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Production Of Three-Phase Electric Locomotives Using IGBT Technology To Implement The HOG Scheme

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ABSTRACT

To alleviate noise and air pollution, the Indian Railways has implemented an environmentally friendly and energy efficient solution in passenger trains. The technology transforms locomotives and coaches, allowing them to be used in Head-On Generation. The railways have created and improved converters for use in electric locomotives. Diesel generators can also be replaced by these converters. The converters allow locomotives to be converted to run-on head-on generation technology. There will be no more power generator cars, which used to create a lot of noise and emit a lot of emissions. In place of two such generator cars, one standby quiet generator car will be deployed in the event of an emergency. LSLRD (LHB Second Luggage, Guard &Divyaang Compartment) will take the place of the other vehicle. This LSLRD will also be able to convert power from the overhead supply so that it can be used throughout the train, as well as provide space for a luggage guard room and additional passengers. Self Generation (SG), in which the train has only a few air-conditioned coaches, and End on Generation (EOG), in which the train has all air-conditioned coaches, such as in the Rajdhani, Shatabdi, and Duronto trains, are the two most frequent systems now in operation. The Railway Board had issued instructions via letter No 95/elec(G)/114/13 Pt dtd. 25/10/07 for the implementation of the HOG scheme by producing three phase electric locos with IGBT technology and at least two 500 KVA hotel load converters on locos and one under-slung DA set in SLR for Rajdhani/Shatabdi trains.

The purpose of this paper is to look at the existing use of locomotives in the IR system, the rolling stock generation technique, the HOG scheme, and the issues that come with implementing HOG on the IR network.

Keywords: Indian Railways, HOG, Hotel load Convertor, LHB, Rolling Stock

Introduction

WAP5, WAP7, and WAG9 locomotives are manufactured by Indian Railways at Chittaranjan locomotive works (CLW). These locomotives get their electricity from the OHE, which is routed through the pantograph to the traction transformer. The power source to coaches is supplied by a hotel load winding on the WAP5 and WAP7 traction transformers (also referred to as Hotel Load).

With technological advances in the development of power electronics, control systems, and power supply systems, Indian Railways has chose to adopt an energy efficient power supply system known as Head On Generation (HOG) for Rajdhani/Shatabdi trains, which are currently using a "End on Generation" (EOG) system. Since of the special architecture of their inter vehicle mechanical linkage, LHB type coaches are particularly fit for adoption of the "Head on Generation" (HOG) system because rake integrity is expected to be preserved. Meanwhile, in July 2010, CLW delivered the first HOG-based electric locomotive, No. 30277 (WAP7), which featured an M/S Siemens 2X500 KVA Hotel Load Converter and a single hotel load winding transformer (LOT-7500). Since 21.02.201 1, this locomotive has been in regular train operation in the 12005/06 NDLS-KLK Shatabdi Express across Northern Railway.

IR conducts 13523 passenger trains every day, including long-distance and short-distance. ICF (Integral Coach Factory) and LHB (Linke Hofmann Busch) coaches are used on the long-distance train. Due to the limitations in ICF and old technology, the railway adopted LHB technology as part of the TOT (Transfer of Technology) programme, which includes features such as stainless-steel construction for light weight, advanced pneumatic disc brake system, anti-telescopic, improved suspension system, and more. Its application is LHB. CBC (Centre Buffer Coupling) This style of coupling is called "anti-telescopic," meaning it does not turn over or flip in the event of a collision, reducing the number of deaths. Screw Coupling is used by ICF. The passenger is not safe with these screw couplings. The breaking of a screw or buffer occurs during an accident, resulting in train derailment and catastrophic casualties. In 2016, IR made the decision to swap all ICF coaches with LHB coaches, and ICF coach production ceased in 2018. LHB has one disadvantage over ICF: it cannot employ the Self Generation method to meet the rake's hotel load requirements, therefore it must rely on EOG (End on Generation). Power cars are situated on either side of the rake in this setup, and electricity is provided to the rake's hotel requirements via a diesel generator. As the LHB rake demand grows, so does the amount of power cars, resulting in massive diesel consumption and the utilisation of two coach spaces for power cars. Railways devised the HOG (Head on Generation) technique to solve this issue.

