

# **DEVELOPING BUSINESS CASES FOR INTEGRATED ECP BRAKING PLUS DISTRIBUTED POWER**

Dr. Dave van der Meulen  
Specialist (Technical)  
Spoornet, South Africa

E-mail [davevdm@transnet.co.za](mailto:davevdm@transnet.co.za)

Telephone +27 12 315 3182

Fax +27 12 315 3089

Mobile +27 83 275 7004

## **INTRODUCTION**

### **Heavy haul in South Africa**

Spoornet, a division of Transnet, operates two heavy haul routes in South Africa, namely the 540-mile Sishen-Saldanha line, and the 260-mile Ermelo-Richards Bay line. Both lines were commissioned in 1976, using the best technology available at that time. Over the ensuing years, several upgrade programs were implemented, on both lines, to increase capacity by one or more of the time honored means, namely higher axle load, increased train length, strengthened car- and locomotive fleets, and additional trackage. Nevertheless, the fundamental technology remained essentially that of the original generation, and necessarily embodied its well-known shortcomings.

### **New train technologies**

Meanwhile, train technology had advanced, among other, to development of electronically controlled pneumatic (ECP) braking, and its natural extension, integrated distributed power. In particular, appreciation grew that ECP braking plus DP, as an integrated package, sharing an intra-train communication system, could eliminate traditional heavy train problems associated with high longitudinal forces, and both steady state and transient non-uniform brake cylinder pressure from car to car.

Spoornet implemented a pilot scheme to evaluate these new technologies. Kull (2001), Saarinen (2000), Van der Meulen & Cortie (2000), and Van der Meulen (2001a), have previously described the cable-based PLT10-transceiver-equipped train, evaluation methodology, and detail findings. During the course of that pilot scheme, radio-based ECP braking and full-emulation car control devices receded from prominence, while cable-based solutions emerged as the likely industry standard.

### **Application examples**

Spoornet's pilot train experience was positive, with some caveats. This paper addresses the construction of business cases to support conversion of the abovementioned air-braked operations with head end power, to cable-based integrated ECP braking plus distributed power. The author discusses two examples, namely the Ermelo-Richards Bay coal export operation, and the Sishen-Saldanha iron-ore export operation.

## **BUSINESS CASE FUNDAMENTALS**

### **First economics, then strategy**

Not all contributions by new technologies are expressible in economic- or financial terms. Business cases that include such items must thus necessarily blend quantifiable contributions and strategic considerations. In the present context, the approach was first to establish a positive return from quantifiable benefits, and then to sweeten the decision-making process with additional strategic benefits. The following paragraphs address items that formed the substance of a business case for integrated ECP braking plus distributed power.

## **Costs of conversion**

Unless ECP braking (and possibly also DP over the same intra-train communication system) were applied to a new heavy haul operation, the present early phase of ECP braking technology diffusion would imply conversion through retrofitting existing air-braked car and locomotive fleets. In many instances, the rolling stock will not be new; hence, the incremental cost of conversion could represent a substantial proportion of the depreciated value of the equipment. It may seem trite to mention, but under the circumstances, rigorous containment of the costs of conversion, both regarding initial purchase and over the life cycle, is the entrée to constructing a viable business case. The following paragraphs develop this perspective.

## **A preference for all-electric ECP braking**

Spoornet specified an overlay system for its pilot train, to eliminate the risk of a stoppage for system failure during evaluation. Nonetheless, it shared the industry's expected preference for all-electric ECP braking, with a pneumatic emergency portion, for subsequent conversion of an entire fleet. The preference for fleet conversion remains all-electric, but it does have a bearing on other options. In particular, minimizing investment in feeder service interoperability, to keep costs down, called for careful thought.

## **Car equipment configuration**

A clean break from one technology to another encouraged critical review of basic design premises. Digital car control devices have an inherent ability to control multiple cars electronically rather than pneumatically, which could therefore be attractive from a cost-of-conversion perspective. Spoornet has already configured the bulk of its coal car fleet, specifically the larger 114.6-ton cars, in rakes of four. The downside risk is that availability may decline, due to removing multiple cars from service to repair a fault on one. If reduced life cycle costs outweigh possibly reduced availability, such configuration could become the heavy haul industry standard.

