Electrics of Diesel locomotive

Introduction

Most of the Diesel Electric Locomotives serving in Indian Railways are single engined with one DC self ventilated, separately excited, single bearing main generator. However, in order to improve the reliability and reduce maintenance DC generator is replaced by a Traction Alternator and rectifier in latter generation locomotives.

This supplies power to six nose suspended, force ventilated, series wound DC motors connected in three series pairs.

Of late, Indian Railways have introduced GM locomotives with state of the art AC-AC locomotives. These locomotives have AC Traction Generator and AC Traction Motors.

Power for electrically driven auxiliaries and control circuits is obtained from a self-excited, self ventilated auxiliary generator mounted on the end of main generator. This also supplies the battery charging current. Output of auxiliary generator is maintained constant at different speed by a voltage regulator. It also takes care about the limit of current going out to avoid damage to the generator. 8 lead acid batteries in series with four cells per battery, being provided for starting the engine by motoring the main generator, and to supply all the control circuits and the locomotive lighting.

The locomotive is provided with electrical end jumper cables to enable it to work in multiple with a number of other locomotives.

Power Circuits

The main generator is basically separately excited with or without a differential series field to give the required characteristic form (Fig.E 2.1).

Each traction motor has separate reversing switch contacts for reversing the field current, and also field diverting arrangements (Fig.E-2.2).

Wheel slip sensing arrangement is provided between all three motor pairs using three relays, WSR1, WSR2 and WSR3 (Fig. E-2.3).

Ground fault sensing arrangement is provided in the generator circuit using a relay GR, to avoid damage to the electrical machines and circuits (Fig. E-2.4).

Starting Circuit

For starting the engine, the generator is motored by the battery by closing two cranking contactors, CK1 & CK2 (Fig. E-2.5)

Field weakening and Transition

As has already been mentioned the series type dc motors are used as transaction motors. This type of motor draws a high current at low speed and a low current at high speed. If its load is heavy, it runs at low speed: if light, it runs at high speed.

Generator delivers power as show in Fig. E–2.6. When the load resistance is low the amperes are high and when resistance is high the amperes are low.

To active minimum fuel efficiency, the engine should be loaded in such a way so that it gives constant horse power for a particular speed setting, and accordingly the fuel for each throttle setting is scheduled.

So to get most of the engine, one should stay on the constant horsepower curve. As the traction motors are the load and current changes with change in speed of the motor, the voltage also changes accordingly being the power constant.

When the train accelerates, ie. The motor speed increases, the voltage output of main generator goes on increasing and at a particular train speed, generator voltage reaches its limit and horse power is reduced by the excitation system. With this situation more train speed cannot be achieved.

To get higher train speed, either the motor fields are weakened or the motors are re-arranged in the circuit. This increases traction motor current. With higher current now the motor speed starts increasing.

Normally the motor field is made weak connecting resister in parallel to the field and rearrangement is done by changing the motors from, series-parallel to parallel grouping.

The change in motor circuit is done by an automatic regulator on getting signal about locomotive speed.

EXCITATION CONTROL

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.

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.

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.

Where does 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.

Excitation systems

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.

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.

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.

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. 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).

DYNAMIC BRAKING

The installation of dynamic braking on diesel electric locomotives has become quite common. By taking advantage of the traction motors ability to act as a generator, the diesel electric locomotive offers a form of braking power which, without the use of air, can be used as a speed controlling brake on grades or a slowing brake on level track. Use of dynamic brake lessens brake shoe and wheel wear on both locomotive and train. On long down grades dynamic brake operation enables a train to be handled with fewer air applications. This results in safer train operation, due to the locomotive and car wheels running cooler. In Fig.1 the action of wheels with dynamic braking is shown. The momentum of the train turns the wheels. This drives traction motor as generator and forces current through the braking resistors as shown by the arrows and the resistors heat up. The traction motor, working as a generator, resists the turning of the wheels and tends to stop it, so the motor is used to do the same thing as the brake shoes. In this case the braking resistor and motor instead of the brake shoes and wheel get hot. Hence, the blowers must cool them. The wheels and brake shoes do not wear because there is no rubbing. To have dynamic braking the wheels must be turning. This is because generator generates only when it is turning. So the dynamic braking cannot be used to hold or stop train. For this purpose air brakes are to be used.

In Fig.2, how dynamic braking works on a four motor locomotive is shown. The momentum of the train pushes the locomotive and turns the wheels, which drives the motors. The output of the motors is fed into the braking resistors. The driver controls the braking by moving the selector handle. A load-meter shows him how much braking current he is getting.

