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THE HISTORY OF FLICKER LIMITS

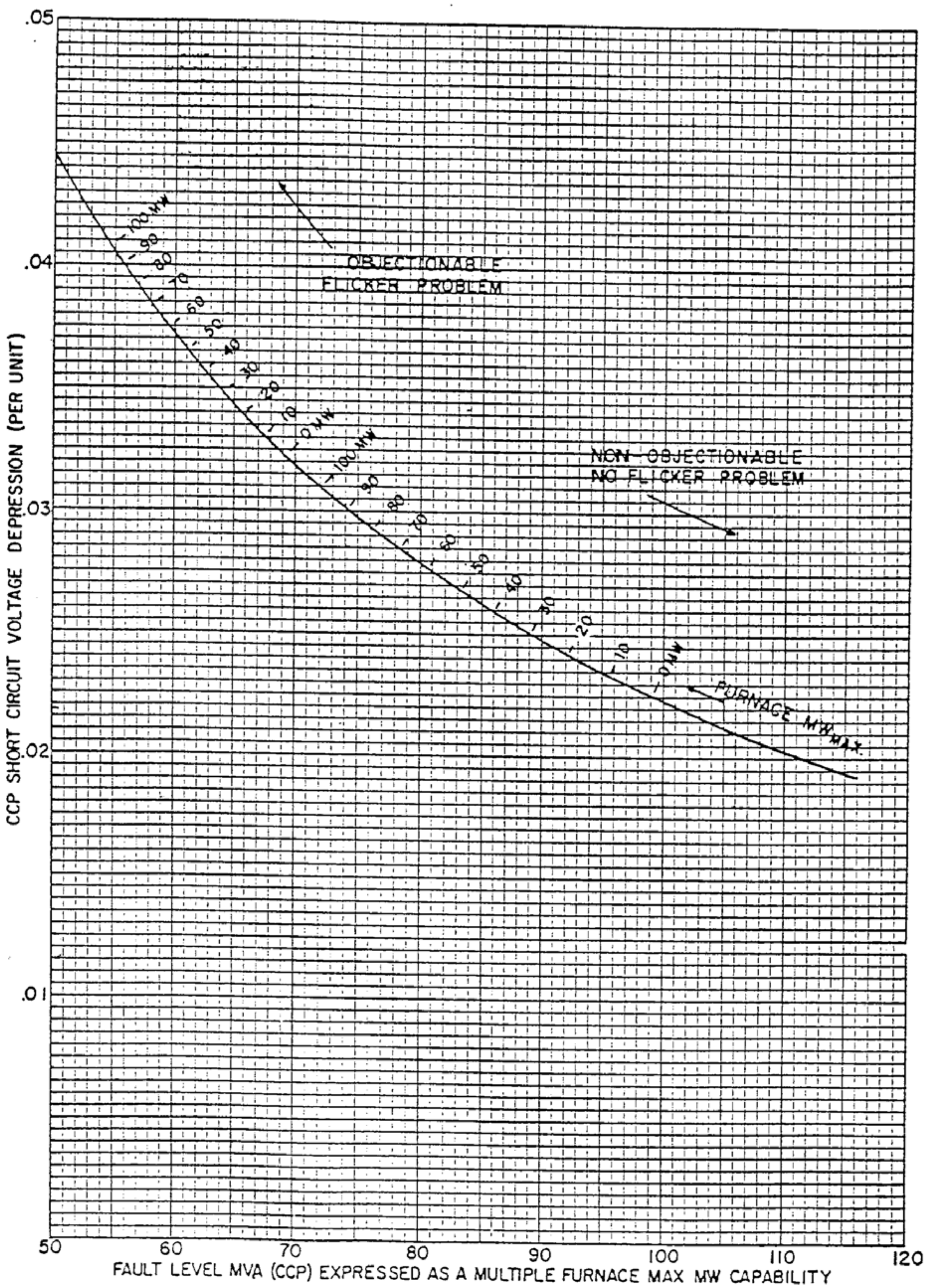
Flicker generally refers to lighting variations that are detectable by the human eye. It is caused by voltage fluctuations on the utility system most commonly due to large industrial arc furnaces. Much has been written with regard to limiting flicker as far back as the 1920's. The most recent standard with regard to flicker limits is IEEE Standard 1453 – 2004, "Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems". This standard adopts IEC-61000-4-15 – 2003, which gives details for flicker calculations and measurements. (It should be noted that IEC-61000-4-15 was updated in 2010.) A brief summary of the recent history of how these new standards were developed is given here.

