11. POWER SUPPLY SYSTEM

11.1 COVERAGE

Traditionally, electric traction is used in Metro systems as a prerequisite for requirement of high acceleration and pollution-free services in urban areas. There are three standard and proven systems of electric traction for use in suburban and metro lines, viz., 750V dc third rail, 1500V dc overhead catenary and 25kV ac overhead catenary system. Presently, all these three systems are in use in India (750 V dc third rail in Kolkata & Bangalore Metro, 1500V dc catenary in Mumbai suburban of Central & Western Railways and 25kV ac catenary in Delhi, Jaipur, Chennai and Hyderabad Metro & Indian Railways). 1500 V dc system of Central and Western Railways in Mumbai suburban is currently being converted to 25kV ac.

Keeping in view the ultimate traffic requirements, standardization and other techno-economic considerations, 750 V DC traction system is considered to be the best solution and hence, proposed for adoption.

This chapter broadly covers the Power supply system – power requirement for various horizon years, design load, source of supply and an outline of the distribution network & major equipments etc. for the Varanasi metro.

11.2 POWER REQUIREMENT

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc) and 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.

The power supply system is proposed to be designed for peak PHPDT of 24000 for BHU to BHEL Corridor and PHPDT of 18000 for Benia Bagh to Sarnath Corridor.
The Power Supply System design has been conceptualized considering 3 car rake and train operation at 144 seconds and 192 seconds headway for BHU to BHEL corridor and Benia Bagh to Sarnath corridor respectively. The designed system shall ensure high reliability and adequacy of the system to meet unforeseen growth in traffic demand.

The ultimate (design) power requirement for this corridor will be conceptualized considering following norms, directives/guidelines,

- Train operation with 3 car rakes with carrying capacity of 766 passengers (standing @ 6 passengers/ m²).
- Peak period headway of 144 seconds for BHU to BHEL corridor and 192 seconds headway for Benia Bagh to Sarnath corridor.
- Specific energy consumption of rolling stock – 75 KWh / 1000 GTKM
- Regeneration @20%
- At grade/ Elev. station load – initially 200kw, ultimate design 300 kW
- Underground station load – initially 1500 kW, ultimate design 1800 kW
- Depot auxiliary load – initially 1500kW, ultimate design 2000 KW
- Power factor of load – 0.9
- Transmission losses @ 5%

Keeping in view of the above norms, the power demand estimation for the proposed MRTS corridors is given in Table 11.1.

**TABLE 11.1 : POWER DEMAND ESTIMATION (MVA)**

<table>
<thead>
<tr>
<th>Corridor</th>
<th>BHU to BHEL Corridor</th>
<th>Benia Bagh to Sarnath Corridor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2023</td>
<td>2031</td>
</tr>
<tr>
<td><strong>Traction</strong></td>
<td>7.45</td>
<td>9.25</td>
</tr>
<tr>
<td><strong>Auxiliary</strong></td>
<td>25.43</td>
<td>27.31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>32.88</td>
<td>36.56</td>
</tr>
</tbody>
</table>

The calculations for the traction and auxiliary power demand estimation are shown in Annexure 11.1 (a) and Annexure 11.1 (b). This requirement has been worked out based on the conceptual design and therefore, needs to be reaffirmed and fine-tuned by conducting necessary simulation study during detailed design stage of project implementation.
11.3 NEED FOR HIGH RELIABILITY OF POWER SUPPLY

The proposed MRTS corridors viz. BHU to BHEL and Benia Bagh to Sarnath corridor are being designed to cater to about 24000 and 18000 passengers respectively per direction during peak hours (PHPDT) when trains are expected to run at high frequency of 144 seconds and 192 seconds respectively. 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. Effect on signal and communication may affect train operation and passenger safety as well. Therefore, uninterrupted power supply is mandatory for efficient metro operations.

In order to ensure high reliability of power supply, feed from more than one Receiving Sub Station (RSS) have been planned for the proposed corridors. Under normal circumstances, each RSS will feed specific sections of the corridor. In case of emergency condition i.e. when one RSS fails, the other RSS will feed the section of the RSS under outage. Therefore, it is essential that all the sources of supply and connected transmission & distribution networks are reliable and have adequate built in redundancies.

