UNIT 5 EXCITATION CONTROL

UNIT 5.1 BASIC INFORMATIONS OF SYSTEMS

UNIT 5.2 ELECTRONIC EXCITATION SYSTEM

UNIT 5.1 BASIC INFORMATIONS OF SYSTEMS

OBJECTIVES

After completion of this unit, you should be able to:

- Understand where does excitation come from
- Appreciate role of excitation during locomotive operation
- Understand different types of excitation systems and their principle of operation

STRUCTURE

1. Introduction
2. What is excited and why
3. Job of a locomotive
4. Job of Excitation System
5. Where does the Excitation come from
6. A type Excitation System
7. B- type Excitation System
8. C- type Excitation System
9. D- type Excitation System
10. E- type Excitation System
11. Summary

1. WHAT IS EXCITED AND WHY

The voltage output of a generator depends on the speed of the armature and the amount of field excitation. The current, on the other hand, depends on the circuit connected to the generator (usually called "load"). In a diesel electric locomotive, the load is the combination of traction motors connected with their cables and switches. These motors should have the right voltage at all the times. To get the right voltage, the current in the generator field must be varied to suit the locomotive operating conditions. This is known as excitation control.

2. JOB OF A LOCOMOTIVE

A diesel electric locomotive must be able to start a heavy train, bring it up to running speed, slow it down and stop it. Starting and gaining speed require a large amount of torque on the wheels. As the traction motors drive the wheels, they must develop a large amount of torque to start a train. Then as it speeds up, less and less torque is required.

3. JOB OF EXCITATION SYSTEM

A diesel engine gives maximum fuel efficiency if it is loaded in such a way so that it develops constant HP with each throttle setting. In a diesel electric locomotive, load is the combination of traction motors, and the current through them varies with their change in speed. So to keep main generator power constant, the output voltage must be varied accordingly.

Excitation system controls the out put voltage of the main generator to (1) maintain constant horse power (2) limit the current at stand still condition of the locomotive (being the series motor, they draw excessive current at stand still. (3) Limit the voltage to avoid flash over at higher speed of the locomotive. For these jobs it must respond automatically to any movement of the throttle handle, to any change in load on the generator, or to any combination of both.

4. WHERE DOES THE EXCITATION COME FROM?

Excitation systems can be roughly classified in two groups, internal and external. In internal system, the main generator and exciter is built to operate in such a way that without interference of any other control device, main generator develops constant power at different load condition. In an external system, control apparatus outside the main generator and exciter is used to get these results. The whole problem is to properly vary the current in the field of main generator. This current may come from a storage battery, the generator's own armature, another dc generator, or a combination of the above.

A good excitation system produces a generator characteristic curve of constant power. A typical main generator characteristic curve produced by a good excitation system is shown in Figure E-3.1. Power output at any point on this curve is equal to the voltage multiplied by the current. This is kept constant for each throttle setting by the excitation system.

5. EXCITATION SYSTEMS

5.1 A - TYPE

In this method, excitation is controlled with the help of an amplidyne generator used as exciter. The machine needs only a small current to excite its field. Also a small change in this field current produces a large change in voltage output. A governor operated variable resistance, called Load Control Rheostat (LCR) controls the amplidyne field current, as shown in Figure E-3.2.

5.2 B - TYPE

The system is known as 3-field excitation system. In this system, the exciter is having three fields namely the self-excited field, differential field and battery field. The self-excited field is connected as a shunt field with some limiting resistors in series to it. The differential field is connected in parallel to the main generator commutating field. This field acts as an opposition to the other two-exciter fields. The battery field or separately excited field is supplied through battery and a governor-operated rheostat, called load control rheostat controls the current through this field. This decreases the effect of battery field inserting resistance in the circuit, if governor tries to increase more fuel to maintain speed for that throttle position. Figure E-3.3.

5.3 C - TYPE

Split-pole excitation system is C-type excitation system. It is a good example of internal system. The exciter is a special type of dc generator. Its pole pieces are split in two sections, a differential section and a shunt section. The differential field is wound on the differential section of each pole piece and is connected in series with traction generator. It opposes the action of the shunt field wound around shunt section and differential section of each pole piece. With these two fields the curve of constant power can be achieved. Figure E-3.4.

