ECP Braking and PTC for Increasing Heavy Haul Railway Capacity

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Summary: An update on Electronically Controlled Pneumatic (ECP) braking and Positive Train Control (PTC) is provided, with a discussion on how both of these new technologies can be applied to increase heavy haul railway capacity as an alternative to track infrastructure expansion.

Index Terms: ECP, PTC, capacity

INTRODUCTION

Electronically Controlled Pneumatic (ECP) braking systems are now in revenue service in Heavy Haul railway applications in North America, South Africa, and Australia. This has followed 14 years of development and many pilot test trains, in parallel with establishment of interoperability specifications by the Association of American Railroads (AAR). Interoperable ECP trains are now in service, which can freely mix car, locomotive, and end-of-train devices from both Wabtec and Knorr. A brief overview of ECP brake system features, benefits, and the current status of AAR standards is provided in the following sections.

There are multiple economic and safety benefits with ECP braking. However, the largest financial justification of ECP braking normally is related to how it can contribute towards increasing network capacity, reduction of cycle time, and associated rolling stock utilization.

Another new technology change coming to freight railway operations is related to implementation of “Positive Train Control” (PTC) systems. New PTC systems are based upon “Communications Based Train Control” (CBTC) to supplement and eventually replace conventional wayside fixed block signal systems. PTC provides another set of opportunities for increasing capacity. The combination of both ECP braking and PTC working together leads to a higher level of “intelligent train control” which can bring heavy haul rail operations of the future to even higher productivity and network capacity. This provides the opportunity for railways to increase capacity with lower capital investment than would be needed by building more track, using standard braking and signal control systems.

The international heavy haul railways industry has enjoyed strong growth in demand over the past 15 or more years, which has driven large capacity expansion. The current world wide recession has interrupted this growth, with some cases of declining demand. During the “boom” years, introduction of ECP and other technology advances have sometimes been difficult based upon reluctance to allow rolling stock to be taken out of service, impacting short term hauling capacity. In some cases, the network and rolling stock were being pressed to full capacity, with no room to make-up lost trains. The current economic downturn relieves this problem, and provides the opportunity to consider how to take advantage of new technology, in preparation for expected economic recovery, and resumption of long term growth in demand for heavy haul railway capacity.

ECP FUNCTIONS SUMMARY

The AAR sponsored standards and interchange requirements for ECP brakes have been defined in the “S4200” series of specifications. Technical details of ECP braking have been provided in other papers, but the basics are outlined as follows:

- Two-conductor trainline cable provides 230 VDC power distribution from locomotives to cars, as well as powerline overlay data communications.
- Pneumatics still provides the braking power, but con-
• The brake pipe is normally operated as a pneumatics supply line, which continuously charges during ECP braking applications.
• Emergency pneumatic back-up is still provided by the brake pipe.
• The ECP trainline also supports other communications applications, including health monitoring and distributed power.

The braking performance improvements provided by ECP include:
• Simultaneous application and release of car brakes over the entire train length.
• Ability to support “graduated release” of brakes.
• Feedback to the locomotive of car braking status and health.

The simultaneous application feature of ECP means that braking distance is improved over that of conventional trains, and that trains of any length will have close to the same braking capability. Typical North American freight trains with 100 to 150 cars, will have full service braking stopping distances from line speeds reduced in the range of 30% to 60%, depending upon grades, loads, and other variables.

Transnet, in South Africa, currently operates the world’s longest ECP trains, with 200 wagons, also tied to control of a rear of train locomotive consist with Wireline Distributed Power (WDP). The train handling and stopping distance advantages of combining ECP braking control and WDP control of remote locomotives has been well documented in past papers delivered by Transnet (former Spoornet).

In addition, the graduated release capabilities of ECP greatly enhance train handling for downgrades and undulating terrain. This greatly reduces the risks of train handling related derailments, which of course has a detrimental impact to capacity.

ECP car systems can be provided as “overlay” and “standalone” configurations. Early pilot trains were usually equipped as “overlay”, which retains the conventional pneumatic service portion and allows the car to operate in either ECP or pneumatic modes. “Standalone” replaces the conventional ECP service portion, and can only operate in ECP mode. The end objective for most railways has been to plan for standalone operation. This has been driven by two main factors:
• Lower car cost, with only one brake system to maintain.
• Forces the discipline to maintain operations as 100% ECP.