Introduction to the Generational Needs of Coaches/Rakes

IR, as one of the world's biggest passenger-carrying modes of transportation and India's "Lifeline," employs a variety of coach types for its passenger operations, providing a variety of services to various classes of people. Although the type of service offered and the inside of the coach differ, the passenger operation for all types of trains, including loco haul trains, is the same. There is just one locomotive to draw the entire rake (a number of passenger coaches joined together, excluding Loco), but what about the hotel load required to service the entire rake's electrical appliances?

As a result, there is a need for power generation to meet the rake hotel load.

The following are the three basic forms of generation that have been employed in IR to date:

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

Self-Generation (SG):
One of the most extensively used methods for generating electricity in IR is self-generation. This technology was employed in ICF type coaches since it is clean and environmentally friendly. The alternator, battery, inverter, and rectifier are all used in this manner. The alternator is attached to the axle pulley, which is connected to four V-belts, so that when the wheel turns (train is moving), the V-belts rotate the alternator, producing three-phase power. This voltage is rectified and applied to the field winding until full voltage is achieved. The Rectifier Regulating Unit (RRU), also known as the Electronic Rectifying and Regulating Unit (ERRU), converts three-phase voltage into a regulated DC 120V output, which is then stored in the battery. When the battery is fully charged, the inverter in the coach provides power to meet the hotel's needs. The main advantage of this method is that it does not require the use of a rake. The coach can couple or decouple from one rake to the next utilising SG.

The restriction of SG is that it fails/is not relevant for premium trains like the Rajdhani and Shatabdi trains, which have all air-conditioned carriages. If this is the case, the locomotive must both pull the train and rotate the alternator, requiring more power from the locomotive, resulting in slow speed (acceleration) and the inability to generate enough electricity to power all of the rake's air-conditioned coaches. As a result, SG is only available on trains with a few air-conditioned coaches, such as superfast, mail, and express trains.

End on Generation (EOG):
EOG is introduced to overcome SG's limitations. At each end of the rake, a power car, also known as a Generator car, is situated. Each power car is equipped with two Diesel Engines and two Diesel Alternator (DA) sets that provide 750 volts 50 Hz power in a three-phase (four-wire) configuration.

Inter-Vehicle (IV) Couplers, which consist of two parallel wires called Feeder-A and Feeder-B that run the length of the train, convey the electricity generated (rake). The ground wire and two control wires are also carried by these IV couplers.

This energy is then distributed to each coach, which has a 50 KVA transformer for conventional coaches, a 60 KVA transformer for LHB AC coaches, and a 9/15 KVA transformer for LHB Non-AC coaches. This Step-Down transformer reduces a 750 V 3 AC 4 wire 50 Hz supply to 415 V/190 V/110 V, depending on the application. [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).

Because a power car generates electricity and is installed on both ends of a train, it is known as End on Generation (EOG). The turbocharged, water-cooled diesel engine provides 490 BHP at 60 degrees Celsius at 1500 rpm and is paired with 500 KVA alternators. The supplied alternator has a capacity of 500kVA, is 0.8 pf 3-phase, 4 wire 750 volts 50 HZ ± 3%. The alternator is a self-ventilated brushless design with dual-type voltage regulation (electric and electronic). EOG is being employed in IR as one of the better methodologies. This strategy adds a second coach to the mix and can be employed for high-speed travel.

