Design Criteria Implementation for the Network Development Plan – Hursthill Substation

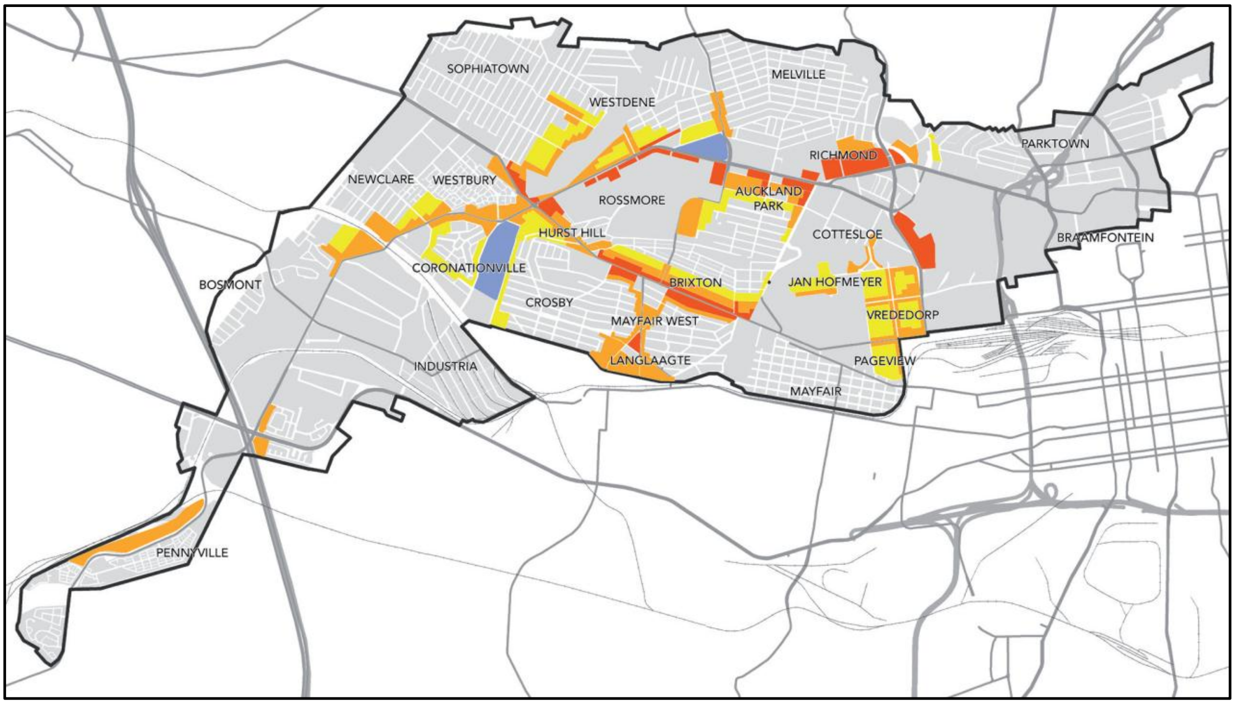
Presenter : Riaan Swanepoel PRTechEng

1 Introduction

The City of Johannesburg is embarking on a new spatial vision for the City in line with its growth and development strategy 2040, based on Corridor Orientated Development. This approach envisage that growth of the future City will be guided by well-planned transport corridors allowing for high densified mixed residential developments in close proximity to affordable transport nodes. The high residential developments must be supported by commercial and retail developments to support work and leisure opportunities.

The legacy spacial planning left the City with sprawling low density areas without a viable public transport system. The majority of poor and working class citizens still live on the fringes of the City, resulting in long distances to travel to work at a high expense. The National Household Travel (2003) conducted by Stats SA found that the average travel time for commuters making use of public transport is 59 minutes. This excludes the time to walk to the designated pick-up or dropped of points. For a Johannesburg resident staying in an area like Diepsloot or Orange Farm, it means waking up before dawn to ensure getting to work on time in the CBD or Northern suburbs.

One of the proposed corridors is the Empire Perth Corridor. The proposed corridor will create a link between Soweto and the Northern Business areas like Rosebank and Parktown. The role of City Power will be to create a favourable environment along the corridor by ensuring adequate capacity exists for the development of high density residential and commercial zones along the Corridor of Freedom. Within the current focus area affected by the COF, the population count is 25 242. With the creation of the corridor the expected future population count for the focus area will be 155 245.