11.4 SOURCES OF POWER SUPPLY

Varanasi City has 220kV, 132kV, 33kV power transmission and distribution network to cater to various types of demand in the vicinity of the proposed corridor. Keeping in view of the reliability requirements and considering the complete length of corridors, three Receiving Substations (RSS) are proposed to avail power supply for traction as well as auxiliary services from the U.P. Power Transmission Company Limited (UPPTCL) grid sub-stations at 132 kV voltage level through cable feeders or transmission lines for proposed Varanasi Metro corridors.

M/s UPPTCL has been communicated for availability of power supply for proposed corridors of Varanasi Metro. M/s UPPTCL vide letter no. 372/ETD-1(V) dated 13/02/2016 as enclosed at Annexure 11.2 has confirmed that the power
supply may be made available from their Grid Substation (GSSs) located at Gajokhar, BHU/Manduadih and Sarnath/Cantt.

### TABLE 11.2 : SOURCES OF POWER SUPPLY

<table>
<thead>
<tr>
<th>Grid sub-station</th>
<th>RSS of Metro Authority</th>
<th>Approx. Distance from GSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gajokhar GSS</td>
<td>BHEL RSS at Ganeshpur Depot (132kV/33kV)</td>
<td>20 km Transmission Line</td>
</tr>
<tr>
<td>BHU/Mandyadug GSS</td>
<td>BHU RSS (132kV/33kV)</td>
<td>6 km Double Circuit Cables</td>
</tr>
<tr>
<td>Sarnath/Cantt GSS</td>
<td>Sarnath RSS (132kV/33kV)</td>
<td>5 km Double Circuit Cables</td>
</tr>
</tbody>
</table>

#### 11.4.1 Power Supply Distribution for MRTS

- **Receiving Sub-Station**: The HT power supply from grid substations at 132 kV voltage levels will be stepped down to 33kV supply for traction power supply and auxiliary power supply at the Receiving cum Traction Substations (RSS) of MRTS authority.

- **Traction Power**: In the Traction Substations, 33 KV is stepped down by transformer rectifier set to 750 Volts D.C. and fed to 3rd rail for traction purpose. The average spacing of traction sub stations is 2~3 Km.

- **Auxiliary Power**: In the Auxiliary Substations, 33 KV is stepped down to 415 Volts for lighting, Air conditioning and Ventilations, Pumps, Escalators, Signalling and Telecommunication etc. The Auxiliary substations (ASSs) are proposed to be provided at every station to meet the station auxiliary load requirements.

33 kV cable will be laid from RSS along the viaduct/ tunnel and will consist of two separate networks i.e. Traction network and Auxiliary network. Each network will consist of two cables, each having the possibility to be fed from each RSS. The two circuits will loop in- loop out at alternate TSS and ASS. The entire power supply system & auxiliary power supply system shall be monitored and controlled from a centralized Operation Control Center (OCC) using a SCADA system.
The summary of expected power demand at various sources is given in Table 11.3.

For BHU to BHEL Corridor in normal conditions, BHEL RSS will feed the section from BHEL to Kashi Vidyapeeth, BHU RSS will feed from Kashi Vidyapeeth to BHU and Sarnath RSS will feed Beniabagh to Sarnath Corridor. In case BHEL RSS fails, the feed can be extended from BHU RSS.

**TABLE 11.3 : POWER DEMAND PROJECTION FOR VARIOUS SOURCES**

<table>
<thead>
<tr>
<th>Name of RSS</th>
<th>Peak Demand – Normal (MVA)</th>
<th>Peak Demand – Emergency (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHEL RSS at Ganeshpur Depot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traction</td>
<td>3.84 4.77 6.14 7.43 7.45 9.25 11.90 14.42</td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td>13.18 14.25 15.31 16.33 25.43 27.31 29.19 31.03</td>
<td></td>
</tr>
<tr>
<td>Total (A)</td>
<td>17.02 19.01 21.44 23.77 32.88 36.56 41.09 45.45</td>
<td></td>
</tr>
<tr>
<td>BHU RSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td>12.25 13.07 13.88 14.70 25.43 27.31 29.19 31.03</td>
<td></td>
</tr>
<tr>
<td>Total (B)</td>
<td>15.86 17.55 19.65 21.69 32.88 36.56 41.09 45.45</td>
<td></td>
</tr>
<tr>
<td>Sarnath RSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traction</td>
<td>2.47 3.45 3.95 4.69 6.31 8.22 10.08 12.12</td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td>12.72 13.62 14.51 15.40 25.90 27.86 29.82 31.73</td>
<td></td>
</tr>
<tr>
<td>Total (C)</td>
<td>15.18 17.07 18.46 20.09 32.21 36.08 39.90 43.85</td>
<td></td>
</tr>
</tbody>
</table>