1. A paper written by General Electric Company in 1975 gives guidelines for applying large arc furnaces based on the most recent data at that time concerning flicker. Based on the MW rating of the furnace, the user can determine the MVA short circuit that is required such that flicker will not be objectionable. Figure 1 gives the key guideline graph developed in the paper. For example, if a plant was installing a 100 MW arc furnace, the MVA short circuit at the point of common coupling would need to be greater than 7200 MVA for flicker to be non-objectionable based on Figure 1. If the MVA short circuit was less than 5500 MVA, the flicker would be objectionable. If the MVA short circuit was between 5500 and 7200 MVA, flicker would be borderline. The short circuit voltage depression at the point of common coupling can be read from the scale along the x-axis. The voltage depression was based on typical arc furnace impedance quantities.

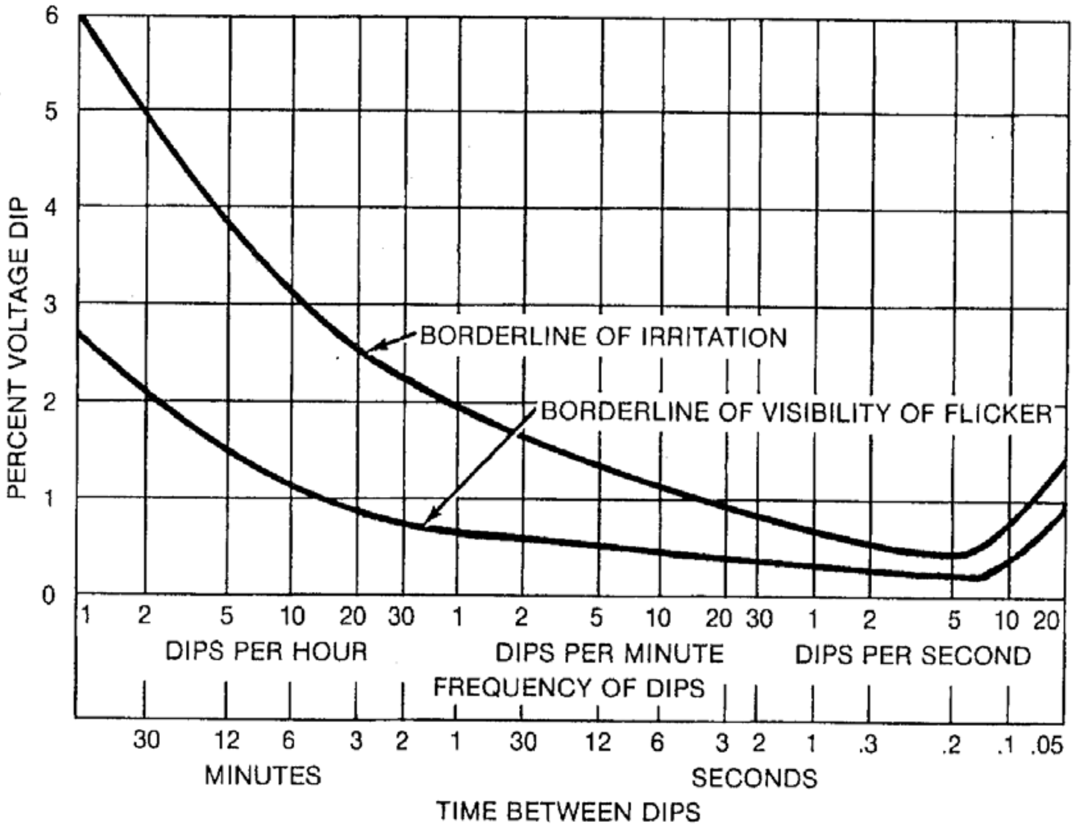
2. Section 3.9 of the Red Book (Standard 141-1986) gives a guideline curve for flicker based on the magnitude and frequency of the supply voltage change. There are errors in this information and it is recommended that it not be used.

