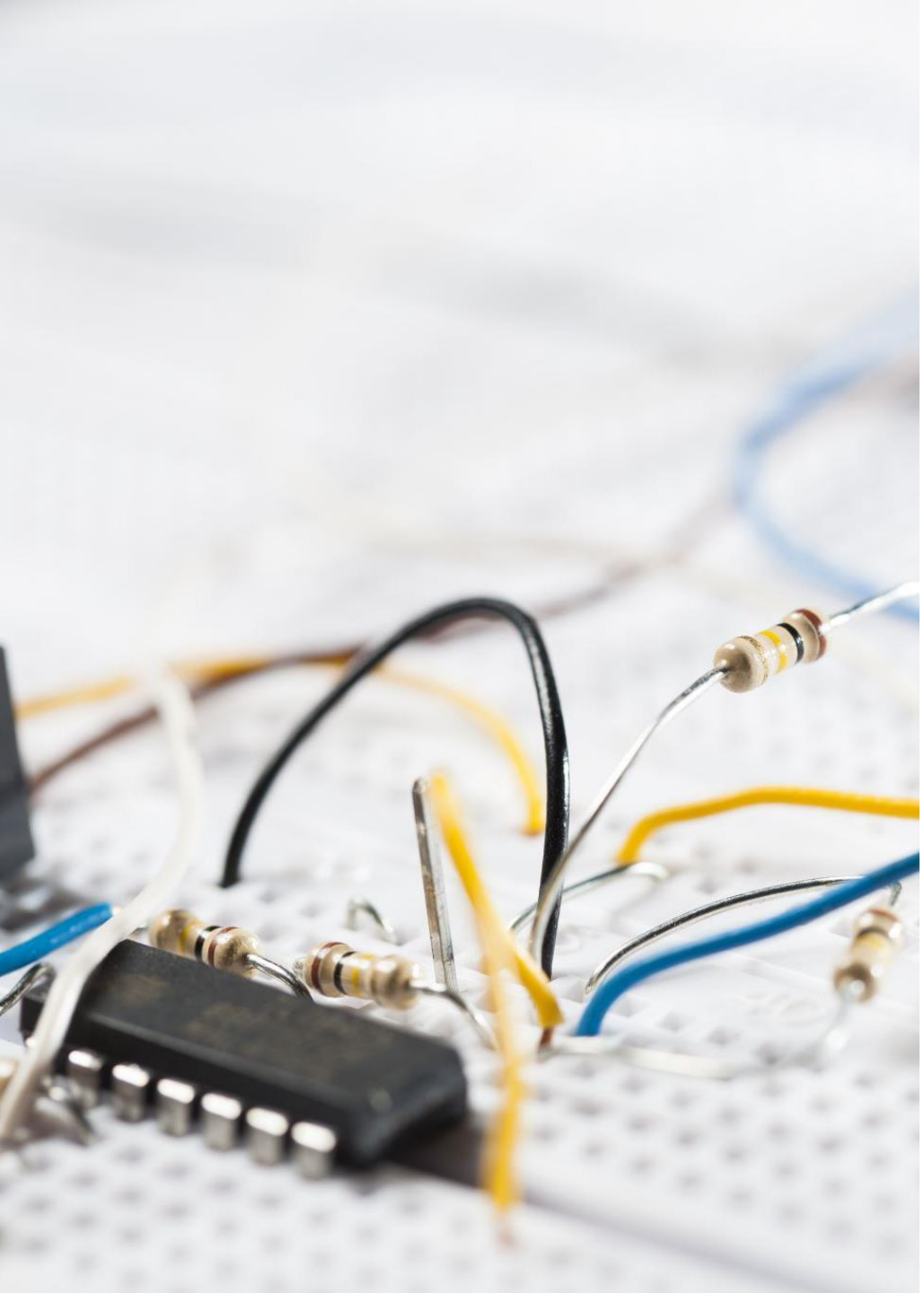


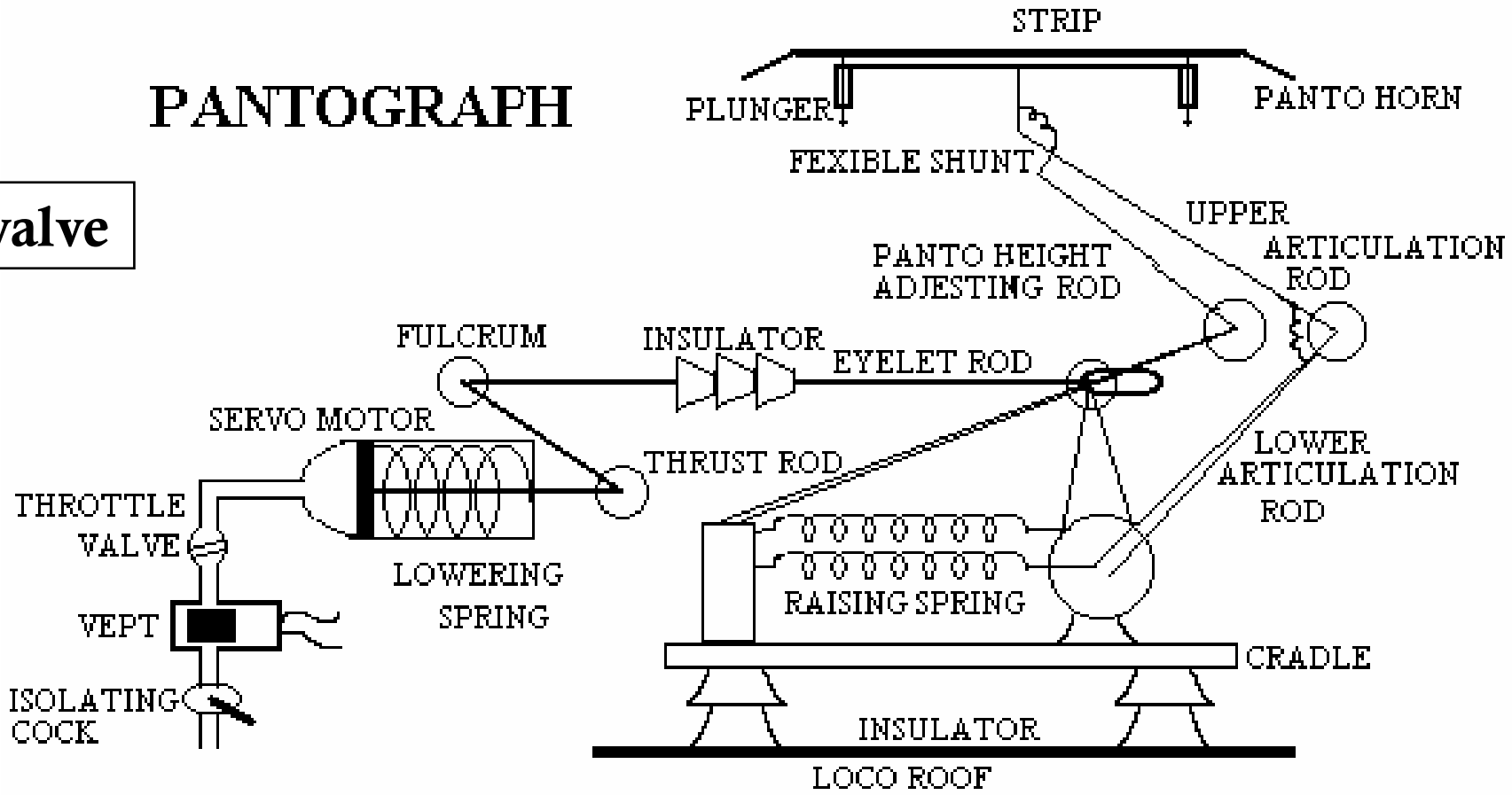
EMU POWER CIRCUIT AND ELECTRICAL EQUIPMENT

Silabhadra Das

P(MIS)