5.4 D - TYPE

This type is known as Static Excitation System. In this system, the exciter alternator supplies the current to the main generator field. The field of alternator is fed from battery and is fixed. The output of exciter alternator is connected to three identical Power Reactors, one in each phase. These reactors control the current flow according to different input signals received by them about speed of diesel engine, terminal voltage of main generator, main generator current, etc. The output of all these reactors is rectified to D.C. and connected to main generator field. (Figure E-3.7).

5.5 E - TYPE

Electronics Excitation System is known as type -E excitation system. In this system, a D.C. generator called 'exciter' excites the main generator field. Field of exciter is fed from battery through control. The average current flowing through exciter field is controlled by a power transistor called “Exciter Field Transistor” working in switching mode. A magnetic amplifier called pulse width modulator controls the ON period and OFF period of EFT on getting different input signals of engine speed, main generator voltage and main generator current. (Figure E-3.8).

6. SUMMARY

This is a control system, which controls the excitation to the traction generator for loading the diesel engine in an efficient manner to maintain the steady state of the engine in order to have lowest possible specific fuel consumption. To minimize the energy spent to impose control and to reduce the sizes of the control equipment, an exciter is used as the source of the excitation current, whose field current is controlled. There are developments in stages to have modern and least maintenance prone system to ensure better reliability and lowest possible downtime of the locomotive. In Indian Railways locomotives excepting type-A, rests were used. However, type-B and type-E were popular systems and type-E has maximum population.

7. SELF-ASSESMENT EXCERCISES

1. What is the need of Excitation control in diesel loco?
2. Write short notes on different types of excitation controls of diesel loco.

UNIT5.2 ELECTRONICS EXCITATION SYSTEM

OBJECTIVE

After going through this unit, you will be able to

- Understand the necessity of Excitation control
- Appreciate the Generator load curve
- Appreciate the family of notch curves
- Understand the basic functioning of the system
- Appreciate the system components
- Analyse the circuit
- Appreciate the load control activity
- Appreciate the corner point suppression on load curve

STRUCTURE

1. INTRODUCTION

In a locomotive, the load on the main generator at any fixed engine speed varies as locomotive track speed increases due to the counter EMF created by the rotating armatures of the traction motors. The load is also changed by shunting the traction motor fields or changing connections from series to parallel. Therefore, the excitation control must act to keep generator horsepower demand constant over a wide variation of terminal voltage to run the diesel engine with maximum fuel efficiency.

The "electronics excitation system" is a system using semiconductor components. The system controls exciter generator field current; i.e. the exciter output. The system provides the function of current limit, voltage limit on the generator and keeps the generator power constant at eight different levels as far as possible at each of the eight engine speeds available.

2. GENERATOR LOAD CURVE

The required performance is illustrated by the "Typical Generator characteristics" curve, Fig.1. The curve is drawn for 8th notch (full power) operation.

The slightly rising line from the origin of the curve at O volts and O amperes to the point B is known as the IR line. This represents the voltage obtained at various generator currents with the motors connected, but with the train not yet moving. The current in the motors at stand still is equal to the voltage across each motor divided by the motor resistance.

The portion of the curve denoted by line BC is the current limit for the generator. Currents in excess of the values shown by this line would produce excessive slippage when starting a train and also may cause damage to the main generator and traction motors.

The current and voltage combinations represented by points along the line CF indicate a constant rarted engine horsepower, expressed in electrical terms. Voltage and current to the right of this line would represent a higher load on the diesel engine. If the excitation system were allowed to load the engine in such a manner, the engine speed would drop, because of limit in fuel, resulting in loss of power and controlled operation could not be obtained.

The dotted lines represent the characteristic provided by the excitation system to approximate constant engine horsepower. System tolerances (+ 2.1/2%) are such that actual generator characteristic may fall anywhere in the band shown, meaning that it may, in some instances, slightly exceed the normal. When this occurs, generator characteristic may be trimmed to meet the desired constant H.P curve by the load control potentiometer actuated by the engine governor.

