4.9 Architectural Works

4.9.1 Station Locations and Characteristics

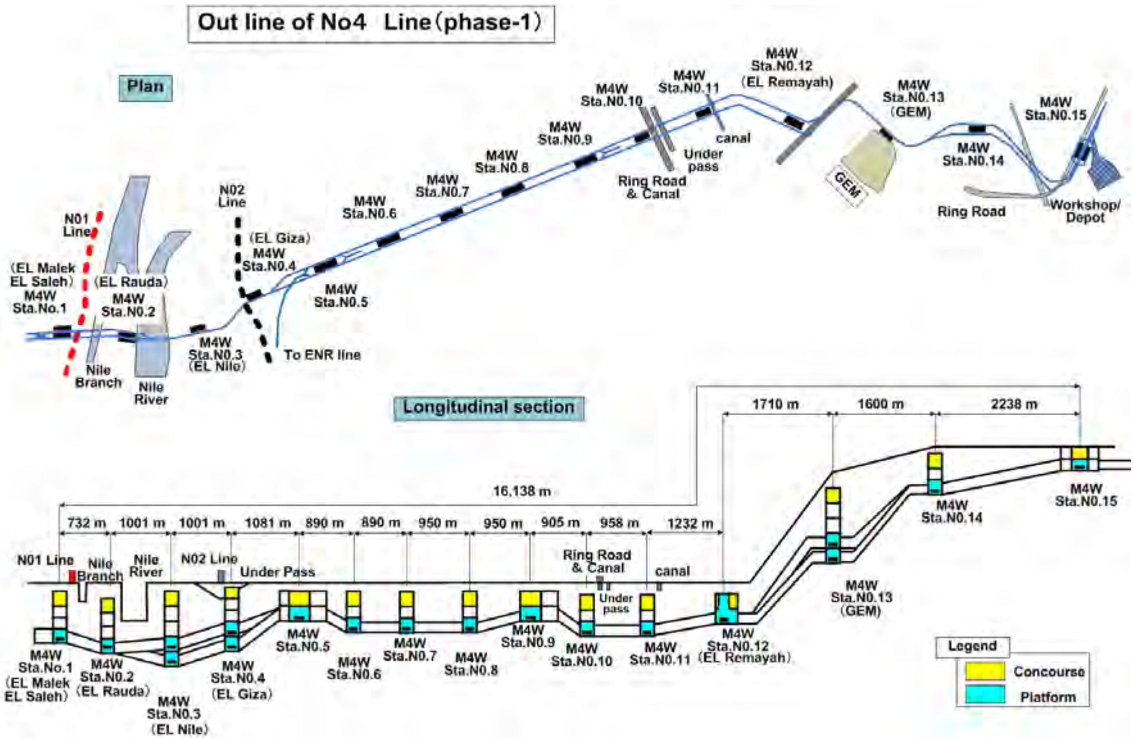
In total, 15 underground stations are proposed for Phase 1 of Metro Line 4 starting from the easternmost station of El Malek El Saleh station, ending at M4W Sta. No.15, which is the westernmost station of the line.

JICA Study Team has evaluated the characteristics of the geographical and surrounding environment at each station with consideration of track alignment conditions in developing the layout and section plans of all stations.

Four stations are proposed as modal interchange stations, which need to provide short and medium distance bus terminals and facilities for taxis and private cars. JICA Study Team has developed conceptual master plans for those four stations: First of these is for a underground temporary terminal and transfer to Metro Line 1 at El Malek El Saleh Station with a proposal of redevelopment for commercial and other facilities. Second is M4W Sta. No.4 (El Giza Station) for a underground transfer to Metro Line 2 and the ENR with a proposal for underground development and a transportation plaza. Third is M4W Sta. No.12 (El Remayah Station) for a large and shallow underground station including a bus terminal to 6th October City, multi level car parking and underground commercial development. The fourth plan is M4W Sta. No.15 as a terminal station, with a large open car park and bus terminals to and beyond 6th October City, in view of further development and growing populations. While these facilities will be of different sizes and configurations, the same components (park and ride for cars and parking bays on roads) will apply in each case.

As for the various types of station, some are five floor levels below ground, while the others will have only two or three underground floors depending on the vertical track alignment.

The location and symbolic configuration of every station are shown in Figure 4-277. Detailed characteristics of each station are also enumerated in Table 4-83.



Source: JICA Study Team

Figure 4-277 Outline of Metro Line 4

Table 4-83 Classification of Station Characteristics

Station Name	Station Characteristic	Number of Floors	Type of Platform	Platform width(m) Length(m)	Station width(m) Length(m)	Rail Level Below GL
No.1 El Malek El Saleh Station	Tranfer to Metro Line 1	B4	Island+ Side Type	10.5+8 170	26 190 +Scissors	-29.4
No.2 El Rauda Sta.		B5	Island type	8+8 170	24 190	-34
No.3 El Nile Station	Substation included	B5	2 Sides Vertically Stacked Type	12 170	16.5 235	-32.5
No.4 El Giza Station	Transfer to Metro Line 2 & ENR	B5	2 Sides Vertically Stacked Type	13 170	18.5 220	-26 -34
No.5 Station	Substation included	B2	Island type	12 170	21 215	-17.5
No.6 Station Typical Station		B3	Island type	12 170	21 190 +Scissors	-24.5

No.7 Station Typical Station		B3	Island type	12 170	21 190	-24.5
No.8 Station Typical Station		B3	Island type	12 170	21 190	-24.5
No.9 Station		B2	Island type	12 170	21 190	-17.5
No.10 Station Typical Station		B3	Island type	12 170	22 190	-27
No.11 Station Typical Station	Substation included	B3	Island type	12 170	21 190	-27
No.12 El Remayah Station Signature Station	Transfer to Bus terminal	B2	Island type	14 170	23 245 +Scissors	-20
No.13 Station		B5	2 Sides Vertically Stacked Type	12 170	16.5 190	-37.5
No.14 Station	Substation included	B3	Island type	12 170	21 230	-23
No.15 Station		B2	Island type	12+12 170	40 220	-18

Source: JICA Study Team

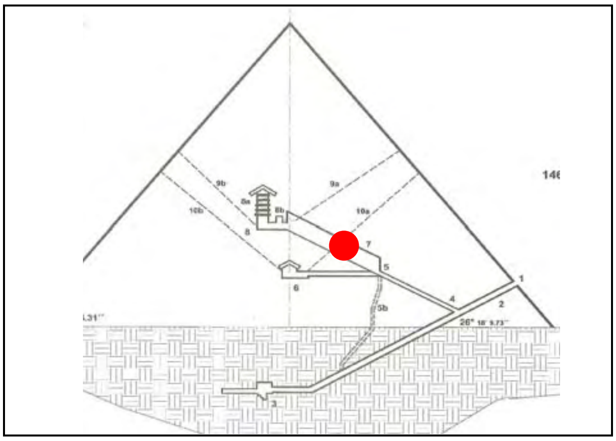
4.9.2 Station Design Concept

(1) Signature Station

Metro Line 4 will be a gateway line to the world heritage Pyramids and the Grand Egyptian Museum (GEM).

