Brake systems used by IR
by S Krishnamorthy

- Comparison of air brakes and vacuum brakes
- Components of air brake and vacuum brake systems
- Advantages of air brakes over vacuum brakes
- Comparison of single-pipe and twin-pipe systems
- Schematic diagrams of single-pipe and twin-pipe systems
- Comparison of conventional and bogie-mounted air brakes

This page details the air and vacuum brake systems used for passenger coaches and freight wagons by IR. The material has been adapted from official IR documentation. Also see: EMU brake systems

Comparison of air brakes and vacuum brakes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Air Brakes</th>
<th>Vacuum Brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle of working</td>
<td>The compressed air is used for obtaining brake application. The brake pipe and feed pipe run throughout the length of the coach. Brake pipe and feed pipe on consecutive coaches in the train are coupled to one another by means of respective hose couplings to form a continuous air passage from the locomotive to the rear end of the train. The compressed air is supplied to the brake pipe and feed pipe from the locomotive. The magnitude of braking force increases in steps with the corresponding reduction in brake pipe pressure and vice-versa.</td>
<td>The vacuum brake system derives its brake force from the atmospheric pressure acting on the lower side of the piston in the vacuum brake cylinder while a vacuum is maintained above the piston. The train pipe runs throughout the length of the coach and connected with consecutive coaches by hose coupling. The vacuum is created in the train pipe and the vacuum cylinder by the ejector or exhauster mounted on the locomotive.</td>
</tr>
<tr>
<td>Pressure</td>
<td>Effective cylinder pressure = 3.8kg/cm²</td>
<td>Effective pressure on piston - 0.5kg/cm²</td>
</tr>
<tr>
<td>Pipe diameter</td>
<td>Feed pipe - 6kg/cm², Brake pipe - 5kg/cm²</td>
<td>Nominal vacuum on train pipe - 510mm.</td>
</tr>
</tbody>
</table>

Components of air brake and vacuum brake systems

<table>
<thead>
<tr>
<th>Air Brakes</th>
<th>Vacuum Brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake pipe and feed pipe (twin pipe system for coaching stock, single pipe system for goods stock).</td>
<td>Train pipe -- single pipe</td>
</tr>
<tr>
<td>Air brake cylinder - 355mm dia</td>
<td>Vacuum brake cylinder- 24&quot; type 'F'</td>
</tr>
<tr>
<td>Distributor Valve</td>
<td></td>
</tr>
</tbody>
</table>
Passenger Emergency Alarm Signal Device  
Passenger Emergency Valve  
Guard's Emergency Valve  
Slack Adjuster  
Hose coupling for brake pipe and feed pipe  
Auxiliary reservoir 100 l capacity  
Cut off Angle cock  
Check valve with choke  
Dirt collector

**Advantages of air brakes over vacuum brakes**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Air Brakes</th>
<th>Vacuum Brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency braking distance (4500 t level track, 65 kmph)</td>
<td>632m</td>
<td>1097m</td>
</tr>
<tr>
<td>Brake power fading</td>
<td>No fading</td>
<td>At least by 20%</td>
</tr>
<tr>
<td>Weight of equipment per wagon (approx.)</td>
<td>275kg</td>
<td>700kg</td>
</tr>
<tr>
<td>Pressure Gradient</td>
<td>No appreciable difference in air pressure between locomotive and brake van up to 2000m.</td>
<td>Steep reduction in vacuum in trains longer than 600m.</td>
</tr>
<tr>
<td>Preparation time in departure yards (45 BOX or 58 BOXN)</td>
<td>Less than 40 minutes.</td>
<td>Up to 4 hours.</td>
</tr>
<tr>
<td>Safety on down gradients</td>
<td>Very safe</td>
<td>Needs additional precautions</td>
</tr>
<tr>
<td>Overall reliability</td>
<td>Very good</td>
<td></td>
</tr>
</tbody>
</table>

Electric locos derive tractive effort from Traction Motors which are usually placed in the bogie of the locomotive. Usually one motor is provided per axle but in some older generation of locos two axles were driven by a single Traction Motor also.

However apart from Traction Motors, many other motors and equipments are provided in electric locos. These motors are collectively known as the Auxiliaries. The aim of this article is to provide an insight into the various Auxiliary Machines provided in the Electric Locos operational on the Indian Railways.
But to understand the reasons why these auxiliaries are needed, it is necessary to understand the manner in which the electric locos operate. An important part of the electric loco is the Power Circuit. A short description of the power circuit of Electric Locos operational on the Indian Railways can be seen here. The article referred to describes the main components of the Power Circuit of the Electric Locomotive comprising of the following parts:

1. **Transformer (including Tap-Changer)**  
2. **Rectifier**  
3. **Smoothing Reactor**  
4. **Traction Motors**  
5. **Main Starting Resistances (in DC Traction on Dual Power Locos only)**  
6. **Dynamic Braking Resistance Cooling Blower**

A common feature running through all the above electrical equipments is that all of these generate a lot of heat during their normal operation. Even when they are not in use, they might generate a nominal amount of heat. Normally any electrical equipment generates heat as by-product during operation. But traction vehicles tend to generate more heat than normal. This is because day-by-day the demand on traction vehicles is increasing. But an increase in the power output more or less translates into increased size of the relevent equipments too. But a major problem with traction vehicles is that you cannot increase their size beyond a certain limit. This is due to "Loading Guage Restrictions". Hence, the power output of the locomotives has to be increased indirectly without increasing their size. This is done by "pumping"more power through the equipments and cooling them at a suitable rate at the same time.

Hence the different auxiliaries provided for cooling and other purposes in these locos is described below. All the motors are of the AC 3 Phase squirrel cage induction type and require very little maintenance and are simple and robust. They are described with regard to their relationship to the major power equipments

**Auxiliaries of the Transformer**

**Transformer Oil Circulating Pump (MPH)**

The transformer tank is filled with oil which serves two purposes. It provides enhanced insulation to the transformer and its surroundings and the oil absorbs the heat generated in the transformer and takes it away to the Transformer Oil Cooling Radiator. The circulation of this oil is carried out by the MPH.

A flow valve with an electrical contact is provided in the oil circulating pipe. As long as the oil is circulating properly, the contacts on the relay remain closed. However, in case the MPH fails or stops the relay contacts open which in turn trips master auxiliary protection relay Q-118. This trips the main circuit-breaker(DJ) of the loco. Thus the transformer is protected.

**Transformer Oil Cooling Radiator Blower (MVRH)**

The MPH circulates the transformer oil through a radiator array on top of the transformer. Air is blown over the radiator by the MVRH. This discharges the heat from the radiator into the atmosphere. A flow detecting relay is provided in the air-stream of the MVRH. The flow detector is a diaphragm type device. The flow of air presses the diaphragm which closes an electrical contact. This relay is known as the QVRH. In case the MVRH blower fails the the QVRH releases and trips the DJ through the relay Q-118.
The transformer and its cooling equipment. The small vertical motor on top left is the MPH and the horizontal larger motor in the top centre is the MVRH and behind it is the oil cooling radiator. Click for a larger view.

**Auxiliaries of the Rectifier Block (RSI 1 & 2)**

**Rectifier Cooling Blowers-MVSI-1 and MVSI-2**

One blower is provided for each of the rectifier blocks. As rectifiers are semiconductor devices, they are very sensitive to heat and hence must be cooled continuously. The switching sequence of the MVSI blowers is setup in such a way that unless the blowers are running, traction cannot be achieved. A detection relay of diaphragm type is also provided in the air stream of these blowers. However, the detection relay (QVSI-1 & 2) are interlocked with a different relay known as Q-44. This is a much faster acting relay with a time delay of only 0.6 seconds. Hence the failure of a MVSI blower would trip the DJ in less than 1 second.

**Auxiliaries of the Smoothing Reactors (MVSL 1 & 2)**

In WAM-4 locos only one MVSL blower is provided for the cooling of the Smoothing Reactors SL 1 & 2. However in WAG-5 and other locos two blowers namely MVSL 1&2 are provided for each of the SL's. Their running is "proved" by the Q-118 relay.

*In railway parlance Proving means to verify whether an equipment or device is working properly.*
**Auxiliaries of Traction Motors (MVMT 1 & 2)**

In the course of normal operation the traction motors also generate a lot of heat. This heat is dissipated by two blowers namely MVMT 1 & 2 which force air through a duct into the traction motors of Bogie-1 namely TM-1, TM-2, TM-3 and Bogie-2 namely TM-4, 5, 6 respectively. The traction motor cooling blowers require a large quantity of air which is taken from vents in the side-wall of the loco. Body-side filters are provided to minimise the ingress of dust into the loco. Their running is detected by Air-Flow sensing relay QVMT 1 & 2 (Pic-2) which in turn give there feed to the Q-118 relay.

MVMT-Traction motor cooling blower motor and impeller covered by a hood. Click for a larger view.

**Other Auxiliaries**

**Air Compressors (MCP 1, MCP-2, MCP-3)**

Electric locos need compressed at a pressure ranging from 6 kg/cm$^2$ to 10 kg/cm$^2$. Compressed air is used for the loco's own air brake system as also for the train brakes, for raising the pantograph, for operating the power switchgear inside the loco such as the power contactors, change-over switches, windscreen wipers, sanders, etc.