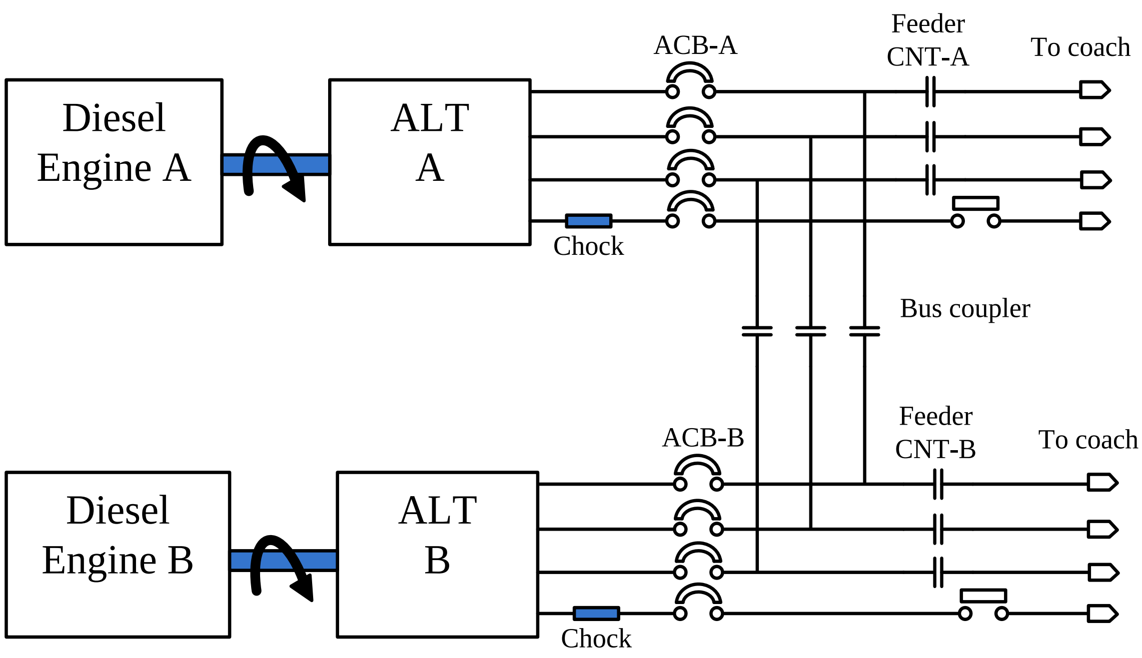

Fig -1: Power car block diagram with EOG supply

This approach was first used for Rajdhani type premium trains, but as LHB coaches became available in India, the demand for power cars soared. Due to its FIAT bogie and Disc brake, the LHB coach is unable to use the SG system. As a result, when the superfast, mail/express train was converted to the LHB rake, the EOG system was also utilised.
EOG has a drawback in that it uses a lot of fuel.

The EOG approach necessitates the engagement of two more coaches (power car.

Require hue instalment (each coach cost more than 3 crore)

Noise and air pollution were produced by power cars.

Head on Generation (HOG)

The locomotive, which generates energy, is at the centre of this arrangement, serving the train's hotel load requirements.

Since the manufacture of IR conventional coaches (ICF) was halted in 2015 and all IR trains were converted to Lhbf, demand for power cars grew day by day, resulting in massive diesel consumption that was not environmentally friendly. IR has already begun exploring for other options. WAP-5 and WAG-9 locomotives from ABB were introduced into India in 1995. These locomotives used 3-phase traction motors controlled by modern microprocessor-based control technology, which were supplied by GTO based converters.

Head on generation was a feature of the WAP-5 locomotive.

WAP-5 was the fastest locomotive in the IR network until recently, but it had a low Tractive Effort, thus CLW and RDSO engineers collaborated to create WAP-7 (Co-Co type bogie) for passenger service, capable of accelerating a 1430t load to 100km/h in 235 seconds, compared to 325 seconds for a WAP-5.

WAP-5 and WAP-7 are now produced by IR, with WAP-4 production ending in 2015. When imported from ABB/Switzerland, WAP-5 includes a Head-on-Generation function (HOG). A hotel load winding is installed in the locomotive's primary transformer to provide power for the train's hotel load.