Motors as generators

We know that DC machine can be used as either a motor or a generator. Fig.3 (a) shows the motoring connections. Current is being pumped through the motor armature and field by the generator. This causes the motors to turn and move the locomotive. In Fig.3 (b) switches have been shown to change the motor connections. Now the generator pumps current through the motor fields only. Two things have happened to the armature-

1. It was cut off from the generator,
2. It was connected across the braking resistor.

Now we have separated the motor field from its armature and are pumping current through the field only. If the locomotive is moving, the wheels are turning and driving the armature. It is connected across a resistor so that it has load. In electrical language we have a separately excited generator with a load resistance.

In Fig.3 (b) we see that the field current is flowing in the same direction as in 3(a). But the armature current is reversed in (b). If wee reverse the field current 39(c), the armature current will flow in the same direction as in motoring (a) i.e. if we change from motoring to braking if the field current stays the same, the braking current will reverse. If the field current is reversed, the braking current will stay the same. There are some points about the Fig.3 circuit to be known for understanding dynamic braking: -

The more current we put through the motor field, (within certain limits) the more braking current we will get.

The lower the braking resistance, the higher the braking current (this resistance is fixed when the locomotive is built).

3. The faster the armature turns, the higher is the braking current.
4. The higher the braking current, the more braking we get.

CONTACTORS & RELAYS

On diesel Electric locomotives remote control switches are used to close or open the circuits. These are contactors and relays.

Normally contactors are used in circuits, where more than 10 A current is likely to flow. Relays handle lesser current.

1. To close a circuit, we must have (a) a force to butt the leads together; (b) at least one movable contact to bring it closer to other; (c) a bare contact surface.
2. To carry current, the contacts must be held together.
3. To open a circuit, we must have (a) an opening force; (b) a way to put the arc out.

A contactor does all these things. Contactors used on Diesel Electric Locomotives are of two types; air operated and magnetically operated.

1. Air Operated Contactor

In the main traction circuits that carry heavy currents, contactors operated by air pressure are used. This contactor has a spring-loaded piston in a cylinder. The spring brings the piston back against stop. The other end of the piston rod is connected to a lever, which moves one of the contact tips.

There is a supply of low-pressure air in the locomotive, called “control air”. Air entering the cylinder builds up pressure and pushes the piston away from the contactor base. This is the force that closes the contact tips.

An electrically operated magnet valve is used to control the flow of air to the cylinder.

2. Magnetically Operated Contactor

Magnetic contactors are operated directly by electricity. When current flow through its operating coil, core becomes a magnet and pulls armature towards it. This force closes the contact tips and completes the circuit. When the current flow to the coil is stopped, the core ceases to be a magnet. A spring, known as armature spring pulls it back against the stop. This force opens the contact tips.

3. Flexible Shunts

To built the contacts together, at least one lead must be flexible. All contactors have a flexible load, called a shunt. It is made up of very fine copper wire and lasts for several hundred thousand operations of the contactor.

4. Contact Tips

The exposed surfaces which actually make contact and complete the circuit are called contact tips. Contacts are designed to carry current on the heel, and interrupt on the toe to avoid damage at the contact surface due to arc formed during break of contact.

Contact tips are so arranged that when a contactor closes, the tips touch each other prior to the final movement of the armature. This means though the tips have touched already, the armature still keeps moving. It gives “proper pressure between contacts”, “wear allowance” and “wiping action”.

5. Putting the Arc out

When a contactor opens a circuit carrying current, an arc is drawn between the contact tips. In the contactor, a coil is provided called “blow out coil”. It carries same current which i carried by the contactor, and creates a magnetic field which blows the arc out in upward direction to prevent damage of the contact tips.

6. Interlocks

Interlocks in a contactor are used for getting sequence wise operations and interlocking in circuits. Some interlocks are “normally open” type i.e. the interlock circuits are open when the contactor is not operated. Interlocks may also be of “normally close” type i.e. the interlock circuit is closed if the contactor is not operated. After operation of the contactor, the normally open interlock circuits get closed and normally closed interlock circuits get opened.

7. Relays

A relay looks like a contactor used to relay a signal. Relays are normally having three to four sets of contacts. Operation of a relay can be understood if interlock operation is known. Different circuits are energized sequence wise with the help of relays. Relay contacts are also provided with flexible shunts and wear allowance facilities.