AC-AC Traction System

For HHP Locomotives
Development of HHP (EMD) Locomotives

IR purchased 4000 HP WDG-4 and WDP-4 locomotives from General Motors, USA in 1995 and 1996.

- For indigenous manufacture of these locomotives, Transfer of Technology contract was also executed with Electro Motive Division of General Motors in 1995.
- 13 WDG-4 locomotives were supplied in fully assembled condition in 1999 to UBL shed of SWR and 8 WDG-4 locomotives were supplied in PKD condition.
- 10 WDP-4 locomotives were supplied in fully assembled condition in 2000 to UBL.
- First indigenous 4000 HP locomotive was manufactured at DLW in March 2002.
## HHP(EMD) Locomotive Manufactured at DLW

<table>
<thead>
<tr>
<th>Locomotive</th>
<th>HP</th>
<th>Year</th>
<th>Loco No with System</th>
<th>Remarks</th>
<th>Loco Population till date</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDG4</td>
<td>4000 GTO</td>
<td>March’02</td>
<td>12022</td>
<td>Siemens TCC,ECC+ EMD LCC</td>
<td>127</td>
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<tr>
<td>WDG4</td>
<td>4000 GTO</td>
<td>March’03</td>
<td>20011</td>
<td>Siemens TCC,ECC+ EMD LCC</td>
<td>43</td>
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<tr>
<td>WDG4</td>
<td>4000 IGBT</td>
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<td>12102</td>
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<tr>
<td>WDG4</td>
<td>4000 IGBT</td>
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<td>20040</td>
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<tr>
<td>WDG4</td>
<td>4500 IGBT</td>
<td>May’07</td>
<td>12114 EMD</td>
<td>EMD(ECC1+TCC) AC-AC System</td>
<td>168</td>
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<tr>
<td></td>
<td></td>
<td>Oct’09</td>
<td>12253 EMD</td>
<td>EMD</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Sept’08</td>
<td>12169 MEDHA</td>
<td>EMD</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Jan’10</td>
<td>12276 SIEMENS</td>
<td>EMD</td>
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<tr>
<td>WDP4B</td>
<td>4500 IGBT</td>
<td>July’08</td>
<td>20047 EMD</td>
<td>EMD(ECC1+TCC) AC-AC System</td>
<td>13</td>
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<tr>
<td></td>
<td></td>
<td>Mar’07</td>
<td>20040 EMD</td>
<td>EMD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apr’10</td>
<td>40001 MEDHA</td>
<td>EMD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sept’10</td>
<td>40018 SIEMENS</td>
<td>EMD</td>
<td></td>
</tr>
</tbody>
</table>
## HHP(EMD) Locomotive Manufactured at DLW

<table>
<thead>
<tr>
<th>Locomotive</th>
<th>HP</th>
<th>Year</th>
<th>Loco No with System</th>
<th>Remarks</th>
<th>Loco Population till date</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDP4D</td>
<td>4500 IGBT</td>
<td>Sept’10</td>
<td>40014 MEDHA</td>
<td>AC-AC System with Dual Cab</td>
<td>MEDHA -40</td>
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<td>Aug’12</td>
<td>40090 SIEMENS</td>
<td>AC-AC System with Dual Cab</td>
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<tr>
<td>WDG4D</td>
<td>4500 IGBT</td>
<td>Dec’12</td>
<td>12681 MEDHA</td>
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<tr>
<td>WDG5</td>
<td>5500 IGBT</td>
<td>Feb’12</td>
<td>50001 EMD</td>
<td>AC-AC System</td>
<td>EMD - 1</td>
</tr>
</tbody>
</table>
Is Horse Power alone a relevant factor?

- Locomotive HP is relevant in the context of eventual balancing speed for a particular load.

- Importantly the Tractive Effort determines the capability of a locomotive to start trains on different grades.
ADVANTAGES OF AC-AC OVER AC-DC SYSTEM

- Substantially more adhesion and tractive effort than AC-DC system.

- Lower maintenance and better reliability due to absence of commutator and carbon brushes.

- No contactors and switches for transition and reversal.

- AC-AC technology permits finer control and is tolerant to wheel slip.

- All modern locomotives with high Tractive effort are with AC-AC technology.
Basics of Traction Control System

• The demand for control of electric power for electric motor drive system and industrial controls existed for many years, and this led to early development of the Ward – Leonard system to obtain a variable dc voltage for the control of dc motor drives.

\[ V = K \Omega w \]
\[ T = K \Omega I \]
\[ P = \omega T \]
Basics of Traction Control System

- Power Electronics have revolutionized the concept of power control for power conversion and for control of electrical motor drives.

- Power electronics means “power, electronics and control”.

- Power deals with the static and rotating power equipment for the generation, transmission and distribution of electric power.

- Electronics deal with the solid-state devices and circuits for signal processing to meet the desired controlled objectives.

- Control deals with the steady state and dynamic characteristics of closed loop systems.
• Power electronics may be defined as the applications of solid state electronics for the control and conversion of electric power.

• Power electronics is based primarily on the switching of the power semiconductor devices. With the development of semiconductor technology, the power handling capabilities and the switching speed of the power devices have improved tremendously.

• The development of microprocessor/microcomputer technology has a great impact on control and the application for the power semiconductor devices.
Semiconductor Devices

- Diode
- Thyristors (SCR)
- GTO
- IGBT
Gate Turn-Off Thyristor (GTO)
Insulated-gate Bipolar Transistor (IGBT)
GTO

- Older technology (developed in 1960’s)
- Requires high power for control
- Requires complex snubber circuits
- Lower efficiency
- Switching frequency is low.

