Electrical Equipment - Course 230.2

GENERATORS: PART 5

INFINITE BUS OPERATION

---

1. OBJECTIVE

The student must be able to:

1. Define an "infinite bus".
2. Explain how the current in a generator increases as it is loaded.
3. Explain how a generator, connected to an infinite bus, behaves when:
   (a) it is supplying a constant MW load and its excitation is varied.
   (b) its MW load is varied with the excitation remaining constant.

2. INTRODUCTION

Lesson 230.22-1 dealt with a generator operating on no load and supplying an isolated system. This lesson explains how a generator behaves when it is loaded onto an infinite bus.

The next lesson explains how a generator behaves when it is loaded onto a non-finite bus grid.

3. THE INFINITE BUS

3.1 Definition

By definition, an **infinite bus has constant voltage and frequency.**

All generators, when loaded onto a power system, will to some degree alter the system's voltage and frequency. However, when a **small** generator is loaded on a **large** system, it will have **negligible** effects on the voltage and frequency and consequently, with respect to the small generator, the system behaves as an infinite bus.

4. GENERATOR LOADED ON TO AN INFINITE BUS

4.1 Generator MW Loading Increased From Zero

When a generator is connected to an infinite bus, its terminal voltage is the same as the infinite bus voltage and therefore remains constant. When more mechanical power is produced by the turbine the generator converts this additional mechanical power into additional active electrical power P.

As the generator produces more active power P, it also produces more current I_a. This is explained by the relationship.

$$P = \sqrt{3} V_L I_a \cos \theta .$$

It follows that as P increases ($\sqrt{3} V_T$ is constant) then $I_a \cos \theta$ must increase. Typically, the magnitude of $\cos \theta$ (power factor) will vary between 1.0 to 0.8. Consequently, the magnitude of the load current I_a will increase almost in proportion to an increase in load power P.

4.2 Generator on Constant MW Load, Excitation Varied

When a generator is producing watts but no vars, (1.0 pf) it is operating with **optimum excitation**, ie, the excitation is just sufficient to cause the generator to produce all active power and no reactive power.

When a generator is on full load at 1.0 pf and its excitation is varied, the flux produced by the field also varies, see Figure 1.

A decrease in excitation will cause the generator to be **underexcited** for the constant MW load and the power factor will become **leading.** This effect was explained in the previous lesson.

It must be noted that reducing the excitation will increase the load angle. Should this load angle exceed 90° then pole slipping will result.

An increase in excitation will cause the generator to be **overexcited** for the constant MW load and the power factor will become **lagging.** Again this effect was explained in lessons 230.25-1 and 230.25-2.

The vector diagrams in Appendix 1 of this lesson illustrate these effects.

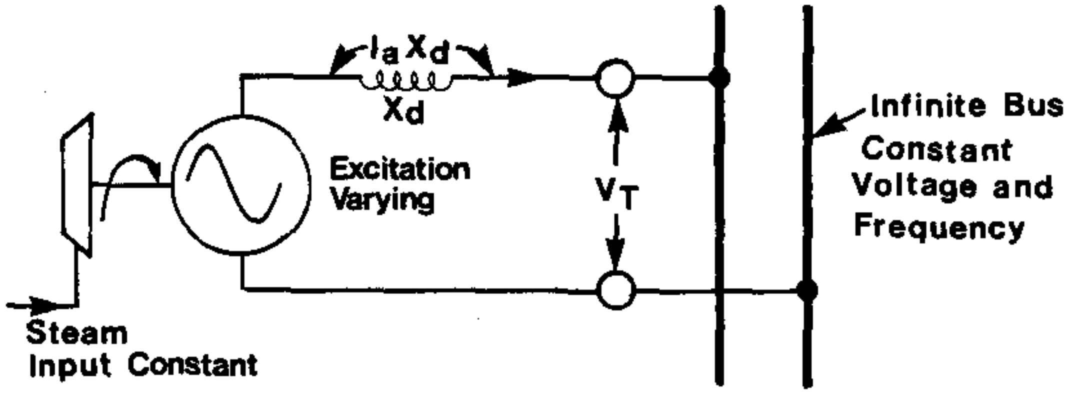


Figure 1: Equivalent circuit excitation varying, MW load constant.

