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# A Step Towards Increasing the Efficiency of Head on Generation (HOG) Scheme in an Alternative Way using the Proposed Technique of Over End Generation (OEG)/ Over Mid Generation (OMG) - in Indian Railways

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**Abstract –** *As like the nervous system network in our body IR (Indian Railways) has a network in India which connects north to south and east west zone. A small idea/innovation for IR can bring a huge impact all over India.*

*The paper aims to study briefly the IR current use of locomotives, rolling stock in terms of their generation method, introduced HOG scheme and challenges faced to implement HOG to IR network.*

*There is investigation done on the current HOG scheme and discovered certain limitations, hence proposing an alternative solution to maximize use of HOG scheme in an alternative way, will make Rake (Rolling Stock) Locomotive independent with economic and social benefit.*

***Key Words***: **Indian Railways, HOG, EOG, SG, WAP-7, WAP-5, WAP-4, Hotel load Convertor, ICF, LHB, Rolling Stock, Locomotive**

## 1. Introduction to IR (Indian Railways)

Indian Railways is one of the best organizations with the highest number of employees who serve to Indian Railways day and night with a lot of dedication and passion. Due to these people's effort and worship to their work, Indian Railways is achieving new milestones day by day.

### 1.1 Introduction to Coach type used in IR

IR daily runs 13523 passenger trains for both long distance and sub urban sections. The long-distance train uses both ICF (Integral Coach Factory) and LHB (Linke Hofmann Busch) coaches. Due to certain limitations in ICF and old technology railway adopted LHB technology under TOT (Transfer of Technology) and it have certain features like made of Stainless-steel result in light weight, advanced pneumatic disc brake system, anti-telescopic, improved suspension system etc. LHB is its uses CBC (Centre Buffer Coupling) This type of coupling considered to be "anti-telescopic", which means they do not get turned over or flip in case of a collision which reduces the no. of casualties during the accident. Whereas ICF uses Screw Coupling These types of screw coupling are not safe for the passenger. The breaking of screw or buffer is they're during the accident which causes the derailment of trains & major casualties [8]

IR in 2016 decided to replace all ICF coaches to LHB type coach and ICF coach production shut down in 2018. LHB has one limitation over ICF, it can't use Self Generation method to cater hotel load requirement of the rake so LHB depends on EOG (End on Generation). In this system power cars are placed on either side of the rake and with the help of diesel generator electricity is fed to cater the hotel requirement of the rake. As the LHB rake demand increase results in a greater number of power cars result in huge consumption of diesel and two coach spaces used for power cars. So, to overcome this limitation, railways come up with the HOG (Head on Generation) scheme.

## 2. Introduction to need of Generation in Coach/Rake

IR is one of the largest passengers carrying means of Transport in all over the world and also called Lifeline of India, hence uses different types of Coach for its passenger operation which provide different kinds of service to different classes of people. The kind of service provided and the interior of the coach is different, but the passenger operation is the same for all types of train which include a loco haul train. Here there is a locomotive only to pull the entire rake (a number of passenger coaches coupled together excluding Loco), But what about the hotel load needed to cater electrical appliances for the entire rake?

So, with this requirement for generation of electricity to cater hotel load of rake.

There come the basic three types of Generation used in IR till date which are as follows:

1. Self-Generation (SG)
2. End on Generation (EOG)
3. Head On generation (EOG)

Types of Generation (Brief) used in IR

**2.1. The Self Generation** method is one of the most widely used methods for Generation of electricity in IR. This method is clean and eco-friendly and was used in ICF type coaches. This method includes alternator, battery, Inverter and rectifier. Alternator is connected to the axle pulley which is connected with 4 V- belt, so when wheel rotates (train in motion) V-belt tend to rotate the alternator and produce 3-phase electricity

This produced voltage is rectified to the field winding till such time full voltage is generated. Rectifier Regulating Unit (RRU) and later called as Electronic Rectifying and Regulating Unit (ERRU) is used to convert 3-phase voltage to regulated DC 120V output, this power is stored in the Battery. Battery when charged supply power to cater hotel requirement in the coach through inverter. The essential advantage of this method is that it is rake independent. The coach using SG can couple or decouple from one rake to another.