IGBT

- Newer technology (developed in 1980’s)
- Low power required for control
- No snubber circuits needed
- Higher efficiency
- Switching frequency is high
Half Wave Rectifier

Full Wave Rectifier

OUR LOCOS MOVE THE NATION
DC-DC Converter

1Ø Inverter
3Ø Inverter

Gate Pulse for IGBT (V/f control)

(a) Gate signal generation

(b) Output voltage

OUR LOCOS MOVE THE NATION
## Features

<table>
<thead>
<tr>
<th></th>
<th>MEDHA</th>
<th>SIEMENS</th>
<th>EMD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drive</strong></td>
<td>Individual motor control</td>
<td>Individual bogie control</td>
<td>Individual bogie control</td>
</tr>
<tr>
<td><strong>Invertors</strong></td>
<td>Six traction invertors for each traction motor</td>
<td>Two traction invertors for each bogie</td>
<td>Two traction invertors for each bogie</td>
</tr>
<tr>
<td><strong>IGBT Devices</strong></td>
<td>ABB make, $V = 6.5 , K , V$, $I = 600\text{Amps}$, 2 devices/phase module</td>
<td>Siemens make, $V = 6.5 , K , V$, $I = 600\text{Amps}$, 6 devices /phase module (total 6 phase module used) Now RDSO has given clearance for 4.5 with 1200 Amps</td>
<td>Mitsubishi make, $V = 4.5 , K , V$, $I = 1200\text{Amps}$, 4 devices /phase module</td>
</tr>
</tbody>
</table>
Medha IGBT schematic
Motor Control

Total Phase Module-18

OUR LOCOS MOVE THE NATION
Siemens IGBT schematic

Bogie Control

Phase Module

Total Phase Module-12

OUR LOCOS MOVE THE NATION
EMD IGBT Schematic
Bogie Control

Total Phase Module-12

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Sinusoidal Pulse-Width Modulation

- In multiple-pulse modulation, all pulses are the same width.
- In Sinusoidal Pulse width Modulation, pulse width vary according to the amplitude of a sine wave evaluated at the center of the same pulse.
Generate the same gate pulses with one sine wave

\[ M = \frac{A_r}{A_c} \]
OUR LOCOS MOVE THE NATION
Generate the gating signal

2 Reference Signals, $v_r$, $-v_r$
Comparing the carrier and reference signals
3-Ø AC motor

Constant torque region
Increasing V and f - Constant V/f & field.

Field weakening region
(N=120xf/P)
Increasing f - constant V and I.
AC-AC TRACTION SYSTEM
Diesel Electric Locomotive
Energy conversion

Chemical energy → DIESEL ENGINE → Mechanical energy → Generator → Electrical energy → Motor → Kinetic energy
AC-AC TRACTION DRIVE

- DIESEL ENGINE
- ALTERNATOR & RECTIFIER
- DC LINK & CAPACITOR
- TRACTION CONTROL CONVERTER
- TRACTION MOTOR
- FLEXIBLE COUPLING
- 3 PHASE CONTROLLED OUTPUT

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Location of Electrical Machines

- DB Fans
- Alternator
- Aux Gen
- Radiator Cooling Fans

ECC1
TCC
ECC#2
Right side
ECC#3
Right side
AC-AC LOCO CONTROL SYSTEM AND TRACTION INVERTERS

- **Auxiliary Generator**
- **Grid Resistors**
- **Diesel Engine**
- **Governor**
- **Traction Alternator**
- **Companion Alternator**
- **Sensors**
- **DID Display Unit**
- **Braking System**
- **DPC**
- **Locomotive Control Computer**
  - Excitation
  - Propulsion
  - AG Control
  - Engine Control

**TCC**
- TC + TI
- TC + TI
- TC + TI
- TC + TI
- TC + TI

**Control Console**


- **OUR LOCOS MOVE THE NATION**
OUR LOCOS MOVE THE NATION

IGBT BASED TCC BY M/S. SIEMENS & EMD

- **SCR ASSLY**
  - EXCITATION CONTROL
  - ALTERNATOR & RECTIFIER
    - LOCO CONTROL COMPUTER
      - BRAKE CONTROL
        - IGBT TCC # 1
          - NEW
          - FRONT BOGIE (TRAC. MOTOR – 1, 2, 3)
        - IGBT TCC # 2
          - NEW
          - REAR BOGIE (TRAC. MOTOR – 4, 5, 6)
AC-AC Traction System:

- **TCC** Traction Control Converter
- **ECC1** Electrical Control Cabinet #1
- **ECC2** Electrical Control Cabinet #2
- **ECC3** Electrical Control Cabinet #3
TCC(Traction Control Converter)

- Traction inverter TCC1 and traction inverter TCC2 invert the DC link voltage into variable voltage, variable frequency, 3 phase AC power for the induction traction motors. Inverters are controlled by a primary computer known as the EM2000 Locomotive Control Computer (LCC) that monitors and controls many locomotive functions.
- Houses the IGBT modules, TCU, DC link capacitor.
OUR LOCOS MOVE THE NATION
**Technical Details**

- **Input:**
  - Voltage: 620 - 2600 V DC (max 2700 VDC in DB)
  - Current: max 1200 A DC

- **Output**
  - Voltage: 0 V AC --- 2000 V 3Φ AC
  - Current: max 1100 A AC
  - Frequency: 0 Hz - 110 Hz
  - DC link Capacitor: 7mF (4 x 1.75 mF)
  - TCU supply: 74 V from ECC#1.

- **Weight:** 2400 Kg
- **Outer Dimension:** l x w x h = 1833 x 2140 x 1450 mm
- **IGBT Modules for PWM Inverters** (3 nos) contains mainly all power devices required to convert DC link voltage to 3Ø AC for TM.

- **Gate control circuit** converts the control signals into Gate trigger signals for the IGBTs for PWM inverter.

- **Protection Thyristor Set Crowbar modules:** Used for surge protection and discharge of DC link capacitor voltage.
DC LINK CAPACITORS (C1,C2,C3,C4): stabilize the DC-link voltage. The capacitors -C1 and -C2 are used for one inverter section and -C3, -C4 are used for the other inverter section inside TCC (1.75mF, 2800 V DC).

Discharge Resistor (-R11, -R12, -R21, -R22): They are connected in series and across the DC-link. The center point is tied to the locomotive ground together. They keep the DC-link voltage symmetrical to ground.

