CHAPTER 9

POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF

TABLES

FIGURES

Chapter - 9

POWER SUPPLY

SYSTEM OF TRACTION AND POWER TARIFF

9.1 POWER REQUIREMENTS

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc) workshops, depots & other maintenance infrastructure within premises of metro system. The power requirements of a metro system are determined by peak-hour demands of power for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following requirements:-

(i) Specific energy consumption of rolling stock – 75 KWh/1000 GTKM
(ii) Regeneration by rolling stock – 30%
(iii) Elevated station load – initially 250KW, which will increase to 400 KW in the year 2041
(iv) Underground Station load – initially 2000 kW, which will increase to 2500 kW in the year 2041
(v) Depot auxiliary load - initially 2000 KW, which will increase to 2500 KW in the year 2041

Keeping in view of the train operation plan and demand of auxiliary and traction power requirements projected for the year 2016, 2021, 2031 and 2041 are summarized in table **Table 9.1** below:-

Table 9.1: Power Demand Estimation (MVA)

Corridor		Year			
		2016	2021	2031	2041
North-South Corridor – 1 Automotive Sqre to Khapri Station. [19.658 kms & 17 Stations (15 Elevated, 2 at Grade)].	Traction	4.32	5.01	5.84	7.16
	Auxiliary	7.72	7.84	9.14	11.49
	Total	12.04	12.85	14.98	18.65
East-West Corridor – 2 Prajapati Nagar to Lokmanya Nagar [18.557 kms & 19 Elevated Stations].	Traction	4.24	4.57	5.73	7.01
	Auxiliary	8.34	8.46	9.88	12.48
	Total	12.58	13.03	15.61	19.49

Detailed calculations of power demand estimation are attached at **Annexure 9.1**

9.2 NEED FOR HIGH RELIABILITY OF POWER SUPPLY

The Nagpur metro system is being designed to cater to crush load about 17000 passengers per direction during peak hours when trains are expected to run at 3.5 minutes intervals in 2041. Incidences of any power interruption, apart from affecting train running, will cause congestion at stations. Interruption of power at night is likely to cause alarm and increased risk to traveling public. Lack of illumination at stations, non-visibility of appropriate signages, disruption of operation of lifts and escalators is likely to cause confusion, anxiety and ire in commuters, whose tolerance level are low on account of stress. Effect on signal and communication may affect train operation and passenger safety as well. Therefore, reliable and continuous power supply is mandatory for efficient metro operations.

To ensure reliability of power supply, it is essential that both the sources of Supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. It is desirable to obtain power supply at grid voltage of 220KV, 132 KV or 66kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority themselves.

9.3 SELECTION OF TRACTION SYSTEM

On techno-economic consideration, it is recommended to adopt 25 KV single phase AC Traction. In addition it has the following merits.

- Lower initial cost.
- Lower operating and maintenance cost as in case of 25 KV ac traction the regeneration is up-to 30% and the line losses are around 0.5% in comparison to D.C. losses up-to 6 – 7%.

- A.C. system poses lesser Fire hazards as current levels are much lower than D.C.
- No Stray current problems and hence the corrosion is controlled.

9.4 SOURCES OF POWER SUPPLY

The high voltage power supply network of Nagpur City has only 220kV and 132kV network on the periphery of the city to cater to various types of demand in vicinity of the proposed corridor. 220/132 kV sub stations are far away from the alignment and therefore, it involves substantial cable and it's laying cost.

Keeping in view the reliability requirements, two input sources of 220 kV or 132KV Voltage level are normally considered for each corridor. Therefore, to achieve the desired reliability, two Receiving Sub Stations (132/33/25 kV or 220/33/25 KV) are proposed to be set up for each Corridor – 1 & Corridor – 2. The intersection of the two corridors will be at Sitaburdi station (Elevated station of Corridor – 1).

It is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations at 220/132kV through cable feeders.

A meeting was convened by with the officials of Maharashtra State Electricity Board and DMRC on dated:-09.10.2012. As per MSEDCL letter No./CE/NUZ/Tech/1379, dated:-01.12.2012 has confirmed the following power sources for the Nagpur Metro.

Table 9.2: Sources of Power Supply

Corridor	Grid sub-station (with Input voltage)	Location of RSS of Metro Authority	Approx. length of cables
North-South Corridor – 1 Automotive Sqre to Khapri Station.	1. 132 KV Uppalwadi Grid Sub-station.	2 x 132 KV bays near Automotive station	7 route km, 132 kV (Double Circuit cables).
	2. Proposed 220 KV Butibori Grid Sub-station.	2 x 220 KV bays at Khapri Station	4 route km, 220kV (Double Circuit cables).
East-West Corridor – 2 Prajapati Nagar to Lokmanya Nagar.	3. LILO of proposed 132 KV Pardi-Jattarodi ckt.	2 X132 KV bays near Prajapati Nagar station	4 route km, 132 kV (Double Circuit Cables).
	LILO of proposed 132 KV Hingna – Lendra Ckt.	2 x 132 KV bays near Suhash Nagar station	10 route km, 132 kV (Double Circuit Cables).