This compressed air is obtained by providing three air compressors, each having a capacity to pump 1000 litres of air per minute. However depending on the current requirement, more than two compressors are rarely needed.

Main air compressor. Click for a larger view.
**Vacuum Pumps (MPV 1 & 2)**

In locos equipped to haul vacuum braked trains, two vacuum pumps are also provided of which at least one is running in normal service and sometimes both may have to be run if train brakes are required to be released in a hurry.

**Dynamic Braking resistance Cooling Blower (MVRF)**

In locos equipped with internal dynamic braking resistances, MVRF blower is provided for cooling the resistances during braking. While all the Auxiliary machines run on the power supply provided by the Arno convertor / Static Convertor / Motor-Alternator set, the MVRF blower runs off the supply derived from the output of the Traction Motor itself and is connected in parallel to the Dynamic Braking Resistances.

**Main Starting Resistance Cooling Blowers (MVMSR)**

These blowers(four in number)are provided in WCAM-1, WCAM-2, WCAM-3 locos and are used during DC line working to cool the Main Starting Resistances(MSR). The MSR is used for regulating the voltage supplied to the Traction Motors during DC line working and carry the whole current of the traction motors which results in a lot of heat generation which must be continuously dissipated. The working of the MVMSR's is also proved by respective sensing relays(QVMSR's) of the diaphragm type which in turn are interlocked with the relay Q-118 in the manner described later in this article.

**Switching and operational sequence**

The auxiliary machines mentioned above are energised as per the requirements in the loco. Some of them are run continually while some may only be required intermittanly while in rare cases, some may not be required at all during the whole run of the loco. Also the working sequences of the same auxiliary machines may differ across different models of locomotives as also in different working environments. For the purpose of this article, I've described the switching sequences of the WAG-5 loco except for the case of dual power locos such as the WCAM-1, WCAM-2, WCAM-3 which will be described seperately.

It should be kept in mind that all the above mentioned machines are of large horsepower and hence consume a lot of power and draw a lot of current from the power supply. In addition when any motor starts, initially it draws a current which may be up to 3-10 times its normal current. Hence, if all the motors or even a few motors are started simultaneously, it would cause a tremendous demand on the power supply in terms of the current drawn. This might also cause the power supply to trip because the supply is only equipped to deal with the normal running current of the machines and not such a huge current. To prevent such a situation, the starting of some of the motors is staggered which prevents heavy load currents from being drawn.
Electronic time delay relays for sequential starting of auxiliary machines. Click for a larger view.

View of three-phase busbar cubicle and contactors for auxiliary machines complete with interlocking contact block assemblies. Click for a larger view.

In the following table the starting and running sequence of the auxiliary machines is laid out:

<table>
<thead>
<tr>
<th>AUXILIARY</th>
<th>STARTS (CONTACTOR NO.)</th>
<th>PROGR AM SWITCH PROGRA SWITCH PROGRA SWITCH PROGRA SWITCH REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPH</td>
<td>On DJ being closed (Direct supply from Three-Phase Busbar via HPH)</td>
<td>HPH (Provide d on the Auxiliary panel)</td>
</tr>
<tr>
<td>MVRH</td>
<td>MPJ in Forward/Reverse or BLVMT ½ being closed (C-107)</td>
<td>HVRH OFF (Provide d on the Auxiliary panel)</td>
</tr>
</tbody>
</table>

**Remarks:**
- MPH: On DJ being closed (Direct supply from Three-Phase Busbar via HPH)
- MVRH: MPJ in Forward/Reverse or BLVMT ½ being closed (C-107)
<table>
<thead>
<tr>
<th>Model</th>
<th>Condition</th>
<th>Action</th>
<th>Circuit</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVSI 1&amp;2</td>
<td>On DJ being closed (Direct supply from Three-Phase Busbar via HVSI 1&amp;2)</td>
<td>HVSI 1&amp;2 (Provided on respective RSI block itself) OFF Normal Running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-1 - MCP 1/2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-2 - MCP 2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-3 - MCP 1/3 running (In dual-brake locos, an interlock is provided wherein the only one compressor can be run if the Vacuum Exhauster is running while working vacuum braked trains. In such cases compressed air is regulated by the auto pressure switch which normally adjusts the running pressure.)</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RGCP is the auto pressure switch which normally regulates the running of the compressor for vacuum braked trains. In such cases, RGCP adjusts the pressure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVSL 1&amp;2</td>
<td>On DJ being closed (Direct supply from Three-Phase Busbar via HVSL)</td>
<td>HVSL 1&amp;2 OFF Normal Running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-1 - MCP 1/2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-2 - MCP 2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-3 - MCP 1/3 running (In dual-brake locos, an interlock is provided wherein the only one compressor can be run if the Vacuum Exhauster is running while working vacuum braked trains. In such cases compressed air is regulated by the auto pressure switch which normally adjusts the running pressure.)</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RGCP is the auto pressure switch which normally regulates the running of the compressor for vacuum braked trains. In such cases, RGCP adjusts the pressure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVMT 1</td>
<td>Five seconds after MVRH starting (C-105)</td>
<td>HVMT 1 (Provided on the Auxiliary panel) OFF Normal Running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-1 - MCP 1/2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-2 - MCP 2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-3 - MCP 1/3 running (In dual-brake locos, an interlock is provided wherein the only one compressor can be run if the Vacuum Exhauster is running while working vacuum braked trains. In such cases compressed air is regulated by the auto pressure switch which normally adjusts the running pressure.)</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RGCP is the auto pressure switch which normally regulates the running of the compressor for vacuum braked trains. In such cases, RGCP adjusts the pressure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVMT 2</td>
<td>Five seconds after MVMT-1 starting (C-105)</td>
<td>HVMT 2 (Provided on the Auxiliary panel) OFF Normal Running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-1 - MCP 1/2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-2 - MCP 2/3 running</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCP at position-3 - MCP 1/3 running (In dual-brake locos, an interlock is provided wherein the only one compressor can be run if the Vacuum Exhauster is running while working vacuum braked trains. In such cases compressed air is regulated by the auto pressure switch which normally adjusts the running pressure.)</td>
<td>Motor</td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RGCP is the auto pressure switch which normally regulates the running of the compressor for vacuum braked trains. In such cases, RGCP adjusts the pressure.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
On closing BLPV (C111/C112 for low speed and C121 and C122 for high speed) ZPV and other brake interlocks OFF

- MPV-1, MPV-2
- On the initiation of dynamic braking from master controller (is in parallel with the DBR load resistances and also constitutes part of the load on the traction motors)

- MVRF (In locos provided with internal DBR)
  - Motor isolated
  - Running detecting
  - Normal

- New locos being turned out by CLW
  - Motor to have a three-phase motor to run the MVRF blower and it takes supply from the Static Convertor.

- MVMSR-1-4 (In dual power locos only)
  - On DS being closed (Provided on the Auxiliary panel)
  - Motor isolated
  - Normal

- HVMSR 1 and 2
  - Motor running detecting
  - Normal

Note: The control circuit of MVMSR has been modified in WCAM-1 locos and HVMSR switches have been removed. In case of failure of any MVMSR, the loco must be declared failed. However, the same loco in this condition may be energized and run normally in AC line working.
Power Supply

Depending on the locomotive, power for the auxiliary machines is obtained through three different methods. A separate power supply arrangement is needed because the motors require three phase supply while the OHE supply is of the single phase type. So the main requirement of the power supply for the auxiliary machines is for a device which can convert single phase AC into three phase AC. It becomes a little more complicated for the dual power locomotives such as the WCAM-1, WCAM-2, WCAM-3.

The three main types of equipments used to supply power to the auxiliaries are discussed below.

**Arno Convertor**

This is a rotary convertor which has a combined set of windings and is used to convert the single phase supply from the Tertiary winding of the Loco transformer to Three-Phase AC which is fit for use by the various Auxiliary machines in the loco.
The Arno is basically a split-phase induction motor with an additional winding on the stator for the generating phase. In an induction motor the rotating field of the stator creates a corresponding field in the rotor squirrel cage too which causes the rotor to start rotating at "slip" speed which is slightly less than the speed at which the stator field is rotating. However, this rotating field of the rotor is additionally utilized in the arno to create power in the generating phase winding which gives the three phase output of the arno convertor. In the stator winding of the arno, the motoring phases carry the load as well supply currents of the arno in opposite direction which causes a net reduction in the actual current carried by the windings in the stator but the generating phase carries only the load current which causes a voltage drop in the generating phase. To counteract this, up to 20% more turns are provided in the generating phase winding.

See Reference 1 listed below for more details.

**Precautions during arno starting**

The Arno starts as a split-phase induction motor by inserting a resistance momentarily in the generating phase winding as shown in the diagram above. This starting resistance must be removed as the rotor approaches 90% of its normal speed. If this resistance is left in the circuit, it can cause heating of the generating phase winding and excessive vibrations. If the starting resistance is removed prematurely it can take longer for the arno to reach synchronous speed. Hence, to maintain proper timing two methods could be employed-either measure the speed of the arno by attaching a tacho-generator or measure the output voltage of the generating phase.