Crowbar Resistor (IPR1, IPR2): The crowbar resistor is used to dissipate DC-link energy if hazardous DC link voltages occur. It is located outside the inverter. Having resistance, nominal R = 2.94 Ω

Voltage across resistor
- Rated U = 3040 V DC
- Peak U = 3600V
**DC-link Voltage Transducer** (-U31, -U32): Function: The transducer measures the DC-link voltage. The output is a current proportional to the applied voltage on input side.

**Motor Current Transducer** (U11, U12, U21, U22): measures the inverter output current. The output is a current proportional to the primary current.

**SIBAS (TCU) FILTER-Z1:** The filter protects the TCU transients on the 74 V DC supply.

**DC-DC Converter (Power supply)**: The power supply converts the battery voltage from 74V DC to 24V DC. This voltage is used to supply the IGBT phase modules.
SIBAS is German name for Siemens Traction control system and it is developed specially for Rail applications. SIBAS is a platform and the units used in WDG4 / WDP4 locomotives have the following sub units / cards. In this chassis total 19 nos cards available.
Central Processing Unit (CPU) G075

- It is the main processing unit in Sibas32.
- It communicates with EM2000 externally and with SIP (Signal Processing Unit) modules internally.
- A 32-bit microprocessor Am486DX-2 is used.
- It has various control logic and memories.
- The CPU is equipped with a 16 Mb EPROM.
Comparison of features of different AC-AC Traction System make:

<table>
<thead>
<tr>
<th>Features</th>
<th>MEDHA</th>
<th>SIEMENS</th>
<th>EMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCC</td>
<td>In house of ECC#1</td>
<td>In house of TCC</td>
<td>In house of ECC#1</td>
</tr>
<tr>
<td>Traction Computer</td>
<td>In house of TCC</td>
<td>In house of TCC</td>
<td>In house of ECC#1</td>
</tr>
<tr>
<td>DCL</td>
<td>In house of TCC</td>
<td>In house of TCC</td>
<td>In house of ECC#1</td>
</tr>
</tbody>
</table>
ECC#1 (HVC#1)

- CB Panel
- Test Panel
- SCR Assembly
- GP RELAY
- LCC
- B3,B4 Contactor
- DCL Contactor

OUR LOCOS MOVE THE NATION
The ECC#1 panel of WDG4/WDP4B locomotives is basically high voltage cabinet (HVC).

Houses the Loco Control Computer chassis & power supply chassis.

Electromagnetic contractors (Braking contactors), DCL contactors,

SCR bridge assembly, various ckt brakers, Relays, various types of TBs, insulated bus bars and plugs.
- MAIN CONTROL PANEL
- ENGINE CONTROL PANEL
- CIRCUIT BREAKER PANEL
- DC LINK SWITCH GEAR
- BRAKING CONTACTORS
- EM2000 COMPUTER CHASSIS
- EM2000 Module
- TCC BLOWER CONTACTORS –
- DISPLAY Unit (DID)
- SCR BRIDGE
DC LINK SWITCH GEAR(DCL123/R1, DCL456/L1): Used for transfer DC link current to TCC.

DYNAMIC BRAKING CONTACTORS (B1, B2, B3, B4) During DB operation the DC link energy from the TM applied to the grids, through the braking contactors, and dissipated as heat. Contactors are rated to carry 1200 amperes. Brake contactors B1 and B2 connect grids to the DC link with B1 at the positive side of the link whereas B3 and B4 connect grids to the DC link with B3 at the positive side of the link.

IMGF(GENERATOR FIELD CURRENT TRANSDUCER): Current transducer placed in series of the Main Generator Field circuit and SCR, which provides EM2000 with an accurate field current measurement.
- **TCC 1 SS-TCC 2 SS – TCC BLOWER CONTACTORS 02 NOS.** These contactors connect three phase AC from the companion alternator to the TCC’s blower motors. The auxiliary interlocks provide contactor status feedback to EM2000.

- **GFC (GEN. FIELD CONT.)** provides AC O/P from CA to SCR. The contactor picks up when circuits are complete for power operation, dynamic braking, or load testing. Controlled by EM2000.

- **1B1-2 (GRID PATH #1 AND #2 CURRENT TRANSDUCERS):** Current Transducers measure current in both grid paths.

- **IBKBL1,IBKBL2 TRANSDUCERS:** Current Transducers measure grids blower motor current to communicate EM2000 regarding open/shorted motor condition and seized bearings.
TCC 1 & 2 - DC LINK CURRENT TRANSUDCERS: These current transducers measure the DC Link current to each inverter & communicates to EM2000.

SCR BRIDGE (SILICON CONTROLLED RECTIFIER): AC power from the companion alternator is rectified and applied to the main generator in controlled amounts by this rectifier assembly. The locomotive control computer (EM2000) determines how much power the SCR conducts to the generator field.
2 Pole /to connect /disconnect & as a safety for control circuit.

2 POLE CIRCUIT BREAKER

- 3 Amp: DCL, EVENT RECORDER
- 15 Amp: COMPUTER CONTROL, AC CONTROL, CAB FAN, AIR DRYER, CCB.
- 10 Amp: TCC1, TCC2, AUX GEN FEEDBACK, AUX. GEN FIELD
- 30 Amp: FUEL PUMP, TURBO, LIGHT, GOV. BOOSTER PUMP, LOCAL CONTROL, TCC BLOWER, FILTER BLOWER
- 35 Amp: HLPB (Head Light)
- 40 Amp: CONTROL

3 POLE CIRCUIT BREAKER

- 50 Amp: TCC-TCC2 BLOWER
- 90 AMP: GEN FIELD
This panel is used by maintenance personnel to measure:

- main generator field voltage (DC)
- companion alternator voltage (Max 230VAC)
- battery voltage (DC).
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Engine Control Panel

- Isolation, Run/start Switch
- Emergency Fuel Cutoff Sw.
- Engine Prime / Start Switch
- Marker Light Switch
- Engine Room Light
- Dynamic Brake cut out switch
- Battery Ammeter
- Alerter Alarm
## EMD LCC Modules

