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THREE FIELD EXCITATION

The 3-field system is an external excitation system used for exciting the field of the Traction Generator of a diesel electric locomotive. The Traction Generator usually has three fields but this is not the reason for the system being called a 3-field system. As can be seen from Figure 1 the traction generator has a starting field that comes into play only at the time of starting of the engine. This field is in series with the generator armature so that the machine works as a series wound motor getting its supply from the loco batteries. The commutating field is also in series with the armature and is essential for getting good commutation which is always a problem with large D.C. machines. The shunt field of the TG is excited by the Exciter and controls the generator output depending on the level of excitation that is provided. It is only this shunt field that plays a role in excitation control.

In the 3-field system, the exciter also has three fields and it is for this reason that it is called the 3-field system. The fields of the exciter are controlled in this system which cause the exciter output and hence the generator field excitation to be controlled leading to control of the output of the generator. In some other systems also, the field of the exciter is controlled to get the same effect but the control is by other means. In the static excitation system, however, the generator field is directly controlled by controlling the output of the exciter.

A simplified diagram of the system is given in Figure 2. Note that the system has three fields of the exciter, namely, the shunt field, differential field and the battery field.

Shunt field

The shunt or self field is connected in parallel with the exciter armature with a series of limiting resistances also in the circuit. This field is dominant in the high voltage part of the output of the generator. This is the portion DF of Fig. 3. This figure gives the output of the generator in electrical terms.

Differential field

The differential field is connected in parallel with the generator commutating field. Some variable resistors are also normally in the circuit. This field is so arranged that it is in opposition to the other two fields. The differential field dominates at the time that the locomotive is starting, i.e. the portion AB in Figure 3.

Battery Field

The battery or separately excited field is supplied from the locomotive batteries through suitable control circuits. When the engine runs under its own power, the supply is from the locomotive Auxiliary Generator. This field controls the general level of excitation at each notch. Notching circuit is in the battery field circuit and field excitation is controlled according to the running notch. Normally, the battery field remains at constant excitation at a particular notch. The Load Control Potentiometer (LCP) is also in the battery field circuit and regulates excitation when necessary to prevent overloading of the engine. The LCP is usually located in the engine governor but can also be a separate unit.

How the system works

Assume that the engine has been started and is idling. Also assume that all power and control circuits are connected for the forward movement of the locomotive. At this point, with the engine idling, both the TG and the exciter are rotating but neither is generating any voltage. To enable them to build voltage, the operator must move the throttle handle to the first notch. The moment this happens, the exciter battery field contactor is closed and the batteries start supplying current to the battery field. With the exciter battery field excited, the exciter builds up voltage. At this point the exciter starts supplying current to its self-field which is connected across it. Thus, exciter voltage builds up. The amount of current supplied for excitation at each notch depends on the resistance in the excitation resistance panel. The arrangement is such that the resistance of the panel decreases as the notch increases. Thus, with increased notch, exciter output is increased thereby increasing the generator output.

As the exciter builds up voltage, the generator field is getting excited. The TG thus builds up voltage. The amount of voltage will depend on the engine speed and the amount of excitation current in the exciter battery field.

As the generator builds up voltage, current starts flowing to the traction motors. Since the traction motors are series wound motors, current demand is very high at starting time. However, the amount of current the generator should supply at each notch has to be limited to give better operating conditions by preventing wheel slip, controlling draw bar and allowing smooth transition from rest to start. This is achieved through the exciter differential field. This field is connected across the generator commutator field and as the generator current flows to the traction motors, a part of it flows through the differential field also. The differential field is so arranged that it opposes the battery and self fields. As load current, i.e. the current flowing through the traction motors increases, the current flowing through the differential field also increases and a stage is reached when the effect of this field exactly balances the effect of the other two fields. At this instant exciter field just balances and the maximum load current for each notch is thus fixed.

We have seen from the above discussion that for each notch the generator voltage is limited by excitation resistors and the current by the differential field. The parts AB and DF of the curve in Fig. 3 are fixed. However, overloading of the engine takes place in the part BD of the curve and some control is necessary for this part so that the generator demand matches the constant power output of the engine. This is achieved by the LCP in the battery circuit. Any overloading will slow down the engine. This will be sensed by the engine governor which in turn will operate the LCP to add resistances to the battery circuit to lower the level of excitation. Thus the excitation of the TG is reduced and the electrical load taken off. The generator demand follows the curve BCF and not BF. The working of the LCP is explained in more detail in the Note of Governors. It is also explained in the Governor Note, how the movement of the throttle handle causes speed solenoids to be energised which in turn permits the engine speed increased by increasing the fuel supply. Also, as the throttle is advanced, the resistance in the battery field is reduced, leading to increased excitation and consequent higher output from the TG. Load current is limited by the differential field and constant power output is achieved by the action of the LCP as explained above.

We thus see that the effect of the three windings of the exciter is to give a generator output that follows the constant power output of the diesel engine and at the same time limits the current and the voltage. Through control of the battery field through the LCP, excitation can be appropriately controlled at the time of wheel slip, transition change, etc also.

