Without these power supplies, we may have no way of monitoring, controlling and cooling the reactor if all station power has failed.

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* *These design basis events vary from station to station.*

Obj. 1.8 ⇔

LOAD TRANSFERRING

Under certain circumstances, it may be desirable to transfer the loads from one source to another. There are three transfer schemes that perform this: parallel, fast and slow.

Figure 1.3 illustrates a typical distribution system of a generating unit with four supply buses. The SST takes power from the switchyard and the UST takes power from the generator. For simplicity, the loads on the four buses and system voltages are not shown.

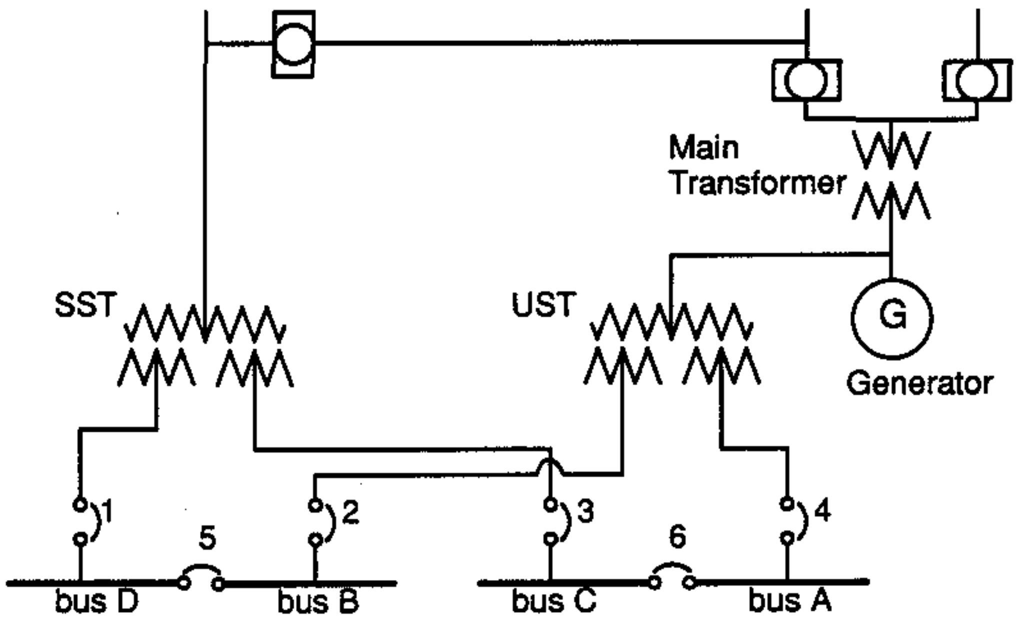

Figure 1.3: Simplified Unit Distribution System

Note that, depending on breaker states, the buses may be supplied by the grid via the SST, by the generator via the UST, or both.

Assume that supply breakers 1,2,3 and 4 are all closed and tie breakers 5 and 6 are open (this would be the normal operating state for this system*). If, for some reason, it is necessary to remove the generator from service**, a **parallel transfer** of the loads on buses B and A can be performed. A parallel transfer is a make–before–break transfer scheme.

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* *Not all stations have power requirements shared between UST and SST, but this example uses this arrangement for ease of explanation of load transferring.*

** *This is typically as a result of a turbine generator mechanical problem. A parallel transfer is not initiated by an electrical fault.*

NOTES & REFERENCES

Tie breakers 5 and 6 are closed, momentarily paralleling the two supplies. Note that the two power sources must be synchronized (proved by a series of interlocks) for the tie breakers to close. Supply breakers 2 and 4 then quickly open. The supply breakers must open immediately after the tie breakers close to avoid the problems associated with parallel power sources*. The unit service load is now being fully carried by the SST.

Again assume the system is functioning normally with loads being shared between the SST and the UST (supply breakers 1,2,3,4 are closed; tie breakers 5 and 6 are open).

If an electrical fault develops causing the loss of the SST as a source of supply, the loads on the affected buses must be transferred. This can be done by a **fast transfer**. A fast transfer is a break–before–make transfer scheme with a very short (about 2–3 cycles) interruption of supply. The actuate signal is given simultaneously to the breakers of the lost source and the back–up source of supply, but a differential in closing time versus tripping time is responsible for the brief power interruption. This power interruption ensures that the electrical fault is not transferred to the healthy supply. Fast transfer also requires that the sources be in synchronism immediately prior to transfer.

