

CHAPTER THREE

ORIGIN OF FLICKER VOLTAGE

3.1 The Origin Of Flicker

Flickervoltages may originate in the power system but most frequently in the equipment connected to it.

3.1.1 Generating Equipment

Prime Movers:

Engine driven generators are probably responsible for most of the rare cases of flicker originating due to the power system itself. Curve (a) of Fig [3.1] shows the variation in tangential force of a four cylinder 300 rpm Diesel engine at full load, and Curve (b) shows the corresponding percent change in angular velocity of the rotating parts. With all other factors constant, this non-uniform rate of rotation produces a fluctuation in amplitude of the generator voltage. This variation in voltage is the same as the total variation in speed (in this example 0.7 percent). (see chp2 fig[2.1]). The frequency of the variation is equal to the rpm times the number of power strokes per revolution, in this case $300 \times 2 = 600$ per minute or 10 per second. This problem can be solved by increase the flywheel effect, or changing the speed to get within a less objectionable frequency range.

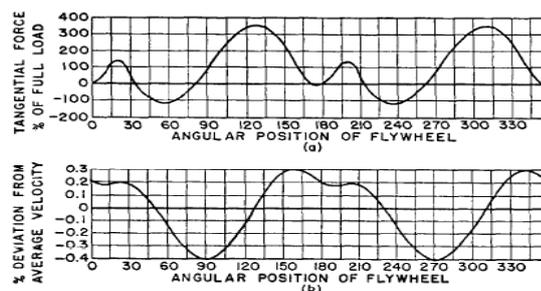


Fig [3.1] Curves from a four-cylinder 300 rpm Diesel engine at full load driving a generator.

In this actual case, the flicker of the original installation caused many complaints and it was satisfactorily corrected by increasing the flywheel effect.

Generators:

A symmetrical generator with constant load, excitation and angular velocity produces a constant terminal voltage. If any of these quantities varies, however, the terminal voltage also varies. Abrupt changes of load on generators produce corresponding changes in the terminal voltages. This voltage fluctuation is the result of two factors: the change in speed is unusual to be significant factor in large station because of large total generating capacity. Even, if the speed change, however, the rate at which the voltage drops is ordinarily so slow. Fig [3.2] show a typical voltage-time regulation curve of a large turbine generator, following sudden application of load. Speed and excitation voltage are assumed constant.

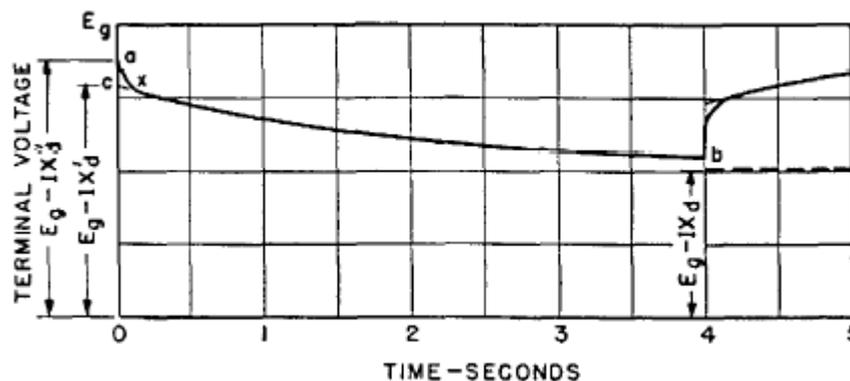


Fig [3.2] Voltage-time regulation of a large turbo-generator following sudden application of load.

Point (a), (b), and (c) are of especial interest. Point (a) is the voltage immediately following the application of load; point (b) is the voltage after the voltage has settled; point (c) is an extrapolation of the curve from (b) back to zero time. Each of these points may be determined closely by the use of the appropriate generator reactance. To calculate Point (a), we use the sub-transient reactance " x_d'' " of the machine. Initially when machine is unloaded,

the voltage (O-a) is the vector difference between the no-load voltage and the product of the load current times the subtransient reactance. That is,

$$O-a = E_g - I_x d'' \dots\dots\dots (3.1)$$

The voltage rapidly falls further to a point (x) and at a much lower rate to point (b). That is due to decrease in the field flux which affected by the set up armature currents . The change in voltage from (x) to (b), is slow.

