Progress with Evaluation of Cable-based ECP Braking and Distributed Power

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Summary: An integrated ECP braking plus distributed power pilot scheme, employing cable-based technology, is up and running on the Ermelo-Richards Bay coal export line. It is undergoing evaluation with a view to preparing a business case for ultimate fleet conversion. The results have been encouraging, and the work described here gives insight into the case developed thus far.

1. INTRODUCTION

1.1. The context

This paper describes the approach to evaluating electronically controlled pneumatic (ECP) braking and distributed power (DP) on the Ermelo to Richards Bay heavy haul railway. The project converges three streams, namely the need to develop core railway technology to the next level, possible solutions available in the broad technology landscape, and the ability of the supply industry to offer appropriate solutions. It describes the path taken to move forward to a balanced solution.

Now that the project is well under way, and the benefits are becoming clear to a broad group of stakeholders, this paper offers a high-level view of the history and prospects. The time of writing is one of intense questioning, firstly regarding system performance, and secondly how the technologies could integrate with the operation and solve its problems. The challenge of implementing a fundamentally new technology in a working railway is immense. This paper addresses issues that, in the humble opinion of the author, need attention to move from the status quo to a new dispensation. That course has commenced, not without trepidation, and it has now become clear that it needs pushing to finality. This paper builds on previously published work regarding development of the pilot scheme, and looks forward to how one would initiate a fleet conversion from conventional direct release pneumatic braking to ECP braking.

1.2. The fundamental drivers

Experience with 200-wagon, 18 000-to-20 800-tonne coal trains revealed two sets of problems. First, relatively slow propagation and non-uniform distribution of brake force, due to the limits of physics inherent in air brakes. Second, broken trains due to high longitudinal forces. The setting includes European-oriented signaling and North American-oriented trains. It demands high brake ratios to stop within short stopping distances, but incurs high wagon-to-wagon brake force variance at the small brake pipe reductions typically used to maintain speed on long descending gradients. Despite the positive attributes of direct release braking, it is difficult to curb occasional undesirable train handling through descending gradient inflections, which thermally overloads wagon wheels. High longitudinal forces, due both to non-uniform distribution of brake cylinder pressure, and to high head-end power, increase drawgear distress or risk of derailment [1].

1.3. Possible solutions

The original systemic design set parameters for major configuration variables, for example locomotive- and wagon axle load, train length, ruling gradient, locomotive adhesion, signal spacing, and train driver competence, in such a way that they were optimized simultaneously [2], and hence very little change was possible. The above mentioned problems were thus recognized as symptomatic of underlying systemic issues, rather than of a need to search for incremental improvements in individual components or sub systems.

Notwithstanding these problems, the Ermelo-Richards Bay coal export line ranked world’s lowest cost per net ton-kilometer in a 1994 Mercer Management Consulting benchmarking study. Coming as it did some five years after rollout, thus having had teething problems shaken out and operations honed, this achievement was interpreted as confirmation that the systemic design package was the best that could be achieved with the technology of the time. It arguably represented the pinnacle of Industrial Age technology integration in heavy haul.

Initially, only DP was contemplated, to contain longitudinal forces. However, this approach would have only partially addressed air brake physics limits regarding non-uniform distribution of brake cylinder pressure. As such, it would have been an anachronous prolongation of Industrial Age technology. During the gestation period, ECP braking appeared on the technology horizon. Appreciation dawned that ECP braking and DP, as an integrated package, sharing intra-train communication, could offer major synergy in addressing both sets of closely related problems through application of Information Age technology.

1.4. Supply industry contribution

Management examined both cable-based and radio-based intra-train communication technologies. A consensus eventually formed around the superiority of cable-based technology. By late 1998, two suppliers were prepared to bid on a pilot scheme, and it was decided to equip a 200-wagon train and four 25kV locomotives through open tender. An overlay system was specified, to minimize risk of a train out of service during assessment. A contract was placed with Wabtec in March 1999, and the equipment was commissioned in July 2000. It has been described elsewhere [1] [3] [4].