PANTOGRAPH

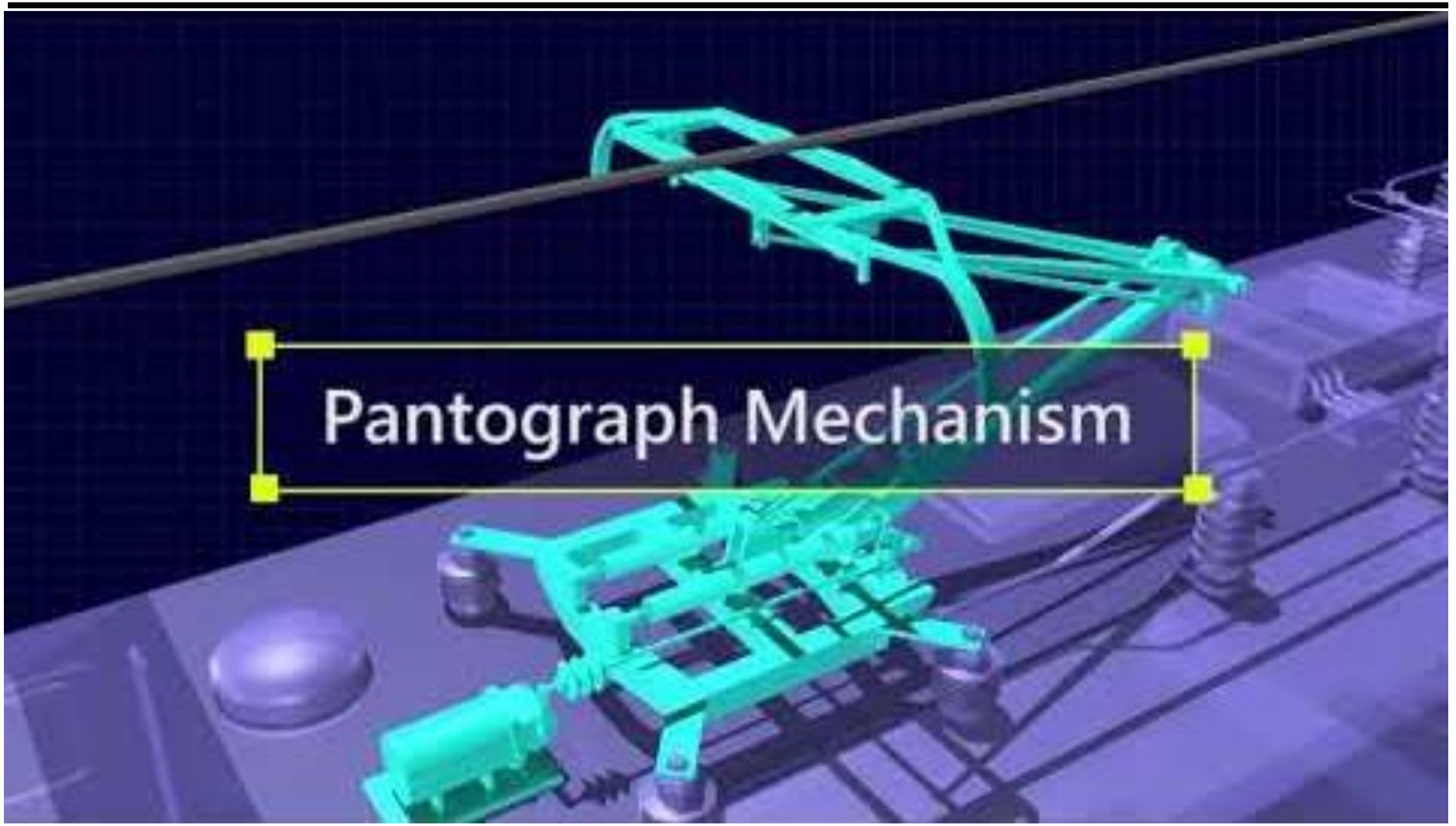
panto Set/trip valve



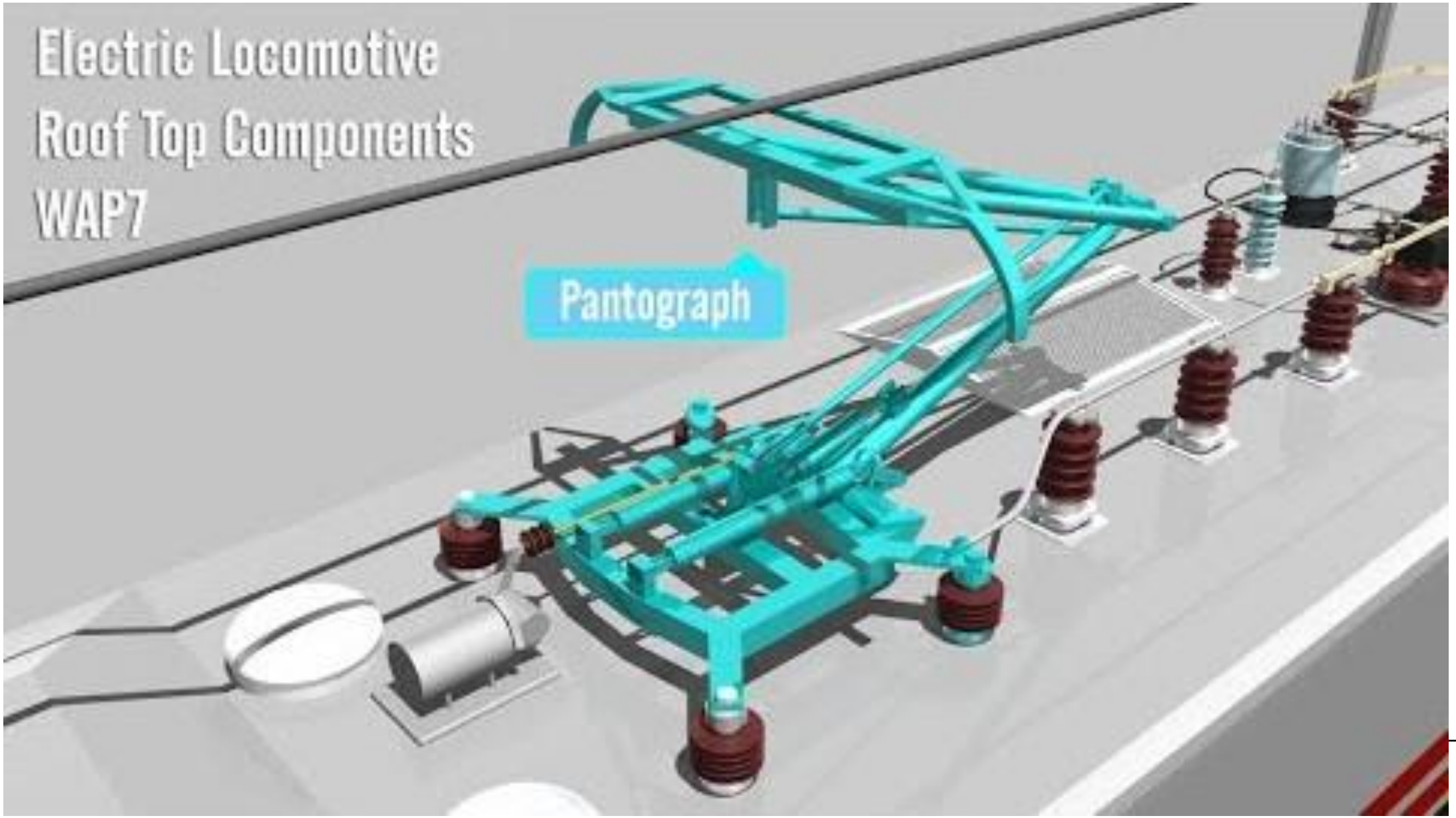
PANTOGRAPH

- It is a collapsible framework made of metallic tubes and articulated by ball bearings.
- It is used for smooth and spark-less current collection from OHE and to feed the transformer primary winding through Circuit Breaker.
- It is designed to maintain the continuous flow of current in spite of oscillation at high speed and the variation in height of the contact wire at different places.
- Pantograph is held in the raised position by means of compressed air supplied from panto reservoir in HT compartment.
- The raising and lowering of pantograph is controlled from driving cab by means of two operating valve (latch type) which are controlled with 110V DC supply.
- Minimum air pressure of 4.5 kg/cm2 required to raise the panto
- Current collection to be with least sparking.
- The contact loss is of the order of 0.2 percent

PANTOGRAPH



PANTOGRAPH



TRANSFORMER

- The main transformer is a under gear mounted step down transformer which is having three separate secondary windings
- The transformer oil circuit consists of a main transformer tank, a reactor tank (including smoothing, tapping and dropping reactors), oil pump and a radiator. The cooling air for the radiator is drawn through the radiator block from the coach sole-bar level by two axial flow fans mounted behind the radiator.
- The direction of oil flow is from the main transformer through the oil pump to the radiator inlet. From the radiator oil flows to the reactor tank and back to the transformer oil inlet..

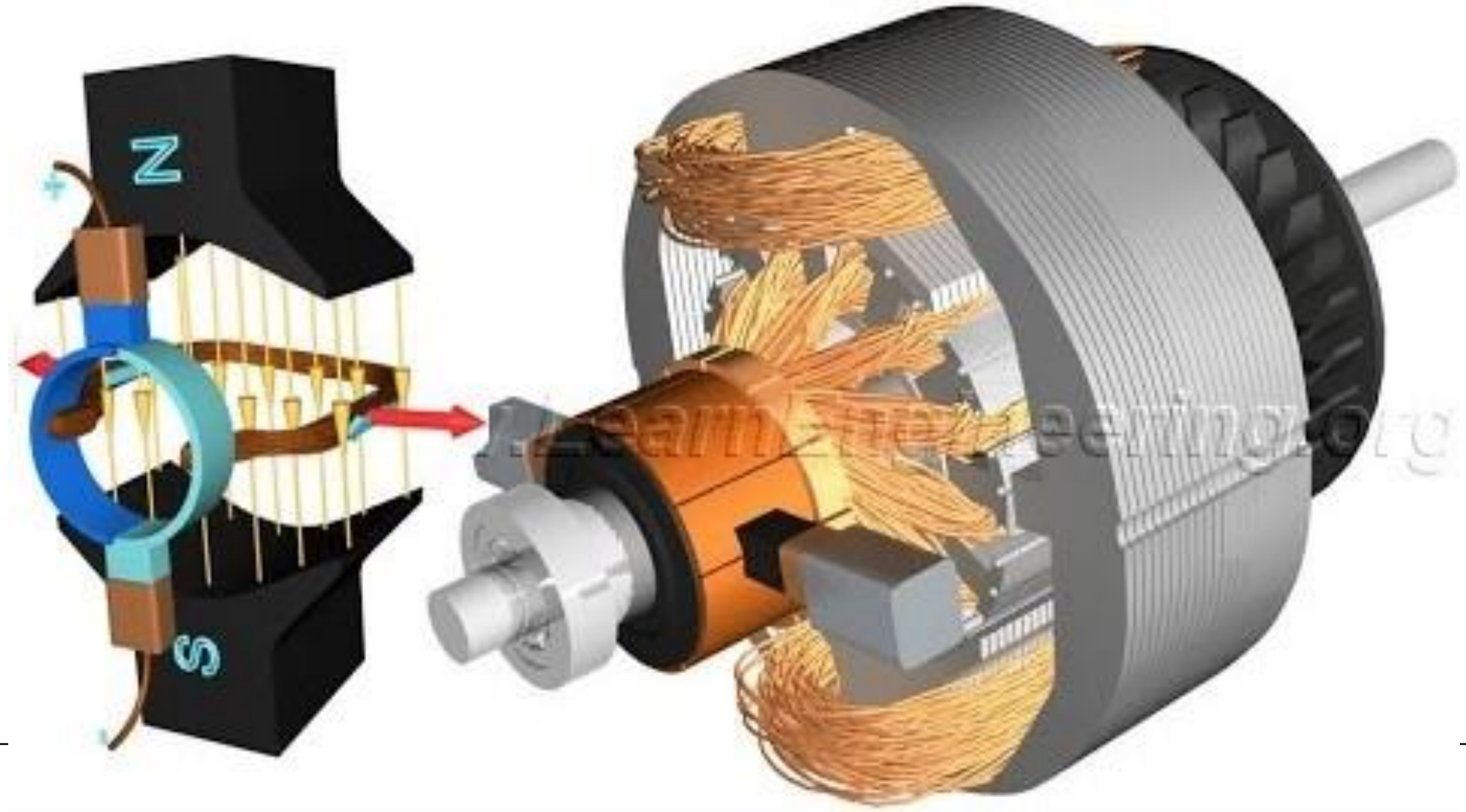
TECHNICAL DETAILS OF TRANSFORMER

Make	BHEL
Continuous Rating	1000 KVA at 25 kV
Primary winding	25 kV/40 Amp.
Secondary winding	782 Volt/ 1280 Amp.
Auxiliary winding I	266 Volt/55 Amp.

TECHNICAL DETAILS OF TRANSFORMER

Make	BHEL
Auxiliary winding II	141 Volt/250 Amp
frequency	50Hz
cooling	OFAF
Thermostat setting	75 C
Oil quantity	675 litres

DC TRACTION MOTOR



DC TRACTION MOTOR

- The EMU Traction Motors are DC series, self excitation type motors. There are 4 Traction motors in each motor coach and connected in parallel with the main rectifier DC output.
- The motors are axle mounted and nose suspended. A single reduction gear (ratio 20:91) is used for transmission of power to the axle.
- Each traction motor is operated through individual contactor, both at positive and negative side.