The limitation of SG is that it Fails/Not applicable for premium trains having all air-conditioned coaches like Rajdhani, Shatabdi trains.

If this is in practice loco has to pull the train as well as to rotate the alternator which will require more power from the locomotive resulting in slow speed (acceleration) and also cannot generate electricity to power all air-conditioned coaches in a rake. So, SG is limited to trains where the train has few air-conditioned coaches like superfast, Mail/express trains.[4]

## 2.2. End on Generation (EOG)

To overcome the Limitation of SG there comes EOG. In this method, a power car also known as Generator car is placed at either end of the rake. Each power car is equipped with two Diesel Engine and two Diesel Alternator (DA) sets generating 3-phase (four wire) power supply of 750 volts 50 Hz.

The power generated is transmitted with the help of Inter-Vehicle (IV) Couplers having two parallel cables termed as Feeder-A and Feeder-B running through the whole length of the train (rake). These IV couplers also carry the earth wire and 2 wire for circuit control.

This power is then fed to each coach having 50 KVA transformer in Conventional coach, 60 KVA in LHB AC coach and 9/15 KVA for LHB Non-AC.

This Step-Down transformer steps down 750 V 3 Φ AC 4 wire, 50 Hz supply to 415 V/190 V/110 V, as per requirement.[9] Single power car has the capacity to take the hotel load of the entire rake and there is a 100 % backup for spare capacity (kept one power car for stand-by).

As a power car produces electricity and is placed on both sides of the train hence it is called End on Generation (EOG). The Diesel Engine provided is turbo charged, water cooled delivering 490 BHP at 60 DegC at 1500rpm coupled to 500 KVA alternators. The alternator provided has a capacity of 500kVA, 0.8 pf 3- phase, 4 wire 750 volts 50 HZ +\- 3 %. The alternator used is self-ventilated brushless design with voltage regulation of dual type i.e., both electric and electronic.

EOG is one of the best methods and is currently used in IR. This method adds up an additional coach and can be used for high-speed operation.

Earlier this method was introduced for Rajdhani type premium trains but when LHB coaches came in India under TOT power car requirement increased. This is because the LHB coach cannot use SG system due to its FIAT bogie and Disc brake. So, when superfast, Mail/express train upgraded to LHB rake they also used EOG system. [1][3]

**Limitation of EOG:**

- EOG method consumes a lot of diesel
- EOG method require two additional coach (power car)
- Require hue instalment (each coach cost more than 3 crore)
- Power car produced noise pollution and air pollution

## 2.3. Head on generation (HOG)

In this scheme head is the locomotive which produces electricity, to cater hotel load requirements of the train.

As IR conventional coaches (ICF) production was stopped in 2015 and all IR trains were being Lhbfied so power car demand was increasing day by day which led to huge consumption of diesel and was not Eco-friendly.

IR already started looking for alternative solutions for the same.

In 1995 Indian Railways imported WAP-5 and WAG-9 from ABBs locomotives. These locomotives were 3-phase traction motors supplied by GTO based converters which are controlled by advanced microprocessor-based control technology.

The WAP-5 locomotive had an additional feature called Head on generation.

Till date WAP-5 became the fastest locomotive in IR network but the Tractive Effort was very low, so CLW and RDSO engineer together taking WAG-9 as base design changing in Gear ratio, they gave birth to WAP-7 (Co-Co type bogie) made for passenger service, capable of accelerating a 1430t load to 100km/h in 235 seconds as compared to 325 seconds for a WAP-5.[1][2]