SPLIT POLE SYSTEM

This system for excitation is a good example of an internal system. However, its principle of working is very similar to the 3-field system.

A diagrammatic representation of the system is given in Figure 4. Note that the shunt field of the TG is separately excited by the split pole exciter. Output of the exciter controls the output of the TG.

The split pole

The exciter is a special DC generator driven by the diesel engine. Its speed is thus proportional to the engine speed. The characteristic of this system is that the exciter field poles are made up of two sections, namely, a differential section and a shunt section. Hence the name split pole.

The differential field

The differential field is wound round the differential section of each pole. It is connected in series with the TG and, therefore, carries full generator load current. In the three field system, on the other hand, the differential field is carrying only part of the generator load current. But as in the three field system, the name differential field describes the field, i.e. it opposes the effect of the shunt field. The shunt field winding is wound around both the differential and shunt field sections of each pole piece. The shunt field serves the purpose of both the shunt and the battery fields of the three field system.

System working

The principle of working is almost exactly that of the three-field system. When starting a heavy train from standstill, the resistance in the TG power circuit is very low. Therefore, current will be very high in the TG circuit. The exciter differential field, however, will also be very high as it is connected in series with the TG output. As the differential field subtracts the shunt field, the exciter armature voltage will be low and hence the TG voltage is also kept low.

As the locomotive accelerates, the TG load current decreases because back emf increases from the traction motors. When load current decreases in the TG, current also decreases in the differential field of the exciter thus increasing the exciter output. Therefore, current in the TG shunt field increases leading to increase in the output. This allows the output characteristic of the TG following the constant horsepower curve.

As in the three field system, the Governor LCP comes into play if the engine is overloaded for any reason. The only difference is that instead of acting through the battery field, the LCP here acts through the shunt field only.

