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A Hybrid Self-Propelled Accident Relief Train (SPART) with 3-φ PMSM as Traction Motors for India

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Abstract — *Accidents can happen any time and anywhere on the Railways network due to various reasons/unforeseen circumstances. The Relief Train movement should be possible in an hour's time if the Accident Relief Train is kept ready always with necessary Equipments. Hence, in its latest orders on Accident Relief measures, the Ministry of Railways has advised each of the Divisions in the Zonal Railways to keep a Self Propelled Accident Relief Train always ready with necessary equipments required for Relief operation such as Generators, Gas Cutters, Cranes, Operation Theatres, emergency medicines, provisions for Staff etc. A Coach is also turned into a 12 Bed-Ward for the purpose of keeping the Patients. Another Coach is allotted for the accompanying Staff members which comprises of Doctors, Engineers, Nurses and other operating Staff. On report of an Accident, an Accident Relief Train is supposed to start within 30 mins - 1 hour for the Accident Site. Waiting for a Locomotive to haul the Train would further delay it. Hence, the SPART has to be self propelled similar to the Power Car of a Multiple Unit. Also, the SPART has to be designed to clock a Speed of 140 - 160 kmph so as to reach the Accident site at the earliest. Keeping all the mentioned points in view, a Traction Drive System for SPART capable of running both on Electrified and non-Electrified routes along with the capability of Auxiliary Power Supply has been designed and Simulated in this Sub-section. While stationary at the Accident Site, the onboard Diesel-Engine - Alternator Assembly can also be used as a Generator Set to run the Electrical Loads of the Coaches comprising the Operation Theatres, Medical Wards and the Staff resting Area.*

Keywords — *Dual Supply, Electric Traction, Diesel-Electric Traction, PMSM, Accidents, Accident Relief, Tractive Effort.*

I. INTRODUCTION

Indian Railways is one of the largest Railway Systems in the World. It has both Electrified and non-Electrified sections. Accidents can happen in both the sections and at the same time, due an accident, the OHE may be damaged thus causing disruption in traffic/movement of trains. A self propelled train robust enough in carrying the necessary relief equipment in a short span of time is the need of the hour. This relief train should clock at least 160 kmph. A Diesel-Electric propulsion system has its own constraint because of the Alternator capacity and cannot run beyond 130 kmph whereas an Electric propulsion system can run at speeds higher than 150 kmph depending on the Tracks capacity. Running the Electric Power Car can be a problem in OHE failure hence the Authors of the paper suggest a Hybrid Propulsion cum Power Supply System to the Relief Train by using both Electric and Diesel-Electric Traction Systems with Permanent Magnet Synchronous Motors as Traction Motors.

II. THE EXISTING TECHNOLOGY AND HOW IT CAN BE IMPROVED

Accident Relief Train drawn by a Locomotive and Self Propelled Accident Relief Trains capable of moving in either direction are stationed at various strategic locations in Indian Railways. These Trains contain the equipment required for providing medical care inclusive of Operation Theatre and Wards. The Train also consists of Staff resting area. It is also equipped with Cranes and other accessories required for lifting up coaches, cutting through the coaches and for restoration of traffic on the affected tracks. As the cranes and other equipments require power supply to operate, the Power is drawn from nearby sources or through Diesel Generators. To overcome the few drawbacks like finding power supply and to find suitable locomotive, the Authors of this paper have come with a novel idea of Hybrid Self Propelled

System for traction and also to provide power supply in accident site from the same Alternator used for Traction.

III. CONSTRUCTION OF THE DRIVE SYSTEM

The construction of the Traction Drive System for SPART is described in this Section. The Power Circuit for SPART consists of an IGBT Drive System for Traction in both Electric and non-Electric sections and an Auxiliary Power Circuit designed to operate the high Power Devices of the mobile Operation Theatres that can be made operational at the Site of Accident. The Simulink Connection Diagram of the Traction Drive System for SPART is shown in Fig. 1.