As the power supply is available at 220 KV and 132 KV levels that too at a substantial distance from the alignment, one sub-station of each line to be considered with one set of transformers and add another set as the traffic grows.
The above sub-stations are being considered as a conventional sub-station. In case a 220 KV or 132KV GIS is to be provided, there will be an additional cost of Rs. 20 Crores or 15 Crores per sub-station respectively.

Summary of expected power demand at various sources is given in **Table 9.3**.

Table 9.3: Power Demand Projection for various sources

Corridor	Input Source / Receiving Sub Station (RSS)	Peak Demand – Normal (MVA)				Peak Demand – Emergency (MVA)			
		2016	2021	2031	2041	2016	2021	2031	2041
North-South Corridor – 1 Automotive Sqre to Khapari	**At Depot near Khapri station**								
	Traction	2.60	2.75	3.50	4.30	4.32	4.65	5.84	7.16
	Auxiliary	4.62	4.70	5.54	6.89	7.72	7.84	9.14	11.49
	Sub – Total (A)	7.22	7.45	9.04	11.19	**12.04**	**12.50**	**14.98**	**18.65**
	Near automotive station								
	Traction	1.72	1.90	2.34	2.86	04.32	04.65	05.84	07.16
	Auxiliary	3.10	3.14	3.60	4.60	07.72	07.84	09.14	11.49
	Sub – Total (B)	4.82	5.04	5.94	7.46	**12.04**	**12.50**	**14.98**	**18.65**
	TOTAL (A + B)	**12.04**	**12.49**	**14.98**	**18.65**				
East-West Corridor – 2 Prajapati Nagar to Lokmanya Nagar .	**Near Subhash Nagar station**								
	Traction	2.54	2.77	3.43	4.21	4.21	4.57	5.73	7.01
	Auxiliary	5.00	5.06	5.98	7.48	7.48	8.46	9.88	12.48
	Total	7.54	7.83	9.41	11.69	**12.58**	**13.03**	**15.61**	**19.49**
	Near Prajapati Nagar station								
	Traction	1.70	1.80	2.30	2.80	4.21	4.57	5.73	7.01
	Auxiliary	3.34	3.40	3.90	5.00	7.48	8.46	9.88	12.48
	Total	5.04	5.20	6.20	7.80	**12.58**	**13.03**	**15.61**	**19.49**
	TOTAL (A + B)	**12.58**	**13.03**	**15.61**	**19.49**				

The 220 kV or 132 KV power supply will be stepped down to 25kV single phase for traction purpose at the RSS of Nagpur Metro and the 25kV traction supply will be fed to the OHE at viaduct through cable feeders. For feeding the auxiliary loads, the 220/33 kV or 132/33 KV power supply received will be stepped down to 33 kV and will be distributed along the alignment through 33kV Ring main cable network. These cables will be laid along the viaduct and tunnel walls. If one RSS trips on fault or input supply failure, train services can be maintained from the other RSS. In case of total grid failure, all trains may come to a halt but station lighting & other essential

services can be catered to by stand-by DG sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well.

Fig. 9.1 : Typical High Voltage Receiving Sub-station

The 220 kV or 132 KV cables will be laid through public pathways of Maharasthra Grid Sub-stations to RSS of Metro Authority. For corridor – 1, one substation near Automotive station shall be provided with 2nos. (one as standby) 132/25 kV, 10 MVA single-phase traction Transformers for feeding Traction and 132/33 KV, 15 MVA three phase Transformers for feeding auxiliary loads and other near Khapri Depot shall be provided with 2nos. (one as standby) 220/25 kV, 10 MVA single-phase traction Transformers for feeding Traction and 220/33 KV, 15 MVA three phase Transformers for feeding auxiliary loads. For corridor – 2, one RSS near Subhash Nagar and other RSS near Prajapati Nagar station shall be provided with 2nos. (one as standby) 132/25 kV, 10MVA single phase traction Transformers for feeding Traction supply and 132/33 KV, 15 MVA three phase Transformers for feeding auxiliary loads. Interconnection will provide at 33KV & 25KV level to meet emergency requirement at Sitaburdi in case of failure of two RSS of any one corridor. The capacity of transformers may be reviewed considering the load requirement/distribution of both the corridors at the time of detailed design.Conventional Outdoor type 132 kV Switchgear is proposed for RSS's to be located in approx. 100 X 100 m (10000 sq. mtr.) land plot and for 220 KV

Conventional Outdoor type switchgear is proposed for RSS to be located in 120 x 100 m (12000 sq.mtr.). The availability of land in depot area may not be a constraint.The land at Automative station, Subhash Nagar and near Prajapati Nagar station to be allocated. Requirement of land for 220 KV GIS substation will be approx. 70 X 80 m (5600 sq. m) and for 132 KV GIS substation land requirement will be approx. 60 X 70 m (4200 sq. m) but the cost of substation works will increase by nearly Rs. 20 Crore and 15 Crores respectively. 220/132 kV Grid sub stations are far away from the alignment and therefore, it involves approx. Rs.20 Crores extra cable and it's laying cost.

