# UNIT 4 TRANSITION

## OBJECTIVES

- After going through this unit, you should be able to:
- Appreciate the need for transition in Diesel Electric Locomotives
- Understand field weakening process
- Understand Transition
- Understand Wheel Speed Based transition and its regulation system
- Appreciate Voltage-Ampere Based transition
- Understand and identify the components involved in transition regulation

## STRUCTURE

1. Introduction:
   1.1. Role of Traction motor
   1.2. Traction Generator
   1.3. Diesel Engine
2. Process of field weakening and paralleling:
   2.1 Forward Transition
   2.2 Backward Transition
3. Automatic transition regulation
4. Wheel speed based transition
   4.1. System components
   4.2. System operation
5. Generator Volts and Ampere based transition
6. Summary
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# 1. INTRODUCTION

The purpose of transition is to keep the diesel engine working on the full horse power part of the generator curve for the maximum possible period of locomotive operation- from its low speed to the maximum speed. In this we change the traction motor circuits, so that they draw value of current that falls on horsepower curve, as the locomotive speed changes. This change of motor circuits is called transition.

For better understanding of the transition let us review our knowledge of traction motor, traction generator and diesel engine characteristics.

## 1.1 TRACTION MOTORS:-

We use series type D.C. motors for traction purposes. 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. The way such a motor acts is shown in Fig.E4.1. While doing Foot-plating, this can be noticed on the load meter.

## 1.2 TRACTION GENERATOR: -

The traction generator is a d-c generator. It takes mechanical power from the diesel engine and converts it to electrical power for the traction motors. We have seen in the chapter on Excitation system how the generator is controlled so that it delivers power as shown Fig.E4.2. When the load resistance is low the amperes are high. When the load resistance is high the amperes are low. The generator characteristic can be obtained from the load test.

## 1.3 DIESEL ENGINE: -

The diesel engine converts the energy of burning fuel into mechanical power. With the throttle at 8th: notch and full fuel the engine will run at its rated speed and produce its rated horsepower. If we try to get more power it will stall. If we try to get less power, the racks will back 'off' (the engine will take less fuel). To get the most out engine we must stay on the full horse power part of the generator curve Fig.E4.2.

The purpose of transition is to obtain higher speed of the locomotive and still utilize the constant horsepower of the engine at a speed setting. The out put characteristic of the traction generator, as determined by the excitation system, is such that it holds the diesel engine at approximately constant horse power at a particular speed setting.

When the locomotive is starting, and at low locomotive speeds, the main generator supplies a high current to the traction motors. As the traction motor armatures begin turning, they generate a voltage commonly called back EMF. This back EMF, as if increases the effective resistance to the current flow. Therefore, as the locomotive speed increases, the generator voltage must increase to maintain the traction motor current. The traction motor current will decrease however because of the constant power characteristic of the generator (Fig.E4.1). With further increase in locomotive speed, if the back EMF reaches the voltage limit of generator, the generator current starts falling and the horsepower reduces (Fig.E4. 2).

However, by changing the generator motor connections, the back voltage is reduced and the generator can force more current to the motors to enable acceleration. To achieve higher starting torque, sometimes, two traction motors are connected in series during starting of the locomotive. In these locomotives, changing their connections from series to parallel can reduce the back emf. Weakening the motor fields can also reduce back emf. The change in the motor connections, or weakening of fields is known as an event of transition. The number of events is decided from the generator characteristic and the number of motors.

## 2. PROCESS OF FIELD WEAKENING AND PARALLELING

## 2.1 FORWARD TRANSITION

We want to keep the engine working on the constant horsepower part of the generator curve as much of the times as possible. To do this we use what is called transition. That is, as the locomotive speed changes, we change the traction motor circuits so that they will draw a value of current that falls on the horsepower curve. Let us see how transition is used to accelerate a train.

At the start the traction motors are connected to the generator as shown Fig.E4.3 (This connection is called 2S-3PFF i.e. two traction motors in series and three parallel paths with full field). This means the generator supplies current through three paths to run six traction motors. So it has to supply only three times the signal motor current in starting. Even though the current drawn by each motor is very high, by using such a circuit the generator is kept to a reasonable size.

