CHAPTER III

DESIGN OF REGULATOR SYSTEM

The first step in designing the regulator system is to evaluate types of regulator that meet all the requirements specified and then choose the most economic one.

As stated in the preceding chapter that the SCR type voltage regulator is the most economic type of solid state voltage regulator when the regulator output rating is high, the SCR type voltage regulator will be chosen for this work where it will be used in composite with alternator that require a high rating regulator.

3.1 System Block Diagram [3]

The basic principle of the SCR type voltage regulator for alternator is similar to the DC power supply voltage regulator. The function of this system can be arranged into six basic circuits as illustrated in the block diagram of Figure 3.1 . There are sensing circuit, comparison or error detector, error amplifier, firing circuit, power controller and stabilizing network. In many cases, a single transistor or stage function as both the comparison element and error amplifier.

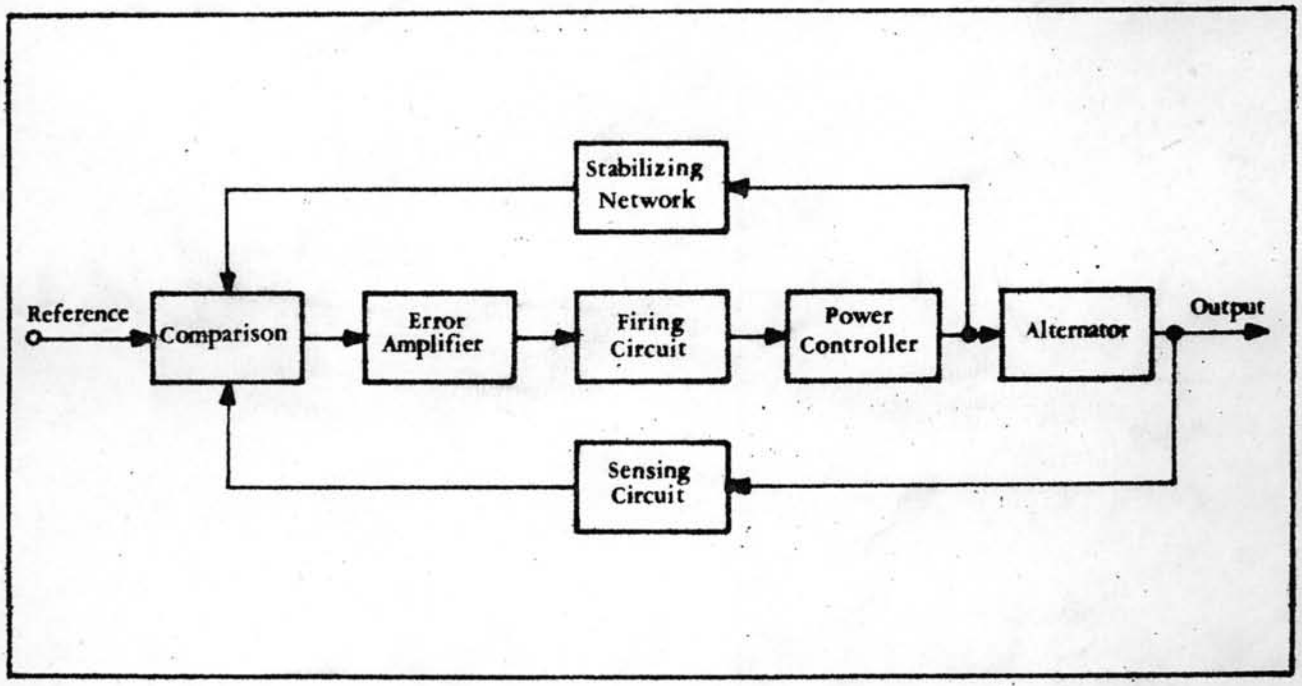

Figure 3.1 : Voltage Regulator System Block Diagram

3.1.1 Sensing Circuit

The sensing circuit senses the alternator terminal voltage. This voltage is reduced to a proper value by means of a potential transformer. The reduced voltage is rectified and filtered and the resultant DC signal is fed to the comparison stage. The sensing circuit selected for this design consists of a potential transformer T_1, a rectifier bridge which is composed of D_1 to D_4 and a simple L - section LC filter circuit as shown in Figure 3.2.