TECHNICAL DETAILS OF TRACTION MOTOR

Parameters	4601 AZ	4601 BZ
Continuous Rating (KW)	167 KW	187 KW
Continuous Rating (HP)	224 HP	250 HP
Current	340 Amps	380 Amps
Voltage	535 V	535 V
Speed (RPM)	1200	1182
Gear Ratio	20/91	20/91

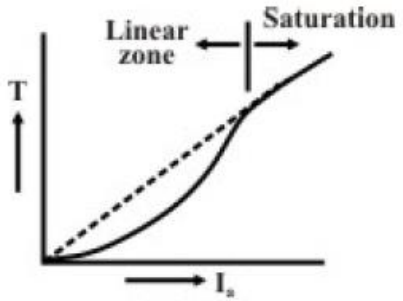


Figure 39.14

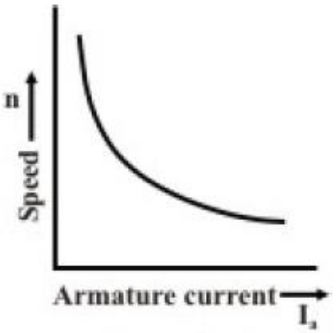
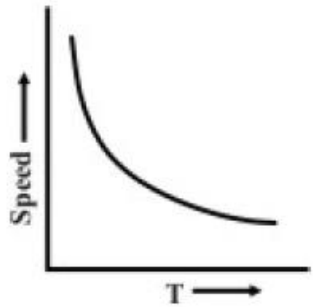


Figure 39.15



A series wound DC motor has a low resistance field and armature circuit. Because of this, when voltage is applied to it, the current is high (Ohms Law: current = voltage/resistance). The advantage of high current is that the magnetic fields inside the motor are strong, producing high torque (turning force), so it is ideal for starting a heavy object like a train. The disadvantage is that the current flowing into the motor has to be limited somehow, otherwise the supply could be overloaded and/or the motor and its cabling could be damaged. At best, the torque would exceed the adhesion and the driving wheels would slip.

As the DC motor starts to turn, the interaction of the magnetic fields inside it causes it to generate a voltage internally. This "back voltage" opposes the applied voltage and the current that flows is governed by the difference between the two. So, as the motor speeds up, the internally generated voltage rises, the effective voltage falls, less current is forced through the motor and thus the torque falls. The motor naturally stops accelerating when the drag of the train matches the torque produced by the motors.

RECTIFIER

- EMU rectifier is an under gear mounted cubicle, divided into two parts – main rectifier unit and Aux. Rectifier unit.
- Main rectifier : Voltage from the transformer secondary, collected by tap-changing contactors is fed to the main rectifier. The rectifier is having three bridges.
- Each bridge consists of four silicon diodes and is protected with fuses 1000V/1450A for short circuit protection.
- The function of rectifier is to convert AC supply to DC for further feeding to traction motor circuit.
- Rating:
- Input - 782 V AC, 1ph, 50 HZ
- Output - 535V DC, 2640 Amps.
- Each diode is provided with an aluminum heat sink which is forced air cooled by rectifier fan motor mounted inside the rectifier cubicle.

VCB

- In VCB, two interrupters are used in series and are mounted in the horizontal support insulators. Each interrupter houses a pair of contacts.
- The pneumatic dual piston operating mechanism is mounted in the main cradle between the interrupters.
- The compressed air supplied to it from the main system of the vehicle is regulated automatically within the circuit breaker to 5.0 kg/cm2; thus consistency of operation is assured.

VCB

- The purpose of any circuit breaker is to break or open the electrical circuit between the source and the load.
- This would seem simple if it weren't for **electrical arcs.**
- Opening an electrical circuit will form arcs
- The circuit breaker should extinguish arc quickly.
- Failure will “eat” away the contacts .
- In extreme situation this can lead to a deadly **arc blast.**

VCB CONT'D

- The vacuum inside the chamber has insulation qualities for quick arc quenching.
- The contacts need minimum movement - perhaps a centimeters vs 10 of centimeters required in atmosphere .
- Consequently, the vacuum circuit breaker is compact

VCB CONT'D

- A bellow allows one of the contacts to physically move while maintaining the vacuum inside the chamber
- This movement opens the electrical connection between contacts while maintaining the vacuum
- Vacuum has excellent insulating properties and therefore very small gaps are required between contact faces to withstand extremely high voltages.
- Excellent Arc extinguishing properties
- More reliable
- Requires less maintenance
- Quieter and more efficient

MCB

RELAYS

- Relays are electric **switches** that use electromagnetism to convert small electrical stimuli into larger currents. These conversions occur when electrical inputs activate electromagnets to either form or break existing circuits. May be normally open or normally closed

- **When to Use a Relay:**
- 10A or less current
- Up to 250VAC
- 1 phase

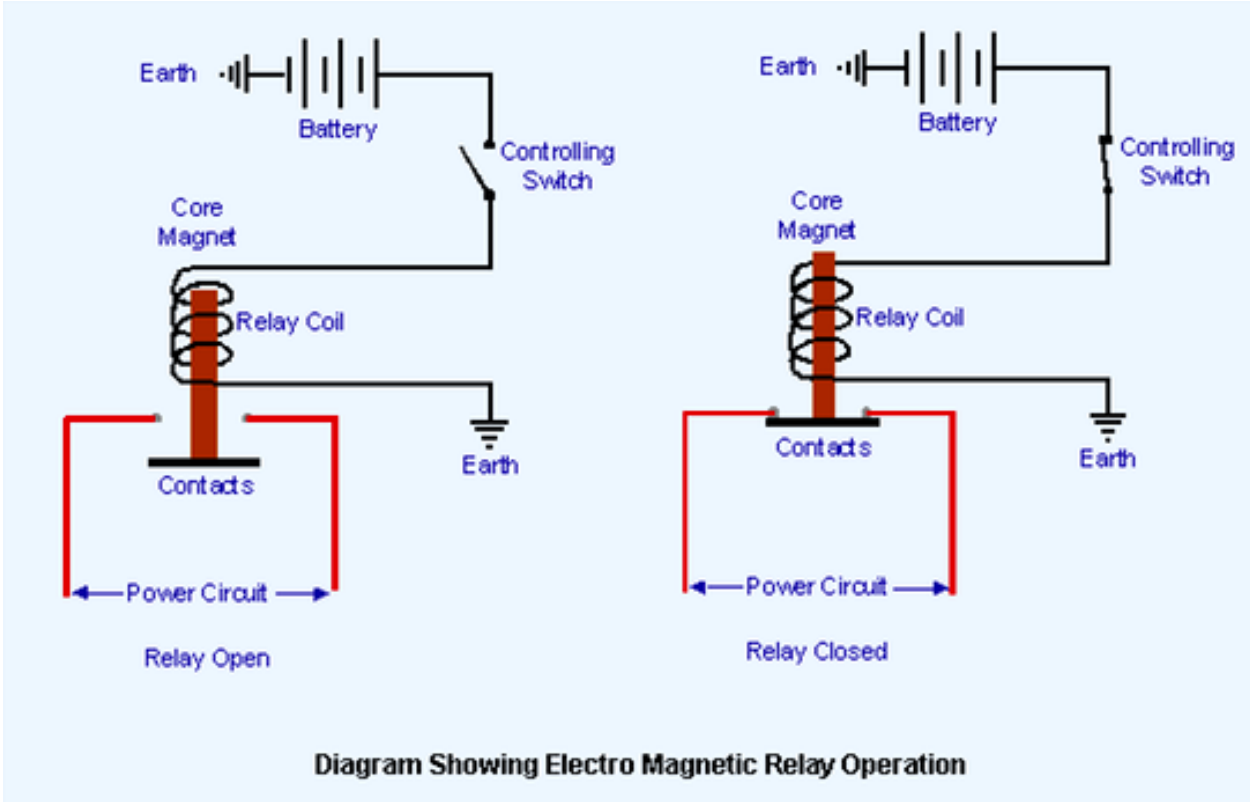


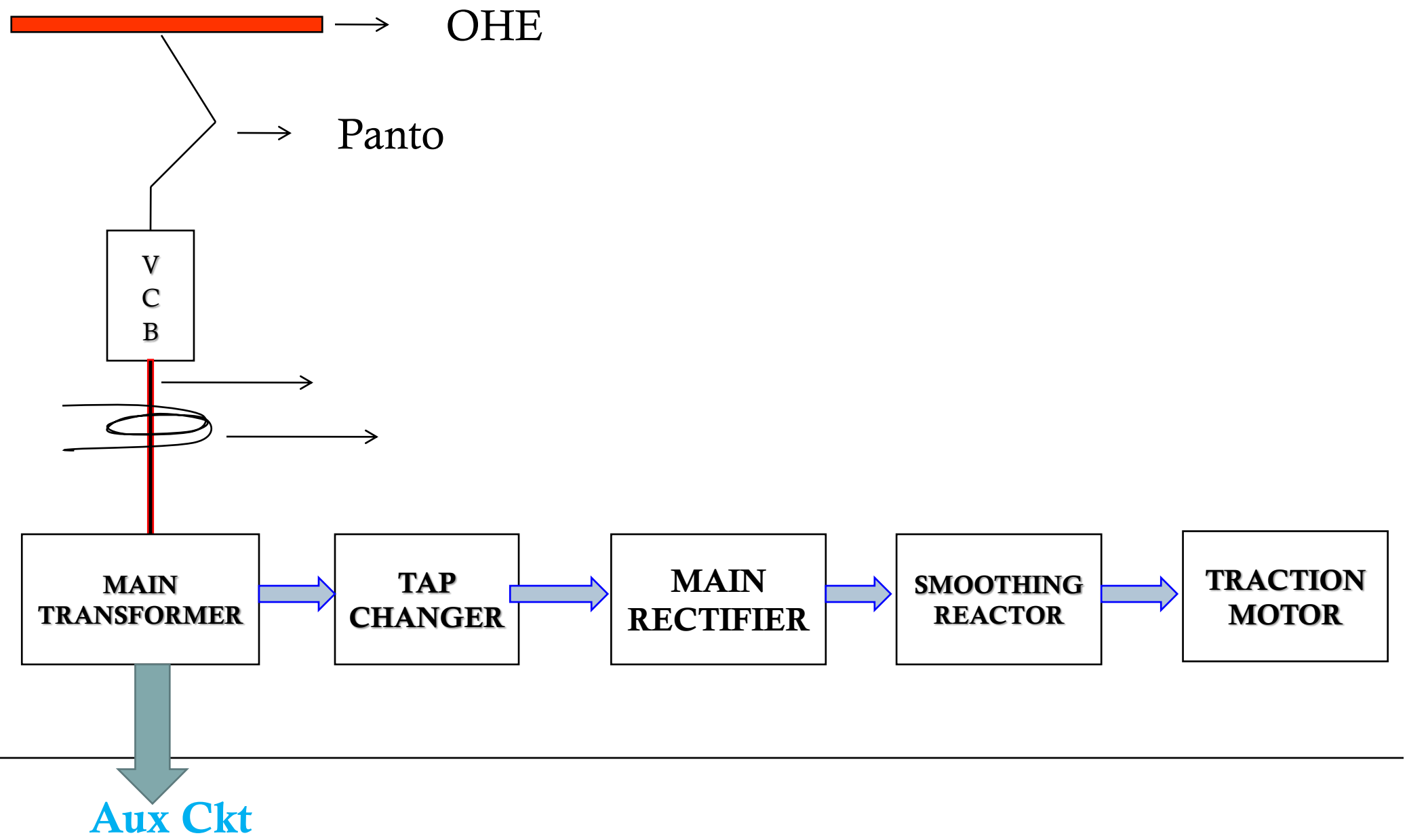
Diagram Showing Electro Magnetic Relay Operation