The voltage measurement method has been found to be more effective and is used in this system. The voltage between the generating phase and the neutral of the arno convertor remains at a low
value till just before the arno reaches its synchronous speed when it reaches its full value and is measured by the relay named QCVAR. It picks up when the voltage rises to near maximum value. The energisation of the QCVAR causes the starting contactor C-118 to open which disconnects the starting resistance. The normally open (NO) contacts of the QCVAR are also interlocked with the Q-118 relay. This interlock is used to ensure that if the QCVAR fails to operate within 5 seconds, the Q-118 interlock trips the DJ. A bypass switch named HQCVAR is also provided which can be used to bypass the HQCVAR relay in the Q-118 branch so that DJ tripping does not occur but in such a case the Arno must be monitored continuously to ensure that its not overheating.

**Static Invertor**

The Arno convertor suffers from various disadvantages chief of which is output voltage imbalance which can cause heating up of the auxiliary motors, varying output voltage because of the variations in OHE voltage, problems related to starting of the Arno, etc. To overcome these shortcomings and to improve loco reliability, the Indian Railways have started providing Static Invertor power supply for auxiliary machines in locomotives.

See [Reference 2](#) listed below for more details.

The Static Invertor comprises a force commutated rectifier, a DC link and an Invertor which is usually composed of six IGBT switches.

The Static Invertor broadly works in the following manner:

The supply from the transformer tertiary winding is fed into the rectifier of the Invertor which is force commutated and is usually composed of IGBTs. The rectified supply is fed into the DC link which is a large capacitor and is charged by the DC supply. The DC link also has an inductor to suppress the AC ripple left over from the rectification cycle and harmonics generated by the invertor. Additionally the DC link maintains the supply to the invertor in case of temporary supply failure and also absorbs transient voltages generated during switching heavy loads. In some models if the Static Invertor, an IGBT type switch is provided which is used to switch the DC link in and out of the circuit as per requirement.

The DC from the rectifier/DC link is converted into three phase AC by the Invertor module by switching the IGBTs in proper sequence which creates a near sine wave AC displaced by 120 degrees. Voltage control is achieved by the Pulse Width Control (PWM) method. This ensures that the output voltage of the Static Invertor is near constant irrespective of the input voltage from the transformer.

Apart from improving the reliability of the power supply system, one of the most important advantages of the Static Invertor is that it has considerably reduced Auxiliary Motor burnouts due drastic improvement in the power quality in terms of voltage.

Additionally the Static Invertor also detects earth faults, single phasing and overloading hence these functions are no longer needed to be monitored by external devices.

An electronic control system is provided which monitors the complete functioning of the Static Invertor. The control system gives the gate firing impulses to the various IGBTs and also controls the phase angle of the firing pulse to ensure proper phase sequencing. In addition it monitors the Static Invertor for internal and external faults.
Motor-Alternator Set (used only in the WCAM-1 and the WCG-2 locos)

Motor-alternator set provided in WCAM-1 locos. The MA set is the green machine to the right. The silver box to the top left is the FRG (Frequency Regulator). Click for a larger view.

The MA set is used to generate power for the Auxiliary machines in both the AC as well as DC sections because the Arno cannot run in DC line supply. The MA set comprises of a DC motor coupled to an AC alternator by a mechanical coupling. When the loco is under AC line supply the DC motor of the MA Set is fed by the tertiary winding of the transformer via an auxiliary rectifier known as RSI-3. While running in DC line sections the DC motor of the MA Set is supplied directly by the OHE line supply. The switching between the AC and DC modes is determined automatically by the position of the Panto changeover switch ZPT which in turn determines the position of the Change-Over switches.

A stable AC supply output consists of two main parameters namely the frequency and the voltage. The frequency of the output supply is directly dependent on the speed at which the alternator is running and the output voltage is dependent on the field excitation voltage of the alternator. Generator speed tends to fall as the electrical load on the generator increases and vice-versa. To keep the speed of the alternator near constant a frequency regulator is provided which continuously monitors the frequency and as per requirement controls the speed of the alternator by reducing or increasing the field excitation of the DC motor. A bypass switch for the frequency regulator is also provided in case the FRG becomes defective.
Electrification - Circuit Diagrams

Shown below are three schematic circuit diagrams for electrification systems used on IR. These show the power flow from the 25kV AC catenary through the locomotive. Also see the traction power supply feeding schematic for the details of the circuit between the regional high-voltage grid and the 25kV catenary. For more information on this and related topics, see the FAQ sections on electric traction and electric locomotives.
• The first figure shows a simple feeding system. Catenary current \( I_c \) is returned as rail current \( I_R \) and earth currents \( I_E \).

• The second figure shows the use of booster transformers to force return current through a separate return conductor instead of through the rails or earth. Insulated rail joints ensure that currents flow in the rails only in occupied track sections. Inductive interference is reduced since the return wire is close to and parallel to the catenary.

• The third figure shows an auto-transformer system (also known as the 3-wire system or 2x25kV system). Inductive interference is reduced as the negative phase feeder and catenary carry equal but opposite currents and are close to each other and parallel. The supply voltage to the locos can be kept close to the 25kV figure by tap changers on the autotransformers. (Note: In the autotransformer case the currents drawn do not have to be symmetric across the autotransformers on the left and right of the loco -- they can vary, as long the currents add up to half the current drawn by the loco.)
Simple Catenary Feeding System

Booster Transformer Feeding System with Return Conductor and Insulated Rail Joints

Autotransformer feeding system (2 x 25 kV)
Electric Traction - I

Contents

This page

- Voltages used
- History
Electric traction voltages

**Q. What are the voltages used for electric traction in India?**

Voltages used are 1.5kV DC and 25kV AC for mainline trains.

Calcutta had an overhead 3kV DC system until the '60s.

The 1.5kV DC overhead system (negative earth, positive catenary) is used around Bombay (This includes Mumbai CST - Kalyan, Kalyan - Pune, Kalyan - Igatpuri, Mumbai CST - Belapur - Panvel, and Churchgate - Virar). There are plans [2/04] to change this to 25kV AC by 2010. In preparation for this, BHEL has been retrofitting some Alstom EMUs with AC drives to allow them to operate with both DC and AC traction as the system conversion proceeds (see the section on EMUs). Conversion to 25kV AC has already been done on the Titwala-Kasara section; next to be converted are Khapoli-Vangani, Vangani-Thane, and Titwala-Thane. The Madras suburban routes (Madras-Tambaram in the '60s, extended later to Villupuram) used to be 1.5kV DC until about 1967, when it was converted to 25kV AC (all overhead catenary supply). (This is where the MG DC locos were used, e.g., the YCG-1 series.)

The 25kV AC system with overhead supply from a catenary is used throughout the rest of the country. The WCAM series of locomotives are designed to operate with both DC and AC traction as they move towards or away from the Bombay DC section. The new [2003] AC-DC EMU rakes used in Mumbai are also designed to operate with both DC and AC traction as the Bombay area switches over to the 25kV AC system. Read more about Mumbai area electrification.

The Calcutta Metro uses 750V DC traction with a third-rail mechanism for delivering the electricity to the EMUs.

The Calcutta trams use 550V DC with an overhead catenary system with underground return conductors. The catenary is at a negative potential.

The Delhi Metro uses 25kV AC overhead traction with a catenary system on the ground-level and elevated routes, and uses a rather unusual 'rigid catenary' or overhead power rail in the underground tunnel sections (Line 2).

History of electrification

**Q. What's the history of electric traction in India?**

The first electric train ran between Bombay's Victoria Terminus and Kurla along the Harbour Line of CR, on February 3, 1925, a distance of 9.5 miles. In 1926, Thana and Mahim were connected. In 1927, electrification was complete up to Kalyan. In 1928, Borivili in the north was connected (Colaba-Borivili of WR being inaugurated on May 1). In 1929, Kalyan - Igatpuri section was commissioned. In 1930, the Kalyan - Poona tracks were opened to electric trains.
Was Mumbai's the first electric service in Asia?

It is sometimes stated that the electric train in 1925 was Asia's first electric, or electric suburban, train service. This is however not true, because electric services were running in Japan since Jan. 31, 1895, on the Kyoto Electric Railway (officially listed under 'Exploitation Department', Kyoto Municipality, in the annual reports of the Government of Japan's Department of Railways), but this is sometimes classified as a tramway instead of a light rail system. (Interestingly, this was also the year that the first Japanese steam locomotive was manufactured.) Electric railcar services ran on the Government Railways of Japan from about 1905, and (German-built) electric locomotives were introduced in Japan in 1911. In 1919 the first the first entirely Japanese electric locomotive was built (a class ED-40). In Indonesia, the first electrified section (1500V DC) of the State Railways opened at Batavia (Jakarta) in 1925, the same year as in Bombay.

On November 15, 1931, electrification of the meter gauge track between Madras Beach and Tambaram was inaugurated (1.5kV DC). After that the only electrification project undertaken was Borivili - Virar, finished in 1936. For mainline traffic, GIPR undertook electrification of the Karjat-Pune and Kasara-Igatpuri sections because it was realized that the heavy traffic to and from Bombay would be suitable for electric haulage.