**Table -1:** Passenger Locomotive used in IR technical specification [5][6][7]

| Technical Specification | WAP-4 | WAP-5 | WAP-5 HOG | WAP-7 | WAP-7 HOG |
|---|---|---|---|---|---|
| **Length over Buffer** | 18794 mm | 18162 mm | 18162 mm | 20562 mm | 20562 mm |
| **Overall Width** | 3055 mm | 3142 mm | 3142 mm | 3100 mm | 3100 mm |
| **Height of Roof (in Panto lock down position)** | 4232.5 mm | 4255 mm | 4255 mm | 4255 mm | 4255 mm |
| **Weight of Loco** | 112.8 T | 78 T | 78 T | 123 T | 123 T |
| **Axle Arrangement** | Co- Co | Bo-Bo | Bo-Bo | Co-Co | Co-Co |
| **Gear Ratio** | 58:23 | 1:3:65 | 1:3:65 | 72:20 | 72:20 |
| **Horse power** | 5060 hp | 5440 hp | 5440 hp | 6120 hp | 6120 hp |
| **Transformer** | 5400 KVA | 7500 KVA | 7775 KVA | 7500 KVA | 7775 KVA |
| **Traction Motor** | 6-Hitachi T.M Type HS-15250A | 4 T.M Type-6FXA7059 3-phase Squirrel-cage induction motor | 4 T.M Type-6FXA7059 3-phase Squirrel-cage induction motor | 6 T.M Type-6FRA6068 3 -phase Squirrel-cage induction motor | 6 T.M Type-6FRA6068 3-phase Squirrel-cage induction motor |
| **Hotel load** | Not Available | One single phase hotel load winding | First Locomotive Equipped with HOG (no. 30140) | One single phase hotel load winding | Equipped with Hotel load convertor (2X500 KVA) |

At present IR is producing WAP-5 and WAP-7, production of WAP-4 is closed in the year 2015. WAP-5 when imported from ABB/Switzerland having an additional feature of Head on generation (HOG). In the main transformer of the locomotive there is arrangement of hotel load winding to cater power supply for Hotel load of the train.

The design received from ABB/Switzerland under TOT (Transfer of Technology) there was arrangement for single phase hotel load winding & there was no hotel load converter (convert single phase to 3-phase). The single-phase output was directly connected to Inter Vehicle (IV) coupler from the main transformer and provided to the rake as per hotel load requirement. But this feature could not be used because coach require 3- phase instead of single phase to run the appliances (AC)

As their continuous advancement & innovation in the field of electronics IR decided to make Hotel load convertor of 2x500KVA for WAP-7 locomotive, this was earlier for WAP-5 locomotive as this loco having HOG winding so WAP-7 adopted the main transformer of WAP-5 locomotive (LOT 7500). The main aim was to convert the single phase of hotel load to 3-phase hotel load through Hotel load converter and through IV coupler transfer that electricity to the entire rake to feed the requirement of hotel load.

So, IR left the original design of WAP-5 and was successful in installing HLC in the WAP- 7 locomotive. In Jully'2011 CLW rolled out the first hotel load converter locomotive WAP-7(HOG) no. 30277 having single hotel load winding of 945 KVA in (LOT 7500). The single hotel load winding diagram shown in Figure-1.[1][2]

### 2.3.1 Problem Faced in single winding

In Traction Transformer LOT 7500 there were failure reports of 60 KVA coach transformer, 100 VA coach transformer and other coach equipment's. The HLC were connected in parallel to single hotel load winding, resulting in unreliable operation. This was due to parallel connection which resulted in circulating current; by single winding both of the HLC operations was not possible. So, IR engineers came up with a solution by changing LOT 7500 to LOT 7775 and providing two separate hotel load windings for input supply. Newly designed M/s Hi-Volt make modification to loco traction transformer (7775 KVA) having two secondary hotel load winding of 2X622.5 KVA, 960 V i.e. separate winding for each converter was installed in WAP-7 loco no. 30365 at ELS/GZB (Electric Loco Shed/Ghaziabad) of NR (Northern Railways). In this locomotive, M/s Siemens make 2x500 KVA hotel load converter (HLC) has been provided. M/s Siemens has provided external R-C filters to reduce Line to earth voltage harmonics in output of the hotel load convertor. The schematic diagram of Hotel Load convertor with dual hotel load winding is shown in Figure-2[1][2]