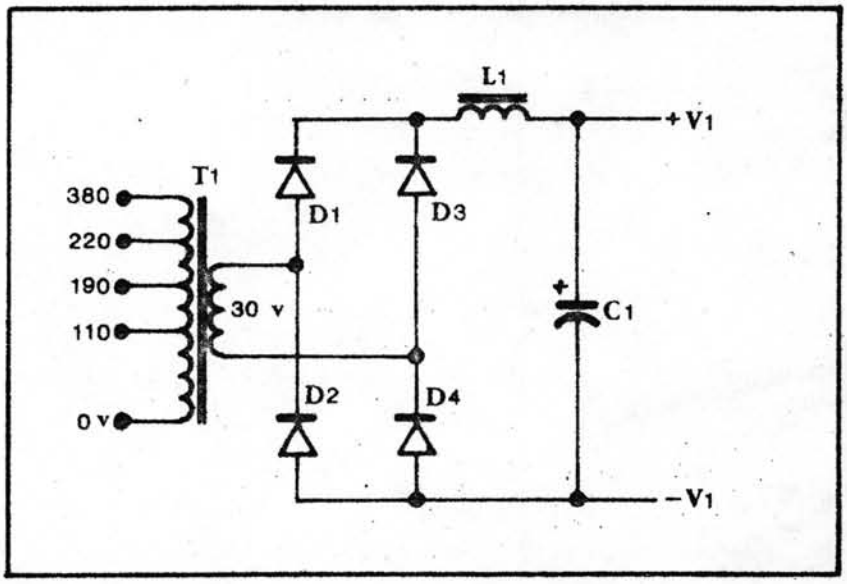

Figure 3.2 : Sensing Circuit

3.1.2 Comparison and Error Amplifier

A single transistor stage as shown in Figure 3.3 was chosen for the comparison and error amplifier stages.

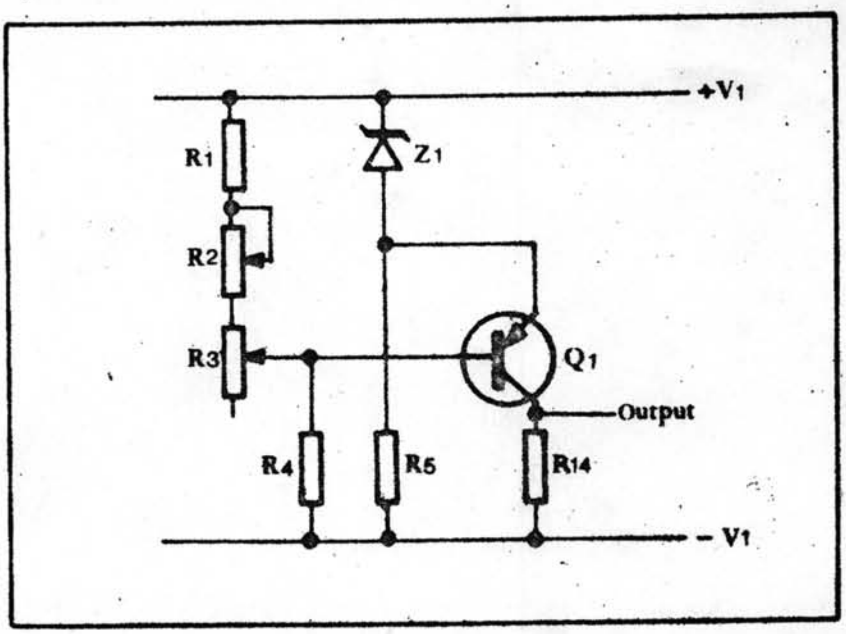

Figure 3.3 : Comparison and Error Amplifier Stage

This stage takes a sample voltage from sensing circuit to compare with the reference voltage and produces a signal that is proportional to the difference between the sampled voltage and the reference voltage. This signal is amplified and fed to the firing circuit.