4.3 Generator on Varying MW Load, Excitation Constant

Figure 2 shows a generator connected to an infinite bus. The MW load is varied while the excitation is held constant.

Increasing the active power output from 75% of full load at 1.0 pf, will cause more current to flow in the generator stator. This will cause more armature reaction which will weaken the fluxes in the generator. The generator will become **under-excited,** ie, it now has insufficient excitation for it to operate at 1.0 pf. Consequently, the pf of the generator will be **leading** and the generator will consume vars.

Decreasing the active power output from 75% full load at 1.0 pf will cause less current to flow giving less armature reaction. This will cause less armature reaction which will strengthen the fluxes in the generator. The generator is now **overexcited** ie, the generator now has more than enough excitation for it to operate at 1.0 pf, and its pf will be **lagging.** Excessive excitation, for a given MW load, will cause exessive production of lagging vars.

This information is illustrated by the vector diagram, see Appendix 2 of this lesson.

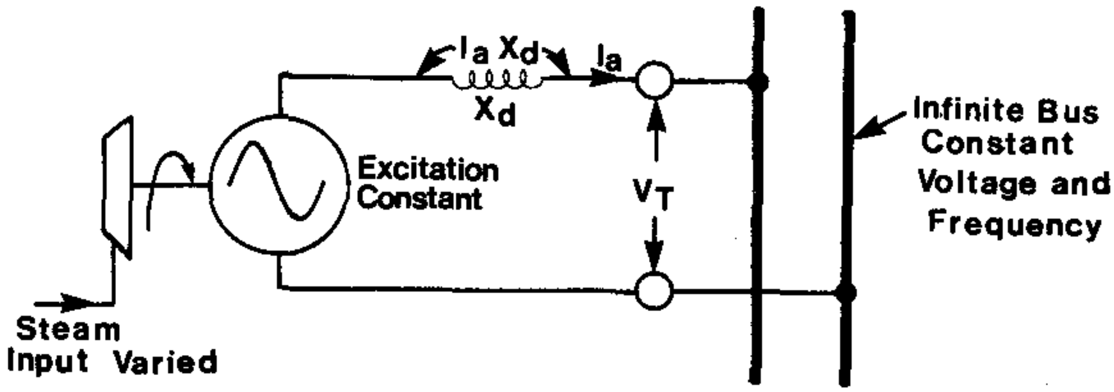


Figure 2: Equivalent circuit, excitation constant, MW load varying

5. SUMMARY FOR A GENERATOR CONNECTED TO AN INFINITE BUS

(a) A generator, overexcited for a given MW load and terminal voltage, operates at a lagging pf.

(b) A generator, underexcited for a given MW load and terminal voltage operates at a leading pf.

(c) Increasing MW load on a generator with constant excitation, will make the generator's power factor become more leading.

An operator, when loading a generator, will have to take care to ensure that adequate excitation is provided. Failure to do this can cause the load angle to exceed 90°. Pole slipping will result.

(d) Decreasing MW load on a generator with constant excitation, will make the generator's power factor become more lagging.

An operator, when unloading a generator, will have to take care to ensure that excessive excitation is not provided. Failure to observe this precaution can give excessive fluxes which can cause excessive production of lagging vars.

ASSIGNMENT

1. By definition, what is an "infinite Bus"? By definition, what is a "non-finite bus"?

2. A generator is supplying an infinite bus. Explain, using labelled diagrams, why the power factor of the generator becomes:

   (a) more leading when the excitation is decreased.

   (b) more lagging when the excitation is increased.

   (c) more leading when the MW load is increased.

   (d) more lagging when the MW load is decreased.