<table>
<thead>
<tr>
<th>Modules</th>
<th>Qty/Loco</th>
</tr>
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<tbody>
<tr>
<td>Central Processing Memory Module (CPM500)</td>
<td>1 No</td>
</tr>
<tr>
<td>Signal Conditioning Module (SCM300)</td>
<td>1 No</td>
</tr>
<tr>
<td>Analog to Digital to Analog Module (ADA305)</td>
<td>2 Nos</td>
</tr>
<tr>
<td>Digital Input Output Modules (DIO300)</td>
<td>3 Nos</td>
</tr>
<tr>
<td>Firing Circuit Feedback Module (FCF301)</td>
<td>1 No</td>
</tr>
<tr>
<td>Firing Circuit Driver Module (FCD300)</td>
<td>1 No</td>
</tr>
<tr>
<td>Main Processing Unit Module (MPU 400)</td>
<td>2 Nos</td>
</tr>
<tr>
<td>Analog Signal Conditioning Module (ASC300)</td>
<td>1 No</td>
</tr>
<tr>
<td>Trainline Filter Module (TLF301)</td>
<td>1 No</td>
</tr>
<tr>
<td>Power Supply Modules (PRM305, PRM312, PRM315 &amp; PRG301)</td>
<td>4 Nos</td>
</tr>
<tr>
<td>Digital Voltage Regulator Module (DVR301)</td>
<td>1 No</td>
</tr>
</tbody>
</table>
- **CPM 500: CENTRAL PROCESSING UNIT & MEMORY**: The CPU module contains the central processing unit which performs the actual computing operation. The MEM module is the archive memory that remembers the dynamic locomotive parameters and archive fault and operational data that is required when all power has been removed from the EM2000 system.

- **SCM300: COMMUNICATIONS**: The COM module provides an interface for communication between the EM2000 locomotive computer, with Knorr air brake system computer.

- **DIO300: DIGITAL INPUT/OUTPUT MODULE**: The digital inputs and outputs to and from EM2000 are handled by the 3 DIO modules. The DIO modules act as an interface between the locomotives 74VDC systems and the computer 5 VDC system.

- **ADA305: ANALOG TO DIGITAL TO ANALOG**: The ADA module converts analog input signals (Pressure-Temperature-Voltage-Current-Speed) into digital signals for the computer and converts digital computer output signals into analog signals. (Speed indicators, tractive effort meter)
**DVR301 : DIGITAL VOLTAGE REGULATOR:** The DVR module regulates auxiliary generator output by controlling auxiliary generator field current. The auxiliary generator output voltage can vary from 72.5V to 77.5 V depending on battery box ambient temperature.

**FCD300: FIRING CONTROL DRIVER:** The FCD module amplifies the SCR’s gate signals from the EM2000 CPU. The Green LED on the module faceplate must be “ON” during normal operation.

**FCF300: FIRING CONTROL FEEDBACK MODULE:** The FCF module provides feedback from the Companion Alternator to the EM2000 CPU. This module contains the zero cross detection circuit which tells the CPU when each of the companion alternators phase crosses from the negative half cycle to the positive half cycle.

**ASC300: ANALOG SIGNAL CONDITIONER MODULE:** The ASC module converts and conditions analog feedback signals into DC voltage signals that are suitable for the Analog to Digital to Analog module ADA.

**TLF301: TRAINLINE FILTER MODULE:** The TLF module converts the +74 VDC train line signals into a form that can be processed by the EM2000.
PRG 301 POWER REGULATOR: The PRG 300 is the power conditioner for the PSM modules. It received its input from the Aux. Gen./Battery circuitry and will function properly when the input voltage is between 20 to 95 VDC, and output voltage to 64-73 VDC.

PSM 305 POWER SUPPLY MODULE: The PSM 305 steps down the 74 VDC input from the PRG 301 to +5 VDC and distributes the power to the computer chassis.

PSM 312 POWER SUPPLY MODULE: The PSM 312 steps down the 74 VDC input from the PRG 301 to +/- 12 VDC and distributes the power to the computer chassis.

PSM 315 POWER SUPPLY MODULE: The PSM 315 steps down the 74 VDC input from the PRG 300 to +/- 15 VDC and distributes the power to the PDPs (Power distribution panels) and the computer display screen.
• Self- Tests
  – Air Brake Test
  – DCL Shorting Test
  – Self Load(B1-B4)
  – Excitation / SCR
  – Wheel Slip
  – Contactors / Relays
  – Cooling Fans
  – Radar
  – TE Meters
  – TCC Blowers
The ECC#2 panel of WDG4/WDP4B locomotives houses the resistor ST1 & ST2, Auxiliary starting Contactor (STA), ST (Starting Contactor), Battery Charging Assembly (BC Asm), Circuit Breaker Aux. Generator & Terminal Boards are in the use for EMD locomotives.
ECC#2

Aux Gen CB

ST,STA CONTACTORS

BCASM - BATTERY CHARGING ASSEMBLY

RE 11 & RE 12 RESISTORS IN STARTING CIRCUIT

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ECC#3

- The ECC#3 panel of WDG4/WDP4B locomotives, houses the FCF1A, FCF2A, FCF1B, FCF2B, FCS1, FCS2 Contactors, MRPT (Main Reservoir Pressure Transducer), DIP80 (Diode Input Panel), CMU4 (Connector Multiplex Circuit) and terminal boards are in use for EMD locomotives.
OUR LOCOS MOVE THE NATION

3P CBs FOR RADIATOR FAN

MRPT SENSOR

DIP MODULE

AIR FILTER

COOLING FAN CONTACTORS - SIX NOS.
FEATURES AVAILABLE IN HHP Locomotives

- LOW IDLE (to save fuel)
- BLENDED BRAKE
- AUTOMATIC EMERGENCY BRAKE SYSTEM (AEB)
- SPEEDUP OF COLD ENGINE
- SELF LOAD TEST
- PRE/POST LUBE
- Hot Engine Control
- AIR COMPRESSOR CONTROL
- TRACTIVE EFFORT LIMITING
- EVENT RECORDER
- VIGILANCE CONTROL SYSTEM
**LOW IDLE:**

When the locomotive is in IDLE for more than 10 minutes, The LCC give commands to governor for reducing the engine RPM is to 200 rpm by energizing AV and DV for reducing the fuel oil consumption.