3. Section 3.9 of a later version of the Red Book (Standard 141-1993) gives a guideline graph for flicker used by many utilities and is based on both the magnitude and frequency of changes to the supply voltage. This guideline graph is shown in Figure 2.

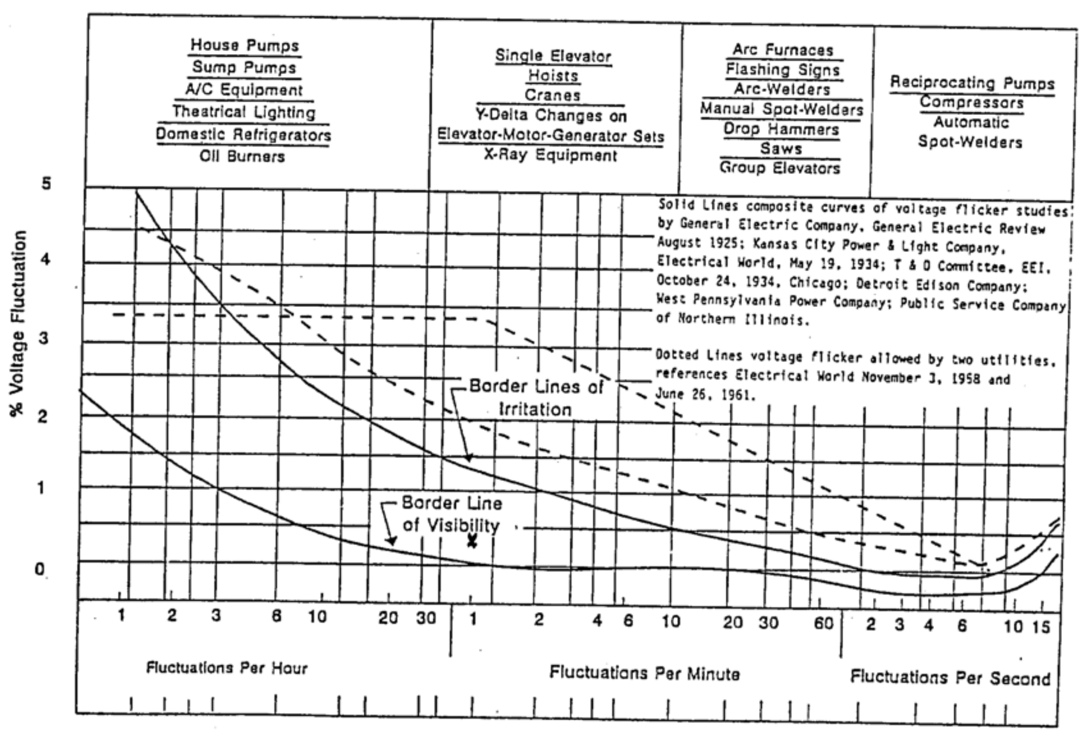
4. Figure 3 gives the graph from Section 10.5.1 of IEEE Standard 519-1992 and shows that it is very similar to the graph in the Red Book. It should be noted that the x-axis of this graph is suspect and is not recommended for actual engineering use.



