Analysis and design of Tbus overhead.

Aims -

- Reliable supply of traction power
- Safe and rugged
- Allow high service speeds
- Visually unobtrusive
- Cost effective

Summary -
Using increased line voltage of the order of 800-1000v results in being able to use lighter, cheaper, less obtrusive running wire. Knock-on effects include smaller fittings, and lighter cross span wires. Changing UK practice to a wider wire gauge of 700mm follows current continental practice. Whilst new installations could import Swiss equipment, the opportunity could be taken to take maximum advantage of the need to minimise visual intrusion and incorporate the latest understanding of trolleybus movement dynamics by designing and manufacturing new fittings. Although negotiations would have to be entered into to allow higher voltages there is little that is inherently more dangerous by increasing the voltage by a factor of 1.25 over continental practice.

References -

- BICC catalogue of UK standard fittings c.1950
- Current Collector Manual, Brecknell, Willis & Co. c.1990
- Modern trolleybus Operation, Brecknell, Willis & Co. 1997
- Trolleybus Equipment, Furrey+Frey 2000-07-18
- Private Communication, Peter Price, 2000

Historic practice -
Negative wire min. from kerb, 2.1 - 4m, ie. 25% of road width
Height above road, min. 6.4m or with max. sag, 6m
Maximum longitudinal span, 36.6m, normally 32m
Maximum bracket arm length, 4.9m, ie, max. road width of 7.9m
Running wire gauge, 609.6mm
Collector wire standard, 81.3 sq.mm, 4swg grooved
Mounting system, rigid steel
Voltage, 500 - 600v
Spacers, Steel or wood
Span wire, Steel

Current practice -
Negative wire min. from kerb, 0m
Height above road, typical, 5.4m or with max. sag, 5m
Maximum longitudinal span, 40m, preferred 36m
Running wire gauge, 600-700mm
Collector wire standard, 85-107 sq.mm, 4+ to 6swg grooved
Mounting system, flexible, Kevlar 6mm
Voltage, 600 - 750v
Spacers, aluminium and fibreglass
Span wire, Stainless Steel or Kevlar 10mm

Requirements-
Height above road, 5.4m or with max. sag, 5m
Maximum longitudinal span, 40m
Running wire gauge, 700mm
Collector wire standard, 70 sq.mm, 3swg grooved
Mounting system, flexible
Voltage min. 1000v

Considerations -
A reduction in diameter of the running wire has advantages of less visual intrusion and greater cost effectiveness. Power carrying ability and mechanical strength need to be assessed. Current maybe reduced to give an equal power capacity by increasing voltage.

a)Power

Theoretical current rating of 4swg grooved wire, at 600v

rating	temperature rise	max. temperature	copper	copper cadmium
continuous	40ºC	75ºC	380amp/228kw	365amp/219kw
short term (3')	115ºC	150ºC	660amp/396kw	640amp/384kw

Practical ratings are given as 2500amps/sq inch at min. voltage, 500v = 315amp/158kw

Theoretical current rating of 3swg grooved wire, at 1200v

rating	temperature rise	max. temperature	copper	copper cadmium
continuous	40ºC	75ºC	330amp/396kw	378amp/219kw
short term (3')	115ºC	150ºC	680amp/396kw	660amp/384kw

Practical ratings are given as 2500amps/sq inch at min. voltage 1000v = 272amp/272kw

The power capability of 3swg wire at a higher line voltage is increased over 4swg wire and is therefore suitable. An equivalent voltage to give equal power would be 581v. If line voltage can be prevented from ever dropping below this value, or more practically 600v, then 3swg wire is capable of supplying power. If greater demands are placed on the system then line voltage in range of 700-800v may be suitable. Increasing line voltage may also be advantageous to lengthen isolated sections to save costs, but with a trade-off of less operational flexibility.

b)Mechanical

The maximum sag in the running wire is given as 305mm. Assuming the use of Copper Cadmium with greater breaking strength and to minimise tension, the maximum values of sag and tension needed at various temperatures are -

4 swg based on 33.3% reduction for wear and on breaking load divided by a safety factor of 2

temperature ºC	36m span		40m span	
	tension, kg	sag, mm	tension, kg	sag, mm
-5	1134	107	1321	107
15	788	152	924	152
38	476	249	566	249

Nominal breaking load of 66% of 4swg = 2222kg, ie. permitting 152mm sag

3 swg based on 33.3% reduction for wear and on breaking load divided by a safety factor of 2

temperature ºC	36m span		40m span	
	tension, kg	sag, mm	tension, kg	sag, mm
-5	974	107	1143	107
15	681	152	800	152
38	417	249	490	249

Nominal breaking load of 66% of 3swg = 1969kg ie. permitting 152mm sag

The mechanical characteristics of 3swg wire equal 4swg in that the decrease in weight corresonds to lower breaking load. With a greater line gauge, greater sag would be permissable to avoid shorting in winds, but would increase the likelihood of dewirement. This might preclude 40m span lengths.

c)Span wires

Loads on poles, imposed by span wires are dependant on running wire and hanger weight plus the cross span wire itself. Loads in kg are -

36m running span	Light fittings, 3SWG running wire	Light fittings, 4SWG running wire	traditional fittings, 4SWG running wire
Running wire weight	22.45	25.98	25.98
4x single ear hangers	5.44	5.44	
2x double hangers			13.61
Sub total	27.89	31.43	39.59
cross wire and shackles	1.99	1.99	3.29
Running wire from pole	12m	12m	12m
Sag	.5m	.5m	.5m
Cross span	18.3m	18.3m	18.3m
Load to pole	208.47	234.75	334.29
Cross wire size	6swg	6swg	7swg
Break strength	552	552	926

Kevlar equivalents have equal strength, half the weight but greater elongation. 6mm cable is commonly used.

Conclusions -
With an increase in line voltage of 800-1000v, the current can be reduced, resulting in smaller running wire that will still have sufficient strength to provide reliable service. Advantages of cost and visual intrusion can be gained, together with smaller, lighter fittings that can be re-designed to be reduced in size and mass by a factor of 80%.

Appendix.

Comparison of cable strengths (US data) -

Cable	Nominal Diameter In.	Breaking Strength Lbs	Weight per 100' Lbs	Elongation Per 100'	% Elongation
3/16" 1 x 7 EHS steel	.1875	3990	7.3	6.77	.56%
1/4" 1 x 7 EHS steel	.25	6700	12.1	3.81	.32%
HPTG6700 Kevlar	.22	6700	3.1	13.20	1.10%
HPTG8000 Kevlar	.29	8000	3.5	8.90	.74%
5/16" 1 x 7 EHS steel	.31	11200	20.5	2.44	.20%
HPTG11200 Kevlar	.32	11200	5.5	5.45	.45%
3/8" Fibreglass	.375	13000	9.7	5.43	.45%
HPTG15400 Kevlar	.36	15400	6.9	4.93	.41%