1.5. Why a pilot scheme?

It is reasonable to expect that cable-based ECP braking and DP will eventually become common cause in heavy haul- and intermodal railways. General insights will undoubtedly develop from ground zero over time. However, problem solving, rather than competitive advantage, drives the present project, although the latter appears to be a factor with which to reckon. The notion of a pilot scheme was thus born out of the need to assess claimed and potential advantages under local conditions, with a view to rapid fleet conversion if the benefits proved convincing. Management therefore chose to test the water rather than wait for the experience of others to percolate through the industry. Being an early adopter has both advantages and disadvantages, as this paper will suggest.

1.6. Organizational learning

At time of writing (November 2000), commissioning is complete. Preliminary test runs have also evaluated performance, and determined a train configuration for extended evaluation. The pilot scheme train comprises an ECP braking- plus DP equipped lead locomotive and three through-cabled locomotives in the head end consist, 200 wagons of 20 tonnes tare/104 tonnes gross equipped with cable-based ECP braking, followed by an ECP braking-plus DP equipped lead locomotive and a through-cabled locomotive in the rear end remote consist. All locomotives are 25kV Class 7E1s.

The train is now in revenue service, where it turns around in approximately two days. The evaluation will span at least four consecutive seasons, to ensure exposure to the full range of local environmental conditions. A sufficient body of data could however accumulate earlier or later, to encourage a decision one way or the other. Consequently, the project has already started evolving, from an assessment of technology to laying a foundation for fleet conversion. This process has introduced a somewhat disorderly, though not undesirable, dimension, because evaluation has sought to identify quick, significant hits.

2. EVALUATION METHODOLOGY

2.1. Objectives

The research design set out to achieve five objectives. First, assess the technical workability of intra-train communications, stand-alone ECP braking, stand-alone DP, and combined ECP braking and DP. Second, assess the potential to ameliorate quantifiable problems and undesired incidents related to existing air brake operation and/or train configuration. Third, assess the potential to open new opportunities by applying information technology to align trains with the information technology environment of the freight logistics industry. Fourth, assess alignment among local requirements and relevant AAR standards. Last, nudge stakeholders toward a credible strategic recommendation, to hopefully turn concepts into a profitable investment decision.

2.2. Research design

The assessments rest on comparing a 200-wagon test train with cable-based ECP braking plus DP, and a 200-wagon control train with conventional air brake and head-end power. They were repaired to as near identical condition, and are deployed in as near identical service, as practicable. This design enables comparing the two configurations with each other in a defined environment, to ensure confidence in the findings. The project maintains a structured evaluation approach for two reasons. First, if, as has already happened, emphasis shifts after data become available, there is still a plan in place to avoid the bias that may accompany new perceptions. Second, if a change of ownership materializes before or during fleet conversion, due diligence will find it grounded on sound understanding.

Data accumulates from four sources that map to existing, quantifiable problems. First, project-specific physical variables that measure train performance, for example displacements, forces, pressures, speeds, and temperatures. Second, an operations log, that records movements, tonnages, etc., and follows up with structured driver debriefing. Third, financial records, that measure expenditure on consumables and rolling stock maintenance. Last, an integrated train condition monitoring system, located at intervals along the lineside, routinely reports on the condition of all wagons, including those on the test- and control trains. These observations will ultimately drive economic and statistical analyses.

3. CUMULATIVE FINDINGS

3.1. Previously reported

Early impressions and formal measurements regarding the pilot scheme have been previously reported [1]. Compared with the existing pneumatic-braked, head-end-powered existing trains, they include shorter stopping distances, smoother train action, lower in-train forces, lower train-track forces, lower wagon wheel temperatures, and shorter cycle time. This paper, which reports additional insights beyond those previously published, forms a sequel.