9.5 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS & DEPOT

Auxiliary sub-stations (ASS) are envisaged to be provided at each station (2 ASS's for Underground stations and 1 ASS for elevated station) for stepping down 33 kV supply to 415 V for auxiliary applications. A separate ASS is required at depot. The station ASS's will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 250kW for elevated / at-grade stations which is likely to increase up to 400 KW in the year 2041 and 2000 kW for Underground Station which is likely to increase up to 2500 KW in the year 2041. In order to meet the requirement of auxiliary power two dry type cast resin transformers (33/0.415kV) of 500kVA capacity are proposed to be installed at the elevated stations (one transformer as standby) and two transformer of 2.5 MVA at each underground ASS. For Property Development within the footprints of the station, a provision to add third transformer at a later date may be kept at elevated station.

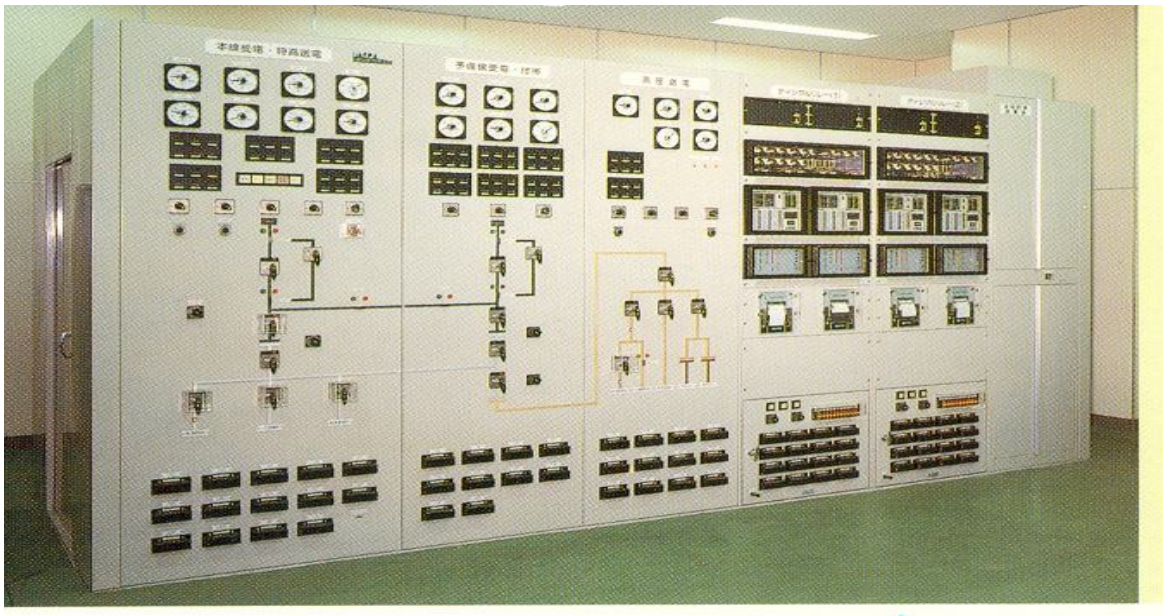

Fig. 9.2 : Typical Indoor Auxiliary Sub-station

9.6 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

25kV ac traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Booster Transformer and Return Conductor (BT/RC) System is proposed for EMI mitigation. Concrete structures of elevated viaducts are not good electrical earths and therefore, Earthing and Bonding of the traction system shall be in accordance with the latest standards EN50122-1, IEEE80 and other relevant standards. Two earth conductors –Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC) are proposed to be laid along with elevated via duct and all the metallic structures, structural reinforcement, running rails etc will be connected to these conductors to form an equiv-potential surface & a least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25kV OHE and the elevated viaduct.

Detailed specification of equipment e.g. power cables, transformer, switchgear, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecomm, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.

9.7 25KV FLEXIBLE OVERHEAD EQUIPMENT (OHE) SYSTEM

25kV ac flexible OHE system shall comprise 150/107 sqmm Hard drawn copper contact wire and 65 sq.mm Cd-copper catenary wire. Return conductor (RC) shall be All Aluminum Conductor (AAC) of 233 sq.mm cross section. From safety considerations, Hydraulic type Anti-Tensioning Device (ATDs) are proposed on mainlines which does not require use of balance weight for tensioning of OHE conductors. Proven catenary fittings are proposed similar to DMRC system.

9.8 RATING OF MAJOR EQUIPMENT

25kV ac Overhead Equipment (OHE) shall comprise 107mm^2 HD-copper contact wire and 65 mm^2 Cd-copper catenary wire. Return conductor (RC) shall be All of OHE conductors.