The requirement to handle single cars at a few unloading sites, that were originally designed to handle cars of different lengths, or that have tipplers that do not rotate about the coupler centre, as at some sites that support the Ermelo-Richards Bay operation, is a confounding factor. At such sites, one must uncouple the cars to pass them through the tippler. This has forced a choice of one CCD per car, for some 5% of the coal car fleet.

## **Integrated air/electric connectors**

The pilot scheme indicated that reliability of intra-train communication continuity was an issue worth getting right. Two problems emerged. First, passage through rotary tipplers proved to be the weakest link. Recognize however that this perspective resulted from cables that were somewhat shorter than the AAR standard. This aspect will be corrected during fleet conversion. Second, cables that had not been re-coupled, at loading sites where trains were cut, caused delays. It is common cause that conventional air brake hose connections reliably survive both environments. Spoornet is therefore looking to cable connectors integrated with glad hands to support the fleet conversion, by piggybacking on a connector sub-system of proven reliability.

## **Train brake tests**

Initial terminal tests serve to ascertain brake pipe continuity and pressure gradient, as well as mechanical functioning of the brake valve and brake cylinder. The traditional procedure of walking a train is time consuming, and contributes significantly to the turnaround time. The alternative procedure of driving by a train is quicker but less rigorous. Moreover, there is still no certainty regarding the effectiveness of brake rigging, from pistons to brake shoes, even after performing a terminal test. Statistically, terminal tests have revealed few defects other than leaks. Therefore, one could arguably extend the interval between visual examinations, without material loss of knowledge regarding the condition of a train. Spoornet is therefore investigating alternative ways of ascertaining the condition of a train brake system, using technology.

The continuity assurance and self-diagnostic functionalities of ECP braking establish a sound basis from which to start. Nevertheless, as with conventional air brakes, uncertainty remains as to whether the brakes are functioning after the piston. On the Ermelo-Richards Bay operation, Spoornet has implemented an integrated train condition monitoring system that, among other, measures the temperature of every wheel as it passes specific locations along the route, and records it in a database. It enables complete assessment of the brake system, all the way to application of braking force to car wheels, by enabling comparison of the temperature of each wheel both with that of other wheels on the same train, and with the expected value at each location, i.e. hot (brakes applied) or cold (brakes released). Hence the proposed procedure not only forfeits no knowledge of brake system condition, it rather transcends the traditional regime to test functioning of the brake system in its entirety.

The intention is to eventually extend visual examination to much longer than the present once at the start of each empty or loaded trip. The Ermelo-Richards Bay operation has already modified their process, by omitting the terminal test on ECP-braked trains returning from the harbor at Richards Bay, which yielded a saving of 45-60 minutes. Thus far, the experience has been positive.

## **Credit for released equipment**

A conversion to all-electric ECP braking releases service portions that have value in the second hand market, and it therefore raises a credit in the business case. In addition, Spoornet can potentially use released equipment internally, for conversion of non-heavy haul operations from vacuum- to air brakes, which may yield a premium over simply disposing of it.

## **Strategic perspectives**

### **People and work**

Spoornet, in common with several other railways, is finding that new hires, in entry grades that lead to train driver, are not as receptive to challenges, as were their predecessors. In particular, they prefer not to work under what they regard as high stress conditions. Planning to ensure that the direct release brake system of a long, heavy train is adequately charged for prevailing circumstances, including deviations from routine

handling during partial failure and/or infrastructure maintenance, and keeping dynamic coupler forces below failure limits through skilled train handling, are perceived to be high stress activities. In combination with other negative hygiene factors, such as irregular working hours and isolated working conditions, driving trains is relatively less attractive than it used to be.

Furthermore, affirmative action has resulted in progression from new recruit to heavy train driver in Spoornet now being rapid. While materially shortening the learning curve can still deliver a train driver who is competent to deal with normal operational conditions, it frequently denies aspirants the exposure and seasoning that come with extended career development. Short development leads, among other, to inability to recognize impending train-handling trouble, such as the onset of a train break under extreme tractive effort, and absence of the seat-of-the-pants feel that keeps train slack prepared for the unexpected at all times.