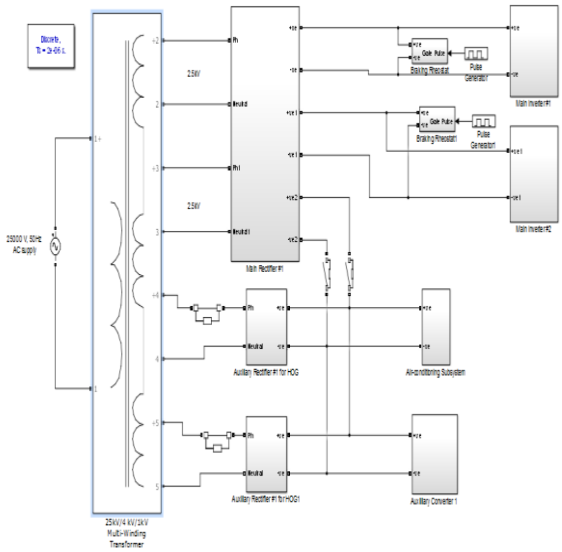


Fig. 1: Simulink Diagram of SPART

A. Main Transformer and 1-φ Rectifier Units

Main Transformer: A Multi-Winding 1-φ Transformer is used in this Circuit. The ratings of the Transformer are 25 kV, 1-φ, 50 Hz AC on the Primary Side and 4 kV / 1 kV, 1-φ, 50 Hz on the Secondary Side. Two tappings of 4 kV each are taken in the Secondary Side to be connected to Traction Rectifiers. For the Auxiliary Circuits, two tappings of 1 kV are used.

***Traction Rectifier Circuit*:** Two 4-Pulse Bridge Rectifiers with IGBTs as Switches are connected in parallel to form one unit of Traction Rectifier. The input to the Rectifier is 2500 V, 50 Hz AC supply fed from an AC source through the Main Transformer. There are two Rectifier Units in the proposed Circuit. Each Rectifier Unit has its own Sinusoidal PWM Generator with a switching frequency which is double that of the line frequency. The output of the Rectifier is fed to the DC Link.

Auxiliary Rectifier Circuit: The Coaches in SPART have to be cooled in advance. While on the Platform in preparation for starting, the Coaches can be cooled from the Electrical Sources at the originating station. In order to provide Power Supply to the Coaches while on the run in Electric mode of Traction, two Auxiliary Converter Systems have been designed. Two uncontrolled full Wave Diode Bridge Rectifiers are connected to the Auxiliary Terminals of 1 kV each on the Secondary Winding of the Traction Transformer. Circuit Breakers are provided at the Transformer Output Terminals to cut off supply to the Auxiliary Power Circuit when the Drive is not working on Electric mode of Traction. The Diode Bridge Rectifiers are connected to IGBT Inverters through the DC Link consisting of a 200 mH Inductor and 100 μF Capacitor to filter out the Harmonics. The Auxiliary Inverters work at Industrial Frequency of 50 Hz. To the first Inverter (3-φ), Eight Squirrel Cage Induction Motors of the ratings of 22 kW, 415 V, 4-poles, 50 Hz are connected in order to simulate the Air-Conditioning Compressor Motors for the Coaches. To the second Auxiliary Inverter (1-φ), 1-φ RLC Load of P = 100 kW, Q_L = Q_C = 100 kW to simulate the illumination of mobile Operation Theatres etc. as shown in Fig. 3.

B. Diesel-Engine Alternator and 3-φ Rectifier system

Traction Alternator: The Traction Alternator to be used in this Simulation for SPART is a 3 MVA, 4000 V, 50 Hz Synchronous Machine. The Machine is adapted to work on constant Power mode of operation. The Machine is rated to work at 1000 rpm and has 6-poles. This Synchronous Machine is driven by a Diesel Engine designed to operate the Alternator to work in Constant Power mode.

***Traction Rectifier Circuit*:** 6-Pulse IGBT Bridge Rectifier is used in a Converter system. The Rectifier Output Voltage is a pulsating DC of magnitude of about 2.2 kV. The Rectifier is controlled by means of a Sinusoidal PWM Generator. A resistance of 3 MΩ connected to the Bridge Rectifier for introducing Braking in Diesel-Electric mode of Traction. Four Circuit Breakers are provided at the Output Terminals of the Rectifier to make and break the connection to the DC Link to alternate between 25 kV, 1-φ Supply and 2.5 kV Alternator supply during the running of the SPART. The circuit diagram of the Diesel-Engine - Traction Alternator - 6-Pulse Bridge Rectifier / Diode Bridge Rectifier - Main DC Link Circuit is shown in Fig. 2.

Auxiliary Rectifier Circuit: This Auxiliary Rectifier is designed to operate the Traction Alternator on Generator mode when the SPART is stationary at the accident site. A 3-φ Step-Down Transformer of 3.5 kV / 1 kV, 50 Hz is connected to the output terminals of the Traction Alternator through a 3-φ Circuit Breaker. The Circuit Breaker can be 'Close' whenever Power generation is required from the Alternator for Auxiliary Supply. An uncontrolled full wave 3-φ Diode Bridge is connected to the terminal of the Transformer. The Auxiliary Rectifier Output is connected to the Auxiliary DC Link described in Sub-section ***A*** above.