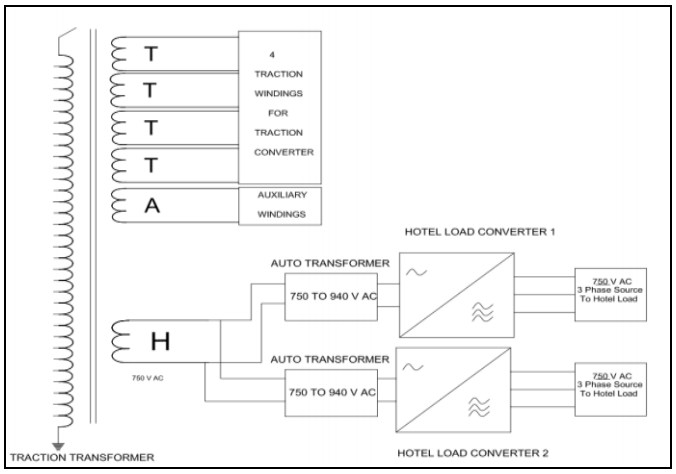


**Fig -1:** HOG schematic with single hotel load Winding in loco transformer (7500 kVA)[1]

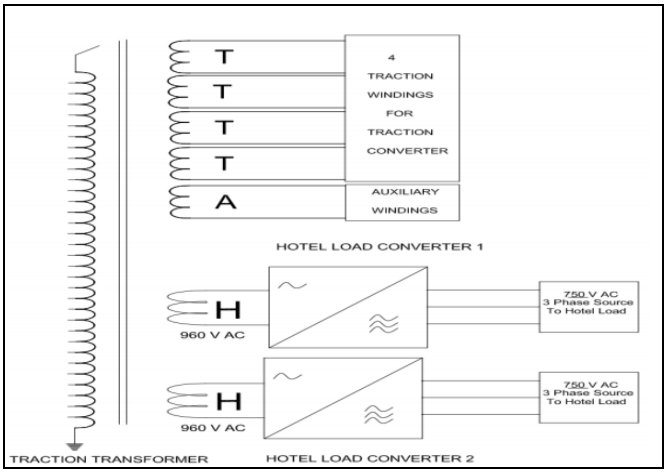


**Fig - 2:** HOG schematic with dual hotel load Winding in loco transformer (7775 kVA) [1]

## 3. Problem Identification and Formulation of current HOG scheme

According to the survey on HOG based locomotive "WAP-7", current system problem found such as:

**Case 1:** During Loco reversal (rake reversal)-the train reverses direction on a regular basis during its journey (refer Table:2 Case-1A & Table:3 Case-1B)

**Case 2:** Maintenance & Checking of rake at washing line before departure on a regular basis (refer Table:4 Case-2A & Table:5 Case-2B)

**Case 3:** HOG Connected EOG running at the time of departure (refer Table:6)

**Case 4:** Offlink in case of failure of locomotive

**Case 5:** In case of Link/Slip express types trains where the rake is amalgamated and detached (refer Table:7)

**Case 6:** Incident with Kalka Shatabdi and Amritsar Shatabdi train compatible with HOG Scheme (at New Delhi Station) (refer to Table:8)

**Case 7:** Pollution (air & noise) from HOG enabled trains majorly at their originating Junction/station such as New Delhi Station, and at Washing Line (refer to Photo 1,2 & 3)

In all above-mentioned points due to the protocol of railways locomotives are detached from the rake and to give continuous supply for hotel load to the entire rake EOG (End on generation) is used. In EOG electricity to power, the hotel load of entire rake is generated through generator set.