### **Removing negative hygiene factors**

ECP braking shortens stopping distance to the extent that a train driver can almost drive on sight, as with a road vehicle. Its graduated release characteristic and continuous reservoir charging eliminate the stress of planning. Well-designed distributed power renders a heavy train all but unbreakable in most circumstances. These attributes of the new technologies remove major negative hygiene factors, thereby aligning the train driver's job with the people designated to do it.

### **Repositioning for competitiveness**

When train performance variables approach limits in several critical areas simultaneously, operations tend to become too unstable for sustained throughput. It is nevertheless vital to be able to reliably deliver throughput at growing capacity levels. Through eliminating problems that can sporadically disrupt service, integrated ECP braking plus distributed power gets to the nub of repositioning a heavy haul railway at a higher level of competitiveness.

## **THE ERMELO-RICHARDS BAY BUSINESS CASE**

### **Scope**

The Ermelo-Richards Bay pilot scheme demonstrated economic and strategic advantages from integrated ECP braking plus distributed power over a period of one year. Spoornet therefore is planning to retrofit a fleet of approximately 6700 cars, and 200 locomotives to varying degrees, with appropriate equipment.

### **Feeder services**

### **Diversity and its implications for ECP braking**

In common with many heavy haul railways, Spoornet supports complex and diverse feeder services between mine loading sites, intermediate exchange yards, and the

marshaling yards at Ermelo and Vryheid where line haul trains are assembled. Upwards of forty mines are involved, located in several coalfields. Conventional air brakes accommodate such operational diversity seamlessly. Although the conversion will result in a dedicated fleet of cars, interoperability remains a key issue. The following paragraphs describe the major services: One-off deviations, not mentioned here, do exist.

### **The Mpumalanga Coalfields**

Mines in these fields are located to the north west of Ermelo, the farthest being some 100 miles distant. Predominantly 3kV DC electric mainline locomotives service them. Diesel locomotives service the remainder. They generally have rapid loading facilities, which Spoornet supplies with blocks of 100 cars. Many of them rely on low-speed-equipped Spoornet locomotives to move trains through the loaders. Either mechanical indexers, or a variety of locomotive types, work the remainder.

### **The Waterberg Coalfield**

Spoornet services this field with 100-car trains, hauled first by diesel locomotives to Thabazimbi, then by AC electric locomotives to Pyramid South, and then by DC electric locomotives to Ermelo, a total distance of 400 miles. This traffic is relatively low volume, around one train per week.

### **Yard working at Ermelo**

At Ermelo, blocks of 100 loaded cars from the mines, hauled by DC electric- or diesel locomotives, arrive in what is known as the D-Yard. A pair of diesel locomotives then combines two of them and hauls them round a balloon to the loaded 200-car train departure A-Yard, where the AC locomotives are attached. In the empty direction, 200-car trains arrive from Richards Bay in the B-Yard, hauled by AC locomotives. A pair of diesel locomotives then hauls them round a balloon and places 100 cars on each of two roads in the empty departure C-Yard, from which they return to the mines once more.

### **The KwaZulu Natal Coalfields**

Mines in these fields are small, and Spoornet typically supplies them with blocks of 50 cars. This territory, electrified at 3kV DC, extends from Vryheid to exchange yards near the mines, some 90 miles distant. From these yards, either Spoornet- or mine-owned diesel locomotives place the cars in mine yards. Thereafter, some mines cut the trains into blocks of around eight cars for loading, using small industrial switching locomotives. The process reverses after loading.

### **The Ermelo-Vryheid-Richards Bay main line**

Feeder trains are combined at Ermelo and Vryheid into 200-car trains, for haulage to the harbor at Richards Bay, by either five or six Class 7E1/3, or four Class 11E, 25kV locomotives, currently at the head end of the train. Applying integrated ECP braking plus distributed power to this core operation will in essence scale up the pilot scheme from one train to all trains. Distributed power will enable the currently incompatible Classes

7E1/3 and 11E to run in the same physical consist, but in two logical consists grouped within a fence. The tractive effort will be apportioned approximately  $\frac{2}{3}$  lead,  $\frac{1}{3}$  remote.