Point (x) is not directly calculable by using standard machine reactance alone. Point (c), is calculated by use the transient reactance as follow

$$O-c = E_g - I_x d' \dots\dots\dots (3.2)$$

Similarly, point (b) is calculated from synchronous reactance:

$$O-b = E_g - I_x d \dots\dots\dots (3.3)$$

For single load applications more than 10 cycles in duration (on a 60-cycle system), the voltage regulation point (c) of Fig [3.2] calculated from the transient reactance, is the determining quantity. (see chp2 fig [2.4]). shows that there is little difference in perception lasting from 5 to 15 cycles of voltage drop . For load duration less than 5 cycles, it is likely that the regulation as calculated from the sub-transient reactance determines the permissible flicker. While the voltage drop at the end of 5 cycles is greater than initially, the transition is gradual and it is doubtful if the eye can discern so small a difference. For load durations between 5 and 10 cycles, it is probable that an average between sub-transient and transient reactances should be used to calculate flicker voltages for comparison with perception data similar to those given in.

The proper reactance to be used to calculate the effect of cyclic variations depends upon the frequency of their occurrence. The following rang in table [3.1] is suggested for generators 5000 kva and above.

Table [3.1] The range of proper reactance to be used to calculate the effect of cycle variation:

Pulsation Frequency Cycles per Second	Reactance
1-4	x_d'
5-12	$\frac{x_d' + x_d''}{2}$
12-30	x_d''

Excitation Systems

Excitation systems are rarely the cause of flicker voltages in central station practice. In larger generators, field time constants above 3 seconds cause variation in armature voltage to be very gradual no matter how fast the excitation may change. Since the alternator field constant is usually too high to permit exciter fluctuations to show up in the alternator terminal voltage, then amount of generator flicker depends upon its inherent reactance characteristics and cannot be substantially improved by excitation control.

Short Circuits and Switching Surges

Due to a large magnitude short circuit currents there is a large voltage drops and attendant flicker occur. To reduce the amount of voltage drops we need to change in the layout of the system which is not feasible and so cost. But the duration of the voltage drops can be reduced by the use of high speed relays and breakers. Short circuit is rarely to cause flicker. Line switching also rarely produces flicker unless load is picked up or dropped, or lines with large charging currents are switched.

3.1.2 Utilization Equipment

customer's utilization equipment are probably responsible for the most of the flicker on control station systems .

Motor Starting

For general purpose, most of motors need to start its motion with high current (5-to-10 times its full load value) to produce sufficient starting torque. Most motors for example (induction motors) may be started by connecting them across full voltage(directly from the power lines), a most are started in that way .In many cases, however the high inrush current associated with full voltage starting can cause a large voltage dips in the distribution system, and light may dim or flicker.Three general classes of motor installations are of importance in the flicker problem.

(i)Single phase fractional horsepower motors

These motors commonly used in homes and small stores, with one glass (used in domestic refrigerators and oil burners) designed specifically for frequent starting with low starting current.

(ii)Integral-horsepower polyphone

These motors are operated from secondary distribution circuits, and are potential source of flicker. Usually, such motors are used in areas of high load concentration. In some case, however, the size of motor is out off proportion with its supply lines, hence a starter must be used to limits the initial inrush of current and prevent objectionable lamp flicker.

(iii)Large integral-horsepower three-phase motors

These motors are operated from primary lines, mostly by industrial concerns, where power lines are inherently heavy and where wider limits of voltage drop are permissible.

Motor-Driven Reciprocating Loads

We mean, type of load that varies with each power stroke and produces a corresponding variation in the line current. Thus, comparatively small variations of voltage may be objectionable if the pulsation occurs 6 to 12 times per second. Since in flicker problem, the change in load is of greater concern than the magnitude of the load, the average power factor is of no particular interest the preferable procedure, if complete motor data are available, is to calculate the changes in the bus supply voltage to the motor due to changes in the load on the motor. The method is illustrated in the vector diagrams on Fig [3.3] Vector diagram (a) shows the vector relations for a synchronous motor operating at full load and 80 percent power factor lead. E_s , E_{bus} and E_m are respectively the system voltage, bus supply voltage to the motor and the internal voltage of the motor. $I R_s$, and $I x_s$ are the voltage drops through the system impedance. $I x_m$, is the drop through the motor where x_m may be the synchronous, transient or sub-transient reactance depending upon the rate of load fluctuation compared to the time constant of the machine. Using diagram (a) as the starting point where the motor power factor angle ϕ is known along with the average load, E_{bus} and all of the reactances, the change in bus voltage can be obtained as shown in vector diagram (b). For all sudden changes in load the system voltage, E_s , and the internal voltage of the motor, E_m remains substantially constant. To determine the sudden dip in bus voltage it is necessary to calculate a curve of bus voltage against motor load or motor load change. This requires for each point on the curve that a magnitude of current be assumed and the voltage drop through the system and motor determined. This will locate the internal voltage E_m with respect to the system voltage E_s (In Fig.[3.3] E_m , and also E_s , in the diagrams (a) and (b) have the same magnitude).

