Electrical Equipment - Course 230.2

GENERATORS: PART 7

OVERFLUXING

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1. OBJECTIVE

The student must be able to:

1. Explain the two conditions which can cause overfluxing in a generator and its associated transformers.

2. Explain how a generator can be damaged by overfluxing.

3. Explain how a transformer can be damaged by overfluxing.

2. INTRODUCTION

It is possible to damage a generator and its associated main and auxiliary transformers by what is known as "overfluxing". Overfluxing occurs when a generator or a transformer is subjected to flux levels which are above the permissible limits. Overfluxing can occur when a generator or transformer is made to:

(a) produce rated voltage at below rated speed (frequency).

(b) produce greater than rated voltage at rated speed (frequency).

Because of the two problems outline above, great care must be taken to ensure that:

(a) a generator is at or close to operating speed **before** excitation is applied which will give rated output voltage.

(b) a generator is **not allowed** to produce a voltage in excess of its rated value.

The following sections detail how this overfluxing occurs and how it can damage a generator and its associated transformers.

2. GENERATOR OPERATING AT RATED SPEED

When a generator is running, prior to synchronization, at its rated speed and has sufficient field current applied to give the rated no load voltage output, the generator is operating at its rated point on its voltage to excitation curve, see Figure 1. Under this condition the generator is operating normally and no overfluxing problems exist.