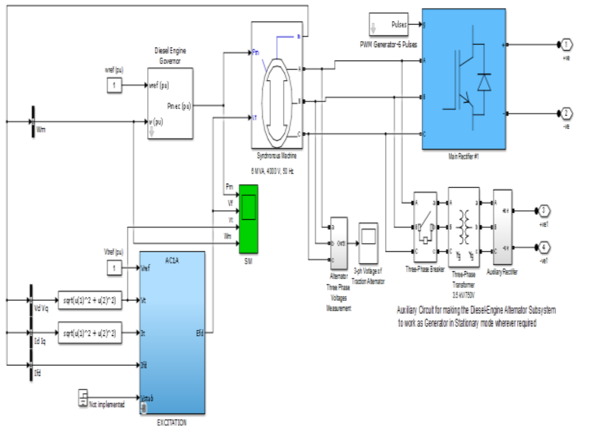


Fig. 2: Simulink Diagram of the Diesel-Engine - Traction Alternator - 6-Pulse Bridge Rectifier / Diode Bridge Rectifier - Main DC Link Circuit

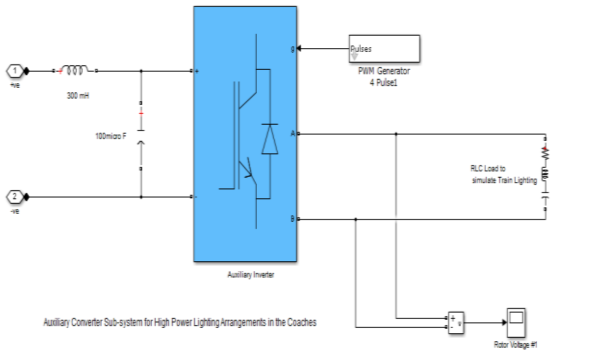


Fig. 3: Simulink Diagram of the High Power Train Lighting

C. The DC Link-Traction Inverter-Traction Motor Circuit

DC Link: The Traction Rectifier output of both the types of supply circuits is connected to the DC Link. The DC Link consists of a Capacitor Bank of 815µF and 11.43 mF connected in parallel to filter out the harmonics in the DC Voltage. A Diode is connected in the DC Link to ensure unidirectional Current. The output of the DC Link is connected to the Traction Inverter. Simulink Diagram of Traction Rectifiers - DC Link Circuit is shown in Fig. 4.

Traction Inverter: The Traction inverter is a 6-Pulse Bridge Inverter circuit with IGBTs as switching devices and is capable of generating sine waves displaced by a phase difference of 120˚. The Gate Pulse is delivered by means of a PWM generator such that the frequency of Inverter Operation can be varied according to the speed required at the wheel. The output of the Traction Inverter is fed to the Traction Motors. The axle configuration used in this Simulation is Bo-Bo where in all four axles are Powered by a Traction Motor individually. A Traction Inverter will drive a pair of Traction Motors.

Traction Motors: Four Permanent Magnet Synchronous Motors are used as Traction Motors in a Power Car in this Traction Drive Circuit. The Traction Motors are rated at 600 kW, 2200 V, 4-poles, 50-120 Hz as frequency of operation.

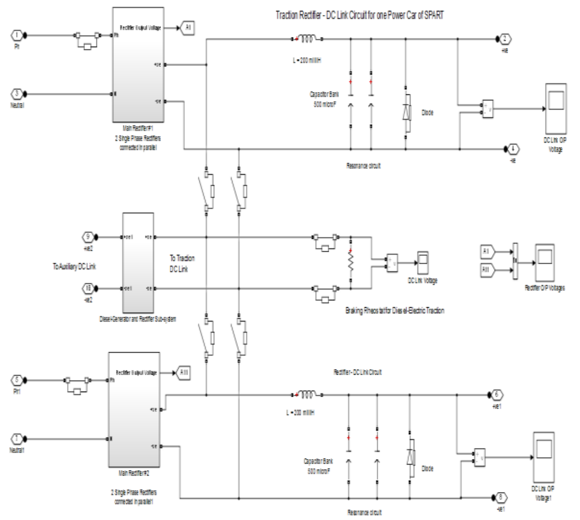


Fig. 4: Simulink Diagram of Traction Rectifiers - DC Link Circuit

IV. RESULTS AND DISCUSSION

The simulation of Traction Drive System of SPART is done on two modes. In the first 35 seconds of Simulation Time, the Traction Drive System and Auxiliary Drive System work together in running mode on both type of Traction. From time *t=35* seconds to *t=50* seconds, the Traction Drive System is de-activated and only the Auxiliary Drive System works signifying that the SPART is at Stand-still at the site of accident. As it has been mentioned in the introduction for SPART, the Speed set for the Simulation is 160 kmph at the Wheel for Electric Traction and 120 kmph for Diesel-Electric Traction.