### 3.1. Case Study done for the above mention limitation

**Table-2:** CASE 1A- Loco Reversal for Start of Return Journey (Date: 11 July,2018)

| Rake reversal Station | Train Number | Train Name | Loco Type | Loco Number/ Shed | OffLink/ On Link | Arrival Time | | Departure Time | | Time Taken for Reversal (EOG Put on) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Schedule | Actual | Schedule | Actual | |
| Ranchi | 12019/ 12020 | Howrah-Ranchi Shatabdi Express | WAP-7 | 30455/HWH | Onlink | 13:15 | 13:11 | 13:45 | 13:51 | 30 min |

**Table-3:** CASE 1B - Loco Reversal at The Time of Rake Reversal (Date: 12 July,2018)

| Rake reversal Station | Train Number | Train Name | Loco Type | Loco Number/ Shed | OffLink/ On Link | Arrival Time | | Departure Time | | Time Taken For Reversal (EOG put on) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Schedule | Actual | Schedule | Actual | |
| Netaji SC Bose Jn Gomoh | 12019 | Howrah-Ranchi Shatabdi Express | WAP-7 | 30455/HWH | Onlink | 9:52 | 9:51 | 10:12 | 10:18 | 25 min |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Netaji SC Bose Jn Gomoh | 12020 | Ranchi-Howrah Shatabdi Express | WAP-7 | 30455/HWH | Onlink | 16:55 | 16:55 | 17:15 | 17:18 | 27 min |

**Table-4:** CASE-2A: Maintenance and Checking of Rake at Washing Line (Date: 23 March,2019)

| Days | Train No | Train name | Time start for testing of rake (washing line) EOG is on | Schedule departure | EOG running timing | Diesel consumed ( 1 hour = 55 litres) |
|---|---|---|---|---|---|---|
| MON - SAT | 12005 | New Delhi- Kalka Shatabdi Express | 11:00 | 17:15 | 6 hrs | 330lt * 6 =1980lt |
| SUN | 12005 | New Delhi- Kalka Shatabdi Express | 13:00 | 17:15 | 4 hrs | 220lt |

**Table-5:** Case 2B –Time Taken, Rake to Go from Washing Line (SRC) To Howrah Jn (Date: 24 Jan,2020)

| Train No. | Train Name | Loco Type | | Status | | Time taken, Rake to go from Washing line (SRC) to Howrah Jn. | Schedule departure | EOG running timing | Diesel consumed ( 1 hour = 55 liters) |
|---|---|---|---|---|---|---|---|---|---|
| | | Front | Rear | EOG | HOG | | | | |
| 12863 | Howrah – Yesvantpur SuperFast Express | WDS-6 (shunt) | WAP-7 | On | Not Connected | 1:15 | 20:35 | 1:15 hrs **(atleast)** | 55 + 8.25 = 63.25lt |
| 12262 | Howrah – Mumbai AC Duronto Express | WDS-6 (shunt) | WAP-7 | On | Not Connected | 1:15 | 08:20 | 1:15 hrs **(atleast)** | 55 + 8.25 = 63.25lt |

**Table-6:** CASE-3 HOG Connected EOG running at the time of departure
It's been found many times that WAP-7 HOG connected with the rake and ran with EOG. The operator says if there is any problem in HOG they can't resolve as HOG is there in loco, and during the running time, it's not possible, if there is any trouble, they switch to EOG and do not take the risk.

| Date | Station | Train Number | Train name | Loco Type | Loco Number/Shed | OffLink/ On Link | Status |
|---|---|---|---|---|---|---|---|
| 11 Oct 2019 | Jalandhar City Junction | 12030 | Amritsar - New Delhi Swarna Jayanti Shatabdi Express | WAP-7 | GZB | Onlink | HOG connected |
| 25 April 2019 | Jalandhar City Junction | 12030 | Amritsar - New Delhi Swarna Jayanti Shatabdi Express | WAP-7 | 37043/GZB | Onlink | HOG connected |
| 16 June 2018 | New Delhi Station | 12301 | New Delhi-Howrah Rajdhani Express | WAP-7 | 30504/HWH | Onlink | HOG connected |
| 16 June 2018 | New Delhi Station | 12314 | New Delhi-Sealdah Rajdhani Express | WAP-7 | 30469/HWH | Onlink | HOG connected |
| 3 March 2018 | Ambala Cantt. Junction | 12011 | New Delhi - Kalka Shatabdi Express | WAP-7 | GZB | Onlink | HOG connected |