2 Hursthill Area

The proposed developments cover various substation zones within the City Power supply area. A key focus area within the Hursthill substation area will be used to discuss the change in planning philosophy to accommodate the increase in demand in a small area.

Hursthill substation Area is 99km². It is a fully build up area with 42604 residential customers and 941 Large Power Users. The areas have limited commercial developments, and include areas like Auckland Park where key customers like SABC, University of Johannesburg, Helen Joseph and Milpark hospitals are housed.

The area is fully utilised and an increase in the demand at the substation is mainly due to the natural growth of the existing customers and not new developments to date.

3 Planning Methodology

The existing City Power Electricity grid system is a mixture of various methodologies been used by different municipalities. It does mean that different methodologies do exist throughout the network and cognisance must be taken when future network development plans are implemented.

The Hursthill substation falls within the Central Grid of City Power. Capacity is purchased from Eskom at 275kV at Fordsburg substation. The capacity is stepped down to a voltage of 88kV. The capacity is transferred to Orlando switching station from where radial feeds provide capacity the relevant substations. The transmission grid always operates at N-1 condition ensure the load to any substation will not exceed the current carry capacity of 1 overhead line. Each substation also has an independent standby transformer able to carry the capacity of any 11kV feederboard at the station in case of an outage/loss of a transformer. Hursthill substation is equipped with 3 x 45 MVA 88/11kV transformers. The existing demand at the substation is approximately 80MVA. The Substation has been identified in the Transmission Masterplan for the installation of an additional Power transformer and 11kV feederboard at a later stage. With the initiative to establish the Corridors of Freedom, the planned upgrade will have to be brought forward and an additional substation will be required.

All the proposed developments in the Hursthill area will be in close proximity to the existing substation. The network development plan for the area must consider methods to develop the electrical infrastructure in the area. A section of the proposed development will form the basis of the distribution planning methodology that will be used in the area. For ease of reference it will be called Area A.

3.1 Determining the diversified demand usage in Focus area A

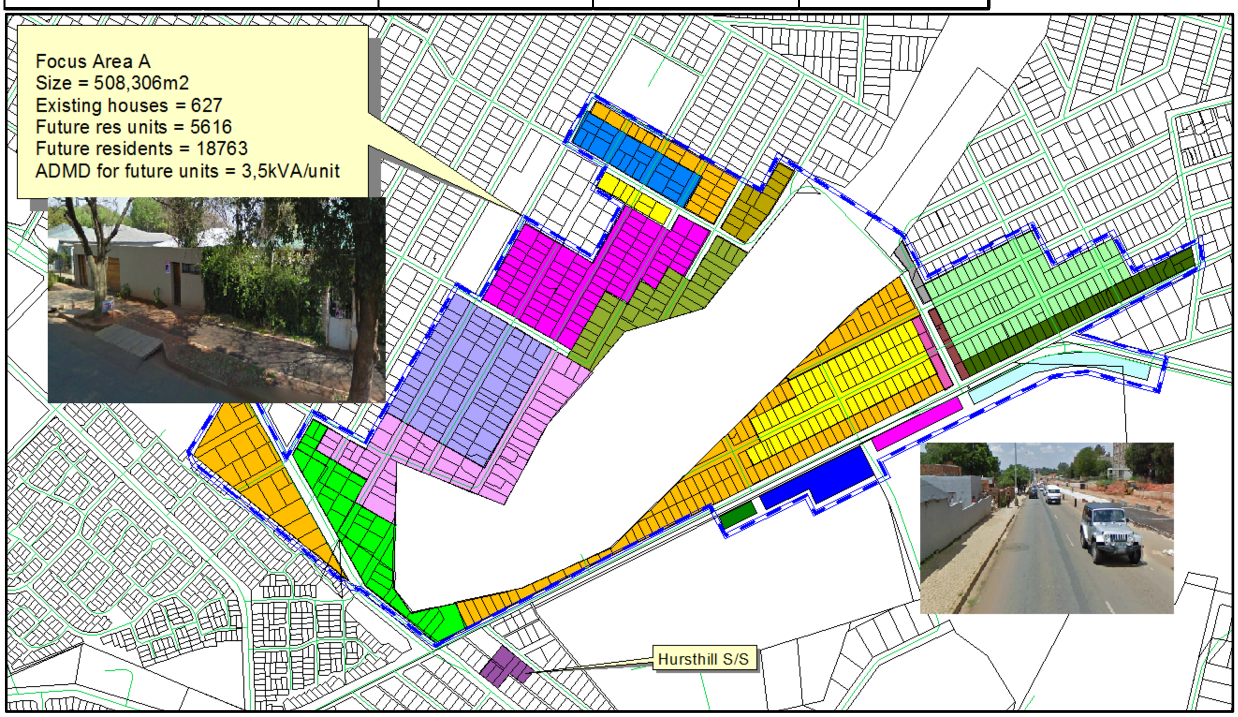
The focus area is located North West of the Hursthill Substation. It is directly adjacent to the Bus Rapid Transit route making it an ideal area for the densification and redevelopment of residential units. At the present moment, the area is zoned as residential one units and utilisation coverage of the houses is about 70%.