In this example, the fault removes the SST from service and causes supply breakers 1 and 3 to open. Two to four cycles after breakers 1 and 3 open, tie breakers 5 and 6 close to restore power to the A and C buses.

Slow transfer schemes exist as a back–up to fast and parallel transfer. This break–before–make method requires the residual voltage on the affected bus to decay to a level considerably below rated before connecting the back–up source. This typically results in a power interruption to the loads of a few seconds duration. Breaker operation, for the above example of the loss of the SST, would be similar to the fast transfer case. Breakers 1 and 3 would open and, once the voltage on buses A and C had decreased to a specific value for a certain period, breakers 5 and 6 would close.

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* *Paralleling of two sources can result in twice the fault current from one source alone flowing through a load breaker if a fault develops on the load side of the breaker. Course 335.02–1 can be referred to for more details.*

NOTES & REFERENCES

SUMMARY OF THE KEY CONCEPTS

- The station power distribution is separated into two sources of power, odd and even. These power supplies are separated to improve the reliability of the station electrical supplies to station systems. Redundancy in equipment may allow continued operation at full/partial capacity if one of these supplies is lost.
- The Class IV power supply is the least reliable, and the classes of power increase in reliability all the way to Class I power.
- The Class IV power supply is normally taken from the grid and/or the unit service transformer.
- The Class III power supply normally taken from the Class IV system. Backup power can be supplied by the standby generators and by another unit's system service transformer through transfer buses (in a multi–unit station).
- The standby generators will start on the loss of Class IV power and on a HPECI initiation signal (at some stations). This ensures that power will be available to control, and in the longer term, cool the reactor.
- The Class II power supply is normally supplied by the Class I DC system through inverters. If power cannot be supplied by the inverters, power can be supplied by a tie to the Class III system.
- The Class I power supply is normally supplied by the Class III system through rectifiers. If the rectifiers fail or lose power, batteries connected directly to the Class I buses will supply back–up power.
- The emergency power system includes generators that will also start on the loss of Class IV power and on a HPECI initiation signal under conditions where the standby generators and/or Class III switchgear may not be operational (ie. earthquake, steam line break). This ensures that power will be available to control/cool the reactor.
- Loads may be transferred from one power source to another by a parallel, a fast or a slow transfer scheme. During parallel transfer, momentary paralleling occurs. Fast transfer results in a brief interruption of supply to the loads. Slow transfer requires time for voltage decay on the affected bus, a power interruption of a few seconds will occur.

Pages 10–12 ⇔

You can now do **assignment questions 1–15**

NOTES & REFERENCES

ASSIGNMENT

1. Explain what is meant by odd/even power supplies:

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____

____

____

2. Class IV power is the (most / least) reliable source of power in the station.

3. Class IV can be supplied from the following sources.

   a) ____

   ____

   b) ____

   ____

4. Typical Class IV loads may include:

   a) ____

   b) ____

   c) ____

   d) ____

5. Class III power is (more / less) reliable than Class II power.

6. Typical Class III loads may include:

   a) ____

   b) ____

   c) ____

7. Class III power normally comes from:

   ____.

   The backup supply for Class III power comes from:

   ____

   ____.

NOTES & REFERENCES

8. Class II power is (more / less) reliable than Class I power.
9. Typical Class II loads may include:
   a) ______________________________
   b) ______________________________
   c) ______________________________
10. Class II power is supplied by:

    ______________________________.

    If this source of power is unavailable, Class II is supplied by:

    ____

    ______________________________.
11. Typical Class I loads may include:
    a) ______________________________
    b) ______________________________
    c) ______________________________
12. Class I power normally comes from:

    ______________________________.

    The backup supply for Class I power comes from:

    ____

    ______________________________.
13. Explain the role of standby generators in NGSs:

    ____

    ____

    ____

    ____

    ____
14. Explain the role of the emergency power supply in NGSs:

    ____

    ____

    ____

    ____

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NOTES & REFERENCES

15.

a) During ______________ transfer of loads, paralleling of sources occurs, but it is only ________________ .

b) ________________ transfer of loads results in a temporary ___________________ of supply to the loads on the affected bus.

c) As a back–up load transferring method ___________ transfer requires time for _________________________ on the affected bus to decrease.