3. FAMILY OF NOTCH CURVES

Fig.2 shows the family curves representing generator characteristic from first notch through eight notch as developed by the excitation system. The actual position of each curve is determined by an engine speed signal continually fed to the excitation control. When the engine accelerates from one notch value to the next higher one, the generator current increases smoothly until it reaches a new notch value as the engine gets to the corresponding speed for that notch.

4. BASIC EXCITATION SYSTEM

Fig.3 shows a basic block diagram of the Electronics Excitation System. The exciter shunt field is fed from the locomotive battery through a network of resistors and exciter field transistor EFT1. The power transistor functions as a switch and is turned "ON" and "OFF" 800 times per second by pulses generated by the oscillator. The pulse width modulator (PWM) controls the duration of "ON" time as compared to "OFF" time during each pulse, thus regulating the average current in the exciter field PWM responds to several "feed-back" signals as shown in the block diagram, Fig.3 and described in detail below.

Generator armature current is measured by a special reactor called armature current control reactor (ACCR). Generator voltage is measured by a reactor called voltage control Reactor (VCR).

The outputs of these reactors are fed to the reference mixer network. Only the greater of the two outputs is used at any one time. When the output of either ACCR or VCR is greater than the reference current, a current is put through the main winding of the pulse width modulator to limit generator excitation.

The function generator circuit modifies the output of ACCR in relation to generator voltage to produce the constant horsepower portion of the generator characteristic curve for notch 8. In the lower notches, the function generator also responds to engine speed to prodvide the proper separation of the notch curves.

5. SYSTEM COMPONENTS

5.1 EXCITER-GENERATOR

The exciter - generator is a shunt wound d-c machine. The generator is mounted on the traction generator gear box and gear driven from it at a speed proportional to engine speed.

5.2 EXCITATION PANEL

The excitation panel is a steel fabricated housing with component parts mounted on seven plug in type cards, which slide out of the housing for easy inspection. Three rheostats are mounted on the face of one card. One adjusts main generator characteristic and two adjust dynamic braking efforts .

5.3 OSCILLATOR

The oscillator is an a-c power supply used to supply power for various control functions. It operates from a d-c input voltage from the locomotive battery. The schematic diagram of the oscillator is shown in Fig.4.

The oscillator transformer (OST) has number of secondaries to supply a-c power to various circuits as follows:

WINDING	FUNCTIONS
1.	Excitation Transistor (EFT1)
2.	Oscillator Feed Back.
3.	Pulse Width Modulator (PWM)
4.	Spare
5.	A C C R.
6.	V C R.

The power supply consists of a saturating transformer alternately energised in opposite directions. Transistors which function as switch, causes flux reversal in the transformer core. The oscillator changes d-c input to a 400 CPS (cycles per second) square wave output.

To avoid the need for a stiff voltage divider for the oscillator supply, the fact that a series resistor having constant current in it will deliver the same voltage at its centre terminal is utilized. The principle is used in the self pulsing circuit by having a secondary winding on the oscillator transformer (shown at the top left among the various windings of the oscillator), feeding its rectified output through the resistors OVDR1 and 2 to maintain a current through these resistors proportional to oscillator secondary voltage.

If more load is placed on the secondaries, more current will flow through the resistors and the supply voltage to this oscillator will be decreased. This will decrease the voltage to the secondary supplying the constant current through its rectifier ERT3 and bring the current through OVDR1 and 2 back to normal.

The starting circuit consists of two sections utilising the resistor OR54, capacitor OC16, shockley diode ORD3 and resistor OR55 in conjunction with the transformer winding connected across emitter of OT2 and negative and another section connected across the secondary supplying VCR. This latter section consists of ER13, ER14, EC11 and ERD5.

On initially starting the oscillator by energizing wire 50, a transient current will flow through OR54 and upward through the capacitor OC16, then down to the negative side of the battery. This will ordinarily cause the potential to increase at lower plate of the capacitor OC16. At a voltage (shockley breakdown voltage), the shockley diode ORD3 starts conducting and the current flows from wire 38 to OR54, ORD3, OR55, transformer winding and negative.