In Fig.E4.3 we can see how the current drops off as the train moves out. This is shown by the arrows on the horsepower curve .At about 10 miles an hour we get on the full horse power portion of the curve. From this point it is necessary to stay on this part of the curve to get constant power from the engine. If we have a locomotive with 75 MPH gearing and 40 inch wheels, when we reach about 19.2 MPH (30.8 KMPH) point C in Fig.E4.3 is reached, the motor current will have dropped so much that continued acceleration would be at reduced horsepower along the field limit line.

To prevent this, the motor fields are shunted as shown in Fig.E4.4 (this is called 2S-3P WF, i.e. two motors in series three parallel paths with weak field). Part of the motor current then flows around the field) through the shunting contractors (FS21, FS22 etc.), and the shunting resistors. This causes motors to draw more current from the generator, because of fall in counter emf. With this, operating point moves back down toward the bottom of horsepower curve as show n in Fig. E4.4. On some locomotives field shunting is done in two or more steps. This is done to keep the motor current to safe value.

**MATHEMATICALLY**

$$N = \frac{V - I_a R_a}{K\emptyset}$$

By reducing K, speed N can be increased

Also $T = \emptyset \times I$

When voltage is reduced, torque remaining the same, I has to increase so we slide down from point 3 to point 2 in Fig.E4.4.

As the train continues to accelerate, the generator current, will again decrease as shown by the arrows in Fig. E4.4 (the generator current decreases as with the locomotive speed the back EMF of traction motors goes on increasing). At 30 M.P.H. (48 km/h), it will be back at the top of horsepower curve again. To prevent unloading, the motor current must be again increased by 2nd.transition. This time we do this differently. We change the motor connections from series parallel to parallel as shown in Fig.E4.5. Instead of three paths for the generator current there are now six. This causes generator current to increase. The operating point is now back at the bottom of the horsepower curve again as shown in Fig.E4.5 (We call this 6P-FF i.e. six traction motors in parallel with full field.).

In making second transition the shunting contractors (FS21, 22 etc) Fig.E4.4 are first opened. This unshunts the motor fields. Then the series contactors S1, S2, S3 in Fig.E4.4 are opened and finally the parallel contactors, P1, P22, P31, P2, P22 and P32 in Fig.E4.5 pick up. This may happen in different sequence on various locomotives, but the end result is the same. Since the generator is at high voltage when this sequence begins its voltage must be reduced before switching of motors can be safely accomplished. This is done by opening the generator field contactor- G.F.

This transition should take place at the right time. If it occurs too late, or at a too high a speed locomotive will loose power before transition. If it occurs too soon, there will be a loss of power after transition. In either case the operating point will not fall on the full horsepower curve.

As the train continues to accelerate, the generator current again drops off. By the time speed reaches 50.8 M.P.H. (81.7 kmph), the generator will again be operating at the top of the horsepower curve, point C in Fig.E4.5. Now we go for parallel field shunting (transition 3). As in series field shunting, part of the motor current bypasses the motor field through the shunting resistor. The increased generator current moves the operating point down the horsepower curve as shown in Fig.E4.6, permitting further acceleration at full horsepower.

## 2.2 BACKWARD TRANSITION

If the train hits sufficiently steep grade, it will begin to slow down. As the speed drops, motor current increase as shown in Fig.E4.7. Suppose the train is travelling at 49 m.p.h. when it hits the grade. This point P is shown near the top of the curve. As the train slows down, generator current increases. At a speed of ground 30 m.p.h. the locomotive will be operating at the bottom of the full horsepower curve, point B. Something must be done or the operating point will go below B on locomotives without current limits this could mean overheating the generator. With current limit the locomotive will operate at reduced power, which reduces engine efficiency. The current that the generator must supply can be reduced by making a backward transition. This will transfer the operating point back to the top of the horsepower curve point as shown. If the speed continues to drop unshunting is done.