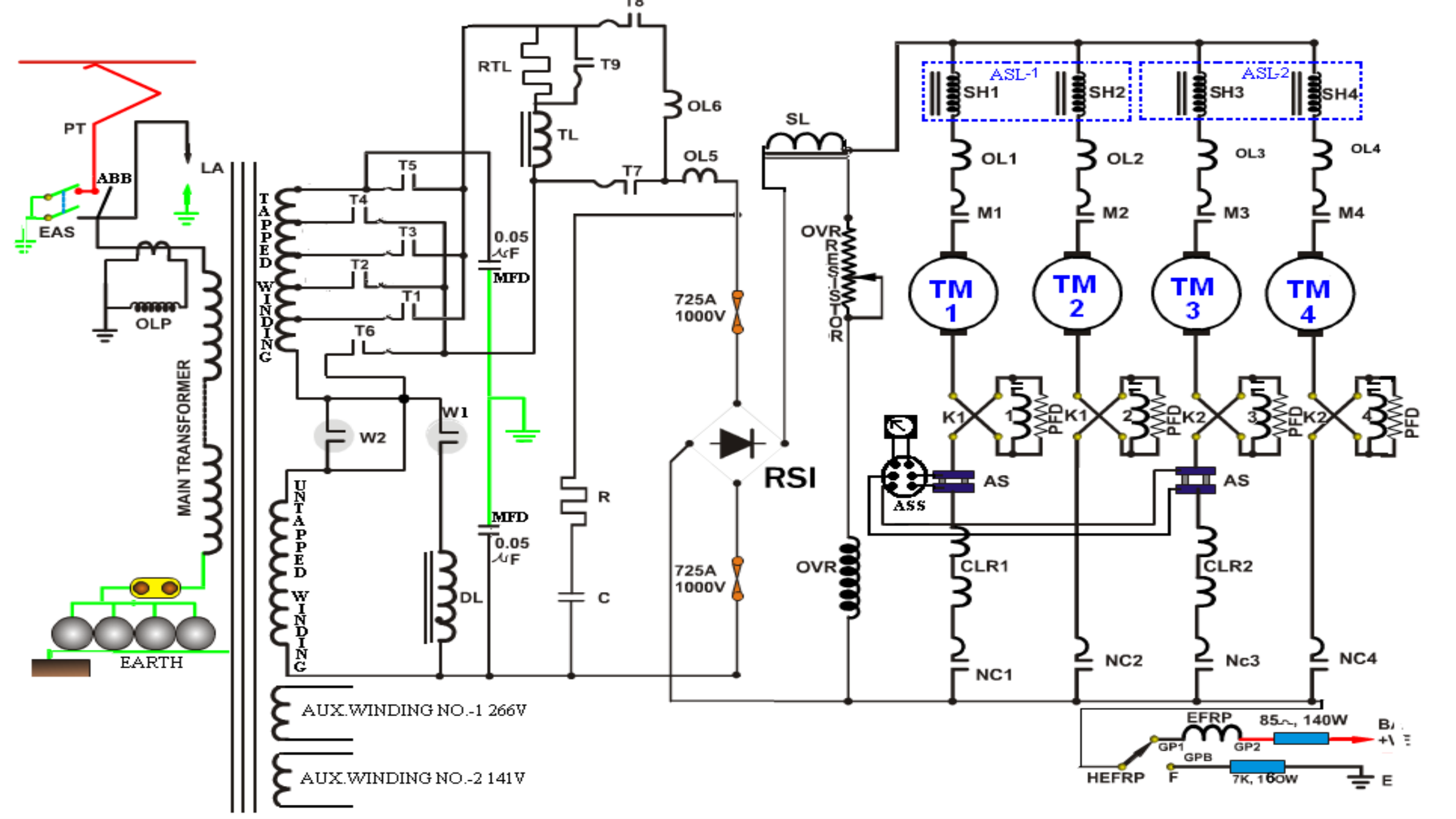
RELAY

CONTACTORS

- Contactors are typically built for and used in 3-phase applications where a relay is more commonly used in single phase applications. A contactor joins 2 poles together, without a common circuit between them, while a relay has a common contact that connects to a neutral position. Normally open.
- 9A or more current
- Up to 1000VAC
- 1 or 3 phase

AC EMU/MEMU POWER CKT


OHE
Panto
V
C
B
MAIN TRANSFORMER
TAP CHANGER
MAIN RECTIFIER
SMOOTHING REACTOR
TRACTION MOTOR
Aux Ckt


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T5
T4
T3
T2
T1
T6
T8
T9
T7
RTL
TL
OL6
OL5
0.05 MFD
MFD
0.05 MFD
W1
W2
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 16OW
E

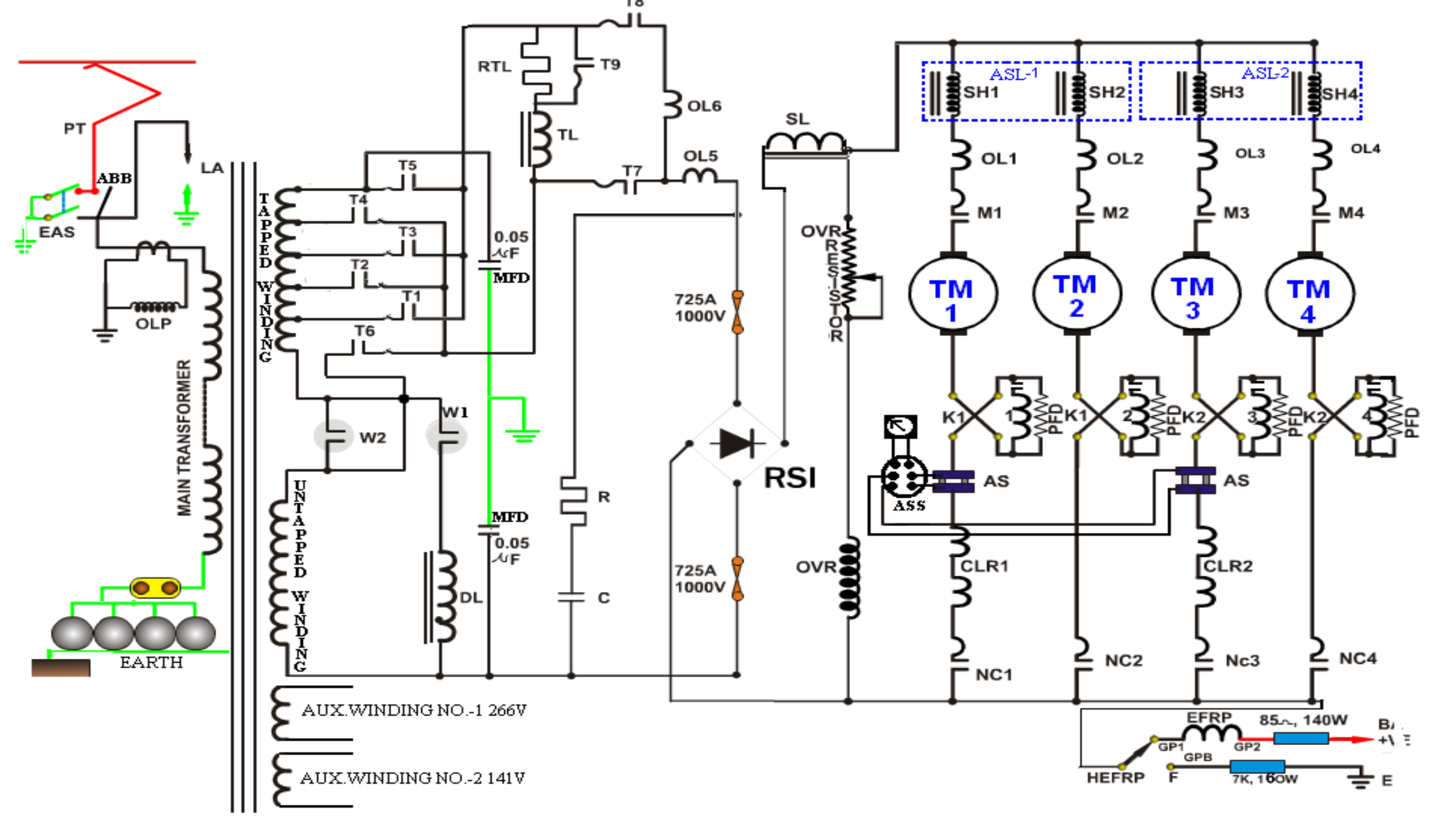
POWER CIRCUIT DESCRIPTION

1. Current at 25KV is taken from OHE to the primary winding of the main transformer via the pantograph, the vacuum circuit breaker and HT cables which passes through the coach.
2. The return path of this current is via the earthing brushes mounted in the axle cap of each traction motors and the running rails.

TAP CHANGING SEQUENCE NOTCH	W1/W2	TAP CHNGING CONTACTORS	TRANSFER SWITCHES
OFF 0	W1	----	------
SHUNT 1	W1	T1	T7 &T9
2	W1	T1	T8
HALF 3	W1	T2	T8 &T9
4	W1	T2	T7
5	W1	T3	T7 &T9
6	W1	T3	T8

TAP CHANGING SEQUENCE NOTCH	W1/W2	TAP CHNGING CONTACTORS	TRANSFER SWITCHES
7	W1	T4	T8 &T9
8	W1	T4	T7
9	W1	T5	T7 &T9
10	W1	T5	T8
11	W1	T6	T8 &T9
12	W1	T6	T7

TAP CHANGING SEQUENCE NOTCH	W1/W2	TAP CHNGING CONTACTORS	TRANSFER SWITCHES
Full power 13	W2	T1	T7 &T9
14	W2	T1	T8
15	W2	T2	T8 &T9
16	W2	T2	T7
17	W2	T3	T7 &T9
18	W2	T3	T8
19	W2	T4	T8 &T9
20	W2	T4	T7
21	W2	T5	T7 &T9
22	W2	T5	T8


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T5
T4
T3
T2
T1
T6
T8
T9
T7
RTL
TL
OL6
OL5
0.05 MFD
MFD
0.05 MFD
W1
W2
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 16OW
E

POWER CIRCUIT DESCRIPTION

3. The 25 KV primary voltage is stepped down to 782 V. The transformer secondary consists of two separate tapped and untapped windings each of 391V. One half tapped winding is divided into five sections each 78.2V.
4. In the first half of the notching sequence, only the tapped portion of the winding is used, while for the remaining notches both tapped and untapped portions are connected in series.