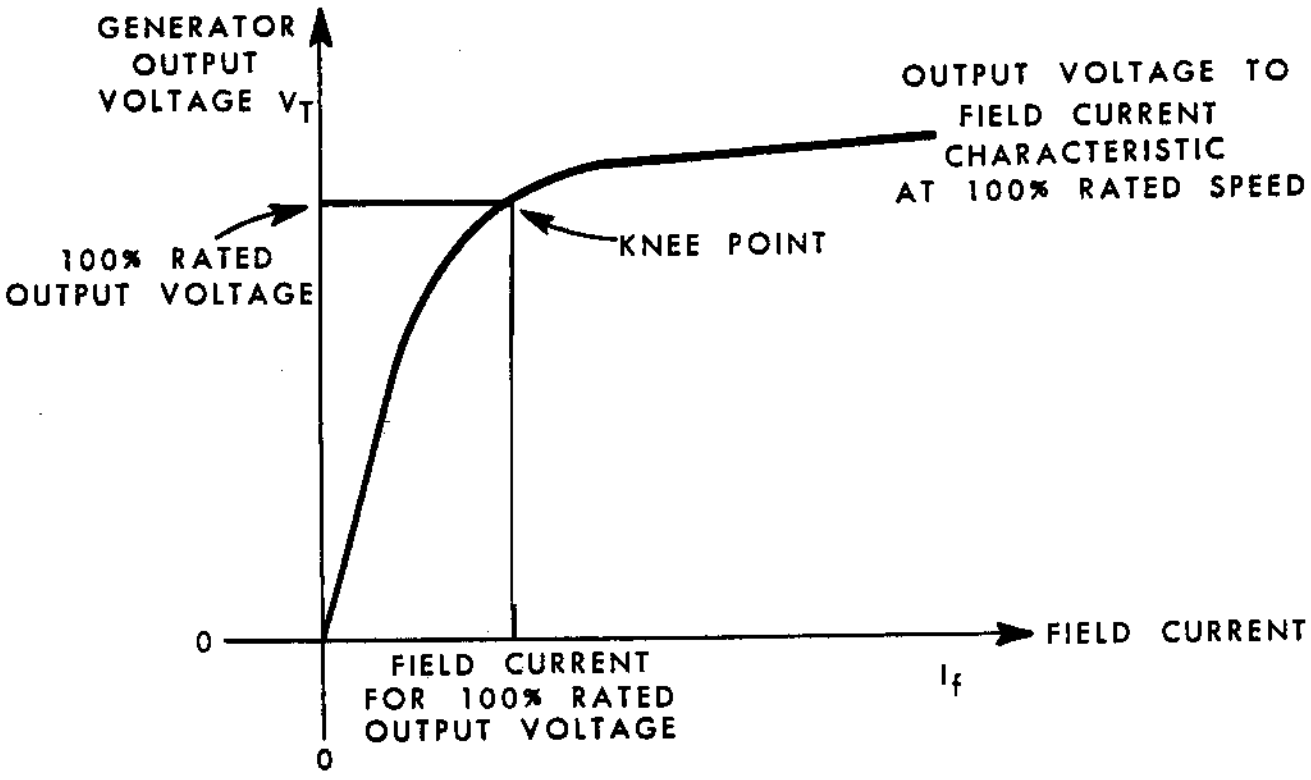

Figure 1: Open circuit output voltage to field current characteristic for a generator at 100% rated speed.

3. GENERATOR OPERATING AT BELOW RATED SPEED

If the generator speed falls, for the generator to continue producing the rated output voltage V_T, the excitation must be increased. This is explained by the formula given below. The increase in excitation can be done manually or by the action of the AVR.

The output voltage V_T is obtained from the formula:

$V_T = 4.44N\Phi_m f$ $\quad$ Φ_m = flux

or $V_T \propto f$ $\quad$ f = frequency

because N is constant, $\quad$ N = number of turns in the generator (remaining constant

$V_T \propto {}_m f$

Once a generator has been synchronized to the Ontario Hydro system, because the system is large, the generator voltage and frequency are determined by the system. Under this condition, unless the system voltage increases excessively or the frequency falls excessively, the flux Φ_m is constant and overfluxing cannot occur.

However, when a generator is disconnected from a system, for example prior to synchronizing or following a trip, problems occur when the generator is made to produce rated voltage at below rated speed. This situation can be due to equipment malfunction or operator error.

Figure 2 shows typical output voltage to field current characteristics for a generator operating at 100% rated speed and 80% rated speed. Note that the iron core of the generator is now saturated or **overfluxed** and that the field current has increased by a factor of 2.5. Overfluxing and excess rotor currents cause three problems. The explanations of these problems follow.

