CHAPTER II

THEORETICAL BACKGROUND

2.1 Voltage Fluctuation[1]

Voltage regulation must be considered when some electrical equipment in a circuit is either started or stopped. This consideration increase with the size of the electrical equipment, the frequency of starting and stopping, and the detrimental effects of this starting and stopping with its corresponding demands on the alternater has on the plant operation.

When a large electrical equipment is suddenly started, it instantly adds to the current and kilowatt load on the alternator, and the horsepower load of the engine. This cause a momentary reduction in the speed of the engine, and a momentary reduction in the voltage of the alternator. The governor on the engine acts to restore the speed of the engine, and the voltage regulator on the alternator acts to restore the voltage of the alternator.

The reduction in the speed of the engine is cushioned by the inertia of the engine flywheel and the alternator rotor. This prevents an instantaneous reduction in speed and allows time for the governor to start operating. The overall effect, then, on the engine is slight.

Unlike the speed reduction in the engine, the voltage drop is instantaneous since electricity has no inertia. After this instantaneous drop in voltage, there is still another slow drop, and after this the voltage regulator function to bring the voltage back to normal. When a load is switched off, just the opposite will happen, that is the engine speed will tend to increase, and the alternator voltage will rise. Again the engine speed increase will be cushioned, but the voltage increase is instantaneous.

A complete cycle of either an instantaneous voltage drop followed by bringing the voltage back down to normal, is called a voltage fluctuation. This characteristic of an electrical circuit is unavoidable, and no voltage regulator available today can completely eliminate the fluctuation in the alternator voltage when a load is either added or deducted from a circuit. Voltage regulators are designed, however, to restore or bring down voltage as quickly as possible when a load is added or deducted from the circuit.

2.2 Effects of Voltage Fluctuation (1)

The detrimental effects of voltage fluctuation depends largely on the function of the plant. For example, a hospital could tolerate very little voltage fluctuation because of the need for constant, steady light and the operation of the voltage sensitive X-ray machine. A warehouse, on the other hand, would be considerably less effected by fluctuation since light flicker would not impair it function.

Following are some of the detrimental effects of voltage fluctuation :

(a) Light : Lights will flicker with a sudden, appreciable drop in a voltage. A 220 - volt lamp will cause an observable flicker with 4 volts drop; the flicker becomes increasing objectionable as the size of the drop increases.

(b) X-ray equipment : X-ray equipment, including Deep-Ray therapy machines, will vary their X-ray radiation with a sudden, appreciable change in voltage.

(c) Magnetic brakes : Magnetic brakes used on some types of electric motor will set when the voltage falls 10 - 15 percent under normal.

(d) Tube welders : Tube welders (continuous electric seam welders) require the voltage fluctuation not to exceed 5 percent.

(e) Motor control : Motor control, or similar types of equipment that hold switches closed by some magnetic principle, will release and open the switch if a 40 to 60 percent voltage drop occurs.

2.3 The Extent of Voltage Fluctuation (1)

The extent to which the alternator's voltage will fluctuate with a sudden increase or decrease of the load will depend on the following factors:

(a) The kva rating of the alternator.

(b) The regulation of the alternator itself.

(c) The current and power factor of the load change on the alternator.

(d) The load condition of the alternator, that is, the percent of full load kva the alternator is operating at, and the power factor of the load when the load change occurs.

2.4 Methods of Controlling the Voltage Fluctuation[1]

In the instances where control of voltage fluctuation becomes important, various methods are available to reduce the fluctuation to a minimum. The extent the fluctuation will be reduced will depend on the need for control, the equipment in the plant itself, and the cost. Followings are some of the common methods for controlling voltage fluctuation:

(a) Split the power and lighting loads so a separate alternator can be used on each.

(b) Limit the current inrush of current variation by modifying motor control or the other changes in the load. For example, used a reduced-voltage type starter if a large starting current is causing the trouble. Also, large motors may be started before the remainder of the plant load.

(c) Use alternator of good, full load regulation characteristics. That is particularly true if the plant's load is mainly lighting, plus a few small motors.

2.5 Voltage Regulator (1)

Alternator voltage could be regulated manually by controlling a rheostat in the exciter field circuit but this is rarely practical because of widely fluctuation load. Therefore, an electric set normally incorporates a voltage regulator that control the output voltage as nearly constant as possible.

In general, a voltage regulator will do the following things:

(a) It prevents low voltage by keeping up the average rated voltage despite the load on the alternator.

(b) Keeps voltage at rated values within limits if the speed of the engine should drop due to a heavy load.

(c) Allows adjustment of plant voltage. For example, voltage can be increased to compensaate for the loss of voltage in a long line.

A voltage regulator can not, however, do the followings:

(a) Eliminate instantaneous voltage fluctuation if there is a large, rapidly fluctuating load on the alternator (for example, starting a squirrel-cage induction motor). The regulator will, however, act to prevent a further drop, and act to restore the voltage.

(b) Will not restore voltage to normal if the alternator and its exciter are loaded beyond their full load capacity.