The ADMD from the latest Load centre/MSS readings indicates that individual residential units are using between 5 and 6kVA at the local load centre/MSS. The units are all zoned as “Residential 1” and the typical stand size is in the region of 250m² with a FAR of 70%. The proposed developments are all to be zoned as “Residential” 3 and 4 areas, with target densities between 80 and 220 dwelling units per hectare. This results in a tenfold increase for the housing requirements within the existing developed area which will result in smaller apartments with less energy requirements. The typical ADMD load profiles for low to middle income groups living in medium to high rise buildings is between 2.1 to 2.85 ADMD. The design allows for an ADMD of 3.5KVA at MV distributor level, allowing for 23% growth per load allocation.

A key factor to consider is the limited space on the sidewalks, along the main BRT corridors the sidewalks are limited to about a meter, while on secondary roads it is roughly between one and two meters. The sidewalks contain all other services (Water, Telkom, Fibre and Sewer) and the ability to install new cables is limited.

The existing distribution network in the area is also more than 40 years old. Part of the new design must consider the possible replacement of the existing networks. These proposed developments will all be driven by private development. This will result in sporadic development within the defined area and exactly what each development will consist of is not known. For the design City Power will use the maximum rezoned density that the City will allow in the RSDF and develop a network that can accommodate 100% re-development of the area.

LOAD REFERENCE	DENSITY TARGET (DPH)	DWELLINGS FUTURE	FUTURE POPULATION	MVA @ 3,5KVA/UNIT
21	100	204.59	724.77	0.72
22	120	334.95	1076.84	1.17
23	80	70.79	257.37	0.25
24	80	147.79	530.37	0.52
25	100	180.96	638.88	0.63
26	80	364.03	1302.08	1.27
27	80	265.94	971.81	0.93
53	130	337.43	1099.28	1.18
54	80	340.62	1246.85	1.19
55	100	83.59	286.78	0.29
56	220	133.31	399.94	0.47
57	220	378.37	1135.12	1.32
58	220	191.18	573.55	0.67
59	220	328.72	986.17	1.15
74	100	379.23	1296.68	1.33
81	150	91.10	300.29	0.32
82	150	104.79	353.36	0.37
83	180	95.14	303.43	0.33
84	180	981.11	3240.33	3.43
85	150	412.27	1380.80	1.44
97	150	190.86	662.58	0.67
TOTAL		**5617**	**18767**	**20**



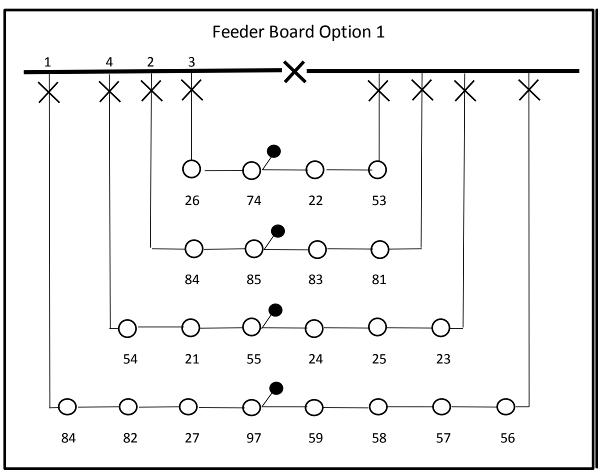
3.2 Distribution networks (Capital Cost Considerations)

