

Implementation of a Pioneering Light Rail System in Bordeaux – Looking Forward

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ABSTRACT

Implementation of LRT in historic well-consolidated downtown areas can introduce an extraneous element which conflicts with its surroundings. One of the most innovative approaches to the integration of LRT within the surrounding environment was recently implemented in a new LRT system in Bordeaux, France. Use of a ground level power supply system, rather than the traditional overhead contact system (OCS), allows the critical integration of modern transport in a centuries old town. This paper provides a historical summary of ground electrification for streetcar systems, presents the state of the art LRT system recently opened for service in Bordeaux, discusses the advantages and issues encountered in implementation of such a system based on the author's site visits and technical discussions, and provides a look into its future.

INTRODUCTION

A key strength of light rail transit (LRT) is its ability to integrate well into an urban environment sharing the public right-of-way with motorists, bicyclists and pedestrians. It is this characteristic that makes LRT successful in those urban corridors which require a high-capacity mode of transportation that can operate well in both an exclusive and a shared right-of-way. Downtown urban areas are high transit demand locations where LRT service is typically implemented. On the other hand, implementation of LRT in historic well-consolidated downtown areas may introduce an extraneous element that conflicts with the surroundings.

Conflicts may arise due to the implementation of a new system that did not exist previously, because of the scale and size of the light rail vehicles (LRVs) to be used (large vehicles with non-historical elements), or because of the visual intrusion caused by the physical elements required (poles, mast arms, signal heads, overhead electrical wires, etc.). Transit agencies and municipalities have addressed these issues in different ways: by designing the LRT system to follow existing bus or discontinued streetcar alignments, by selecting LRVs that are historic or historical replicas and by installing LRT control and power systems that fit well within the surrounding character and that can be consolidated with already existing street elements, e.g. light poles or traffic signal masts.

One of the most innovative approaches to integration of LRT within its surrounding environment was recently implemented in a new system – the provision of ground level power supply system rather than the traditional overhead contact system (OCS). This paper provides a historical summary of ground electrification for streetcar systems, presents the state of the art LRT system recently opened for service in Bordeaux (France), discusses the advantages and issues encountered by implementation of such system, and provides a look into its future.

BACKGROUND

The concept of providing electrical power from ground level is not new. In addition to third rail above ground power collection systems which are not suitable for use within street environments, two different underground electrical power systems (600 volts DC) were implemented in the late 1800s. One was the *conduit system* (London, Washington DC, Paris, New York) (Figures 1 and 2) (1) where streetcars used *ploughs* to reach the electric conductors through a slot approximately 3 centimeters wide located between the two running rails.



Figure 1
Capital Traction Company electric streetcar, 1898 –
Currently at the National Museum of American History,
Washington DC



Figure 2
Example of 1890s Ground Level Conduit System
Technology – Washington DC

The other electrical power variant was the *stud system* (Paris, 1898). The studs were located along the center line between the two running rails, approximately 5 mm below the road surface and at 2.5-meter intervals. For safety reasons these studs were designed to be energized only when a skate, located under a streetcar, passed over them. Unfortunately however the studs sometimes remained live after the streetcar had passed, with unpleasant results for pedestrians and other road users, such as dogs and horses.

Although these underground power systems worked well, they were expensive to install and their maintenance frequently required detailed work and trenching. In addition, special underground work was required for the installation of track crossings and switches. It was also operationally easier to reattach a trolley pole to the overhead electrical wire than an underground plough or stud to the underground system. Furthermore, these systems were also blamed for creating problems with stray electric currents interfering with the subterranean utilities, especially in rainy weather when water entered the conduit.

Due to their construction, maintenance, operational and safety issues, underground power systems were gradually discontinued and replaced by overhead catenary systems. Parisians saw the closure of their last remaining underground power system in 1937, London in 1952 and Washington DC in 1962. (1, 2)

THE RETURN OF GROUND LEVEL POWER SUPPLY

Since the mid- to late- 1990s there have been trials of three competing center rail ground level power LRT systems suitable for street use, Ansaldo Breda (Italy), Spie Enertrans (France) and Alstom (France). All three systems work on the principle that conductors will be only energized when the LRV is located over it. The Ansaldo Breda system was developed first (1994), based on magnetism and tested in Trieste. Power is provided to the LRV by a flexible power plate resting at the bottom of an electrically isolated conduit. A large magnet located in the undercarriage pulls the band upwards, creating physical contact and providing power. After the LRV moves forward, the band returns to the bottom of the conduit under its own weight.