The four windings in series are wound so that the voltages produced in them will all add together. In other words, this is like a single continuous winding with three taps. The current flowing upward through the winding across emitter of OT2 and battery negative, gives an induced emf. in all other windings with positive polarity on the lower end.

Positive polarity on the lower winding provides a small current flowing through the base to the emitter and through resistor OR3 back to the negative side of the lower winding. This turns transistor OT2 on fully. Meanwhile, the top winding has the reverse effect on transistor OT1 because it has applied a voltage across base emitter junction with positive voltage on the emitter "clamping" the transistor OT1 off so that no current can flow from its collector to its emitter. Current will flow from wire 38 through the transistor OT2 and transformer winding to wire 4 only as long as it continues to rise in the inductive circuit.

When it reaches a maximum value, the lower winding voltage will collapse and reverse the action on transistor OT2, clamping it off. This will result in a reversal of polarity on all the windings. Transistor OT1 will turn on, and current will flow upward from wire 38 through the collector of the transistor OT1 and its emitter to the transformer winding and back to the 4 wire. The action of each half cycle is the same in each half of the oscillator, with each of these halves alternating in function. Thus on the first half cycle and each succeeding odd half cycle, OT2 will conduct, and on the second half cycle and all succeeding even half cycles OT1 will conduct.

It is possible that when the system was shut off last time, the transformer might have been left saturated in such a direction that the current flow through the starting winding would be such as to try to further saturate. This could not be done. For this reason, the secondary feeding VCR during operation of the oscillator, charges capacitor EC11 on each positive half cycle through ERD5 and ER14, with some slight discharge occurring on each negative half cycle through ER13, but not enough to fully discharge EC11. When the oscillator is shut off, EC11 will discharge through ER13 and the secondaries feeding VCR in such a direction as to de-saturate it, so that the condition above, which would prevent proper starting , can not occur.

Rectifier ORD1 and capacitor OC2 permit the voltage developed by the inductive effect of the transformer windings between wire 38 and the emitter of transistor OT1 to be discharged without over-stressing transistor OT1 with voltage, when it is suddenly shut off. Thus capacitor OC2 is charged on each half cycle. To get it ready for the next charge, resistor OR1 is provided to discharge it. Rectifier ORD2 works in conjunction with OC2 in the same way on alternate half cycles.

The combination of ORD19 and capacitor OC1 protects the transistors in the oscillator circuit from voltage surges resulting from discharge of other inductive apparatus on the locomotive. These devices have nothing to do with the operation of the oscillator but simply provide protection for it.

5.4 ARMATURE CURRENT CONTROL REACTOR

The armature current control reactor is a measuring device which when powered by an a.c. source produces a signal proportional to main generator current. A reactor offers the advantage of isolating the output circuit from the main or high voltage input circuit. The a.c. input is fed to the a.c. winding from a secondary of the oscillator.

The reactor consists of a large busbar, two cores, two a.c. windings single turn d.c. winding and a 1740 turn d.c. winding. The large busbar is made to encompass the d.c. and a.c. windings. Fig. 5 shows a cross sectional view of the reactor.

The one turn d.c. winding is copper wire connected to the large busbar, and forming a parallel path for current in the busbar. The cores, with the a.c. and d.c. windings, are assembled around the one turn d.c. winding. The reactor is calibrated and the complete magnetic structure is sealed in epoxy.

The ACCR is connected in series with the main generator. The majority of the main generator current passes through the busbar with only a small fraction of the generator current passing through the single turn d.c. winding. Since the current in the single turn winding is directly proportional to the main generator current, it may be measured by the reactor to obtain a signal proportional to main generator current.

The more d.c. input in the one turn winding, the more a.c. output. If current is also passed through the 1740 turn winding, the a.c. output will increase. Further discussion of the use of 1740 turn winding is contained under the heading "Function Generator". The a.c. output of the reactor is rectified and fed to the mixer circuit.