POWER CIRCUIT DESCRIPTION

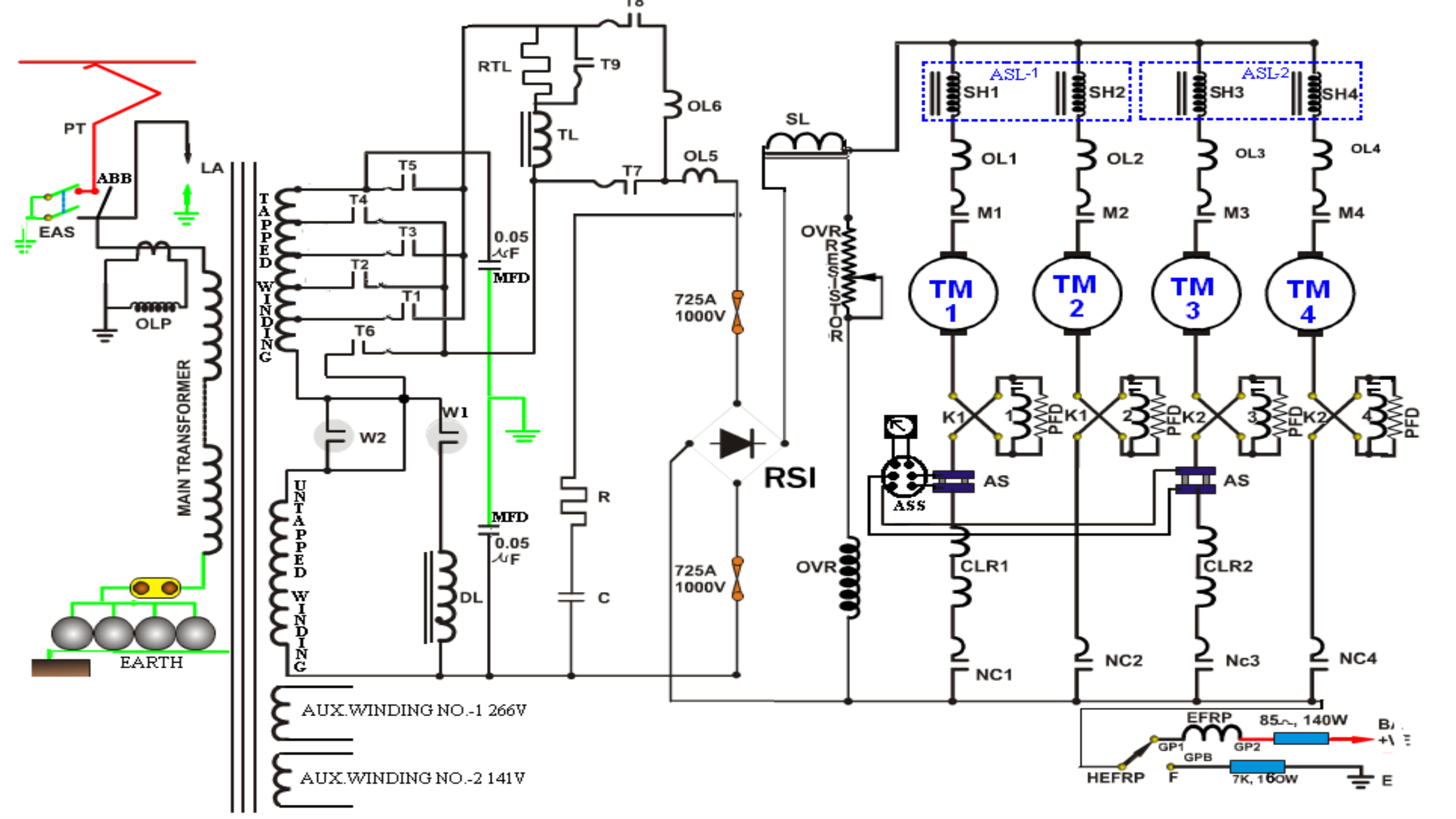
5. The changeover is effected by means of contacts W1 and W2 on the winding- grouping switch and are only operated off load.
6. This arrangement gives a total of 22 notches/ voltage steps by various connections of transformer tapings and voltage dropping reactors.

DROPPING REACTOR DL

- The reactor DL is connected in such a position in the circuit that for all notches when only the tapped half of the secondary winding is in circuit, it is in series with the output.

The purpose of this reactor are

1. To steepen the notching curves on low taps
2. To reduce the notching current swing.
3. To increase the short-circuit reactance of the transformer in the low taps


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T5
T4
T3
T2
T1
T6
T8
T9
T7
RTL
TL
OL6
OL5
0.05 MFD
MFD
0.05 MFD
W1
W2
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 16OW
E

POWER CIRCUIT DESCRIPTION

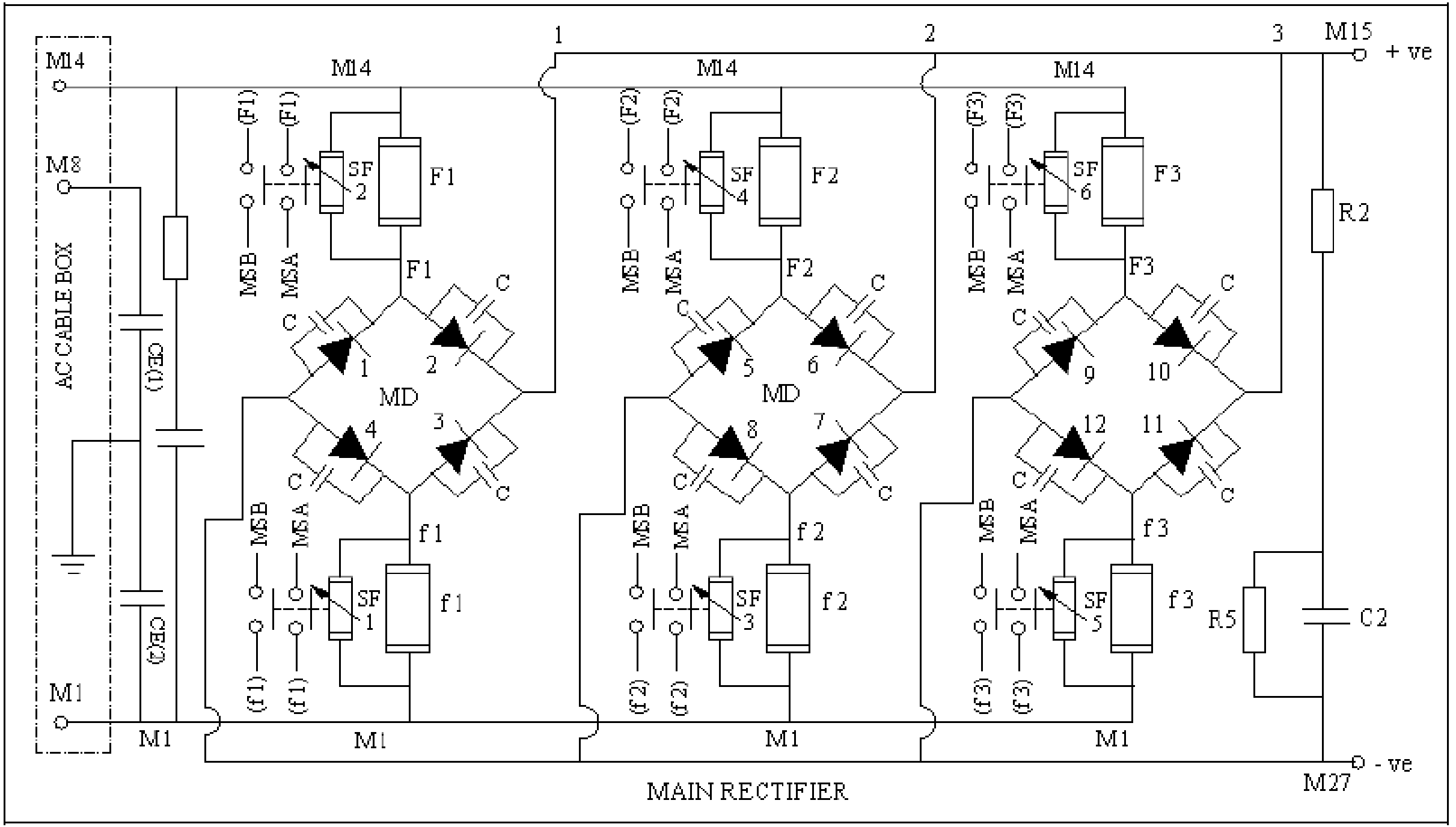
- The switching of the transformer sections are carried out by the tap changer contactors T1 to T9.
- Contactors T1 to T6 are connected to transformer tapings and the required voltage is selected.
- Tap changing is carried out by means of a reactor TL, in conjunction with the two reactors T7 and T8 to give alternate notches with and without the reactor in the circuit.

POWER CIRCUIT DESCRIPTION

- A resistor is also provided in series with the reactor but this is in circuit only during the actual tap-changing operation being immediately cut out of circuit when T9 closes.
- The purpose of this resistor is to ease the duty on the opening contactor by reducing the circulating current
- Two capacitors of 0.05 microfarads are connected between the two secondary windings and earth to prevent the build up of high voltages to earth on the windings when they are not connected to the traction circuit earth.