There are two main issues to support going directly to “standalone” ECP operation:
• Equip sufficient locomotives with ECP to support the car equipping plans
• Plan unit trains with all ECP cars

Even with plans to go the “standalone” ECP route, there may be occasions for needing to move cars without having ECP equipped locomotives. This has generally been handled by providing pneumatic emulation modes as part of the ECP car software, which allows limited battery power operation, with application of brakes based upon conventional brake pipe reductions. However, the pneumatic performance is generally not the same as with modern AAR brakes, such as Wabtec ABDX, which leads to operating speed and train length limitations while in emulation mode.

Most new ECP applications over the past few years have elected to go the “standalone” path, and operating experience as proven this to be manageable.

**ECP BENEFITS SUMMARY**

Capacity and increased rolling stock utilization usually represent the largest quantifiable benefits, and are expanded upon later in this paper. However, other benefits can be summarized as:

1. **Fuel/Energy Savings**: The energy savings potential is very operational specific, and is mainly related to the ability to more precisely handle trains with lower average braking, and use of graduated release to eliminate the need for power braking.

2. **Wheel Savings**: ECP provides more accurate and uniform brake block pressures, with less chance for over applications leading to wheel skids and excessive thermal conditions. In addition, ECP provides a platform to support monitoring of hand brake releases. Failure to release hand brakes is a leading cause of wheel damage on many railways.

3. **Car wear reduction**: The lower in-train forces with ECP braking reduce the car stress levels, which can lead to lower damage and longer useful life.

4. **Derailment Risk Reduction**: Handling long heavy haul trains is greatly improved with ECP, which reduces in-train forces associated with braking actions, with corresponding reduced risk of derailments. Likewise, the risk of “runaways” based upon excessive brake cycling is virtually eliminated.

5. **Safety with Shorter Braking Distances**: Emergency braking for abnormal incidents which lead to the need to stop the train to avoid a collision or track failure/obstruction will be safer, with shorter stopping distance.
and lower in-train forces.

6. Car Monitoring, Maintenance: ECP provides the means for alarming brake system faults, such as brake cylinder leaks, to support maintenance on an as required basis. This can be further extended with car vibration and other “smart car” sensors to support alarms during train operation as well as the need for preventative maintenance.

7. Platform for Wireline Distributed Power: Locomotives equipped for ECP operation can also be equipped for WDP operation, for a relatively small additional investment. This provides the ability to distribute trains within the consist, which provides traction related in-train forces and fuel savings benefits. ECP based communications provides advantages of radio based distributed power, based upon close to continuous communications and eliminating need for radio repeaters for tunnels and other loss of radio coverage areas.

8. Rail Infrastructure Stress: Conventional braking places a higher level of stress on the front portion of the train, which transfers to the rail infrastructure. ECP braking allows the braking effort to be distributed more evenly over the train length.

9. Train Control Enforcement Accuracy: ECP provides a much higher level of braking capability predictability, which allows lowering margins in braking distance calculations within on-board train control penalty brake enforcements systems.

10. Reduced Driver Training Requirements: If a railway is able to convert to all ECP operations, train handling is greatly simplified, which can also reduce the level of training needed to qualify new drivers.

11. Platform for ATO: ECP braking, with related car heath monitoring and WDP provides a strong basis to support future Automatic Train Operation (ATO) implementations. ATO can be considered in steps, with a focus on providing a high level of total train control optimization.

The level of these benefits will vary widely by railway, and are also difficult to quantify. However, they can contribute to the total business case to support ECP investment decisions.

AAR ECP STANDARDS STATUS

The industry has long recognized that ECP success depends upon development of interoperability standards supported by at least two suppliers. This has been a long process, over the past 14 years, lead by the AAR in development of the “S4200” series of specifications. The standards were developed in parallel with many different pilot train projects by both Wabtec and Knorr. There have been many changes along the way, but the core system requirements have been stable over the past few years. The standards have also expanded to include Wireline Distributed Power (WDP) functions, which share the same trainline and data messaging structure with ECP braking functions.

As a brief background, the AAR interoperability requirements are focused on allowing free mixing of cars, locomotives, and end-of-train devices within trains, regardless of supplier. This means definition of required functions, messaging protocols, and trainline cables/connectors. However, the AAR specifications do not standardize the detailed system implementations within car and locomotive designs. They also allow for implementation of optional functions which may be railway or supplier specific. There is also a structure in the messaging protocol to support future growth of “smart car monitoring” and other functions for future development.