5.5 VOLTAGE CONTROL REACTOR (VCR)

The voltage control reactor is a measuring reactor which provides a signal to the mixer circuit to limit main generator voltage. This reactor, part of the voltage control reactor card in the excitation panel, is a device about the size of a large pocket watch and enclosed in epoxy. The reactor consists of two toroidal cores around which an a.c. winding and two d.c. windings are wound.

The operation of the reactor is similar to the operation of ACCR, ie. more d.c. input the more a.c. output. One d.c. winding is connected through suitable resistors across the main generator and measures main generator voltage. Here again, a reactor is used so that the output circuit is isolated from high voltage input circuit. The circuit is adjusted so that the a.c. output of VCR will be greater than the a.c. output of ACCR when main generator voltage and current reach the upper corner point of the horse power curve.

The second d.c. winding is used on locomotives with dynamic braking. This winding is connected across the braking grids so as to measure traction motor voltage during braking. It operates to increase a.c. output in VCR the same as the other d.c. winding which measures main generator voltage.

5.6 PULSE WIDTH MODULATOR (PWM)

The pulse width modulator (PWM), mounted in the excitation panel, is a small self-saturating reactor with five d.c. control windings and two a.c. windings fed by one of the oscillator transformer secondaries. The function of the pulse width modulator is to control the time that the exciter generator shunt field is excited thus controlling the main generator output. This reactor is used in the excitation system to control rather than to measure.

The pulse width modulator contains two cores. There is an a.c. winding on each core; the five d.c. windings are wound about both cores. Refer to Fig.6 for simplified circuit.

The output of each a.c winding is rectified and half of the input cycle is used from each coil. Since the oscillator frequency is 400 Hz, there will be 800 times ON pulses per second fed to the base emitter circuit of transistor EFT1. This causes the transistor to be fully turned on.

Referring to Fig.6 during the positive half cycle of the oscillator voltage at OST current will flow from point A through ERD13, the top PWM winding, EFT1 and resistor ER5. During the negative half cycle, current will flow from point A1 through ERD14, the bottom PWM winding and back to OST via the same path as the positive half cycle; this makes both halves of the cycle appear as positive pulses between B and C of Fig.6.

This action of the d.c. windings is such that when current flows through them, they block the a.c. output for a period of time during each half cycle and thus reduce the duration of the turn-on pulse being fed to the transistor. Therefore, the more current flow in the d.c. windings, the shorter the pulse and, in turn the less average excitation for the main generator (Fig.7). Each of the various d.c. windings are wound with a polarity such that the current flowing through the winding to the dot shown at one end of the winding will be additive to currents flowing similarly in any of the other windings. The effect of current flowing through the winding to the dot is to turn off the pulse width modulator by making it saturate later in the half cycle thus producing a shorter transistor turn on pulse.

This principle of changing the pulse width or duration, which controls the turn-on time of the exciter field transistor EFT1, is shown in Fig.7.

The function of each d.c. winding is as follows:

1. Exciter suicide and stabilization winding reduces exciter voltage to nearly zero when GF contactor is open and also provides exciter stabilization when GF contactor is closed.

2. Main excitation control winding fed by mixer circuit turns excitation off to maintain proper load.

3. Wheel slip power reduction winding reduces excitation during the operation of wheel slip system.

4. Dynamic braking stabilization restrains changes in excitation to avoid roughness when going from one braking level to another.

5. Dynamic braking anti-negative control prevents the excitation system from producing excessive negative generator voltage when suddenly reducing braking effort called for by the engine man.

The oscillator secondary winding produces 400 Hz square wave as shown in curve A. The voltage across the PWM a.c. winding is as shown in curve B. Because of diodes ERD13 and 14, the positive oscillator output is across one winding and with the negative output across the other, producing 800 pulses per second. The line with the small arrow shows how a change in current flow in the d.c. control windings changes the pulse width by causing the PWM to saturate early or late in each half cycle.

After the PWM saturates, its impedance falls almost to zero and most of the oscillator output voltage then appears across the transistor and ER5 (curve C). This causes the transistor to conduct as shown in curve D. Curve D also shows the change in average current flow through EFT1 and thus the exciter field, controlling the main generator.