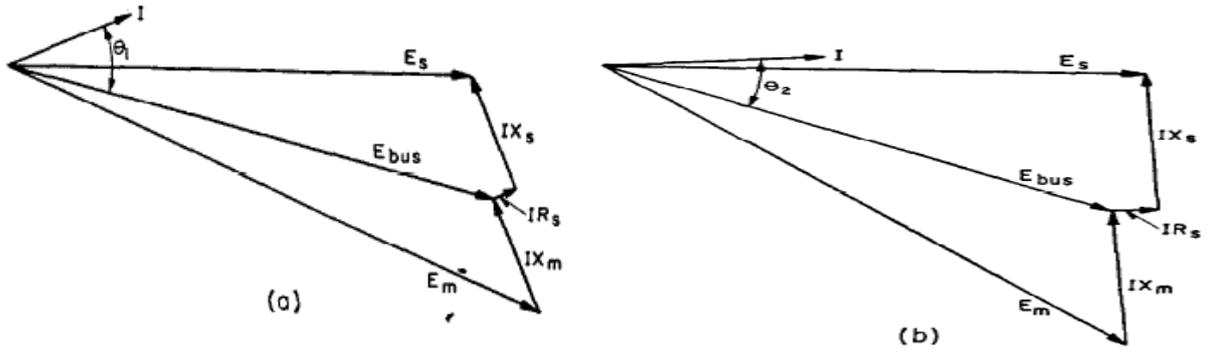


Fig [3.3] Vector diagrams illustrating method of obtaining magnitude and phase position of synchronous motor current air and magnitude of bus voltage with change of load.

The position of the voltage drops will then determine the position of the current vector as well as the bus voltage vector E_{bus} . Using the current, voltage (E_{bus}) and the angle between them the power can be found. With the curve of bus voltage against motor load change the voltage for any desired change in motor load can be obtained.

Motor Driven Intermittent loads

Saw mills and cool cutter, are typical examples for these types of loads, where the cycles is of long and irregular period. The motor current in such installations vary rapidly from light load, through pull-out at heavy current and high power factor to locked-rotor current at low power factor. Punch presses and shears are examples of applications where the load goes through wide variations, but where flywheels and other design features limit both the rate of application and magnitude of the load swings. Motors used to drive intermittent loads are likely to have been designed with special characteristics. If possible, the fluctuation in current and power factor should be obtained by test or from the manufacturer.

Electric Furnaces

There are three general types of electric furnaces-resistance, induction, and arc. The resistance furnace usually causes no more flicker than any other resistance load of comparable size. Most induction furnaces operate at high frequency, and therefore, are connected to the power line through a frequency changer and consequently represent a fairly steady load. Three-phase steel melting arc furnaces of the are being used to a considerable extent to make high grade alloy steel, and frequently cause voltage flicker. During the melting down period, pieces of steel scrap will at times, more or less, completely bridge the electrodes, approximating a short circuit on the secondary side of the furnace transformer. Consequently, the melting down period is characterized by violent fluctuations of current at low power factors, single-phase. At refining period, the steel has been melted down to a pool and arc lengths can be maintained uniform by automatic electrode regulators, so that stable arcs can be held on all three electrodes. The refining period is, therefore, characterized by a steady three-phase load of high power factor. The size of load fluctuations during the melting down period is influenced by a number of factors, of which the rate of melting is perhaps the most important. The furnace-supply transformers have winding taps for control of the arc voltage (fig [3.4](a)) and in the smaller sizes (about 6000 kva and below) have separate built-in reactors to limit the current and stabilize the arc(fig [3.4](b)).

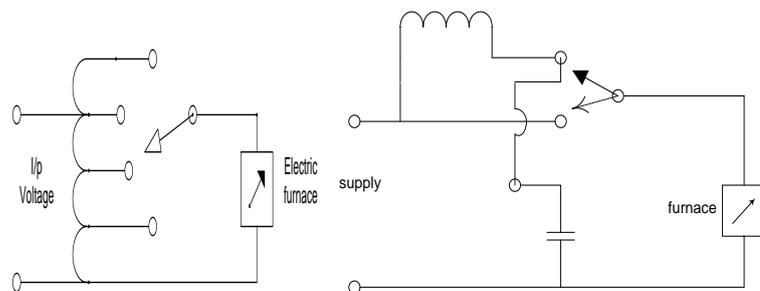


Fig [3.4] winding tap for control of the arc voltage (a) and a reactor to limit the current and stabilize the arc (b).