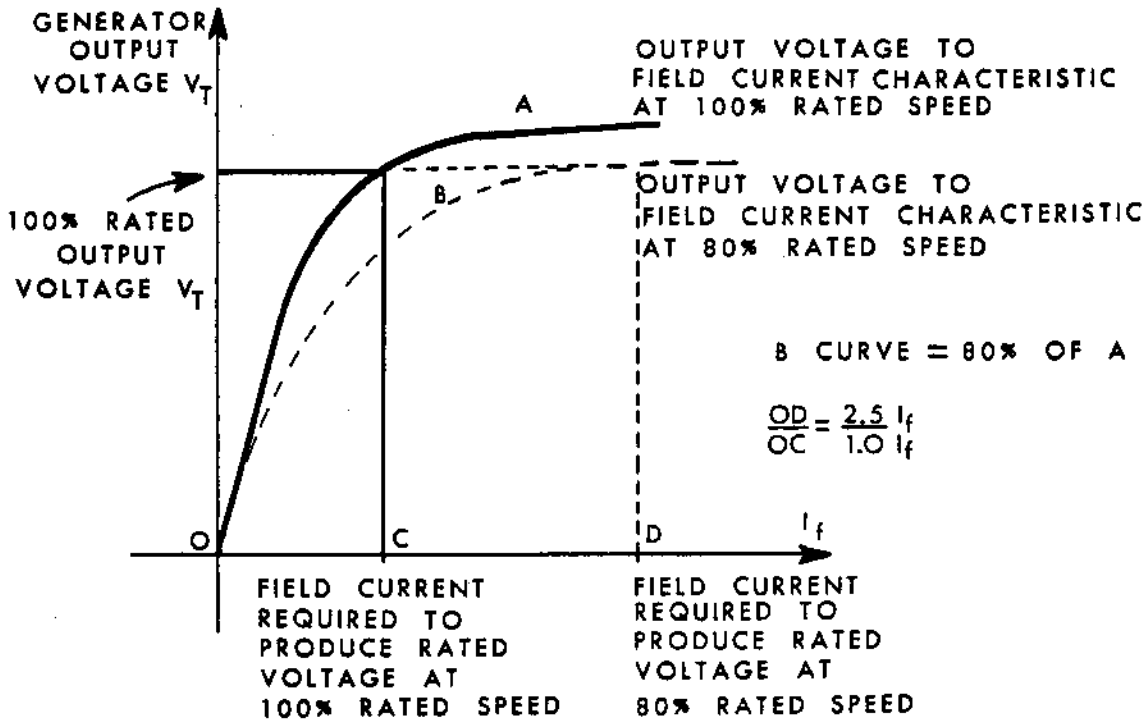

Figure 2: Open circuit output voltage to field current characteristics for a generator at 100% and 80% rated speed.

(a) Rotor Overheating. Much more field current is now required compared with that required to produce rated voltage at rated speed. In this case, the current required is 2.5 times as much. This will cause $(2.5)^2 = 6.25$ times the heating in the rotor. With the cooling system operating at 80% speed, the cooling will be less effective (typically 50%) and serious overheating may occur in the rotor.

(b) Generator Stator Damage. Figure 2 shows for the generator to produce rated voltage at 80% rated speed, the flux must be increased in the ratio $\frac{100}{80}$,

ie, 1.25 times. Consequently, the iron in the stator core is highly fluxed and almost fully saturated, ie, it is overfluxed. Overfluxing gives excessive eddy current and hysterisis heating, and thus the iron can be overheated in the matter of minutes. It should also be appreciated that as the magnetic fluxes increase, the mechanical forces created by the fluxes also increase.

Because of these thermal and mechanical considerations, manufacturers state that the flux in a generator core must **not** be kept at a value greater than **10% above normal, for more than a few minutes.**

(c) Transformer Damage. On large installations, the generator/main transformer and the unit auxiliary transformer are directly connected to the generator. Therefore, if **rated voltage** at **below rated frequency** is produced in the generator, this voltage is applied **directly** to the transformers. Remembering that the voltage flux and frequency relationship also applies to the transformers, ie,

$$V_T \propto f$$

then if overfluxing occurs in the generator, it also occurs in the transformers. While a generator, from a mechanical point of view, can withstand overfluxing reasonably well, large transformers are more susceptible to damage from overfluxing. In a transformer core, the heating effects are similar to those of a generator. However, the core is made of long thin laminations which are difficult to clamp and support. Overfluxing can cause the core to distort or overstress the core clamping bolts and plates, due to excessive magnetic and thermal expansive forces. This can cause the core to become loose, leading to mechanical failure of the core.

4. GENERATOR OPERATION AT HIGHER THAN RATED VOLTAGE

A generator and its associated transformers can also be overfluxed if the voltage is allowed to rise above normal, with the generator operating at rated speed. Again, overfluxing is due to the relationship

$$V_T \propto \Phi_m f$$

and if the voltage is excessive for a given frequency, the flux Φ_m must also be excessive. The same overfluxing problems, as stated in sections 3(b) and 3(c), will occur.

5. SUMMARY

To prevent generator rotor winding, generator stator core and transformer core damage, great care must be taken to prevent overfluxing. (Some generators have relays which measure the frequency and voltage ratio and trip the generator field breaker before serious overfluxing can take place).

Overfluxing occurs when

(a) a generator produces rated voltage below rated speed.

(b) a generator produces above rated voltage at rated speed.

ASSIGNMENT

1. Care should be taken when exciting large turbo-generators under no load conditions. Explain clearly why this is important, paying particular attention to the deterimental effects than can be produced on the generator rotor and stator and on any other equipment connected to the generator.

2. A generator trips from full load. From the overfluxing point of view, explain why it is necessary to rapidly reduce the level of excitation to that required to produce rated voltage at no load.

3. Is "overfluxing" of a generator's main transformer likely to occur when the transformer is connected to the grid? Explain.

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