In case of failure of BHU RSS, then BHEL RSS will feed from BHU-BHEL i.e. complete length of the corridor and in the eventuality of failure of Sarnath RSS, BHU RSS or BHEL will feed the additional section from Beniabagh to Sarnath.

The equipment rating of the RSS cum TSS will be determined considering the normal as well as emergency situation. When one RSS fails, the traction supply will be maintained by extending feed from adjoining RSS. However, in case of total grid failure, all trains may come to a halt but emergency lighting, fire, hydraulics and other essential services can be catered to by stand-by UPS/ DG sets.

Each RSS shall be provided with 2 nos. (one as standby) 132/33KV three phase
transformers with 30MVA (ONAN) /45MVA (ONAF) Capacity to meet peak traction demand in case of outage of adjoining RSS. If one RSS trips on fault or on input supply failure, services can be maintained by extending supply from the other RSS. However, in case of total grid failure, trains will come to stop but station lighting & other essential services can be catered to by stand-by power backup.

FIGURE 11.1 : TYPICAL HIGH VOLTAGE RECEIVING SUB – STATION (RSS)

11.5 AUXILIARY POWER ARRANGEMENTS

The auxiliary power will be required for

- Lights & fans for station
- Service Buildings
- Foot over Bridges/Subways.
- Maintenance Depots
- Air-conditioning
- Lifts
- Escalators
- Water Supply Pumping Stations – for washing, toilets as well as fire protection measures.
- Equipment – Signalling, Telecom, Automatic Fare Collection etc.
Auxiliary sub-stations (ASS) are envisaged to be provided at each station for stepping down 33kV supply to 415V for auxiliary applications. The ASS will be located at mezzanine or platform level inside a room. The demand of power at each elevated station is expected to be about 200 kW in the initial years and is likely to reach 300 kW in the horizon year. Similarly, for the underground stations, the auxiliary load requirements have been assessed at 1500 kW for underground station which is likely to increase to 1800 kW in the horizon year. The average load considered for elevated station and underground station will have to be fine tuned to suit station requirement at the time of detailed design.

Each elevated station shall be provided with an Auxiliary Substation with two 33kV/415V, 3-phase, 500 kVA dry type cast resin transformers and the associated HT & LT switchgear. In addition, provision shall be made for one DG set at each station for emergency loads. Two transformers (33kV/415V, 3-phase) of 2000 kVA at each underground ASS for the underground stations are proposed to be installed (one transformer as standby).

Apart from stations, separate ASS is required at each depot with 2x2000 kVA auxiliary transformers to cater to depot cum workshop load.

**FIGURE 11.2: TYPICAL INDOOR AUXILIARY SUB-STATION (ASS)**

**11.6 Traction Power Supply**

Based on emergency demand expected at each RSS as shown in Table 11.3, 2 nos. traction transformers of 132/33 kV, 30MVA (ONAN) /45MVA (ONAF) capacity each at BHEL RSS, BHU RSS and Sarnath RSS are proposed. Similarly, 2 nos. Auxiliary transformers (132/33 kV) of 30 MVA capacity each are proposed to be provided at all the four RSSs.
33kV switchgear shall be rated for 1250 A being standard design. 33kV XLPE insulated FRLSOH cable ring network is proposed for Aux. ring main network, which shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations.

Initially equipments may be installed to cater to the expected power requirements during initial years of operations. As and when the traffic builds up in year 2031, the power supply system will need slight augmentation by way of adding traction transformer-rectifier sets. However, cables of adequate rating to meet designed power demand should be laid at the initial stage itself keeping in view the difficulties associated with laying of cables at a later stage.