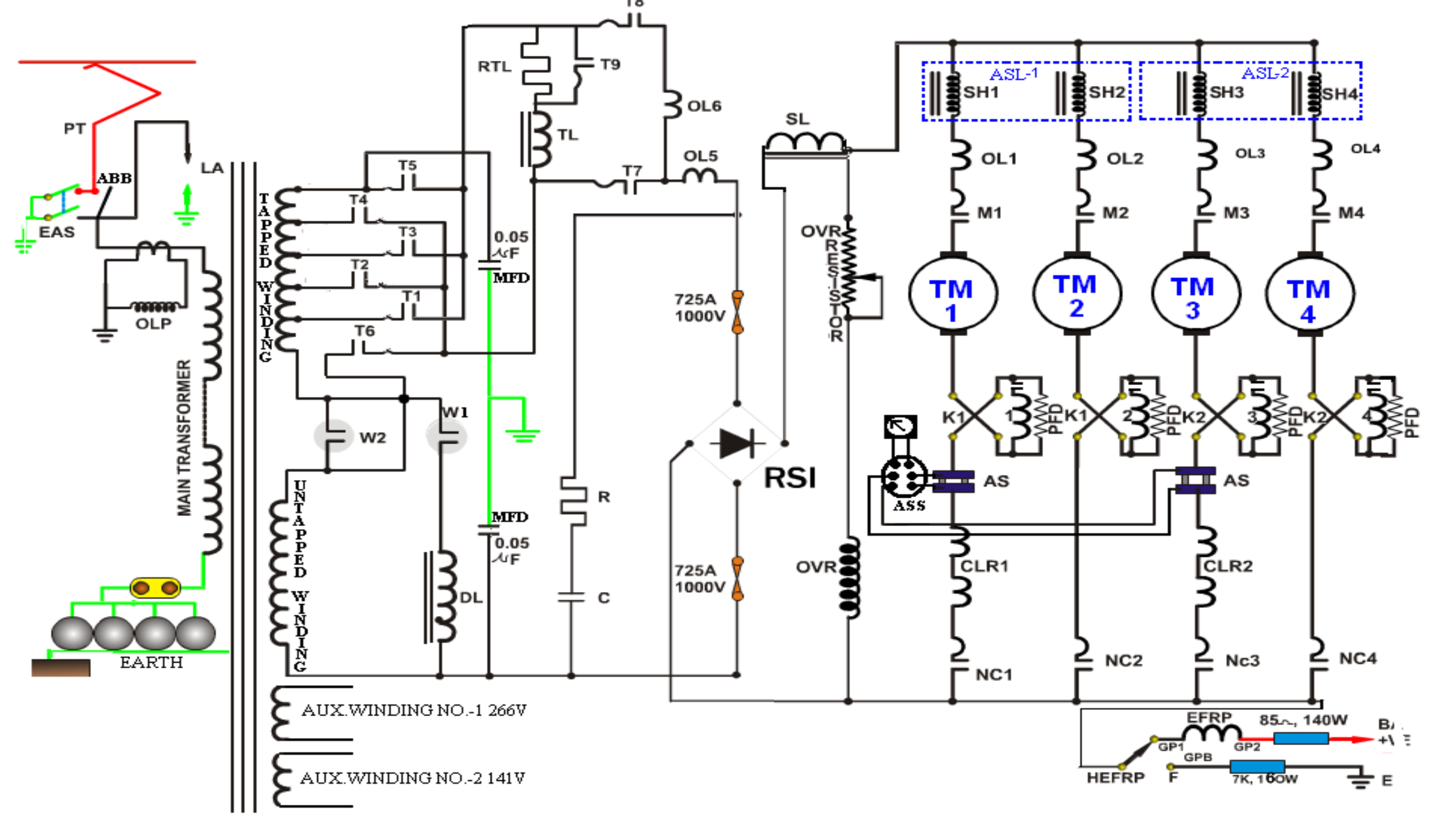
POWER CIRCUIT DESCRIPTION

- This voltage which is controlled by the tap changer contactors, is applied to the silicon rectifiers, the full wave output of which is fed to the traction motors via the smoothing reactor.
- The silicon-rectifier assembly consists of six bridge circuits in parallel.
- Each bridge being protected on its AC side by fuses.
- A surge-absorbing capacitor and series resistor are connected across the AC input to the rectifier bridges.


M14
M8
M1
AC CABLE BOX
CE(1)
CE(2)
M14
(F1)
(F1)
MSB
MSA
SF 2
F1
F1
C
1
2
MD
4
3
f1
SF 1
f1
(f1)
(f1)
1
M1
M14
(F2)
(F2)
SF 4
F2
F2
5
6
7
8
f2
SF 3
f2
(f2)
(f2)
2
M1
M14
(F3)
(F3)
SF 6
F3
F3
9
10
12
11
f3
SF 5
f3
(f3)
(f3)
3
M1
M15
+ ve
R2
R5
C2
- ve
M27
MAIN RECTIFIER

POWER CIRCUIT DESCRIPTION

- The output from the rectifier assembly is taken through a smoothing reactor to the motor circuits.
- The motors are permanently connected in parallel are cooled with filtered air taken from the coach interior.
- The four motors are arranged in parallel, and are connected in circuit as required by the four motor contactors M1 to M4.


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T5
T4
T3
T2
T1
T6
T8
T9
T7
RTL
TL
OL6
OL5
0.05 MFD
MFD
0.05 MFD
W1
W2
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 16OW
E

POWER CIRCUIT DESCRIPTION

- Each motor is protected by an overload relay which trips the motor contactor in case of overload.
- The direction of rotation of the traction motor is reversed by reversing the connections to the motor field windings.

POWER CIRCUIT DESCRIPTION

- Motors 1 and 3 have current limit relays connected in their circuits to control the automatic acceleration of the train.
- The normal setting of the relay is 500 amp., which is reduced to 425 amps immediately before the transition from notch 10 to notch 11 and again before the weak field.

POWER CIRCUIT DESCRIPTION

- Operation of the motor cut-out switches (MCOS) allows the unit to operate with any one motor cut -out, or with a bogie pair of motors cut-out.
- In any motor cut-out condition the current-limit relay setting is reduced to 450 amp.

POWER CIRCUIT DESCRIPTION

- **An earth fault relay(EFR)** trips the air-blast circuit-breaker/VCB in the event of an earth fault occurring in any part of the motor circuit. The relay has a flag which leaves an indication that a trip has occurred.
- Protection against interruptions of line voltage is given by a no-volt relay(NVR) which opens the contactors in the traction circuit in the event of failure of line voltage

CHOKE TANK:

- The choke tank is mounted in under-gear of the motor coach. It consists of SL, DL & TL.

SMOOTHING REACTOR

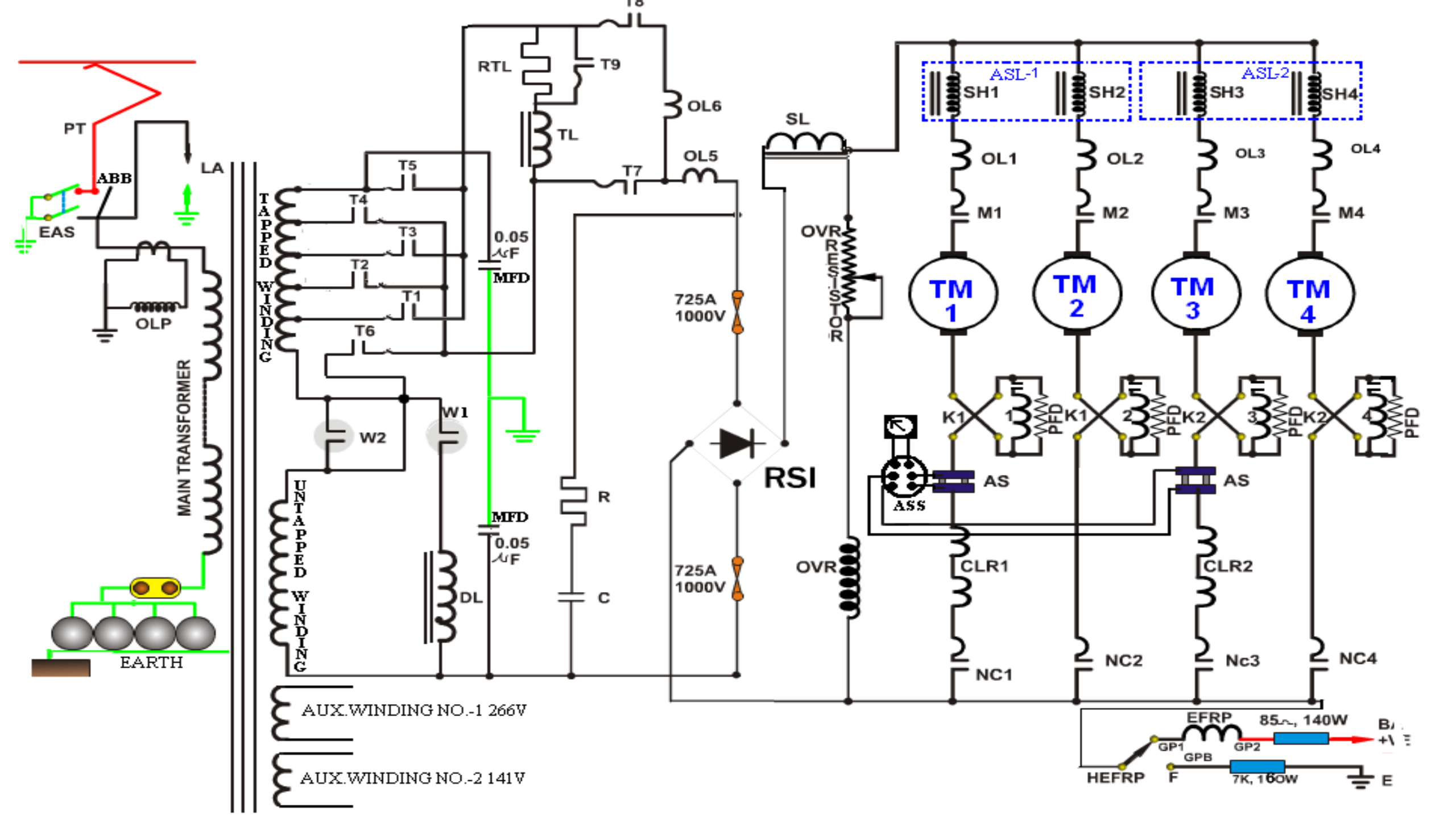
- SL - Its function is to smooth the DC out put by eliminating the AC ripples.

DROPPING REACTOR

- DL- The dropping reactor is called DL. The reactor DL is connected in such a position that it is in series with the output of all notches when the tapped half of the secondary winding comes in the circuit. The purpose of the reactor is:
- To steepen the notching curves on low taps and thus to reduce the notching current swing.
- To increase the short circuit reactance in the low taps.

TAP CHANGER REACTOR

- TL – The tap changing reactor is switched into circuit during alternate electrical notches to give an intermediate increase in voltage to make notching and hence acceleration smoother.


