An Introduction to Distributed Power Control Systems for Indian Railways

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Abstract
Distributed Power Control Systems (DPCS) better known as Locotrol® gives a radical new method for running longer trains for higher throughput. This article provides the reader with an insight into the development and deployment of Distributed Power Control Systems on the Indian Railways.
The history of development of DPCS technology in the world is re-traced and also the initial trials on the Indian Railways are discussed. The current developments and the new challenges are covered which provide easy initiation into the technology that makes long trains a reality.

Introduction

Higher payload throughput is the immutable aim of any rolling stock engineer. In a simple mantra, this translates into heavier, faster and longer trains. However, implementation of this mantra is reciprocally complex compared to the apparent simplicity of the statement.

The difficulty in implementation stems from the requirement of upgrading the full railway system (track & signal infrastructure and the rolling stock), simultaneously in order to achieve increased throughputs. Such upgrades require huge resources and time and as a result once a railway is setup, the increase in throughput is normally a result of increased train density rather than improvement of payload tonnage, speed or the length of the train.

Distributed Power is a radically different solution that permits running faster and longer trains on existing railway systems with minimal upgradation of the locomotives only. The concept is novel because of the simplicity and ease of implementation. However it is not without its pitfalls.

This article aims to familiarize the reader about the basic concepts; historical events and new developments for distributed power on the Indian Railways. En route the development of the technology the world benchmarks are also discussed.

Distributed Power Simplified

The common understanding of a train is that of a locomotive that pulls a set of series connected payload vehicles which are mechanically (coupler) and pneumatically (brake pipe) coupled.

A variation of the concept is the use of bankers; locomotives that assist in pushing the train up a grade. Bankers are used to supplement the tractive effort to haul a train up a steep grade where the traction of locomotive(s) at the head of the train is not sufficient to overcome the grade and / or coupler forces are excessive.

Extending the concept, distributed power is the use of locomotives (or groups of locomotives) spread over the length of the train that aid the lead locomotive at the head of the train in traction and braking and thus provide increased traction and quicker braking while reducing coupler forces.