Both French systems, Spie Enertrans (Innorail) and Alstom (Aliss) are based on a similar, but slightly different, principle than that of Ansaldo Breda. In both systems the center power rail is fixed, embedded in the pavement and is composed of separate electrically isolated segments, which are shorter than the total LRV length (Figure 3). The Innorail power rail segment is 11 meters long with 8 meters of conductor rail and 3 meters of insulating rail. The LRV is then equipped with two pickup shoes approximately 3 meters apart so that at least one of them is located over an energized power rail segment. Under the Aliss system, the insulating rail section is only a few centimeters long so that LRVs require only one pick up shoe, which can bridge over two separate conductor rail sections at the same time.

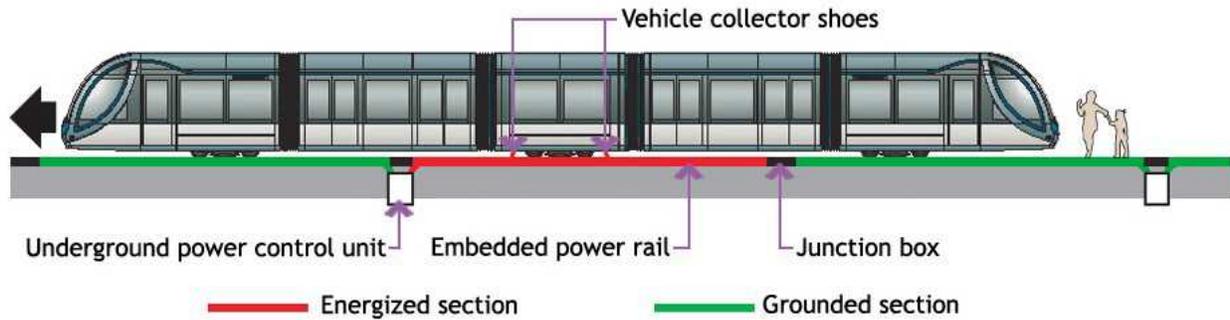


Figure 3
Light Rail Ground Level Power Supply System

The LRV detection principle is also different for each system. Innorail incorporates an induction loop that signals the presence of a vehicle. As the vehicle advances, its transponder provides a coded signal which is used to sequentially energize the power rail segment located immediately below the LRV. In contrast, each Aliss power rail segment is equipped with its own detection system that detects the LRV presence and provides and energizes the rail. The Innorail system was first laboratory tested at Vitrolles (Bouches-du-Rhône, France) in early 1999. A full scale test of the Innorail system took place on a 500-meter long section in an exclusive right-of-way segment of line 68 of the Marseille LRT system between December 1999 and May 2001 using a modified PCC-type streetcar (Figure 4). In the meantime, the Aliss system initiated testing in early 2000 at Alstom’s site at Aytré (Charente-Maritime, France). Subsequent to initial testing, Alstom acquired Spie Enertrans’ technology and now promotes the Innorail system for commercial applications using its Citadis low floor vehicle operating at 750 volts DC.

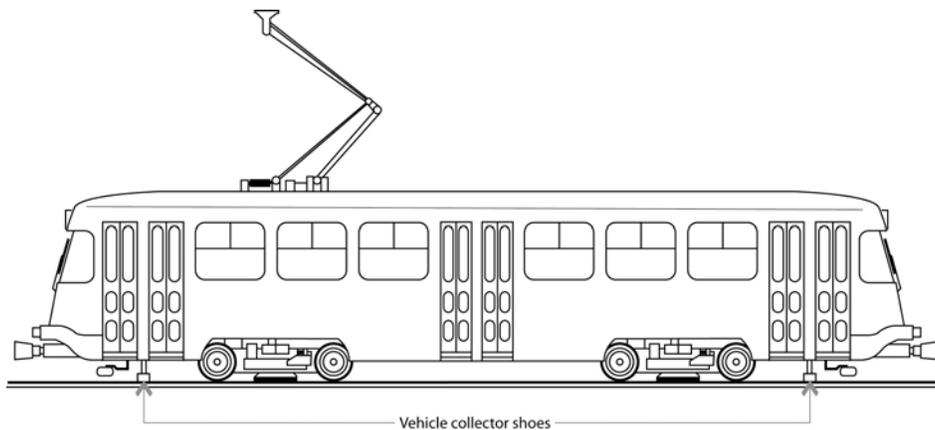


Figure 4
Modified PCC streetcar equipped with two pickup shoes for center rail ground power system and a pantograph – Line 68 Marseille, 1999

THE BORDEAUX LRT SYSTEM

The original electrical streetcar network within the city of Bordeaux opened in 1900 and provided service until 1958; it was equipped from its inception with an underground conduit power supply system in the downtown area in order to prevent that “overhead wires and other unsightly elements do not prevent contemplating the beautiful stonework” (3). Thus, when the reintroduction of rail transit in Bordeaux was first proposed the concept of wireless LRVs was quickly embraced by the Bordeaux residents without a doubt as a way to preserve the historic city center from the visual intrusion of a modern LRT system. The Bordeaux transit agency selected Innorail as the most appropriate ground power system, based on the results of the testing conducted by Spie Enertrans and Alstom.

