Light Rail (UK)

All Party Parliamentary
Light Rail Group

House of Commons
London SW1A 0AA

Electric Traction beyond the Wires

Scott McIntosh

July 2011

There are potential ways of using low cost recycled tramway equipment for use on Community Railways. Electrification at 600-750V dc can be undertaken at lower cost than is initially thought. Nevertheless, there are lines where even low-cost electrification would not be economic, but this does not necessarily preclude the use of recycled tramway equipment.

The photograph above shows a train on the Rotterdamsche Tramweg Mij. (RTM) a series of interurban light railways to the south west of the city of Rotterdam. The system was an early user of diesel-mechanical railcars in the 1930s. Damage during the Second World War meant that the company had to buy, rebuild and operate new vehicles from a number of sources. In 1959 several vehicles had to be withdrawn due to accidents/fire. This allowed the RTM to embark on their most ambitions effort; railcar set M 1701 +1700 + 1702, a 3 car unit created in 1963. This consisted of two electric trams, previously operated by Deutsche Bundesbahn (DB) on a light rail line in west Germany, sandwiching a home built generator trailer.

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This trailer contained a diesel electric generator, a small supplementary passenger/luggage saloon and two end vestibules and was styled to match the two tramcars; it fed current through the tramcar controllers to the existing traction motors on the trams.

When the railway was run down and closed in the mid-late 1960s M1700 was acquired by the Zillertalbahn in Austria in 1966. It was used in regular service until new railcars arrived in 1984, since then it has formed part of the reserve fleet, although there have been attempts to return the unit to the Netherlands for use on a preserved railway.

RTM 1701+1700+1702 returned to the Netherlands in 1999 and is in use on the museum-line in Ouddorp since 2002. http://www.rtm-ouddorp.nl/

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The photograph above shows the general arrangement of the set in use on the Zillertalbahn. The two ex DB trams are little modified apart from the provision of a power bus line in replacement for the pantograph. The home-built generator trailer is a remarkably good visual match; it runs on bogies recovered from a scrapped carriage.
The leading vestibule of the trailer had provision for the fitting of a controller so the set could be run as a two car set if required – I have no evidence that this was ever done - there is then an entrance vestibule and a 2-bay seating area, the 3 bays with toplights only is the motor-generator space.

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The advantages of this arrangement are;

- the passengers are well insulated from the noise and vibration of the motor-generator
- the weight is distributed across a larger number of axles
- the tramcars need minimal alteration
- the maintenance facility can be a short shed only covering a single car.

A little history

These ideas are not new. Heilmann's experiments in France in the 1890s explored a variety of electric traction systems, including locomotives and trains where each vehicle was powered by a through train busbar, fed from a conductor rail or a power station on wheels.

Experience in Argentina

During the prosperous 1920s in Argentina the Buenos Aires Great Southern Railway (BAGSR) was interested in electrifying their suburban lines around the capital and ordered two electric multiple units from the UK. The CME of BAGSR was reluctant to initiate full electrification of the lines around Buenos Aires due to its cost, but believed in the idea of powered coaching stock, in this case drawing power from a diesel electric generator set installed in a 'mobile power house'. Accordingly, two 1,200hp mobile power houses, numbered UE 1 & 2, were delivered in late 1930; each was powered by two Sulzer 8LV28 cylinder engines developing 600hp at 700rpm, powering an Oerlikon main generator. Traction motors under the coaches were powered by the mobile power houses.
They remained in service at least until 1948.

The success of this experiment led BAGSR to order three 1700hp mobile power houses in 1933. Numbered UE 3, 4 &5 they were used to haul eight coaches. As with UE 1 & 2 the performance of these three trainsets was impressive, particularly in light of their quick turn round times at the termini, however for most of their lives they slotted in to steam diagrams. These mobile power houses remained in service at least until 1959.

A view from a 1933 issue of Diesel Railway Traction advertising Sulzer diesel engines shows the two 1,700hp mobile power houses with a lengthy train.

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On November 8th 1933 the chairman of the BAGS included this statement about the early diesel experiments on the BAGS in Argentina: "....experiments with diesel engines were started by us some five years ago. Trials have convinced us that this form of traction for branch lines and similar light service has outstanding potentialities. We sent out two mobile power houses, each of 1,200bhp. Encouraged by the results obtained from these original power houses the company acquired three more powerful units, each of 1,700bhp. These were put into service in June this year (1933) and up to the present have run some 45,000 miles. Each of these 1,700bhp power houses operates an eight coach train, weight of which is 526 tons. Seating capacity is provided for 916 passengers.