3.2. Intra-train communication

The pilot scheme requires intra-train communication to support more than the 160 wagons envisaged in AAR specifications. Unique to this application, every car control device (CCD) supports in-train repeater functionality. During setup, the driver designates any wagon, typically the 100th, as active repeater. The system supports 200-wagon operation, and extends instantaneous and simultaneous braking to train lengths hitherto not imagined. However, a repeater consumes bandwidth, by doubling network traffic. This is suspected of contributing some of the nuisances described later. It can also be a nuisance in the absence of vehicle sequencing, because the designated wagon may not be in the position it is thought to be. Superseding the existing PLT-10 transceiver by the PLT-22 transceiver, which can handle 220 nodes, will eliminate this issue. Possible train length then extends to almost 440 vehicles using two wagons per CCD, and almost 880 vehicles using four wagons per CCD. This ought to accommodate all future train requirements.

3.3. Distributed power performance

The DP over cable has performed without incident for the duration of the pilot scheme. Although many suspected that remote electric locomotives would not be entirely trouble free, because they have a propensity to trip out much more frequently than diesel locomotives, the experience has been positive. Some trip-outs need resetting on the affected locomotive, and some need the train to be standing still, so there nevertheless remains a threat to mission reliability.

Thus far, remote locomotives have occasionally refused to pick up power after automatically powering down through a neutral section. They frequently pick up power again after the next neutral section, and if full power is fortuitously not required until then, shut-down remote locomotives are not necessarily a problem. Lightning strikes that knock out first the overhead power supply, and then the locomotives, may be more insidious. The lead locomotives are close to the train driver, who can restart them when required. However, if the remote locomotives' battery supply is insufficient to last until the driver or some other competent person can get there (2½ km away at the rear of the train), then the delay may be long.

3.4. Train handling under distributed power

Distributed power control permits the train driver to place the various locomotive consists in the same group and control them synchronously, or to place them in different groups and control them independently. Local experience has shown that one could regard synchronous operation of lead- and remote locomotive consists as the normal driving mode. The number of situations in which independent operation of remote locomotives is preferred, is small.

One of them, namely passing over a crest, is generic. It is therefore amenable to automation — see paragraph 4.5. The remaining situation is picking up a train from standstill, which, because the circumstances can differ widely, requires train driver discretion. A pool of experienced train drivers, who developed their skills on banked and double-length trains, is currently available, but the future will need to accommodate people who did not know that environment.

The DP control system does not permit simultaneous traction at a head-end locomotive consist and dynamic braking at a remote consist, which may tend to part a train. Distributed power has eliminated the risk of break-in-twos, thereby making driver stress insignificant.

3.5. Condition of brake equipment

The ECP braked train has had many low-reservoir warnings, that were at first thought to be spurious. However, upon investigation, the functionality to measure reservoir pressure on each wagon was found to have revealed that the operating rods of some release valves had been jammed open, presumably to release the brakes at coal loading sites. The low reservoir warnings were not all false indications, but suggested possible equipment misuse. Surprisingly, these wagons had passed the normal terminal test. Once over the hurdle of negative perceptions, incidents such as this are building confidence in the ECP braking system as a viable alternative for routine brake testing.

3.6. Driver training

The present application integrates ECP- and conventional braking into a single handle, so that retraining with respect to train handling is almost a non-issue. Driving in fact becomes almost intuitive. However, now that the driving task has been cascaded down, from the section managers who drove the commissioning- and test trains to a small group of regular drivers, adaptation to a new information technology environment has brought awareness that setup procedures and fault recognition have become important competencies. The group has deliberately been kept small, to ensure consistent post-trip feedback, and to capture descriptions of elusive occurrences. Nevertheless, skill requirements appear to be lower, if somewhat different from those traditionally sought. This finding complements the transformation drive to align Spoornet's workforce with population demographics. In practice, this means that people will drive heavy trains with considerably less experience than heretofore.

3.7. Maintenance training

A negative attitude is evident among wagon repairers. So-called electrical work is not in their current job description, and they do not see it in their future. They have been reluctant to get involved in the pilot scheme, whereas other groups have had an open-minded attitude. Locomotive maintainers of course went through this phase decades ago. It is short-sighted, and no doubt, rationality will prevail.