El Remayah Station, a terminal station for Phase 1, is important for foreign visitors and to those who travel to 6th October City from the station using public buses, taxis and private cars.

This station will be the signature station for Metro Line 4, and will be designed to emphasize a great expectation for the world heritage concept. Not only the annexed structures are above ground, but also the interior design of the station's public areas will be in harmony with the image of this great heritage. A design image of the station interior is inspired from the gallery at the heart of the Great Pyramid (Figure 4-278). The platform space will be sufficient for passenger circulation and safe evacuation with an extensive view (Figure 4-279).



Source: JICA Study Team

Figure 4-278 Gallery at the Heart of the Great Pyramid (Khufu)

Source: JICA Study Team

Figure 4-279 Signature Station El Remayah

(2) Typical Stations

Because of the similarity of geographic, topographic and social environment conditions, the stations located in Pyramids Road will be designed as typical stations.

A typical station has three underground floors with a minimum length of 190 m required for both technical and station operation facilities. This figure of 190 m is derived the sum of 170 m platform length (160m train length plus 5m of clearance for both ends of the train) and an 10 m from both ends of the platform, which is added for the provision of rooms required for station operation.

Despite densely packed situations, space for the concourse areas is given generously to enhance the expansiveness of these areas. Vertical circulations are arranged so that passengers will have no difficulty of orientation for every day use and in case of emergency. This design can help a safe evacuation in case of any disaster. By contrast, other types of stations have two underground floors due to shallower rail levels and also different station lengths due to a required additional space for the substation needed for train operation.

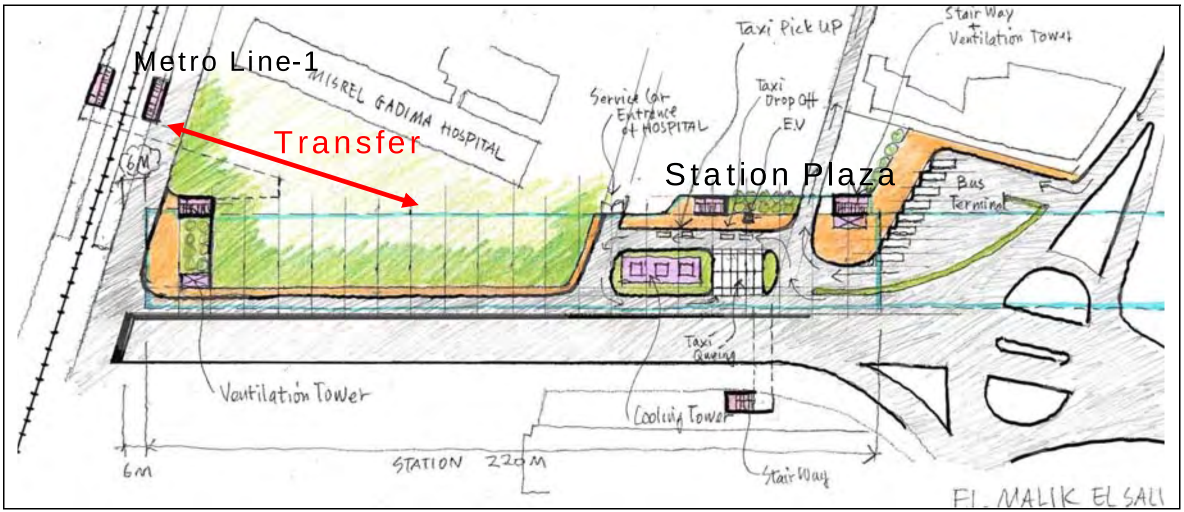
(3) Modal Interchange Stations

Modal interchange stations are proposed for Phase 1 of Metro Line 4 as mentioned in the first paragraph. The concept sketches propose the new street level station plaza and rehabilitation scheme of the site which will provide convenient transfer facilities for railway users, as well as regional redevelopment for the nearby areas.

a) El Malek El Saleh Station (M4W Sta. No.1)

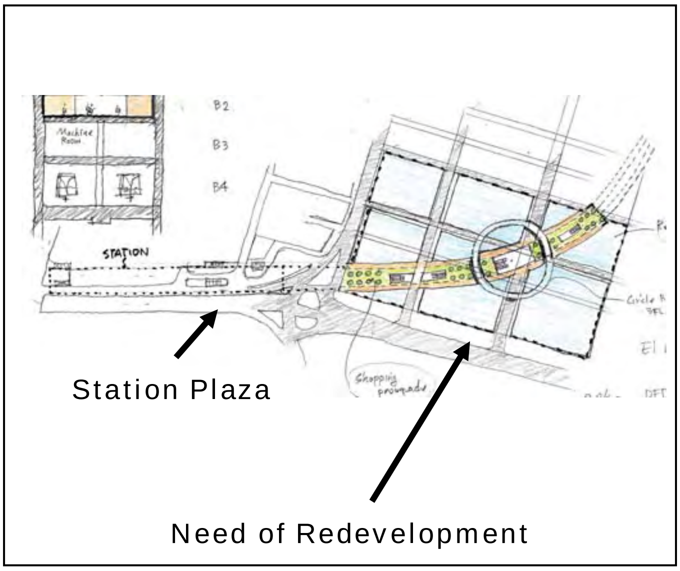
The sketch illustrated in Figure 4-280 proposes the construction of a station transportation plaza, with queuing areas for short and medium distance buses and taxis, Also, private car approaches from the eastern end of the station site, so as not to disturb the nearby Misrel Gadima Hospital located in front of the western end.