- **Full Speed (at 8th notch)**: 954 RPM
  - **Normal Idle Speed**: 269 RPM
  - **Low Idle Speed**: 200 RPM

**BLENDED BRAKE:**

With provision of this feature, the LCC and the air brake computer apply both air and dynamic braking in proportion on the locomotive when the AUTO brake handle is anywhere in the SERVICE ZONE. (a slide switch has been provided in Switch panel for CUT IN/CUT OUT for enable /disabling of feature).

**AUTOMATIC EMERGENCY BRAKE SYSTEM (AEB):**

Indian railway is having steep Ghat sections upto 1 in 37 continuous falling gradient. "A run away train" can take place when the driver is incapacitated or fails to apply any type of brake or the driver reacts very late for brake application. To avoid such "run away train" automatic penalty brake application feature is required in a locomotive operating in the ghat section. The system should automatically operate to apply the brake at a pre-determined speed (25 KMPH) through user variable parameter option.
**SPEEDUP OF COLD ENGINE:**

- Raising of engine rpm on TH2 for rising the water temperature above 125°F (If temp is below 115°F).
- Above 125°F engine return to idle.
- Engine water inlet temperature should be allowed to reach 49°C (120°F) at idle before moving the throttle handle above TH2 position.

**SELF LOAD TEST:**

- The self-load testing will result in reduction in maintenance time & result in manpower savings.
- It facilitates load testing of the loco instantaneously at any place without changing any connections.
- The microprocessor automatically configures the power circuit to connect the dynamic brake grids as a fixed resistive load to the traction alternator.
- A fixed resistor external resistor load box is therefore not required.

**PRE/POST Lube:**

- A separate automatically started motor driven turbocharger lube oil pump is used to supply oil to the turbocharger prior to starting the engine and whenever the engine is shut down.
- HOT ENGINE CONDITION:
  - The engine cooling water temperature is sensed at the water pump inlet.
  - When the temperature becomes excessively high, the computer will display the “HOT ENGINE - THROTTLE 6 LIMIT” message & limit engine loading when operating in throttle position 7 or 8.
  - This condition will remain in effect until the temperature returns to a safe limit.

- AIR COMPRESSOR CONTROL:
  - LCC controls the loading/unloading of compressor through Magnet Valve MV-CC (Magnet Valve Compressor Control).
  - The LCC reads main reservoir air pressure from the main reservoir pressure transducer, or MRPT placed in ECC-3.
- **AIR DRYER CONTROL:**
  - The compressed air from the air compressor contains moisture which can be detrimental to the air system components.
  - The operation of the dryer is controlled by LCC. The computer controls the operation.

- **Vigilance Control System:**
  The vigilance function is performed by LCC. When the locomotive brakes are released, the computer requests an acknowledgment from the locomotive operator from time to time (Vigilance cycle reset button pressed, Change of throttle handle position, Application of dynamic brakes, Operation of horns, Operations of sanders, Application of brakes).
**TRACTIVE EFFORT LIMITING**

- Tractive Effort Limiting feature shall be implemented through a manual switch (TE LIMIT) by limiting the tractive effort to 29.4 tonne.

**Event Recorder:**

- This data is useful for accident analysis purpose.
- In this there are 2 types of recording, Short term and Long term in both Internal & External memories.
- Internal recording is inbuilt in to the system & External is additional memory card is provided.
- Short term is for every 1 sec for the last 12 hours of data
- Long term is for every 20 sec for 90 days of data.
- In MEDHA system, it is inbuilt in to the system, whereas in EMD & Siemens it is additional unit fitted in ECC#1.
**Event Recorder:**

This system records the following events in memory unit:

- Train Brake pipe pressure Kg/cm²
- Loco Brake Cylinder pressure Kg/cm²
- Operation of VCD - Status of penalty brake application (T2 cycle)
- Operation of VCD - Status of penalty brake application (T3 cycle)
- VCD Acknowledgement/Reset switch
- VCD fail
- Vigilance control system Isolated
- Notch position (idle, 1st to 8th)
- Status of power application (motoring/braking)
- Direction of movement of loco (FOR/REV)
- Locomotive speed (Kmph)
- Status (ON/OFF and Dim/Bright) of headlight
- Status (ON/OFF) of flasher light
- TE limit switch ON/OFF
- Shed name
- Loco No.
- Distance in Km.
- Date
- Real time in hours, minutes and seconds
- TE limit current
M/s Siemens make AC-AC Traction System

- DLW PO No.090950170.09116403 dt 05.10.09 placed on M/s Siemens for supply of two no complete set of AC-AC Traction system for 4500 HP (including LCC, ECC#1,2,3 and TCC).
- The first prototype Loco no 12276 has been manufactured in Jan’10 and dispatched to UBL shed.
- Second set has been fitted on WDP4B Loco nos 40018 at DLW and dispatched to KJM on sept’10.
- Further DLW has placed another PO No.10116598 dt 20.08.10 on M/s Siemens for supply of 10 nos AC-AC traction system and the same has been fitted on WDG4/WDP4B locomotives.
4500 HP WDP4B LOCOMOTIVE WITH HOTEL LOAD
Hotel Load WDP4B Locomotive

- The Hotel load supply of 750 V, 50Hz, 3 phase AC supply fed to coaches from a diesel power car through IV coupler.

