Going electric
The rail industry approaches an inflection point

Rail has always been an efficient means of transport, but the industry is beginning to demand even better performance in both freight and passenger applications. Electric trains offer some distinct advantages over their diesel counterparts, but the infrastructure costs associated with electrification makes the choice less clear. However, as rail technology advances and fuel costs continue to rise, electrification may become viable for a wider range of rail systems.

Rail and petroleum

The transportation sector accounts for 28 percent of all energy use and the same percentage of all greenhouse gas emissions in the US according to the Energy Information Administration and the Environmental Protection Agency. (The figures for Canada are 31 percent and 37 percent.) In the United States, 95 percent of all energy used in transportation comes from petroleum fuels. Clearly, then, there is an opportunity to diversify the fuel mix and reap both economic and environmental benefits by going electric.

Electrified rail is already prevalent in Europe and Asia, owing in part to the particular histories of the regions in question. In North America, the development of rail transport has followed a different path that often placed it in the shadow of the automobile, at least for passenger trains. Today, there are no electric freight lines and only a handful of electric heavy rail lines for mass transit, mostly concentrated in the Boston-Washington corridor.

Where electrified rail has succeeded in North America is in metropolitan light rail systems and some commuter lines. What will drive the electrification beyond these markets? Environmental concerns—and associated regulations—will certainly play a role but in the near term it will likely be rising fuel costs that push electrification beyond its traditional strongholds.

According to EIA, crude oil is by far the largest component of diesel fuel prices, accounting for 61 percent of the total retail cost. What's more interesting is that, despite an oil renaissance in the United States, which now ranks as the world's top producer, crude oil prices have remained stubbornly high. This is due largely to the fact that oil is truly a global commodity. It is produced in many regions of the world and is traded on global exchanges. The price, then, is not significantly impacted even by the bonanza currently going on in North America.

Electricity prices are rising, too, but not at the same rate as oil. According to EIA, the price of electricity for transportation use has risen 47 percent over the past ten years. By contrast, crude prices are up 45 percent over the past five years, 150 percent over the past ten years, and 375 percent over the last 15 years.

The benchmark Cushing, Oklahoma price per barrel has averaged around $100 over the past three years (through 2013) in spite of an economy that until recently was growing at historically slow rates. EIA projects this trend to continue, with power prices rising more slowly than petroleum fuel prices. The agency also notes that electricity prices will experience less volatility than oil prices.

The case for (and against) electrification

All of this sets the stage for increasingly favorable economics for electrified rail, but how much of a difference can it make? Indeed, it presents both exciting potential and daunting challenges.

On the plus side, electric trains are extremely energy-efficient. Diesel locomotives use 2.5 to 3 times as much energy per unit of work as all-electric locomotives. Electrics can also accelerate and brake faster than diesels, allowing for an estimated 15 percent increase in the capacity of existing rail lines, according to a report from the Electric Power Research Institute. EPRI also points out that electric motors are unaffected by cold and incur much lower maintenance costs over a longer lifespan than diesels. Finally, going electric eliminates the multiple point emissions associated with diesel locomotives, an important consideration in tunnels, switchyards and locations close to population centers where emissions can be concentrated.

The main downside to electrification is infrastructure cost. Installing a catenary or third rail can be prohibitive, but there are also simple physical limitations. A catenary may not be feasible, for example, for trains with tall container cars. Still, there are some systems where it might make sense. Ontario's GO Transit, for example, conducted a large study in 2010 and found that electrifying certain lines would make sense financially over the longer term. Avoided fuel cost and reduced maintenance were the primary drivers.

Technologies that can make a difference

There are also new technologies poised to make the economics of electrified rail more appealing to the system operator. SEPTA, the Philadelphia transit operator, installed a first-of-its-kind energy storage system that allows the energy from braking trains to be captured and re-used rather than lost as heat through a resistor. The system delivers energy back to the trains as they accelerate, but it is also capable of providing on-demand power to the surrounding grid. The grid operator, PJM, pays SEPTA for providing these so-called ancillary services.

The results have been encouraging: SEPTA reports that through the first six months of regular operations, the energy storage system has generated a return of $250,000 via energy savings and new revenue.

In light rail applications, where electric drive has been the industry norm for decades, refinements in the onboard power system are making an impact not just on the efficiency of the train—typically EMUs—but also on capacity and passenger comfort. Traction transformers, for example, are specialized devices that change the voltage of the power supply coming from the catenary and traditionally they are housed in a "machine room" inside the car. Now, advances in design have drastically reduced the size and weight of these units so that they can be placed under the floor or on the roof, thus freeing up more space for passengers. Noise levels are also reduced, and the weight savings further contribute to overall efficiency.

If we broaden our perspective to include the supporting power infrastructure, there are proven technologies that can reduce the cost and construction time associated with growing rail systems. For example, if a given line is at the limits of what the power grid can provide, the system operator faces the prospect of building additional feeders to deliver power and provide stability to the system. An alternative would be to install power electronics devices known as FACTS that can deliver the same voltage support and system reliability but at a lower cost and shorter implementation time.

Clearly the environmental and economic advantages of electrification are appealing, and they are likely to become more so going forward. Electrification still carries major capital investment implications, but as we've highlighted here there are solutions to mitigate these costs. These technologies will not make electric drive viable for every rail system—long-haul freight is likely to remain the province of diesel locomotives for some time—but they could tip the balance for an increasing number of passenger and freight operators.

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