The sketch also rouses the possibility for redevelopment of the eastern residential blocks (as shown in Figure 4-281), since this area will be excavated for construction of a station box, which accommodates a long railway scissor crossing, in the case that the northern route is applied in Phase 2. The sectional sketch (Figure 4-282) shows an image of a multi-floor redevelopment for this particular area.



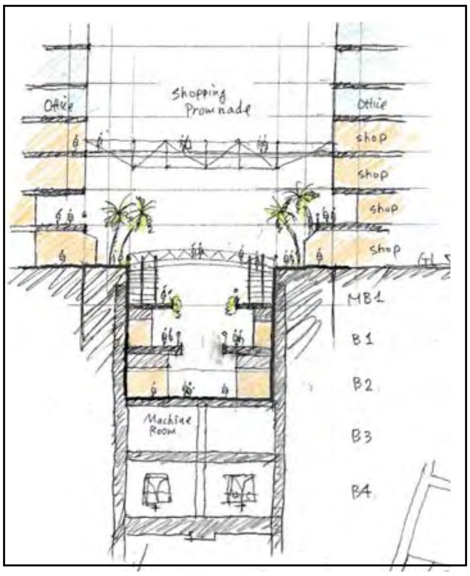
Source: JICA Study Team

Figure 4-280 El Malek El Saleh Station Plaza



Source: JICA Study Team

Figure 4-281 Need of Redevelopment

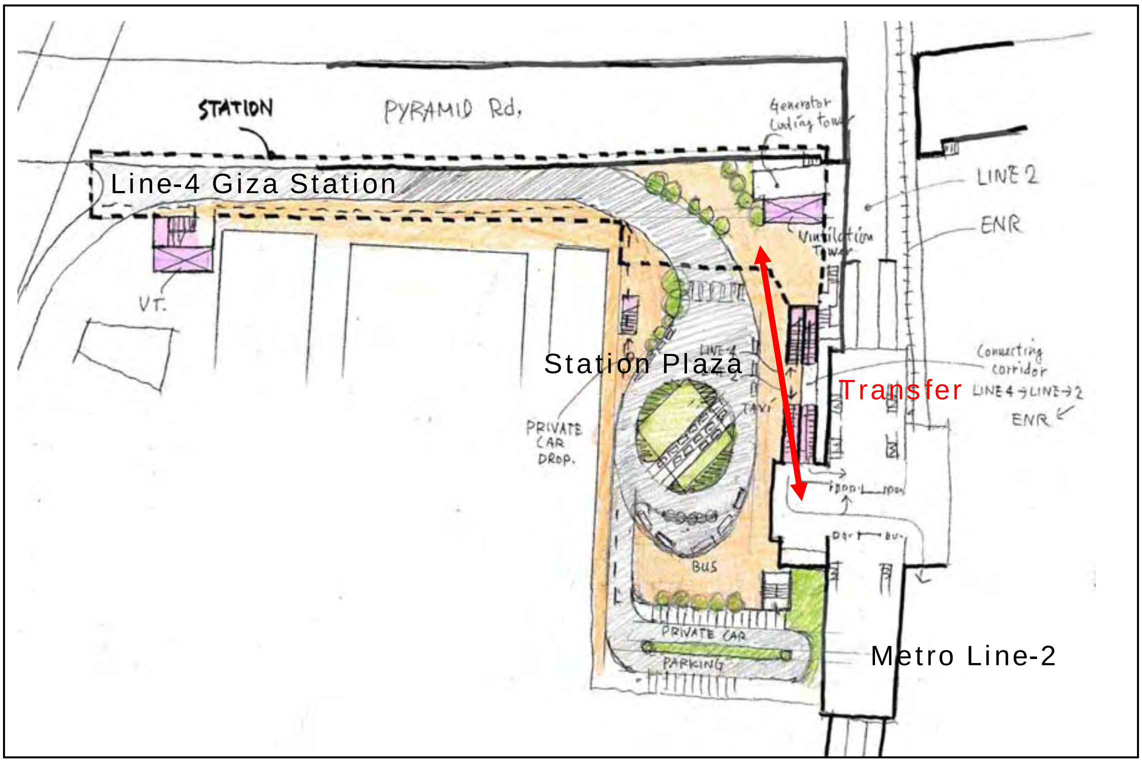


Source: JICA Study Team

Figure 4-282 Section of Redevelopment Area

b) El Giza Station (M4W Sta. No.4)

The conceptual sketch (Figure 4-283) proposes an above-ground modal interchange terminal at the El Giza Station, where Metro Line 4 would cross with Metro Line 2 and the Egyptian National Railway (ENR). A bus terminal, taxi queuing areas and private car approaches are provided to enhance the efficiency of passenger circulation. Meanwhile, a commercial development is proposed beneath the station plaza to provide convenience and quick daily shopping for transferring passengers. The El Giza station transportation plaza will have a circular layout, with taxi and bus stops facilities provided along the side walk, while a multi-level car park will be provided on the rear of the traffic circle. Pedestrian access and egress between the terminal and stations will be provided for Metro Line 4 by means of escalators, elevators and underground walkways; while for the Metro Line 2 and ENR stations via escalators and a pedestrian overpass.