Fault Level MW_{MAX} Ratios and Accompanying Short Circuit Voltage Depression
Figure 1

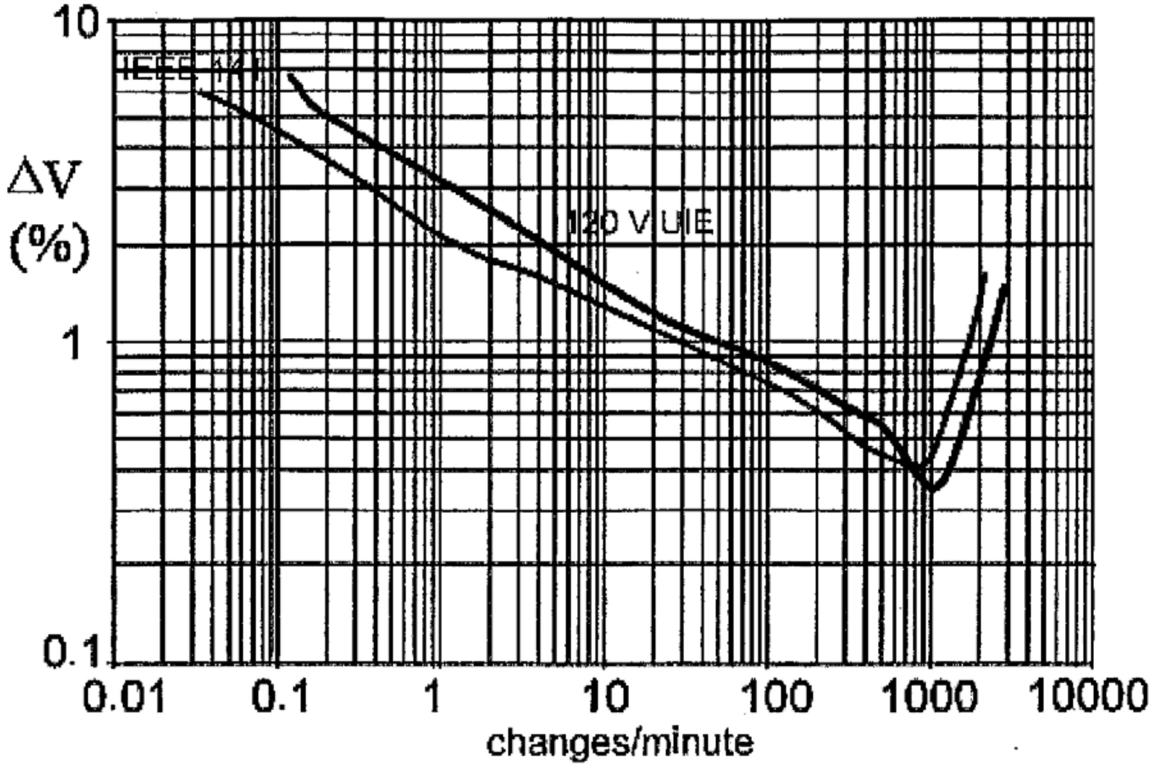


Range of Observable and Objectionable Voltage Flicker versus Time
Figure 2



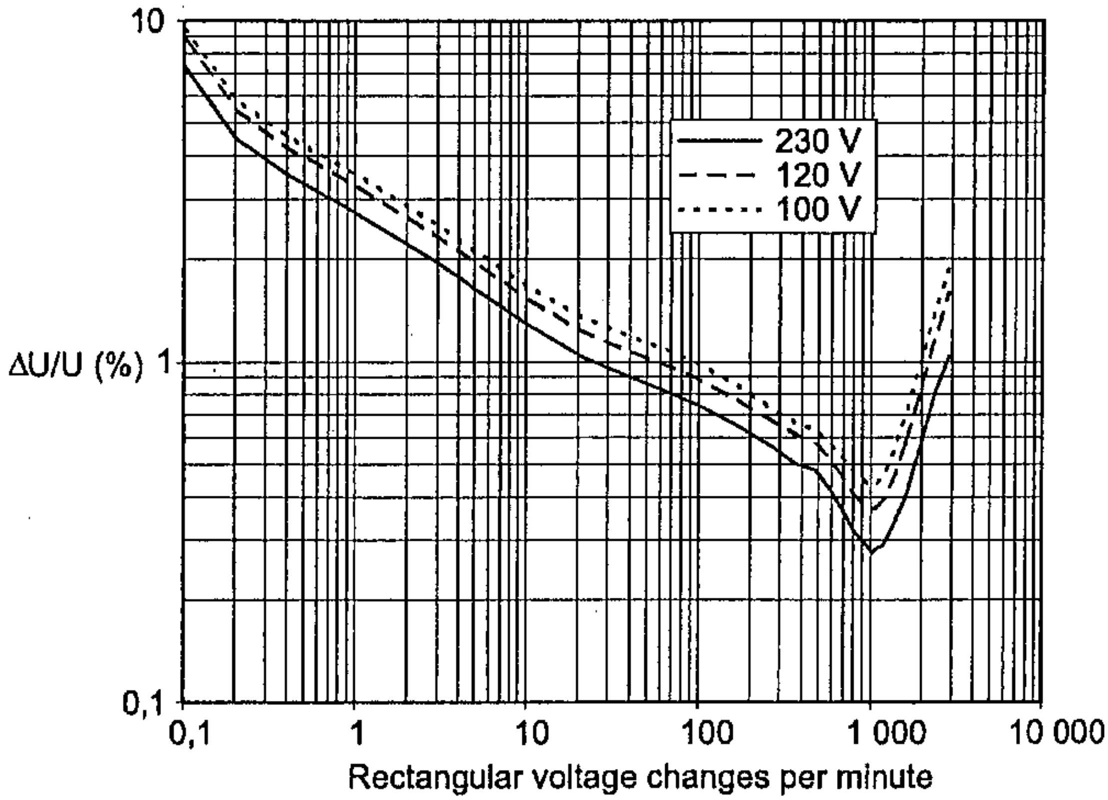
Maximum Permissible Voltage Fluctuations
Figure 3

5. The most recent guidelines for flicker are given in IEEE Standard 1453-2004. Annex A of this standard gives a brief history of the development of voltage flicker limits in the United States. The most recent guidelines are designed to include loads that produce modulation of the voltage magnitude that is more complex than what was expected by the original flicker curves. Figure 4 comes from Annex A of IEEE Standard 1453-2004 and includes what is referred to as the Pst = 1 curve. This curve is labeled 120 V UIE and the actual test points used for the curve are given in an accompanying table.



Comparison of IEC 61000-4-15 and IEEE Standard 141-1993 for Irritation
Figure 4

The Pst = 1 curve is then compared to the borderline of irritation curve shown on the flicker tolerance graph in IEEE Standard 141-1993 and it can be seen that they are very similar. When comparing graphs, care must be taken to be sure that the x-axis of the graphs being compared are in the same units. One must know that 1 dip per second equates to 2 changes per second and the term dips per second is used interchangeably with the term frequency. This is discussed and illustrated in Annex B of IEC-61000-4-15. The Pst = 1 curves are slightly different for 230V, 120V and 100V utilization systems. This is illustrated in IEC 61000-3-7, and the key graph is shown here in Figure 5.



Note – Two consecutive voltage changes (one positive and one negative) constitute one "cycle", i.e. two voltage changes per second mean a 1 Hz fluctuation.

Pst = 1 Curve for Regular Rectangular Voltage Changes
Figure 5

6. The development of the Pst = 1 curve gives a means for quantifying the borderline of irritation for flicker based on both the magnitude and rate of fluctuation of the supply voltage. A Pst value that is greater than 1 indicates a relatively high probability of flicker problems. Measurement equipment can now be used to "measure" flicker in term of a discrete Pst value. It is important to realize that the Pst method is useful but does have its limitations. For instance, if the system voltage is measured and found to have a Pst value of 1, it indicates that flicker can be a problem. However, it does not allow you to determine the voltage dip or the rate of fluctuation. It only indicates that it is somewhere on or below the Pst =1 curve.

7. The application of the Pst value of flicker can be quite complex and almost always requires some degree of engineering judgment. Annex B of IEEE Standard 1453-2004 is helpful in understanding some of these complexities.

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