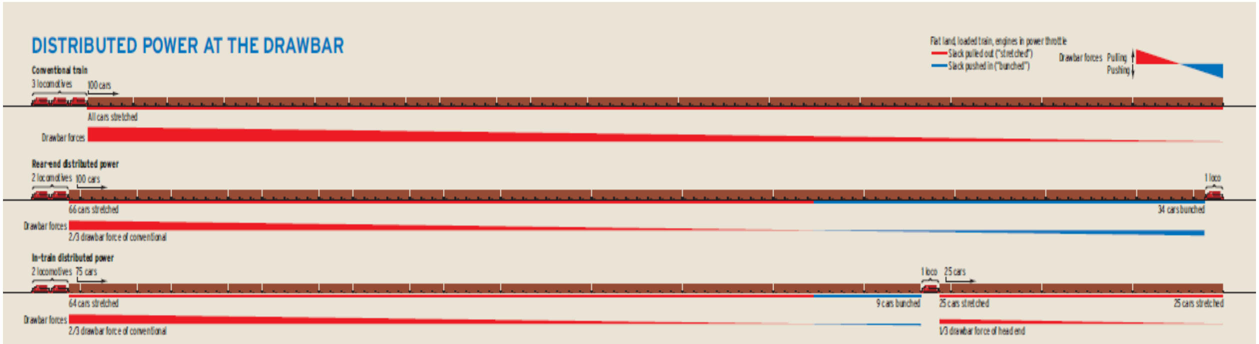
Advantages and disadvantages

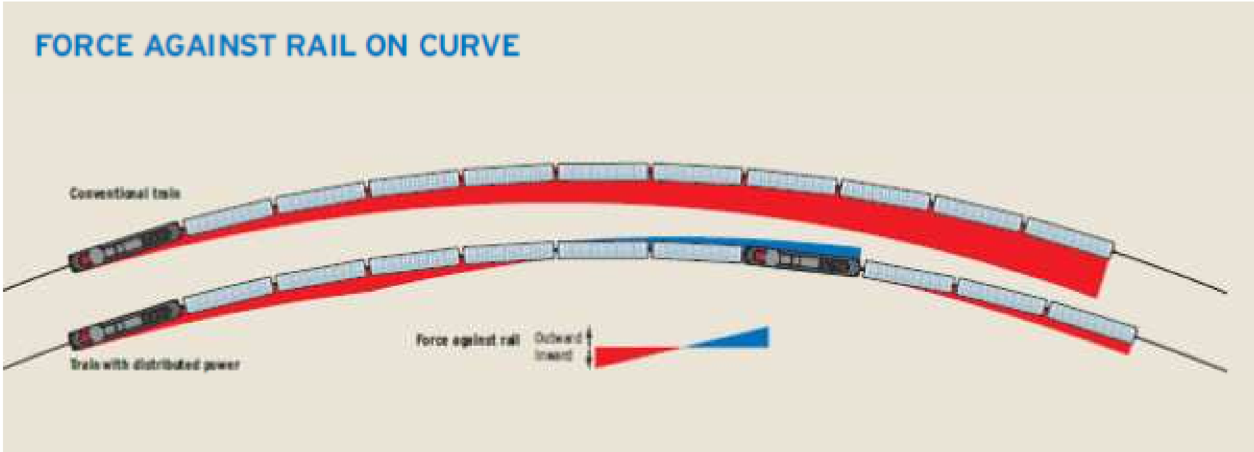
The conventional train configuration that puts all the locomotives at the head of the train also creates the highest drawbar pull on the leading vehicles of the train. Since these forces cannot be increased indefinitely the length of train is restricted by the maximum permissible coupler forces.

Similarly the brake propagation on a conventional train becomes a limitation as the length is increased. Since brake application / release is initiated by the locomotive at the head of train, the propagation of signal along the train becomes a concern when the lengths increase.

The obvious benefit of using distributed power train configuration is the reduction of drawbar pull on the front cars of a train versus what would be required if all the power exerted were at the head end. On an undulating track profile, a skillful engineer can manipulate the relative power outputs, dynamic and air brake applications to minimize run-in and run-out of the coupler slack throughout the train.

This reduced drawbar pull also reduces the lateral force between wheel and rail on curves, thus minimizing wear on various components. Lower friction results in fuel savings and/or provides the capability of running heavier trains.





Another benefit is quicker application of standard air brakes. When distributed-power locomotives are directed to set the brakes simultaneously, the desired air pressure change will reach more cars sooner. This is particularly true when the additional locomotives are in the middle of the train.

The main disadvantage, especially with mid-train units, is the time and track configuration required to add and remove additional locomotive consists.

Development of distributed power

Since the 1960s, railroad distributed power technology has been dominated by one company, Harris Controls, originally Harris Corporation—Controls and Composition Division, later purchased by General Electric, and now known as GE Transportation Systems Global Signaling.

GE have manufactured and marketed a patented radio-control system known as Locotrol® that is the predominant wireless distributed power system in use today around the world.

With its origins in the early days of SCADA technology for the remote control of pipelines and electric utilities, and from an early concept of Southern Railway President D.W. Brosnan, Locotrol® was a product of the North Electric Company (Galion, Ohio) which was later purchased by Radiation Inc. (Melbourne, Florida) and—in turn—purchased by Harris Corporation (also headquartered in Melbourne, FL), and was first tested on the Southern Railway in 1963. The first production Locotrol was installed on the Southern Railway in 1965. Other initial Locotrol® customers included the Norfolk & Western RR, Canadian Pacific and Australia's Mount Newman Mining and Queensland Rail.

Initially the electronics was mounted in a separate railcar which used to be marshaled adjacent to the locomotives. However, these have since been miniaturized into relatively small cabinets with much of the functionality contained in software.