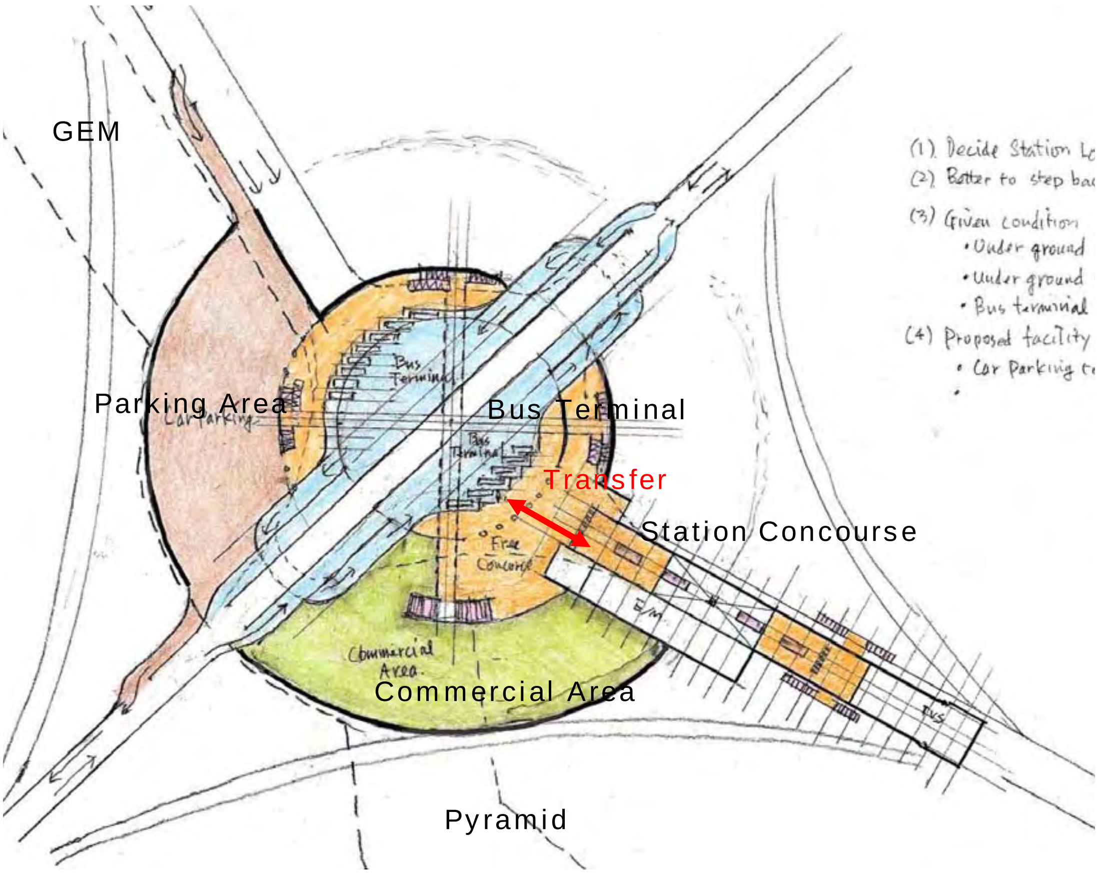
Source: JICA Study Team

Figure 4-283 Giza Station Plaza

c) El Remayah Station (M4W Sta. No.12)

Owing to its location and the great expectations of visitors, this has been designated as the signature station, but it also has the practical function of providing commuters with daily convenience.

Realizing an inter-modal terminal station, which will avoid disturbance of above-ground tourist area, most of the proposed facilities will be constructed beneath El Remayah Square. The bus terminal, from which passengers will transfer to 6th October City, will be accessed directly through the station automatic ticket collecting machine, which is planned at the first basement level along with the terminal. A multi-level car park is proposed in an adjacent area for a park and ride facility. The commercial facilities (Figure 4-284) are so important for this particular location to provide great amenity to tourists who will visit the Pyramids and the Grand Egyptian Museum (GEM) by using Metro Line 4.



Source: JICA Study Team

Figure 4-284 El Remayah Station

d) M4W Sta. No.13

The width of the plot for this station is too limited to apply a typical station design. Therefore, the station will take shape in a similar manner to M4W Sta. No.3, which has five underground floors.

Access to the station is located at the side of El Remayah Apartment..Only escape stairs are located on the other sides of the station.

e) M4W Sta. No.15

As a terminal station, M4W Sta. No.15 has two island platforms, each accommodating two tracks. In view of growing populations near the station, as well as for park and ride passengers from the 6th October City area, the integration of facilities, such as open car parking, taxi ranks, and bus stops, should be considered for this site. An open space in front of the station entrance, or "station plaza", surrounded by commercial and residential buildings, should increase the urban amenity of this station.

4.9.3 Design Standard

(1) Station

Station size is basically defined according to the following criteria.

The concourse floor length is designed considering the accumulated dimensions of minimum concourse length, station offices, E&M rooms and station and tunnel ventilation rooms.

The platform length is designed in accordance with the car composition of future train sets (8 cars) plus 5-m clear spaces at both ends of the platform.

Platform width is the total of the dimensions of minimum stairway requirement, escalator width, and reasonable width (2.5 m) between stairway wall and Platform Screen Door (PSD).

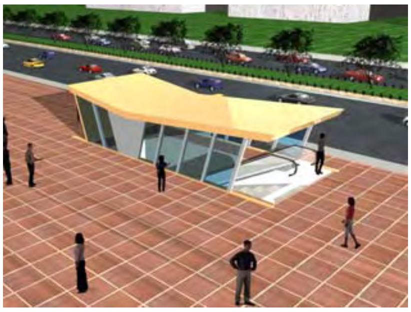
Critical vertical dimension is composed of reasonable ceiling height (3.0-3.5 m), ducting and cabling space (1.5-2.0 m) under the soffit respectively, while the sum of other dimensions, such as railway level, construction gauge, and overhead tunnel exhaust duct, is to be considered to know the internal space of the station concrete box.

(2) Entrance (Figure 4-285)

Entrances will be positioned in relation to roads.

Commercial premises and pedestrian traffic areas will be easily recognized due to attractive appearance. Each entrance will contain a closure device for during non-operational hours and which may be used for crowd control.

Canopies and flat roofs will be designed in such a manner as to offer adequate protection against the weather, as well as to protect escalators at these locations from rain.



Source: JICA Study Team

Figure 4-285 Entrance

Parapets will be provided as vertical enclosures to the station entrances. The minimum height to the top of the parapet will be 1,100 mm.

(3) Ventilation Shafts/Cooling Towers (Figure 4-286 and Figure 4-287)

The location and design of annexed structures like station ventilation shafts and cooling towers are carefully considered, given the need to avoid disturbance of the surrounding historical landscape,

Source: JICA Study Team

Figure 4-286 Ventilation Shaft

particularly in Pyramids Road and Alexandria Desert Road. It is necessary to keep distance between the inlet of air intake shaft and the outlet of exhaust shaft in order to avoid short circuit of air. The vertical location of the outlet of air exhaust shaft will be higher than five meters from ground level, while that of the inlet of air intake shaft outlet will be two meters from ground level.