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T5
T4
T3
T2
T1
T6
T8
T9
T7
RTL
TL
OL6
OL5
0.05 MFD
MFD
0.05 MFD
W1
W2
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 16OW
E

AC EMU
AUXILIARY CIRCUIT

AUXILIARIES

- Oil pump (OP)
- Radiator fans(two) (KF1,KF2)
- Main rectifier fan (RF)
- Battery charger
- Auxiliary compressor
- Main compressor
- Passenger lights
- Passenger fans

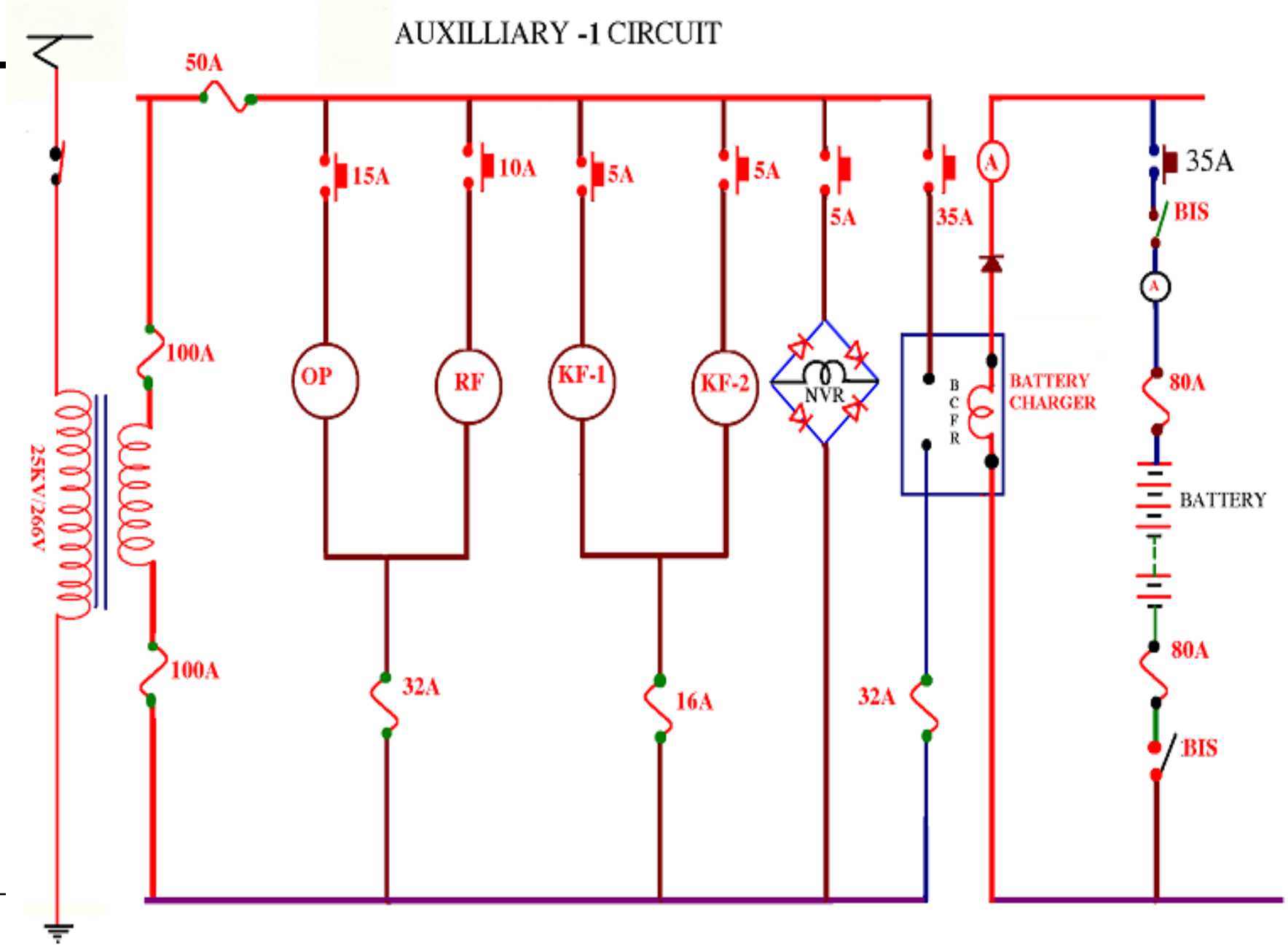
AUXILIARY CIRCUITS

There are two separate auxiliary circuits,

I. 266V AC

II. 141V AC

AUXILIARY I CIRCUIT


AUXILLIARY -1 CIRCUIT
50A
15A
10A
5A
5A
5A
35A
35A
100A
100A
25KVA/2x6V
OP
RF
KF-1
KF-2
NVR
B
C
F
R
BATTERY
CHARGER
32A
16A
32A
80A
80A
BATTERY
BIS
BIS

266V A.C. AUXILIARY CIRCUIT

- This circuit is fed from Auxiliary winding on the main transformer Aux. I and gives a nominal 266V AC Output.
- It is used to feed the battery charger and the single phase induction motors driven auxiliary machines.

266V A.C. AUXILIARY CIRCUIT

Auxiliaries are:

1. **Oil pump (OP)**
2. **Radiator fans(two) (KF1,KF2)**
3. **Main rectifier fan (RF)**
4. **Battery charger**

266V A.C. AUXILIARY CIRCUIT

- **No-Volt Relay (NVR)**
- **This is a DC relay fed by a bridge rectifier, and is used to detect whether the transformer is ‘live or not.**
- **The NVR circuit is protected by a miniature circuit breaker.**
- **On failure of OHE voltage, NVR drops out and disconnects the traction circuit by means of its Interlocks in the control circuit.**

OIL PUMP

- **It is provided to circulate the transformer oil to keep it cool & the entire unit is mounted in transformer oil pipe line.**
- **The motor is of 4 pole, squirrel cage(induction motor), capacitor start and operates with its rotor immersed in oil.**
- **Rating: 1.5 HP, 240V AC, 50 Hz, 6.5 A, Single phase, 1420 RPM.**
- **Pump capacity: 364 lpm against 7.32m head.**

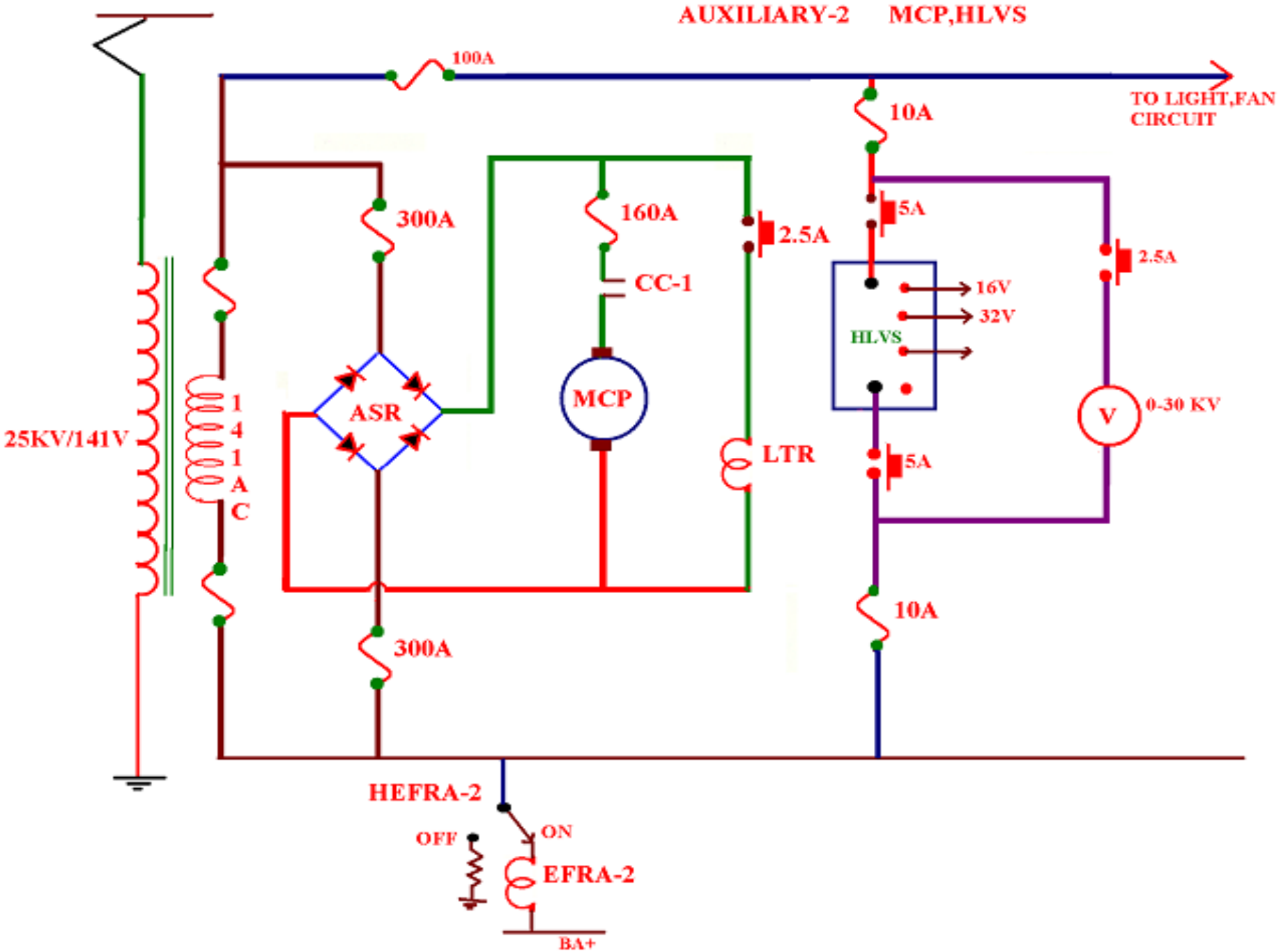
RADIATOR FANS

- **These are provided for air forced cooling of transformer oil and are fed by auxiliary I circuit of transformer.**
- **Rating: 0.5 HP, 240 V AC, 50Hz, single phase, 2.5A, 1410 rpm.**

RECTIFIER COOLING FAN

- It is provided to cool the heat sinks of rectifier diodes and is fed by auxiliary-I circuit of transformer.
- Rating: 1HP, 240V, AC, single phase, 3.6A, 1430 rpm.