London Transport proposals for the Metropolitan Line

London Transport studied these units and one of the options for modernising the Metropolitan Line under the 1935-40 'New Works Programme' was to introduce electric multiple units, with mobile power houses being coupled on at Rickmansworth to take the train beyond the end of the conductor rails to the end of the line. The war and post war spending restrictions killed the idea and when modernisation was finally approved it was the far les innovative scheme of taking the conductor rails to Amersham and giving up the rest.

Proposals for Blackpool

The author looked at the concept when examining the possibility of an early tram-train operation in Blackpool in the early 1990s. The concept was that trams would run 'on the wire' to Starr Gate and then use a diesel generator to run over the Blackpool South – Preston line as far as Lytham.

There appeared to be two ways of doing this; taking one saloon in a Progress Twin-car set out of passenger use and inserting a diesel generator in its place. The trailers were robustly built in the 1960s and preliminary discussions with the rolling stock team at Blackpool indicated that the car could carry a generator set – Blackpool already had some experience of fitting such a set in the former passenger saloon of a works car.

The problem with this approach was that it would reduce passenger capacity by 25%, the noise and vibration would be closer to the passengers and the dead weight of the generator set would have to be carried under the wire from Starr Gate to Fleetwood providing a small fleet of generator trailers. These adopted the concept of the BR Brake Tender of the 1960's, in that they would be low enough for the driver of a tram to look over the tender to see the line ahead. A generator tender would be waiting at Starr Gate, the tram would couple up to it and it would then be pushed to Lytham as it provided the traction current. The unit would be towed in the reverse direction and then dropped off at Starr Gate to await the next tram. The advantage of this system is that it insulates the passengers from the noise and vibration; there would be no dead weight to haul 'under the wires' and only a limited number of trailers would be required.

This seemed to offer an inexpensive option for extending tram services over the line.

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When diesel locomotive haulage of unfitted goods trains was first introduced, it was considered that the locomotives would have insufficient brake power to control their trains, so some special "diesel brake tenders" were introduced. These were heavy wagons (35½ - 37½ tons) fitted with automatic vacuum brakes. On some BR Regions they were usually pushed by the loco, but on the Southern Region it was normal practice to pull them.

Experimental operation of a standard Stadtbahn car in Essen coupled to a natural gas – powered generator trailer. The unit was used to provide demonstration runs in 1999 as part of plans to bring a non-electrified industrial railway back into service as a light railway

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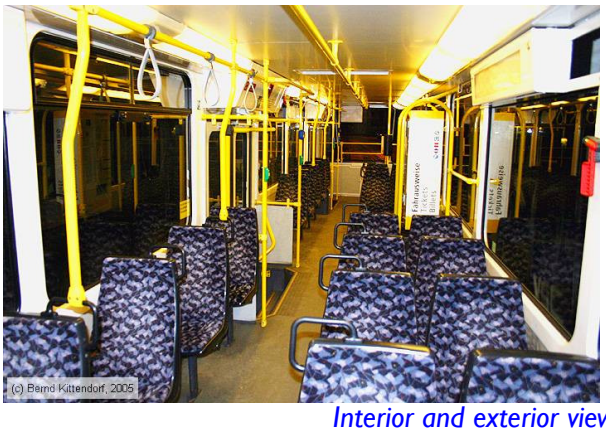
Applicability today

Non electrified lines

The RTM concept could be applied to the provision of a lightweight tram-train for non electrified lines in the UK. The ex-Berlin Tatra T6 cars have been considered for reuse on a non electrified line. The car is a single ended, single sided car, some 15m long. Coupling a pair of these cars back to back would produce a double-ended set. The front doors could be left in their existing location to provide driver's access and emergency detrainment, the rear doors would be plated over and the redundant equipment used to provide an off-side door.

The two centre doors would then be raised to provide UK platform-level access.



Interior and exterior views of Berlin rebuilt T6 cars

If a pair of these T6 cars was used to sandwich a central generator trailer then a modern version of the RTM M1700 set would be achieved.

Tatra bogies identical to those in use under the T6 are readily available on the second hand market at scrap metal prices. The majority of these bogies are motorised, but it is a simple matter to remove the traction motors, retaining the drive train and cardan shaft friction brakes. One motor could be left on one truck, thus permitting the motor trailer some limited manoeuvring capacity, independent of the rest of the train, whilst under limited local control. An alternative would be to obtain some of the trailer trucks provided under the Tatra trailers supplied to east Germany and Russia. All of these bogies could be controlled from the motor cars, thus providing a fully-braked train.

