MELBOURNE AND METROPOLITAN TRAMWAYS BOARD

PROJECT 3 - 75

REPLACEMENT OF SUBSTATION EQUIPMENT.

1979

1. INTRODUCTION.

It is proposed to commence a programme of substation improvement by the replacement of rotary converters by silicon rectifiers. The majority of the 25 existing rotary converters were installed between 1924 and 1930. Two were installed in 1916 and one in 1935. Details of the existing system are given below.

Replacement of rotary converters with silicon rectifiers will bring about the following principal benefits

- reduced power consumption
- greater reliability
- reduced maintenance requirements.

It is proposed that two new rectifiers with associated equipment be installed each year at an estimated total cost of $150,000 per annum. This is a pre-tender estimate. The equipment is of a specialized nature and immediate quotes are not available.

It is proposed that two new rectifiers be installed at the following locations;

1975/76	Substation S, South Melbourne
1976/77	Substation M, Malvern
1977/78	Substation Y, Fitzroy, Young Street.

2. DESCRIPTION OF SYSTEM.

The Board's electric tramway system operates on a nominal 600 volt direct current supply having the overhead trolley wire at positive potential. The rails are used as the negative conductor. The trolley wire and rails are connected to substations by positive and negative feeders respectively.

The 216 km of double track rails are continuous and connected to the negative bus bars of the substations at appropriate locations.

The overhead trolley wires however are divided into 83 isolated sections to allow effective electrical protection of the system. Each of these sections is supplied via its own feeder cables and feeder equipment in one, two or three of the 26 substations throughout the system area. Including auxiliary feeder equipment which can be connected to any feeder cable, the number of feeder panels in each substation varies from three to eleven depending on the location and installed capacity of the converting equipment.

Supply to the feeder equipment is drawn from the positive bus bars connected to the output of the converting equipment.

Each of the 26 substations has one, two or three converting equipments, details of which are shown in the following table.

Power is provided to each substation by the Supply Authority at either 6,600 volts or 11,000 volts alternating current. It passes via high voltage bus bars and switchgear to the transformers of the converting equipment to provide the correct AC voltage for the production of the nominal 600 volts DC. This AC voltage is 436 volts, 6 phase, for rotary converters, 560 volts, 6 phase or 12 phase, for mercury arc rectifiers or 477 volts, 3 phase, for silicon rectifiers. The transformers are specifically

designed for the type of converting equipment with which they will be used. An additional small transformer is provided in each rotary converter substation to provide control power at low voltage for the automatic starting sequence of the rotary converter equipments. This control transformer is not required in mercury arc or silicon rectifier substations because the main power transformer, which is continuously energised, has a low voltage tertiary winding to provide this control power.

The direct current output of the converting equipments passes through protective switchgear equipment to the DC bus bars then to the feeder equipment as mentioned above.

Rotary converter and some mercury arc substations are automatically operated on time switch and load demand control. One equipment is started in time to provide power in the trolley wires for the first tram in the morning and closed down after the last tram returns to depot at night. In a two equipment substation the second equipment is automatically started when the load on the first becomes excessive during peak traffic periods and closed down when this load is reduced to single equipment capability. In this way the use of rotating equipment and its maintenance is reduced to a minimum. Because for safety and maintenance purposes, it is necessary to keep the overhead trolley wires energised continuously, mercury arc and silicon rectifier equipments are operated continuously during the after hours, light load period.

The control and protective switchgear associated with rotary converter equipments must provide for the equipment to be energised at the correct time and closed down when not required, the armature to be started from rest and run to synchronous speed, the magnetic field windings to be energised in the correct polarity and reversed if incorrect, and the DC load to be applied after the output voltage has reached the correct value. Protective equipment is provided to lock the rotary converter out of service should an excessive time or any fault occur at any stage in the starting sequence. This switchgear is therefore much more complicated and requires more maintenance than that required for static silicon rectifier equipments.

CONVERTING EQUIPMENT INSTALLED IN M. & M.T.B. SUBSTATIONS.

Sub.	Location	Converting Equipments			Total Substation Capacity kW	Year of First Service
		No.	Type	Capacity Each kW		
A	Ascot Vale	2	R	500	1,000	1924
B	Brunswick	1	R	500	1,000	1924
		1	"	500		1925
C	Carlton	3	R	1,000	3,000	1926
Ch	Clifton Hill	1	MA	600	600	1955
Cl	Melbourne	2	Si	1,000	2,000	1975
Co	Coburg	2	MA	600	1,200	1957
Cw	Camberwell	1	R	500		1924
		2	"	500	1,500	1925
D	Deepdene	1	MA	500		1934
		1	"	600	1,100	1945
E	St.Kilda	2	Si	1,000	2,000	1967
Es	Essendon	1	MA	600	600	1943
F	Fitzroy, George St.	1	MA	1,000	1,000	1956
G	Glenhuntly	1	R	500		1924
		1	MA	600	1,100	1949
H	Hawthorn	2	R	200		1916
		1	"	500	900	1924
K	North Kew	1	MA	600	600	1953
M	Malvern	2	R	1,000	2,000	1930
Mg	Maribyrnong	2	MA	600	1,200	1943
N	Northcote	1	MA	555		1953
		1	"	600	1,155	1956