Following this there was a long gap, and the next electrification project started only 1953 or 1954, in the Calcutta area (Howrah-Burdwan via Bandel, Sheoraphulli-Tarakeshwar), using 3kV DC traction. At this time, the idea of mainline electrification (Howrah-Mughalsarai) was seriously mooted. Support for 25kV AC traction was also growing at about this time, especially after some trials of AC locos from SNCF, and studies that concluded that the single-phase load from electric traction would not seriously unbalance the 3-phase regional grids.

So the Calcutta area electrification was done keeping in mind the eventual migration to 25kV AC system, in terms of the technical requirements (insulator specifications, etc.). The first 25kV AC electrified section was Burdwan-Mughalsarai, completed in 1957, followed by the Tatanagar-Rourkela section on the Howrah-Bombay route. The first actual train run (apart from trial runs) using 25kV AC was on December 15, 1959, on the Kendposi-Rajkharswan section (SER). Howrah-Gaya was electrified by about 1960. Electrification till Kanpur on the Howrah-Delhi route was done by about 1972, and the entire Howrah-Delhi route was electrified on August 5, 1976. The Bombay-Delhi route was electrified by February 1, 1988. Through the 1960s and early 1970s numerous studies were commissioned to investigate the question of which of diesel or electric traction was really more economical and better in the long run for IR. Most of these leaned towards electrification, especially for high-traffic sections. The rise in oil prices in the mid-1970s tilted the argument further in favour of electric traction as electricity generation in most of India is hydroelectric or coal-based.

India took the plunge from DC to AC electric traction in the mid-1950s, as mentioned above. Since French developments led the field, the AC locomotives supplied at first (from SNCF) followed that country's practice, whether built in India or France. These were the eight-wheeled WAM-1 locomotives that are still in operation in some places.

The first train to be hauled by an electric locomotive from Delhi Jn. was the Assam Mail. Bombay-Delhi (WR) route was fully electrified by Dec. 1987. The CR route was fully electrified by June 1990, when the Bhusaval - Itarsi section was electrified.

The 2 * 25kV AC system (see below) began to be put in place in the 1990s; the first regular service using this system was between Bina and Katni (CR) on January 16, 1995. This was later extended to Bishrampur.
With the BG conversion between Tambaram and Madras Beach complete, the only electrified MG line on IR is the Tambaram - Villupuram stretch. However, no train uses electric traction (the YAM 1 locomotives used to service this section have been dismantled). Madras Beach - Tambaram was originally on 1.5kV DC electrification but was converted around 1968 to the 25kV AC system.

After a period of about 25 years of aggressive electrification, now IR has most of the busy routes of its network electrified (although not all), and this has resulted in about 65% of the traffic being hauled by electric traction. Recently, therefore, IR has decided to slow down the pace of electrification -- about 2600km of routes are scheduled to be electrified in the next 10 years, compared to 5100km in the past 10 years. The focus will be on consolidating electric traction for the busiest sections; some of the sections that will be converted to electric traction in the next few years are Pune-Guntakal, Bina-Kota, and many 'B' sections of NR.

See also CORE's chronology of IR electrification.

Three phase locomotives

Q. How do the new 3-phase AC locos (WAP-5, etc.) work, and how do they compare with the earlier locos?

Three-phase AC locos such as WAP-5 use some fairly new technology as compared to the earlier generations of diesel-electrics and electrics. In most of the earlier locos, the traction motors driving the axles are DC motors. DC motors were used because they afforded (in those days) far superior speed and torque control compared to AC motors — the latter require variation of input frequency and voltage for effective control, which was not an easy matter earlier.

Modern microprocessor technology and the availability of efficient and compact power components have changed that picture. In 3-phase AC locos, the input (single-phase AC) from the OHE is rectified and then 3-phase AC is generated from it, whose voltage, phase, and frequency can be manipulated widely, without regard to the voltage, phase, frequency of the input power from the OHE. AC traction motors can thus be driven with a great degree of control over a wide range of speed and torque.

AC traction motors are also used on diesel-electrics nowadays. The WDP4 & WDG4 are examples of this.

Details: There are 3 main stages in the power circuit of a 3-phase AC loco.

Input Converter: This rectifies the AC from the catenary to a specified DC voltage using GTO (gate turn-off) thyristors. A transformer section steps down the voltage from the 25kV input. It has filters and circuitry to provide a fairly smooth (ripple-free) and stable DC output, at the same time attempting to ensure that a good power factor presented to the electric supply. There may also be additional mechanisms such as transformers, inductors, or capacitor assemblies to improve the power factor further.

The transformer section is designed with high leakage impedance and other characteristics, which together with the fine control possible with the GTO switching, allow the loco to present nearly unity power factor, a very desirable situation from the point of view of the electricity suppliers (the grid). The main transformer also has some filter windings which are designed to further attenuate harmonics from the loco's traction motors which may pass through the filtering in the DC link.
The input converters can be configured to present different power factors (lagging or leading) to the power supply, as desired. IR's WAP-5 and other 3-phase AC locos are generally configured to present a unity power factor (UPF). (Note: the power factor cannot be changed on the run.)

**DC Link**: This is essentially a bank of capacitors and inductors, or active filter circuitry, to further smooth the DC from the previous stage, and also to trap harmonics generated by the drive converter and traction motors. Since the traction motors and drive converters present non-linear loads, they generate reactive power in the form of undesirable harmonics; the DC link acts as a reservoir for the reactive power so that the OHE supply itself is not affected.

During regenerative braking this section also has to transfer power back to the input converter to be fed back to the catenary. The capacitor bank in this section can also provide a small amount of reserve power in transient situations (e.g., pantograph bounce) if needed by the traction motors.

**Drive Converter**: This is basically an inverter which consists of three thyristor-based components that switch on and off at precise times under the control of a microprocessor (pulse-width modulation). The three components produce 3 phases of AC (120 degrees out of phase with one another). Additional circuitry shapes the waveforms so that they are suitable for feeding to the traction motors. The microprocessor controller can vary the switching of the thyristors and thereby produce AC of a wide range of frequencies and voltages and at any phase relationship with respect to the traction motors. Various kinds of thyristor devices are used to perform the switching.

Currently produced modern locos generally use GTO thyristors (Gate Turn-Off thyristors), but it is expected that soon insulated-gate bipolar transistors (IGBTs), which offer extremely high switching speeds allowing for finer control over the waveforms generated, will be the switching technology of choice. The WAP-5, WAP-7, WAG-9, and WAG-9H models all use GTOs. At present [5/02], no Indian loco uses IGBTs; some trial locos such as the 12X from Adtranz do use this technology, as do many light-rail and metro locomotives or EMUs around the world. [5/02] The new AC-DC EMUs in the Mumbai area (introduced on WR) use IGBTs.

The 3-phase AC is fed to the AC traction motors, which are induction motors. As the voltage and the frequency can be modified easily, the motors can be driven with fine control over their speed and torque. By making the slip frequency of the motors negative (i.e., generated AC is 'behind' the rotors of the motors), the motors act as generators and feed energy back to the OHE — this is how regenerative braking is performed. There are various modes of operation of the motors, including constant torque and constant power modes, balancing speed mode, etc. depending on whether their input voltage is changed, or the input frequency, or both.

AC motors have numerous advantages over DC motors. DC motors use commutators which are prone to failure because of vibration and shock, and which also result in a lot of sparking and corrosion. Induction AC motors do not use commutators at all. It is hard to use a DC motor for regenerative braking, and the extra switchgear for this adds to the bulk and complexity of the loco. AC motors can fairly easily be used to generate power during regenerative braking. In addition, DC motors tend to draw power from the OHE poorly, with a bad power factor and injecting a lot of undesirable harmonics into the power system. AC motors suffer less from these problems, and in addition have the advantage of a simpler construction.

**Neutral zones / dead zones / phase gaps**
Q. How are phase breaks (AC) or power gaps (DC) handled by the locomotives?

The catenary has breaks or gaps in its electrical continuity every once in a while at points where successive sections are connected to different substations. A neutral section of catenary is usually provided between the two live sections of different phases or connected to different substations. At such points, single locomotives do not drop their pantographs, although on-board equipment such as the traction motors, compressors, blowers, etc. are switched off manually by the driver before the neutral section is entered. The main circuit breaker (DJ) is also opened. (Warning boards at 500m and 250m before the neutral section are provided for this purpose). (Earlier, locos used to routinely drop their pantographs for all neutral sections; this is no longer standard practice.)

In the case of multiple unit operation, however, pantographs are usually dropped on all the lashed-up locomotives, to avoid the possibility of short-circuiting adjacent sections of the catenary. (The possibility is remote, as normally there is no power flow between lashed-up units, hence the pantographs may not always be dropped, depending on the particular operational procedures of a division.)

Q. Why is the neutral section provided with a dummy (neutral or electrically dead) cable? Why can't it be a real gap?

Pantographs of electric locomotives have a spring mechanism or compressed-air assembly that keeps the pantograph pushing up against the contact wire with a certain specific pressure. If the neutral section were not wired and the contact wire simply ceased to exist, then then possibility exists that if the driver has not dropped the pantographs at the time the loco reaches the neutral section, then the pantograph will suddenly rise upwards unchecked; when the loco reaches the other end of the neutral zone, it is then likely to smash into the catenary where the next contact wire section begins. It should be noted that in practice, at neutral sections where it is or was a requirement to drop the pantographs, it has been observed that IR crews almost never forget to do so. But now with more locos and neutral sections coming up which do not require the pantograph to be dropped, this does become a concern.