The chassis of the generator trailer would be easy to fabricate and the body would only need to be a lightweight cover for the motor generator unit – unless it is desired to provide some limited passenger and luggage capacity on the trailer.

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The motor generator set could be a normal commercial unit, since many of these are designed to be housed within a normal sea container there should be few problems in fitting them within the confines of a normal rail vehicle. It is recommended that thought is given to improving the environmental performance of the set by introducing a form of 'hybrid drive'; this could be achieved by 'floating' the output of the generator, using a battery, flywheel accumulator or a bank of super-capacitors. Such an arrangement would allow the unit to accelerate by drawing on the energy store and to decelerate using the regenerative capacity of the tram – feeding the current into the energy store.
Similar arrangements are used on 'hybrid drive' road vehicles, in the Bombardier super-capacitor tram and in the Parry People Mover.

A 3 car set of T6+GT+T6 would be around 45m long and provide a capacity of over 150 passengers (72 seated and 80 standing in the two T6s, plus whatever is proposed for the generator trailer. The train would have a top speed of around 65kmh and an acceleration of around 1m/s/s. This performance may not make such a set suitable for longer-distance interurban work, such as the Penistone Line, but it would certainly be an attractive substitute for a Pacer on shorter lines (St Ives branch, Stourbridge, Severn Beach, rebuilt Alnwick, etc.) where there is no need for physical inter-running with main line trains.

Part Electrified lines

If a line with partial electrification is considered (e.g. Blackpool – Lytham) then the option of providing 'loose' generator trailers with trains coupling up to them at the end of the electrified section, pushing the trailers to the far terminal then towing them back and dropping off the trailer for collection by the next service coming off the electrified section has many attractions; the deadweight of the generator is not carried over the electrified line; the number of generator units is reduced; wear and tear of the generator trailers is reduced; trains would not be rendered unsuitable for service if 'their' generator fails; the brake power of the train when in heavy diesel electric mode would be supplemented by the brakes of the generator trailer

Experiment

An experimental set could be built comparatively cheaply; the T6 cars are currently available at low prices from Germany, spare parts are readily available at scrap metal prices and the diesel generator set would be a standard commercial product. All that is required is the fabrication of the diesel generator car body and the modifications to the two T6 cars. If the experiment is not a success then the diesel generator set can be recovered and sold on, reducing the overall cost of the experiment.

This experimental set could then be compared with the cost and performance of existing diesel railcars in the 14X, 15X series – and the Parry cars at Stourbridge.

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Whilst the current proposal is for a relatively small train, there is no reason why the concept could not be enlarged to allow larger articulated trams to be used and the uncouplable generator trailer concept could be used to allow through operation of trams in places such as Manchester or Sheffield the concept could also be expanded to allow the extension of Merseyrail services over the Bidston-Wrexham line – without the cost of electrification. It is important to note that in the Manchester, Sheffield and Mersey cases this type of operation could be considered as an intermediate stage in the development of a full electric network; hybrids could prove the business case and then the generators redeployed elsewhere once the funds for electrification are available.

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Annex

Some historical examples

1. An early scheme in Ireland

The Dublin and Blessington Steam Tramway was an Irish standard gauge (5ft 3 ins) steam tramway opened in 1888. By 1911 the locomotives of the Steam Tramway were coming into disrepair due to the unsuitable nature of the work, especially the six initial locomotives known as the 'kettles'. Number 4 had already been retired to the Templeogue depot to work as a static engine to power machinery. In 1911, a major proposal was put forward for the electrification of the line as far as Crooksling. A new depot and power station would be provided near Jobstown, which would provide electric power for the line, and also for electric lighting throughout the local district, and which would enable the closing of the Terenure and Templeogue depots.

The advantage of this, apart from the better economy that would be enabled, was that through traffic from Nelson's Pillar in the centre of Dublin could finally be accomplished. Electric cars could work through all the way as far as Crooksling. Thereafter, a small, portable electric power plant carried in a special van would be hooked on, and this would supply the necessary power for the remainder of the journey to Blessington and Poulaphouca. The steam locomotives would be abandoned altogether.

This was a very ambitious scheme, which could have had long lasting implications for the success or otherwise of the line. The next thing to happen, however, was the First World War, followed by the Irish 'Troubles' and that put paid to any further developments.