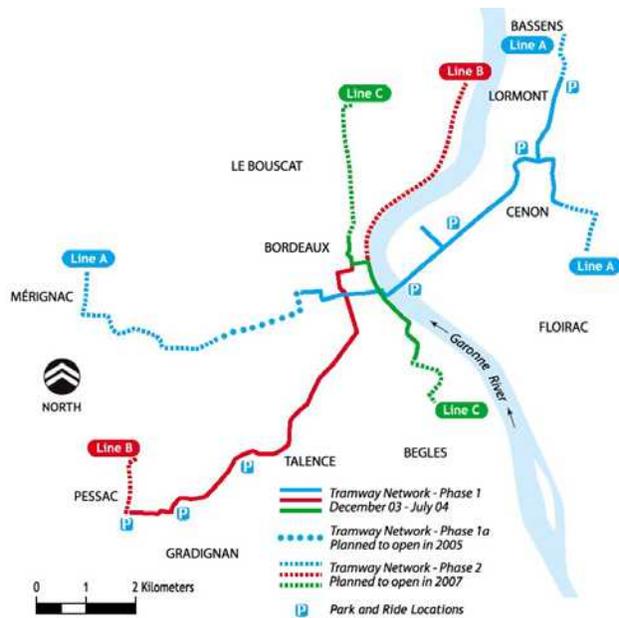


Figure 5
Bordeaux LRT System

The Bordeaux LRT system consists of three major phases (Figure 5) (4). Phase 1 includes three lines, 47 stops and 22.5 km of track, of which 9 km in the downtown area are equipped with ground level power supply. Line A operates from Mériadeck to Cenon and Lormont, Line B from Quincoces Square to the University campus, and Line C from Quincoces Square to the St. Jean railroad station. Construction started in February 2000, and 46 months later, in December 21, 2003, Line A was opened for service with 350,000 residents plus the president of the French Republic, Jacques Chirac, and the mayor of Bordeaux, Alain Juppé, in attendance. Line C was opened for service in April 25, 2004 and Line B opened in July 4, 2004.

Phase 1a is under construction and planned for opening in spring 2005. It is a 2.5-km extension of Line A to the Bordeaux’s regional medical center with six stops and it is also equipped with ground level power supply. Phase 2 is currently planned for opening in 2007 and includes extensions of all three lines, adding 31 stops and 19 km of track, of which up to 5 km in the downtowns of Mérignac (Line A) and Pessac (Line B) could be equipped with ground level power supply.

The ground level power supply system in Bordeaux is made of 11-meter long rail sections with 8 meters of conductor and 3 meters of electrical insulation each, operating at 750 volt DC. The rail is installed flushed with the roadway surface resolving most of the construction, maintenance and operational issues of last century’s technology (Figures 6 and 7). There is one modular power control unit located every 22 meters controlling two power rail segments and one insulating control box also located every 22 meters to mechanically and electrically join the ends of the power rails. About 970 power control units have been installed during Phase 1 at an approximate cost of 2,500 € per unit (5).



Figure 6
Bordeaux Ground Level Power Supply Rail

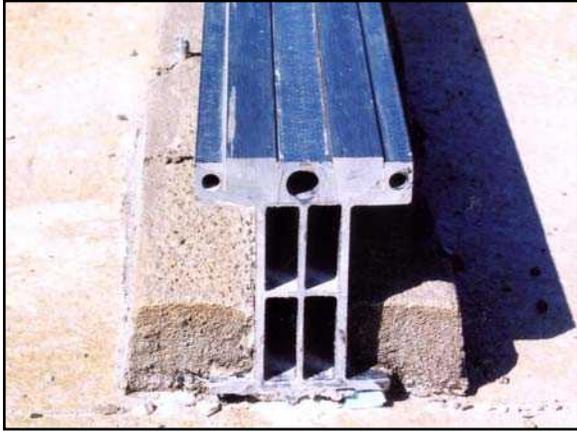


Figure 7
Bordeaux Ground Level Power Supply Rail

Service is provided by low-floor 33-meter and 44-meter long Alstom Citadis LRVs operating at four-minute headways during the peak, 10-minute headways in the early morning and late evening, and 8-minute headways the rest of the day. In early April 2004, four months after its first opening, Line A carried an average of 30,000 passengers per day, 40 percent more ridership than the bus service it has replaced, at a commercial speed of 18 km/h (6). Transition from the ground level power supply in the downtown area to the overhead catenary system in the remainder of the network and vice versa is initiated by the operator while the LRV is stopped at the station boarding and alighting passengers.