There is one little difference in backward transition 3 to 2 from forward transition 2 to 3 on some locomotives, which at times is confusing. The generator field is left on in backward transition, but not in forward transition. There is a reason for it. If we look at the horsepower curve Fig.E4.8

we will see that backward transition takes place at point B where the generator current is high and the voltage is low. At this low voltage there is little chances of generator flashing ever when switching is done. Also during switching, this provides for the quickest rise to full voltage after the switching is completed so, we are still operating at full horsepower, but not at top of the horsepower curve.

From the above, we can understand that transition takes place back and forth as train speed and load change. Its purpose is to hold operating point on the generator horsepower curve. This keeps the engine delivering full horsepower at all times. Let us now see how transition is done.

## 3. AUTOMATIC TRANSITION

We have seen that transition is made at a definite train speed and also at a definite point on the generator horsepower curve. This makes possible two methods of bringing about transition automatically, e.g.

(i) Train speed based transition.
(ii) Generator volts and amps based transition.

## 4. WHEEL SPEED BASED TRANSITION (Electronically controlled)

## 4.1 CONTROL SYSTEM COMPONENTS

The type E transition control is a fully automatic transistorised system for controlling traction motor field shunting and connections. It consists of an axle driven generator and a control panel.

### 4.1.1. CONTROL PANEL

The panel is a steel fabricated housing contains semiconductor components mounted on plug-in-type cards with necessary adjusting facilities.

### 4.1.2 AXLE ALTERNATOR

The alternator has 40 poles made up of permanent magnets imbedded in a plastic stator, and a rotor carried on a shaft driven by the locomotive axle. The rotor rotates within the stator. Voltages are induced in the stator coil by the action of alternator ‘L’ shaped and straight soft iron bars in the rotor. The ‘L’ shaped bars guide the flux in a path enclosing the coil while the straight bars short circuit the flux to avoid enclosing the coil. This voltage has a frequency proportional to the speed of the axle driving the rotor. Only a few volts are generated, even at high speed, at a frequency of 20 cycles per revolution.

## 4.2. SYSTEM OF OPERATION

### 4.2.1 THEORY

In order to properly control transition and since transition is based upon locomotive track speed, an accurate indication of that speed is required. The axle alternator in combination generates this speed sensitive signal with a saturating transformer.

The saturable transformer requires the same amount of volt seconds to saturate it regardless of the speed at which saturation is achieved. The saturation characteristic at low speed and high speed of the axle alternator is shown in Fig.E4.9. The area of each pulse remains same regardless of speed. However, when rectified and filtered, the high-speed signal will result in a higher average voltage than the low speed signal since there are more pulses per unit time due to higher frequency. Since average voltage is directly related to frequency and frequency is directly related to speed, a straight-line characteristic of average volts versus speed can be obtained to give an accurate measure of speed.

Fig.E4.9 shows a basic, linear speed measuring circuit in conjunction with a transistor switch. The speed varying voltage is sensed by a voltage divider connected to a NPN transistor and 5 volts zener diode. As the speed varying voltage increases, a point is reached where the sampling point on R1 is 5 volts which exactly equals the battery voltage of the reference diode. Any further increase in speed will raise the voltage of sampling point above the reference diode voltage and cause a current to flow from the base to the emitter of the transistor. This will turn "ON" the transistor and initiate the desired control function. A drop in speed will cause control functions to ease. Resistor R2 allows sufficient current to flow in the Zener diode to insure its operating beyond the knee of its characteristic and give sharp control.

### 4.2.2. ACTUAL CIRCUITS

A typical automatic transition circuit is shown in Fig.E4.10. The 3-phase axle alternator feeds the circuit, with the leads connected to the automatic transition panel, providing an a-c. Voltage proportional to train speed. This a-c signal is rectified by a full wave bridge rectifier TRT consisting of potentiometers in series, the number of circuits being determined by the number of events to be controlled.