When it is necessary to work 200-car loaded trains over the 1.52% graded original line, during maintenance occupation or service disruption, six manned diesel pusher locomotives are added to the train, currently at the rear. Distributed power will eventually control these pusher locomotives, to give one driver control over the entire train. If the event is planned, the remote electric locomotives will be placed at mid-train upon departure from Ermelo, and the pusher locomotives added at rear where required. If the event is unplanned (i.e. it occurs after departure from Ermelo), and the remote electric locomotives are already at rear, the pusher locomotives will be cut in at mid-train.

## **Interoperability with feeder services**

### **Traction**

In the light of the diversity of locomotive types that support the core operation, that are in line for conversion to work ECP-braked trains, it appears advantageous to constrain diversity to minimize costs. Furthermore, where the benefits of conversion accrue to the railway operator only, and mine operators perceive no benefit other than a distant prospect of negotiating more favorable haulage rates, the latter seem reluctant to bear the cost of converting locomotives. Spoornet has therefore specified transition vehicles, or transition devices, to avoid undue costs for small, one-off, fleets of non-mainstream locomotives. Such costs may include non-recurring engineering, provision of backup locomotives during maintenance, and additional operator- and maintainer training, to name a few. This solution will complement the core fleet of mainline ECP-equipped locomotives to support seamless operation. The jury is still out on whether the transition equipment should be car-borne or packaged for portability, and if portable, whether it should be attached to the last locomotive or the first car. As specified, transition equipment and distributed power will be mutually exclusive.

The author recognizes that the array of Spoornet's and its customers' traction types may elevate the complexity of conversion. On the one hand, this situation illustrates one of the inherent disadvantages of electric traction, in that the power supply network typically does not cover an entire operation. On the other hand, otherwise comparable, but less diverse, railways ought to be able to build a commensurately more robust business case for ECP braking.

### **Braking**

A few mines cut the trains supplied by Spoornet into smaller blocks (less than ten cars), to work them through their loading stations by means of light industrial locomotives. The latter are typically equipped with 24V automotive electrical systems: It is not considered viable to equip such locomotives with specially engineered ECP braking equipment, nor to provide a transition car or -device for such small cuts of cars. Spoornet therefore requires the following functionalities. First, car control devices must wake up on application of brake pipe pressure. This will allow cars to go into sleep mode at such loading sites, to conserve battery charge, and wake up when required to support

movement, without the application of cable power. Second, car control devices must provide limited emulation, by which they monitor brake pipe pressure modulation and direct the appropriate pressure to the brake cylinder. This will permit air brake equipped light industrial locomotives to move small cuts of cars at low speed over short distances.

## **Fundamental business case content**

### **Generic benefits**

Some benefits of integrated ECP braking plus distributed power are generic, and apply across several content items, as follows:

Integrated ECP braking plus distributed power enhances train handling fluency, for the following reasons:

The graduated release characteristic in combination with continuous reservoir charging enables a train driver to drive without thought for the state of charge of the system.

Short stopping distances enable a train driver to drive almost on sight, without regard for difficult stops.

The ability to control the train more precisely through bracketing it between the lead and remote locomotive consists.

Over-the-road train performance is thus significantly faster.

The ability to start a train on any ascending grade means that there is no need to hold trains back while preceding trains clear a section. Note that Spoornet designates critical signals on ruling ascending grades, at which dispatchers and drivers should not stop heavy trains.

Continuous reservoir charging means that there is no delay should a train stop on a steep descending grade. Note that asymmetrical ascending- and descending grades, of respectively 0.625% and 1.52%, mean that locomotive independent brakes cannot hold a train while recharging the automatic brake: Use of the holding brake incurs a time loss of some thirty to forty minutes per application.

Set-up and testing is faster with ECP brakes than with conventional air brakes.