IMPLEMENTATION OF A PIONEERING SYSTEM

The birth of a new LRT system or line always brings unexpected early implementation problems. These problems are magnified when pioneering technologies are an integral part of the system, such as in the case of the new Bordeaux LRT. Service malfunctions started shortly following the inaugural service trip on December 21, 2003. LRVs operating in the historic downtown where ground level electrification had been installed experienced sudden loss of power and stopped, halting the entire system.



Figure 8
Power Control Boxes, Bordeaux LRT System

The recurrent problem was traced back to higher than expected sensitivity and software design components of the power control units. Further problems arose in January 2004 due to waterproofing issues in the control units caused by the frequent rain. These implementation problems recommended the postponement of the planned opening of Lines B and C, originally planned for February 2004. The contractor quickly initiated the replacement of the defective power control units, which were somewhat easily swapped as they are modular (Figure 8).

Minor interruptions of service of less than 30 minutes took place during the month of February, but major power system failures occurred again in March when the entire service was suspended for two days. Further improvements were incorporated into the power control boxes and some sections of the underground power cable were replaced with a new type of cable resistant to corrosion and capable of underwater duty.

Only minor disruptions of service occurred in April through early May. However, during the second half of May service was again severely disrupted due to failures unrelated to the underground power system. Some electrical substations overheated during rising temperatures and automatically disconnected from the power network as a safety measure. This caused a snowball effect triggering further disconnections and ultimately rendering most of the system powerless. The higher temperatures also affected the on board climate control units and the variable arrival and destination signage. The LRT system returned to normalcy in early June and the final component of Phase 1, Line B, opened to the public at the beginning of July. In August, the three lines reported a combined reliability level of 95 percent. (7)

The actual cost of the underground power supply system of the Bordeaux LRT has been the subject of major debate, and is not yet completely understood. Cost comparisons are difficult because of diverse information sources, lack of specificity of components included in or omitted from the estimates, and the year when the cost estimate was actually made. In general terms, it can be said that the cost estimates made at the early planning stages was 0.94 million € per km, compared to 0.5 million € per km for a standard OCS. More recent estimates developed in 1999 assuming an eight-kilometer underground power supply segment increased to 1.2 million € per km. The estimated cost in 2001 for the 10.5-km segment ultimately built in downtown Bordeaux as part of Phase 1 and 1a was raised to 1.45 million € per km. Finally, the cost for the segments of the currently planned extensions of Lines A and B (Phase 2) to be equipped with underground power supply are between 1.7 and 2.9 million € per km, depending on the actual length of track to be ultimately built. (8)

LESSONS LEARNED – LOOKING FORWARD

The implementation of a pioneering LRT system in Bordeaux that makes extensive application of an innovative underground power system has not occurred without birthing problems. The first transition from controlled laboratory and testing conditions to full scale commercial application has brought to light certain defects of the Innorail ground level power supply system, mostly affecting the design and installation of the modular power control units. These problems have already been addressed by the manufacturer who has subsequently replaced the original units with upgraded models. At the same time, some sections of the underground power cable have also been replaced with a more corrosion resistant and better waterproof type. The major early implementation problems and subsequent service disruptions seem now to have been left behind. In addition, there had not been any accidents since the LRT system opened associated with the ground level power supply system.

In spite of the early implementation issues which caused substantial service unreliability during the first eight months since its initial opening, the Bordeaux residents have embraced their new LRT system and are proud of its pioneering features (Figures 9, 10 and 11). Responses by citizens interviewed by the city planning agency (La Cub) included expressions such as urban rebirth, visual unobtrusiveness, open green space and feeling of a grand boulevard (9). Similar sentiments will no doubt extend to other European and North American cities currently planning new or expanded LRT systems.



Figure 9
Ground powered LRV in front of the Saint André
Cathedral – Bordeaux



Figure 10
Ground powered LRV at Rue Vital-Carles – Bordeaux



*Figure 11
Ground powered LRV crossing the Pont de Pierre – Bordeaux*

The cost of the underground power supply system of the Bordeaux LRT is still unclear and comparisons with standard OCS varies from about two to four times the amount, depending on the length of track to be constructed. On the other hand, it is expected that as this innovative technology becomes better understood and its use more widespread the actual costs should diminish, although not reach levels comparable to standard OCS but sufficiently to be considered for potential applications in downtown or otherwise visually sensitive areas.

Finally, it will be interesting to explore the feasibility and cost implications of retrofitting existing LRT systems and/or LRVs from operating under standard OCS to underground power supply for very specific applications. One case in point being the potential extension of a historic streetcar line in San Francisco (California) through waterfront open space, as well as registered historic and National Park areas. Installation of Bordeaux's power supply system to the U.S. seems possible, but would require adequate resolution of some key issues such as safety certification by U.S. agencies, only one supplier of proprietary technology and foreign manufacturing.

ACKNOWLEDGEMENTS

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