A voltage regulator employs an error-sensing circuit that compares the alternator terminal voltage, either directly or indirectly, with a reference voltage and uses the error signal to control the excitation level of the alternator. The regulator holds alternator voltage at any desired level within the limits of the alternator exciter design capability.

When field excitation of the alternator is provided by a rotating exciter, the voltage regulator operates indirectly by controlling current in the field of the exciter instead of the field of the alternator itself. The voltage regulator senses alternator voltage and regulates the flow of rectified current to the field. When there is a sudden increase in load, for example, causing a drop in alternator output voltage, the regulator senses this change and boosts the field current to a high level for quick recovery. The resulting increase in the field current raises the alternator output voltages. As the alternator voltage rises toward normal, the regulator cuts back the exciter to minimize voltage "overshoot".

All voltage regulators include a voltage adjusting rheostat for manual setting of the desired voltage range.

2.5.1 Voltage Stability and Regulation [2]

An alternator equipped with an automatic voltage regulator maintains approximately constant voltage at any steady state load, but the voltage may vary slightly above and below the average. This slight variation is referred to as voltage stability or modulation and is usually stated as a plus-or-minus percentage of rated voltage.

For most alternator-regulator systems, the average voltage is not the same at one steady load as at another. The difference in the voltage from one steady load to another is referred to as regulation. Specifically, regulation is defined as the difference between the average steady voltage at no load and at full load. It is usually expressed as a percentage of rated voltage as equation 2.1 below

$$\% \text{ Regulation} = \frac{V_o - V_l}{V_o} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

Where V_o = Alternator terminal voltage at noload

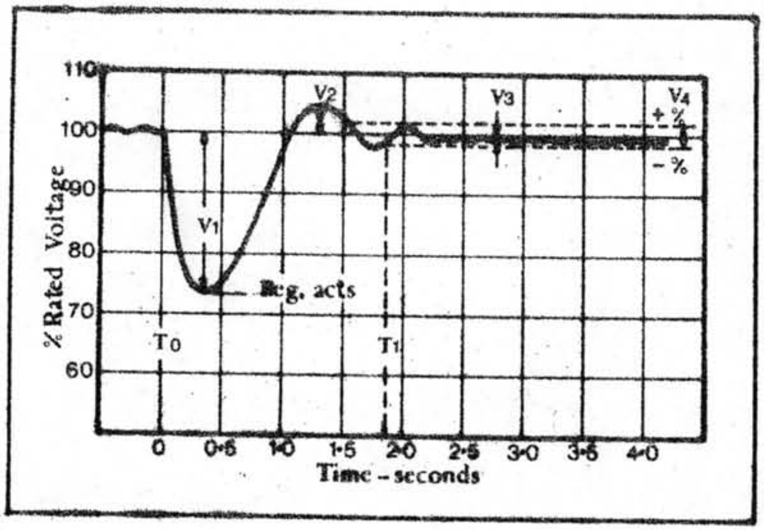
V_l = Alternator terminal voltage at full load

This will usually include tests made at all loads from noload to full load and from unity to rated power factor.

2.5.2 Voltage Dip and Recovery [2]

Sudden load change causes a momentary voltage deviation. The voltage then recovers and settles out near its former level. The momentary dip or rise as load is applied or removed often must be limited to avoid light flicker or malfunction of sensitive equipment. Both the magnitude of the deviation and the recovery time may be of concern. Voltage dip limit is usually expressed as a percentage of rated voltage, and the recovery time is stated as the time in seconds to recover to and remain within a specified steady-state band.

A typical voltage response to a step load application is illustrated in Figure 2.1.



V_1 = Maximum transient voltage dip.

V_2 = Maximum transient voltage overshoot.

V_3 = Steady state regulation.

V_4 = Stability band width.

T_0 = Time at which load is applied.

T_1 = Time to recover to and remain within allowed band width.

$T_1 - T_0$ = Recovery time.

Figure 2.1 : Alternator Voltage Transient Response VS. Time for Load Application.

The voltage dip abruptly, rises again under the influence of the voltage regulator, overshoots the regulation band slightly, decrease and settles out within the band. Its new average steady value may be slightly different from its original value, depending on the regulation characteristic of the regulator.

2.6 Types of Voltage Regulators.[1]

Selection of voltage regulators depends on such factors as:

- Comparative initial cost.
- Accuracy.
- Speed of response.
- Simplicity.
- Ability to be mounted on the alternator.
- Suitability of a particular regulator for the particular installation.

Several different methods are used in the various regulators for alternators available on the market to control the excitation of the alternators, giving rise to several difference types of regulators listed below and described in the following paragraphs.

2.6.1 Rheostatic Type Voltage Regulators

The rheostatic type voltage regulators derive their name by doing what is equivalent to regulating rheostat in the shunt - field of the exciter or, in some cases, in the field of the alternator directly. This type of regulator control the voltage of the alternator by varying the resistance in the field circuit. The regulator operates only when a correction in the voltage is necessary.

2.6.2 Vibrating-Contact Type Regulators

Vibrating-contact type regulators control the excitation by means of one or several pair of vibrating contacts which are actuated by voltage sensitive solenoids. The design of vibrating contact regulator depends on the rapid opening and closing of a circuit that shunts the field rheostat and thus changes the resistance in the field circuit of the alternator to be regulated.