Together, these benefits reduce the amount of cars and locomotives needed to deliver a given throughput tonnage. When packaged and ranked in descending order of percentage of total contribution, they stack up as follows:

### **Reduce car fleet requirements—39%**

Integrated ECP braking plus distributed power accelerates turnaround through more fluent train handling and quicker brake testing. Faster turnaround enables a railway to convey a static volume of traffic with a smaller car fleet, or to grow traffic volume with less-than-proportionate car fleet growth. Either way, there is a saving in car fleet investment. This means that the Ermelo-Richards Bay operation can accommodate static traffic volume without replacing cars written off in derailments, or accommodate growing traffic at less cost than investing in more-of-the-same.



### **Reduce derailment damage—14%**

Multivariate statistical analysis of derailments revealed that four archetypes accounted for 80% of the cases (Van der Meulen, 2001b). In order of increasing severity, they are:

- Empty trains that derailed on ascending grades, at relatively high speed, following rapid deceleration.
- Loaded trains that derailed on ascending grades, at low speed, following coupler failure.
- Loaded trains that derailed on descending grade inflections, at relatively high speed, following axle bearing failure.
- Loaded trains that derailed on descending grade inflections, at moderate speed, following wheel failure.

Distributed power addresses loaded trains that derail on ascending grades by reducing coupler forces below the threshold that risks failure. ECP braking addresses the other three archetypes, first through applying car brakes simultaneously throughout a train, with uniform pressure at each brake cylinder, and second through graduated release encouraging release of brakes over grade inflections. Eliminating such derailments avoids expenditure on repairing infrastructure damage, and making good rolling stock losses. This item does not include loss of lading, which is carried at owner's risk.

### **Reduce locomotive fleet requirements—14%**

This item also relates to faster turnaround. The locomotives turn around faster, for the same reasons as the cars, and hence fewer locomotives are required for a given level of traffic. The value of the benefit is however different: Because of the diversity of locomotive types, locomotives and cars operate on different turnaround cycles.

### **Reduce rolling stock maintenance—10%**

Integrated ECP braking eliminates wheelset damage due to uneven distribution of braking thermal load. The car-level intelligence and intra-train communication that comes with ECP braking is expected to eliminate the remaining risk in respect of overheated wheels, namely inadvertently applied handbrakes, through provision of force detectors after the application points of brake cylinder and hand brake force in the brake rigging. Spoornet has not yet quantified this latter benefit, and it is therefore not included in the business case.

Distributed power reduces coupler forces, so that drawgear life is not shortened, and maintenance costs are correspondingly reduced.

### **Salvage air brake equipment—9%**

The business case includes the estimated value of selling service portions, which are released when all-electric ECP braking is implemented, into the second hand market. Spoornet may be able to realize a marginally higher value if it redeploys them to convert vacuum brakes to air brakes, in which case they could be worth the new valve that would otherwise be needed.

### **Reduce energy cost—6%**

Distribution of a portion of the total tractive effort to the rear of a train, through distributed power, minimizes the amount by which the lateral component of stringlining forces off-track wheelsets, and so reduces energy consumption. Consequently, a distributed power train balances at a slightly higher speed than a head-end power train under the same conditions, which also contributes to turnaround time reduction (this is included under the headings *Reduce car fleet requirements* and *Reduce locomotive fleet requirements*).

The graduated release feature of ECP braking eliminates occurrences of train drivers powering against train brakes, or allowing speed to rise unduly against a train brake application, in situations where direct release air brakes do not allow sufficient time to recharge if a release were to be made. As an aside remark, it is enlightening to note that such undesirable train handling, that wastes or incorrectly dissipates energy, occurs at the same descending grade inflections that account for the two most severe derailment archetypes: Thoughtless energy dissipation is therefore not only a problem per se, but one can often follow its flow to a consequential problem.

The author has observed that, when operating lead- and remote locomotive consists independently in conjunction with the automatic brake, as when passing over a crest, where the driver must optimize three control variables, drivers tend to lose sight of simultaneous application of power and braking. This will be an issue for thorough training as the operation is cut over to full ECP braking plus distributed power, to ensure that reduced energy costs are realized in practice.

### **Reduce train delays—6%**

This item reflects the benefits of integrated ECP braking plus distributed power in rendering service delivery more reliable. It relates to the one above for *Reduce derailment damage*, and accounts for avoiding loss of capacity due to disruption of the service by derailments and train partings. It also includes elimination of undesired emergency brake applications and pneumatic-brake-related train stoppages.