In the early years of this technology, Wabco also had—for a relatively brief period—a competing system called 'RMU' (Remote Multiple Uniter) which was installed on a few North American railroads. However this system did not prevail and soon went out of production.

Prior to the advent by North Electric of the proprietary 'LOCOTROL' name, the product was referred to as 'RCE' (Radio Controlled Equipment) or 'RCS' (Radio Control System) and the lead and remote units as 'master' and 'slave'. The colloquial 'master' and 'slave' terms, though, were not formally used by the manufacturer. In some U.S. railroad parlance, Locotrol® trains are referred to as 'radio trains'.

Since 1975, both Queensland Rail and Mount Newman Mining (now called BHP Billiton Iron Ore) in Australia have used the system on coal and iron ore trains, permitting the doubling in the size of trains without exceeding draw-gear strength, through the use of mid-train locomotives.

Union Pacific Railroad and BNSF Railway are the major North American Locotrol® operators.

GE Locotrol® Technology

A locomotive that has been fitted with Locotrol® DP equipment may be set up as either a Lead or Remote 'active' unit; the Lead unit being the controlling locomotive. Only one distributed power-equipped locomotive in any Lead or Remote consist (group) is active. Other locomotives MU-coupled to this 'active' unit operate conventionally as multiple units.

There are two basic modes for over-the-road distributed power operation. Locomotive control can be synchronous (MU), whereby control commands made by the engineer in the Lead unit are transmitted instantly via radio telemetry to—and are followed immediately by—all Remote units in the train, or independent whereby the engineer may set up and independently operate the Remote locomotives as a 'front' and a 'back' group (or with Locotrol III and subsequent versions; as 'Lead', 'Remote-forward', Remote-intermediate', 'Remote-rear', and 'Remote-trail' groups—this latter at the rear of the train). The front group always includes the Lead locomotive, and all Remote locomotives in the front group follow the commands made by the engineer using the Lead locomotive controls. Which Remote locomotives are in the front or back groups are selectable by the engineer in real time. One DP train cannot affect another DP train or another individual DP-equipped locomotive not in a train; and an individual DP-equipped locomotive not in a train cannot affect any DP train or other individual DP locomotive regardless of proximity.

Distributed power was originally able to be provided at only one intermediate location within a train. These forerunner systems (Locotrol 102-105 and Locotrol II) required a radio-relay car to be attached via standard multiple-unit jumper cabling to the remote locomotive(s) to provide the radio-control commands and facilitate feedback signals. Later, Locotrol II evolved into the 'Universal' system in which the radio-control equipment was installed on the locomotives themselves, rendering the relay car (variously referred-to as an 'RCU' for remote control unit or 'LRC' for locomotive remote control) redundant.

Locotrol III was the next development—being compatible with both the Knorr-Bremse / New York Air Brake CCB and Wabtec's EPIC electronic locomotive brake equipment, and permitting multiple Remote unit locations as described above. The latest incarnation of this equipment is Locotrol Electronic Brake (LEB), which integrates the GE Locotrol technology with K-B/NYAB's CCBII brake

IR's Quest for distributed power

Unknown to many readers, Indian Railways quest for distributed power started in 1988, when the Railway Board placed order on Harris Controls for four sets (four lead and four trail units) of Locotrol® II. These systems were fitted in WDM_2 locomotives homed at the Bondamunda Diesel Loco Shed of South Eastern Railway and YDM_4 locomotives of the New Guwahati Diesel Loco Shed of Northeast Frontier Railway.

Experience on the North East Frontier Railway

The systems on the NF railway were commissioned around Oct 1989 and trials were conducted on the Lumding Badarpur section (MG) which has regular grades of 1 in 50 and a particularly steep falling grade of 1 in 37. Regular train operations on this section used one YDM_4 with 650t trailing or two YDM_4 in multiple configuration with 1050t trailing. RDSO trials of the Locotrol® were conducted with 1300t trailing load trains. However the results were not encouraging as marshalling of trains for Locotrol® operations required remote locomotive unit to be placed at $2/3^{rd}$ of the length (measured from the head) of the train. This required shunting at terminals, which created operational constraints. The poor reliability of the equipment also proved a strong disincentive.

