A Railroad View of Electrification

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At the outset I would like to clarify exactly what we mean by railroad electrification and to outline briefly the present status of electrification in this country. Electrification does not mean simply using electric power to drive our locomotives. In that sense, America's railroads are already electrified and have been since the diesel locomotive became the primary type of motive power some 25 years ago. The diesel locomotive is a mobile power plant using petroleum fuel to drive a diesel engine that in turn drives a generator or alternator to produce electricity. The electric power is applied directly to traction motors that propel the locomotive.

By electrification we mean the replacement of the internal-combustion engine and generator or alternator by the large-scale purchase and distribution of commercial electric power. Railroad electrification in its simplest form would consist of a power-transmission system along the railroad right-of-way, most likely consisting of an overhead catenary line from which trolley pickups on the locomotive would draw power for the traction motors. It would also require power substations between the generating plant and the catenary system at intervals ranging from 30 to 80 km (20 to 50 miles). Finally, a complete new fleet of electric locomotives would be needed.

Because of the high capital costs of catenary, substations, electric locomotives, and some additional costs that will be discussed later, only the most heavily used railroad lines can even be considered for electrification. The figure that has usually been advanced as a minimum for justifying electrification is 36 gross Tg (40 million gross tons) annually.

On the Southern Railway System, for example, only about 4.5 percent of our track, representing about 18 percent of our total operation in terms of load and motive power, has a traffic density of this level and has ever been considered for electrification. This is Southern's main line from Cincinnati through Chattanooga to Atlanta, a distance of some 775 road km (485 road miles) or 1160 track km (725 track miles). In terms of capital cost, we are talking about $75 000 to $90 000/km ($120 000 to $140 000/mile) and, including locomotives, a total cost of $150 million.

Electrification in this country dates back to 1895, when a 6-km (4-mile) section was installed on the Baltimore and Ohio Railroad Company's line at Baltimore. The system continued to grow into the 1930s, when the Pennsylvania Railroad put into operation its 11-kV 25-Hz system. At its peak, electrification in this country covered fewer than 3200 km (2000 miles), and a portion of this trackage is not in use today. More recent electrification projects, if we exclude rapid-transit systems, consist of a 24-km (15-mile) coal-hauling railroad at Zanesville, Ohio, and the 125-km (78-mile) Black Mesa and Lake Powell Railroad installation at Page, Arizona. U.S. railroads are less than 1 percent electrified, in contrast to other major industrial countries—the Soviet Union is 25 percent electrified, France 25 percent, West Germany 30 percent, Japan 40 percent. Some of the smaller countries are totally electrified, such as Switzerland, which has some 14 500 route km (9000 route miles). Italy, Sweden, Norway, and the Netherlands are 50 to 70 percent electrified.

With the rest of the industrialized nations largely electrified and moving even more rapidly in that direction, why has electrification not made more progress in this country? In a nutshell, from the railroad standpoint, any decision to electrify trackage will depend on economic considerations. While I cannot say it positively, I do strongly believe that economic considerations in other countries took a back seat to what could be called the national interest.

ADVANTAGES AND DISADVANTAGES OF ELECTRIFICATION

One uncertainty in considering electrification is the changing pattern of advantages and disadvantages of electric versus diesel-electric locomotives. Another is the state of the art in the developing technology of electric locomotives and power-transmission systems. Two other considerations are the unpredictability of the cost of electric power and the competition of other necessary improvement projects for the capital investment dollars we have available.

A number of railroads in recent years have shown interest in electrification, but to keep things simple I will concentrate specifically on Southern's proposed electrification project. We have been studying the electrification of our Cincinnati-to-Atlanta line for many years, but this study took on added importance at the time the energy crisis produced a rapid escalation of diesel fuel costs. During this most recent period of study, we have made adjustment for the changing costs of electricity and petroleum fuel, the comparative costs of locomotives, traffic projections, and probable maintenance costs. We have not reached a decision, but we know a lot more about how electrification will affect us. I believe much of what we have learned will apply to railroads generally.

The most obvious advantage in electrification is the potential for lower fuel costs. On the surface it would seem more economic to generate power at a central location than in mobile power plants like the diesel locomotive. Far more flexibility would exist in the choice and use of fuel. Coal, nuclear power, and perhaps solar energy are all potentially usable in the centralized generation of power. Diesel-electric locomotives are limited to petroleum fuel, which suffers from uncertain supply and therefore is subject to rapidly escalating costs. Large-scale use of atomic energy or the development of solar energy for power generation are truly considerations for the future. Greater dependence on coal is a very real possibility, since we have substantial coal reserves and the technology exists to use them.