### **Reduce track maintenance—2%**

Placing all locomotives at the head end of a heavy train may disturb the track structure, by straining it longitudinally under high tractive effort, which in turn deranges clips, pads, ties and ballast. Placing locomotives in two, distributed, consists reduces the concentration of tractive effort to below a threshold at which it contributes unduly to track maintenance.

### **Other benefits**

One can identify several other benefits. However, the weight of the last item in the foregoing list suggests that they would be marginal, and therefore not worth pursuing in the context of a business case.

One of the items from which a benefit was expected, but which did not materialize, was a significant reduction in wheel- and brake shoe wear. At the level of accuracy of analysis,

no difference between the pilot- and control trains was evident. In retrospect, the faster running times seem to demand more rapid braking during speed reduction, which may negate the preference given to dynamic braking over friction braking.

## **Current status**

### **Process**

At time of writing, the Transnet Board had authorized conversion of the entire fleet of Ermelo-Richards Bay coal cars, plus sufficient locomotives, to integrated ECP braking plus distributed power. At time of writing, a specification was in preparation, with a view to inviting tenders for the conversion of the entire fleet. The intention is to award the business late 2002/early 2003.

The conversion program will prioritize locomotives, to mitigate the risk of non-availability of a suitably equipped locomotive rendering an all-electric train immovable. Transition cars or -devices will cover the residual interoperability risk. Each contractor will provide two pre-production trains (200 cars), to demonstrate that the offered equipment meets expectations, before mass conversion commences. Spoornet needs reasonable assurance that the new technology will support consistent throughput, through and beyond the conversion process. It will therefore specify an extended guarantee.

### **Program**

The Class 11E 25kV AC locomotives will be equipped for ECP braking and distributed power, as part of an upgrade program that is already in progress. They will ultimately constitute the backbone of the distributed power sector of the operation. The remaining distributed power lead locomotive requirement will be converted out of a portion of the Class 7E1/7E3 25kV AC fleet. Locomotives from this class that are not equipped as distributed power lead locomotives, will be equipped with intra-train communication through cabling, so that any locomotive allocated to the 25kV AC sector will be able to operate at least as a trailing locomotive in an ECP braked train.

Class 10E 3kV DC locomotives, and Classes 34 and 37 diesel locomotives, operate the feeder trains, which will remain head end power only. The Class 10E locomotives will therefore be equipped for ECP braking only. As mentioned previously, the diesel locomotives used for pusher service will be equipped for ECP braking and distributed power; the remainder will be equipped for ECP braking only. These classes of locomotive typically operate in consists of four or more: Locomotives equipped for ECP braking only will constitute approximately 50% of the allocated fleet, to mitigate the risk of lead locomotive failure, for a non-ECP-braking reason, failing a complete train. Locomotives from these classes that are not equipped as ECP braking lead locomotives, will be equipped with intra-train communication through cabling, so that any locomotive allocated to the feeder services will be able to operate at least as a trailing locomotive in an ECP braked train.

### **Pilot train upgrade**

When Spoornet awarded the pilot scheme business in 1999, PLT10 was the current transceiver technology. This has subsequently advanced to PLT22, which is not compatible with PLT10. The fleet conversion will comply with PLT 22 specifications. At time of writing, arrangements were therefore underway to upgrade the pilot train (i.e. 208 cars and 4 Class 7E1 locomotives) to PLT22, so that it can interoperate with equipment that will come later.

## **THE SISHEN-SALDANHA BUSINESS CASE**

### **Scope**

The insights gained from the Ermelo-Richards Bay pilot train provided a starting point from which to approach a business case for integrated ECP braking plus distributed power on the Sishen-Saldanha operation. The following additional considerations apply:

First, the nature of the benefits included in the Ermelo-Richards Bay business case suggested that a further pilot scheme on Sishen-Saldanha would not deliver significant new insight. The outcome is therefore not expected to differ materially from that of the Ermelo-Richards Bay operation, although the distribution of the benefits could well differ.