Based on emergency demand expected at each RSS as shown in Table 9.3, 2 nos. 220 or 132/25kV traction transformers of 10 MVA capacity and 2 nos. 132/33 KV, 15 MVA capacity Auxiliary transformers shall be provided at each RSS in Corridor –I and 2 nos. 132/25kV traction transformers of 10 MVA capacity and 2 nos. 132/33 KV, 15 MVA capacity Auxiliary transformers shall be provided at each RSS in

Corridor –II, being standard design (one to be in service and second one to serve as standby). The 132kV incoming cable 3-phase single core XLPE insulated with 630 mm^2 Aluminum conductor for corridor-1 & Corridor-2 and 220kV, 3-phase single core XLPE insulated with 800 mm^2 Aluminum conductor for corridor-1 shall be used to meet the normal & emergency loading requirements and fault level of the 132 kV and 220 KVsupply.

33kV and 25kV switchgear shall be rated for 1250 A being standard design. 33kV cable ring network shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations and accordingly 3 number of Single core 150 mm^2 FRLSH Aluminum conductor cable XLPE insulated 33kV cable is proposed for ring main network.

Adequate no. of cables are required for transfer of traction power from Metro's RSS to 25kV OHE. Single-phase XLPE insulated cables with 240mm^2 copper conductor are proposed for traction power. Based on current requirements, 2 cables are required for each of the two circuits to feed power to OHE.

The above capacities of transformers, switchgear, cables etc. have been worked out based on the conceptual design. Therefore, these may be required to be revised for better accuracy during design stage of project implementation.

9.9 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide a standby DG set of 200 KVA capacity at the elevated stations and 2 X 1250/750 KVA at Underground stations to cater to the following essential services:

(i) Essential lighting
(ii) Signaling & telecommunications
(iii) Fire fighting system
(iv) Lift operation
(v) Fare collection system
(vi) Tunnel Ventilation (for Underground Stations)

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

9.10 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs)

shall be provided. Optical fibre provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 33kV ac switchgear, transformers, 25kV ac switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

9.11 ENERGY SAVING MEASURES

Energy charges of any metro system constitute a substantial portion of its operation & maintenance (O & M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement during initial years of operation. Subsequently, traction power consumption increases with increase in train frequency/composition in order to cater more traffic. The proposed system of Nagpur Metro includes the following energy saving features:

(i) Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.

(ii) Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25kV ac OHE to be consumed by nearby trains.

(iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100%) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc).

(iv) Machine-room less type lifts with gearless drive have been proposed with 3-phase VVVF drive. These lifts are highly energy efficient.

(v) The proposed heavy-duty public services escalators will be provided with 3-phase VVVF drive, which is energy efficient & improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by passengers.

(vi) The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc) has been incorporated in the system design.

(vii) Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

(viii) LED lighting is proposed in certain areas

9.12 ELECTRIC POWER TARIFF

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25 – 35% of total annual working cost. Therefore, it is the key element for the financial viability of the project. The annual energy consumption is assessed to be about 36 million units in initial years (2016), which will increase to about 56 Million Units by year 2041 for Corridor – 1 and about 31 million units in initial years (2016), which will increase to 52 Million Units by year 2041 for Corridor – 2. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff be kept at a minimum in order to contain the O& M costs. Therefore, the power tariff for this Corridor should be at effective rate of purchase price (at 132/220 kV voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. This is expected to be in the range of Rs. 5.00 per unit with Rs.125/KVA/month fixed charges. It is proposed that Government of Maharashtra will take necessary steps to fix power tariff for Nagpur Metro at “No Profit No Loss” basis. Financial analysis has been carried out based on this tariff for the purpose of finalizing the DPR. Similar approach is being pursued for Delhi Metro.

MAHA

M. S. ELECTRICITY DISTRIBUTION CO. LTD.

NO:CE/NUZ//Tech/ 13795 Date.: 1 DEC 2012

To,
The Executive Director / Electrical
Delhi Metro Rail Corporation Ltd.
Metro Bhawan, Fire Brigade Lane,
Barakhamba Road,
New Delhi - 1100001

Subject: **Power Supply requirement for Metro Railway at Nagpur City.**

Ref: (1) Y.O.Lt.No. DMRC/Elect/DPR/Nagpur/2012/Part-I/33275 Dt. 29.11.2012.
(2) Meeting held at this office on Dt. 09/10/2012

Dear Sir,

With ref. to above subject and as intimated by Transmission authority, for North – South & East – West Corridor of proposed Nagpur Metro Railway project, the possible 132 KV sources are indicated as follows.

I) 40 MVA requirements for North South Corridor 1

(1) From 132 KV Uppalwadi Sub station to Metro Receiving Station at Automotive Square (North Point).

(2) From proposed 220 KV Butibori- II Sub station to Metro Receiving Station at Depot Station (South Point)

II) 48 MVA requirement for East – West Corridor.

(1) The LILO of proposed 132 KV Pardi – Jattarodi ckt. at Metro Receiving Station at Prajapati Nagar (East Point).

(2) The LILO of proposed 132 KV Hingna I – Lendra ckt. at Metro Receiving Station at Subhash Nagar (West Point)

Further details will be confirmed after receipt of result of Load Flow Studies by State Transmission Utility.

Submitted for further needful please.