Experience on the South Eastern Railway

Locotrol® equipment was commissioned in August 1989. Operations with distributed power were conducted on the Kiruburu Hatia section with two locomotive consists each of three WDM_2 locomotives. These locomotives units were placed at head and middle of the 112 BOXN load.

The section has falling grades of 1 in 50 and rising of 1 in 100 in the direction of travel of the loaded train.

Instrumented trials had been conducted by RDSO in December 1985, using the same train configuration which allowed 9000t trailing loads However, these trials involved manual control of the locomotives and did not use Locotrol®.

In all 16 running trials were conducted during August - November 1989 followed by 23 more runs using Locotrol®. Distributed power based operations were then abandoned due to operational constraints and frequent equipment breakdown.

Lessons Learnt

Although the distributed power experiment was abandoned, valuable lessons were learnt. The most important include:

- Seamless control of pneumatic brakes is essential.
- Interchangeability of Lead and Remote units i.e. any locomotive can be configured as lead or remote is vital for operational flexibility.
- Indigenous service and spares support base for equipment is must for equipment upkeep.
- Training of maintenance and operations staff a must for sustainable operations.
- Distributed power can be successfully used for long trains on difficult grades and technology overcomes many conventional restrictions of rail operations.

Indigenous development

RDSO had framed the technical specification for the first purchase of distributed power control systems (DPCS) in 1986. Another specification for DPCS for EMD (HHP) locomotive was also framed in 2005.

Around this time a number of microprocessor based systems were already 'at home' on the diesel electric locomotives and the time was ripe for a second attempt at the development of distributed power systems.

Development efforts were now taken up by the indigenous manufacturers and soon enough prototypes were developed for both the microprocessor equipped and conventional locomotives. The sustained effort of the personnel of Indian Railways nurtured this technology resulting in successful deployment and operations. The following table details the locomotives equipped with DPCS in operation on the Indian Railways.

Loco Class	Base Shed	Numbers Fitted	Equipment Provider	Usage
WDG_3	Kazipet	4	Lotus	Coal circuit
WDG_4	Hubli	2	Medha	Iron ore circuit
WDG_3	Sabarmati	2	Lotus	Trials
WDP_4	Tughlakabad	2	Medha	Trials
WDP_1	Tughlakabad	2	Lotus	Trials
WAG_7	Kazipet	2	Lotus	Trials
WAG_7	Tatanagar	2	Lotus	Trials

The deployment and use is currently nascent however the indigenous development has allowed many issues to be examined closely, the most important is interoperability.

The challenge of interoperability

The technological dominance of the Locotrol® has created a scenario where interoperability is not discussed as there was nothing to interoperate with. World over Locotrol® has been synonymous with DPCS.

The scenario on the Indian Railways is however different due to the presence of home grown systems and IR's initial experiences. Interoperability of DPCS has been identified as being vital for seamless and unconstrained operations.

The challenge has been addressed jointly by RDSO and the equipment manufacturers by creation and adoption of a common communication protocol. This protocol has been adapted from the AAR protocol for EOTT (End Of Train Telemetry) applications described in the AAR standard S-5701.

The common protocol is presently issued in draft form for trials under controlled conditions. However, to meet the operational requirements, the manufacturers are permitted to use their own protocols to pair with their own systems.

This dual protocol approach permits development of protocol while supporting DPCS operations based on already developed technology.

Another small but significant departure from the norms followed on other railways is the nomenclature for designation of locomotives. The traditional designations used for distributed power, such as “lead /remote” have been replaced by “master and remote”. This is done specially to remove ambiguity from the designation “lead”. The designation of “lead” locomotive is common with locomotives configured as multiple units (MU) and also in distributed power mode. However, as the DPCS configuration allows MU locomotives in distributed power mode, the lead designation assumes dual definition, needing disambiguation.