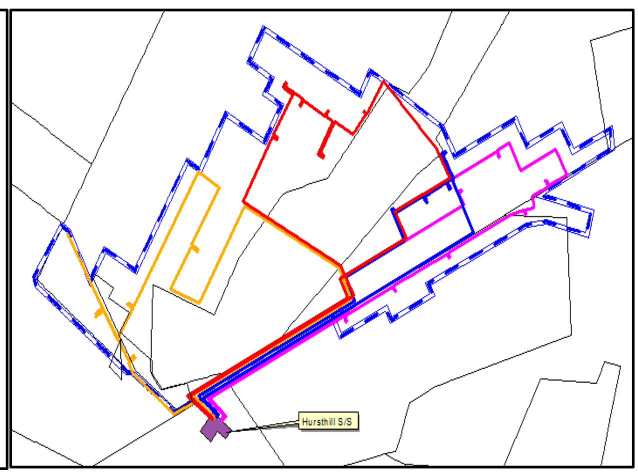
Method 1

The conventional distribution network for City Power can be summarised as follows. The majority of City Power's distribution network operates at 11kV. For main or radial ring systems, City Power use 185mm² x 3c Cu or 300mm² x 3c Alu cables. The designed capacity City Power use per cable is 6MVA. Cables are normally loaded to 5 MVA allowing about 15% for natural growth.

At a substation a 11kV feederboard consist of 2 x 2500A Incomers, 1 x 2500A Bus section and 14 x 800/630A distribution feeders. Two 45 MVA transformers are connected to a feederboard, one to provide the capacity, while the other floats and will be connected with an automated chop over scheme if the feeder transformer trips. Seven feeders are connected on one side of the bus section and return via the area to the same feeder board. Loading each of the rings to a maximum of 6MVA results in a maximum demand of 42 MVA per feederboard with full N-1 contingency. The scheme is a very reliable scheme and the utilisation factor of the cables and breakers are 50%.

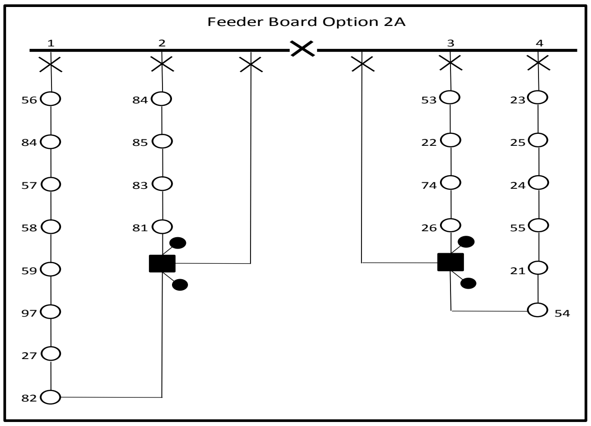
Four (4) Ring feeders will be required to reticulate the focus area. Each ring feeder design will allow for a maximum connected demand of 5MVA allowing spare capacity for future growth. The total length of MV cable required will be 13,5km utilising 8 switches at the feederboard. Using this scheme within the Hursthill Substation area, will result in a total cable requirement of 65km and 26 new 11kV feeders breakers (2 x feeder boards) at the substation. This will become impractical at both the substation and sidewalks to install all additional services.

