Look—no wires!

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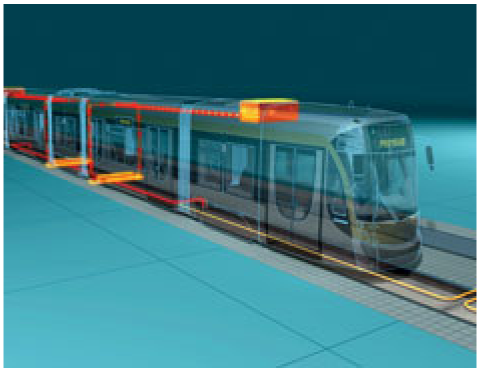

For well over a century, catenary has been a familiar fixture in cities with light rail. But an abundance of innovative catenary-free systems is emerging that could enhance the visual impact of LRT. U.S. transit planners are closely monitoring the trend.

The positioning of catenary masts and wires can sometimes be a contentious issue in cities building light rail lines, and threading power lines through environmentally sensitive areas is often a source of intense public debate. Furthermore, power systems represent a significant proportion of the capital and maintenance costs of LRT.

The search for a viable alternative to overhead catenary dates back almost as far as the introduction of electric trams in the 19th century. The Diatto ground power supply system used studs set into the road surface, which only become live when actuated by an electromagnet mounted underneath the tram. The stud contact system was first used in 1899 in the French city of Tours, but mercury leaked from the studs, making the system unreliable, and it was abandoned in favor of overhead catenary in 1911. Diatto was also used in Paris, but it too was removed in 1913.

Fittingly, French cities have also been at the forefront of ground-level power supply technology in the 21st century. In 2003, Bordeaux became the first city to operate LRVs using Alstom's APS system, which has obviated the need for catenary on 8.4 miles of the city's 27.3-mile network. APS uses a 750 volt d.c. conductor rail embedded in the road surface, and the power supply is activated by a coded signal from the LRV as it passes overhead, meaning there is no danger of pedestrians being electrocuted. A cast iron collector shoe on the vehicle collects the power, while a block of roof-mounted batteries allows the vehicle to maintain power at stations or if a power control unit fails.

Despite some initial teething troubles, APS has operated successfully in Bordeaux, and Alstom says the system has operated at 99% reliability since the end of 2005. Earlier this year, Bordeaux celebrated nearly four million miles of APS operation. Three other French cities, Angers, Reims, and Orléans, decided in 2006 to install APS sections on their new light rail networks, and Alstom won its first contract for the system outside Europe last year when it was selected for Dubai's Al

Safooh Tramway.

Another company now offering ground power supply technology for light rail applications is Ansaldo STS, which recently revealed its Tramwave system. Like APS, Tramwave uses a box embedded in the road surface containing a contact line that is only activated when an LRV passes overhead. A series of contact plates are fitted along the upper surface of the box at 50-centimeter (19.7-inch) intervals, which feed power from a cable inside the box to the collector shoe fitted inside the vehicle bogie. The shoe is surrounded by an grounded safety ring, which operates whenever the LRV is drawing current from the modular boxes. The boxes also include a path for return currents, meaning the running rails do not need to be used for this purpose. Ansaldo STS says this means Tramwave cancels the effects of stray currents, offering significant maintenance savings.

Tramwave also allows the equipment of an onboard energy management system, which optimizes the performance of power collected from the contact rail with energy from the regenerative braking system. The system is designed for new vehicles, although it can also be retrofitted to AnsaldoBreda Sirio LRVs, nearly 300 of which are already in service in eight cities including Milan, Athens, and Gothenburg.

Bombardier's answer to catenary-free operation is also based on ground power supply, but draws its energy through induction using the same principles of power transfer used in an electric toothbrush. Primove LRVs take their power from a cable buried between the running rails, which forms a primary circuit. This produces a magnetic field that is converted back to electrical energy by a pickup coil mounted underneath the vehicle, and fed to the traction motors. The cable is only energized as the vehicle passes overhead, and can be laid under any surface, including tarmac, concrete, and grass. This means the ground power supply elements are not visible on the surface, and because there is no direct contact between the components, wear is minimized.

Another benefit of Primove is that it can be connected to Bombardier's Mitrac energy saver, which has undergone extensive testing in the German city of Mannheim. Mitrac stores electrical energy generated during operation and braking using double-layer capacitors, which can then be reused by the LRV's onboard systems. Bombardier says this can reduce energy consumption by up to 30%.