6. CIRCUIT ANALYSIS

6.1 EXCITER GENERATOR CIRCUITS

The exciter field circuit (Fig.8) is fed from the locomotive battery through a network of resistors EFR1, EFR2, EFR3, EFR4 and the transistor EFT1.

The power transistor EFT1 is turned on and off 800 times in one second by a control network as previously explained. With the transistor conducting, the negetive end of the exciter field on the 61G wire is practically at negetive battery potential and the positive end on wire 61F is approximately 30V above battery negetive, being fed from the voltage divider consisting of EFR3 and EFR4. With the transistor EFT1 switched off, no current passes through the transistor and wire 61G operates at a potential somewhat above that of 61F permitting reverse current to flow in the exciter field from 61G to 61F. This helps to more rapidly reduce exciter voltage when necessary and permits a negetive exciter voltage to be available to provide reverse generator excitation to overcome residual voltage of the generator, preventing a surge of current when entering dynamic braking or when taking notch one. This rectifier ERT4 permits current in the exciter field to find a closed path during periods when the transistor EFT1 is not conducting. If ERT4 were not provided, a high voltage would be developed by the inductive effect of the exciter field, which would break down the transistor EFT1.

6.2 SUICIDE AND STABILIZING

With the throttle in the idle position, the generator field contactor GF is dropped out and the exciter is connected to a suicide circuit through the PWM winding connected from 4 to 61EE, the normally closed GF interlock 61EE - 61E and the ER15 resistor 61E - 61A. This direct current in the PWM winding effects the current in its ac winding in such a way that it causes the transistor EFT1 to shut off and cut off current in the exciter field (PWM ac winding in OST circuit supplies base current to EFT1). Because an excess of current in PWM winding, 4 - 61EE, could cause reverse saturation of the core and in turn uncontrolled level of excitation, such excess is prevented by the combination of diodes ERD20, 21, 22 and 23 across the PWM dc winding. This action depends on the facts that each of these diodes maintains approximately 0.7 volts across it at maximum in forward direction. Thus the current can come up to a value corresponding to 1.4 volts across the winding and go no higher because excess current bleeds through the appropriate pair of the diodes. The EC2 and EC1 capacitors are used to stabilise the exciter output during motoring operation, with EC1 capacitor switched out of the circuit above notch 3. The prime reason for this is to get higher stabilizing effect in lower notches and a lower degree of stabilization in higher notches for quick change in generator voltage (quick response for wheel slip etc).

6.3 MIXER REFERENCE

6.3.1 MIXER NETWORK

The mixer network, Fig. 9, is where the signals from ACCR and VCR are compared against each other and the reference signal. Two outputs are in such a way that only whichever is larger actually supplies the circuit and as if the other one has no effect in the external circuit. Current goes out from the mixer circuit is the amount equal to the largest of these three. The adjustments are so made that at point F, VCR output exceeds that of ACCR and the line FG on the generator characteristic (Fig.10) is determined.

6.3.2 ENGINE SPEED REFERENCE

The tachometer generator on the diesel engine generates alternating voltage, with the frequency proportional to the engine RPM. This is fed into a saturable core transformer (ESST) whose secondary voltage is proportional to the frequency with minimum error either due to temperature or variations in flux of the core (due to change in voltage).

One function of the tachometer generator is to control the generator characteristic on the basis of engine speed such that characteristic shrinks as lower speeds are set. This provides a smooth change in level of power, when throttle handle is moved. To do this, a reference voltage is used which is fed by a three phase secondary on the saturating transformer (ESST), being rectified by a full wave rectifier (ECR3). Fig. 9. The voltage is fed to wire 22FF through the resistor ER7, adjusting rheostat MLR to the 32D wire of mixer circuit. Approximately 38 to 84 appears between wires 22FF and 4 in idle to 8th. notch.

6.3.3 CIRCUIT OPERATION

The net reference current flowing in the mixer network is determined by the difference between 84 volts of the engine speed reference and the 24.4 volts of the battery bias, or approximately 50 volts. This current will flow from the 22FF wire of the speed reference circuit through resistor ER7, the adjusting rheostat MLR to the 32D wire, mixer rectifiers ERT2 and ERT1, the load control potentiometer LCP, and back to the 4 wire of ECRT3. Rheostat MLR is used to calibrate the system by adjusting 8th notch generator characteristic.