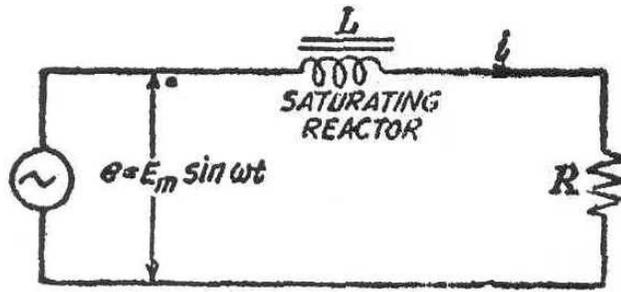


Fig. - 1 Circuit diagram

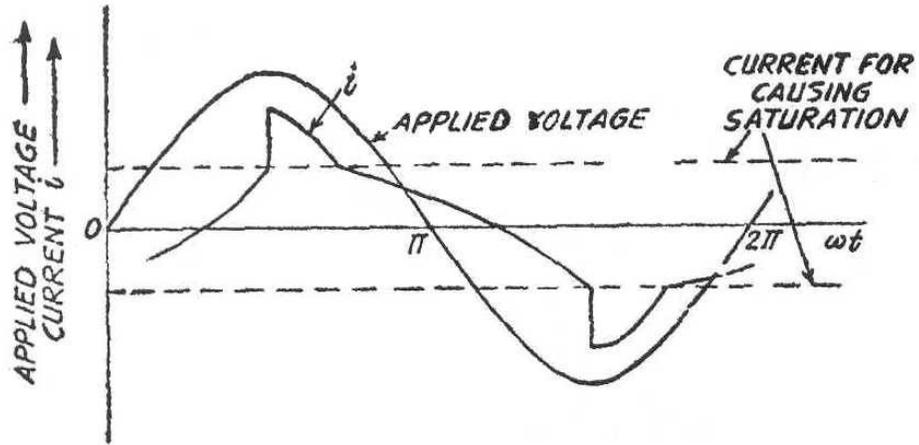


Fig. - 2

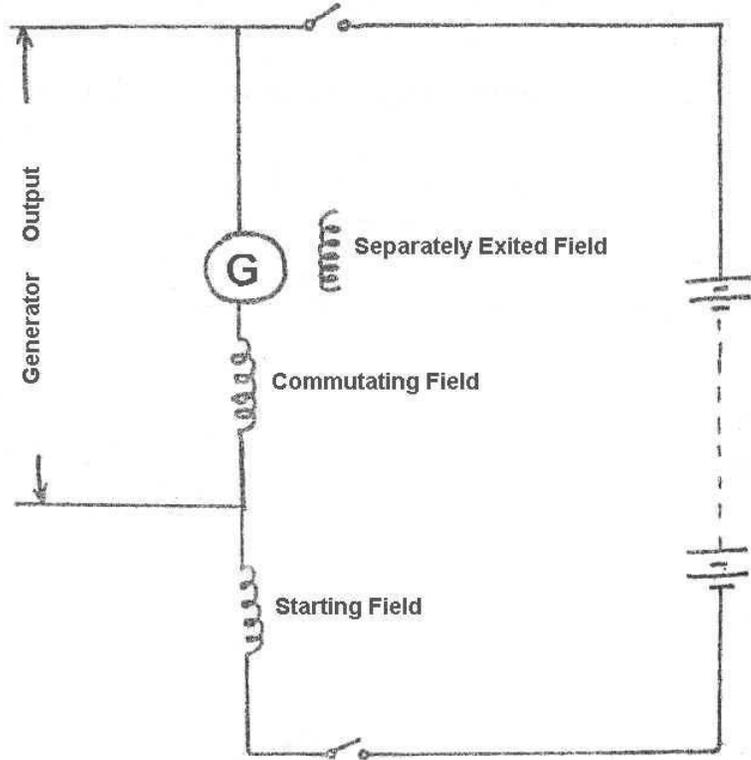
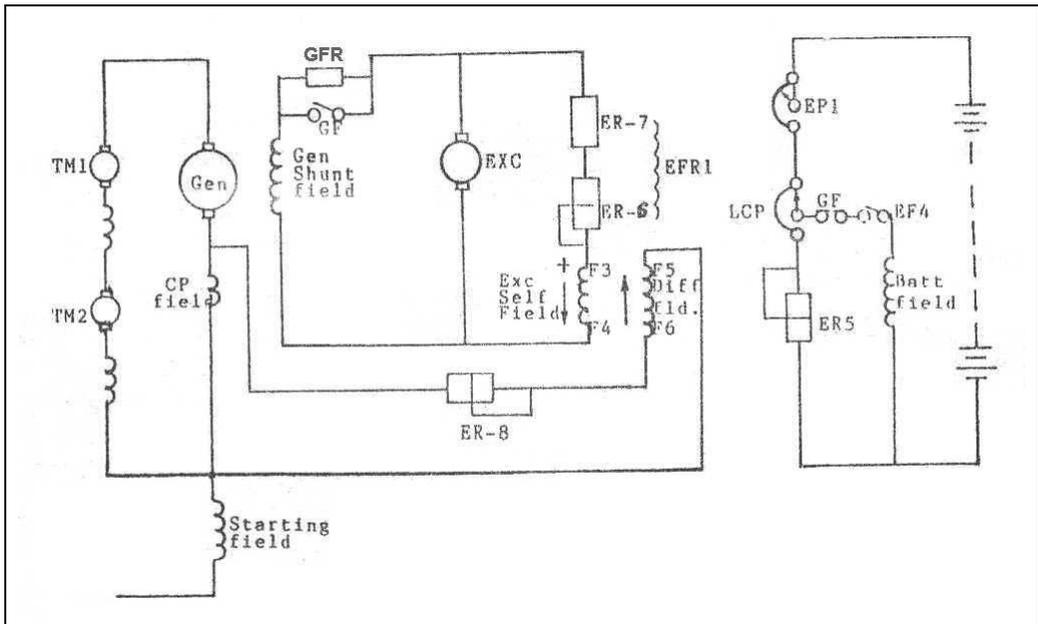
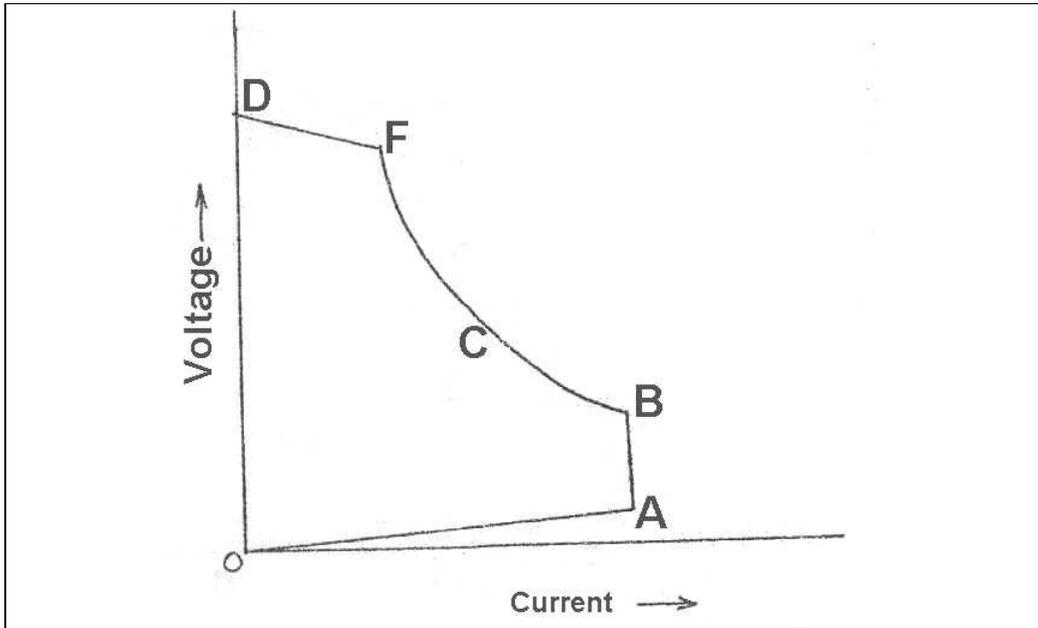


Fig. 1



SIMPLIFIED 3-FIELD EXCITATION SYSTEM

Fig. 2



Characteristics of Traction Generator

Fig. 3