The variable resistor R_2 was provided for adjusting the alternator voltage. When the resistor is adjusted for its maximum resistance, the minimum alternator voltage will be obtained and on the contrary the maximum alternator voltage is obtained with the minimum resistance. Resistor R_3 was provided to vary the limit of R_2. Normally R_3 is set to provide R_2 with an adjustment range of $\pm$ 10% of nominal voltage of the alternator.

3.1.3 Firing Circuit

The firing circuit interprets the signal from the error amplifier and makes an adjustment in firing time necessary to fire the SCR at a proper angle. A transistor-controlled variable frequency unijunction transistor relaxation oscillator as illustrated in Figure 3.4 was chosen for the firing circuit.

Transistor Q_2 acts as a variable resistor which resistance varies inversely with input signal to its base. The UJT oscillation frequency is determined by the values of its emitter capacitor (C_5) and its emitter resistors (R_{15}, R_{16} and internal resistance from collector to emitter of the transistor Q_2). This oscillation frequency or period can be determined directly from equation 3.1 [4]

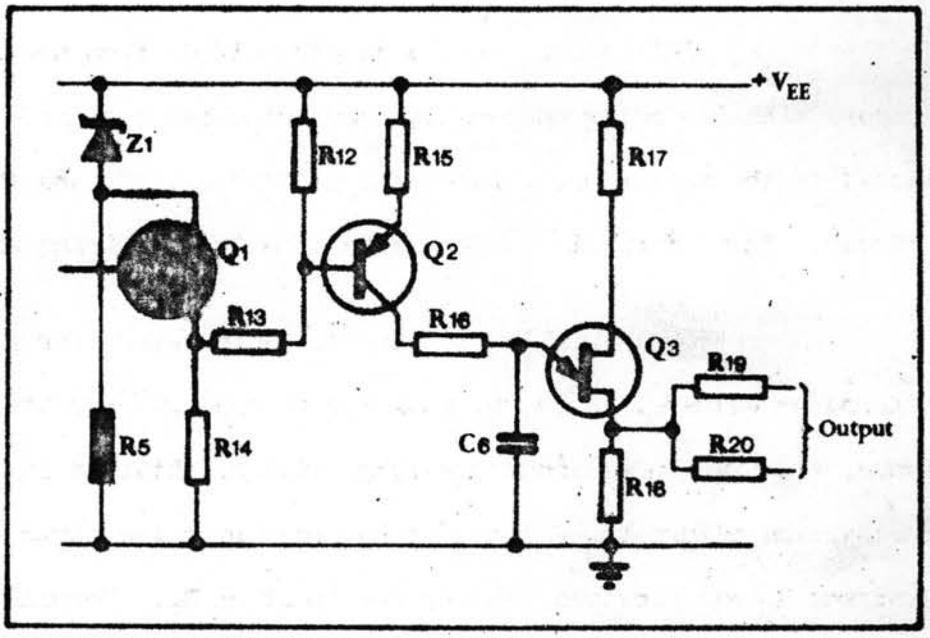

Figure 3.4 : Firing Circuit

$$C_E = \frac{t}{R_E \ln\left(\frac{V_{EE} - V_e}{V_{EE} - v_c}\right)} \quad \text{.........................} \quad (3.1)$$

Where C_E : emitter capacitance (See Fig. 3.5) (farad)

t : period of pulse = 1/frequency (sec.)

R_E : emitter resistance of the UJT (see Fig. 3.5) (ohm)

V_{EE} : DC supply voltage (volt)

V_e : initial charge voltage (volt) = V_v

v_c : final charge voltage (volt) = V_p

The oscillation or output pulses period of the UJT is long when the alternator is at no load condition and will become shorter when the load on the alternator is increased.