AUXILIARY II CIRCUIT


AUXILIARY-2 MCP,HLVS
100A
TO LIGHT,FAN CIRCUIT
10A
300A
160A
2.5A
5A
CC-1
2.5A
16V
32V
HLVS
ASR
MCP
V
0-30 KV
25KV/141V
1
4
1
A
C
LTR
5A
10A
300A
HEFRA-2
OFF
ON
EFRA-2
BA+

141V A.C. CIRCUIT

- **This circuit is fed from a secondary winding Aux. II (141V AC) and is protected by two fuses AF3 and AF4, located inside the transformer connection chamber.**
- **A rectifier-fed relay LTR is provided to prove that fuses AF3 and AF4 are intact and the auxiliary supply rectifier (ASR)is working normal.**

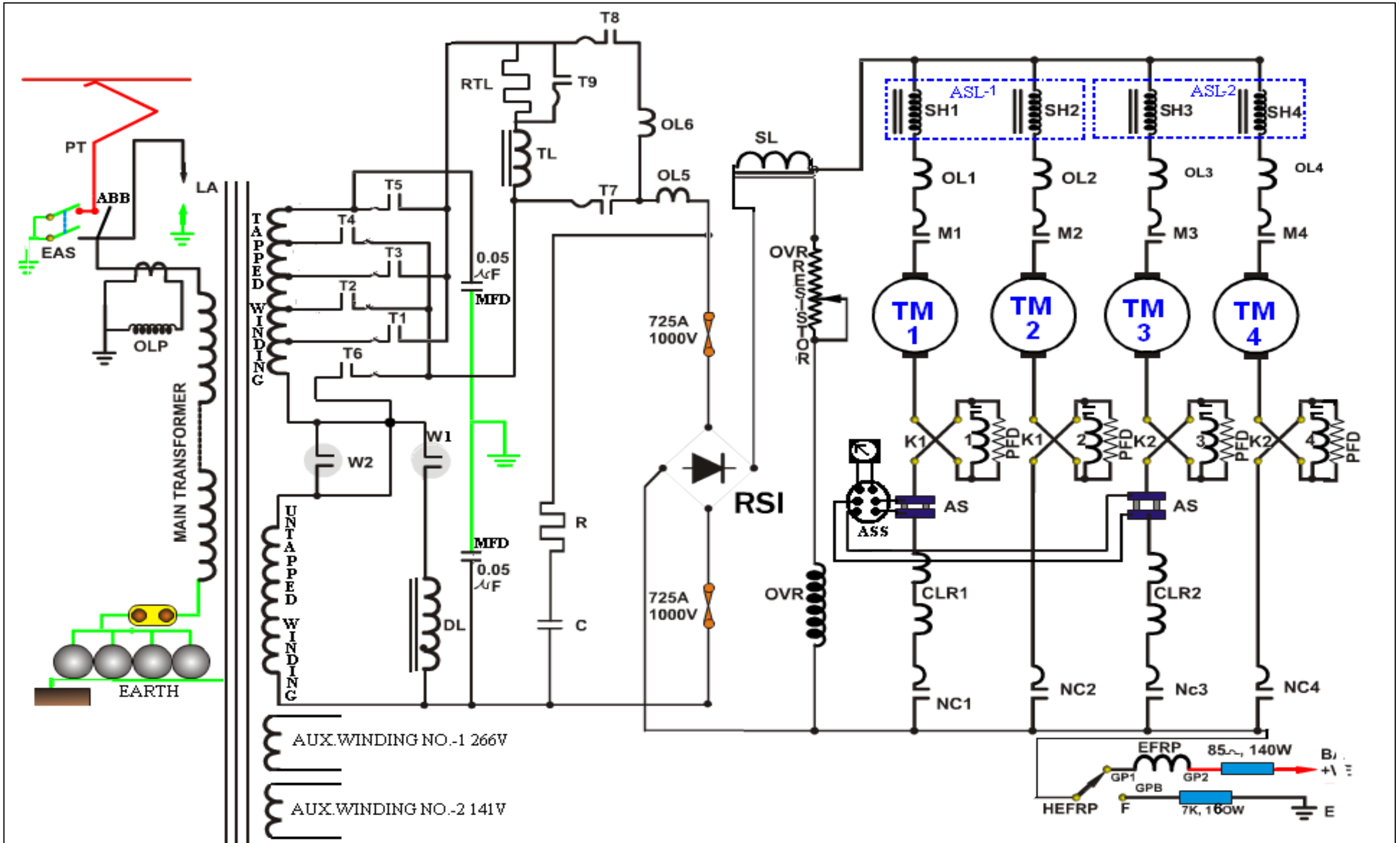
141V AC CIRCUIT

- **The circuit of LTR is protected by a miniature circuit breaker.**
- **A surge suppression capacitor with a series resistor is provided across the input to ASR.**

141V AC CIRCUIT

Auxiliaries are

- **Main compressor**
- **110V DC, 8.5KW, 1150rpm, 1075lpm**
- **Passenger lights and fans**
- **Fans: 32 fans of 60W each coach**
- **Lights**
- **16 normal lights of 18W each coach**
- **12 emergency lights of 18W in each coach**


PT
ABB
LA
EAS
OLP
MAIN TRANSFORMER
EARTH
TAPPED WINDING
UNTAPPED WINDING
T8
T9
T7
T6
T5
T4
T3
T2
T1
W1
W2
RTL
TL
OL6
OL5
0.05 µF MFD
MFD
0.05 µF
DL
R
C
725A 1000V
725A 1000V
RSI
SL
OVR RESISTOR
OVR
ASL-1
ASL-2
SH1
SH2
SH3
SH4
OL1
OL2
OL3
OL4
M1
M2
M3
M4
TM 1
TM 2
TM 3
TM 4
K1
K2
PFD
AS
ASS
CLR1
CLR2
NC1
NC2
Nc3
NC4
AUX.WINDING NO.-1 266V
AUX.WINDING NO.-2 141V
EFRP
85Ω, 140W
GP1
GP2
GPB
HEFRP
F
7K, 160W
E

SETTING OF PROTECTIVE DEVICES

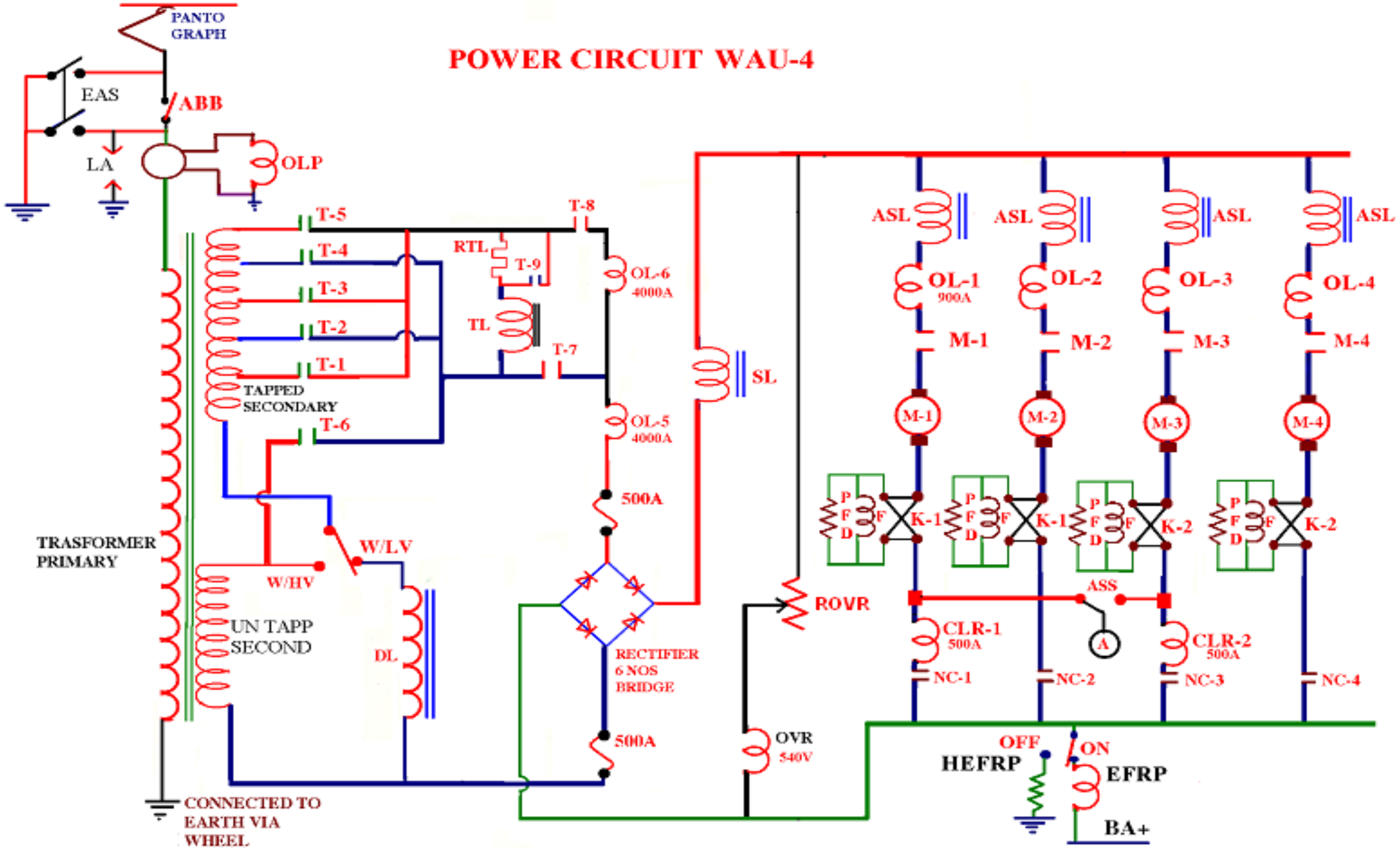
EQUIPMENTS	DETAILS
Lightning arrester	42KV
Overload protection	0.7A/163A
TM overload relay OL1-4	900A
Transformer secondary OL5 &OL6	4000A
Current limit relay	Sets at 500A, Trips at 425A,
Earth fault relay	50V
Over voltage relay	540V

OVER CURRENT RELAY FOR MAIN TRANSFORMER

- **OLP-** : This will energize when the primary current exceeds 163 amps and ABB will trip and can be ‘reset’ once only
- **OL-5** over current relay for main rectifier

  This relay will energize when current exceeds 4000 amps and ABB will trip

POWER CIRCUIT WAU-4



SAFETY RELAYS

- **OL-6** over current relay for secondary winding (4000 amps)
- It protects against short circuit current in sec. Winding of the transformer and ABB will trip

OLR FOR TRACTION MOTORS

- **OL 1-4** protects the traction motors 1-4 from over current.
- This relay will energize when current exceeds 900 amps in traction motor.
- If OL1 or 2 acts M1&M2 will open and if OL 3&4 acts M3 or M4 will open
- These relay can be reset by ‘OL reset switch’

OVER VOLTAGE RELAY

OVR: over voltage relay

- If the voltage exceeds 540 volts when MPT in full power position this relay will energize
- If energized, further progression stops on next even notch through AOVR.

CURRENT LIMIT RELAY

- **CLR-1** in TM-1 circuit & **CLR-2** in TM-3 circuit.
- CLR: Picks up at 500 amps

  trips out at 425 amps
- CLR-1 & CLR-2 are provided in switch group-1 & switch group-2 respectively
- If CLR energized, its interlock open in tap changer circuit which stops further progression.

EARTH FAULT RELAY (EFR)

- EFRP – Earth Fault Relay for Power circuit
- It protects the power circuit equipment from earth fault.
- If energized a red target will be shown and ABB will trip.
- It can be reset by ‘OL resetting switch’
- If not able to reset isolate TMs one by one.
- If able to reset, keep HEFRP in ‘fault’ position and reset.

THANK YOU