- The power for the Hotel load converter is derived from DC link of the locomotive. Firstly Power from DC link fed to Buck Chopper then to Inverter Panel. The Inverter receives power from DC link (through Buck Chopper) with a voltage varying from 1200V to 2600 V and converted to fixed 1050 Volt DC which is input to the Inverter. Inverter provides a suitable output supply at 750±5%, 3 phase 50Hz The hotel Load Converters is rated for 500KVA power which is compatible with existing EOG Power cars.
WDP4D (Twin cab)

- Dual CAB locomotive has two driver cabins with one control console of each cabin.
- The Dual cab Locomotive control is based on BL Key concept of Electric Locomotives. Each CAB will have a BL Key. Existing CAB (SH side) is named as CAB#1 and new CAB (LH side) is named as CAB#2.
- In which cab, BL key is inserted and turned to 'ON', is called Active CAB other one Inactive cab. We can operate locomotive from Active CAB only.
MAJOR ASSEMBLIES OF DUAL CAB LOCOMOTIVE

- Electrical control cabinet ECC#1 (minor modifications)
- Electrical control cabinet ECC#2
- Electrical control cabinet ECC#3
- Electrical control cabinet ECC#4 (new)
- Traction control cabinet TCC
- Control Console for CAB1 (new)
- Control Console for CAB2 (new)
- Harness for Dual cab loco
Proposed layout plan for dual cab control Console for Cab 1 & 2

OUR LOCOS MOVE THE NATION

- **Speedometer**
- **Head Lt sw 1 & 2**
  - Same as Exiting G4/P4B loco
- **Alerter lamp**
- **Switch panel asm (Engine Run, Cont & FP, Gen Field & Dyn. Brake Control CB)**
  - Same as Exiting G4/P4B loco
- **Air gauge complex same as existing G4/P4B loco**
  - (MR/ER, BP/BC & AFI)
- **Sw Panel asm**
  - (Flasher Lt 1 & 2, cab fan, cab lt, gauge lt, attendant call & Dimmer gauge reohastat)
  - Same position as existing G4/P4B loco.
OUR LOCOS MOVE THE NATION
Distributed Power Sytem:

- Distributed power control system is being introduced in WDG₄ locomotives for long haul trains.
**WDG4 with DPC System**

- For operation of longer and heavier trains, locomotives are required to be placed at distributed locations to provide distributed tractive efforts to the train.

- For synchronous operation of these locomotives, control commands are transferred through radio link transmission with control from leading locomotive. This system is called Distributed Power Control System.

- Distributed power control system has been introduced on WDG-4 locomotives. First such system was fitted on loco No. 12169 and 12189 and after successful field trials, these locomotives are working in commercial service.

- Further PO has been placed on M/s Siemens for 8 Loco set DPCS along with Hotel Load. Two DPCS against above PO had fitted in WDG4-12747 & 12748 Locomotives.
CAB EQUIPMENT (Control Consoles)

WDG4 Control Console

- LOCOMOTIVE CONTROLLER
- BRAKE CONTROLLER
- AIR COMPLEX GAUGES
- TE/BE METER
- SPEED INDICATOR
- INDICATING LIGHTS PANEL
- ALERTER
- HORN AND SANDING SW
- FLASHER SWITCH
- FAN/LIGHT SWITCH
Thank You
Indicating Devices, Logics and other communication Interface for HHP locomotive
LCC Logic for controlling HHP loco digital parameters

- Control Console 1 → Digital Inputs
- Control Console 2 → Digital Inputs
- Switches & Breakers → Digital Inputs
- Contactors, Relays, Solenoids, LEDs → Digital Inputs
- Digital Inputs → LCC (Micro Controller)
- Digital Outputs → LCC (Micro Controller)
- LCC (Micro Controller) → Various output devices like contactors, relays etc. are directly energized by the system as per the software logic.
- The status of the output devices are identified through status of their respective auxiliary contacts connected as digital inputs.

Input signals from master handle, start/stop button etc. are directly connected to the system through their respective digital inputs.

Various output devices like contactors, relays etc. are directly energized by the system as per the software logic.

Input signals from master handle, start/stop button etc. are directly connected to the system through their respective digital inputs.

The status of the output devices are identified through status of their respective auxiliary contacts connected as digital inputs.
Various parameters like Voltages, Currents, Pressures, Temperatures are measured through different sensors and are connected as analog inputs to the system.

LCC system will generate required analog outputs to drive meters like Speed, TE/BE meters.
LCC Logic for controlling HHP loco Speed parameters

System will generate two PWM signals to control the field of Auxiliary Generator and Traction Alternators.

Engine RPM signal, Turbo RPM signal and RADAR signals are measured through sensors and are connected as frequency inputs to the system.

Digital Inputs
Aalog Inputs
Analog Outputs
Digital Outputs
LCC (Micro Controller)
SCRD PWM, AG PWM
Speed, TE/BE meters
Voltage Current Pressure Temperature Sensors

Contactors, Relays, Solenoids, LEDs
RADAR, EPU, TPU
Frequency Inputs
Frequency Outputs
Control Console 1
Control Console 2
Contactors, Relays, Solenoids, LEDs
LCC Logic for communication with CCB & Display

Different communication ports are available to communicate with Display unit, CCB etc.,

Control Console 1
Control Console 2

Switches & Breakers

Contactors, Relays, Solenoids, LEDs

RADAR, EPU, TPU

Digital Inputs

Digital Outputs

Display, Data logger, CCB etc

LCC (Micro Controller)

Analog Inputs

Analog Outputs

Frequency Inputs

Frequency Outputs

SCRD PWM, AG PWM

Current Pressure Temperature Sensors

Speed, TE/BE meters
Excitation Control of Main Alternator

- Comp. Alternator
- MGFI
- Main Alternator
- Rectifier Panel
- MGFI
- DC Link Voltage
- To TCC

- Analog Input Interface
- DCLV

- ZCD Txfr. Module
- SCR Assembly
- Gate Drive circuit
- Zero Crossing Detection
- MLCC
Auxiliary Generator Control and Battery Charging (Integrated with LCC)

- Aux. Generator
- Battery Charger
- Analog Input Interface
- MLCC
- Regulated Aux. Voltage 74 V DC (72.5 to 77.5)
- BATI
- BTAT
- PWM DRIVE
Engine Control through Governor Load Control and Control of Auxiliaries

- DIESEL ENGINE
- Governor
- Starter Motor, Turbo Lube Pump, Radiator Fan, etc.
- Control Console
- MLCC
- Digital Input Interface
- Digital Output Interface
- Analog Input Interface
- Solenoid Driving
- Load Control