It is most practical to start the design of UJT relaxation oscillator circuit by selecting a trial value for emitter resistance R_E rather than for emitter capacitor C_E. This is because R_E must meet certain conditions for the oscillator to operate properly. If R_E is too large, the UJT will never fire; if R_E is too small, the UJT will not turn off. These conditions can be explained by means of the emitter characteristic curve of Fig.3.5 (This curve is not drawn to scale in order to have more detail)

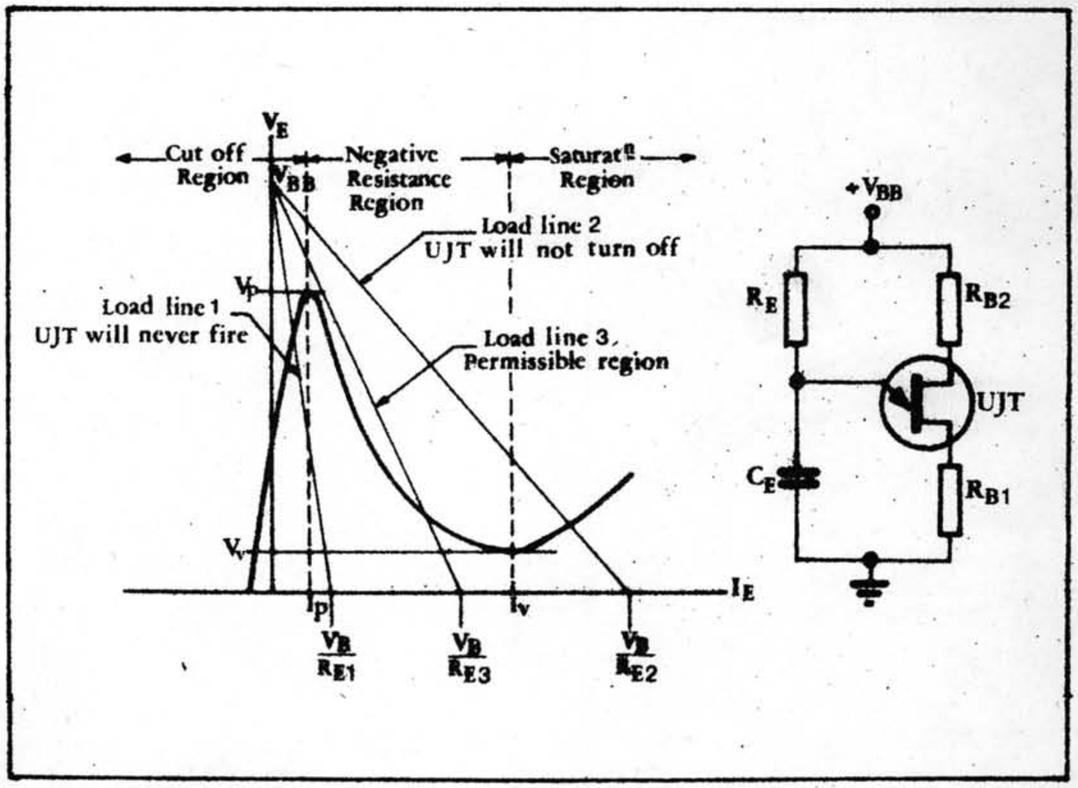

Figure 3.5 : UJT Emitter Characteristic Load Lines

<u>Selecting Emitter Resistor (R_E)</u>. The emitter capacitor C_E will charge until the emitter voltage is equal to the peak-point voltage V_p. At this point the emitter current is peak-point current I_p, and in order to fire the UJT, the value of R_E must be small enough to allow a current somewhat larger than I_p to flow. Thus R_E must be small enough to keep the UJT in the negative resistance region. R_E must, therefore, meet the requirement specified in equation 3.2[5]

$$R_E \leq \frac{V_{EE} - V_p}{I_p} = R_E\ (max) \qquad (3.2)$$

Where I_p : peak-point current (amp.)