Second, the Sishen-Saldanha operation comprises single track, whereas the Ermelo-Richards Bay operation comprises double track. This distinction renders the former sensitive to turnaround time issues and benefits. Thus, the largest contribution is expected from faster turnaround, and hence reducing rolling stock requirements. Improved train handling, higher speeds on descending grades, and less time spent on brake testing before departure, will enable these benefits.

Third, the Sishen-Saldanha operation is relatively simple, without complex feeder services. Rather than using transition devices or -vehicles, it will probably be cost effective to simply convert all rolling stock to integrated ECP braking plus distributed power.

### **Fundamental business case content**

Strategic development could prove to be a major determinant. At envisaged traffic levels, there is no need to contemplate doubling the line, although intermediate passing loops have been provided, and options for traffic growth are thus in principle confined to higher axle load, longer trains, and faster turnaround.

Although the business case for upgrading to the present 33.1 tons/axle did not include peripheral issues, some have emerged. These include constraints at both loading- and unloading terminals, where the additional volume of iron ore per unit time resulted in longer turnaround time, and dipped rail joints. It is therefore improbable that axle load will be further increased.

If train length, and hence tonnage, were to be increased beyond present parameters, continued use of head-end power only would push coupler forces beyond prudent limits,

thereby threatening system reliability. Distributed power can increase aggregate tractive effort per train, while decreasing the force applied at any particular coupler.

A possible solution is to use radio-based distributed power only. However, it would address high coupler force issues, but offer no benefit in respect of thermal loading on car wheels, simultaneous response on all cars, and terminal brake testing. In addition, the time to link distributed locomotive consists may prove to be a negative benefit.

Faster turnaround offers the largest quantifiable benefit, by reducing time spent on brake tests, of the order of 90-120 minutes per terminal, in a total cycle of some 60 hours.

### **A practical simulation**

Instead of a pilot scheme, the author undertook a real-train simulation, to establish a basis for a business case. The responsiveness of ECP braking was simulated, for test purposes only, by adding sufficient extra locomotives to the regular train to use their dynamic brakes to substitute for energy dissipated by car wheels, at any speed. It proved possible to handle the train with dynamic braking only (other than for stopping), thus simulating the instantaneous response of ECP braking. The test train drivers had been given an opportunity to handle the Ermelo-Richards Bay pilot train, to encourage them to drive a conventional air braked train as if it were a graduated release ECP braked train. That is, when they needed to graduate the brake off, they could simply reduce dynamic braking. The train consisted of the regular 216 cars, loaded to 132.2 tons gross, plus two instrumentation cars, for a trailing load of 28650 tons. The locomotives were placed in three consists: the regular two Class 9E 50kV electric locomotives leading, but the regular five Class 34 diesel locomotives at the rear, to simulate distributed power both in traction and dynamic braking; in addition Class 9E locomotives, two in front and five in the middle, provided dynamic braking only. As currently set up, Class 9E locomotives provide 4800 horsepower in traction and dynamic braking, and Class 34 locomotives provide 2000 horsepower in traction and dynamic braking, all at rail. The regular tractive and dynamic braking power is 19600 horsepower; a supplementary dynamic braking capacity of 33600 horsepower was available to simulate the instantaneous graduated release response of ECP braking. Permissible speed on long descending grades was raised from 31 mph to 38mph, to simulate the benefit of uniform thermal loading on car wheels characteristic of ECP braking

The simulation was less successful than expected, for two reasons. First, despite the prior exposure and coaching en route, the train drivers had difficulty in shifting their train-handling paradigm from air brake to ECP brake. No doubt, one could overcome that with sufficient practice runs. Second, the simulation was predicated on a reduction in running time, and South African train drivers are reluctant to deliver slick performance during a recorded test run. In the event, the simulation delivered a running time reduction of 40 minutes, from 17 hours 30 minutes to 16 hours 50 minutes. Subjectively, the author expects a one-hour reduction under routine conditions.

### **Current status**

The operation is growing. Although it can handle the current contractually committed 32 million tons per year with existing assets, when demand increases beyond that, further

investment will be required. Integrated ECP braking plus distributed power is attractive, because it offers faster turnaround, through shorter running times and quicker terminal tests. Of the growth options available, integrated ECP braking plus distributed power offers the highest profitability index. The author expects a decision when the next tranche of capacity is committed.