Although standards have been driven by the AAR, which is controlled by North American Class 1 railways, there have been important contributions and inputs from international heavy haul operators. A primary example is Transnet in South Africa, who awarded contracts in 2006 to both Wabtec and Knorr for retrofit of locomotives and cars on the Richards Bay coal line, for both ECP and WDP operation. A key stipulation in these contracts included guarantees from both suppliers to demonstrate interoperability. This was the first project to place firm schedule demands on proving interoperability between Wabtec and Knorr systems. In the process of interoperability testing between suppliers, there were many detailed issues within the S4200 specifications which needed to be clarified to eliminate interpretation differences. This lead to formalizing updated specification revisions in early 2008. Wabtec and Knorr performed formal interoperability rack testing in late 2007, and fielded initial trains to the updated standards in early 2008.

Important industry progress was achieved in 2008, driven by the U. S. Federal Railway Administration (FRA). The FRA recognized the increased safety benefits of ECP braking, and offered to provide regulatory relief to the railroads to help support ECP adoption. An important regulatory change was related to required brake inspection and testing intervals. The main safety rationale was based upon taking advantage of ECP continuous health status monitoring capabilities, which provides alarms to the locomotive driver in event of failures. Historically, trains have been limited to 1,000 miles (1,600 km) between inspections, with provisions to allow extending to 1,500 miles (2,400 km) for dedicated intermodal trains. The FRA passed regulations permitting ECP trains to operate up to 3,500 miles (5,600 km) between brake inspections.
The FRA regulations also permitted ECP trains to depart terminals with 95% of cars with operative brakes, and to continue line operations with only 85% operative brakes. This was based upon the safety benefits of reporting operative brakes to the driver, combined with the superior performance of ECP brakes. The impact of this regulatory relief is to provide greater flexibility in operations, to deal with car failures with minimal impact to overall traffic.

The FRA regulations are also tied to compliance with the AAR S4200 series of specifications. This has further reinforced railway and supplier compliance with the current interoperability standards.

There will be continuing revisions to the AAR S4200 specifications. However, these are mostly refinements and addition of standards for optional functions, based upon field experience with current ECP trains. Future specification changes are expected to maintain backwards compatibility with existing specifications and systems, without requiring hardware changes to installed systems.

The AAR specifications do allow for optional features which can be selected on an individual railway basis. Closed network international heavy haul railways can base requirements on the S4200 specifications, but still have latitude to define their own sets of options and extensions.

**ECP TRAINS IN OPERATION**

After many years of pilot train testing, there is now a growing experience level with ECP trains operating in revenue service. A brief summary of ECP trains expected to be in-service as of mid-2009, including equipment supplied by both Wabtec and Knorr:

**United States:**
- BNSF with Southern Company Coal Cars; 2
- Norfolk Southern, Coal; 6
- Union Pacific, Intermodal; 2

**Canada:**
- Quebec Cartier Mining, Iron Ore; 2
- CP Rail, Coal; 2

**Australia:**
- Queensland Rail, Hunter Valley, NSW Coal; 4
- Pacific National, Queensland Coal; 1
- Fortescue Metals Group, Iron Ore; 4

**South Africa:**
- Transnet, Richards Bay Coal; 4

Many of these examples are operating with mixed equipment between Wabtec and Knorr, and have also proven the ability to interoperate in accordance with AAR S4200 specifications. While the number of ECP trains in operation is still modest, the length of successful operations and diversity of applications have provided a high confidence factor in the system design and reliability. This has lead ECP braking to being under consideration for multiple heavy haul railway applications around the world, especially for new start-up operations.

**POSITIVE TRAIN CONTROL**

The terminology of “Positive Train Control” (PTC) generally relates to application of new “Communications Based Train Control” (CBTC) system designs as the means to provide automatic enforcement of train movement authorities. PTC can be applied as overlay to existing signal and dispatching systems to provide enforcement of operating rules and signals. It can also be applied as a standalone train control system, replacing conventional wayside signal systems.

Wabtec is the North American leader for development of PTC systems for freight railway applications, with a product line called “Electronic Train Management System” (ETMS). BNSF was the first railroad to deploy ETMS, on their Beardstown, Illinois sub-division, starting in 2004. This lead to being the first (and still only) system to have received “Product Safety Plan” approval by the FRA (in Dec. 2006) to permit applications in revenue service. BNSF has extended ETMS to two additional sub-divisions, and is in the process of expanding to a large part of their 50,000 km network.

Wabtec ETMS has also been adopted as the basis for PTC testing and deployment plans by Union Pacific, Norfolk Southern, CSX, and CP Rail. These Class 1 railways, together with BNSF, have teamed to drive North American PTC interoperability standards. The reasons for needing interoperable PTC systems are essentially the same as for ECP braking, in support of North American interchange traffic. Railroads are increasingly operating locomotives and crews across property borders and need to support “seamless” traffic movements.