Forcing the furnaces production by rising the arc voltage, reducing the series reactance, and rising the regulator setting, may increase both the magnitude and the violence of the load swings.

Calculated curves in Fig [3.5] show the electrical characteristics of a 10000-kva, three-phase arc furnace . These curves were prepared on the assumption that the maximum attainable current would be approximately twice normal at 50 percent power factor. The effective impedance of the arc (based on 11 500 volts in the primary) is plotted as the abscissa. For convenience, zero ohms, as plotted, represents the minimum arc resistance as determined by the so-called short circuit condition. Actually, at this point there is appreciable voltage drop at the electrode tips, and considerable arc energy; the curves are plotted in this manner only to show the working range. It is of interest that the point of maximum power is not that of maximum kva. The usual melt-down range is probably between the points corresponding to 0 and 10 ohms, the arcs fluctuating during this period so that the heating effect is some sort of an average between these limits. The refining range is probably above 10 ohms. On small furnaces, the current may reach a maximum of 3.5 times that at full load, but the process of reaching this value is usually through a series of small increments, and as noted previously the annoyance to lighting customers is largely a matter of the rate of change rather than the total change.

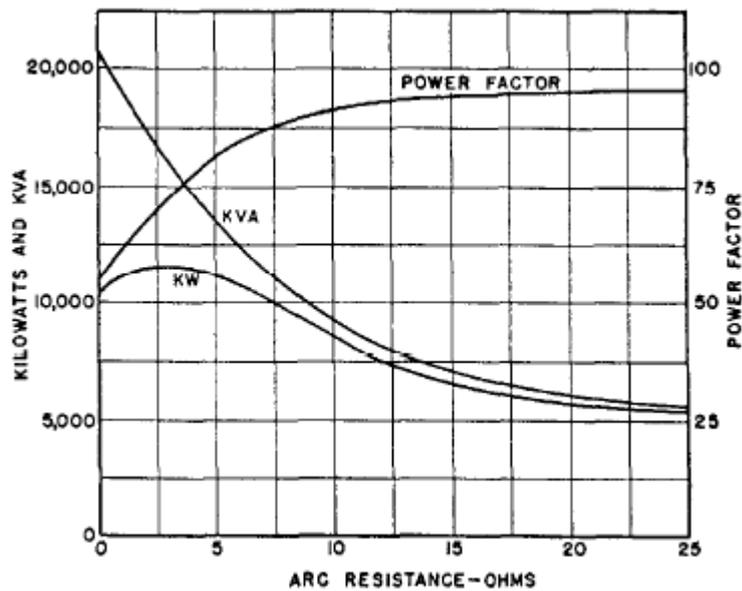


Fig [3.5] Electrical characteristics of a 10 000 kva, three-phase arc furnace.

The kva swings given in Fig [3.6] are equivalent swings. The frequency of occurrence of these swings corresponds to the Extremely Frequent classification as given in (chp2 Table [2.1]). Load swings can occur more rapidly, but their magnitudes are less than those in Fig [3.6]. The information shown in Fig [3.6], together with suitable system constants should give a fair approximation of the flicker voltage to be expected.

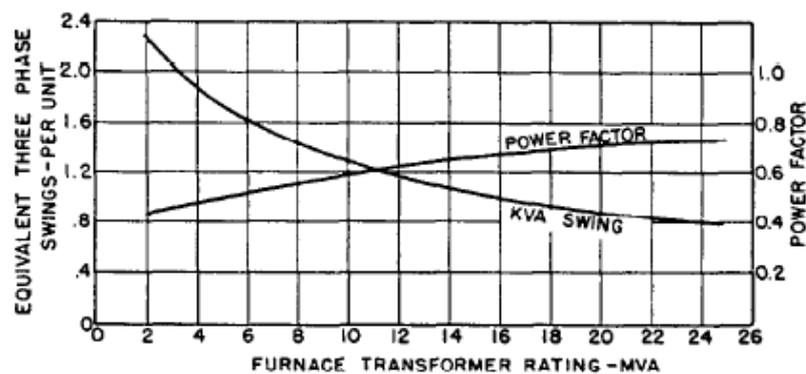


Fig [3.6] Equivalent kva swings in an electric arc furnace..