CHIEF ENGINEER
NAGPUR URBAN ZONE
NAGPUR.

Copy s.w.rs.to:
The Regional Executive Director-III, MSEDCL, Nagpur.
Copy f.w.c.to:-
The Chief Engineer, EHV CC (O&M) Zone, MSETCL, Nagpur.
Copy to:-
(1) The Superintending Engineer Nagpur Urban / Rural Circle, MSEDCL, Nagpur.
(2) The Superintending Engineer, EHV (O&M) Circle, MSETCL, Nagpur.

349

OFFICE OF THE CHIEF ENGINEER.
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Approximate Energy Consumption	NAGPUR METRO																																			
	CORRIDOR - 2 (East-West)												CORRIDOR - 2 (East-West)												CORRIDOR - 3 (East-West)												Total					
	Prajapati Nagar to Agrasen Chowk												Agrasen Chowk to Subhash Nagar												Subhash Nagar to Lokmanya Nagar												Prajapati Nagar to Lokmanya Nagar					
Year	Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year-2016	Year-2021	Year-2026	Year-2031	Year-2036	Year-2041
LENGTH (KM)	4.76	KM	4.76	KM	4.76	KM	4.76	KM	4.76	KM	4.76	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	18.17	18.17	18.17	18.17	18.17	18.17
No. of trains per direction in a day*	51		54		70		74		83		99		102		108		140		158		166		198		51		54		70		74		83		99							
WEIGHT OF TRAIN & PASSENGER	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T						
SFC (NET) with 30% regen	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM	53	KWH/ 1000 GTKM						
Yearly Traction Energy consumption with 365 days working with 30% regen	**1.70**	**million units**	**1.81**	**million units**	**2.34**	**million units**	**2.47**	**million units**	**2.77**	**million units**	**3.31**	**million units**	**5.86**	**million units**	**6.21**	**million units**	**8.05**	**million units**	**9.08**	**million units**	**9.54**	**million units**	**11.38**	**million units**	**1.87**	**million units**	**1.98**	**million units**	**2.57**	**million units**	**2.71**	**million units**	**3.04**	**million units**	**3.63**	**million units**						
Station aux power requirement																																											
Elevated/at-grade station	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW						
U/G station	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW						
no. of elevated/at-grade stations	6		6		6		6		6		6		9		9		9		9		9		9		4		4		4		4		4		4		19	19	19	19	19	19
no. of U/G stations	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0
Total Station Aux Power requirement	1.50	MW	1.50	MW	1.80	MW	1.80	MW	2.10	MW	2.40	MW	2.25	MW	2.25	MW	2.70	MW	2.70	MW	3.15	MW	3.60	MW	1.00	MW	1	MW	1.20	MW	1.20	MW	1.40	MW	1.60	MW	4.75	4.75	5.70	5.70	6.65	7.60
Depot Aux power requirement	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	2.10	2.20	2.30	2.40	2.50
Total Aux Power requirement	1.50	MW	1.50	MW	1.80	MW	1.80	MW	2.10	MW	2.40	MW	2.25	MW	2.25	MW	2.70	MW	2.70	MW	3.15	MW	3.60	MW	3.00	MW	3.1	MW	3.40	MW	3.50	MW	3.80	MW	4.10	MW	6.75	6.85	7.90	8.00	9.05	10.10
Total Aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	**1.85**	**MVA**	**1.85**	**MVA**	**2.22**	**MVA**	**2.22**	**MVA**	**2.59**	**MVA**	**2.96**	**MVA**	**2.78**	**MVA**	**2.78**	**MVA**	**3.34**	**MVA**	**3.34**	**MVA**	**3.89**	**MVA**	**4.45**	**MVA**	**3.71**	**MVA**	**3.83**	**MVA**	**4.20**	**MVA**	**4.32**	**MVA**	**4.69**	**MVA**	**5.06**	**MVA**	**8.34**	**8.46**	**9.76**	**9.88**	**11.18**	**12.48**
Diversity factor of aux loads	0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40							
Yearly Aux Energy consumption 20 hrs/day and 365 days working (million units)	**4.60**	**million units**	**4.60**	**million units**	**5.52**	**million units**	**5.52**	**million units**	**6.44**	**million units**	**7.36**	**million units**	**6.90**	**million units**	**6.90**	**million units**	**8.28**	**million units**	**8.28**	**million units**	**9.66**	**million units**	**11.04**	**million units**	**9.20**	**million units**	**9.50**	**million units**	**10.42**	**million units**	**10.73**	**million units**	**11.65**	**million units**	**12.57**	**million units**	**20.70**	**21.00**	**24.22**	**24.53**	**27.75**	**30.97**
Net Annual Energy Consumption (Traction & Aux)	**6.30**	**million units**	**6.40**	**million units**	**7.86**	**million units**	**7.99**	**million units**	**9.21**	**million units**	**10.67**	**million units**	**12.76**	**million units**	**13.11**	**million units**	**16.33**	**million units**	**17.36**	**million units**	**19.20**	**million units**	**22.42**	**million units**	**11.07**	**million units**	**11.48**	**million units**	**12.99**	**million units**	**13.44**	**million units**	**14.69**	**million units**	**16.20**	**million units**	**30.13**	**31.00**	**37.18**	**38.80**	**43.11**	**49.29**