The Simulation of the Circuit is started on Electric Traction with 1-φ, 25 kV, 50 Hz, AC being supplied from the Voltage Source. This Voltage is stepped down to 4 kV, AC by the Traction Transformer. A pulsating DC is observed at the Terminals of the 4-Pulse Bridge Traction Rectifiers which slowly builds up from 'Zero' to 3.9 kV. A straight line DC Voltage of magnitude 3.9 kV is seen across the Diode Terminals in the DC Link after the initial transients that last a few milli seconds. The DC Link Voltage observed in SPART Circuit is shown in Fig. 5. At the same instance as that of the Pulsing of Traction Rectifiers, the Traction Inverters.

The Voltage steadily built up to 3800 V in about 1.5 seconds of the Simulation Time. The initial transient observed in the Rectifier Voltage was also observed in the Inverter Voltage. The Traction Inverter Output Voltage Waveform when on Electric mode of Traction is shown in Fig. 6 in section labelled *(a)*. The Traction Motors notched up a Speed of 2798 rpm corresponding to a Speed of 160 kmph set in the Embedded MATLAB Program written to determine the Traction Inverter Switching Frequency as per the Speed requirements at the Wheels of the Power Car. The Frequency of operation of the Traction Inverter was 93 Hz. The Free-running Period was maintained until time *t=20* seconds on Electric mode of Traction. At time *t = 20* seconds, the Circuit Breakers on the Traction Rectifier Input Terminals were 'Opened' and simultaneously, the 3-φ Rectifier connected to the Output Terminals of the Traction Alternator was pulsed. The 3-φ Rectifier was connected to the DC Link of the Traction Drive System by 'Closing' of the Circuit Breakers connecting both of them. The mode of Traction was switched from Electric to Diesel-Electric mode without Braking, as a SPART has to be run non-Stop until the Destination is reached. With the 'Opening' of Circuit Breakers on the Electric Traction Side, the Voltage in the DC Link momentarily fell and again raised to 4 kV with the imposition of the Supply from the Traction Alternator. This can be seen in section labelled *(b)* in the Inverter Output Voltage Waveform shown in Fig. 6. At the same time the Speed of the Traction Motors was reduced to 2098 rpm corresponding to 120 kmph at the Wheel. The Voltage in the Circuit is maintained at 4 kV to keep Torque constant in order to compensate for loss in Tractive Effort due to reduction of Speed in Diesel-Electric mode of Traction. This Free-running period on the Diesel-Electric mode of Traction is continued until time *t=35* seconds. At time *t=35* seconds, Braking is initiated by 'Closing' the Circuit Breakers connecting the Brake Grid Rheostats and the 3-φ Rectifier such that the generated Alternator Voltage is diverted to the 3 MΩ Braking Rheostat. With the Circuit Breakers on the Electric Side already 'Open', there is no Voltage in the DC Link and as a result in the Traction Inverter. This is shown in section labelled *(c)* in Fig. 6. The Speed of the Traction Motors also fell to 'Zero'. The Speed-Time Curve in rpm of the Traction Motors is shown in Fig. 7 for both Electric and Diesel-Electric modes of Traction. The Speed-Time Curve in kmph expected at the Wheels of the Power Car is shown in Fig. 8.

The Auxiliary Circuit consisting of the Electrical Loads have to be kept Switched On even during the running Instances of SPART. In order to deliver Power to the Auxiliary Loads in Electric mode of Traction, Circuit Breakers provided at the Input Terminals of the Auxiliary Rectifier are initially in 'Closed' position. A Voltage of 1 kV is imposed on both the Auxiliary Diode Bridge Rectifiers. In order to filter out the Harmonics in the Rectifier Output Voltage, an Auxiliary DC Link consisting of an Inductor of 200 mH and a Capacitor of 100 μF is used in the Auxiliary Power Circuit. The Voltage steadily built up across the Capacitor in the DC Link. The DC Link Voltage in the Auxiliary Circuit is shown in Fig. 9.