OUR LOCOS MOVE THE NATION
RADAR Signal

RADAR

TM Speed Input from TCC

Frequency Input

Communication Interface

LCC

Loco Speed calculation
Wheel slip Control
Starting the Engine
Precautions Before Starting the Engine

- Ensure that Throttle Handle of both control console in IDLE, Reverser handle in center position, ISOLATE Switch in ISOLATE position.
- Ensure sufficient oil level of Compressor oil, Engine Lube Oil and Governor Oil.
- Ensure sufficient coolant water level in the water tank (Engine dead – Full).
- Ensure that no one is working on the Engine, Generator Room, Compressor Room etc and all doors are closed.
Precautions Before Starting the Engine

- Ensure that the **MU Engine Stop button** is in RUN position (For RUN press Green portion inside).
- Ensure that the engine **over speed trip mechanism (OST)** is in normal condition.
- Ensure that the **Governor Low Lube Oil shutdown (LOS)** plunger is in reset condition.
- Ensure that the positive **Crankcase (oil pan) pressure** and **Low water pressure detector** reset buttons are reset (pressed inside). If low water button found ejected, press and hold it for 15 seconds.
Steps to Start the Engine

• Close the Battery knife Switch.
• Ensure that the Starting Fuse is installed in good condition and it is correct rating. (800 Amps for WDG4/WDP4B).
• Switch ON all the circuit breakers in a sequence (Black, White & Yellow label) in the Circuit Breaker Panel.
• Switch ON the CONTROL & FP slide switch on control console No. 2. This allows fuel pump to RUN, when FP/ES switch is in Fuel prime or Engine Start position.
Steps to Start the Engine

- Turn the FP / ES switch lever to PRIME and hold it there (normally 10 - 20 sec then release it) until the fuel flows clear and free from bubbles in the return fuel sight glass.
- Turn the FP / ES switch lever to ENGINE START and hold it there until the Engine Start and speed increases to Low Idle RPM (200).
- After holding the engine RPM above 200, release the FP / ES switch.
- Check Low water pressure detector reset button on EPD after Engine start:
  - If the detector trips, press continuously for 15 seconds.
  - If the detector is not reset, the engine shuts down after a short time delay.
 Steps to Start the Engine

CAUTION:

• To prevent over heating of starting motors, which may damage them, system will restrict cranking if time exceeded more than 20 seconds.

• If engine fails to start after cranking for 20 seconds, system will allow cranking after 2 minutes only, to cool starting motors before cranking engine again.
Follow-up actions

- Follow specified standard Railroad precautions in setting of LEAD / TRAIL switch for safe operation.
- Follow correct Air Brake equipment setup procedure to avoid delay and incorrect operation.
- To perform Air Brake System normal working, keep LEAD/TRAIL switch in LEAD position on required control console, in other control console it must be in TRAIL only.
- Check the Display for CREW MESSAGES one by one and follow as per the Computer advice.
- Keep Auto Brake Handle in Full Service on working control console, and observe the following message after 10 seconds.
  - Message: To restore normal Air Brake operation, keep Auto Brake Handle in RUN position.
Stopping the Engine
Stopping the Engine

• The normal way to shutdown a Diesel Engine is to cause the Engine Governor to bring the fuel injector to the NO FUEL position.

• Pressing any of the following switches shuts down the engine.

1. **EFCO/STOP**: The Emergency Fuel Cutoff & Engine Stop push Button switch mounted on the high voltage cabinet Engine control panel in the cab.

2. **EFCO 2**: The emergency fuel cutoff push Button switch mounted on the left side of the locomotive just above the fuel tank filler.
Stopping the Engine

3. **EFCO 3**: The emergency fuel cutoff push button switch mounted on the right side of the Locomotive just above the fuel tank filler.

4. **MU ENG. STOP**: The multiple Engine Stop / Run switch mounted on the control console #2 pressing the STOP portion of this switch stops all engines in the consists.
   - This is the result of the pickup of SDR relay, when SDR picked up, governor DV solenoid energize and Fuel Rack comes to No Fuel position.
Stopping the Engine

Other conditions:

- The Governor will also bring the fuel injectors to the NO FUEL position, if any of the following conditions occurred.
  - Engine lube oil pressure is too low.
  - Engine lube oil is too Hot.
  - Engine coolant water pressure is too low.
  - Engine crank case pressure is too high.
User Interface

Display Unit
Display Unit (MDS737)
Display Unit

- Designed to be “user friendly" for operating and maintenance
- Needs little or no computer experience
- A graphical Vacuum Fluorescent Display has been used as the monitor for this Display Unit
- A ‘DISPLAY ON/OFF’ key has been kept, pressing it once will clear the screen making the display blank
- Various parameters can be monitored, configured and tested through this unit.
Status Display Screens

- These inform the status of the system by means of values of the certain predefined parameters.
- This provides an overview of the present status of the system.
- If any parameter’s value is observed beyond its acceptable limits, appropriate action can be taken by the user.
- These screens can be configured by means of a laptop and a cable.
- These data will be shown if the user requests for these screens from the menu.
- All these screens are configurable through laptop.

![Status Display Screens Image]
Displaying Faults

- The MAS696 system has the ability of recording the faults that are occurring in the system.
- When the faults occur, the system records the values of the parameters at that instant, the previous 5 seconds and the following 3 seconds data for further analysis.
- This data can be downloaded into a pen drive.
Displaying Faults

- The options available at the start of Fault Archive are
  - Display Archive faults,
  - Reset Annunciator
    - “Reset annunciator” option is used to store faults from the time when the user presses this key.
  - Acknowledge
    - The Acknowledge All Faults Option in the menu list will acknowledge all the faults which have acknowledgment pending from the user.
Display Archive faults

- In this option another screen opens up where the user is given the choice of viewing
  - Entire faults
  - All active faults
  - All inactive faults
  - Faults since annunciator
  - Faults since a Date & Time
Display Archive faults

- Display shows fault screen which gives the following information:
  - Loco no
  - Date and time
  - Fault text
  - Number of times the fault occurred in 24 hours time and
  - Fault status of whether the fault is active or inactive or acknowledged.
MAS 696

Other Features
Vigilance Control Device / Alerter

➢ Why VCD....