POWER REQUIREMENTS	NAGPUR METRO																																			
	CORRIDOR - 2 (East-West)												CORRIDOR - 2 (East-West)												CORRIDOR - 3 (East-West)												Total					
	Prajapati Nagar to Agrasen Chowk												Agrasen Chowk to Subhash Nagar												Subhash Nagar to Lokmanya Nagar												Prajapati Nagar to Lokmanya Nagar					
	Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year-2016	Year-2021	Year-2026	Year-2031	Year-2036	Year-2041
Traction power requirements																																									
No of cars	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)	3	(2DMC +1TC)						
Passenger weight	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T						
Train Tare weight	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T						
Total train weight	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T						
Section length	4.76	KM	4.76	KM	4.76	KM	4.76	KM	4.76	KM	4.76	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	8.19	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	5.22	KM	18.17	18.17	18.17	18.17	18.17	18.17
Headway	13	mts	12	mts	10	mts	9	mts	8	mts	7	mts	6.5	mts	6	mts	5	mts	4.5	mts	4	mts	3.5	mts	13	mts	12	mts	10	mts	9	mts	8	mts	7	mts						
Specific Energy consumption	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM						
No. of trains/hr in both directions	9		10		12		13		15		17.1		18		20		24		27		30		34.29		9		10		12		13		15		17							
Peak traction power requirement	0.60	MW	0.65	MW	0.78	MW	0.87	MW	0.98	MW	1.12	MW	2.08	MW	2.25	MW	2.70	MW	3.00	MW	3.38	MW	3.86	MW	0.66	MW	0.72	MW	0.86	MW	0.96	MW	1.08	MW	1.23	MW						
Less Regeneration @ 30%	0.18	MW	0.20	MW	0.24	MW	0.26	MW	0.29	MW	0.34	MW	0.62	MW	0.68	MW	0.81	MW	0.90	MW	1.01	MW	1.16	MW	0.20	MW	0.22	MW	0.26	MW	0.29	MW	0.32	MW	0.37	MW						
Depot power requirements	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	1.50	MW	1.60	MW	1.70	MW	1.80	MW	1.90	MW	2.00	MW						
Total traction power requirement	0.42	MW	0.46	MW	0.55	MW	0.61	MW	0.69	MW	0.78	MW	1.45	MW	1.58	MW	1.89	MW	2.10	MW	2.36	MW	2.70	MW	1.96	MW	2.10	MW	2.30	MW	2.47	MW	2.65	MW	2.86	MW	3.84	4.14	4.74	5.18	5.70	6.35
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf	**0.47**	**MVA**	**0.51**	**MVA**	**0.61**	**MVA**	**0.67**	**MVA**	**0.76**	**MVA**	**0.87**	**MVA**	**1.61**	**MVA**	**1.74**	**MVA**	**2.09**	**MVA**	**2.32**	**MVA**	**2.61**	**MVA**	**2.98**	**MVA**	**2.17**	**MVA**	**2.32**	**MVA**	**2.54**	**MVA**	**2.73**	**MVA**	**2.93**	**MVA**	**3.16**	**MVA**	**4.24**	**4.57**	**5.24**	**5.73**	**6.30**	**7.01**
Station aux power requirements																																									
Elevated/at-grade station--power consumption	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW						
Underground station--power consumption	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	MW	2.10	MW	2.2	MW	2.30	MW	2.40	MW	2.50	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW						
No. of elevated/at-grade stations	6		6		6		6		6		6		9		9		9		9		9		9		4		4		4		4		4		4		19	19	19	19	19	19
No. of Underground stations	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0
Total Station Aux Power requirement	1.50	MW	1.50	MW	1.80	MW	1.80	MW	2.10	MW	2.40	MW	2.25	MW	2.25	MW	2.7	MW	2.70	MW	3.15	MW	3.60	MW	1.00	MW	1	MW	1.2	MW	1.20	MW	1.4	MW	1.6	MW	4.75	4.75	5.70	5.70	6.65	7.60
Depot Aux power requirement	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW						
Total Aux Power requirement	1.50	MW	1.50	MW	1.80	MW	1.80	MW	2.10	MW	2.40	MW	2.25	MW	2.25	MW	2.7	MW	2.70	MW	3.15	MW	3.60	MW	3.00	MW	3.1	MW	3.4	MW	3.50	MW	3.8	MW	4.10	MW	6.75	6.85	7.90	8.00	9.05	10.10
Total aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	**1.85**	**MVA**	**1.85**	**MVA**	**2.22**	**MVA**	**2.22**	**MVA**	**2.59**	**MVA**	**2.96**	**MVA**	**2.78**	**MVA**	**2.78**	**MVA**	**3.34**	**MVA**	**3.34**	**MVA**	**3.89**	**MVA**	**4.45**	**MVA**	**3.71**	**MVA**	**3.83**	**MVA**	**4.20**	**MVA**	**4.32**	**MVA**	**4.69**	**MVA**	**5.06**	**MVA**	**8.34**	**8.46**	**9.76**	**9.88**	**11.18**	**12.48**
Total traction & aux power requirement (MVA)	**2.32**	**MVA**	**2.36**	**MVA**	**2.83**	**MVA**	**2.90**	**MVA**	**3.35**	**MVA**	**3.83**	**MVA**	**4.39**	**MVA**	**4.52**	**MVA**	**5.42**	**MVA**	**5.66**	**MVA**	**6.50**	**MVA**	**7.43**	**MVA**	**5.88**	**MVA**	**6.15**	**MVA**	**6.74**	**MVA**	**7.05**	**MVA**	**7.63**	**MVA**	**8.2**	**MVA**	**12.58**	**13.03**	**15.00**	**15.61**	**17.48**	**19.49**

