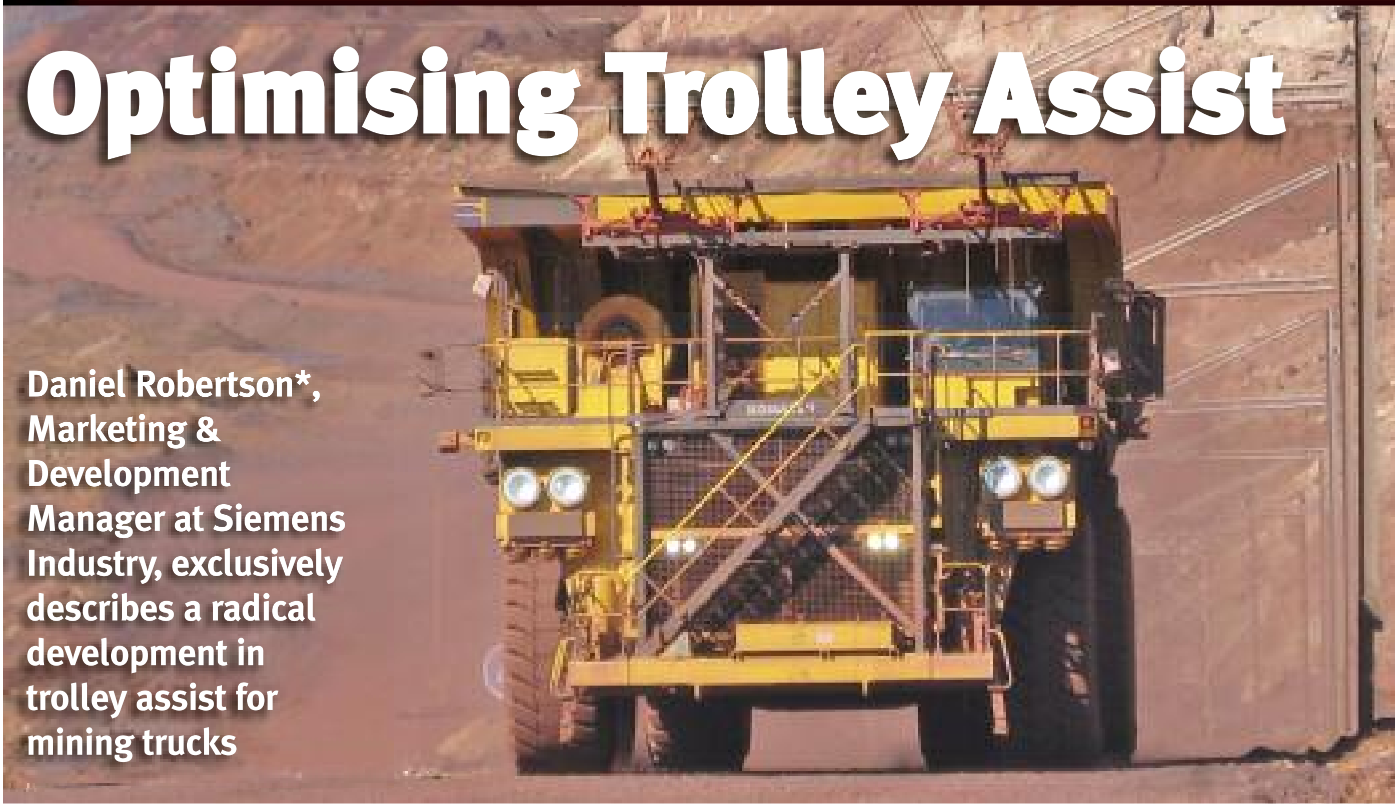
Optimising Trolley Assist



Daniel Robertson*, Marketing & Development Manager at Siemens Industry, exclusively describes a radical development in trolley assist for mining trucks

Often a ground breaking invention comes along that is not fully appreciated or utilised until another invention comes along that improves upon it, and makes it more practical to use. Consider the digital camera – this technology revolutionised the way the world takes pictures, but it was not an instant success. The first digital cameras left a lot to be desired. Pixel resolution was far inferior to traditional cameras and electronic image sensors that turned light into discrete signals were just being developed. Power consumption was very high and only a few pictures could be taken with traditional AA batteries. Memory storage was small and the first digital pictures were stored on 1.4Mb floppy disks. The overall digital camera concept was groundbreaking, but after its original development, it needed several improvements in many of the sub-systems until it was truly ready for the masses.