## **GENERAL CONCLUSIONS**

### **The competencies of integrated ECP braking plus distributed power**

At high level, the business cases introduced here may appear similar, as indeed they are in many respects, but reflection on their differences illustrates the broad-based competencies offered by integrated ECP braking plus distributed power. The technology is applicable to systemic problems in widely divergent operations.

### **Matching benefits to costs**

Spoornet is a vertically integrated railway; hence, costs and benefits accrue within the same set of accounts. This serendipitous circumstance facilitated matching costs and benefits for the Ermelo-Richards Bay business case in a way that supported investment in integrated ECP braking plus distributed power. Where different parties own or operate the cars, locomotives, and trackage that constitute a heavy haul railway, the benefits may accrue to a party that makes no investment, while the party that makes the investment may receive no benefits. Resolution of such a dilemma tends to bog down in price negotiations among parties, which may make resolution elusive or intractable. One should not interpret this position as advocacy for vertical integration, but rather as an example that demonstrates that resolution does exist, and as encouragement to other railways to find a way of identifying and matching the costs and benefits of a worthwhile technology.

### **A new growth option**

Arguably the strongest case for integrated ECP braking plus distributed power, as a package, is that it adds a fifth option to the traditional quartet of approaches to increasing capacity, namely increasing axle load, increasing train length, strengthening car- and locomotive fleets, and adding more trackage. It grows capacity without pushing the envelope of engineering constraints, which tends to be on the limit already in heavy haul railways. On the contrary, while accelerates turnaround time, by reducing running time and terminal time sufficiently to justify itself, it contributes a package of benefits that enhances the humanity, reliability, and robustness of a heavy haul operation. It is a worthwhile technology indeed!

### **A fence around heavy haul?**

The author has previously noted that changing interoperability standards is notoriously difficult and costly, and concluded that high investment requirements for new train technology might trigger a bifurcation of destiny between heavy haul and heavy intermodal traffic on the one hand, and general freight traffic on the other hand (Van der

Meulen, 2001c). The business cases introduced above seem to reinforce that position. Perhaps the greatest challenge in the project reported here has been to define the interoperability interface between ECP braked trains and the rest. The envisaged investment will create a high barrier to entry, and the resultant benefits will be one sided. It is improbable that general freight traffic will support such investment, and without it, its competitiveness could wane.

### **A strategic perspective**

The foregoing content has set out Spornet's business approach to integrated ECP braking plus distributed power. That the investment is regarded as being vital to the ability of the Ermelo-Richards Bay operation to deliver coal at higher capacity levels, attests to the significant contribution of a great train technology.

### **REFERENCES**

- Kull, R.C. 2001. ECP brake applications on heavy haul railways. *Proceedings of the Seventh International Heavy Haul Conference*, pp. 525-532. Brisbane, Queensland: International Heavy Haul Association & Railway Technical Society of Australasia.
- Saarinen, S. 2000. Wabtec ECP brake system. *Proceedings of the 92<sup>nd</sup> Convention*, pp. 71-84. Chicago, IL: Air Brake Association.
- Van der Meulen, R.D. & Cortie, A.L. 2000. Evaluation of wireline ECP braking and DP on the Ermelo-Richards Bay coal export line. *Proceedings of the 92<sup>nd</sup> Convention*, pp. 156-174. Chicago, IL: Air Brake Association.
- Van der Meulen, R.D. 2001a. Progress with evaluation of cable-based ECP braking and distributed power. *Proceedings of the Seventh International Heavy Haul Conference*, pp. 517-524. Brisbane, Queensland: International Heavy Haul Association & Railway Technical Society of Australasia.
- Van der Meulen, R.D. 2001b. Soft science and heavy haul: Multivariate statistics and systemic drivers. *Proceedings of the Seventh International Heavy Haul Conference*, pp. 255-263. Brisbane, Queensland: International Heavy Haul Association & Railway Technical Society of Australasia.
- Van der Meulen, R.D. 2001c. Strategies for freight train integrated ECP braking plus distributed power. *Proceedings of the World Congress on Railway Research* [CD-ROM]. Cologne.