Sub.	Location	Converting Equipments			Total Substation Capacity kW	Year of First Service
		No.	Type	Capacity Each kW		
O	Fitzroy, Holden St.	2	MA	555	1,110	1947
P	Preston	1	MA	500		1930
		1	"	600	1,100	1938
Q	Kew	1	R	1,000		1928
		1	"	1,000	2,000	1930
R	Richmond	2	R	1,000	2,000	1927
S	South Melbourne	2	R	1,000		1928
		1	"	1,000	3,000	1931
St	Prahran	2	Si	1,000	2,000	1967
Sy	South Yarra	1	MA	600	600	1945
W	West Brunswick	1	MA	600	600	1936
Y	Fitzroy, Young St.	2	R	1,000	2,000	1930

NOTES: (1) List as of May 1975.

(2) R = rotary converter
MA = mercury arc rectifier
Si = silicon rectifier

(3) In addition to the substations listed there is a Mobile substation available which has one 600 kW mercury arc equipment.

(4) The mobile substation and the two 200 kW Rotary Converters at Substation H are the only manually operated equipments in service. All others are fully automatic as described.

3. BENEFIT COST EVALUATION.

Proposal.

Existing rotary converters are rated as follows :

14	-	1000 kW
9	-	500 kW
2	-	200 kW

It is proposed that these be replaced with 24 silicon rectifier units each rated at 1000 kW. Two units are to be purchased and installed in the financial year 1975/1976.

At this stage it is considered that replacement of high voltage equipment should be kept to a minimum consistant with safety and State Electricity Commission requirements. This will involve purchase of oil circuit breakers. Installation of complete metal HV switchgear is not feasable without extensive building alterations.

It will be necessary to purchase power transformers, suitable for silicon rectifiers, which have primary windings suitable for both 11 kV and 6.6 kV. This is to comply with agreement with SEC that all future installations will be capable of operating at 11 kV. Rotary converter transformers are not suitable for silicon rectifiers.

Some alteration to the DC switchgear will be necessary but it is not proposed to change the existing system of overload protection (connection of a resistor in series with load). This system may reduce the overall efficiency marginally. It would not be considered for a new substation because more space and a forced cooling system is required. However, this is available and exists

at each rotary converter substation.

On this basis the silicon rectifier can be a simple bridge connected unit with a minimum of control gear. Filters for 300, 600, 900 and 1200 Hz. will be required for each unit.

Capital Cost.

Estimated cost for one unit is as follows :

Material:

1 - HV oil circuit breaker	4,000	
1 - Filter Equipment)		
1 - Power Transformer)		
1 - Silicon Rectifier)	45,000	
Miscellaneous cables and fittings for installation	8,000	
		57,000
Removal and installation		14,000
		71,000

Say $75,000.

Power Consumption.

The efficiency of rotary converters varies with load. At rated load efficiency varies from 80 to 85%. At lower loads, which prevail during the off peak operation, efficiency can be as low as 50%. The weighted average efficiency over peak and off-peak periods is approximately 60%.

The efficiency of silicon rectifier equipment is approximately 97%. Therefore replacement would reduce power consumption by 38%.

The total annual power consumption of rotary converter substations is of the order of 22,920,000 kwh, hence the estimated saving in power is say 8,710,000 kwh per annum, when all rotary converters are replaced. At 1.7 cents/kwh the annual saving would be $148,000.

The equivalent saving from replacing one unit would be approximately $6,200 per annum.

Service Reliability.

The power silicon rectifiers placed in service in 1966 have only had one failure since 1967 when the initial problems occasioned by inadequate design were overcome. The equipments received a minor inspection each month and major inspection once a year.

The number of failures of rotary converter equipments is about 100 per annum. Each unit is taken out of service for regular maintenance once per week.

Maintenance Costs.

Maintenance costs per unit.

Silicon Rectifier Equipment	125	
With associated		
Transformers	750	
Switch gear	375	
Filters	125	$1,375 per annum
Existing Rotary Converter	3,000	
With associated		
Transformers	875	
Switch gear	1,500	
		$5,375 per annum
	Saving:	$4,000 per annum.

Benefit Cost Ratio.

Present cost ($75,000 in year one)	$68,000
Present benefits (10,200 per annum, years 2 to 50)	$91,800
- at 10% discount rate	
Benfit cost ratio: 1.35.	