3. A generator has a manually controlled excitation system. State the actions the operator must take to ensure safe generator operation when MW loading is:

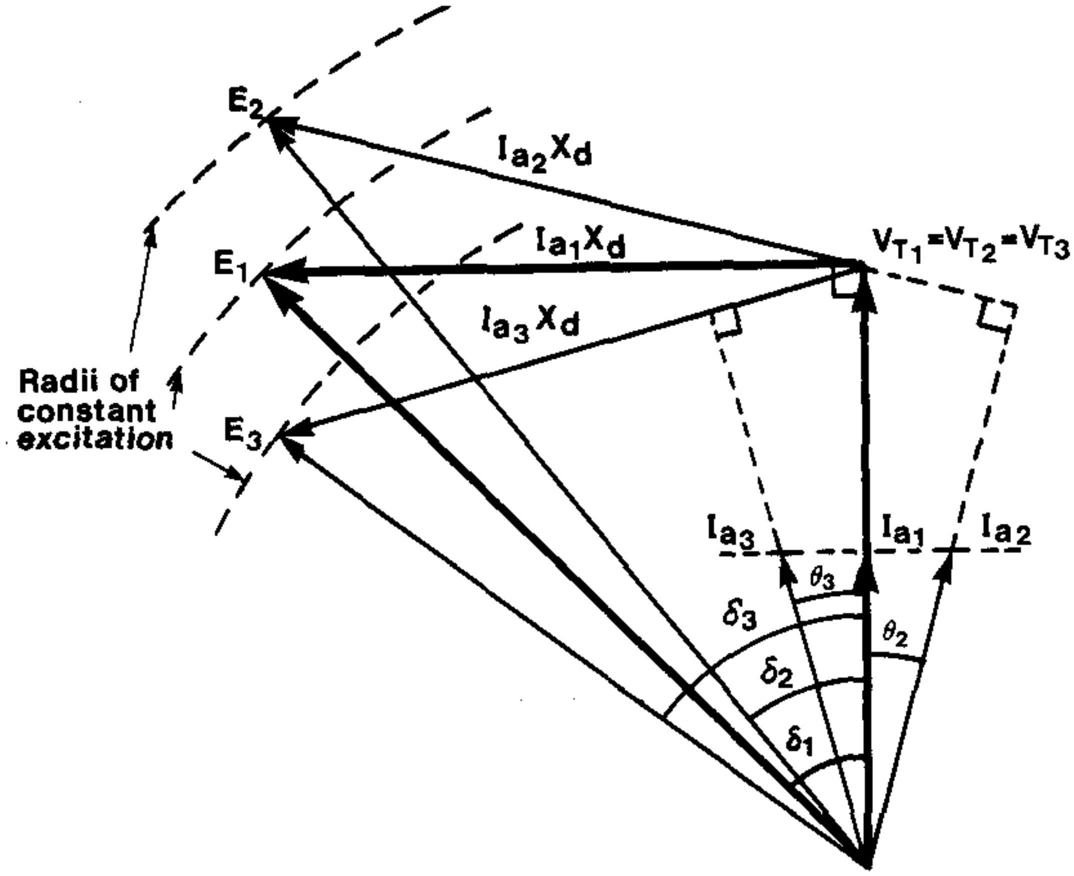
   (a) increased

   (b) decreased

4. A 540 MW generator is supplying a 4000 MW grid. Explain briefly why the grid with respect to this generator, will or will not behave as an infinite bus.

J.R.C. Cowling

APPENDIX 1: Vector diagram showing a generator on full load (constant MW) with the excitation being varied. Generator on an "infinite bus".