In October 2008, the U.S. federal government passed the “Rail Safety Improvement Act of 2008”, which mandates PTC implementation by the end of 2015 for Class 1 and passenger rail operations. The lines to be equipped are based upon the level of hazardous materials as well as passenger traffic, and are expected to include most of the core freight mainlines. Likewise, it is expected most locomotives which support lead consist service will be retrofitted for PTC.
North American railways now face a unique opportunity to consider how both ECP and PTC system implementations can be planned together in support of future capacity growth and efficiency needs. The same logic and system solutions can also be considered for application to international heavy haul railway operations.

CAPACITY PLANNING

The current world economic recession has lowered the pressure on how to plan for increasing capacity. However, at some point economies will turn around, and growth will continue. While the U.S., Japan, and European GDP's are expected to be negative growth in 2009, China and India economies are still expected to grow—although with lower rates than recent past years.

China and India economies are expected to continue being major drivers for international trade of coal and iron ore, with direct impact to heavy haul railway demand around the world. Most forecasters are expecting iron ore and coal demand from China and India to continue increasing at a higher rate than the overall GDP growth.

The premise of this paper is that growth will return, and there will be a need for planning heavy haul rail capacity growth. Ideally, railways can plan capacity growth with a long term view to provide the most cost effective solutions.

Capacity planning is a complex subject, even for dedicated mine to port heavy haul operations. Parameters which need to be considered can be divided into three categories:

1. Infrastructure
   - Track layout, single/double track, etc.
   - Line speeds, Civil speed restrictions
   - Signal, train control system

2. Traffic Demand
   - Train performance capabilities
   - Mix of traffic, priorities
   - Regularity, predictability of schedules
   - Peak traffic demands

3. Operating Issues
   - Track maintenance planning
   - Unscheduled track interruptions
   - Rolling stock cycle time requirements
   - Mine capacity, schedules
   - Port capacity, schedules
   - Quality of service

Computer modeling can calculate “Theoretical Capacity” for a given network, based upon unit trains of the same type running on a fixed schedule, with minimum headway, and no failures. This can define the maximum capacity with everything working correctly. However, it is more important to estimate the “Practical Capacity” which reflects real world conditions, which may include:

- Train failures
- Track failures
- Train control failures
- Unscheduled maintenance
- Uneven traffic demand
- Changing priorities

The “Practical Capacity” to provide service at a reasonable quality of service, using conventional trains and signal systems has been considered to be in the range of 60% to 75% of the “Theoretical Capacity”. The “Practical Capacity” is generally considered as the basis for measurement against current demand and future forecast needs.

LINE CAPACITY GROWTH

Mining railways clearly need to plan the entire path from mine to port to determine capacity growth choke points. As limitations in the port and mine ends are addressed, at some point line capacity becomes the limiting factor. Without changing existing trains and fixed block signal systems, a need to increase capacity normally translates to building more track. This can take multiple forms:

- Single track siding extensions
- Add sidings
- Add sections of double track
- Double track the entire line
- Add 3 or 4 track sections

In the U.S., the highest capacity corridors are for Powder River coal, with track shared by UP and BNSF which has up to four mainline tracks.

Adding track is obviously very expensive, and costs need to be estimated on a case specific basis. One example in the U.S. have been recent estimates for extending double track to an existing single track right of way on a BNSF line between Los Angeles and San Diego. The estimate totaled about $33 million per mile to add the second track.

There are clearly cases where adding track is the only way to add substantial capacity. However, it is suggested both ECP braking and PTC can provide alternative approaches to expanding capacity, replacing expensive track investments.

ECP AND PTC CAPACITY GROWTH

The combination of ECP braking and PTC with flexible
block train control can increase capacity and shorten cycle times on existing infrastructure. The level of increase possible will vary widely between different networks, and needs to be analyzed on a case-by-case basis. Double track lines will generally have higher growth potential than single track, but most all lines can find areas for improvement. Areas to consider for potential gains, for networks which are fully converted to ECP trains with PTC:

1. Shorter braking distances: ECP provides both higher predictability and shorter braking distances, with can be integrated with PTC to support closer headway operation for following moves, as well as consideration of increasing track speeds in selected areas. This will have a larger benefit for double track lines, which could approximately double line capacity.

2. Uniform braking between train types; ECP trains have close to the same braking profiles, independent of train length. This allows consistent traffic flows, with close to the same train separations.

3. Graduated and faster release brakes: This provides the ability to increase train speeds for selected downgrade movements, which would not be safe with conventional braking. ECP brakes also support faster releases from stop, reducing delays after a movement authority is received.