The 3-φ Auxiliary Inverter with IGBT as Switches is pulsed at Industrial Frequency of 50 Hz. With the imposition of the DC Link Voltage across the Input Terminals of the Inverter, the Voltage observed in the Auxiliary Inverter is nearly 1000 V. This is shown in Fig. 10. The Squirrel Cage Induction Motors (Air-conditioning Compressors) connected across the Output Terminals of the Auxiliary Inverter developed a Speed of 1490 rpm (Fig. 11). On the other Auxiliary Circuit, 4-Pulse IGBT Inverter was connected to provide Power Supply to the Lighting Equipments in the Coaches as these were 1-φ Loads.

When the Traction mode was switched over to Diesel-Electric mode at time *t=20* seconds, the Power Supply from the Traction Transformer was cut by 'Opening' the Circuit Breakers connecting the Traction Transformer Terminals with the Auxiliary Rectifier. The Power Supply to the Auxiliary Loads also switched to Diesel-Electric mode. A 3-φ, 1 MVA, 4kV/1 kV Step-Down Transformer was connected to the Traction Alternator Terminals by closing the 3-φ Circuit Breakers. The 3-φ Diode Bridge connected to the Step-down Transformer delivered a pulsating DC of 1000 V to the common Auxiliary DC Link and this in turn was imposed on both the Auxiliary Inverter Circuits. Thus, an un-interrupted Power Supply to the Auxiliary Loads could be achieved in Diesel-Electric mode of Traction. After the initiation of Braking at time *t=35* seconds, the Traction Alternator continued to generate Voltage in Generator mode to deliver Power to the Auxiliary Circuits through the Step-down Transformer as seen in Fig. 10 and Fig.11 whereas the Voltage in the Traction Drive Circuit is 'Zero' as seen in section *(c)* of Fig. 6. The versatility of Diesel-Electric - Traction Alternator System working to drive the Traction Motors and at the same time serving a Generator is demonstrated in this Simulation Study of Traction Drive System for SPART.