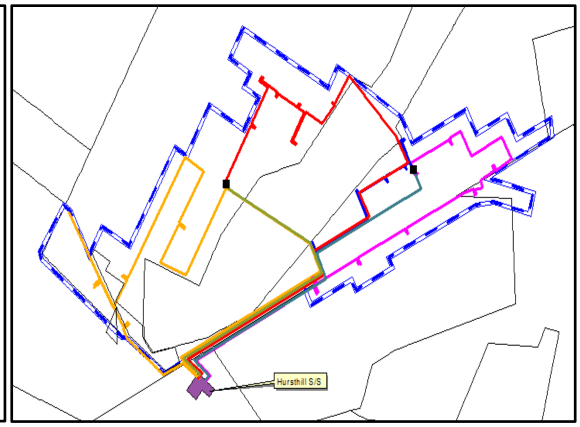




Method 2

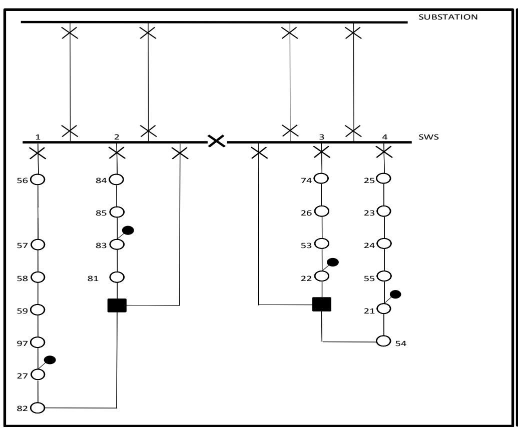
Another approach is to utilize a pure standby distributor within the area. The standby distributor have no load connected to it and are connected to two radial distributors. Each radial distributor can now be loaded to 5MVA as the standby will provide full feedback capacity in case of a first port of call fault. This is done by a three leg design, allowing full N-1 contingency but the third leg will not have a backup supply if an independent fault occurs on the third leg. This option does allow for a saving in capital cost and limit the amount of infrastructure required. Although six cables circuits are required it still proves a problem with the total amount of switches required and available sidewalk space along the BRT route for the cables to be installed. The control point will be at a suitable end point of the distributors. A key disadvantage to consider is the number of customers affected when a first port outage occurs on a distributor as shown below. In Option 1 about 40% less customers will be affected on a distributor outage than in option 2. The affects can be mitigated by moving the open points into the distributors, changing the system from a single point operating system to a two/dual point operating design.

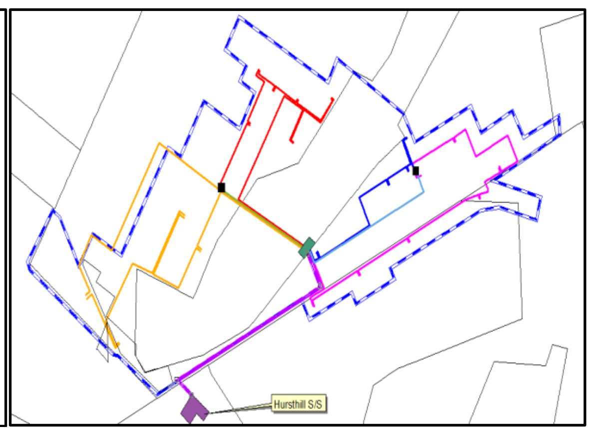




Method 3

Another approach is to create a switching station within the focus area. It will allow for the least amount of 11kV feeders required at the substation which is imperative for the specific application. The feeder cables to the switching station can all operate in parallel, allowing a feeder cable, from the Substation to the switching station, to trip without affecting the customers downstream. Installing 4 x 300mm 3c cu XLPE cables will ensure a firm capacity of 27MVA. With four distributors loaded at 6MVA, the switching station will still be within firm capacity limits.





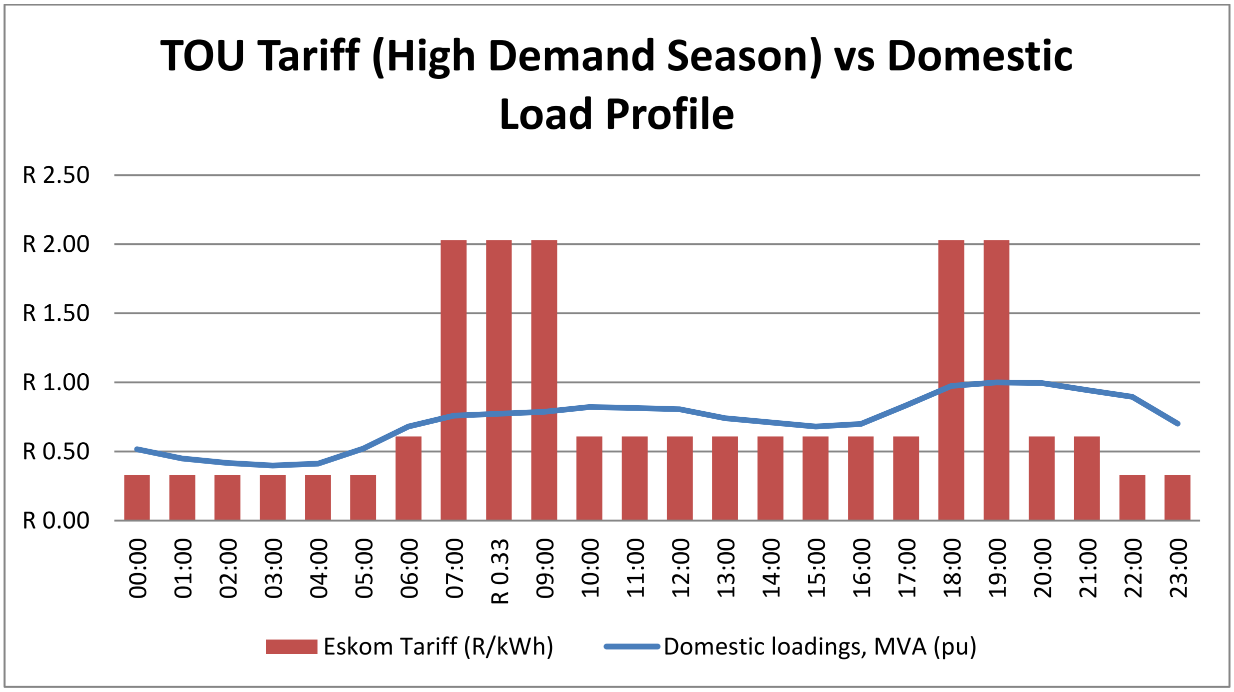
From a pure capital point, Option 1 is the most expensive option. It requires the most amount of cable and switches at a substation. With the standard substation design that City Power implement, the limit of available switches per substation will be exceeded. A big limitation factor is the number of cables to be installed in the road reserve. All the Utilities associated with the City will have to upgrade services to accommodate the proposed amount of people that will reside in the area, thus space on the limited road reserve area will be at a premium.