3.8. Vehicle sequencing

The pilot scheme does not feature vehicle sequencing. One consequence is the need to denote the last vehicle by an end-of-train device. Its reliability has not met expectations. On loaded trains where, as in the present application, a locomotive is the last vehicle, there can be no doubt which vehicle by number is the last. However, on empty trains, that do not use remote locomotives, and where possibly dyslexic personnel must record eight-digit running numbers of identical wagons, an end of train device is prudent. The current AAR-standard requirement is thus essential. It would also have been useful to have the feature to locate wagons that have fault indications.

3.9. Software ergonomics

The software version currently installed requires the driver to step through a menu structure to set up the electronic brake rack, ECP braking, and DP control. During set up, the ECP braking system counts the number of cars it can find, and looks for the repeater, remote consist, and end-of-train device. If it does not find all items present, the sequence may need repetition. This can be time consuming, and leaves an opportunity to make work. For this reason, the setup procedure will be automated. Conceptually, the system will prompt the train driver for inputs, including lever movements, where after it will step through the set up procedure until successful completion. If need be, it should repeat until it does achieve set up, or give a fault message that it can not.

3.10. Software functionality

Two categories of software dysfunction have emerged. First, nuisances that need attention to minimize negative perceptions, and are easy to modify. Second, difficulties that require fundamental reconsideration to modify. The first category includes indications that niggle and/or alarm train drivers. For example, low battery warnings, which in the current software version appear on a fault screen, also reduce the operative brake percentage displayed. Reporting low batteries, which do not affect the correct functioning of CCDs on cable power, is confusing and contaminates the influence of genuine defects, such as cut out brakes. Other examples are communications faults, ghost wagons (present on the train but not recognized by the system), and incorrect brake cylinder pressure. Such nuisances lead to ECP braking being perceived negatively. The agreed solution is to relegate such faults to a lower level screen, for access by service personnel, and only to give train drivers information that they need to operate a train safely. Furthermore, the system should not display faults unless it can associate them with a potentially dangerous condition, or with a wagon number or equipment identification. The system in any case makes a brake application if it enters a potentially dangerous condition.

The second category includes resetting equipment after a lightning strike has shut down locomotives, in a situation where the train brake must be applied. If locomotive batteries are in poor condition, they may not be able to sustain the locomotive low-tension power supply, and hence the DP control, until someone can reset the remote locomotives. This problem is not an issue for diesel locomotives, but unique to electric locomotives. It is also only applicable to an overlay braking system, which needs to raise train pipe pressure under ECP control during setting up. The problem requires a software change, which is still under development. Until then, the situation requires use of the train holding brake on descending gradients where the independent brakes of the leading consist cannot hold the train.

3.11. Inter-wagon cable length

It has been found that the lanyard cable, that secures the Tri-Star connector to the wagon headstock, must pull taught before the BIW connector on the headstock is placed under tension, otherwise the ECP cable will pull through the nut securing it to the BIW connector. Despite using coupler and drawgear arrangements to AAR specifications, the distance between local wagons is shorter than U.S. wagons. For this reason the South African cable, currently at 790mm, is shorter than the U.S. cable, at 1070mm. Note that the brake pipe runs on one side of the train, with a holding brake pipe on the other side, without crossing over between wagons. This arrangement may necessitate a compromise regarding cable length on rotary-dumped wagons. The South African cable seems to be about 50mm too short. However, if it is too long, it incurs the risk of dragging or snagging on track work. Tests are currently in progress on a 840mm cable. This issue could thus be critical for cable-based intra-train communication, particularly regarding rotary dumping.

3.12. Connector quality

A search for possible causes of sporadic unintended uncoupling of inter-wagon cables revealed what appeared to be undue wear, in the pocket in which the security clip locates. The coal mines receive empty wagons in blocks of one hundred. Some of them cut the wagons into blocks of ten or fifty, to facilitate loading. Initially, there was an attempt to avoid mines that separate wagons into blocks of less than 100 wagons. However, averting a potential problem during testing cannot lead to a significant finding. The AAR connector is designed for 1000 separations, after which the separating force must not be less than 13.6kg. Work is now proceeding to establish whether this force is being met. If so, it suggests that the problem is with cable length, not with the connector. There seems to be a real need for integral cable contacts in the pneumatic glad hand, to make both pneumatic and electric connections simultaneously. One hears about such devices, and hopefully they will materialize.