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2. Mobile Power Houses on the Buenos Aires Great Southern Railway

Buenos Aires Great Southern Railway	Sulzer 1,200 hp (2 x 8LV28 600hp @ 700rpm) mobile power house	Armstrong Whitworth 1930, 1-A-2-A-1, 5ft 6in	Oerlikon-main generator; Metropolitan Vickers-traction motors	2	UE1, 2
Buenos Aires Great Southern Railway	Sulzer 1,700 hp (2 x 8LV34 850hp @ 550rpm) mobile power houses	Armstrong Whitworth 1933, Bo2+2Bo, 5ft 6in	Brown Boveri-main generator; English Electric traction motors (8 x 134hp)	3	UE3, 4, 5

1,200hp mobile power houses

In 1929 the Buenos Aires Great Southern Railway bought two 1,200hp mobile power houses, numbered UE 1 & 2, used to power five coaches, three 1st & two 2nd class providing total seating for 554. One was loaned to the FC Buenos Aires Pacifico. The CME of BAGSR, Mr P C Saccaggio, was reluctant to initiate full electrification of the lines around Buenos Aires due to its cost, but believed in the idea of powered coaching stock, in this case drawing power from a diesel electric generator set installed in a 'mobile power house'. These units were semi-permanently coupled to five coach sets, the end coach being equipped with driving compartments, avoiding reversals at the busy Buenos Aires terminals. These two locomotives were ordered just after an order to Beardmore, which would become the first diesel locomotives to work anywhere in South America.

The prime movers required by were not readily available from any builder so on a visit through Europe many components were ordered from a variety of manufacturers. He was familiar with Armstrong Whitworth and the steam locomotives they had previously built for Argentina, thus they were offered the construction of the mechanical portions with final assembly and finishing taking place at BAGS's workshops at Remedios de Escalada. Delivered in late 1930, each was powered by two Winterthur built Sulzer 8LV28 cylinder engines developing 600hp at 700rpm, powering an Oerlikon main generator & two 136hp Metropolitan Vickers traction motors - each coach carried two 125hp motors.

The rigid frame supported four fixed axles, two of which were powered with a pony

truck at each end (1-A-2-A-1 arrangement). Because they were semi-permanently coupled to the coaching stock the MPH's carried only one driving cab, with a driving cab being fitted to the last coach. Locomotive weight was variously reported between 85 tons & 92 tons, total train weight was 314 tons.

These locomotives were built to the 5ft 6in gauge, the increased body width allowing the side by side positioning of the two engines. It also required Armstrong Whitworth to install lengths of 5ft 6in gauge track at their Scotswood Workshops to accommodate these and other rail vehicles of this gauge. The locomotive design carried some influence of the steam locomotive with its 2-8-2 wheel arrangement, the powered axles being mounted in a rigid frame, rather than the more familiar bogies of later designs. All the wheels were of 3ft 1.5in diameter. The styling of the locomotive was very functional, with slab sides and cab front. The roof was curved to match that of the coaches they would haul, the slope of the cab roof dome was minimal.

The coaching stock had been built in the BAGS railway workshops at Remedios de Escalada. The coaches were very large vehicles, 85 ft over buffers and were provided with special shock absorber equipped coupling bars which allowed for easy navigation of the curves despite the coaches great length. Each coach rode on two 2-axle bogies, with the outer axle on each bogie carrying a 125hp traction motor. The electrical output was configured so that each engine provided power to one traction motor on the locomotive and to one traction motor on each coach, thus allowing the train to be operated at half output in the event of one engine failing or working services that were lightly timed.

These two machines provided a comparison with the first diesel on the BAGS railway - a 375hp Bo-Bo diesel electric built by Beardmore. This locomotive's high-tensile steel liners required regrinding after 60,000 km, the cast iron liners of the Sulzer engines showed barely perceptible wear over the same distance. These particular engines were some of the last of their type. The weight of the engine & generator set was fifteen tons.

They were most regularly operated out of the Plaza Constitucion terminal to Quilmes under alternating 16 hour and 8 hour diagrams, their acceleration was superior to the regular steam fleet, but the MPU powered trains generally ran under the steam timings. With a driving position at each end their turn round time at the termini was vastly superior to the steam operated workings. These new trains were to have a mean speed of 28mph on lines 20 to 30 miles long, with stations no more than two miles apart.