There was a mechanism for single phase hotel load winding in the design acquired from ABB/Switzerland under TOT (Transfer of Technology), but no hotel load converter (convert single phase to 3-phase). The single-phase output from the main transformer was directly linked to an Inter Vehicle (IV) coupler and sent to the rake in accordance with hotel load requirements. However, this feature was not available because the coach required three-phase power instead of single-phase power to run the appliances (AC). IR chose to construct a Hotel load convertor of 2x500KVA for WAP-7 locomotive as part of their constant advancement and invention in the field of electronics. This was previously for WAP-5 locomotive because this loco had HOG winding, therefore WAP-7 adopted the main transformer of WAP-5 locomotive (LOT 7500). The major goal was to modify a single phase hotel load to a three-phase hotel load using a hotel load converter and then send that electricity to the entire rake using an IV coupler to feed the hotel load.

As part of their continuous innovation and invention in the realm of electronics, IR chose to build a Hotel load convertor of 2x500KVA for WAP-7 locomotive. WAP-7 adopted the primary transformer of WAP-5 locomotive because this loco has HOG winding (LOT 7500). The main purpose was to use a hotel load converter to convert a single-phase hotel load to a three-phase hotel load, and then use an IV coupler to supply that electricity to the entire rake.

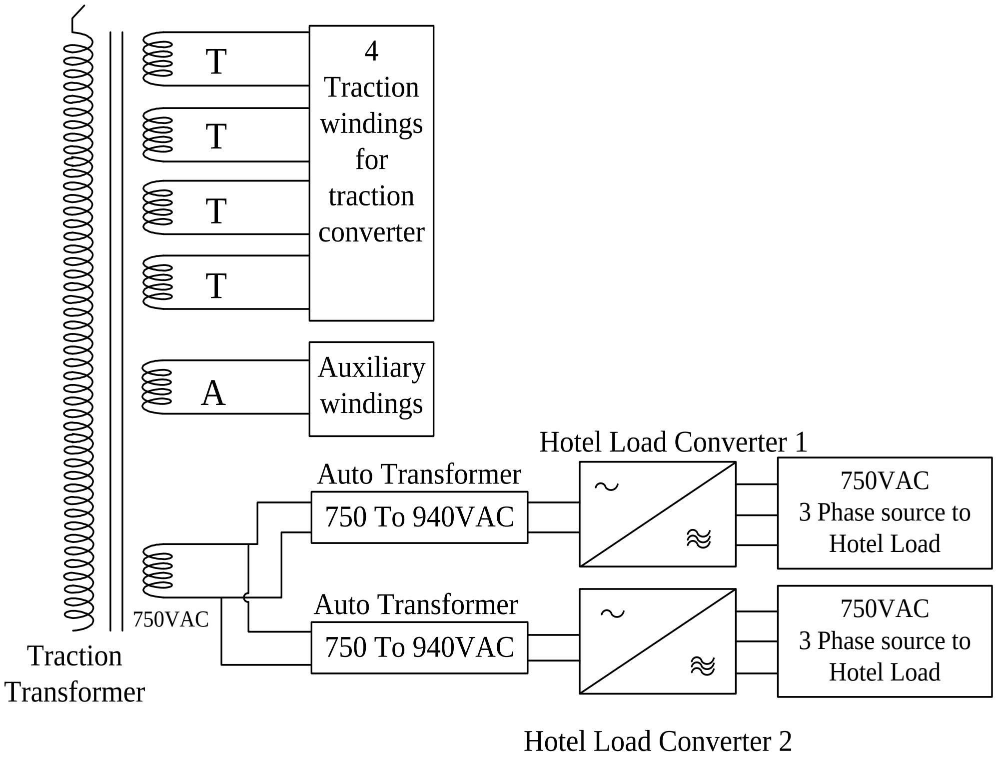

Fig -2: HOG schematic with single hotel load winding in loco transformer (7500 kVA)