Design Comparison										
							Capital Cost Summary of Focus Area A			
Design Option	Number of Distributors @ S/S	Total length of 300mm Cu	Total length of MV cable 300 Alu	Usage Factor Dist	Number of Dist's for COF in HH S/S area	Additional Feeder boards Req	Focus Area Cable Requirement @R1000/m	Substation 11kV Breaker Cost @ R270k/CB	SWS Breaker @ R 270k/CB	Sub Total
1	8	0	13535	50%	26	2	R 13 535 000.00	R 2 160 000.00	R 0.00	R 15 695 000.00
2	6	0	10827	67%	18	1.5	R 10 827 000.00	R 1 620 000.00	R 0.00	R 12 447 000.00
3	4	2892	7614	67%	12	1.5	R 11 084 400.00	R 1 080 000.00	R 2 700 000.00	R 14 864 400.00

3.3 Technical losses within the distribution networks

One of the biggest factors to consider is the I^2R losses that are experienced when current flows through the distribution network. By designing the network into different configurations, these technical losses can be reduced which means a saving in operating cost to the service provider.

Considering the SCADA data in the area and taking a load profile of these typical residential feeders, it can be seen that the highest demand is experienced between 7 and 10 in the morning and then again between 6 and 8 in the evenings. Eskom also charge City Power on a Time of use tariff scheme, resulting in the highest charges being enforced during these peak periods.



Making the following assumptions, that the load will be constant over an hour period and that the resistive component of a cable is constant, we can consider what the typical I^2R loss over a designed network will be. This value will change on a daily basis as the demand usage of an area is consumer usage dependant and that open points in the networks can change. For the comparison the network will be assumed to be un-changed over a 24hour period and the maximum future demand envisaged for the area over the respective distributors will be used.

With Option 1, the cable installed in the ground is about 25% more than the cable used in option 2 or option 3. This is because 8 feeders are installed compared to the 6 in the other options. The distributors are however less loaded which will influence the I^2R losses the cable network will experience. Option 2 requires less cable and the total cable network resistance will be lower, but the current component, which is the main factor, is higher as each distributor operates at a higher MVA loading. This can be mitigated by changing the open points in the network from a single operational point to a two operational point system similar as shown in the switching station design. This will require longer outage periods as operators will have to change two possible open points but the saving in operational costs validates the practice. Option 3 use minimal cables to transfer capacity from the substation to the focus area, these feeder cables are permanently under a high load as they are the main capacity transfer network. The rings from the switching station will have fewer losses as these rings are relatively short.

Network losses experience during peak loading	
Option	**% Increase from lowest**
Option 1	-
Option 2	186%
Option 3	120%
Option 2 with two open point design	108%

3.4 Conclusion

From the above it can be seen that option 2 is the most cost effective option for a new installation. The design will require long distributors from the substation and it does carry a risk of a large number of customers being affected if cables are damaged close to the substation. Option 1 will operate with the least amount of technical losses on a continuous basis, but it does require a high capital cost to install and may not always be feasible to accommodate at the substation level.

With the practical limitation of road reserve space Option 3 is seen to be the best solution, with a cable spacing of 200mm, the four circuits will comfortably fit within the relative small road reserves. It also allows operators to trace and restore cable faults on short ring systems, cutting down on restoration time. All faults can also be operated locally at the switching station and will prevent complete feederboard trips if the feeder breaker fails to operate, thus no large loss of supply from a complete feederboard.