The maximum speeds was set at 45mph. On their first run in February 1930 from Constitucion to San Vicente the journey was completed in forty minutes as against the seventy minutes required for the steam powered workings. Occasionally the two sets were combined. In the early years it was the practice to stop the engines at each station stop, leading to the engines going through the stop/start cycle over two hundred times a day! This stopping and starting of the engines, literally hundreds of times daily caused considerable problems with broken joints, pipes, studs etc. Modifications to the governor control, with the fuel shut off prior to the load being taken of the engine reduced the stresses on the engines. Later practice was to allow the engines to idle while stopped at the stations.

The first general repairs were received during 1932. At the next annual general meeting of the Buenos Aires Great Southern Railway Co Ltd, the chairman said :

"The Diesel-electric trains are working well in our ordinary suburban time-table service, and I made two or three trips in them. The running was smooth throughout, and the starting and stopping quite as rapid as the ordinary electric service. The experiments carried out so far have been so successful that we are ordering ….three larger mobile power houses, so that we can run trains of eight instead of five coaches as at present. The results so far obtained are in every way satisfactory, and I am hoping that we have solved the question of electric traction at a minimum cost with the maximum of efficiency, as we get all the advantages of electric train-running without the necessity for the third rail, overhead wires, or of obtaining power from outside sources..."

UE1 & UE 2 remained in service at least until 1954 with mileages of 1,172,727 & 1,114,906 respectively.

Mobile powerhouses UE 3-5 were direct descendants of the 1930 built UE 1 & 2. Improvements included the use of two four axle trucks rather than the earlier rigid wheelbase. Each unit was comprised of two half units permanently coupled together, each containing an engine generator set, though only one unit had a driving compartment .

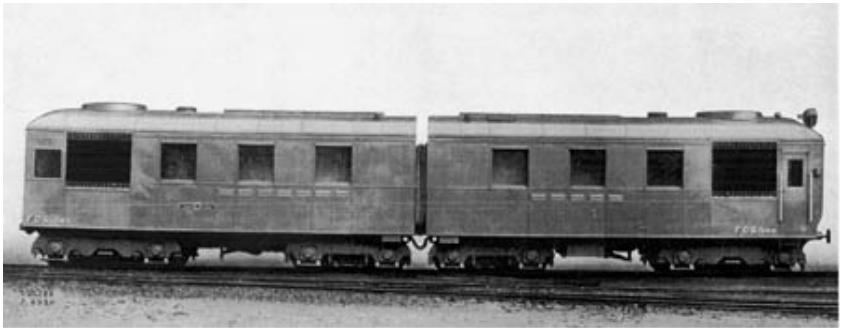
Each Winterthur built Sulzer engine was coupled to a Brown Boveri main generator rated at 570 KW dc and two English Electric axle-hung, nose-suspended, self ventilated traction motors on the outer bogie of each half unit. Each engine generator set supplied power to two motors on the powerhouse and eight motors under the coaches.

The weight of each double unit was 133 tons, with eight coaches in tow the total train weight was 470 tons. These mobile powerhouses were delivered fully assembled during November & December 1932.

As with UE 1 & 2 the performance of these three trainsets was impressive, particularly in light of their quick turn round times at the termini (5 to 10 minutes as compared to 35 - 45 minutes for the steam workings), however for most of their lives they slotted in to steam diagrams where their full potential was not always realised.

The mobile powerhouses were withdrawn between 1959 & 1961, although the official withdrawal dates are recorded as April 1963, with the scrapping date recorded as December 1963.

Final mileage totals:
UE3: 1,610,180 miles UE4: 1,483,888 miles UE5: 1,570,101 miles



A side view of one of the double unit mobile power houses,

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A mobile powerhouses were used, seen here with a rake of eight coaches, with seating capacity for 916 passengers.

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3. Electrification of the LT Metropolitan Line beyond Rickmansworth

LT considered the extension of electrified services beyond Rickmansworth during and immediately after the Second World War. At the time the line used loco hauled stock for through services, hauled by an electric locomotive to Rickmansworth and a steam locomotive (provided by the LNER after 1937) to take the train on to Aylesbury and Verney Junction. The locomotive hauled sets were virtually identical to the Metropolitan Line T-stock and there was already a significant fleet of T-stock trains with plenty of life left in them (they ultimately lasted until 1962). The concept was to refurbish all of this stock and make it one integrated fleet of T-stock EMUs.