Field shunting in series parallel is one event, requiring a potentiometer TP11, a transistor TT11 for actuating the sensitive relay TSSR1 controlling the event, and various resistors. The panel contains sensitive relays for controlling large control relays, a zener diode, various resistors and diode for protecting the transistors from negative voltage spikes and a capacitor for positive spike protection.

Each of the circuits across the filtered output of the secondary winding of saturating transformer WET33 will have a voltage between the negative side of the D-C circuit and the brush arm of its potentiometer. This voltage is proportional to axle generator speed. The potentiometer is set so that the voltage of the zener diode TZD when the speed for the desired event is reached. As an example, considering the first event in a typical locomotive, potentiometer TP11 sees a portion of the d-c voltage resulting from a given train speed. Because field shunting in a series parallel is desired at a certain speed, the adjustment of TP11 is made so that the voltage of its brush arm will equal the breakdown voltage of TZD at that speed. This will feed current through TCR21 into the base of transistor TT11, through the emitter and resistor TCR4 and through the zener diode TZD back to the negative side of the circuit. This turn `ON' transistor TT11 and pick up relay TSSR1 and TSSR1 will then actuate the field shunting relay FSR, which is a heavy duty relay having contacts, which will set up the field shunting circuits.

When the relay FSR picks up, it connects the brush arm of potentiometer TP21 through the new closed S21 finger to the positive side of the d-c circuit and this boosts the voltage at the brush arm of TP11. The actual point on the characteristics of the transistor TT11 and the relay TSSR1. Adjusting the TP21 potentiometer makes an adjustment of dropout speed.

The voltage divider network made up of TCR2 provided approximately 25 volts across each of the transistors between the positive of the locomotive battery circuit and the common connection with the transistor emitters, to protect the transistors from operating at more than their normal working voltage. A small current fed from the locomotive battery negative to bias the Zener diode TZD to make control sharper and to get past the so-called knee of the Zener diode characteristic. This is done because the Zener diode will pass a very small current at a lower voltage than its normal breakdown value and then pass more current as this voltage is raised to the desired breakdown value. If control current is tending to turn ‘ON’ a transistor, it has to flow through the zener diode without the bias current flowing, sufficient current might flow at a voltage lower than the breakdown voltage to turn `ON' the transistor and actuate the system at a lower speed than intended. This speed would vary from day to day, depending on the characteristics of the various devices involved in the circuit. By biasing the diodes with current from another source which has no effect on the transistors, the transistor turn on current will flow only when the breakdown voltage is equalled or exceeded.

## 5. GENERATOR VOLTS AND AMPERES BASED TRANSITION

The second method of controlling automatic transition is based on generator volts and amperes. Relays that pick up on generator voltage at the top of the generator horsepower curve, point C in Fig.E4.2 bring about forward transition. Usually one relay is used for field shunting in series parallel and parallel. Another relay is used for series-parallel to parallel transition. One or more additional relays, that operate in generator current at the bottom of the horse power curve, point B in Fig.E4.2 are also required for backward transition. For satisfactory operation, these relays should be accurately calibrated on the bench.

## 6. SUMMARY

In DC-DC or AC-DC locomotives, where the traction motors are DC series motors, transition becomes unavoidable. Transitions from full field to weak field or series combination to parallel combination of traction motors help in achieving maximum speed of the locomotive by still using rated power of the engine in any of the notches. Automatic transition regulation is and important activity, which ensures the change at correct moment without which locomotive suffers from bad fuel efficiency and time loss in line. Wheel speed based transition is superior to voltage-ampere based transition as the latter has low response control components e.g. relays etc. The sensitivity and maintainability has improved substantially with use of electronic components in the system. The availability of components in the open electronics market is possible which reduces downtime of control panels and requirement of unit exchange spares.

## 8. SELF-ASSESMENT EXCERCISES

1. Explain the need for transition briefly.
2. How does the process of field weakening help in achieving higher loco speed?
3. What do you mean by forward and backward transitions?
4. Which system do you feel better (whether wheel speed based or voltage ampere based) and why?