Primove is currently being tested at Bombardier's Bautzen facility in Germany, using a specially-equipped Flexity LRV. The system is designed to provide a continuous output of 250kW, allowing a 99-foot-long LRV to climb a 6% gradient at 25 mph, although output can vary from 100-500kW according to the operator's specific requirements. Bombardier expects Primove to be commercially available by next year.

A disadvantage of ground power supply is that, like overhead electrification, it involves the installation of fixed infrastructure. The rapid development of Nickel-metal hydride (NiMH) batteries in recent years has allowed several LRV manufacturers to offer an alternative to both overhead catenary and ground power supply.

In November 2007, Nice became the first city in France to use battery-powered Alstom Citadis LRVs. Each vehicle is equipped with roof-mounted NiMH batteries, which are charged from the catenary and allow the LRVs to run through two historic squares where catenary has not been installed. The batteries provide a maximum power output of 200kW, which allows the LRV to operate at up to 20 mph, albeit with a lower rate of acceleration than overhead power provides.

Siemens only began work on its Sistras HES hybrid energy storage system in September 2007, but it has already completed a successful six-month trial of the system, which has been used in passenger service on Lisbon's Metro South (MTS) light rail network since last November. Sistras HES combines a double-layer capacitor (DLC) with a NiMH traction battery, allowing the LRV to store both braking energy and power drawn from the catenary. The roof-mounted modules have been installed in spare roof space on an MTS Siemens Combino Plus LRV, and are electrically connected to the vehicle's power by means of a step-up/step-down chopper.

This simple "independent" connection concept means Sistras HES can be easily retrofitted to older vehicles, including those of other manufacturers. On new Siemens vehicles, the chopper is integrated into the traction converter. Both integrated and independent systems have been approved by Tüv Süd in accordance with the German construction and operating code for tramways (BOStrab).

Sistras HES can complete its charging cycle in just 20 seconds, taking power from the catenary or a charging point while the LRV is standing in a station. This provides sufficient power for the vehicle to run independently for up to 1.5 miles, depending on the operating conditions.

In Lisbon, the test vehicle operated without overhead power supply on a 2.6% gradient with auxiliary power of 5kW and a maximum speed of 20 mph. This vehicle has operated 12,400 miles in revenue service since November 2008 with almost 100% reliability, achieving an energy savings of 10.8% compared with the standard Combino Plus LRVs in the MTS fleet. Siemens says the system can reduce CO2 emissions by up to 80 metric tons per year.

An advantage of Sistras HES is that two systems can be used in parallel in a single LRV to further enhance the energy saving capabilities of the vehicle. Michael Meinert, head of research and development for Siemens Industry, says the energy saving potential of the DLC will increase rapidly in the future as the technology matures and the storage capacity of batteries increases.

Indeed, Siemens hopes to eventually offer a system that completely eliminates the need for overhead catenary.

CAF, Spain, has been developing its rapid charge accumulator (ACR) catenary-free system in conjunction with subsidiary Trainelec and Aragon Technical Institute. ACR is an onboard energy storage system based on ultracapacitors, and CAF claims the system is capable of recovering all excess energy generated by braking.

An ACR-equipped LRV sets off from a station with the system fully charged, supplying power to the traction motors and auxiliary systems. When the brakes are applied, the kinetic energy generated is fully recovered by the roof-mounted ACR module. This is supplemented at the next stop by power from the overhead catenary, and the module can be fully charged in 20 seconds.

ACR has been tested on a CAF Urbos-2 LRV for Seville, and will be available pre-installed on its next-generation LRV, the Urbos-3. CAF says the system can also be retrofitted to older vehicles.

Kawasaki has been testing its Swimo catenary-free LRV in the Japanese city of Sapporo. Swimo uses Kawasaki Gigacell NiMH batteries, which can be fully charged in five minutes through the 600 volt d.c. overhead catenary. This allows Swimo to operate for up to six miles on non-electrified lines under standard Japanese operating conditions, although Kawasaki has run the LRV for 23 miles during tests without recharging the battery. Swimo can also store energy from regenerative braking and use it for traction.

The rapid emergence of catenary-free power reflects both the advance of the enabling technologies and the determination of manufacturers to develop practical, safe, and reliable systems. As a result, customers now have an array of differing systems to choose from, all offering the opportunity to reduce energy consumption and further improve the aesthetics of light rail.