IR shall soon be deploying significant numbers of DPCS equipment capable of interoperable working.

World Benchmarks

Although a large number (12000 plus) Locotrol® are deployed around the world hauling many freight trains, interesting and unique operations are conducted on the Transnet Freight Rail and BHP Biliton Iron Ore lines.

Transnet Freight Rail, South Africa

The Sishen–Saldanha railway line, also known as the Ore Export Line, is an 861 kilometres (535 mi) long heavy haul railway line in South Africa. It connects iron ore mines near Sishen in the Northern Cape with the port at Saldanha Bay in the Western Cape. It is used primarily to transport iron ore and does not carry passenger traffic.

The initial train lengths, on this system, consisted of 3x class 9E electric locomotives, hauling 210 type CR ore wagons with a payload of 80 tons. Upgraded wagons now carry 100 tons. Train lengths have been increased to 342 wagons, employing Radio Distributed Power (RDP) technology. These 4 km long trains (10 locomotives and 342 wagons), are the longest production trains in the world. More than 3,000 of these RDP trains have been operated since launched in December 2007.

Locomotives are distributed within an almost four-kilometre-long consist of 342 wagons, while overall train control is centralized at the lead locomotive with a single crew. The system provides not only single-station power control, but also readily accessible, centralized diagnostics in the event of a breakdown. At Saldanha, trains are broken into three portions of 114 wagons each to suit the harbour tippler which can handle this many at a time.

The most unique feature of this operation is it uses both 50kV AC and diesel locomotives together in distributed power mode on the same train.

BHP – Biliton Iron Ore, Australia

BHP Billiton Iron Ore operate two railway lines and the most diverse fleet of locomotives in the Pilbara consisting of 141 locomotives spread over four distinct classes, or models.

Different types of diesel locomotives are used on the system consisting of EMD SD40 units, GE Dash 8 units, and Alco C636's, GE AC6000's and EMD's SD70ACe model.

The railway system has of primarily two lines. One is 426 km long running from Nelson Point (Port Hedland) to Newman (or Mt Whaleback Mine). While the other line of 208 km runs from Finucane to the Yarrie and Nimingarra mines.

BHP Billiton is currently running 14 trains a day on the Newman line. Train lengths are either 224 or 336 cars, based on a 112 car 'rake' size with the mid-train units controlled via radio link from the lead unit in a using Locotrol® Distributed Power.

Special Test Run-Now a Guinness Record

Special test train on the Australian BHP Iron ore system, is the longest train to ever run in the world, this train is officially in the Guinness book of world records for the longest train. The record was set on June 21, 2001 in Western Australia between Newman and Port Hedland, a distance of 275km (170 miles), and the train consisted of 682 loaded iron ore wagons and 8 GE AC6000 diesel locomotives giving a gross weight of almost 100,000 tonnes and moved 82,262 tonnes of ore, the train was 7.353 km (4.568 miles) long.

This run was done to test the distributed power control systems based on Locotrol®. The Locotrol® train configuration used for the test train was 2 locos-166 wagons, 2 locos-168 wagons, 2 locos-168 wagons, 1 loco-180 wagons then the last locomotive as the last vehicle.

Concluding Remarks

Despite early introduction of DPCS technology on the Indian Railways, widespread deployment and use has not yet been witnessed. However, this is expected to change significantly as pressure on increasing line throughputs increase.

Distributed power control systems are possibly the lowest cost inputs that can substantially increase throughputs and operational efficiencies of a railway system.

Indian Railways has much to learn from the experiences of the other world railways to effectively leverage this technology. However, the beginnings have been made.

Given the developments of the technology, successful deployments and the growing traffic requirements, it would safe to hazard a guess that

Indian Railways is staring into the dawn of a new era, the era of long trains.

References

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