Source: JICA Study Team

Figure 4-287 Cooling Tower

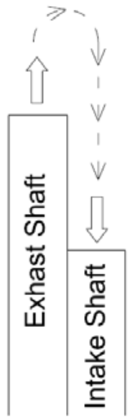


Figure 4-288 Image of the Short Circuit

4.9.4 Station Location Characteristics

Proposed Station Location	**Characteristics**

1. El Malek El Saleh Station Location

Seen from the west side

Since this station will be a transfer station to Metro Line 1, it will be larger in size with two separate platforms. Depending on the required width of the station, the location of the station may affect Misrel Gadima Hospital or the retaining wall of the Salah Salem Road underpass.

On the other hand, this station must have a function as a terminal station until the start of operations of the Phase 2 section. Because of the special surrounding environment with the Misrel Gadima Hospital in front of the proposed station, the station entrances and ventilation tower as well as cooling tower will be carefully arranged so as not to disturb hospital visitors and patients.

Seen from the east side

2. El Rauda Station Location

East side entrance area

West side entrance area

There are dense 7-8 story buildings around this area of Rauda Island, and therefore the station will be partly located under the existing buildings.

This station is proposed because most the of traffic in this island concentrate on the road. One of the high-rise buildings should be under-pinned to avoid demolition. Low-rise buildings at the intersection of Al Roda and Ibnel Mekiass Streets, as well as of Al Doda Street and Abu Raman El Barkouky Streets, should be removed to make access ways passable. The mosque at the corner of Mahmoud zo el Fakar St. will be taken into consideration, since there are a lot of people gathering around it during Friday prayers. The station is cut at the corner so as not to change the situation of the mosque.

Proposed Station Location	Characteristics

3. El Nile Station Location

Giza Flyover

Possible location for west side station entrance with limited open area

The station will be built under the Giza flyover.

A new pedestrian underpass which crosses this flyover is under construction to connect with an existing bus terminal and other sidewalks. Thus, Giza Square under the flyover is very congested in most of the time. It will be necessary to implement a safe and efficient station access route for the passengers. One of the station entrances is combined with the above- mentioned underpass.

The area for the station ventilation and cooling towers will be found in an open area of the building adjacent to Mourad Street.

Although there is not enough sidewalk width for the station entrance in the east side area, a limited open area can be seen in the attached picture.

4. El Giza Station Location

East side seen with the elevated Metro Line 2

West side seen with Pyramid Rd.

The station for connecting with Metro Line 2 needs to be located near the Pyramids Road underpass, where it crosses under the ENR line and a viaduct of Metro Line 2. The Mini-Bus Terminal exists in front of Giza Station of Metro Line 2, therefore the improvement of the terminal and the arrangement of other transportation modes, such as taxis and private cars, should also be taken into consideration in construction planning. There is a possibility of developing commercial facilities on the first basement floor to attract passengers who will transfer between railway lines and who get on and off the train. On the other side of the station site (see attached photo), there is insufficient space for the entrance and the ventilation tower.

The private property nearby will be proposed to be used for the station facilities in this area.

Proposed Station Location	**Characteristics**

5. Typical Stations Location in Pyramids Road

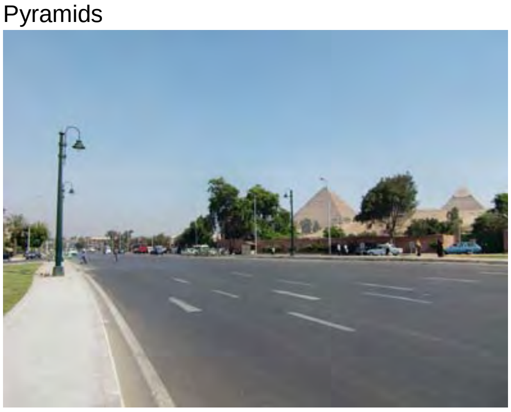
Ventilation tower will be located in median strip of the road

Rotary can be a station entrance location

Five stations are planned as typical stations along Pyramids Road. These typical stations will be located in relatively similar land conditions in terms of the surrounding environment, topographical and geological aspects. There are commercial developments, business and residential areas along the road, where medium-rise buildings are predominant. Most of the typical station entrances will be located on the walkway area and open spaces along Pyramids Road. There are green bands parallel to both sides of Pyramids Road where residents of this area may share a relaxation time sitting on benches under the shade of trees. The median strip width in Pyramids Road is generally 5.0 m, while particular points where car u-turns are permitted have a width of 7.0 m. These strips can accommodate the ventilation and cooling towers, but it is important to decide the size and design of these structures to harmonize with the surrounding city scenery.

6. El Remayah Station Location

Proposed station location with a view of the Pyramids



The first sight which greets visitors as they emerge from the underground station

El Remayah Square is an important strategic location at the intersection of Alexandria Desert Road,and Fayoum Road which connects with 6th October City. The station will be an integral part of the El Remayah Square re-development project, as will be a road tunnel proposed for construction under Fayoum Road and El Remayah Square. This location is important, not only for tourists visiting the Pyramids and the Grand Egyptian Museum, but also for people who transfer to 6^{th} October City by other means. As for park & ride facilities, a short distance bus terminal and car parking areas, as well as commercial areas, are proposed for the same underground level as the station concourse. The significance of this layout is for government (Supreme Council of Antiquities) regulations relating to building and land use in this highly significant tourist area to prohibit the building of large surface structures.

Proposed Station Location	Characteristics
7. M4W Sta. No.13,14 Locations  	Locations for stations No. 13 and No. 14 are similar in nature, both having a boundary with the site of the El Remayah apartment blocks on the eastside and the military area on the northern side.
8. M4W Sta. No.15 Location 	There are no remarkable built structures in this location. Also the surrounding of the site has not been developed. In this case, the location of the station depends mainly on the alignment.

4.9.5 Stairs

The minimum stair width, rise, and tread and the location of flights will be set out in accordance with the Egyptian law on building regulation. The necessary accumulation of stairway width will be calculated in detail in the further design phase following NFPA formula.

4.9.6 Elevators and Escalators

Although a layout of escalators is shown in the proposed drawings of each station, the number and arrangement of escalators will be verified by later reference to the final demand forecast for each station. Elevators will be laid out to provide easy access for passengers, particularly the handicapped.

The elevator shaft will be built in order to serve each level i.e. street, retail premises, concourse and platforms. At least one designated barrier free route with elevators will be designed to allow wheel chair passengers to travel smoothly between ground and platform levels at each station.

At least a single route with elevator is proposed to be installed allowing wheel chair passengers to travel smoothly between the ground and platform levels at each station. The elevators should be large enough and with sufficient technical specifications to accommodate 15 to 20 persons and to allow easy access and egress for wheelchairs.