The rating of major equipments are given below, which have been worked out based on the conceptual design and therefore, these capacities needs to be reaffirmed and fine tuned by conducting necessary simulation study during detailed design stage of project implementation.

**Traction sub station (33kV/ 750V DC)**

Traction sub-stations (33kV/750V dc) are required to be set up for feeding 750V dc power supply to the third rail. In order to cater to traction load as per design criteria, it is proposed to provide traction sub-stations (TSS) at an approximate distance of about 2 - 3 Km as given in **Annexure 11.3 & 11.4**. The TSS along with Auxiliary Sub-Stations (ASS) will be located at station building itself at mezzanine or platform level inside a room. An independent traction sub-station shall be provided for the maintenance depot. The typical layouts for ASS & TSS for elevated sections and underground sections are given in Drawings at **Annexure 11.5 & 11.6** and **Annexure 11.7 & 11.8** respectively.

Traction transformer-rectifier set 33kV/292-292 (750V dc) are proposed to be 2.6 MVA rated capacity with 12 pulse rectification similar to system adopted in BMRCL with overload requirement of 150% for 2 hours with four intermittent equally spaced overloads of 300% for 1 minute, and with one 450% full load peak of 15 seconds duration at the end of 2 hour period. However, type of rectifier rating of transformer etc. may be firmed up during detailed design stage.

Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. Initially, 2x2.6 MVA transformer-rectifier set
shall be provided in the proposed TSS. Whereas, one rectifier transformer will be able to meet the power supply demand, the second set will be standby.

The traction transformer - rectifier set shall produce 750V dc nominal output voltage with 12-pulse rectification so as to minimize the ripple content in the output dc voltage. The IEC 60850 and BS EN 50163 international standard envisages the minimum and maximum voltages of 500V and 900V respectively for 750V dc traction system and therefore, the dc equipment shall be capable of giving desired performance in this voltage range.

33kV XLPE insulated FRLSOH cable ring network is proposed for Aux. ring main network, which shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations.

**FIGURE 11.3 : TYPICAL TRACTION SUB STATION (TSS)**

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 and fine-tuned during detailed design stage of project implementation.

**750v dc third rail current collection system**

For the 750V dc Third Rail Current Collection System, Bottom current collection with the use of composite Aluminum steel third rail on main lines is envisaged from reliability and safety considerations as shown in figure below.
Low carbon steel third rail available indigenously is proposed for the depot because of reduced current requirements. The cross-section of third rail will be about 5000 mm². The longitudinal resistance of composite and steel third rail is about 7 and 20 milli-ohm/km respectively. The life of composite and steel third rail is expected to be 25-30 years.

**Special Arrangements in Depot**

A separate traction sub-station (TSS) shall be provided for the depot so as to facilitate isolation of depot traction supply system from main lines in order to prevent the leakage of return currents to depot area. Tracks of depot area shall also be isolated from main line through insulated rail joints (IRJ). Remote operated sectionilizing switches shall be provided to feed power from depot to main line and vice-versa in case of failure of TSS.

The prescribed limit of highest touch potential in depot is 60V as per EN50122-1 and therefore Track Earthing Panels (TEP) shall be provided at suitable locations to earth the rails in case the rail potential exceeds the limit. In areas, where leaky conditions exist (e.g. washing lines, pit wheel lathe etc.), insulated rail joints (IRJ) shall be provided with power diodes to bridge the IRJ to facilitate passage of return current. A detailed scheme shall be developed during the design stage.

**11.7 Standby Diesel Generator (DG) SETS**

In the unlikely event of simultaneous tripping of all the RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set of 180 kVA at all elevated stations and 2 x
1000 kVA capacity at underground stations to cater to the following essential services,

- Lift operation
- Essential lighting
- Signalling & telecommunications
- Firefighting system
- Fare Collection system

Silent type of DG sets, which have low noise levels and do not require separate room for installation, are proposed. In addition, UPS with adequate power backup may be installed for the very essential lighting load.