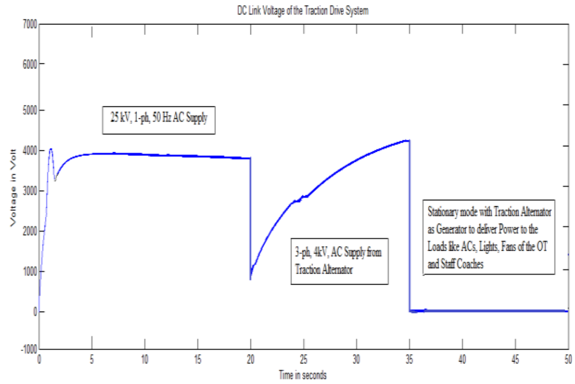


Fig. 5: DC Link Voltage

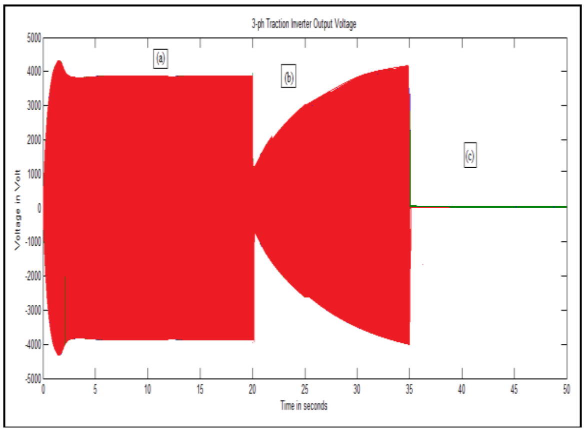


Fig. 6: 3-φ Traction Inverter Output Voltage Waveform

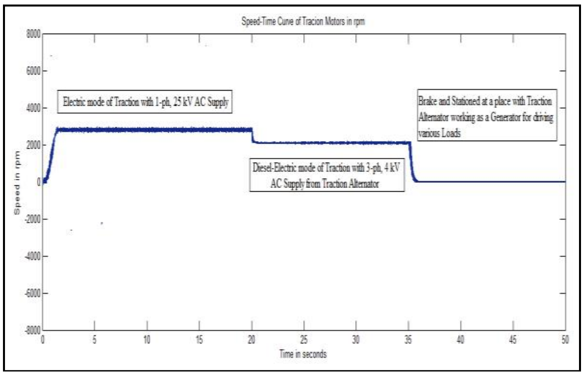


Fig. 7: Speed-Time Curve of Traction Motors in rpm

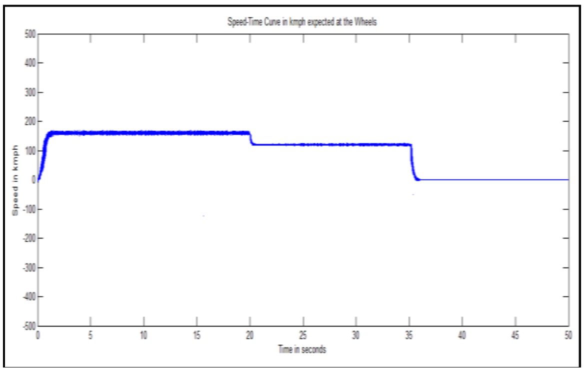
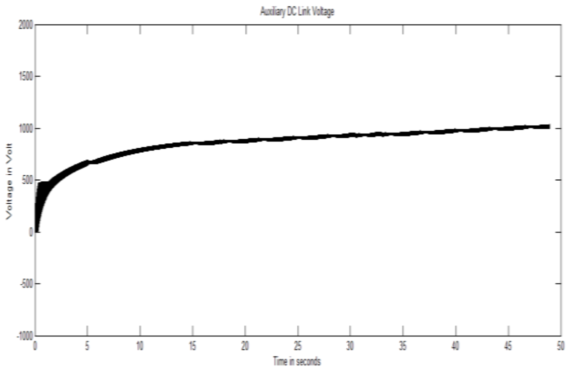


Fig. 8: Speed-Time Curve in kmph expected at the Wheels

Fig. 9: Auxiliary D



C

Link Voltage

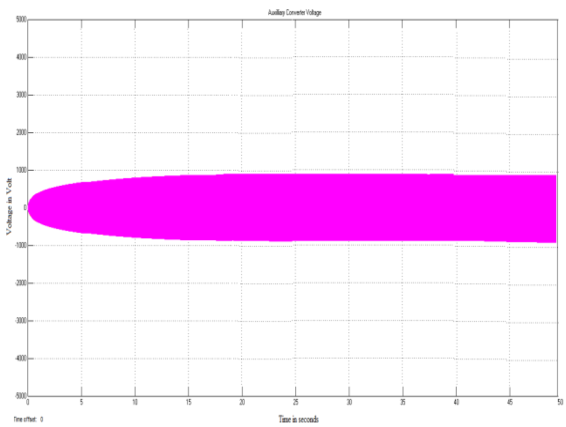


Fig. 10: 3-φ Auxiliary Inverter Output Voltage

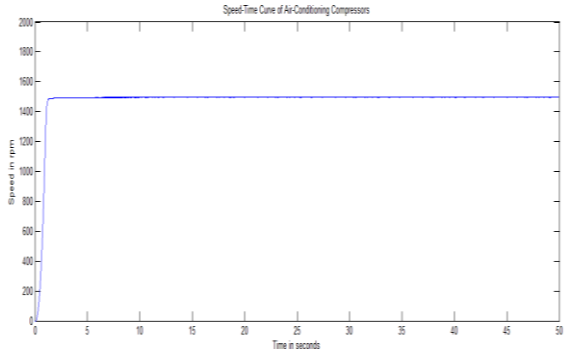


Fig. 11: Speed-Time Curve of Air-Conditioning Compressors

V. CALCULATIONS

A SPART has a combination of four passenger coaches converted into OT, Ward, Staff resting Area

TABLE I
Break-Up of Loads in a SPART

S. No.	*Type of Wagon / Coach*	*Weight in Tonne*	*No. of Coaches / Wagons*	*Total Electrical Loads*
1.	*Passenger Coaches converted into OT, Sleepers, Wards*	*52*	*04*	*300 kW*
2.	*BCNA Wagons*	*56*	*02*	*-*
3.	*Flat Bed Wagon*	*57*	*01*	*-*
4.	*Crane*	*140*	*01*	*100 kW*
5.	*Power Cars*	*35*	*02*	*150 kW*

and Kitchen to cook food for Staff and Passengers of the Train that met with Accident, Two BCNA Wagons for carrying Equipment, One Flat Bed Wagon carrying Tracks, Sleepers and one Crane Unit of 140 Tonne totalling Eight Trailing Units. The Break-Up of the Load in Tonne is shown in Table No. 28. The SPART is accelerated to 160 kmph in 500 seconds and after that, the Speed is maintained at 160 kmph in Electric Traction mode and 120 kmph on Diesel-Electric Traction mode.