Another such example can be seen with the trolley assist trucking option, one of the most radical developments for mining haul trucks whereby the drive power is supplied through an overhead catenary system.

Trolley assist basics

Typically, the power required to operate these mammoth machines is generated onboard the truck itself. A diesel engine turns an alternator, whose AC output voltage is rectified to provide the steady DC link power source from which to run the variable frequency drives controlling the wheel motors. The motoring power that can be generated is limited by the capacity of the engine. However, the wheel motors are actually capable of producing much higher power, as it must be able to prevent a runaway, particularly when loaded and on a decline.

With the trolley assist option, power can be taken from the overhead lines, and the full power of the wheel motors can be utilised for motoring. This results in trolley trucks being able to propel uphill at much higher speeds, typically 150% or greater compared to what it could achieve from the diesel engine. This

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greatly reduces the overall hauling cycle time and therefore significantly increases the overall productivity of each haul truck, and ultimately, the entire mining process.

In addition, while operating from the overhead trolley lines, the diesel engine is idled. This results in a massive reduction in the fuel consumed. A typical simplified hauling cycle consists of loading, hauling, dumping, and returning. Most of the fuel consumed occurs when hauling uphill out of the pit. By removing the fuel consumption required for this part of the cycle, the overall fuel consumption is reduced to only a fraction of that of a standard diesel or diesel/electric truck.

Operational challenges

However, at a recent Voice of the Customer information exchange session, concerns were

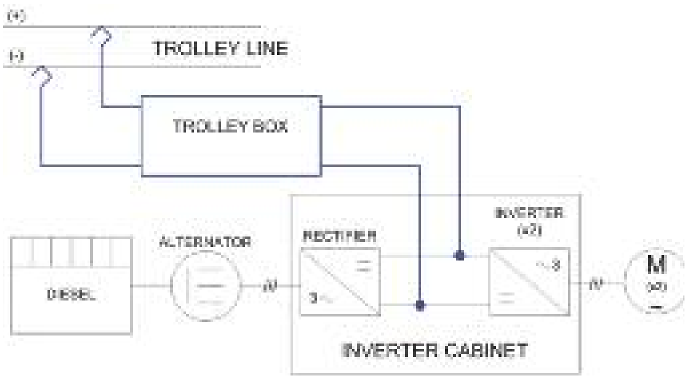

Figure 1. Diagram of typical diesel/electric haul truck with trolley assist option

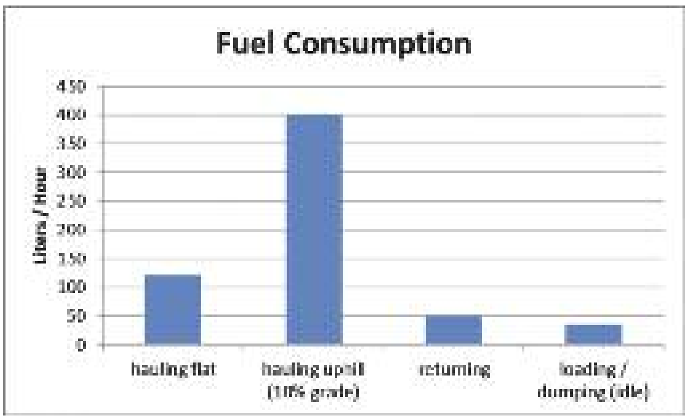

Figure 2. Typical haul truck fuel consumption during various phases of hauling cycle

Figure 3. Example drawing of one type of sensor for detection of overhead line

expressed regarding the ability to realise the full benefits of operating such a trolley truck. It was revealed that the biggest operational challenge has been with keeping the haul trucks under the trolley lines. Particular difficulty was in negotiating turns, or in cases where the trolley lines were not straight.

A train utilising overhead trolley lines has no problem with this. The rails beneath ensure that the train is always properly positioned with respect to the overhead lines. A haul truck, on the other hand, has no such rails to guide it. The operator is tasked to keep the truck on the road, maintain proper speeds at different turns or grades, avoid other traffic on the haul road, and at the same time, look up towards the sky in front of him, to ensure that the pantographs are always positioned under the overhead lines. Taking an operator's eyes off the road is a safety concern. Not ensuring that the pantographs remain engaged with the overhead lines is a productivity and maintenance concern. Obviously, given this scenario, the operators choose to err on the side of safety.