11.8 **Stray Current Corrosion Protection Measures**

11.8.1 Concept of dc Stray Current Corrosion

In dc traction systems, bulk of return current finds its path back to the traction sub-station via the return circuit i.e. running rails. The running rails are normally insulated to minimize leakage of currents to the track bed. However, due to leaky conditions, some current leakage takes place, which is known as ‘stray current’. The current follows the path of least resistance. Return current deviates from its intended path if the resistance of the unintended path is lower than that of intended path. The stray current may flow through the unintended path of metallic reinforcements of the structure back to the sub-station. It is also possible that part of the stray current may also flow into soil, where it may be picked up by metallic utilities and discharged back to soil and then to near the sub-station.

DC stray currents cause corrosion of metallic structure where it leaves the metal. This is shown in schematic Drawing at Annexure 11.9. Pitting and general form of corrosion are most often encountered on dc electrified railways.

11.8.2 Measures for Protection against Stray Current Corrosion

Earthing & bonding and protection against stray current corrosion are inter-related and conflicting issues. Therefore, suitable measures are required to suppress the stray currents as well as the presence of high touch potentials.
Safety of personnel is given preference even at a cost of slightly increased stray currents.

Following measures are required to restrict the stay current:

(i) Decreasing the resistance of rail-return circuit
(ii) Increasing the resistance of rail to ground insulation

Whenever buried pipes and cables are in the vicinity of dc systems, efforts shall be made to ensure that metal parts are kept away as far as practicable to restrict stray current. A minimum distance of 1 meter has been found to be adequate for this purpose.

Generally, three types of earthing arrangements (viz. Earthed System, Floating System & Hybrid Earthing System) are prevalent on metros World over for protection against stray current corrosion. Traditionally, Earthed system was used by old metros. Hybrid earthing system is being tried on experimental basis on few new metros. Floating system has been extensively used by recent metros. As per the trends World over, floating system (i.e. traction system with floating negative) is proposed which reduces the dc stray current to considerable level. The arrangement shall comply with following latest CENELEC standards:

- EN 50122-1:- Railway Applications (fixed installations) protective provisions relating to electrical safety & earthing
- EN 50122-2:- Railway Applications (fixed installations) protective provisions against the effects of stray currents caused by dc traction system

The conceptual scheme of proposed floating system is described below:

i) The running rails shall be adequately insulated as per EN50122-2. The recommended conductance per unit length for single track sections are as under:

   Elevated section: - 0.5 Siemens/ km
   Undergrond section: - 0.1 Siemens/ km

ii) Stray Current Collector Cables {commonly known as structural earth (SE) cable} (2x200 mm² copper) shall be provided along the viaduct and all the metallic parts of equipment, cable sheath, signal post etc. shall be connected to SE cable.
iii) The continuity of the reinforcement bars of the viaduct / tunnel as well as track slabs has to be ensured along with a tapping point for connection with separate earthing for viaduct reinforcement.

iv) A provision shall be made to earth the running rail (i.e. negative bus) in case of rail potential being higher than limits prescribed in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing Track Earthing Panel (TEP) at stations close to platform and at traction sub-stations.

v) In addition, provisions shall be made for connection of SE cable to negative return path through diode only for the purpose of periodical monitoring of stray currents. Under normal operations, switch provided for this connection will be in normally open (NO) position and switch will be closed for monitoring of stray current once or twice in a year as required. The proposed scheme is shown in Drawing at Annexure 11.10.

11.9 **Electromagnetic Interference (EMI) And Electromagnetic Compatibility (EMC)**

AC traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Though, dc traction currents normally do not cause electromagnetic induction effect resulting induced voltages and magnetic fields, yet there is a possibility of electromagnetic interference due to sudden increase/ decrease in traction load. In addition, the rectifier-transformer used in dc traction system produces harmonic voltages, which may also cause interference to telecommunications and train control/ protection systems. The rectifier-transformer shall be designed with the recommended limits of harmonic voltages, particularly the third and fifth harmonics. The proposed 12-pulse rectifier-transformer reduces the harmonics level considerably. Detailed specification of equipment e.g. power cables, rectifiers, transformer, 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 EMC plan will have to be developed during project implementation stage.
11.10 **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 cables 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.