The EMU stock would work electrically to Rickmansworth, drawing up to - and coupling with - a low height bogie 'wagon' diesel generator which would supply power to the train but not to itself. The low height would be such that the driver would remain in the EMU cab and see over the wagon. The wagon would be fitted with several automotive engines - described as "Leyland bus engines" therefore similar to those fitted to the London Transport RT and RM buses - and generators, which would feed traction current to the train bus line. The generator wagon would remain on the front of the train to Aylesbury and on the rear on the return to Rickmansworth. The generator car on the train front it would look very much like the diesel brake tenders which BR once used with diesel locos.

LT wanted something that would simply provide traction power to the EMU – and to the EMUs control system. The comparatively small engines were to make the push unit low enough to allow the driver to see over from the EMU cab. This avoided putting a cab on the generator avoided the driver having to change cabs at the end of the electrified section.

The vehicle was also to be very short with wheelbase no longer than two closely spaced bogies.

Financial problems lead to the integration of the T-stock fleet for the surface lines.
When funding was eventually available in the late 1950s the T-stock had too short a residual life to make the project viable and a less ambitious programme of electrification to Amersham and abandonment of Metropolitan Line services north of that point was adopted.

4. **The Diakofto–Kalavryta Railway, Greece**

The Diakofto–Kalavryta Railway is an historic 750 mm gauge rack railway in Greece. Located on the northern Peloponnese, it runs 22 km from Diakofto through the Vouraikos Gorge to Kalavryta.

The line was to be electrified after the Second World War and EMU s were ordered from Billard, France. Before the cars arrived, the plans for electrification were cancelled, the EMUs were thus not usable when they arrived. A power car carrying a diesel generator was placed in the middle of the two cars. This solution has worked very well for decades.

Billard trainset when first commissioned

Recent view of trainset

The Diesel Electric DMU-2 3001, has a car between the two coaches which holds the diesel motor and the generator. This car is shown in the picture. The electric motors are located in the driving motor coach.

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A closer view of the generator car in the middle of the train.

The first of the modern rolling stock for was built by Billard in 1958. Three similar trainsets built by Decauville were added in 1967. The motors on the Billard cars have an output of 350 horse power, the Decauville cars have in installed power of 500 hp.

These trainsets, both types of similar configuration, consist of two passenger cars (a motor car and a control car) and a generator trailer between them.

The (N1) vehicle has 4 axes and a tare of 11 tonnes. It is the driving vehicle having the electric motor and the driving wheels (rack and adhesion).

The (N2) vehicle houses the motor generator in Greek it is "the vehicle of energy production (OPE)". The OPE weighs 7 tonnes.

The (N3) vehicle is a driving trailer. It weighs 7 tonnes and has 4 axes.

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The RTM set

Edited extract from Modern Tramway c 1966;

"It is rather hard to describe the train units because of the unusual arrangement whereby no single car can run on its own.

The 2 end cars, 17.01 and 17.02, are the former Deutsche Bundesbahn trams ET195.01 and 195.02 of the Ravensburg-Weingarten-Baienfurt line. They now have only one control position instead of the former two, and doors in both sides instead of one. One bogie carries a Kiepe electric motor, driving both axles. There is no current collector, but the control end of the car has ordinary RTM central buffer and drawgear, while the other end has a Scharfenberg coupling.

The centre car looks as if it was built by Duewag, but was in fact built by the Hoogeveen shops of the RTM to match the end cars, using the strengthened underframe of M66 (ex-Maas Buurtspoorweg) and the trucks from M66, but no motors. This car is numbered M17.00, and has a small passenger section at one end and a luggage compartment at the other. Each end has a driving position, using the redundant equipment from the ex-DB motor trams.

The main purpose of this car is to carry a Deutz diesel engine, with 12 cylinders and capable of producing 210hp. The diesel engine drives a generator, which feeds the traction motors in the end cars through the Scharfenberg couplings.

The maximum speed of the new set is 60km/h, but the maximum permitted speed is 50kmph, and this is certainly the fastest unit ever owned by the RTM. The end cars each seat 34 and standing 65, and the generator car seats 13 and stands 17, making a total of 81 seats and 147 standing places for the 3-car train."

5. Electric Locomotives for India

Builder: Hawthorn Leslie & Co, UK. Electricals by English Electric, Leeds, UK Class: YCG/1 Year Built: 1930 Service: SIR (South Indian Railway), later SR (Southern Railway) Wheel Arrangement: Bo-Bo Unique Features: Dual braking (vacuum and air), entrance from balconies at each end.

These locomotives could also work in unelectrified yard lines, on attachment of trailer housing battery accumulators.