To understand the productivity and maintenance impact this has on the pantograph and overhead lines, one must consider the functionality of the trolley system itself. After positioning the truck under the overhead lines, the operator gives the command to raise the pantograph through a push button in the cab. The pantograph is then raised pneumatically to make contact with the overhead lines. The pneumatic system is designed to maintain a constant upwards pressure of the pantograph onto the overhead lines to ensure that proper contact is maintained while traversing down the haul road.

If the haul truck moves out from under the overhead lines under load, several things occur. First, a potentially destructive arc is created as the connection between the pantograph and the overhead line is lost. While under trolley, over 2,700 Amperes can be flowing through this connection. When the connection is broken, an inductive voltage is built up across the contacts which ultimately results in a destructive arc. This arc is capable of damaging the pantograph and/or the overhead lines.

Shortly after clearing the overhead lines, with no overhead force to stop the pantograph, the hydraulic force in the pantograph system will cause the pantograph to rise. At the same time, the operator will notice a sudden loss of power. A common reaction is to quickly try to correct the truck's position by steering the truck back under the overhead lines. However, since the pantograph heads have now risen above the contact wire, the pantographs get tangled in the overhead lines which could result in damage to the pantograph and/or the overhead lines. Damage to the pantograph takes the truck out of operation, at least out of trolley operation. Damage to the overhead lines takes the entire trolley fleet out of operation.

One particular mine revealed that this event occurs so frequently that the maintenance team had never replaced the carbon strip – a consumable part of the pantograph head that makes physical contact with the overhead lines. They had always damaged the pantograph head before the carbon strip could wear out.

Smart Trolley program

After carefully evaluating the situation, Siemens sought to solve the problem through the implementation of a series of operator assist features, or the "Smart Trolley" program. The immediate solution was to provide a feature to assist the operator in maintaining the truck's relative position under the trolley lines. The idea was to use a sensor, or suite of sensors, to detect the overhead line, digitize that information, and use it to provide information to the operator via a dashboard display. The operator would then be able to keep his/her eyes on the road, while augmenting his view with the relative position of the overhead lines.

While this feature would aid the operator, it would not prevent an operator from driving off the line and damaging the pantograph and/or overhead catenary system. Therefore, a second feature was integrated with the existing raise/lower control system for the pantographs. Just before contact with the overhead line is lost, the command is given to lower the pantographs. This eliminates the potential for the pantographs to become tangled with the overhead catenary system.

In order to prevent arcing at the pantograph and overhead connection, a circuit breaker is used to isolate the drive system from the overhead lines. This current interruption then occurs across the circuit breaker, which is designed for opening under load, instead of across the pantograph and overhead lines, thus eliminating damage to the pantograph or overhead lines at all.

These features are all aimed at increasing the safety for the operator, while at the same time decreasing maintenance costs. By increasing the availability of the trucks and the overhead lines, the overall productivity will also be increased.

In the near future, the relative position of the truck with respect to the overhead lines could be used as inputs to a semi-autonomous control system, thereby eliminating the possibility for inadvertent departure from the overhead lines at all. Once under the lines, the operator could transfer control to the semi-autonomous system, which would then monitor/control speed and position to ensure optimum performance.

Today, trolley trucks are commonly utilised at mines with deep pits with relatively long uphill runs. However, this may change in the near future. Driven by some of the industry giants' beliefs that the internal combustion engine must go, an all-electric haul truck could be on the horizon. Due to the immense power consumption of mining haul trucks, factored in with the available power density of existing ultra-capacitors and batteries, trolley lines will be required at strategic locations throughout these mines.

Like most radical innovations, implementation can be much more challenging in reality than in theory. It often takes improvements in related technology in order for the full benefits to be obtained. For deep mines, there is no question that haul trucks equipped with trolley assist options provide a more efficient alternative than traditional mechanical or diesel/electric haul trucks. Now, with the "Smart Trolley" program, these benefits are more easily obtainable. Integrating these technologies provides a reliable platform from which to base the all-electric haul truck. *IM*

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