Q. How are DC locos swapped for AC locos at the point where traction power changes from DC to AC?

Today [3/05] while the Mumbai area is still mostly at 1.5kV DC, there are a couple of important AC-DC transition points such as Igatpuri -- [2/06] now Kasara -- and Virar. In time, when 25kV AC becomes the norm and DC traction is decommissioned, these transitions will be history and there will be no more traction changeovers! Sad for railfans, but perhaps more efficient for IR. Already, CR has recently [2/06] switched the Kasara - Igatpuri section to 25kV AC.

This is what used to happen at Igatpuri for a DC-AC change. The catenary connected to the DC power supply does not reach all the way to the catenary connected to the AC power supply; there is a neutral section between them.

```
  --------------|------------------|           
  ||--------------|-----------------|           
  ||--------------|-----------------|           
  ||--------------|-----------------|           
  DC Section    |<----------------- Neutral Section -------------> | AC Section
```
The catenary spanning the neutral section overlaps with both the DC and AC catenary sections as indicated above. This cable can be connected to either the DC or the AC power supply. Before the arrival of the DC loco, this section is connected to the DC supply. Once the loco gets detached and goes off the main line (a DC branch loop is provided for this purpose from the last DC section), the cable spanning the neutral section is switched over to the AC power supply and energized, so that the AC loco can now come in. Before entering neutral sections, electric locos often switch off power temporarily to the traction motors so as to prevent any transient disturbances and sparking.

Because the neutral section is switched between AC and DC supply, it is also known as the *dynamic neutral section* or the *switched neutral section*. This is a different arrangement for DC/AC changeover than at a point like Virar (see below). Also see the article on Mumbai area electrification.

**Q. How do the AC-DC locos (WCAM series) switch from one power source to another on the run?**

At DC/AC changeover points as on the Virar-Vaitarna section, WCAM locos can switch from one power source to another without stopping.

The WCAM-1 has a selector on the rightmost side of horizontal control panel for selecting the pantograph. It has four positions, DC, AC, DC-ALT and AC-ALT. In DC and AC-ALT mode, pantograph with two collector shoes is raised; in AC and DC-ALT, pantograph with one collector shoe is raised. The DC pantograph has two shoes and is thicker in its contact area than the AC pantograph because it has to carry a larger current corresponding to the lower voltage. The ALT positions allow the DC pantograph to be used for AC traction or the AC pantograph to be used for DC traction, in case of damage to one or the other pantograph. I.e., the pantograph itself does not control whether the DC or AC circuitry is in use; the selector switch controls this. In real life, the driver rarely gets a chance to see which pantograph is up; all he knows is the position of selector switch. Sometimes when a damaged pantograph is replaced, a pantograph of a different kind (one shoe instead of two) may be installed; the loco still works, although perhaps suboptimally.

About the only time the driver must raise or lower the pantographs when the locomotive is in motion is at the AC-DC changeover point a little north of Virar on the Virar-Vaitarna section -- at a 'dead zone' or neutral section where there is a length of overhead catenary with no electricity supplied to it, between the AC and DC catenaries. This usually extends for a length of about two or three catenary sections. About a kilometer before this dead zone, a sign alerts driver with a '1000 meters' warning followed by another for '500 meters' and then a sign saying 'Dead Zone'.

Going from Mumbai towards Dahanu, the driver shuts most of the equipment in the loco off (air compressor charged, traction motors cut off, motor generator switched off, etc.), then lowers the DC pantograph and just waits while the loco coasts without power through the dead zone. until the AC section of the catenary is reached. At this point, he raises the AC pantograph. After about 30 seconds, the voltmeter shows 25 kV and he restarts the traction and other equipment.

Note that this arrangement of the catenary is different from that at Igatpuri (see above for DC/AC loco switchover). There, all locos have to stop and wait for the line voltage to be switched on in the intermediate neutral section.
Just before the dead zone, there is also a sign, 'Open DS for speeds below 40km/h '. The 'DS' is the main Disconnecting Switch, a manually operated circuit breaker in the DC supply path from the pantograph, that isolates and grounds the 1.5kV DC downstream circuits from the 25kV supply. If the speed is below 40km/h, the driver needs to keep on accelerating until the very last moment and then throw this switch to isolate the DC circuits on the fly.

This tricky manoeuvre is necessary when the speed is that low, because of the danger of losing momentum and stopping in the dead zone without power in case of any adverse conditions like emergency brake application, or brake pipe parting, etc. (The dead zone is one length of catenary and considering the cross-over structures on the DC and AC sides it is nearly two lengths, hence the loco and train have to have enough momentum for the loco to get across this distance).

Q. What happens if the wrong selection has been made at the wrong time?

Not all IR locos have protection against incorrect line supplies, and the loco can be severely damaged in such cases.

In some cases, this will blow a fusible link located near pantograph, and the driver will have to raise the appropriate ALT pantograph to continue. No further damage is possible because the only equipment that is live when pantograph is being raised is the voltmeter. All others like the compressor, exhauster, and motor-generator have to be switched on manually after the pantograph is raised and the voltmeter shows the correct reading.

Q. What happens if the pantograph isn't lowered when the loco enters the dead zone?

Usually there is no problem, if the master circuit breaker of the loco has been switched off. In most cases of neutral sections, therefore, the driver does not have to lower the pantograph. If a live loco enters this section without its master circuit breaker turned off, then there is a possibility of sparking or transient disturbances, which can trip protective circuits in the loco and bring the train to a halt. (Rarely, it may trip breakers for the OHE and bring all the traffic to a halt.) Regardless of this, and whether or not the pantograph is lowered, once the loco enters the dead zone it loses power and will grind to a halt once it loses its momentum, if it cannot coast all the way to the next live section.

Q. When does the driver have to lower and raise a pantograph on the run?

Normally, pantographs do not have to be lowered and raised on the run. The principal exception is the case of the AC-DC switchover by the WCAM series locos as described above. Other than that, there are a few points where the catenary has a gap (no cable physically present, not even a neutral or dead section), for instance at level crossings where there is provision for extra-tall road traffic, in which case the pantograph has to be lowered as the loco coasts through the gap. The catenary may also be missing for short sections above diamond crossings or complex track configurations. Also, pantographs may be lowered and raised occasionally for troubleshooting if the driver suspects a problem.

In the AC sections, when the phase of the overhead cable's power supply changes (at the 'phase breaks') the pantograph need not be lowered and raised at the dead zone. This happens in many places, e.g., a couple of times on the Virar-Surat, Surat-Baroda routes. Usually the driver will switch off and switch on the equipment in the loco in order to prevent transient effects from damaging the equipment.
Q. Why do locos sometimes use the rear pantograph and sometimes the front pantograph?

There is in principle no difference between using the front and the rear pantographs for most locos as each is fully capable of delivering the required electric current from the catenary to the loco. (The AC-DC locos are special in that each loco is intended for a different traction supply.) Generally on IR there is no need for both pantographs to be raised at once since there are usually no unusual situations such as frost on the catenary or increased current collection requirements seen with other countries' railways.

Yet, it is often seen that there are some definite patterns in pantograph usage. It has been the practice in many areas for locos to always have their rear pantographs up. It is thought that this practice arises from the idea that entanglement of the catenary by the front pantograph may result in damage to the rear pantograph as well as the debris or broken equipment lands on it, and using the rear pantograph lessens the chance of this. However, in recent years, this does not seem to have been adhered to very much. Another pattern that has been seen, especially in northern India, is for the front pantograph to be used extensively in the winter, but not in the warmer months. As a variation of this, it is also known that in certain divisions or zones, orders have been issued for drivers to use the rear pantographs at night. While the reasons for these usage patterns are not entirely clear, it is thought that there is a concern about condensation and the accumulation of dew on the catenary. An adequate technical explanation for the pantograph usage pattern is not known at this time [1/07]. (Please note - theories about falling water from dew on the catenary causing short circuits in loco equipment are implausible considering that locos operate just fine in heavy rain.) It has been suggested that front pantograph use may be a historical vestige from British practice carried over from conditions in the UK where sometimes the front pantograph was raised to scrape ice from the catenary and allow the rear pantograph to collect current fully, but this has not been substantiated either.

For more on Electric traction, regenerative braking etc, proceed to the next page.

Related Sections

- CORE's chronology of IR electrification
- Mumbai Electrification
- How does electric traction work?
- Regenerative Braking
- Tap-changer Operation
- AC Loco Auxiliaries
- Traction Systems - Schematics
- Traction Power Supply Feeding Schematic
- Locomotives (General)
- Electric loco picture gallery

Off-Site Links

- Electric Traction Glossary
• DC Traction Motors
• AC motors and AC locomotives
• AC Locomotives
• Electric Traction Basics

The IRFCA Forums
JOIN NOW!