4. Reduced derailments and unintended train stops: Train handling advantages of ECP and reduction of risk for “undesired emergency” (UDE) brake applications will reduce the risk of derailments, train break-in-two events, and other unintended train stops, which have large impacts to capacity.

5. Wireline vs. Radio Distributed Power; Radio distributed power is designed to tolerate loss of communications, such that the train reverts to front end pneumatic brake applications with radio loss. Train control systems need to plan brake distances with loss of radio. Wireline distributed power is based upon close to continuous communications over the ECP trainline, with braking from both ends as well as all cars under communications loss conditions. This allows train control systems to take advantage of the much shorter stopping distances with ECP and WDP, in support of closer headway operations.

6. Flexible Traffic Control; PTC could support placing two shorter trains into one siding, with very short headways to support alternative traffic plans for single track lines.

7. Predictive Maintenance; PTC provides a means for data communications from locomotives to dispatch offices, which can also be used to support locomotive health monitoring. Likewise, ECP provides a means for locomotives to receive car health data, which can also be relayed to office maintenance systems. This provides a means to increase predictive maintenance and lower the incidence of in-route train failures impacting capacity.

8. Faster Train Make-up and Turnaround Times: Reduced manual inspections may be supported by ECP brakes, reducing overall cycle times.

The increased flexibility provided by ECP braking and PTC may also open new ways to consider operating trains, to better match mine, port, and end customer needs. For example, it could be more economical to change to higher numbers of shorter trains with increased frequency of operation. This may reduce switching or blending operations at the port.

ECP and PTC also provide a strong platform to extend to different levels of “Automatic Train Operation” (ATO). This can lead to computer based optimization of train routing as well as on-board train handling to save fuel within schedule demand constraints.

Referring to the previous section on Capacity Planning, the issues as outlined above can increase both “Theoretical Capacity” and “Practical Capacity”. The “Theoretical Capacity” for a double track line can easily seen to increase dramatically based upon the ability to support longer trains, with shorter headways. In some cases, this could be as much as four times the capacity (Refer to Figure 1.)

However, there are usually many other constraints, such as port and mine capacities, and rolling stock availability which will limit the capacity growth potential when considering total network issues.

A total network analysis is more likely to focus on “Practical Capacity”, which takes into account more real world conditions with the need to deal with unpredictable schedule variations, train delays, etc. As previously outlined, “Practical Capacity” is normally in the range of 60% to 75% of “Theoretical Capacity”. It is suggested the combination of ECP braking and PTC has the potential for increasing this to the range of 70% to 85% - or a-
about 10 percentage points. This presumption is based upon two main factors:

- Increased ability to make-up for network delays, with higher peak traffic capacity, with shorter headways.
- Reduced risks of causing network interruptions, based upon improved braking and train health monitoring with predictive maintenance capabilities.

The total capacity increase potential can be estimated by combining the “Theoretical Capacity” with the increase in efficiency to convert a higher portion into “Practical Capacity”.

In addition to increasing network capacity, the same benefits of ECP and PTC can increase average train velocity, with reduced cycle times. Similar to capacity, cycle time issues also need to be analyzed on a total network basis.

ECP train experience to date suggests achieving in the area of 10% improved cycle time is achievable, even before adding further benefits from PTC. This directly translates to being able to increase hauling capacity by 10% with the existing fleet, or being able to lower new rolling stock investments to achieve growth targets.

CONCLUSION

International heavy haul railways are going to need to plan capacity growth alternatives as the world economy recovers. ECP braking and Positive Train Control technologies have undergone substantial advancements over the past 15 years, and should be considered as part of the capacity planning process.

The highest benefits can be achieved by converting an entire network operation for both ECP and PTC, with all trains equipped. This requires a long term strategic vision, with a migration plan over a multiple year period. Retrofit of existing locomotives is normally the starting point for a migration plan. There are economic benefits to plan retrofit of both ECP braking and PTC capability on locomotives at the same time. When all locomotives are retrofitted, cars can be planned as “standalone” ECP from the start, and train control can be implemented on a line-by-line basis.

The investment of ECP braking and PTC retrofits to existing heavy haul networks needing capacity expansion can be returned by:

- Reduction of track infrastructure investment
- Reduction of new rolling stock requirements
- Reduced cost for replacing life expired signal systems

There is a compelling case for planning both ECP and PTC for new heavy haul railway projects, in which the incremental costs for using new technology on a total network basis may be less than past conventional braking and wayside signal systems.

REFERENCES