| **Table-7**: Case- 5: For Link/Slip Trains |
|---|
| If Link Slip trains allotted with LHB rake they need a backup option at the time of attaching and detaching of the rake. Example: 18101/Tatanagar - Jammu Tawi Link Express arrive at Muri Junction 16:50 and 18309/Sambalpur - Jammu Tawi Express at Muri Junction 16:55 both rake amalgamates and departs at 17:30 so, at least 40 min backup for one of the two rakes required. If DG used than noise and air pollution problem in that station it's not originating station so providing 750V point option for one train is not a profitable approach. Throughout its journey Train has two Loco Reversal point at Amritsar and Pathankot Junction<br>To connect HOG from loco to rake be it originating station or at Loco reversal time, Loco panto is lowered down along with all following precaution to connect HOG IV Coupler and UIC manually |

| **Table-8:** Case 6: Incident with Kalka Shatabdi and Amritsar Shatabdi train compatible with HOG (at New Delhi Station) |
|---|
| On 23/March/2019 Train-12013-Amritsar Shatabdi, while departure HOG coupler broke (at the time of departure) so due to this train delayed by 41min and Amritsar Shatabdi, went with the EOG system. Due to this 12005-Kalka Shatabdi rake time to arrive on platform delayed and this results in no time for connection of HOG to loco which results in switching to EOG System. Kalka Shatabdi departed at 5:23 (estimate time) |

Case 7-Pollution (Air/Noise) from HOG Enabled Trains Majorly at Their Originating Junction/Station and Washing Line

**Photo- 1**: Santragachi (SRC) Washing Line (Date: 24 Jan,2020)

**Photo- 2:** New Delhi (NDLS) Washing Line (Date: 27 Dec,2018)

**Photo-3:** New Delhi (NDLS) Station (Date: 18 June,2018)

## 4. Proposed Solution for New Method

For the concern to use HOG to its full potential. The proposed idea is instead of using a locomotive for HOG method, designing a coach equipped with the pantograph, HLC, Step Down Transformer and other required devices installed underslung and the remaining area can be utilized for passenger sitting. The coach can be named as Transformer Car and technique can be termed as OEG (Over End Generation) or OMG (Over Mid Generation) as like EOG method OEG/OMG coach which is itself able to fulfil the hotel load requirement of the entire rake. This coach is dedicated for OEG/OMG and will be placed at the end of rake in place of EOG or at middle in place of pantry car and name Transformer cum Pantry car Coach.

In the dedicated coach, there is no interruption of HOG Scheme (be it loco reversal or at washing/maintenance line) The source remains only OHE and at the time of OHE failure perhaps need to have a backup solution. There can be made arrangement for underslung battery lithium-ion(450kwh) with charger cum inverter (500kva) synchronized to 750V feeder arrangement.

### 4.1 Equipment Required for OEG/OMG coach

1.Pantograph

2.Step Down Transformer (1200kva)

3.HLC (Hotel Load Convertor) (1000kva)

4.Baby Compressor

5.Cubicle Control

6.Lithium-ion Battery with Charger cum Inverter

Lithium-ion(450kwh) with charger cum inverter (500kva) synchronized to 750V feeder arrangement. (for trains having both AC and Non-AC Coach like Superfast Express)

-Lithium-ion(450kwh) with charger cum inverter (750kva) synchronized to 750 V feeder arrangement. (For AC trains like Rajdhani Express)

### 4.2 Working of Transformer Car Coach

- From OHE electricity is catered through Pantograph (in the coach itself).
- The Voltage is then stepped down to 960V from the Step Down Transformer.
- Single-phase alternating current is converted to 3-phase alternating current using Hotel Load Convertor (HLC).
- From Cubicle Control current is to be supplied to cater hotel load requirement of the train through IVC (Inter-Vehicle Coupler)

#### 4.2.1 In case OHE failure

- From Cubicle Control switch to Battery Back-Up Mode
- Taking DC current from Lithium-ion Battery
- Charger cum Inverter (DC to AC)
- From Cubicle Control current is to be supplied to cater hotel load requirement of the train through IVC (Inter-Vehicle Coupler)

