OPERATION OF POWER TRANSFORMERS DURING MAJOR POWER SYSTEM DISTURBANCES

By
W. J. McNutt
Product Planning Engineer
Power Transformer Department

- During a major power system disturbance, power transformers on the system may be subjected to underfrequency or overvoltage operation.

- Both of these conditions result in transformer overexcitation (a state of greater than normal flux in the core).

- Transformers are susceptible to thermal damage from excitation beyond the limits prescribed by ASA Standards.

- On a short-time basis there is some capacity for excitation beyond the limit of the Standards. This is defined in Figures 1 and 2.

- Damage can occur as a result of overexcitation for a relatively short period of time. Therefore, automatic methods for detection and correction of abnormal excitation conditions are recommended.

GENERAL ELECTRIC

OPERATION OF POWER TRANSFORMERS DURING MAJOR POWER SYSTEM DISTURBANCES

The extensive power failure which occurred in the northeastern section of the United States on November 9, 1965 has prompted considerable study and re-evaluation of system operating philosophy and protective practices by the power industry. Some of the experiences recorded during the blackout also indicate the need for equipment manufacturers to restate what are acceptable modes of operation for their products. This brief document will consider the unusual conditions to which a power transformer may be exposed during a period of system emergency and will recommend suitable limits for operation under these conditions.

The two unusual operating conditions associated with a major power system disturbance which can have the most significant effect on the operation of a power transformer are:

1. Underfrequency operation.
2. Overvoltage operation.

Underfrequency operation can occur for the system as a whole, or for any sub-divided component part of the system encompassing at least one generator, during a period when load exceeds generation. All power transformers within the affected area will be subjected to the reduced frequency. It should be noted that some transformers may also be overloaded during this condition. Since one of the manifestations of underfrequency operation to an extreme degree is winding overheating, additional winding loss due to overload will tend to further limit the capability of the transformers to operate at reduced frequency.

Overvoltage operation is most apt to occur during load rejection or after a system has been split apart by a disturbance and is being pieced back together again. A transformer at the end of a long unloaded overhead line or underground cable can be subjected to abnormally high voltage because of the voltage rise down the line produced by the flow of the capacitive line charging current.

Both of these conditions (underfrequency and overvoltage) have a similar effect on a transformer. The flux in the core is directly proportional to voltage and inversely proportional to frequency. Therefore, either condition results in greater than normal flux, perhaps even to the extent of core saturation. Generally speaking, both conditions can be described by the term "overexcitation."

The subject of transformer overexcitation has been covered in depth in IEEE Transactions Paper No. 31TP66-83, "Influence of Design and Operating Practices on Excitation of Generator Step-up Transformers," by Alexander, Corbin, and McNutt. A more cursory presentation will be given here and any reader desiring detailed information should consult the paper. (IEEE Transactions Paper No. 31TP66-83 has been reprinted as GER-2368.)

Permissible levels of excitation for power transformers are specified in ASA Standard C57.12-00.400 (1958), which can be summarized as follows:

A transformer shall be capable of:

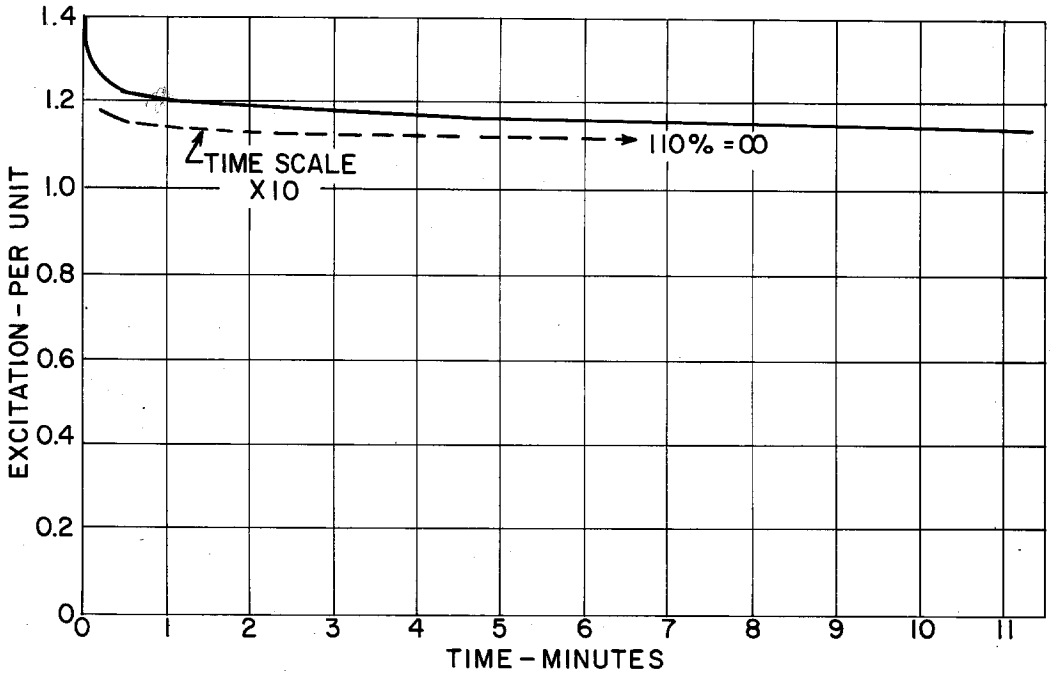
a) Operating at 110% of rated output voltage at no load.
b) Operating at 105% of rated secondary voltage while delivering rated output KVA.