![SCADA System Image](image_url)

**FIGURE 11.5: SCADA SYSTEM**

11.11 **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 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 20% of total traction energy will be regenerated which will 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 (operation or maintenance hours etc).

iv. Machine-room less type lifts with gearless drive and 3-phase VVVF drive. These lifts are highly energy efficient.

v. The proposed heavy-duty public services escalators 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.

vi. The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc).

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

### 11.12 ELECTRIC CONSUMPTION

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 40-50% of total annual working cost. Therefore, it is the key element for the financial viability of the Project. The annual energy consumption for the Varanasi Metro corridors is assessed to be about 166.23 million units in the inception year 2023, 183.92 million units in year 2031, 208.11 million units in year 2041 and 232.34 million units in the design year.

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 MRTS should be at effective rate of purchase price (at required voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. The energy charges as per UPPCL tariff order dated 23rd June 2015 for Metro Railway are Rs. 5.60 per KVAh and Demand charges @ Rs 125/KVA/Month. Financial analysis has been carried out based on this tariff for the purpose of finalizing the DPR.
### Annexure 11.1 (a)

#### Traction and Auxiliary Power Requirement for BHU to BEL Corridor

<table>
<thead>
<tr>
<th>(A)</th>
<th>Traction Load</th>
<th>2023</th>
<th>2031</th>
<th>2041</th>
<th>2051</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average speed (KMPH)</td>
<td>S</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Frequency of service (Sec.)</td>
<td>F</td>
<td>276</td>
<td>228</td>
<td>174</td>
</tr>
<tr>
<td>3</td>
<td>Headways (Km.)</td>
<td>H</td>
<td>2.7</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td>4</td>
<td>Nos of trains per hour</td>
<td>N</td>
<td>13</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>Specific energy consumption (KWh/Thou GTKM)</td>
<td>SEC</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>Gross tonnage of 3 car rake</td>
<td>T</td>
<td>178</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>7</td>
<td>Corridor length (Km)</td>
<td>D</td>
<td>19.4</td>
<td>19.4</td>
<td>19.4</td>
</tr>
<tr>
<td>8</td>
<td>Power factor of load</td>
<td>PF</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Max. demand on TSS (KW) = 6733.7 + 200 = 6933.7

Energy Saving on account of regeneration @20% = 1346.7

Net Demand = 5387.0 + 200 = 5587.0

Depot Traction Load = 1000

Total Traction Load for the corridor = 6387 + 400 = 6787

Max. Demand on TSS in KVA = 7096.7 + 400 = 7496.7

Max. Demand on TSS considering 5% losses (MVA) = 7.45

#### Auxiliary Load

<table>
<thead>
<tr>
<th>(B)</th>
<th>Auxiliary Load</th>
<th>2023</th>
<th>2031</th>
<th>2041</th>
<th>2051</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load of each elevated stations (KW)</td>
<td>200</td>
<td>235</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Nos of at grade/elevated station</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Load of each U/G stations (KW)</td>
<td>1500</td>
<td>1600</td>
<td>1700</td>
<td>1800</td>
</tr>
<tr>
<td>4</td>
<td>Nos of U/G stations</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Load of Depot (KW)</td>
<td>1500</td>
<td>1670.0</td>
<td>1840.0</td>
<td>2000.0</td>
</tr>
<tr>
<td>6</td>
<td>Total load of the stations &amp; 1 Depot (KW)</td>
<td>21800</td>
<td>23410</td>
<td>25020</td>
<td>26600</td>
</tr>
<tr>
<td>7</td>
<td>Power factor of the load</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Total max. power demand of Stations and Depot (KVA) = 24222 + 1500 = 25722

considering 5% loss (MVA) = 25.43

Total Max. power Demand Traction + Aux. (MVA) = 31.32 + 200 = 33.32

Net demand (MVA) considering 5% distribution loss = 32.88 + 200 = 232.88
### Annexure 11.1 (b)