3.13. Pneumatic emergency braking

With ECP braking, it is possible to set up a loaded train as empty. However, the brake cylinder pressure for an empty train is considerably lower that for a loaded train, and risk therefore exists that an incorrectly set up train will not be able to stop. This has happened on one occasion, when the driver eventually stopped with a pneumatic emergency brake application. This incident prompted reflection on the value of retaining the pneumatic emergency feature under ECP braking. Clearly, it saved the day for this train. Note that it is possible to change the setup from empty to loaded in motion, even during a brake application. The issue is thus essentially one of training. Train drivers have also received instruction to do a running brake test soon after departure, to confirm correct braking system set up.

Retention of pneumatic emergency functionality probably implies the need for empty/load detection, and means retention of the pneumatic emergency portion. Whatever empty/load equipment is chosen, should also be compatible with a piloted supply. However, it would be attractive to ultimately dispense with all pneumatic control equipment. This incident has thus focused attention on one of the more critical decisions regarding fleet conversion. It relates also to the previously mentioned issue of operative brake percentage including CCDs that indicate low battery. As long as cable power supply is present, the CCDs will function. However, the critical issue is what happens if the battery is too low to apply the brake on the last vehicle, and it becomes decoupled from the train. This somewhat unlikely sequence of events will still result in a pneumatic emergency brake application, if that functionality is present. If not?

3.14. Cycle time

The pilot scheme train receives special attention, to accumulate the most service exposure in the shortest possible time. It turns around in about 48 hours, which is quicker than the regular trains’ 60 hours. It gives insight into the advantage that accrues to a tightly controlled operation, where the entire train necessarily runs as a true unit train, with no possibility of removing wagons on an ad-hoc basis for maintenance. This also despite delays to get the two 100-wagon halves back from the mines, whereas normal trains permit any two blocks to be coupled to make a 200-wagon train.

4. EXTRACTION OF VALUE

4.1. Unexpected insights

This section reviews learning that has come almost unexpectedly, but which provides valuable insight into how to extract full value from integrated ECP braking plus DP.

4.2. Approximation to a single vehicle

One of the most impressive attributes of integrated ECP braking plus DP is that a train responds as a single vehicle. More correctly, in braking it responds precisely as a single vehicle, and in traction approximately as a single vehicle. Regarding traction, locomotives at both ends influence the entire train, enhancing the approximation to a single vehicle. Locomotives at the head end and somewhere else within the train leave a loose rear end, diminishing the approximation to a single vehicle. Why this is important is because the fundamental difference between driving a road vehicle and driving a train is that a train introduces an extra, longitudinal dimension. That difference influences the skills required, the recruitment pool, the remuneration exacted, and ultimately the tenor of the employer-employee relationship. A long, heavy train may stretch over several gradient changes, and planning for its slow responses typically takes in major topographical features and time commitments of around 30 minutes. Quite simply, appropriate train configuration and integrated ECP braking plus DP place train driving in a different realm, not far removed from road vehicle driving.

4.3. Security

Conventional pneumatic brakes, with angle cocks on each wagon, are exposed to a risk of tampering. One can mitigate the risk by using telemeters, but they are known to suffer communication breaks in some locations. By contrast, cable is uninterruptible by tampering. It is therefore more fail-safe than conventional pneumatic braking. If two angle cocks are closed on either end of a block of ECP-braked wagons, stuck brakes or low reservoirs will result, leading to automatic penalty brake application. Train drivers value the superior security.

4.4. Mission reliability

The integration of ECP braking and DP addresses several detractors of system effectiveness. In particular, it can eliminate the causes of derailments and break-in-twos mentioned in Paragraph 1.2. Systemic throughput capacity is thus significantly enhanced through hardening the system against disturbances that affect mission reliability of trains. This increases reliability of the entire system through removing the primary drivers of unplanned, knock-on delays.