To stop the train,
If Loco Pilot is INCAPACITATED.

• If Brake Cylinder pressure > 2.3 kg/cm² and loco speed is zero, Alerter cycle will be reset.
• Any driver activity (changing throttle handle or pressing horn push button etc.) Alerter cycle will be reset.
• At least driver has to press Alerter reset push button to reset alerter cycle.
Vigilance Control Device / Alerter

- If any acknowledgment is not received by driver for 60 sec (T0 Cycle), Alerter lamp will be made ON and OFF for 8 sec (T1 Cycle).
- If any acknowledgment is not received by driver for 8 sec (T1 Cycle), Alerter Bell as well as Alerter lamp will be made ON and OFF for 8 sec (T2 Cycle).
- After T2 cycle LCC intimates CCB to apply penalty brakes (T3 Cycle).
- To release penalty brakes bring the throttle handle to IDLE, wait for 35 sec (T3 Cycle).
- After satisfying above conditions, operator has to keep auto handle in Full Service for 10 sec. automatically penalty brakes will release.
TE Limit feature

• To avoid putting stresses on weak bridges when Locomotive is crossing them, TE Limiting option is developed to enable the operator to limit the Tractive Effort through toggle switch mounted on Engine control panel.

• The position of the switch indicates to Railroad personnel that the feature has been turned ON and corresponding Light in Indicating Lights panel glows.

• The tractive effort limit will be imposed by train line Input from another locomotive equipped with this feature via the TEL relay.
While traveling through a terrain with a considerable large Down-Gradient, speed of the Train needs to be kept under control.

Indian Railways have studied and defined optimum speeds for every section.

There is always chance that a manually controlled Locomotive may exceed the section speed limit.

To avoid this, Indian Railways incorporated a system is called "Auto Emergency Brake (AEB) / Restricted Air Penalty Brake (RAPB)" Which by default initiates Braking in the event of Train / Loco crossing the permissible set speed.

This feature can be enabled / disabled through RAPB toggle switch provided on the ECC#1, ECP panel.
CCB communication

- CCB
- Communication
- Micro Air Brake
- BP7
- BN
- CB
- ABP
- ABN
- CSB
- RS485
Blended Brake System

- The MAS 696 system Locomotives are equipped with a blended brake system.
- It simultaneously applies Dynamic Braking and Air Braking, when the loco pilot operates the ‘Auto brake handle’ in the service zone.
- The KNORR CCB Air Brake system controls the Air brake on the Locomotives and cars coupled in train, and request some amount of Dynamic Braking from LCC for blended brake operation.
Blended Braking

Auto Brake Handle

Brake request from Operator

Brake cylinder

Wheel

CCB

System Enables Dynamic Brake

MAS

BB active bit enabled
Radiator Fans Control

- Engine temperature monitored by ETP1 & ETP2
- Max of ETP1 & ETP2 considered as engine temperature.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>System Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 85°C</td>
<td>Fans will be made ON</td>
</tr>
<tr>
<td>&gt; 96°C</td>
<td>Power limited to 6th Notch (RPM remains same)</td>
</tr>
<tr>
<td>&gt; 101°C</td>
<td>Hot Engine Indication (RPM + power limited to 6th Notch)</td>
</tr>
<tr>
<td>&gt; 101°C for 5 min</td>
<td>Hot Engine - Extended Time (Engine will come to IDLE)</td>
</tr>
</tbody>
</table>
Indication Lights Panel
Auto Flasher

- The flasher lights will operate automatically whenever Emergency / Penalty brake application taken place
  - This is indicated by the 'Loss of PCS' through the PCR relay dropped by Computer Controlled Brake (CCB) system.
- The flasher can be turned ON manually, if the operator have an emergency, which does not drop PCS.
Wheel Slip Light

- Four conditions cause the wheel slip light to switch ON:
  1. Locked wheel due to mechanically locked Pinion
  2. Wheel Slipping momentarily due to Rail conditions are exceptionally poor
  3. Wheel Slip Light by Train line from consist Locomotives
  4. Wheel Over speed

Note: Need not reduce the throttle, as long as loco is working, during minor wheel slips.
SAND Light

- It indicates that a sanding request has been made to the Locomotive Computer by means of:
  - MANUAL SAND switch actuation on this Locomotive or any Train line to this Locomotive.
    - Manual sanding is allowed only up to 19.6 Km/hr in Motoring.
  - Other Sanding request made by the Automatic function (to help wheel creep or wheel slip control).
Salient features

- Internationally acclaimed IGBT Based Inverter Technology
- Independent Traction Motor Control
- Dual redundant OFC Communication
- Elimination of DVR – Integrated control for Auxiliary Generator
- Traction Inverters designed for 4500 HP power level
- Mounting comparability with existing enclosures for ECC#1, ECC#2, ECC#3, TCC
- Three level DC link over voltage protection
  - 1. Brake Chopper
  - 2. Hard Crow bar Fired by S/W
  - 3. Hard Crow bar Fired by H/W.
Salient features

- All the circuit breakers feedback monitored by system. If any breaker trips, appropriate message will be displayed.
- Integrated Event Recorder – On Card (Internal) and Memory Card (External) data recording.
- Removable Memory Card under lock and key.
- Comprehensive Fault data packs - 5 seconds prior to 3 seconds later of fault instant.
- Data pack analysis can be done thru display itself.
- USB based data down loading and configuration.
- Data downloading thru pen drive.
- Cumulative Data (Life Time Counters).
Salient features

- Fault message, crew message descriptions can be easily changed through laptop.
- Non multiplexed sensing of digital inputs and control of digital outputs.
- Driver ID, Train No, Section name etc setting through display keyboard.
- Forced Air cooled IGBT Heat sinks with heat pipe technology.
- Individual blower for cooling for IGBT heat sink with control at low, medium, and high speeds.
- OFC based IGBT gate drive signal.
Thank You