**TRACTION AND AUXILIARY POWER REQUIREMENT FOR BENIABAGH TO SARNATH CORRIDOR**

#### (A) TRACTION LOAD

<table>
<thead>
<tr>
<th></th>
<th>2023</th>
<th>2031</th>
<th>2041</th>
<th>2051</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average speed (KMPH)</td>
<td>S</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>Frequency of service (Sec.)</td>
<td>F</td>
<td>360</td>
<td>258</td>
</tr>
<tr>
<td>3</td>
<td>Headways (Km.)</td>
<td>H</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>4</td>
<td>Nos of trains per hour</td>
<td>N</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>Specific energy consumption (KWh/Thou GTKM)</td>
<td>SEC</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>Gross tonnage of 3 car rake</td>
<td>T</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>7</td>
<td>Corridor length (Km)</td>
<td>D</td>
<td>9.9</td>
<td>9.9</td>
</tr>
<tr>
<td>8</td>
<td>Power factor of load</td>
<td>PF</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Max. demand on TSS (KW)**

- 2023: 2643.3
- 2031: 3700.6
- 2041: 4229.3
- 2051: 5022.3

**Energy Saving on account of regeneration @20%**

- 2023: 528.66
- 2031: 740.12
- 2041: 845.856
- 2051: 1004.45

**Net Demand**

- 2023: 2114.6
- 2031: 2960.5
- 2041: 3383.4
- 2051: 4017.8

**Max. Demand on TSS in KVA**

- 2023: 2349.6
- 2031: 3289.4
- 2041: 3759.4
- 2051: 4464.2

**Max. Demand on TSS considering 5% losses (MVA)**

- 2023: 2.47
- 2031: 3.45
- 2041: 3.95
- 2051: 4.69

#### (B) AUXILIARY LOAD

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load of each elevated stations (KW)</td>
<td>200</td>
<td>235</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>Nos of at grade/elevated station</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Load of each U/G stations (KW)</td>
<td>1500</td>
<td>1600</td>
<td>1700</td>
</tr>
<tr>
<td>4</td>
<td>Nos of U/G stations</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Total load of the stations</td>
<td>10900</td>
<td>11670</td>
<td>12440</td>
</tr>
<tr>
<td>6</td>
<td>Power factor of the load</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Total max. power demand of Stations and Depot (KVA)**

- 2023: 12111
- 2031: 12967
- 2041: 13822
- 2051: 14667

**considering 5 % loss (MVA)**

- 2023: 12.72
- 2031: 13.62
- 2041: 14.51
- 2051: 15.40

**Total Max. power Demand Traction + Aux. (MVA)**

- 2023: 14.46
- 2031: 16.26
- 2041: 17.58
- 2051: 19.13

**Net demand (MVA) considering 5% distribution loss**

- 2023: 15.18
- 2031: 17.07
- 2041: 18.46
- 2051: 20.09
## Annexure 11.2

### Subject: Availability of power supply for metro rail corridors in Varanasi.

**Group General Manager**  
Urban Transport Division  
RITES Ltd, Gurgaon.

**Dear Sir,**

Kindly refer your office L. No. RITES/UT/CO/DPR/VDA/626/2015 dt. 21.08.15 regarding subject matter. In this connection it is to intimate that the power supply on the various voltage level may be made available as desired in your above referred letter. The feasibility for all the three locations is given in the enclosed detail.

It is therefore requested to kindly depute your authorised officer to examine the locations as proposed by this office. So that the estimate may be prepared after your acceptance of the locations.

(Signed)  
Executive Engineer

---

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Details of location No.</th>
<th>Name of substaion feeding</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depot location No.-01</td>
<td>132KV Substation Gajokhar</td>
<td>By constructing new bay at the substation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220KV Substation Gajokhar</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Depot location No.-02</td>
<td>132KV substation Cantt</td>
<td>By constructing LLO of 132KV Cantt-Smath line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>132KV substation Sarnath</td>
<td>By tapping the existing 132KV Sahupuri-Sarnath line which is only energised at present.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220KV substation Sahupuri</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Depot location No.-03</td>
<td>132KV substation Manduadih</td>
<td>By making LLO of 132KV Sahupuri-Manduadih CKT-I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220KV substation Sahupuri</td>
<td>By constructing GIS based 132KV bays at BHU substation between the place of 132KV substation BHU and 132KV substation BHU(UPTCL).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>132KV substation BHU</td>
<td></td>
</tr>
</tbody>
</table>

(Signed)  
Executive Engineer
CHAPTER 11: POWER SUPPLY SYSTEM

Annexure 11.6
Annexure 11.8