Electric Welders:

This is a class of equipment of great importance in power system flicker. Most, welders have a smaller “on” time than “off” time, and

consequently, the total energy consumed is small compared with the instantaneous demand. Fortunately, most welders are located in factories, where other processes require a large amount of power, and where the supply facilities are sufficiently heavy, so that no flicker trouble is experienced. Sometimes the welder may be the major load in the area, and serious flicker may be imposed on distribution systems adequate for ordinary loads.

The more common types of electric welders are:

- (i) Flash welders.
- (ii) Pressure butt welders.
- (iii) Resistance welders:

In welders the source voltage, usually 230, 460 or 2300 volts is stepped down to send high current through the parts to be welded. Practically all welders in service are single-phase.

(i) Flash welders:

With flash welders, one piece is held rigidly, and the other is held in quasi-contact with it, with voltage applied. An arc is formed, which supplies the necessary welding heat (Fig [3.7]).

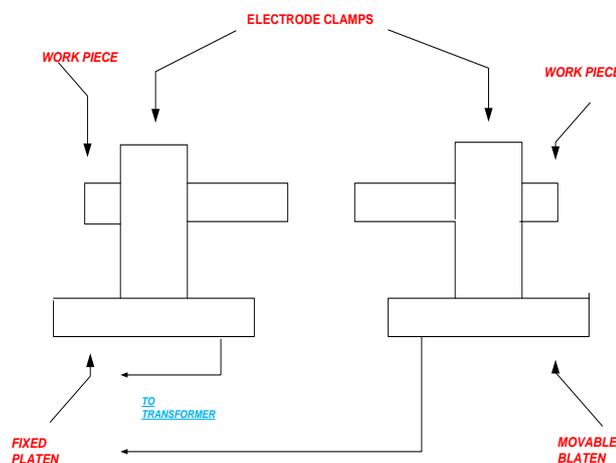


Fig [3.7] flash wilder

The current, drawn during the flashing period, is irregular because of the instability of the arc, so that the flicker effect is obnoxious more than if the current were steady at its maximum value. The average power factor during flashing may be as high as 60 percent. At upset, it is about 40 percent. The flashing may last up to 20 or 30 seconds. The duration of power during upset is usually short; of the order of 0.5 second. This type of welder may draw up to 1000 kva during flashing and about twice this loading at upset.

(ii) Pressure butt welders

Pressure butt welders are similar to flash welders, except for that the parts being welded are kept continuously in contact by a following pressure. From a power supply standpoint the butt welder is more desirable than the flash welder because the welding current once applied, is practically steady and the only flicker produced is at the time power is applied and removed. The range of currents and power factors is about that for flash welders.

(iii) Resistance welders

In resistance welders current is applied through electrodes to the parts to be welded, usually thin sheets of steel or aluminum. The weld is accurately timed to bring the metal just to the welding temperature. The pieces are fused together in a small spot. Resistance welders are characterized by large short-time currents. In spot welders, the current may be applied for only a few cycle (on a 60-cycle basis), with welds following one another in a fraction of a second up to about a minute. Thus, from the flicker standpoint there are a succession of individual voltage dips occurring objectionably frequent interval. The process is a continuous one while a given piece is in the machine, and since the periodicity of the welds is uniform, the flicker can be annoying even for relatively small voltage dips.

Resistance welders drawing energy from all three phases greatly minimize flicker. On small welders, the stored energy of capacitors or inductors can often be used to minimize the peak demand from the source.

3.2 Location Of Flicker Voltage

Load equipment may create flicker conditions in one or more of the following locations:

- (i)Secondary distribution
- (ii)Primary lines
- (iii)Substation busses
- (iv)Generating stations

The location of flicker voltage, or the extent of the afflicted area, has a considerable influence on possible remedies. If the generating station busses are affected, there are usually no commercially practical means of remedying the situation on the power system, and the correction must usually be made at the utilization point. If a substation is affected, but the generation stations are not, then more tie lines or transmission at higher voltage can be employed, or a separate line run from the generating station to the affected area. Sometimes the utilization equipment itself can be corrected. If a primary line is affected, improvements can be made in either the power system or the utilization equipment. If the utilization device is standard equipment, it is usually best to correct the distribution system, and thuds improve other loads as well. If the utilization device is special, it is probably more efficient to correct the device.