Conserving our petroleum supplies is not really a consideration. Electrification of the high-density rail lines in the United States would enable the country to save some petroleum but not very much. The entire railroad industry consumes approximately 3 percent of the total energy used for transportation—or less than 2 percent of total energy consumption. Much of this would still be used, since only a portion of the railroads are even being considered for electrification. A lot more petroleum could be saved if the utility companies would convert to coal.

About 4 years ago the price of diesel fuel began to escalate while the cost of electric power remained relatively stable. In the last 2 years that situation has been reversed and the costs of electric power have escalated at a more rapid rate than have the costs of diesel fuel. There is still some fuel-cost advantage in electrification, and I expect this to continue, but I am not sufficiently confident that I would care to invest $150 million. My confidence will be diminished still further if we begin to see power costs for industrial users raised in order to make rate increases more palatable to individual or residential users of electricity. I have heard this possibility mentioned by executives from the utility field and also by industrial users.

Another significant advantage is the fact the electric locomotive has a higher rate of utilization and longer service life than the diesel-electric power plants we now have. Instead of the diesel locomotive's internal-combustion power plant with more than 3000 wearing parts, the electric locomotive has step-down transformers and now solid-state control systems. These components are needed to reduce the high-voltage alternating current from the catenary to 600-V direct current for the traction motor. The major component parts of electric locomotives are smaller and lighter than those of our present diesel-electric power plants.

The solid-state power and control package, which consists of thyristors and silicone diodes, is a relatively recent development. This solid-state control system makes possible improved wheel-slip controls and should provide the electric locomotive with considerably greater adhesion at the rails than the diesel locomotive has. Comparisons must, however, take into consideration the research now under way by the diesel locomotive manufacturers to provide diesel locomotives with improved adhesion by using similar solid-state control hardware.

Another factor in the generally superior performance of electric locomotives compared with diesels of the same weight is their ability to deliver short bursts of very high power. This is possible because the electric locomotive draws on a virtually unlimited power supply from the catenary transmission line, while the diesel locomotive is limited to the power output of its self-contained generating plant.

All this adds up to the generally accepted estimate that two electric locomotives will do the work of three diesels. But this advantage is largely offset by the fact that two electric locomotives cost about as much as three diesels. The initial cost thus shows no advantage to either. Elimination of the internal-combustion power plant does tend to reduce locomotive maintenance costs and also to increase availability. It might also extend the service life of the locomotive. In our evaluation we assumed a two-thirds reduction in maintenance costs for electric locomotives and a 30-year life, whereas the normally accepted life of a diesel locomotive (excluding switch-engine power) is 15 to 20 years. These assumptions were based on available literature and the recommendation of locomotive suppliers.

TECHNOLOGICAL CONSIDERATIONS

Another thing to be considered is that the 15 to 20-year service life of the diesel locomotive is partly the result of technological obsolescence. There is no question about our ability to continue to operate the locomotive for 30 years without any extraordinary additional expense, with the possible exception of rewiring and some car-body repairs. If we purchased a sizable fleet of electric locomotives that have a life expectancy of 30 years, we might lose some flexibility in adopting improved locomotives, at least without additional major expenditures.

Another item to be considered is the quality of the design of the present electric locomotive being offered. Only recently have electric locomotives been placed in service that might be considered to include the latest in technology, and these are in service in very small numbers. Improving the existing electric locomotive will take more development money from locomotive manufacturers or the federal government or both. At the present time there is not enough interest from the railroads in electrification to stimulate additional development expenditures.

It is also pertinent that, while we may be reducing locomotive maintenance with electrification, we are getting into another area of maintenance for which we have no experience—maintenance of the catenary. We can estimate what it will cost to maintain the power-transmission system, but we cannot be sure our figures are correct.

We can anticipate other difficulties as a result of running power lines over the rails. The power-transmission system is subject to damage in case of derailment. High-voltage power lines might set up stray currents in the track that could affect our signaling system. In fact, the estimated cost of redesigning the signal system that we used was not very far below the estimated cost of installing the catenary. In addition, high-voltage power lines may interfere with train radio transmissions and might also cause some interference with communication systems in communities in which the track runs right through the center of town.

The lack of flexibility in the use of electric locomotives gives some cause for concern. The track from Cincinnati to Atlanta has a main line to St. Louis and another to Knoxville. These lines will have to be operated with diesel power, which will probably result in some loss of diesel utilization both at Danville and at Harriman Junction. We can also expect some problems and perhaps a drop in locomotive utilization on a number of run-through trains for which motive power belonging to Southern and motive power from other railroads operate interchangeably.

