Appropriate Size D.C. Power Supplies For Heritage Electric Tramways

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Introduction

Tramway museums have rather small electric traction power supply requirements compared with the former city systems that they are displaying. Much of their former systems D.C. rectifying equipment is unsuitable in many regards for museum use. In the early days (c1960) of the tramway museum movement in Australasia (and U.K.) provision of a traction power supply was the single greatest barrier to operation.

Most tramway museums have solved their power supply requirements, but it is worth restating the characteristics for future projects.

Initial museum power supplies

Sydney Tramway Museum

It is worth going through Sydney Tramway Museums experience as STM was the first museum to power up in Australia. At the closure of the Sydney Tramways virtually all of the traction substations were rotary converters fed by 6.6kV feeders at 25Hz (then known as 25 cycles per second). The 25Hz generation at Ultimo and White Bay powerhouses then closed down. The only two possibilities for former government tramways substations were Waterloo mercury arc substation and Kogarah trolley rotary converter substation which were the standard 50Hz

Waterloo was not available as it was used to supply D.C. to the remaining Randwick Workshops, it was 5kV supply, the supply available at Sydney Tramway Museum was 11kV so that Waterloo was not in any case suitable.

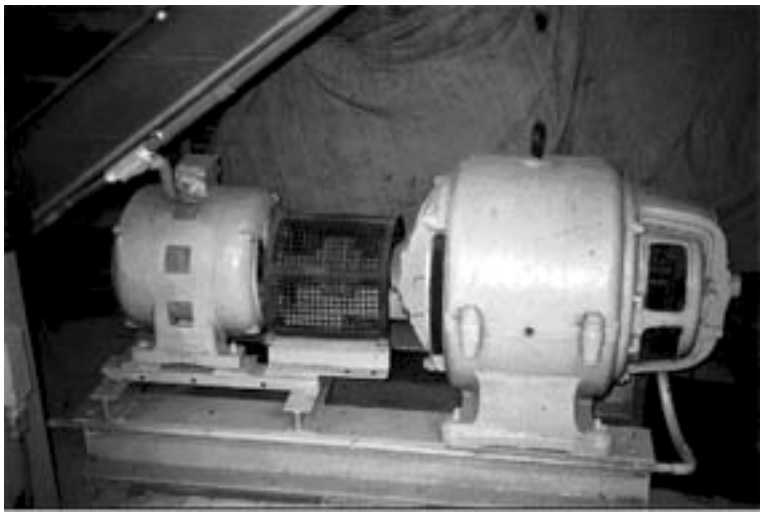
One of the two Kogarah 500kW Rotary Converters was purchased and transported to STM. A brick building was constructed and the rotary converter and switchgear put in place. An outdoor switch and transformer yard was also built.

The electricity distributors 11kV mains were 750m from the museum proposed high voltage metering was to be costly so consideration of a temporary alternative DC supply was made until funds were available to complete the substation.. Automotive batteries were considered, 40 by 12volt car batteries would give a reasonable supply, they could be charged slowly from a small AC power supply but would need replacing every two years.

Rotary Converter in storage

Rotary converter transformer in storage

In the meantime a 20 horsepower 600volt DC shunt motor that has powered a fan in the roof area of Randwick Tramway Workshops became available. It was purchased and connected to a 20 horsepower AC motor and run as a generator from a three phase 55A 415volt electricity distributor supply.



15 HP motor generator now used as a test set

To the surprise of all present it adequately operated L/P car 154 in July 1964. Another DC motor was obtained, second motor generator built and the AC supply upgraded from 55A to 100A. Completion of the 11kV rotary converter substation was indefinitely deferred.

Other museums

AETM St Kilda South Australia installed a 15 horsepower motor generator for initial trials and then installed a locally manufactured transformer and silicon rectifier unit supplied at 415volt.

Bendigo Tramways inherited the former system's rotary converter, but changed to a locally assembled transformer and silicon rectifier supplied at 415volts.

National Transport Museum, Crich, U.K. commenced operation with a diesel motor connected to a trolley bus motor as a generator.

Brisbane Tramway installed a former Brisbane City Council glass bulb mercury arc rectifier supplied at 11kV. Brisbane is unique in having a high voltage supply and a full size tramway substation.

Performance of DC series traction motor

The traditional tramway traction motor has a quite different and beneficial starting performance compared with ordinary three phase AC industrial motors. For the traction motor the current drawn produces the same torque (or tractive effort) at any speed including at starting. For the AC motor at starting, large currents, often three or four times full load current, and produce quite low torques. AC motor power supplies have to allow for heavy overloads during starting.

Heritage tramway operation on DC does not have to provide for such heavy overloads.

This performance benefit of DC heritage tramways is often not understood by electricity distributors and consultants whose main experience is with AC systems. Such organizations are prone to recommend over size installations.