(a) Calculation of Tractive Effort:

Acceleration, α in kmphps will be given as,

$$\alpha = \frac{160}{500} = 0.32\ kmphps$$

Weight of the Trailing Load = W_t = $[(4 \times 52) + (1 \times 57) + (2 \times 56) + (2 \times 35) + (1 \times 140)]$ = ***587 Tonnes***

Effective Weight of the Total Loads = $W_e = W_t \times 1.1$ = 587×1.1 = ***645.7 Tonne***

Tractive Effort for Acceleration (F_a): $F_a = 277.8\, W_e\, \alpha\ \ Newtons$
Tractive Effort required for Acceleration = F_a = 277.8 × 645.7 × 0.32 = $\mathbf{57.4\ kN}$
Tractive Effort required to overcome Train Resistance at 160 kmph is calculated as,
F_{cr} = $9.81 \times 645.7[(1.424) + (0.0054 \times 160) + (0.000025 \times 160^2)]$ Newton = ***19 k N***
Total Tractive Effort required to overcome Train Resistance for a Passenger Train (F_{tr}):

$$F_{tr} = F_r + F_{cr} = 0 + 19\ \text{kN} = \mathbf{19\ kN}$$

Tractive Effort required to overcome Curve Resistance (F_c):

$$F_c = 9.81\, W \left(\frac{700}{R}\right) Newtons = 9.81 \times 645.7 \left(\frac{700}{300}\right) Newton = \mathbf{15\ kN}$$

Tractive Effort to overcome Gravitational Pull (F_g):

$$F_g = 9.81\, W.G\ \ Newtons = 9.81 \times 587 \times 1 = \mathbf{6\ kN}$$

Total Tractive Effort = $F_t = F_a + F_r + F_c + F_g = 57.4 + 19 + 15 + 6 = \mathbf{97.4\ kN}$
Max. Power Output required at the Axles = P_{max} = $[0.277 \times 97.4 \times 160]$ kW = ***4317 kW***
There are two Power Cars with Four Traction Motors in each Power Car. Hence, the Maximum Power Output required per Traction Motor = 4317 ÷ 8 = ***540 kW***
Assuming a Motor Efficiency of 95%, the Power Input to be given to a Traction Motor = 540 ÷ 0.95 = ***568 kW***
Taking in to considerations variations in working conditions, the 3-φ Permanent Magnet Synchronous Motors used as Traction Motors are rated at ***600 kW*** each for SPART

(b) Calculation of Power, Torque and TE developed on OHE Supply:
Voltage per phase = 3800 V
Current per phase = 120 A
Power Factor = 0.86 (Assumed)
Efficiency of the Machine = 97% (Assumed)
Frequency = 50 Hz, No. Of Poles = 4, Diameter of the Wheel = 1092 mm
Efficiency of the Gear = 0.9 Gear Ratio for Drive Cars = G_r = 3.6
Power input to the PMSM = $\sqrt{3} \times Vph \times Iph \times Cos\varphi$ Watts
= $\sqrt{3} \times 3800 \times 110 \times 0.86$ Watts = ***622638 Watts (per Motor)***
Power Output per Motor = 0.97 x 622638 = ***603958 Watts***
Speed of the PMSM = N_{tm} = $\frac{120 \times f}{p}$ rpm = $\frac{120 \times 50}{4}$ = 1500 rpm
Torque developed per Machine at 160 kmph = $\frac{60 \times P}{2 \times \pi \times N}$ Nm = $\frac{60 \times 603958}{2 \times \pi \times 2798}$ Nm = ***2061 Nm***

Total Torque developed by 8 Traction Motors = T_d = ***16490 Nm***

Tractive Effort Developed = $\frac{n_e \times T_d \times G_r}{R_w} = \frac{0.9 \times 16490 \times 3.6}{0.546}$ = ***97.85 kN***

(c) Calculation of Power, Torque and TE developed on Diesel Engine-Alternator Supply:
Voltage per phase = 4000 V
Current per phase = 100 A
Power input to the PMSM = $\sqrt{3} \times Vph \times Iph \times Cos\varphi$ Watts
= $\sqrt{3} \times 4000 \times 100 \times 0.86$ Watts = ***595825 Watts (per Motor)***
Power Output per Motor = 0.97 x 595825 = ***577950 Watts***
Torque developed per Machine at 120 kmph = $\frac{60 \times P}{2 \times \pi \times N}$ Nm = $\frac{60 \times 577950}{2 \times \pi \times 2098}$ Nm = ***2630 Nm***