Before you move on to the next module, **review the objectives** and make sure that you can meet their requirements.

Prepared by:	Nick Ritter, WNTD
Revised by:	Paul Bird, WNTD
Revision date:	July, 1992

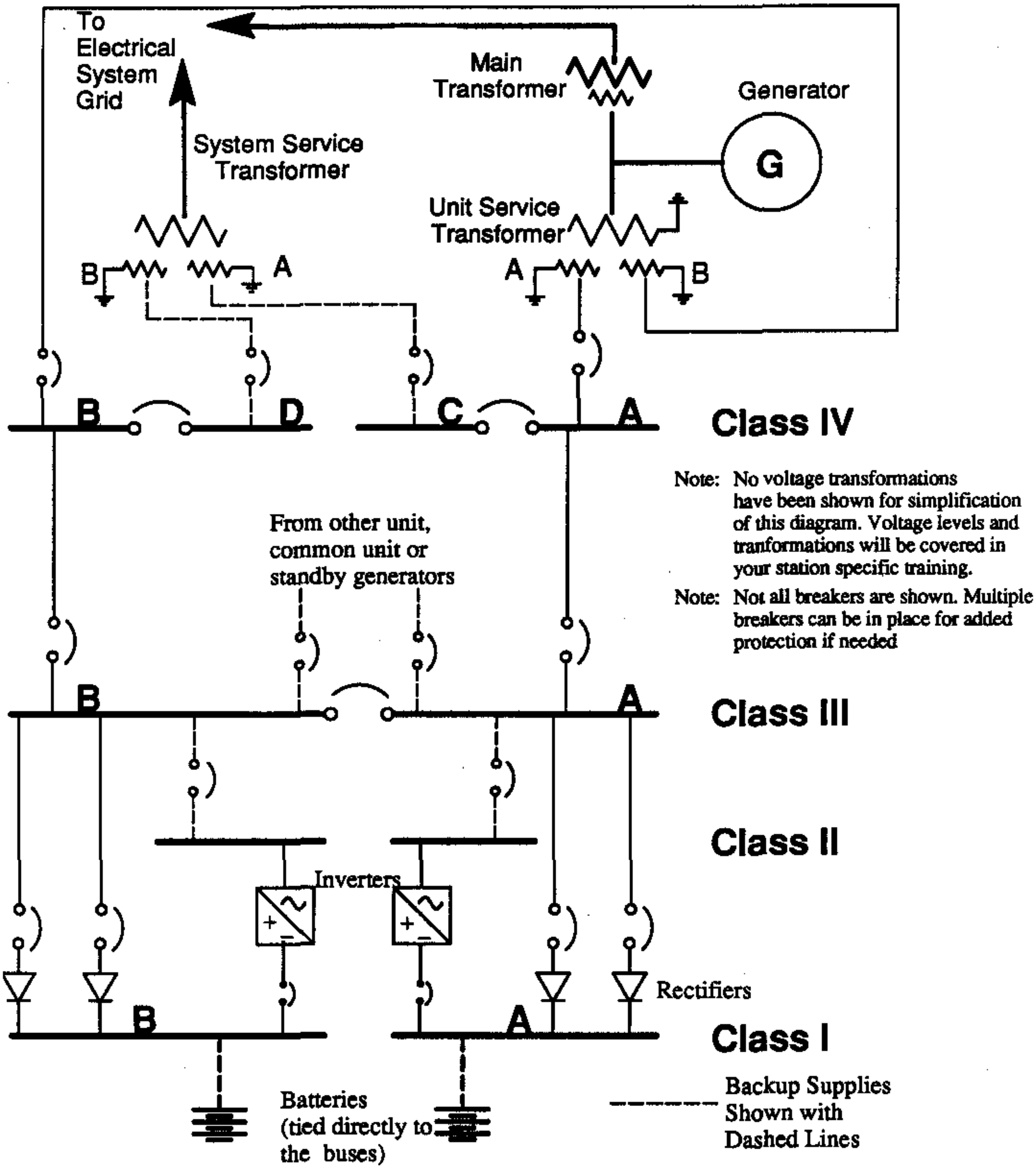

Figure 1.2 – Simplified Electrical System