Note: This site is not officially affiliated with Indian Railways! The official web site of Indian Railways is: http://www.indianrailways.gov.in
Site contact: webmaster@irfca.org
Copyright © 2010, IRFCA.org. About IRFCA  Contact Us  Search this site  Site Map
Links  Acknowledgements  Legal Information & Disclaimers
Electric Loco Tap-changer Operation

by Khalid Kagzi, October 2005

Contents

• Introduction
• Power supply
• Tap-changers
• ABB N32 tap-changer
• Air Servo Motor
• Auxiliary Cam Group Switches
• Relays
• Push-button / Manual operation
• Selsyn Notch Transmitter / Indicator
• Photographs
• Additional Diagrams
Recently I had the chance to visit the Electric Loco Shed at Valsad, and I had the opportunity to shoot a lot of pictures, some of which were of the tap-changers (tapchangers) used in electric locomotives. Below is a write-up on tap-changer operation.

**Introduction**

On the Indian Railways, a large number of electric locomotives are in operation today. Many different models of these locos have been manufactured, many of which have now been scrapped. However, many of those models which are still in service such as the WAM-4, WAP-4, WCAM-1, WCAM-2, WCAM-3, WCAG-1, WAG-5, WAG-7, etc., use almost the same electrical setup (excepting the newer 3-phase AC locos such as the WAP-5 and WAG-9).

In traction duty, the basic characteristics of the traction Vehicle should be such that it can exert a high torque during the starting phase and gradually the torque should decrease and the speed of the vehicle should increase.

These characteristics are obtained in electric locos on the Indian Railways by the use of the series-wound DC traction motor which has an inherent characteristic of exerting a high torque during its starting phase and a high speed during the running phase when the train resistance is minimal.

However in order to have proper speed control over these traction motors the voltage supplied to these motors must be varied. Increasing the voltage to the motor increases its torque and speed and vice-versa.

This variation of voltage is obtained by the use of an on-load tap-changer in the locos.

This is a picture of the tap-changer of a WAM-4 electric locomotive. *(Click to see a larger version.)* More pictures are provided further below, along with an explanation of the components.

**Traction Motor Power Supply Overview**

Before explaining the working of the tap-changer provided in these locos, it will better if the broad outline of the power circuit of these locos is understood properly.
These locos operate on a nominal voltage of 25,000V AC (single phase). The power is supplied from the overhead equipment (OHE). This power is collected from the OHE by the pantograph which then passes it to the main circuit breaker (DJ). From the DJ the supply is fed into the main transformer through a high tension bushing. The transformer is actually composed of two different transformers which are wound on the same steel core. This reduces space requirement and also provides better magnetic coupling.

The first transformer is an autotransformer with around thirty one tappings which are brought out to the tap-changer. The output voltage of the autotransformer depends on the tap at which the selector of the tap-changer is resting. Hence, by changing the position of the tap-changer selector the output voltage of the auto-transformer can be varied conveniently. The Tap-Changer is provided on the high-tension side of the transformer which reduces its size due to the lower current. Insulation is enhanced by filling the selector casing with oil.

The output of the autotransformer is fed to the second transformer which has a fixed ratio and steps down the voltage to a fixed fraction. The output of this second transformer is then fed to the rectifier blocks (RSI 1 and RST 2). These convert the AC into DC. In turn the DC output is fed into a pair of chokes known as smoothing reactors (SL 1 and SL 2). The smoothing reactors are provided to remove the AC ripple which is left over from the rectification cycle.

This smoothed DC is then handed over to the DC switchgear for the line and combination control of the traction motors and then finally to the traction motors themselves.

The subject of this article is the detailed manner in which the above mentioned tap-changer works.

**Tap-changers**

Before going into the details of the actual tap-changer which is used in the Indian Railways locos, it will better to understand in general what tap-changers are.

The output voltage of a transformer varies according to the turns ratio of the primary and the secondary windings of the transformer. It can appreciated that at any point of the primary or the secondary winding the voltage is different from any other point on the same winding because these points are at different ratios with respect to the other winding.

Hence each and every tap brought out from the winding gives a different voltage.

Broadly tap-changers can be divided into two categories-namely off-load and on-load.

Off-load tap-changers cannot be operated while current is flowing in the circuit. Off-load tap-changers are used mainly for non-critical applications where a momentary interruption in the current can be tolerated. Hence, such tap-changers have no use in traction duty.

In traction only on-load tap-changers (OLTC) are used. They are capable of changing the taps rapidly without interrupting the flow of current.

**The Asea Brown-Boveri N-32 Tap-changer**

Although there are many types of OLTCs, the one mainly used on the Indian Railways locos has been designed by Asea Brown Boveri and even today is known as the Brown Boveri type N-32.

This model is a huge success and is used on all the locos which I have mentioned in the introduction.

The general requirements and constraints encountered while designing an OLTC should be clearly understood before going into the specific design of the N-32 type Tap-Changer. This will
also help in understanding the manner in which these have been dealt with in the N-32 type Tap-Changer:

- While the tap is being changed the output current must continue to flow.
- Any two taps must never be directly shorted because the existence of different voltages on the taps causes short-circuit level current to flow between the taps which in addition to damaging the tap-changer can also cause severe damage to the transformer.
- The tap-changer must be able to operate frequently without requiring extensive maintenance.

The N-32 tap-changer has been designed keeping in mind the above mentioned requirements.

In the N-32 Tap-Changer all taps are terminated on a circular contact plate (see Fig. 1) with two concentric circles of contacts. In addition their are two contact rings surrounding the contacts. Two selector arms rotate over the contacts and the rings. One arm provides a short between the outer contact segments and the outer contact ring and the other selector arm provides a short between the inner contact segments and the inner contact ring.

These contacts rings are connected to the transition contactors CGR1 and CGR3 respectively.

In addition a resistance (RGR) is also provided which is inserted momentarily during transition from one notch to another. This insertion and removal of the resistance is carried out by the central contactor CGR2.

Operational details of the N-32 have been described beside each of the diagrams.

In this picture the Transition Contactors (CGR 1, 2, 3) and the Transition Resistance (RGR) as also the selector drum of the Tap Changer are visible clearly. The slotted elements behind the CGR contactors is the RGR. In the front the small cylindrical device with a bluish color with a pipe coming out of its top between the selector drum and the CGR block is the PHGR. The PHGR is a small pump operated by compressed air and is used to circulate the oil in the selector drum. This is done in order to remove impurities which occur in the oil due to particles breaking off from the selector arms and the tap segments due to frequent operation as also nominal arcing occurring during switching. To the right of the Selector Drum a small gear wheel is visible. This is the gear which connects with the Air Servo Motor (SMGR). This motor has been removed from this unit. The SMGR is an interesting study in itself. The shaft of the gear mentioned above is connected to a mechanism in the tap-changer body which operates the selector arms in the drum as also the CGR contactors in a pre-determined and closely co-coordinated sequence. The CGR contactors also have a common drive shaft with rotating cams which ensure that the CGRs operate in their proper sequence.
Figure 1

In the above figure the tap-changer is shown at the position of notch 1 and 2. But its supplying only to notch 1. The long selector is at tap segment 1 which in turn is supplying to the outer contact ring while the short selector is at tap segment 2 and is supplying to the inner contact ring. This ring is connected to CGR3 which is open. During transition from notch 1 to notch 2, CGR2 closes first which brings the RGR into the circuit. Here I should point out that the RGR serves two purposes, first of which is to ensure that when two taps are to be connected together it is done through this resistance which tends to limit the short circuit current which occurs when any two or more taps are connected with each other. Second purpose is to ensure the continuity of supply to the Traction Motors which is carried through the common link above the three contactors.

But a conflict arises while determining the ohmic value of the resistance RGR. If the resistance is too low then when the taps are shorted the short-circuit current would rise to unacceptable levels and if the resistance value is too high then the output voltage would be too low during transition which may cause a jolt when full voltage is restored. Hence, the ohmic value of RGR has to be a compromise between these two extremes.

Now, coming back to the transition from notch 1 to notch 2, CGR2 closes first then CGR1 opens and then CGR3 closes thereby completing the transition. But here you will note that during the transition the selector arms have not moved. As soon as CGR-3 closes the long selector moves to tap segment 3. (See Fig. 2.)
Figure 2

Fig. 2 describes the first phase of transition to notch 3. As CGR-1 is open, no current is flowing through the long selector hence it can move freely between the contacts without causing arcing. As soon as the long selector arrives at tap segment 3 the tap-changer is ready for transition to notch 3. Transition from notch 2 to notch 3 takes place on lines similar to that of the transition between notches 1 and 2. CGR-2 closes then CGR-3 opens and then CGR-1 closes.

As soon as transition to notch 3 is complete the short selector moves to tap segment 4 hence making the tap-changer ready for transition to notch 4. Again the short selector moves while CGR-3 is open so that there is no danger of arcing. (See Fig. 3.) When the short selector arrives at the tap segment 4, transition to notch 4 occurs on lines similar to that of the transition between notches 1 and 2.

Rest of the notches also undergo transition as per the above description. During regression the exact reverse of the transition sequence described above takes place. Although the mechanical process seems to be cumbersome, it's actually very smooth because the basic design is simple and the mechanism is usually well maintained and lubricated with graphite grease.
Figure 3: Transition to Notch 3 completed and transition preparation for notch 4 begins.
Figure 4
The efficiency of the tap-changer can be gauged from the fact that it can operate up to a hundred or more times during a single run of the loco.