Until the current in ACCR output or VCR output equals the reference current flowing from ECRT3 through MLR, no external effect from ACCR or VCR will exist. When the output current of either ACCR or VCR exceeds the reference current, the external circuit through the PWM winding, ER36, rectifier ERD10 and resistor ER8 to the 32D wire comes into action. In this event, only the excess current over the reference current will flow in PWM main turn off winding (IPWM = IACCR or IVCR or Iref - Iref).

Current flowing through the PWM winding to the dot is in the direction of reducing excitation, so that the generator characteristic, Fig.10, will be followed, being controlled by the action of ACCR only for the section BC, and VCR for the section FG. The out put of ACCR is modified by the signal from the function generator to obtain the slopes of the characteristic represented by segments CD, DE and EF.

7. ENGINE LOAD CONTROL

The governor load control potentiometer (LCP) is connected in to the network of resistor LCR1 and LCR2 so that with the LCP in inactive zone, the brush arm is at 24.4

volts above 4 wire potential, with the engine running and auxiliary generator at 75 volts. If the governor goes in to load control, more than 24.4 volts appear at the LCP brush arm and the current flowing in the mixer circuit will be less and excitation is reduced to restore the proper load on the diesel engine.

In Woodward governor, LCP comes into action when fuel need is more than that of fuel schedule, but it works with similar principle.

8. FUNCTION GENERATOR

The generator characteristic (Fig.10) consists of several elements. In Indian Railways applications, the constant horsepower portion of the characteristic involves three slopes. Refer to Fig.10. The IR line is simply a plot of the current the motors will take at various voltages when the motors are not yet turning, as in the beginning to start the train. The current limit portion BC represents the maximum current that can be delivered to the traction motors with system properly adjusted. The slope sections CD-DE-EF together approximate a constant horsepower curve. The maximum voltage section FG provides a limit on maximum generator voltage.

With only output of ACCR resulting from its measuring main generator current, the current limit line BC would continue upwards as a straight line. The is the purpose of the function generator circuit to obtain a portion CDEF.

A voltage divider consisting of resistors and rheostats ER1, ER1A, ER2, ER3, EP20, EP21,ER49, EP22 and ER50 is connected across the main generator between wire 34 and 36, Fig.11. Only a small portion of total generator voltage is impressed on the function generator circuit from the brush arm of potentiometer EP22. This feeds through the rectifier ERD16 and ERD17 through rheostat ER30 to the dc winding (1740 turn) on ACCR and then down through the zener diode EZD3 to wire 36. Until sufficient voltage appears at the brush arm of EP22 to equal or exceed the zener breakdown voltage of EZD3, no current will flow in the ACCR winding 34D - 34C. This is the condition which exists as the voltage rises from point B to point C on the generator characteristic. At point C, the breakdown voltage is reached and current begins to flow in ACCR 34D - 34C. This changes the slope of the generator characteristic to that of line CD, with more and more voltage applied to the circuit as the voltage rises to the level of point D. At the same time generator current is falling very rapidly from level of point C to that of point D.

It will be apparent that to have more generator voltage, the excitation must be allowed to increase, and to do this the exciter field must be turned on for a longer time during each half cycle than before. The total output of ACCR will decrease as we rise along the lines BC and CD. It would be noted that along line BC, ACCR output was governed entirely by generator current because no current was flowing through 1740 turn winding. To accomplish this increase in voltage form B to C, it will be noted that slight decrease in generator current occurs between B and C, allowing excitation to rise. When point D is reached on the generator characteristic, the generator voltage is such that the brush arm of potentiometer EP21 reaches a voltage level equal to the breakdown voltage of zener diode EZD12 and EZD11. This then bleeds current from the supply for ACCR 1740 turn winding as higher voltages are attained. This accounts for the change in slope of the line DE compared to that of CD. So much of current is not put in 1740 turn winding as before for a given rise in generator voltage and slope changes to look more like that of current limit line BC, where no current was flowing in 1740 turn winding of ACCR.