R_E : emitter resistance (ohm)

V_{EE}: DC supply voltage (volt)

V_p : peak-point voltage (volt)

$$V_p = V_D + \eta V_{EE} \qquad (3.3)$$

V_D : emitter diode forward voltage (volt) $\doteq$ 0.6

η : intrinsic stand-off ratio

By keeping R_E smaller than R_E (max), the UJT will turn ON, and C_E will discharge through the emitter of UJT. However, if R_E is too small, and an emitter current larger than the valley current I_V flows, the UJT will not turn OFF. Under these conditions, the UJT will attaining a stable operating in the saturation region. The minimum value of R_E that can be used in order to essure oscillation is set by the condition given by equation 3.4 [5]

$$R_E \geq \frac{V_{EE} - V_V}{I_V} = R_E\ (min) \quad \text{.........................} \quad (3.4)$$

Where R_E : emitter resistance (ohm)

V_{EE} : DC supply voltage (volt)

V_V : valley voltage (volt)

I_V : valley current (amp)

Selecting Base 1 Resistor (R_{B1}). The primary function of R_{B1} for this application is to provide a path for the interbase current. Such a path is necessary for the firing circuit to prevent current from flowing through SCR's gate, which can cause an undesirable turn on of the SCR. Generally, if the UJT oscillator is to trigger an SCR from an output pulse across R_{B1}, the value of R_{B1} can be determined by equation3.5.[5]

$$R_{B1} \doteqdot \frac{0.2 \times r_{BB}(min)}{V_{EE}} \quad \text{............................} \quad (3.5)$$

Where R_{B1} : base 1 resistance (ohm)

r_{BB} : UJT's interbase resistance (ohm)

V_{EE} : DC supply voltage (volt)

Selecting Base 2 Resistor (R_{B2}). The function of R_{B2} is to provide temperature compensation. Practically all UJT characteristics are temperature dependent, some more than others. The interbase resistance and emitter reverse current increase, whereas the peak and valley voltages (and currents), the intrinsic standoff ratio, and the junction diode drop decrease with increasing temperature.

If R_{B2} is properly selected, the peak-point voltage V_p can be made to vary less than 1 percent over a 50°C temperature variation. Practically R_{B2} is chosen from the equation 3.6 (5)

$$R_{B2} \doteq \frac{0.7 \times r_{BB}}{\eta V_{EE}} + \frac{(1-\eta) R_{B1}}{\eta} \quad \text{..................} \quad (3.6)$$

Where R_{B2} : base 2 resistance (ohm)

r_{BB} : UJT's interbase resistance (ohm)

V_{EE} : DC supply voltage (volt)

η : intrinsic standoff ratio

R_{B1} : base 1 resistance (ohm)

3.1.4 Power Controller

The power controller stage interpret the signalling pulse from the firing circuit and makes an adjustment in the alternator field current to a proper value. A typical well-known singlephase half controlled bridge with flywheel diode circuit shown in Figure 3.6 had been employed.

The flywheel diode D_{12} was added to allow current to flow after the SCR had switched to a non-conducting state, thus preventing high voltage transients from appearing across the main field winding. For this design, an additional simple suppression circuit composed of capacitor C_5 and resistor R_{11} had been combined into the bridge circuit in order to reduce wavefrom distortion created by the operation of the SCRs.