One or more escalator units, for each operating up and down, will be provided between ground and concourse levels for a large station, and one upward escalator will be provided for medium and smaller stations. Between the concourse and the platform, 2 units, each up and down, will be provided for a large station, and one unit, each up and down, for medium and smaller stations.

Basic specifications of the proposed escalators are as follows:

- Speed 30 45 m/min
- Capacity transfer 9000 p/h
- An incline of 30^{o}
- Two lane capacity type in width
- Four steps landing type

Each standard escalator is designed as a double type (1600 mm width), which will greatly help the smooth vertical circulation of passengers.

The aforementioned arrangement and numbers are basic guides to be verified by later reference for the final demand forecast for each station.

4.9.7 Access Route to the Ticket Gates

The basic layout of stations is designed in accordance with the arrangement of vertical access routes to the platforms and with the location of ticket gates on the concourse floor.

The number of ticket gates and vertical access routes to the platforms should be decided on the basis of forecast passenger flow.

4.9.8 Passenger Access Arrangement

As for the floor planning, the arrangement of every functional element in space will be standardized as much as possible to achieve an easier orientation for users.

At underground stations, ticket barriers are provided on both the start and end sides of the station, and passengers enter the station from these points, and can access the platform using the stairways, escalators, and elevators. The entrance and exit to the ground is provided at least in four places, from ticket barriers to sidewalks on both sides of the road, and they are connected with one another through the free corridor on the first basement level.

At least one route using elevators will be provided from the ground to the platform floor for each station, so that wheelchair users can move easily.

4.9.9 Queuing

Space will be provided for queuing at all circulation and passenger service points. The queuing area provides space for passengers to queue at various circulation points, service areas and decision points without disrupting the movement of other passenger flow routes. Queuing spaces will be placed from end to end with overlap. They will be considered as part of the general space requirements for any given area, as indicated below;

Location	Minimum queuing space
Escalators from working points	8.0 m
Elevators from threshold	2.5 m
Stairs from working points	4.0 m
Ticket Gates from face	6.0 m
Ticket Vending Machines from face	5.0 m
Ticket Sales Windows from counter edge	5.0 m
Fare Adjustment Machines from face	2.5 m

4.9.10 Station Facilities

(1) Station Control Room

The station control room will be located at the concourse level, as close as possible to the ticket hall. The room will be occupied by the Station Inspector and will be the centre for public safety within the station. The room contains the public address system, fire indication system, environmental control system indicators and other necessary facilities for controlling the station service system.

(2) Ticket Sales Room

This is a room for tickets sales with numbered windows. It will be arranged in a convenient and easily identifiable location next to the Ticket Vending Machines, which are close to the Automatic Fare Collection (AFC) gate.

(3) Passengers' Toilet

Separate toilets for each gender will be located within the paid concourse of each station.

A toilet and washstand suitable for use by wheelchair users will also be arranged.

(4) Supervisor's Office

A supervisor's office will be located in the most suitable position to supervise the movement of passengers to the maximum extent feasible at the ticket hall on the concourse. The office should be located adjacent to the arriving ticket barrier gates.

The AFC gates and ticket machines will be supervised from the office.

(5) Station Master's Room

A room to accommodate the station master will be located adjacent to the station office.

(6) Cash and Ticket Handling Room

The cash handling room will provide space for handling cash boxes collected from ticket vending machines, and storage for carts for carrying cash boxes for the sorting and bagging of money prior to transfer to the bank. The room will contain a built-in safe for the deposit of money and a separate area for the ticket store.

(7) Staff Room

Space will be allocated for staff usage during off-duty breaks. This will comprise a rest room and a mess area. The rest room will be designed to high quality comfort conditions, as staff will continually use the room 24 hours.

(8) Staff Dormitory Facilities

Dormitory areas will be provided for each gender sufficient to accommodate a single bed, with wardrobe unit, dressing table and bedside locker. Each dormitory will have a minimum area of 5.0 m^2, depending on the number of staff employed at each station. This facility will be arranged according to the staff working schedule at each station.

(9) Staff Toilets Lockers and Showers

Separate toilets, showers and lockers for each gender will be located at each station.

(10) Station Storage

A general storage will be suitably located at the concourse or other levels. It will contain items and equipment used daily.

(11) Cleaner's Room and Storage

A cleaner's room and storage will be located at the ancillary area comprising a sink, water supply and space for cleaning equipments.

(12) Commercial Areas and Kiosks

Commercial premises will be provided only in designated commercial areas. Kiosks which are constructed from non-combustible materials will be provided where space is available without disturbing passenger flow.

(13) Station Service Rooms

Rooms for the electrical system air-conditioning, plumbing, tunnel ventilation, and substation systems needed for train operation, will be arranged within each station. In addition to these mechanical rooms, an appropriate number of ancillary rooms will also be provided.

(14) Police Room

Two Police rooms (at least) will be provided at each station. Location and size of rooms will be studied in the basic design stage.

4.9.11 Annexed Structure

(1) Ventilation/Air-conditioning Facilities

Since there is a big difference in congestion between peak and off-peak hours, an operation system with an adjustable ventilation volume depending on the time zone is preferable in order to optimize running costs. A mechanical ventilation system is applied for the underground station, and the volume of ventilation in each room is calculated. Since the noise of the exhaust tower tends to increase with the volume of ventilation, silencing equipment will be installed for the benefit of the surrounding environment at particular places. Smoke extraction equipment will be a mechanical type, and separate systems will be used for the platform, concourse, and other rooms, except for the mechanical rooms. At both ends of the underground station, the air supply and exhaust towers for the station and tunnels between stations will be independently planned. As for the air-conditioning, if a large opening in the concourse slab is provided at the centre, both the concourse and the platforms are considered as an integral space, and a blowing system will be applied through the nozzles from both end walls. In the case of independent spaces when the opening is small, the fresh air supply system will be individually applied through a diffuser from the ceiling. The air supply and exhaust towers will be connected to the ground in the road median strip or on the sidewalk of the street via an underground connecting passage. A central automatic control system will be used to control all equipment so that they can be monitored from the station office.

(2) Water Supply and Drainage Equipment

For water supply, either a direct connection system or a water reservoir tank is selected in accordance with the situation in the city of Cairo. The combined waste (toilet flushing, urinal, wash basin, floor drain, building cleaning, kitchen drain, etc.) is accumulated in the underground sewage tank and then drained to the public drain pipe by pumping.