4.5. Automation of train handling

When passing over a crest, the current procedure is to place the remote locomotives in a separate group before the crest. The train driver commences reducing tractive effort at the lead locomotive consist soon after it passes the crest, and goes into dynamic braking as soon as the accelerometer displays a positive value, an indication that the train is sufficiently far over the crest to start pushing. The remote locomotive consist meanwhile remains at maximum power, because it is in a separate group. When the dynamic brakes of the lead consist can no longer hold the train against gravity, the driver returns the remote consist to the front group. This automatically ramps its power down to zero and then ramps dynamic braking up to the same value as the lead consist. The entire sequence is predictable on a distance basis, and hence amenable to automation.

Automation of the cresting routine, by distance-shifting the response of remote locomotives, using GPS or odometer, seems to be within realistic reach. This is arguably the only situation in which some form of automation could be advantageous. In this respect, it is less than the potential role for automation foreseen in earlier work [5], which proposed exploiting the graduated release characteristics of ECP braking to that end.

4.6. Optimum use of dynamic braking

Graduated release braking promotes optimum use of dynamic braking, and the pilot-scheme train drivers have demonstrated an effortless preference for full rheostatic braking. This has several train handling benefits compared to direct release braking. First, it is insensitive to locomotive rheostatic brake characteristics, e.g. absence of extended range, which is necessary for handling heavy trains with direct release braking. Second, it is insensitive to wagon brake block coefficient of friction versus speed characteristics, which can be a problem through inflections on descending gradients with direct release braking. Third, intermittent poor adhesion while in dynamic braking, during rain or mist, and/or over flange lubricators, requires increasing the amount of train braking to prevent speed from increasing. With direct release, this frequently results in an inordinately heavy brake application, and over speeding or power braking through subsequent gradient inflections to compensate. However, there is no need to retain an inordinately heavy train brake application with ECP braking — the train driver can graduate it off as soon as he or she no longer requires it. Fourth, pre-emptive reduction of dynamic braking, as drivers seek to avoid wheel slide, and which reduces braking on all locomotives in a consist, rather than only on the leading bogie which is prone to slide, is no longer necessary. This increases the aggregate amount of energy dissipated in dynamic braking by an ECP braked train compared to a direct release braked train under the same conditions.

4.7. Brake block coefficient of friction

Spoornet has recently changed from asbestos to non-asbestos brake blocks. The transition has not been without a change in friction characteristics with respect to speed, suspected to now be steeper. ECP braking's graduated release renders train braking insensitive to wagon brake block coefficient of friction versus speed characteristics, whereas direct release braking requires a suitably flat coefficient of friction versus speed characteristic.

4.8. Brake testing

Although intended to be rigorous, the traditional terminal brake test has degenerated to somewhat less than that. Whereas previously examiners used to walk the train, they now do a drive-by examination. It does save time, but audible defects, such as jammed connector rods, simply pass undetected. Similarly, the ECP braking system has detected brake pipe obstructions that passed a terminal test.

The operator reasonably expects to reduce the amount of time spent on brake testing, and ECP braking can offer a reliable means to that end. A self-diagnostic system has the advantage of getting to the truth of the condition of the brakes of a train, and the pilot scheme has started convincing stakeholders of its worth in that regard. When operations people are ready, the intent is to extend the intervals between routine brake testing. The approach will be to separate testing for continuity and wagon brake mechanical condition, so that the ECP system diagnoses performance continuously, and examiners monitor the mechanical condition on a regular basis, once in x trips, where x is yet to be determined.

5. FUTURE PROSPECTS

5.1. A new vision

The comparison of having experienced heavy trains over difficult terrain with conventional pneumatic braking for many years, and then making acquaintance with integrated ECP braking plus DP in the same environment, has confirmed the author's conviction that there is a decisive dimension beyond objective technical measurement. Subjectively, integrated ECP braking plus DP is far more than the sum of its parts. It makes an assemblage of wagons and locomotives come alive in the hands of a train driver. It offers a quantum leap in railway competitiveness, through elevating the vision of what a train can achieve to a new domain. In the present operation, there is no point in contemplating either ECP braking or DP — for heavy haul, the real value resides in their integration! The author has worked on getting trains to handle competently for many years [6], and has implemented high standards. However, nobody who has driven the pilot scheme train has anything but awe for its competence. Ultimately, train drivers have strong influence in accepting or rejecting a new technology.