2.6.3 Synchronous-Contact Type Voltage Regulators

Synchronous-contact type voltage regulators have contacts which operate in synchronization with the frequency of the alternator. This constant frequency makes this type of regulator closely responsive to voltage changes, so restoration of the voltage is started very quickly.

2.6.4 Static Type Regulator

Static type regulator supplies DC excitation directly to the field of the alternator. It controls the amount of excitation by means of reactors, rectifiers, and transformers; thus it has no moving parts.

2.6.5 Electonic Type Voltage Regulators

Electronic voltage regulators available today utilize semiconductor devices to control the excitation current of alternator and thus control the output voltage. This type of regulator is especially useful when the plant load consists of a fluctuation power load, and a lighting load that must not noticeably flicker.

In this thesis solid - state electronic type voltage regulator will be adopted, as this type of regulator seems to offer many advantages over other type. The following sections will describe this type of regulator in more details.

Almost solid state voltage regulator for alternators are self-excited regulator which receives all of its power from the output lines of the alternator and is dependent upon a voltage being available at these terminals under all conditions of alternator loading (see Figure 2.2)

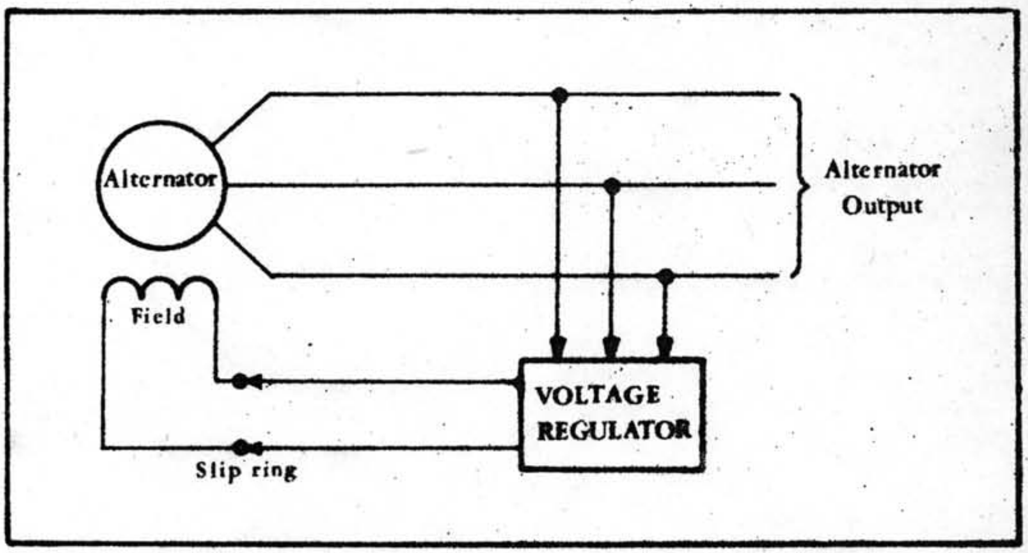


Figure 2.2 : Self-excited Voltage Regulator System

The solid state type voltage regulators available today can be classified into two subtypes, and these are

-Transistorized Voltage Regulator.

-Silicon Controlled Rectifier Voltage Regulator.

a) Transistorized Voltage Regulator

In a transistorized voltage regulator, voltage from the output terminals of the alternator (usually sensed through a potential transformer) is converted from AC to DC by silicon rectifiers. The DC output from the rectifiers is filtered and applied to a voltage comparison network (usually used a zener diode), which compares the output voltage of the alternator with a reference voltage network output. The error voltage is applied to switch one or more control transistors which in turn control a power transistor that control the current in the alternator field or exciter field when a rotating exciter is used with the alternator.

Transistor type voltage regulator has achieved considerable popularity during the past few years. This type of regulator comes to limit when high output of the regulator is required, therefore it is limited to alternator with low output power when used as an exciter and also at high output rating the cost is considerable higher than the silicon controlled rectifier type regulator.

b) Silicon Controlled Rectifier Voltage Regulator

A silicon controlled rectifier (SCR) voltage regulator functions by sensing alternator voltage through a potential transformer. The AC voltage of the transformer is converted to DC by silicon rectifiers and compared with a reference voltage network output.

Typically, the voltage reference is a zener diode, which has the characteristic of maintaining an essentially constant voltage.

The difference between the reference and the sensed voltage constitutes an error signal that controls the firing time of the SCR, enabling it to conduct long enough during each cycle to supply the required alternator or exciter field excitation. When the alternator load changes, causing a voltage rise or dip, the regulator changes the conducting time of the SCR to supply a new level of exciting current to the field winding.

The SCR regulators normally have high waveform deviation factor and generated radio frequency interference (RFI) which is the by-product of this type of regulator. This type of interference is particular troublesome where computers are connected to the alternator, often causing erratic operation and errors in read-out. Where very low RFI levels are required, an RFI filter must be used. For almost applications, however, there are no trouble in using this type of regulator.

The SCR regulators are widely used nowaday because they are reliable and economic, especially in the high rating regulator.