(3) Fire-Fighting Equipment

Fire-fighting equipments, which include fire extinguishers, indoor hydrants, sprinklers, fire alarms, emergency broadcasting equipment, evacuation lights, smoke exhaust equipment, connected water supply pipes, are to be installed. The specifications of this equipment will in accordance with either the the Fire Defence Law and Building Standard Law (both in Japan and in Cairo), or the NFPA standards in the United States. Fire hydrants are also to be installed in the tunnel. The station office of each station can be used as disaster prevention control room and, for this purpose, a disaster prevention panel will be installed. With this disaster prevention panel, it will be possible to control and monitor the smoke extraction facility, fire and smoke shutters, tunnel air extraction equipment, elevators, escalators, etc.

(4) Electric Equipment

The main power consists of two systems: an ordinary system and a priority system. The lighting main consists of three systems: ordinary system, priority system, and DC power system, and for an emergency, a generator is installed. For lighting, general-purpose lamps with easy maintenance are used, and special lamps are partially used in harmony with the architectural design. Lighting fittings which will facilitate easy replacement of lamps are considered. The edges of platforms will be highlighted by bright lamps, and for the entrance and exit of the station, lighting is performed considering city landscape. In case of emergency, lighting will be provided, and the installation of flashing guide lamps with a guide sound will also be investigated.

4.10 System, Facilities and Equipment Plan

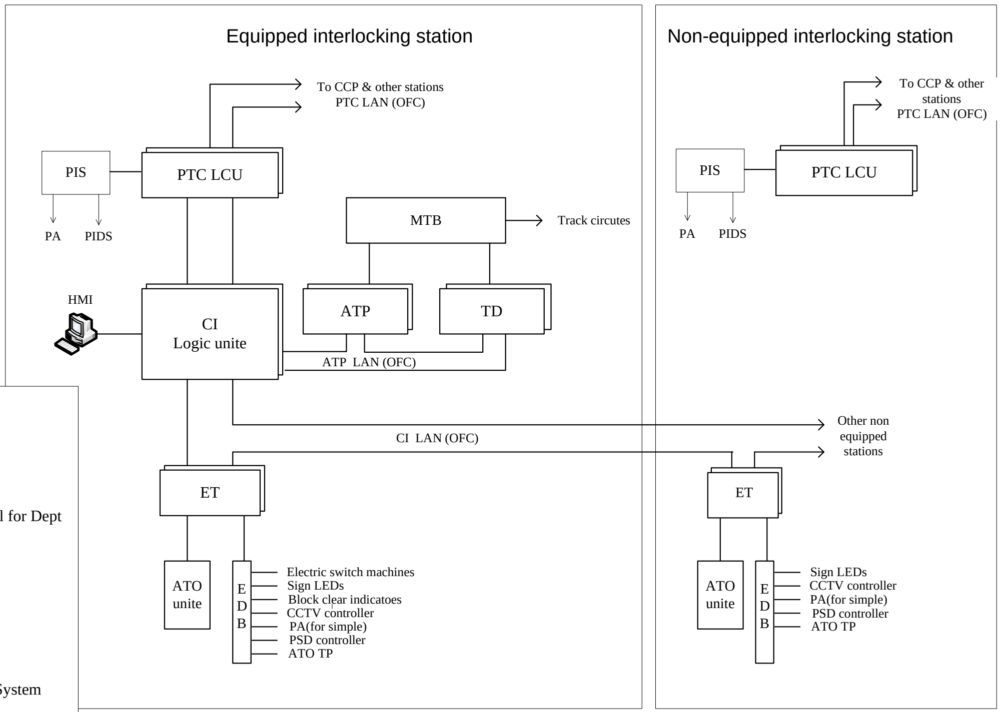
4.10.1 Signalling System

(1) Composition of the signal equipment

The signalling system of Metro Line 1 is a comparatively old type using wayside signals. On the other hand, that of Metro Line 2 is a worldwide standard type of cab signal, such that its safety is of higher level than that of Metro Line 1. This section explains the situation and other significant issues on the existing signalling system of Metro Line 2.

The signal system comprises the following sub-systems for the following functions to be realized:

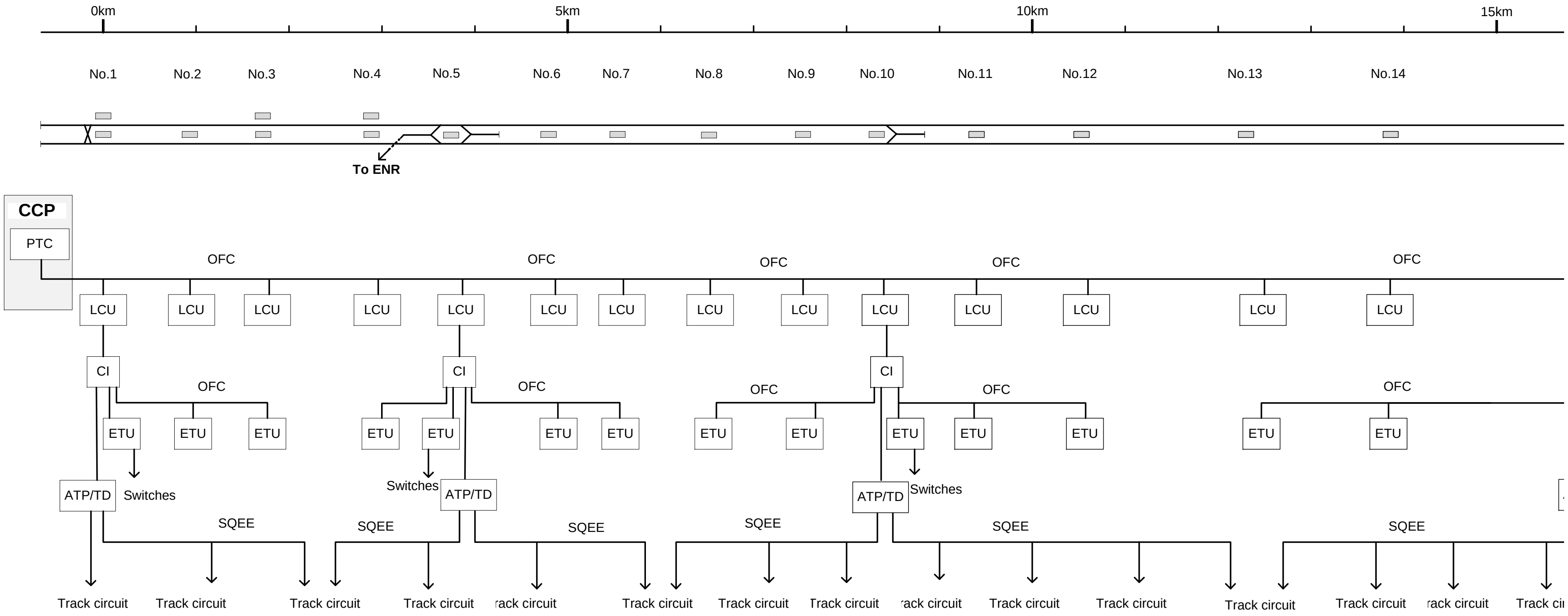
- Route control function: Interlocking device, electric point machines
- Remote route control function: programmed traffic control device, remote route control device.
- Train interval control function: Cab signal (CS), wayside signal (WS), train detection (TD), and automatic train protection (ATP) equipment.
- Train operation support device: Automatic train operation (ATO) device
- Maintenance support function: Signal equipment condition monitoring equipment.
- Signal cables: Optical fibre cable (OFC), ATP transmission cable, signal control cable and cable conduit lines.
- Power supply equipment: Rectifier equipment, uninterruptable power supply (UPS) equipment and emergency power generation equipment.
- The station signalling system is shown in Figure 4-289 and the configuration of the detailed signalling system is shown in Figure 4-290.