Approximate Energy Consumption

NAGPUR METRO

CORRIDOR - 1 (North-South)

	Automotive Sqre to Congress Nagar												Congress Nagar to Khapari												Automotive Sqre to Khapari					
Year	Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year-2016	Year-2021	Year-2026	Year-2031	Year-2036	Year-2041
LENGTH (KM)	7.90	KM	7.90	KM	7.90	KM	7.90	KM	7.90	KM	7.90	KM	11.35	KM	11.35	KM	11.35	KM	11.35	KM	11.353	KM	11.35	KM	19.25	19.25	19.25	19.25	19.25	19.25
No. of trains per direction in a day*	102		108		140		158		166		198		51		54		70		74		83		99							
WEIGHT OF TRAIN & PASSENGER	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T						
SFC (NET) with 30% regen	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM	53	KWH/1000 GTKM						
Yearly Traction Energy consumption with 365 days working with 30% regen	**5.66**	**million units**	**5.99**	**million units**	**7.76**	**million units**	**8.76**	**million units**	**9.21**	**million units**	**10.98**	**million units**	**4.07**	**million units**	**4.31**	**million units**	**5.58**	**million units**	**5.90**	**million units**	**6.62**	**million units**	**7.89**	**million units**						
Station aux power requirement																														
Elevated/at-grade station	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW						
U/G station	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW						
no. of elevated/at-grade stations	9		9		9		9		9		9		8		8		8		8		8		8		17	17	17	17	17	17
no. of U/G stations	0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0
Total Station Aux Power requirement	2.25	MW	2.25	MW	2.70	MW	2.70	MW	3.15	MW	3.60	MW	2.00	MW	2	MW	2.4	MW	2.40	MW	2.80	MW	3.20	MW	4.25	4.25	5.1	5.10	5.95	6.80
Depot Aux power requirement	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2.00	2.10	2.20	2.30	2.40	2.50
Total Aux Power requirement	2.25	MW	2.25	MW	2.70	MW	2.70	MW	3.15	MW	3.60	MW	4.00	MW	4.1	MW	4.6	MW	4.70	MW	5.20	MW	5.70	MW	6.25	6.35	7.3	7.40	8.35	9.30
Total Aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	**2.78**	**MVA**	**2.78**	**MVA**	**3.34**	**MVA**	**3.34**	**MVA**	**3.89**	**MVA**	**4.45**	**MVA**	**4.94**	**MVA**	**5.06**	**MVA**	**5.68**	**MVA**	**5.81**	**MVA**	**6.42**	**MVA**	**7.04**	**MVA**	**7.72**	**7.84**	**9.02**	**9.14**	**10.31**	**11.49**
Diversity factor of aux loads	0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40							
Yearly Aux Energy consumption 20 hrs/day and 365 days working (million units)	**6.90**	**million units**	**6.90**	**million units**	**8.28**	**million units**	**8.28**	**million units**	**9.66**	**million units**	**11.04**	**million units**	**12.26**	**million units**	**12.57**	**million units**	**14.10**	**million units**	**14.41**	**million units**	**15.94**	**million units**	**17.48**	**million units**	**19.16**	**19.47**	**22.38**	**22.69**	**25.60**	**28.51**
Net Annual Energy Consumption (Traction & Aux)	**12.56**	**million units**	**12.89**	**million units**	**16.04**	**million units**	**17.04**	**million units**	**18.86**	**million units**	**22.02**	**million units**	**16.33**	**million units**	**16.88**	**million units**	**19.68**	**million units**	**20.31**	**million units**	**22.56**	**million units**	**25.37**	**million units**	**28.89**	**29.76**	**35.73**	**37.35**	**41.43**	**47.39**