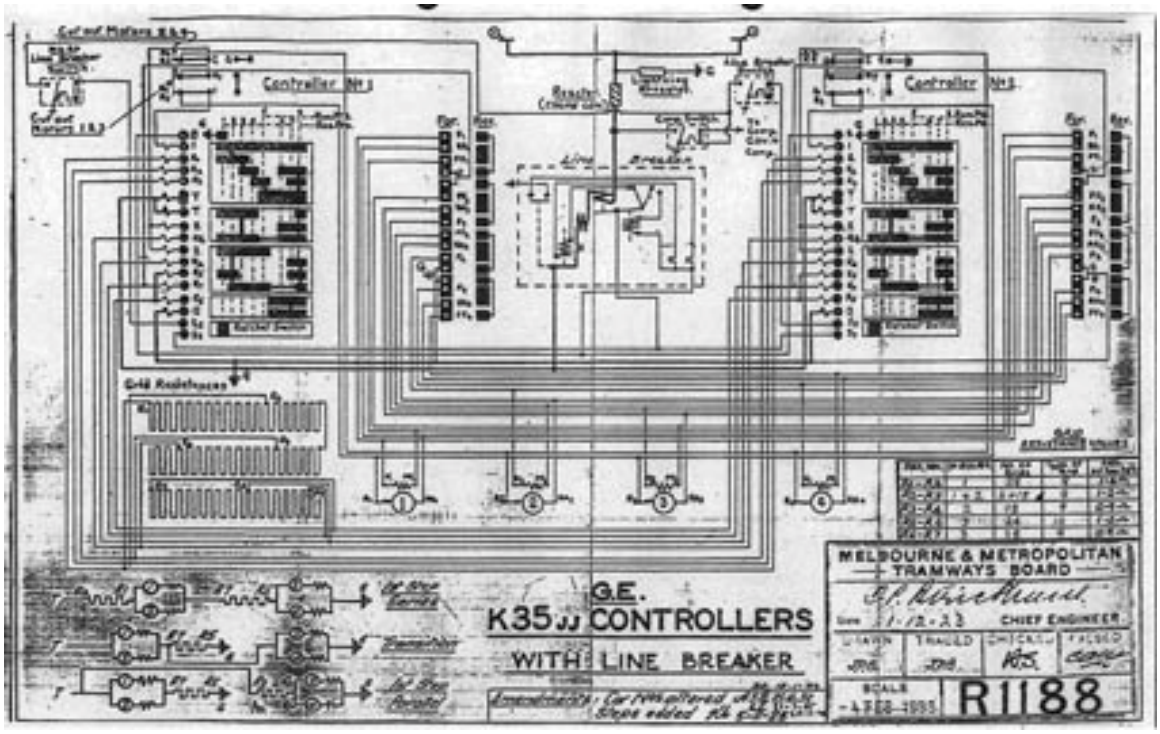
DC motors are limited in their short time overcurrent capacity by the commutator. Overloads can cause flashovers and burning. The controller resistance steps are designed to keep possible overloads under control. This is another feature which gives DC traction a much softer power supply requirement than AC motors.

Finally to summarise;

- for a series DC motor current equals tractive effort (at any voltage)
- voltage determines speed.