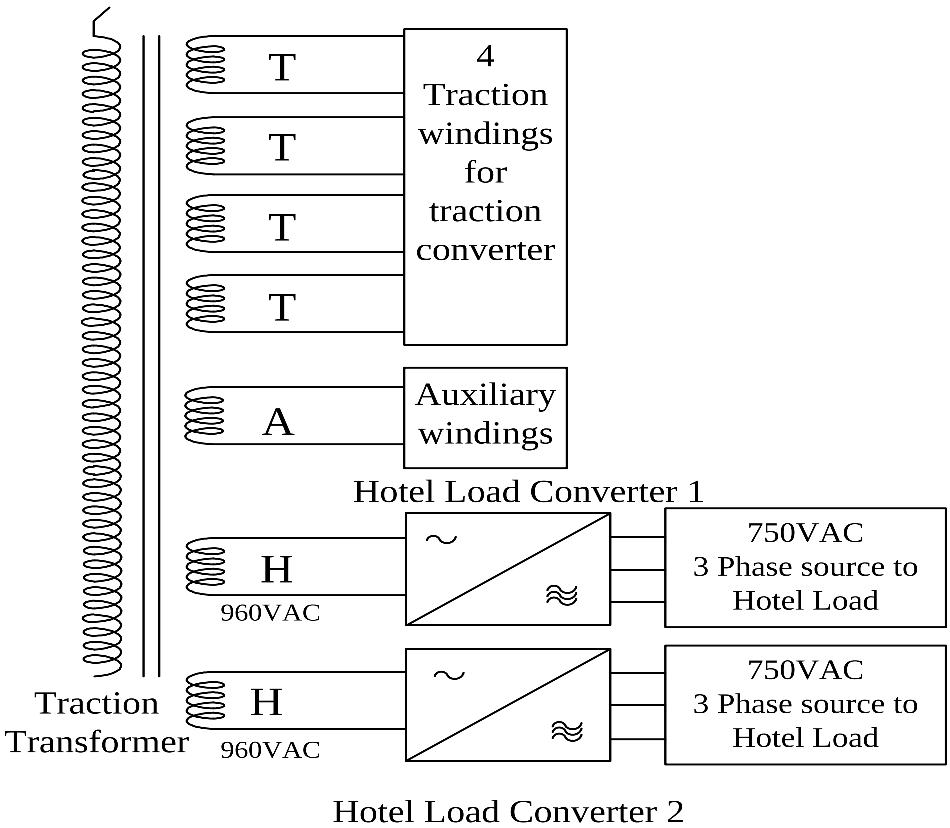

Fig - 3: HOG schematic with dual hotel load winding in loco transformer (7775 kVA)

Solution for the New Method that has been Proposed

For the purpose of maximizing HOG's potential. Instead of employing a locomotive for the HOG technique, the proposed plan is to create a coach with the pantograph, HLC, Step Down Transformer, and other essential devices located underslung, leaving the remaining space for passenger seating. The coach is known as a Transformer Car, and the methodology is known as OEG (Over End Generation) or OMG (Over Mid Generation), similar to the EOG approach. This coach is dedicated to OEG/OMG and will be put at the end of the rake in lieu of EOG or in the centre of the rake in place of pantry car, and will be known as Transformer cum Pantry car Coach.

Conclusion

Increase in revenue and reduce in operational cost:

Increased revenue while lowering operating costs: Creating extra capacity for passengers in the Transformer car coach can produce 212 lac & 728 lac in Kalka Shatabdi & Mumbai Rajdhani, respectively.

Cost saving:

On an annual basis, Kalka Shatabdi (14 coaches) and Mumbai Rajdhani (21 coaches) will save more than 101 lac and 590 lac respectively.

Pollution Free:

Pollution from HOG-enabled trains is primarily emitted in their originating junctions/stations, such as Amritsar, New Delhi, and Howrah. There will be no air pollution or noise.

Better Reliability:

There is no need for further maintenance because no generating equipment is used.

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