These limits apply at rated frequency and the rated voltage and KVA of any tap.

Excitations at levels beyond those prescribed by the Standards may result in the generation of more flux than the core steel can handle. In other words, the core saturates. The overflow flux strays into locations where the presence of flux was not anticipated and links conducting loops in windings, leads, and structural parts. When flux passes through any conductor, eddy currents result. The heating effect of these eddy currents can cause damage to adjacent insulating materials or, in extreme cases, may even deform the metallic parts in which the heat is generated.

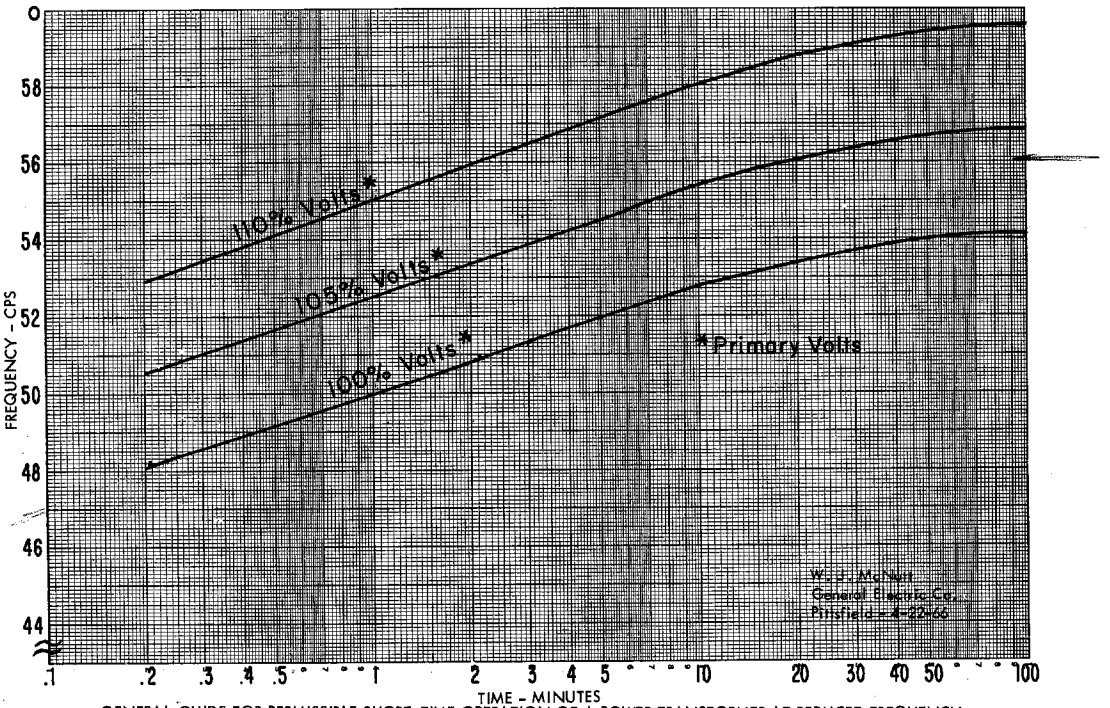
On a short-time basis, there is some capacity for excitation beyond the limits of the Standards, since the heated parts all have finite time constants. The latitude for short-time overexcitation will be a function of each particular transformer design and any general statement concerning it must be conservative. A general guide for permissible short-time overexcitation was presented in the previously mentioned technical paper. It is reproduced here as Fig. 1. This guide has been translated into the more familiar terms of voltage and frequency in Fig. 2. Although the curves of Fig. 2 were prepared for the no-load condition, they may also be applied to full-load or partial load conditions if primary voltage is used, as noted by the asterisk.

Examination of the two figures indicates that there is not wide latitude for overexcitation, even on a short-time basis. It should be evident that an automatic protective device is required which will quickly recognize abnormal conditions and take action to prevent damage to the transformer. The critical quantity to be monitored is volts per cps, since core flux is proportional to this quantity. Transactions Paper No. 31TP66-83 proposes a scheme for automatically detecting and correcting an abnormal excitation condition for a transformer tied directly to a generator. The key element in the circuit is a relay which has a linear volts per cps characteristic. This relay can be used for detection, alarm, and tripping on a transfomer in any application.



GUIDE FOR PERMISSIBLE SHORT-TIME OVEREXCITATION OF POWER TRANSFORMERS AT NO-LOAD

FIG. 1



GENERAL GUIDE FOR PERMISSIBLE SHORT-TIME OPERATION OF A POWER TRANSFORMER AT REDUCED FREQUENCY

FIG. 2

POWER TRANSFORMER DEPARTMENT

GENERAL ELECTRIC

Printed in U.S.A.