Total Torque developed by 8 Traction Motors = T_d = ***21045 Nm***

Tractive Effort Developed = $\frac{n_e \times T_d \times G_r}{R_w} = \frac{0.9 \times 21045 \times 3.6}{0.546}$ = ***125 kN***

(d) Power requirements for operating the Auxiliary Loads:
The total connected Load is = ***550 kW***
As the Crane does not work in the Transit Period, the total connected Load is = ***400 kW***.
The Coaches and the Control Equipments of the Drive Car are operational during the Transit period, with a Diversity Factor of 0.7, the Max. Demand = 0.7 × 400 kW = $\mathbf{280\ kW}$
When running on ***OHE Supply***,
Output Voltage of Auxiliary Winding of Transformer = 1000 V
Output Current of Auxiliary Converter = 100 A
Output Power at each Auxiliary Inverter terminals fed from Auxiliary Windings of Transformer = $\sqrt{3} \times V \times I \times Cos\varphi = \sqrt{3} \times 1000 \times 100 \times 0.86$ = **149 kW**
Power drawn from the two Auxiliary Tapings of the Traction Transformer in a Power Car,
= ***298 kW***
When running on ***Traction Alternator Supply***,
Output Voltage of 3-φ Step-Down Transformer = 1000 V
Output Current of Auxiliary Converter = 100 A
Output Power at each Auxiliary Inverter terminals fed from when Traction Motors running = $\sqrt{3} \times V \times I \times Cos\varphi = \sqrt{3} \times 1000 \times 100 \times 0.86$ = **149 kW**
Power drawn from the two Converters connected to the 3-φ Step-Down Transformers in a Power Car = ***298 kW***
When the SPART is at ***Standstill with Traction Alternator working as Generator***,
The Crane also works and hence the Max. Demand rises to 550 kW.
All four Auxiliary Converters have to be brought into Service and hence,
Power drawn from the four Converters connected to the 3-φ Step-Down Transformers (both the Power Cars) = ***596 kW***

(e) Specific Energy Consumption

Let the total Distance covered by SPART be 600 kms (assuming every Division has one).

Energy output of driving Axles to accelerate the Train (***E_a***):

$$E_a = 0.01072 \times V_m^2 \times W_e$$
$$= 0.01072 \times 160^2 \times 645.7$$
$$= \mathbf{177200\ Wh}$$

Energy output of driving Axles to overcome Gradient (***E_g***):

$E_g = F_g \times D_1$ Watt hours $= 6\ kN \times 10 = \mathbf{60000\ Wh}$

Where D_1 = Distance for which Power is 'On'.

Energy output of driving Axles to overcome Friction (***E_r***):

$$E_r = F_r \times D_2 = 0.277 \times W \times r \times D_1\ \ Wh$$
$$= 0.277 \times 19 \times 600 = \mathbf{3158\ kWh}$$

Where D_1 = Distance for which Power is 'On'.

Total Energy Output of driving Axles = $E_a + E_g + E_r = 177200 + 60000 + 3157800 = \mathbf{3395 kWh}$

Specific Energy Output = $\frac{E}{W \times D} = \frac{3395000}{587 \times 600} = \mathbf{9.63\ Wh/Tonne\ km}$

Where D = Total Distance travelled by the Train

Specific Energy Consumption = $\frac{Specific\ Energy\ output\ at\ driving\ Wheels}{Overall\ Efficiency\ of\ Transmission\ Gear\ and\ Motors} = \frac{9.63}{0.9 \times 0.97} = \mathbf{11\ Wh/Tonne\ km}$

VI. CONCLUSIONS

Self-Propelled Accident Relief Trains capable of working on both modes of Traction and having a Speed range of 140 – 160 kmph can be manufactured as the Technology of Future for taking up quick relief measures in case of Accidents. The use of Diesel-Engine Alternator System as Generator at the Accident Site to generate Power for the operation of Cranes, mobile Operation Theatres, Wards, Staff resting Area and Pantry Car would reduce the reliance on Local Power Supply. The implementation of the proposed Drive would also ensure the working of Relief Train at Nights at the Accident Site and the Simulation results clearly supports the proposed SPART system.

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