5.2. General direction

Although systemic benefits are real, they are difficult to quantify as solutions to existing problems. The initial preference was therefore to justify fleet conversion, where possible, on pilot scheme findings, rather than projected systemic benefits, to secure a robust decision. The requisite hard data will accumulate as the pilot scheme progresses. However, reduced cycle time, plus positive perceptions by drivers and management, have already suggested that investment in integrated ECP braking plus DP, rather than in additional rolling stock, may be attractive to increase system capacity. The pilot scheme has thus changed course from evaluation to preparation for fleet conversion.

5.3. Fast tracking

It is attractive to reap the benefits of integrated ECP braking plus DP, through converting the wagon fleet and sufficient locomotives, as soon as practicable, subject to the pilot scheme demonstrating sufficient economic benefit. The intent is to retrofit a fleet of 6600 wagons and 108 locomotives. To fast track the process, the pilot scheme thus continues, concurrently with tentative planning and financial provision for fleet conversion. If the pilot scheme delivers adverse findings, the plans can be aborted. If it delivers a sufficient body of favourable findings, the benefits can be realized in the shortest possible time.

5.4. Fleet conversion issues

Three dimensions need to be simultaneously optimized. First, the propensity to disrupt operations, through having two incompatible train configurations, seems to require conversion in the shortest possible time. Second, the capacity available to convert wagons and locomotives will define the longest time parameter. Outsourcing the work, which may be advantageous because it does not commit resources permanently, may shorten it. Third, the management of risk regarding teething problems needs careful thought — it is completely unacceptable to ground portions of the fleet. One could probably start operating with a tranche of some 10% of the fleet, with that quantity being used to iron out any systemic issues.

5.5. Configuration issues

Interested parties are exploring the feasibility of one CCD to control a rake of up to four wagons, to reduce investment cost and thereby hasten the convergence between investment required and benefit obtained. This alternative may have a downside if it turns out not to be the industry standard. However, it will more probably turn out to be the industry standard for heavy haul braking. Naturally, maintenance considerations will also influence the size of rake — two- or four wagons. The number of wagons out of service for a defect increases as more are coupled.

Spoornet recently announced an upgrade to its forty-five Class 11E AC locomotives. The scope includes fitting electronic brake racks, in preparation for ECP braking and DP. The rest will come from the Class 7E1 AC locomotive fleet. They are not currently slated for general overhaul or control system upgrade. However, the existing pneumatic driver's brake valve is inclined to leak from the equalizing reservoir and hence increase the brake application over time. An electronic brake rack, to facilitate conversion to ECP braking plus DP, could replace this with benefit.

Existing neutral sections were placed for head end power only. Their placement, with respect to remote consists picking up loads from rest, will probably need attention. It is however not expected that this will be a serious obstacle, because the Ermelo-Richards Bay line operated banked and double-length trains for several years while the track was upgraded, using existing neutral sections.

5.6. A wish list

As a minimum, fleet conversion will also need to lay to rest, through appropriate features and functionality, two issues that have long plagued heavy haul railways. First, detect force in brake rigging, and compare with brake cylinder pressure. A force present when there ought be none indicates stuck brakes or applied handbrake; a force absent when there ought be one indicates mechanical failure. Second, derailment detection plus emergency brake application needs no further explanation.

5.7. Emulating CCDs

The braking and longitudinal force problems mentioned in Paragraph 1.2 have been observed only on the 200-wagon trains on the AC-electrified route between Ermelo and Richards Bay, but not on the DC-electrified or diesel-hauled 100-wagon trains supplied to the mines. A motive power change must be made at Ermelo, in both loaded and empty directions.