**Proposed Circuit Diagram**

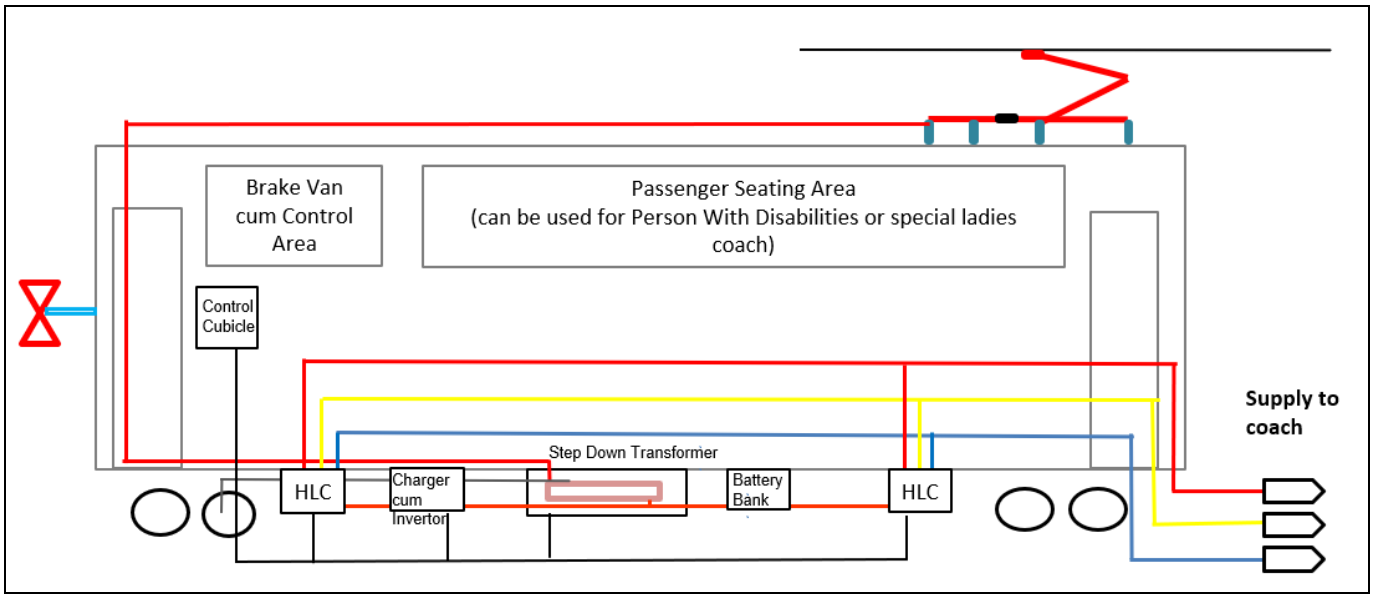


**Fig- 3:** OEG (Over End Generation) installed in proposed Seating cum Brake & Transformer Car coach

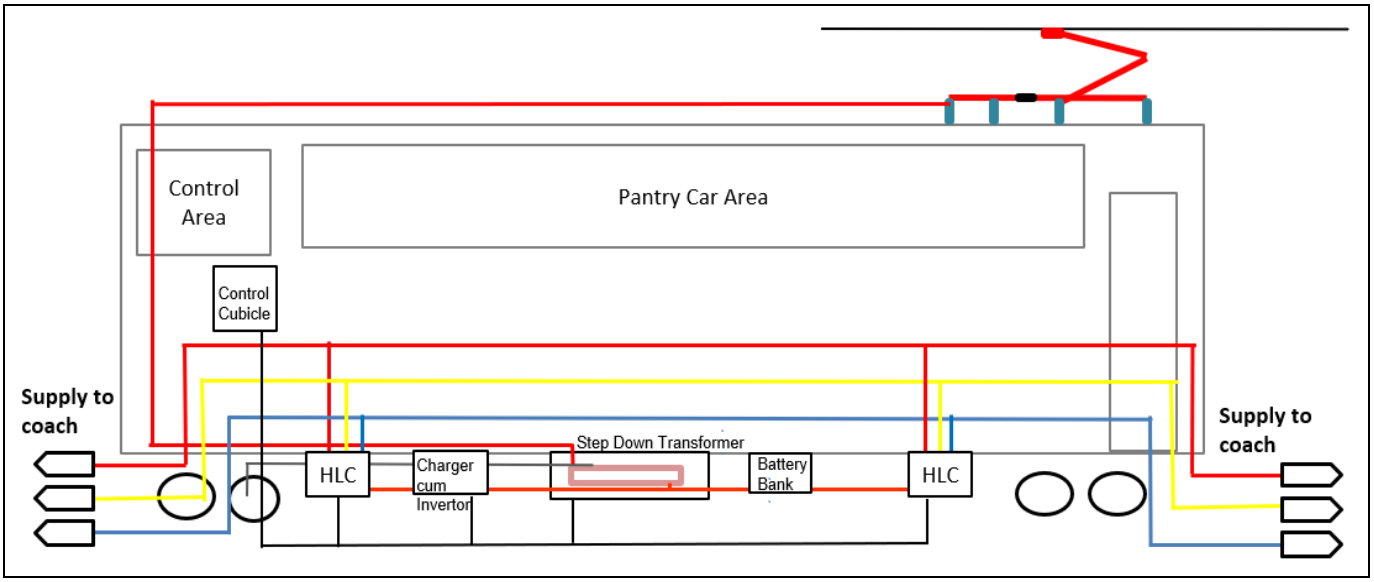


**Fig- 4:** OMG (Over Mid Generation) installed in proposed Pantry cum Transformer Car coach

**Photo-4:** Proposed Prototype (Fabricated at RCF during training period) using Ratio-1:30 to the LHB coach

## 5. Economic Viability on Using OEG/OMG method:

**For OEG (refer Fig-3):** In Transformer car OEG equipment, do not require much space so the rest space can be used for passenger area which will increase revenue for Indian railways, a greater number of passengers can travel in the same train. The ratio can be 30:70 where 30 is for installed equipment and 70 for seating area

**For OMG (refer Fig-4):** In the Pantry Car Coach OMG equipment can be installed within the remaining unused area (where there is space left for the door) for installing control cubicles other equipment's need to be installed under slung. By using this we can add one more coach at the end. The ratio will be 30:70 where 30 is for Brake van cum Guard and 70 for passenger seating are

**Table- 9:** Calculation of revenue on using 70 % space for passenger seating in OEG

| Train Number | Train name | Coach Type | No. of seat (.7X Total seat) | Fare/Seat | Earning in one trip (in Rs) | Earning in round trip (in Rs) | Annual (365 days) Earning (in lakhs) |