As per CLW specifications, the tap-changer must be able to complete a full cycle from first notch to the thirty-second notch in 11-13 seconds and similarly for regression from 32 to 0.

As I've mentioned above the tap-changer is very efficient and smooth but even the best maintained machines sometimes fail. As such in case of failure of any component of the tap-changer it must be ensured that the damage is curtailed as much as possible. For this purpose a series of protective and interlocking relays have been provided and wired in such a way that they can effectively protect the tap-changer and other equipment in the loco. Although detailed circuit descriptions are beyond the scope of this article, I will give a very brief description of the main relays associated with the tap-changer and their place in the larger hierarchy of the locos' complex electrical circuits.

However, before proceeding to the relays, two other sub-assemblies of the tap-changer should also be described without which this article would be incomplete—namely: the air-servo motor (SMGR) and the auxiliary cam group switches ASMGR.

**Air-Servo Motor 'SMGR'**
The SMGR is the motor which drives the mechanism I have described above and it consists of four cylinders which contain pistons driving a common crank-shaft. Depending on the sequence
under which compressed air enters the cylinders the motor can run in each direction as required. In turn the entry of the compressed air into the cylinders is governed by valves provided above the motor. These valves are operated by a camshaft which ensures that the valves operate with proper timing and sequence. This camshaft itself is connected to the crank-shaft of the SMGR and is thus self-perpetuating. It only requires a nudge in either direction to start the motor running in that direction. Hence, no complicated external control is required to run the motor. The Crankshaft also has a heavy flywheel at its other end which enables the motor to run smoothly when required. The above mentioned 'nudge' that I have mentioned is provided by two electro-valves placed opposite each other. One valve is for progression and one for regression. These valves are directly controlled by the master controller (MP) and are designated SMGR VE UP and SMGR VE DOWN, respectively.

As the SMGR is driven by air-operated pistons, it has a high inertia. This ensures that its rotation is highly accurate and does not overshoot. This is very important because each transition between notches requires only a half turn of the motor which (through the various gears) translates into a 10-degree rotation of one of the selectors and a 90-degree rotation of the CGR camshaft.

**Auxiliary Cam Group Switches ASMGR**

The various other electrical circuits and equipments also require feedback from the tap-changer, especially with regard to its current position, etc.

This is achieved by the provision of a number of switches which are operated by rotating cams. Depending on the circular profile cut on the individual cams, the switches open and close in specific sequences. For example some of the switches may remain closed from notches 1-15, another switch may be closed on only the 31st notch. Similarly some of the switches are closed only between notches during transition and some switches are closed only on full notches and remain open during transition.

The camshaft on which the circular discs are mounted is driven directly by the SMGR and this whole control block assembly is mounted adjacent to the SMGR itself.

**Relays associated with the Tap-Changer**

The main relays associated with the tap-changer are Q46, Q49, Q51, Q52, Q44 and QV62.

Q46-Relay GR protection during regression. When the driver puts the MP to 0 position the tap-changer (GR) starts regressing to 0 notch. However, the driver once having put the MP to 0 may not be monitoring the notch indicator and due to some reason the GR may have stopped midway. In such a case relay Q46 acts. It trips the DJ after a time delay of around 5 seconds. It should be noted that although Q46, by itself is not a Time Delay Relay but it acts through relay Q118 which has a time delay of 5 seconds.

Q49-Relay GR Synchronization during MU working -- In order to ensure that all the Tap-Changers work in tandem during MU working Relay Q49 is provided.

Q51-Auto Regression relay -- This relay is used to give regression impulse to the GR in case of wheel-slipping, load-parting, emergency braking, traction supply failure, etc.

Q52-Notch-to-Notch relay -- During progression, this relay ensures that the driver can take only one notch at a time. Even if he keeps the MP at ‘+’ continuously he gets only one notch and must return the MP to ‘N’ before taking the next notch.
QV62 -- Relay to monitor GR reaching '0' position. This relay lights the LSGR lamp on the driver's desk when GR reaches 0 position.

Q44 -- I've kept the explanation of Q44 till the very last because this is probably the most important protective relay related to the tap-changer. Also Q44 relay is a not an ordinary relay but it is a time delay relay. It releases after a delay of 0.6 seconds after the supply to its energizing coil is cut off. In older versions the Q44 was a mechanical relay with a clock mechanism used to bring about the time delay. But newer versions are electronic. Older locos are also being retrofitted with electronic Q44 relays.

Another important feature of the Q44 is that it can be 'wedged' in the closed position, that is in case the Q44 itself becomes defective it can be temporarily wedged so that the DJ can be closed and the section can be cleared.

Coming back to its function with respect to the Tap-Changer, as I've explained above, the transition between two notches must be as fast as possible because the shorting of two taps through the RGR gives rise to almost short-circuit level current which can damage the RGR and the Transformer. Hence, during transition if the tap-changer becomes stuck between notches and the taps remain shorted for a long duration, it can destroy the RGR and the transformer.

In order to prevent such an occurrence there is a contact on the ASMGR which opens between notches, that is during transition. This contact is connected in series with relay Q44. Hence, during transition, supply to relay Q44 coil is interrupted which initiates the de-energizing time delay. However, if during such delay the transition is completed successfully, then the ASMGR contact closes, thereby restoring supply to Q44 and keeps it energised but if the tap-changer gets stuck mid-notch then Q44 drops out and trips the DJ. As such the tap-changer must complete its transition in 0.6 second which is the maximum time which Q44 gives it.

From the above the importance of Q44 can be judged and it should also be ensured drivers do not indulge in wedging the Q44 lightly. Many drivers, for the sake of expediency may wedge Q44 without verifying that nothing is wrong with the tap-changer or some other equipment that the relay protects such as the RSI blocks.

Manual Operation of Tap-Changer and the Air Control Panel

Although the tap-changer is normally controlled by the master controller (MP) sometimes this control may fail. In such a case two other methods of operation have been provided, namely, push-button control and manual control.

Push-buttons are provided on the driver's desk itself, however to initiate push-button control, a switch (ZSMGR) has been provided beside the tap-changer on the air-control panel.

This switch has two positions, 0 and 1. At position 1 normal control through the MP is enabled while at position 0 control through the push-buttons is enabled.

In case of a complete failure of the electrical control system a handle is provided beside the tap-changer which when inserted and operated provides effective control.

The above mentioned equipment is provided on the air-control panel which also has isolating cocks for the SMGR, pressure reducing valves, pressure gauge to indicate supply pressure to SMGR, etc. The isolating cocks, when closed, also cut off the electric supply to the electro-valves used for operating the SMGR. This ensures that during manual operation, incorrect notching does not occur.
It is also important to note that during manual operation relay Q44 shall never be wedged. If Q44 is wedged during manual operation and if the operator sticks the handle mid-way, it can cause heavy damage to the RGR and the transformer and in fact cases of fire have been reported due to this reason.

**Selsyn Notch Transmitter and Indicator**

The notch indicator on the driver's desk is known as the Selsyn Notch Indicator (or Repeater). It has a sensor mounted on the SMGR shaft and is constructed on the lines of a small three-phase generator. When the rotor turns by about 10 degrees per notch it transmits a corresponding deflection on the notch indicator on the driver's desk.

**Photographs**

![Image of the tap-changer of a WAM-4 electric locomotive.](Click to see a larger version.)

In this picture the Transition Contactors (CGR 1, 2, and 3) and the Transition Resistance (RGR) as well as the Selector Drum of the Tap-changer are visible quite clearly. The slotted elements behind the CGR contactors form the RGR. In the front, the small cylindrical device with a bluish colour and a pipe coming out of its top, between the selector drum and the CGR block, is the a pump (PHGR) used to circulate the oil in the selector drum. This is done in order to remove impurities which occur in the oil due to particles breaking off from the selector arms and the tap segments in the course of ordinary (and frequent) operations as also because of a small amount of arcing occurring during switching. The pump is operated by compressed air.

To the right of the Selector Drum a small gear wheel is visible. This is the gear which connects with the Air Servo Motor (SMGR). This motor has been removed from this unit for maintenance and is not visible. The SMGR is an interesting study in itself. The shaft of the gear mentioned above is connected to a mechanism in the tap-changer body which operates the selector arms in the drum as also the CGR. This is a picture of the tap-changer of a WAM-4 electric locomotive contactors in a pre-determined manner and in a closely co-ordinated sequence. The CGR
Contactors also have a common drive-shaft with rotating cams which ensure that the CGRs operate in their proper sequence.

Another picture of the tap-changer of a WAM-4 electric locomotive. *(Click to see a larger version.)*

Yet another view. *(Click to see a larger version.)*
And a final view. *(Click to see a larger version.)*

**Additional Diagrams**

More diagrams follow showing the operation of the tap-changer for transition to notches 3 and 4. Click on any diagram to see a larger version.

Contactors positioned for Notches 1 and 2.
Transition to Notch 3, part 1.

Transition to Notch 3, part 2.

Transition to Notch 3, part 3 / Full Notch 2.
Transition to Notch 3, part 4.

Transition to Notches 3 and 4 completed. CGR 2 opens after CGR 3 has closed.