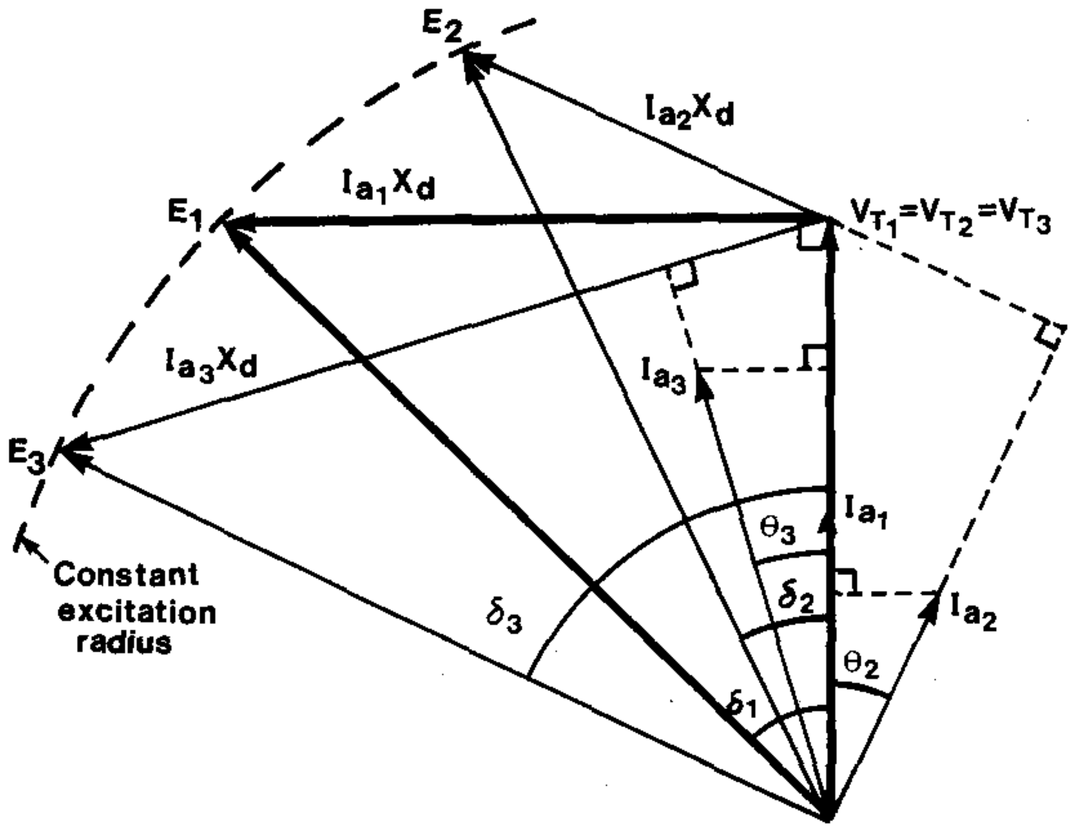
Suffix 1 denotes excitation to give 1.0 pf at full load.
Suffix 2 denotes increased excitation giving lagging pf at full load.
Suffix 3 denotes reduced excitation giving leading pf at full load.

Note the following:

(a) As the generator is on a infinite bus, $V_{T_1} = V_{T_2} = V_{T_3}$.
(b) Increasing the excitation causes the power factor to become more lagging.
(c) Decreasing the excitation causes the power factor to become more leading.
(d) As the power factor becomes less than 1.0 (lead or lag) the current I_a increases for the same MW load.
(e) As the excitation is **increased**, δ **decreases** and vice versa.

As Cos θ is less than 1.0 in Suffix 2 and 3 cases, it follows that I_{a2} and I_{a3} must increase in magnitude relative to I_a at unity pf.

APPENDIX 2: Vector diagram showing a generator with its load varying, excitation held constant. *Generator on infinite bus.*



Suffix 1 denotes excitation set to give 1.0 pf at 75% load.

Suffix 2 denotes load reduced to 50% with constant excitation.

Suffix 3 denotes load increased to 100% with constant excitation.

Note the following:

(a) As the generator is on an infinite bus, V_{T1}, V_{T2}, V_{T3} are constant.
(b) Increasing the load MW causes more current I_a to flow giving a larger value of I_aX_d and vice versa.
(c) Increasing load MW causes the current I_a to become more leading.
(d) Decreasing MW load causes the current I_a to become more lagging.
(e) As the load increases, δ increases and vice versa.