|---|---|---|---|---|---|---|---|
| 12005/ 12006 | Kalka Shatabdi Express | Chair car | 54 | 595 | 32130 | 64260 | 234.54 |
| 12951/ 12952 | Mumbai Rajdhani Express | Three Tier | 48 | 2080 | 99840 | 199680 | 728.83 |

## 6. CONCLUSION

- **Increase in revenue and reduce in operational cost:** It can generate 212 lac & 728 lac in Kalka Shatabdi & Mumbai Rajdhani respectively on creating extra space for passengers in the Transformer car coach.
- **Pollution Free:** Pollution from HOG enabled trains majorly at their originating Junction/station such as
- **Cost saving:**
  Annual Saving of more than 101 lac & 590 lac in Kalka Shatabdi (14 coaches) & Mumbai Rajdhani (21 coaches) will be obtained on energy cost basis only.[1]

- Amritsar, New Delhi, Howrah, etc Air and noise will not be there
- **Better Reliability:** Due to no use of generating equipment no need of extra maintenance required.

IR successfully implemented the HOG scheme in its network but as per case study it shows that IR is not able to use maximum of the HOG scheme on HOG Equipped loco and rake, the proposed OEG/OMG method can be used with maximum efficiency in terms of cost-saving/earning, energy-saving, environment, and all.

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