Annexure:-7.1

POWER REQUIREMENTS	NAGPUR METRO																							
	CORRIDOR - 1 (North-South)																							
	Automotive Sqre to Congress Nagar												Congress Nagar to Khapari											
	Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041		Year 2016		Year 2021		Year 2026		Year 2031		Year 2036		Year 2041	
Traction power requirements																								
No of cars	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)	3	(2DMC+1TC)
Passenger weight	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T	63	T
Train Tare weight	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T	120	T
Total train weight	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T	183	T
Section length	7.90	KM	7.90	KM	7.90	KM	7.90	KM	7.90	KM	7.90	KM	11.35	KM	11.35	KM	11.35	KM	11.35	KM	11.35	KM	11.35	KM
Headway	6.5	mts	6	mts	5	mts	4.5	mts	4	mts	3.5	mts	13	mts	12	mts	10	mts	9	mts	8	mts	7	mts
Specific Energy consumption	75	KWhr/1000 GTKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000 GTKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM	75	KWhr/1000G TKM
No. of trains/hr in both directions	18		20		24		27		30		34		9		10		12		13		15		17	
Peak traction power requirement	2.00	MW	2.17	MW	2.60	MW	2.89	MW	3.26	MW	3.72	MW	1.44	MW	1.56	MW	1.87	MW	2.08	MW	2.34	MW	2.67	MW
Less Regeneration @ 30%	0.60	MW	0.65	MW	0.78	MW	0.87	MW	0.98	MW	1.12	MW	0.43	MW	0.47	MW	0.56	MW	0.62	MW	0.70	MW	0.80	MW
Depot power requirements	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	1.50	MW	1.60	MW	1.70	MW	1.80	MW	1.90	MW	2.00	MW
Total traction power requirement	1.40	MW	1.52	MW	1.82	MW	2.03	MW	2.28	MW	2.60	MW	2.51	MW	2.69	MW	3.01	MW	3.26	MW	3.54	MW	3.87	MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf	**1.55**	**MVA**	**1.68**	**MVA**	**2.02**	**MVA**	**2.24**	**MVA**	**2.52**	**MVA**	**2.88**	**MVA**	**2.77**	**MVA**	**2.98**	**MVA**	**3.33**	**MVA**	**3.60**	**MVA**	**3.91**	**MVA**	**4.28**	**MVA**
Station aux power requirements																								
Elevated/at-grade station--power consumption	0.25	MW	0.25	MW	0.3	MW	0.30	MW	0.35	MW	0.40	MW	0.25	MW	0.25	MW	0.30	MW	0.30	MW	0.35	MW	0.40	MW
Underground station--power consumption	2.00	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW	2	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW
No. of elevated/at-grade stations	9		9		9		9		9		9		8		8		8		8		8		8	
No. of Underground stations	0		0		0		0		0		0		0		0		0		0		0		0	
Total Station Aux Power requirement	2.25	MW	2.25	MW	2.7	MW	2.70	MW	3.15	MW	3.60	MW	2.00	MW	2.00	MW	2.40	MW	2.40	MW	2.80	MW	3.20	MW
Depot Aux power requirement	0	MW	0	MW	0	MW	0	MW	0	MW	0	MW	2	MW	2.10	MW	2.20	MW	2.30	MW	2.40	MW	2.50	MW
Total Aux Power requirement	2.25	MW	2.25	MW	2.7	MW	2.70	MW	3.15	MW	3.60	MW	4.00	MW	4.10	MW	4.60	MW	4.70	MW	5.20	MW	5.70	MW
Total aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	**2.78**	**MVA**	**2.78**	**MVA**	**3.34**	**MVA**	**3.34**	**MVA**	**3.89**	**MVA**	**4.45**	**MVA**	**4.94**	**MVA**	**5.06**	**MVA**	**5.68**	**MVA**	**5.81**	**MVA**	**6.42**	**MVA**	**7.04**	**MVA**
Total traction & aux power requirement (MVA)	**4.33**	**MVA**	**4.46**	**MVA**	**5.35**	**MVA**	**5.57**	**MVA**	**6.41**	**MVA**	**7.33**	**MVA**	**7.71**	**MVA**	**8.04**	**MVA**	**9.01**	**MVA**	**9.40**	**MVA**	**10.33**	**MVA**	**11.32**	**MVA**

	Automotive Sqre to Khapari					
	Year-2016	Year-2021	Year-2026	Year-2031	Year-2036	Year-2041
Traction power requirements						
No of cars						
Passenger weight						
Train Tare weight						
Total train weight						
Section length	19.25	19.25	19.25	19.25	19.25	19.25
Headway						
Specific Energy consumption						
No. of trains/hr in both directions						
Peak traction power requirement						
Less Regeneration @ 30%						
Depot power requirements						
Total traction power requirement	3.91	4.21	4.83	5.28	5.82	6.48
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf	**4.32**	**4.65**	**5.34**	**5.84**	**6.43**	**7.16**
Station aux power requirements						
Elevated/at-grade station--power consumption						
Underground station--power consumption						
No. of elevated/at-grade stations	17	17	17	17	17	17
No. of Underground stations	0	0	0	0	0	0
Total Station Aux Power requirement						
Depot Aux power requirement						
Total Aux Power requirement	6.25	6.35	7.30	7.40	8.35	9.30
Total aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	7.72	7.84	9.02	9.14	10.31	11.49
Total traction & aux power requirement (MVA)	**12.04**	**12.50**	**14.36**	**14.98**	**16.74**	**18.65**