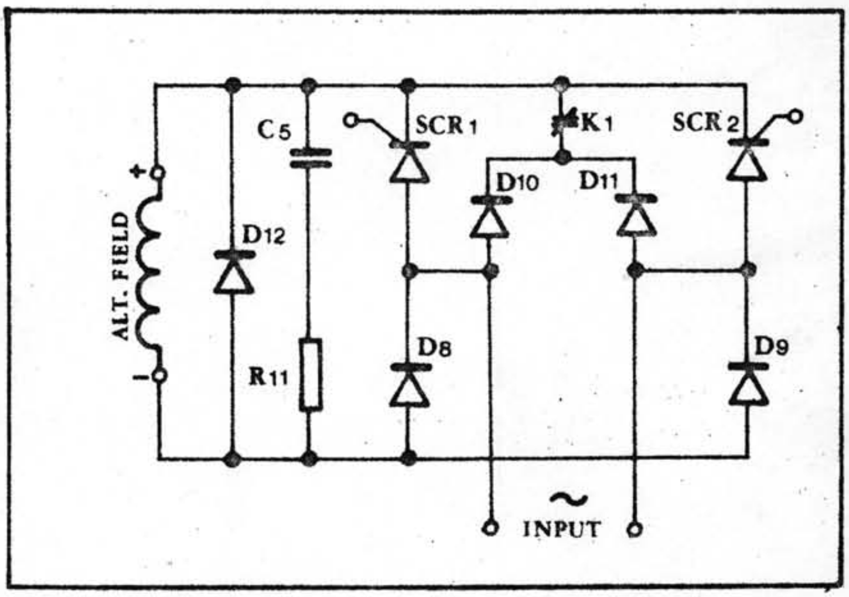

Figure 3.6 : Power Controller Stage

The diodes D_{10} and D_{11} were also presented in the circuit to rectify the residual voltage from alternator during the voltage build-up period. This is because in this period of operation both SCRs are in a non-conducting state. After voltage has built up to approximately 75 percent of nominal rated voltage, the relay contact K_1 opens to cut these diodes out of this function, putting the SCRs into operation.

3.1.5 Stabilizing Network.(6) The stabilizing circuit provide stable operation of the regulator under all operating conditions. It consists of RC stabilizing network as shown in Figure 3.7 which injects a stabilizing signal from the power stage to the error amplifier to prevent oscillations (hunting).

During a change in load on alternator the feedback voltage changes and thus causes a current to flow through capacitor C_3 and resistor R_8. This current serves as negative feedback to the system to provide stable condition as quickly as possible during load changes.

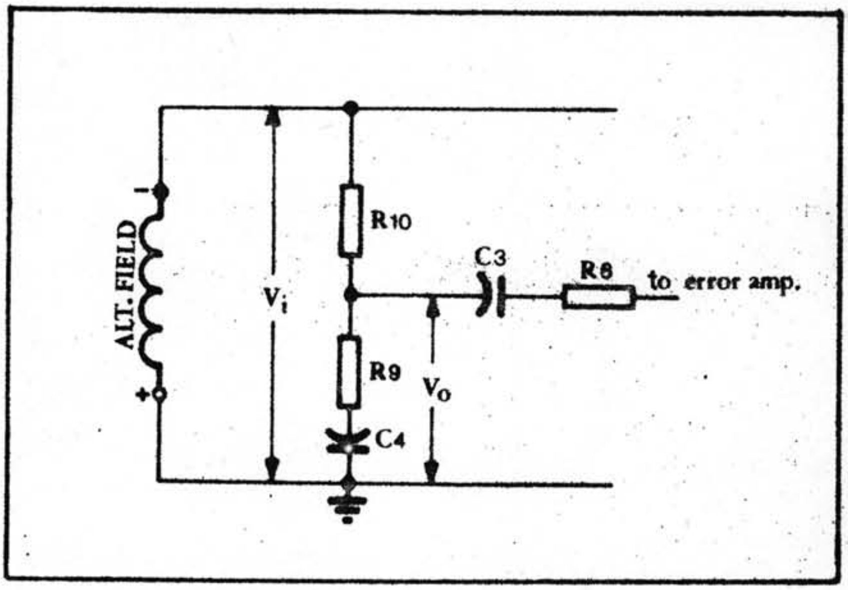

Figure 3.7 : Stabilizing Network

3.2 Initial Voltage Build-Up

The simplest way to provide an initial voltage build-up from alternator residual flux is accomplished by using a normally closed contact relay to provide a current path around the control rectifiers, to allow the alternator residual voltage to be converted to DC by conventional rectifier diodes and apply to the exciter or alternator field directly. When the alternator output voltage reaches approximately 75 % of rated voltage, the relay pulls in, removing the conventional rectifiers, thus allowing the silicon controlled rectifiers to regulate the alternator output voltage.