Related Sections

- Electric Loco Auxiliaries
- Electric Traction
- Electric Locomotives
- Traction Systems - Schematics
- Traction Power Supply Feeding Schematic

The IRFCA Forums
JOIN NOW!

Note: This site is not officially affiliated with Indian Railways! The official web site of Indian Railways is: http://www.indianrailways.gov.in
Site contact: webmaster@irfca.org
Copyright © 2010, IRFCA.org. About IRFCA  Contact Us  Search this site  Site Map  Links  Acknowledgements  Legal Information & Disclaimers
Tao 659

Motor Type TAO-659  Product Overview
CG started manufacturing traction motors type TAO-659 in early 1980’s. The manufacturing is based on the design from Alstom, France, for 25 kV AC loco-motives. The traction motor was then modified with single coil. Subsequently in its latest version, these motors are provided with taper roller bearing arrangement to achieve higher speed and maintenance-free operation. This light weight motor is suitable for 4000 HP, 25 kV AC CO’- CO’, Electric Locomotives type WAM4, WAP1, WAP3, WAG5 and WCAM2 under operation in Indian Railways. These motors are also suitable for dual voltage locomotives such as 25 kV AC / 1500 V DC. This axle hung nose suspended traction motor is designed with robust construction and can be used with different gear-ratios for diversified applications.

Motor Type HS 15250A DC  Product Overview
CG started manufacturing traction motors of type HS-15250A in 1993. The manufacture is based on technical know-how received from M/s. Hitachi Ltd, Japan, who had developed traction motors specially for Indian Railways. The traction motor is designed for 4000 HP and 5000 HP, 25KV AC CO’- CO’ electric locomotives type WAG5, WAP2 and WAG7 being manufactured at Chittaranjan Locomotive Works(CLW). Also the same is being used on AC / DC and DC 5000 HP / 4700 HP locomotives. This axle hung nose suspended traction motor is designed with robust construction and can be used with different gears for diversified applications.

Motor Type 6FXA 7059 AC  Product Overview
CG has successfully started manufacturing of 3-Ø traction motors of type 6FXA 7059 in 1999, with very high power to weight ratio based on technology received from ABB, Switzerland. This traction motor is design and developed for 25 KV AC electric locomotive of 6000 HP, class WAP-5, ‘Bo-Bo’, 3-Ø AC drive system for passenger application being manufactured at CLW Chittaranjan. A fully suspended motor with gear axle hung provides very good angularity on wheel set during running. Brushless, asynchronous traction motor is suitable for inverter-converter drive system with VVVF control, wherein slip and torque are controlled by micro-processor and are also suitable for regenerative braking.
Motor Type 6FRA 6068 AC  Product Overview
Crompton Greaves has successfully started manufacturing of 3-Ø traction motor type 6FRA6068 in 1998 based on technology received from ABB Switzerland. This traction motor is design and developed 25 KV AC electric locomotive of 6000 HP, class WAG-9, ‘Co-Co’, 3-Ø AC drive system for goods application being manufactured at CLW Chittaranjan. Axle hung and nose suspended, brushless, asynchronous traction motor is suitable for inverter - converter drive system with VVVF control, wherein slip and torque are controlled by micro-processor and also suitable for regenerative braking.

WAG 1
- Traction Motors: AEC/Alstom/Siemens MG1420. Two motors (monomotor bogies), force-ventilated, fully suspended.
• Gear Ratio: 3.95:1
• Transformer: MFO, type BOT 3150. 22.5kV / 3000kVA. 32 taps.
• Rectifiers: Secheron A268 Excitrons (four). 510A / 1250V.
• Axle load: 21.3t
• Max. Haulage: 1820t
• Pantographs: Two Faiveley AM-12

[edit] WAG 2

• Traction Motors: Hitachi EFCO HKK (1270kW, 1250V, 1080A, 695rpm, weight 5300kg).
• Transformer: Hitachi AFI AMOC. 32 taps.
• Rectifiers: AEV-48 silicon rectifiers, 2040A / 2550kW.
• Pantographs: Two Faiveley AM-12

[edit] WAG 3

[edit] WAG 4

• Traction Motors: AGEC make, MG 1580 A1 (1160kW, 1270V, 1040A, 690 rpm, weight 5850kg). Fully suspended, bogie-mounted.
• Gear Ratio: 3.95 : 1
• Transformer: Oerlikon BOT 3460. 32 taps.
• Rectifiers: Two GL 82220 silicon rectifiers, 1000A/1270kW/1270V. Weight 650kg each.
• Axle Load: 21.9t
• Hauling capacity: 2000t

[edit] WAG 5

Main article: Indian locomotive class WAG-5

• Traction Motors: Alstom TAO 659 (575kW, 750V, 1070 rpm) or TAO 656; or Hitachi HS 15250A (See description under WAP-4.) Axle-hung, nose-suspended. Six motors.
• Gear Ratio: 62:16 or 62:15 with Alstom motors, some 64:18 (Hitachi motors), many now 58:21 for mixed use.
• Transformer: BHEL, type HETT-3900. 3900kVA, 22.5kV, 182A. 32 taps.
• Rectifiers: Silicon rectifiers (two) using 64 S-18FN-350 diodes each from Hind Rectifier. 2700A / 1050V per cubicle.
• Bogies: Co-Co cast bogies (Alco asymmetric trimount -- shared with WDM-2, WAM-4).
• Axle load: 20t
• Max. Haulage: 2375t
• Pantographs: Two Faiveley AM-12
- Current Ratings: 1100A/10min, 750A continuous

[edit] WAG 6
- Traction Motors: ASEA make (WAG-6A), L3 M 450-2. Six motors, fully suspended, force-ventilated, separately excited, 3100kg; (WAG-6B) Hitachi HS 15556-OIR, bogie mounted, force-ventilated, compound-wound, 3200kg; (WAG-6C) Hitachi HS 15256-UIR, axle-hung nose-suspended, force-ventilated, compound-wound, 3650kg.
- Transformer: (WAG-6A) ASEA: TMZ 21, 7533kVA; (WAG-6B/C) Hitachi AFIC-MS, 6325kVA.
- Thyristor controller: (WAG-6A) 24 YST 45-26P24C thyristors each with 24 YSD35-OIP26 diodes, 2x511V, 2x4500A; (WAG-6B/C) 32 CGOIDA thyristors each with 24 DSP2500A diodes. 2x720A, 850V.
- Pantographs: (WAG-6A) Two Stemman BS 95; (WAG-6B/C) Two Faiveley LV2600

[edit] WAG 7
Main article: [Indian locomotive class WAG-7](https://en.wikipedia.org/wiki/Indian_locomotive_class_WAG-7)
- Traction Motors: Hitachi HS15250-G (a variant of the standard HS15250 with higher current rating (thicker wire gauge, better insulation); see description under WAP-4.) Motors built by CLW and BHEL.
- Gear Ratio: 65:18 (65:16?)
- Transformer: CCL India, type CGTT-5400, 5400kVA, 32 taps.
- Rectifiers: Two silicon rectifiers, cell type S18FN350 (from Hind Rectifier), 64 per bridge, 2700A / 1050V per cubicle.
- Axle load: 20.5t
- Bogies: Alco High-Adhesion bogies, fabricated bogie frame assembly, with unidirectional mounting of traction motors, primary and secondary suspension.
- Hauling Capacity: 3010t
- Pantographs: Two Stone India (Calcutta) type AN-12.
- Current Ratings: 1350A/2min, 1200A/10min, 960A/hr, 900A continuous

[edit] WAG 8
Extremely rare, is about all one can say about this experimental class. These locos (not sure if there was just 1 or 2) were built by BHEL in 1996 and are similar in appearance to the WCAM-2 locos. In power, similar to the WAG-7 at 5000hp. Thyristor chopper control of the DC motors. It probably shared some components with the WCAM-3 which BHEL was building at the time. Thought to have [Flexicoil](https://en.wikipedia.org/wiki/Flexicoil) Mark IV hi-adhesion bogies. More details??

[edit] WAG 9
Main article: [Indian locomotive class WAG-9](https://en.wikipedia.org/wiki/Indian_locomotive_class_WAG-9)
- Manufacturers: ABB, CLW
- Traction Motors: ABB's 6FRA 6068 (850kW, 2180V, 1283/2484 rpm, 270/310A. Weight 2100kg) Axle-hung, nose-suspended.
- Gear Ratio: 77:15 / 64:18
- Transformer: ABB's LOT 6500, 4x1450kVA.
- Power Drive: Power convertor from ABB, type UW-2423-2810 with SG 3000G X H24 GTO thyristors (D 921S45 T diodes), 14 thyristors per unit (two units). Line convertor rated at 2 x 1269V @ 50Hz, with DC link voltage of 2800V. Motor/drive convertor rated at 2180V phase to phase, 971A output current per phase, motor frequency from 0 to 132Hz.
- Hauling capacity: 4250t
- Bogies: Co-Co, ABB bogies; bogie wheel base 1850mm + 1850mm
- Wheel base: 15700mm
- Axle load: 20.5t
- Unsprung mass per axle: 3.984t
- Length over buffers: 20562mm
- Length over headstocks: 19280mm
- Body width: 3152mm
- Cab length: 2434mm
- Pantographs: Two Secheron ES10 1Q3-2500.
- Pantograph locked down height: 4525mm