When point E is reached on the generator characteristic, the generator voltage is such that the brush arm of potentiometer EP20 reaches a voltage level equal to the breakdown voltage of zener diodes EZD10, EZD9 and EZD8. This bleeds still more current from the ACCR winding and increases the slope even more.

At point F, the voltage level is such that no further increase in generator voltage is desired and at this level the voltage control reactor (VCR) 34F - 36 comes into active operation. It is connected between wires 34 and 36 through various resistors and rheostats to measure generator voltage in the same manner as ACCR measures generator current. To measure voltage it must have many turns but in principle of operation it is similar to ACCR.

9. CORNER POINT SUPPRESSION

It can be seen that with no more control than has been described so far, in lower notches a value of voltage equal to that point C (Fig.10) would have to be reached before the slope curve CD could begin, but this would tend to crowed the higher notch power curves closed together. The suppression circuit operates to fool the function generator circuit into starting action at a lower voltage in the lower notches so as to separate the notch curves better. This is done by another secondary of the three phase transformer, ESST, (Fig.11) and associated rectifier ERT5. This circuit provides a voltage proportional to engine speed with positive on 34S wire and negetive on 34T through the network of resistors and potentiometers ER33, ER34, ER41, ER42, ER43, EP2 and zener diode EZD5.

There are three voltages to be considered in the corner point suppression circuit. The ESST secondary voltage is proportional to engine speed and can be measured from A to B as shown in Fig.12. A second voltage can be measured from B to D and a third voltage from C to D. All these three voltages will increase as engine speed is increased above idle. However, it is desired to have current start to flow in the ACCR 1740 turn dc winding (34D - 34C) at a lower generator voltage at low engine speeds than at higher speeds. This is accomplished in the following manner.

Because of zener diode EZD5, there is no current flow from A-C-D until 11 volts appear across it. Therefore, the voltage from C to D is zero until the voltage at 34S reaches 11 volts. This happens just before the engine reaches idle speed.

At this time, the voltage from B to D is great enough to breakdown zener diode EZD3. Current can then flow in the ACCR 1740 turn dc winding.

The amount of current flow is determined by the difference of the two voltage sources B to D and C to D i.e. the potential difference between B and C, added to the voltage from EP22 brush arm to wire 36. As engine speed increases, this voltage difference becomes less and a higher EP22 brush arm (36 wire) voltage is needed to make EZD3 conduct. In this way, point C on the generator characteristic curve is at a higher voltage in each higher notch. See Fig.12 for a plot of the three voltages versus engine speed.

Between 7th. and 8th. notch, the voltage B to C reaches zero and thus in the 8th. notch the voltage from EP22 to the 36 wire without the addition of this voltage controls the point at which slope CD of the generator characteristic curve of Fig.10 starts.

10. SUMMARY

Electronic Excitation System, commonly known as E-type Excitation System is the most popular system for its maintainability and reliability. The system comprises of an Excitation Control Panel (EXCP) consisting of seven plug-in-type cards, Armature Current Control Reactor (ACCR) and a resistor network (EFR1, EFR2, EFR3 & EFR4) available in Field Control Panel (FCP). The system gets engine speed signal from Tacho-generator through Engine Speed Sensing Transformer (ESST) and rectifiers installed in Engine Control Panel (ECP), which is biased by a resistor network (LCR1, LCP & LCR2), to have wider variation of power with notch variation.

The excitation control is through the control over average current flowing in Exciter field. The exciter field is supplied from Battery/Aux. Gen. through Exciter Field Transistor (EFT), working in switching mode. The system provides Pulse Width Modulated (PWM) base drive to the EFT in order to ensure constant power output of the diesel engine at given notch, as far as possible.

11. SELF ASSESMENT

1. Describe the E-type Excitation Control briefly with the help of Block diagram.
2. Write short niotes on:
   ACCR, VCR & PWM.
3. Describe the Function Generator circuit with necessary sketches/diagrams.
4. What do you mean Corner Point Suppression? Explain the utility of Corner Point Suppression with necessary sketches and diagrams.