Since the author's original assessment of ECP braking and DP equipment (in the United States in 1997, and in Australia in 1998), and since committing to the present pilot scheme, a new player has entered the market. Its differentiating feature is that, in addition to ECP braking working off a cable, its electronic CCD can also emulate a conventional pneumatic brake valve in an air-braked train. At time of writing, its products and claims are still subject to evaluation and AAR approval. A key question concerns reliability of the battery when not connected to a cable supply.

It might thus be feasible to use emulating CCDs, instead of non-emulating CCDs as in the pilot scheme. From Ermelo to the mines and back, the emulation feature would permit the existing, normal air brake DC-electric or diesel locomotives, depending on route, to work all trains. This would avoid the incremental capital cost of providing the

DC- and diesel locomotives with electronic brake racks and ECP braking equipment. Only the AC locomotives would be equipped for and use cable-based ECP braking and DP, on the Ermelo-Richards Bay sector. This alternative is still under investigation.

5.8. Residual issues

Even if the pilot scheme proves successful, the risk of customer loneliness exists until an industry groundswell has developed. At present, the only other comparable player is Quebec Cartier Mining, which has already committed to fleet conversion. An operator might thus be delighted with an orphan technology that the supply industry would be reluctant to support. The fallback position for Ermelo-Richards Bay is to implement traditional radio-based DP, which in the light of experience with the pilot scheme, is only a half-way solution to the problems experienced on 200-wagon coal trains. Integrated ECP braking plus DP are at a crucial phase of assessment.

The integration of ECP braking and DP makes a heavy train so easy to handle that the requisite skill is commensurately reduced. There is no objective measure, but subjectively it feels like an order of magnitude. Spoornet's transformation process is delivering train drivers and supervisors with much less experience than previously: Integrated ECP braking plus DP is attractive in that context. However, the jury is still out on whether ease of handling adequately compensates for lack of experience.

It has been noticed that some train drivers are reluctant to exploit the potential of integrated ECP braking plus DP to shorten running times. It thus seems that the possible fleet conversion might be fraught with the union issues so often surrounding train drivers.

There exists apprehension that placing locomotives in remote consists could lead to derailments in places where locomotives are not normally exposed to risk of derailment, through derailed wagons pulling locomotives off ahead or behind them. The scale of heavy haul derailments is such that many wagons can derail in a single incident. On the subject line, over a five-year period, derailments averaged 14 wagons per incident, with a standard deviation of 18 wagons. However, head end locomotives are typically not involved. The position of the last derailed vehicle spanned almost the entire train, from 1st to 199th wagons, but never the 200th wagon. It thus appears that the rear of a train does not expose locomotives to derailment risk higher than at the front. The risk of derailing wagons is of course more acceptable than the risk of derailing locomotives. Besides the risk of derailment, there is no desire to place remote locomotives within a train — indeed operating preferences would have them at the ends. Of course, locomotive placement itself could also influence the dynamics of derailments, and this issue will need attention.

Note that compatibility with general freight traffic has not been addressed here. Note also that integrated ECP braking plus DP have an affinity for heavy intermodal trains. This new technology might finally bifurcate heavy haul- and intermodal traffic from general freight traffic, as railways struggle to remain relevant in the face of competition from other modes. It thus seems realistic to pursue quick payback in heavy trains, without confounding the decision process to accommodate long-term extension to general freight service and the concomitant compatibility requirements.

5.9. The decision process

A broad-based consensus of technical and operational people is driving the decision process, in an open socio-cultural system. The outcome is therefore not predictable. It is important to recognize that the pilot scheme set out to solve real problems: It is easy to forget that and become submerged in the details of fitting ECP braking and DP, which nevertheless are important. The outcome is expected to reflect stakeholders' perception that integrated ECP braking plus DP gives peace of mind.

6. CONCLUSION

The foregoing analysis and discussion suggest that, together with heavy axle loads, long trains, and high throughput, integrated ECP braking plus DP is set to extend the frontiers of heavy haul railways through enhancing their competence and hardening their reliability.

7. REFERENCES

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