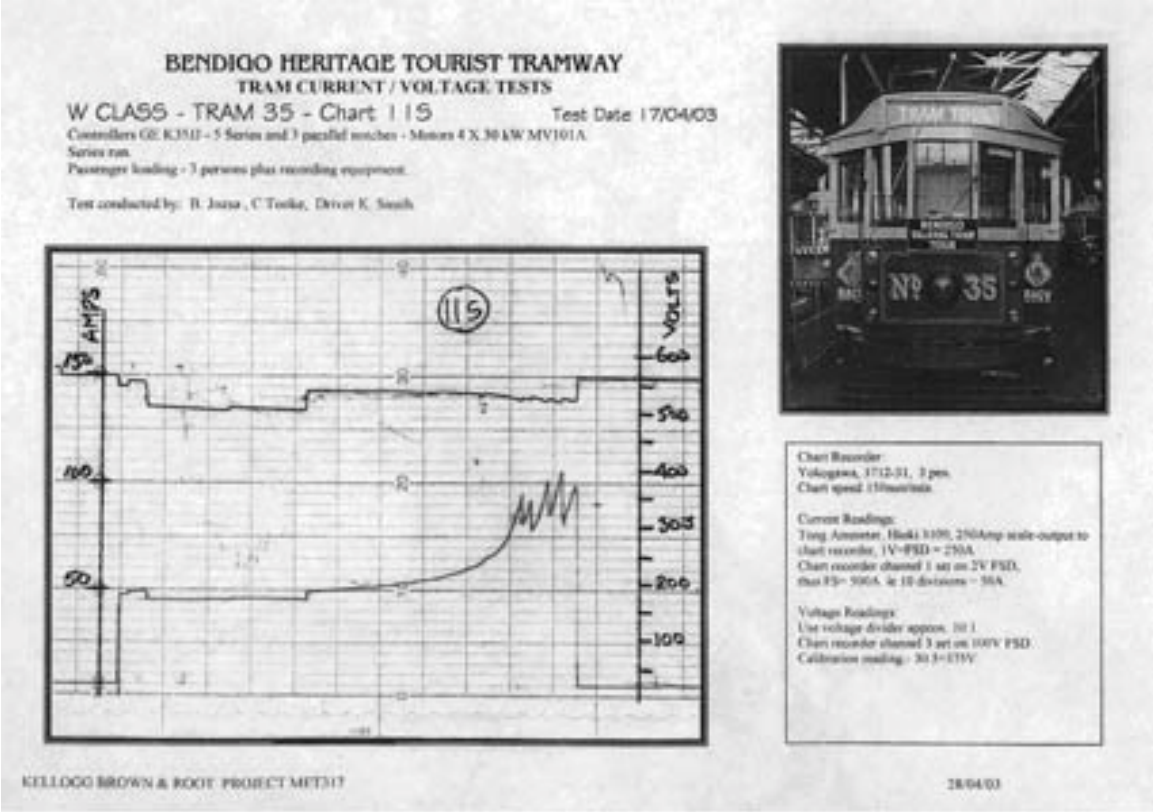
Example of Melbourne W2 class tramcar

The W2 is typical of the larger heritage tramcars. It is now operated on many COTMA members' museums. W2 tramcars have a mass of 17.2t a seating capacity of 56 and powered by four by 40 horsepower motors. In first notch series there are 5.6ohms in the resistance boxes in series with the motors so that the current is 107A or probably just less than 100A if wiring and motor resistance is taken into account.



W2 wiring diagram showing resistances

In museum operation it is not necessary to accelerate to keep up with motor traffic. Notching up to full series can be controlled to keep within the 100A. This was demonstrated in Bendigo in April 2003 with a recording ammeter, Kym Smith as Driver. I must complement Kym on his driving skill; the graphs are almost identical to the theoretical as in Dover's textbook.



W2 current test
Note: Graph goes from right to left

Once in series the current drops off as the speed increases so that on fairly level track, at balancing speed, the current drops to about 45A.

Another peak of current will occur if the controller is moved to the parallel notches, this can be minimised if the tramcar is allowed to reach full series speed before going to parallel.

Sydney tramway museum has been able to operate, over a short distance, both a W2 class car and a Sydney R1 car using a 600volt 50A silicon rectifier. Both these operations, for a demonstration, ran continuously during the day for a two week period.

Present day DC traction rectifiers

Silicon rectifiers have replaced motor generators, rotary converters, steel tank mercury arc rectifiers and glass bulb mercury arc rectifiers. They are cheap and reliable. The diodes that operate Sydney Tramway Museum would fit in ones trouser pocket, the rotary converter they replaced weighs 5tonne.

The rectifiers still, however, require a double wound transformer to isolate the electricity distributors supply. This is the most expensive part of the rectifier unit.

One simple rule is that the DC current is equal to the current on the three phase distributors supply. For example a 50A DC rectifier requires a 50A AC 415 volt supply.

What size power supply for heritage operations?

Sydney tramway museum has operated four motor cars to a limited extent on a 50A rectifier.

W2 car in Canberra on 50A supply Sept 2003

50A rectifier in weatherproof enclosure at Canberra

On the first occasion the 50A rectifier ran R1 class car no 2001at the Australian War Memorial driven by a 75kVA diesel alternator.

On the second occasion the rectifier was powered by ACT Electricity &Water low voltage street mains.

The previous Sydney Tramway Museum Site operated on a 100A supply that allowed the careful operation of two or three trams.

The present Sydney Tramway Museum complex operated on rectifiers of 167A capacity. This allows unrestricted operation on the Museum Line and the Royal National Park line services as well as shunting within the depot complex.

Sydney tramway museum 167A traction substation

Electrical safety aspects

The use of the smaller DC power supplies reduces the damage and risk of injury if a short circuit occurs.

The smallest size copper trolley wire available has a continuous current rating well in excess of 200A so that electrical protection of the rectifier will protect the trolley wire.

High Rupturing Capacity Fuses on the AC side will adequately protect the DC circuits. They are also much cheaper and more reliable than DC high speed circuit breakers.

Arcing faults are unlikely to be sustained on the low current supplies referred to above.

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Questions

Bryce Pender, Wellington Tramway Museum
Q. Back to Back transformers – do you need to protect on the DC side as well?
A. Use a varistor on the DC side. Not necessary to use DC contactors. DC contactors are expensive and may be unreliable.

Richard noted that they have not had a diode damaged by lightning, use varistor only for lightning protection.

Q. Do you have lightning arrestors on the overhead?
A. No, using any. Spark gaps on tramcars. Use varistors to do this.

Q. How many tramcars can be started at the same time?
A. Stagger the start, have not reached a limit yet.

Q. What is the maximum length of overhead that can be operated on before excessive loss.
A. About 2km, the shorter the length the better

Craig Tooke noted that in Melbourne, max in Melbourne is 2.2km, though with Box Hill, 2.6km. Voltage not allowed to drop below 470V. Otherwise trams stop.