All these problems I am mentioning I believe are solvable. Some of them require intense in-house planning and study; for others we do not have sufficient information to make a decision. In reviewing electrification studies by other railroads, I find that very different numbers are being used in calculating the return on investment. But I do not believe any of us know whether the figures we are using are correct. The problem is that nowhere in the United States is there a high-speed heavy-load electrification system like that we were considering between Cincinnati and Atlanta. The most recent project, the 125-km (78-mile) Black Mesa and Lake Powell Railroad, operates one train, does not have a signal system, and does not traverse heavily populated areas. Like any other business decision, the decision to electrify is based on a number of factors; the most important is the return on investment.

There is, in our judgment, no service or reliability advantage to be gained with electrification. We can run the Cincinnati-to-Atlanta line with diesel locomotives as well as we can with electric locomotives. Therefore we are looking for the return on a $150 million capital investment. There are a lot of other necessary and desirable improvement projects to our railroad that are actively competing for this money—new classification yards, additional centralized traffic control, double-tracking projects; all of these have service as well as cost advantages.

Several years ago, when diesel fuel prices began

climbing and the cost of electric power was stable, the rate of return looked very attractive. Now that the cost of electricity appears to have caught up with petroleum prices, it is not as attractive as it once was. And, until we find out about the many unknowns mentioned above, we do not know how attractive the rate of return would be in the future.

SUMMARY

Let us review some of the advantages, disadvantages, and uncertainties that we are concerned with when we consider electrification. There are a number of advantages.

1. Electrification would reduce the dependence of transportation on petroleum. Assuming about 10 percent of the nation's railroads were electrified, savings could be in excess of 7 billion L (2 billion gal) of diesel fuel a year.
2. Electrified lines would have lower fuel costs. However, there are enough uncertainties in the area of future costs that the tendency in making electrification studies is to use a conservative approach, i.e., to project escalation of electric power rates at approximately the same rate as petroleum fuel costs. This conservative approach reduces the estimated return on investment to a marginal level. The calculation of return on investment is more sensitive to fluctuation in electric power rates and diesel fuel costs than any other single item.
3. The railroads would reduce their air pollution problem, returning it to the power plant, where control can be more readily accomplished.
4. The maintenance cost for electric locomotives is two-thirds that for diesels.
5. Electric locomotives have higher adhesion and the ability to furnish short bursts of additional power for climbing grades.
6. Fewer electric locomotives are required, since they have higher availability and less maintenance.
7. There is a decreased need for an inventory of material, including petroleum fuel, lubricating oil, and replacement parts for the internal-combustion engine.

The disadvantages are primarily the high capital cost, low estimated return on investment, and the fact that there are pressing needs for the money elsewhere. There are other disadvantages among the many uncertainties that still exist, specifically:

1. We are not sure the electric locomotive has been developed as thoroughly as it can be.
2. We do not know what it will cost to deal with the problem of signals and communications because we really do not know what kinds of problems a 25 or 50-kV system will create.
3. We do not know where the money for electrification is coming from. Some railroads may be able to afford the substantial investment, assuming that the return on investment were attractive, but for marginally profitable railroads federal assistance, in the form of tax incentives or some other kind of assistance, will probably be required.
4. We do not have any confidence in our ability to predict the cost of electric power over the next few years, much less over the 30-year expected life of an electrified system. Without some reassurance on this point we will not see electrification to any degree in the immediate future without government sponsorship.

I personally believe that electrification of heavy-density rail lines in this country will come, but I do not know when. Many of the uncertainties mentioned above might be clarified as a result of the Railroad Revitalization and Regulatory Reform Act. Specifically, the Secretary of Transportation guaranteed obligations of the Consolidated Rail Corporation up to $200 million for the purpose of electrifying high-density main-line routes. Certainly an expenditure of this magnitude and the upgrading of existing electrified rail lines should produce answers to some of our questions. The sooner we deal with the issues and uncertainty that exist, the sooner we can move forward.

An Economic View of Railroad Electrification

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There are many proponents of railroad electrification and very few vocal opponents. Arguments based on economics and energy policy have been marshalled in favor of substantial investment in electrification. But despite these arguments, no major investment in electrifying rail freight lines has occurred in recent years. It is my position that, even if the major arguments advanced in favor of electrification are correct, many issues need to be resolved before substantial public or private investment in electrification is made. I will here assume that the conclusions reached by general studies are valid and suggest other considerations that have prevented electrification and are likely to continue to do so.

To briefly state the issue, there are two competing motive-power technologies—the diesel electric and the electric. U.S. railroads overwhelmingly use diesel-electric power. Proponents of conversion to full electrification contend that, for certain high-density lines, electrified systems are superior economically and operationally. The findings of several studies (1, 2, 3, 4) are summarized below.