Abbreviation
CI: Computerized Interlocking
HMI: Human Machine Interface
ET: Electronic Terminal
LCU(PTC LCU): Local Control Unite
PTC: Programmed Traffic Control
Dep. PRC: Programmed Route Control for Dept
ATP: Automatic Train Protect device
TD: Train Detect device
ATO: Automatic Train Operation
ATO TP: Trance ponder for ATO
EDB: External distribute Bay
MTB: Matching Transformer Bay
PIS: Passenger Information System
PSD: Passenger Screen Door
PIDS: Passenger Information Display System
PA: Public Address
LAN: Local Aria Network
OFC: Optical Fiber Cable

Source: JICA Study Team

Figure 4-289 Station Signalling System



Abbreviation

CI: Computerized Interlocking
HMI: Human Machine Interface
ET: Electronic Terminal
LCU(PTC LCU): Local Control Unite
PTC: Programmed Traffic Control

Dep. PRC: Programmed Route Control for Dept
ATP: Automatic Train Protect device
TD: Train Detect device
ATO: Automatic Train Operation
ATO TP: Trance ponder for ATO

EDB: External distribute Bay
MTB: Matching Transformer Bay
PIS: Passenger Information System
PSD: Passenger Screen Door
PIDS: Passenger Information Display System

PA: Public Address
LAN: Local Aria Network
OFC: Optical Fiber Cable

Source: JICA Study Team

Figure 4-290 Configuration of the Detailed Signalling System

(2) Traffic Control Function

a) Interlock Equipment

Electro-magnetic relay interlocking device is equipped for interlocking. Its function is sufficient for route control of Metro Line 2, however, it: occupies wide space; needs considerable modification work corresponding to the change in the route of stations; and requires high maintenance cost. Interlock equipment controls the operation of the turnouts that are used to introduce trains at stations, signal stations, depots and other such locations onto the required routes as well as interlocks the point machine until the train arrives. In addition, this equipment also has the function of maintaining the stop indicator until the obstructed route is released on routes with reciprocal sections where the danger of collision exists. Interlocking equipment was a kind of solenoid relay for signalling use until the 1980s when the relay interlocking (RI) device that ensured safety began to appear. Around the middle of the 1980s, computerized interlocking (CI) devices using microprocessor units (MPU), which offered better safety, began replacing the signalling relays. Today, CI devices are the mainstream. The CI device has many benefits when compared to the RI device. The CI offers high safety functionality, high reliability, easy maintainability and less space requirement for installation, aside from other benefits. It is recommended that CI be used on the Metro Line 4. While there are various methods for using CI, there is a need to use a multiplex system consisting of two systems or more.

b) Electric Point Machines

The electric point machine is used in the switch and lock movement system of a turnout. A waterproof type will be used because this equipment is used underground. We recommend that regular type electric point machines be used in the depot.

(3) Remote Control Function (Central Control Point (CCP) Function)

Controls of the entire route of entire stations are performed by remote control from a single CCP. When the same railway operator is operating numerous lines within the same area, it is best to have the same CCP room for all lines. The function of the existing operation control system is limited within the route control consisting of only the automatic route setting and manual one. It is impossible for the system to add functions of data communication, operation logging or statistical data processing because the system is not a computerized type. The layout of the CCPs of Metro Line 1, 2 and 3 within one room is suitable for the communication among operation staffs and for dealing with emergency cases. This method is used by subways and urban railways worldwide. However, when there is a rapid increase in the number of lines, there may not be sufficient space in the original CCP. When the new line sections cannot be handled by the existing CCP, building another independent CCP to handle these lines may be unavoidable. However, under such conditions, it would be beneficial to make preparations that would enable combining all line sections in the future. The following shows the functions of the CCP. Note that traffic control within the depot, which is the control up to the departure/arrival track, is controlled by the CCP using the programmed traffic control (PTC) device. After that, route control is performed by the programmable route control (PRC) device located at the depot.

a) Programmed Traffic Control (PTC) Device

The PTC uses computers that follow an established train schedule to automatically control trains at each station and their dispatch routes, using the schedule and train position as its conditions. And, the dispatch staff can use the information about the concentrations of passengers on trains, or if failures on cars or equipment have caused a disruption of operations, to change the train schedule. The PTC has each type of method in it. This system is characterized by its two methods: one is overall centralized control method that utilizes the centralized control devices installed at the CCP and the other is the distributed method in which there is autonomous control by the PTC Local Control Unit (LCU) device installed at each station and the PTC station devices, which contain each train schedule for each station. Generally speaking, since the control cycles per unit of time needed for route control is low on small-scale track sections, there is no need for high-speed data transmission and the centralized method alone can easily handle it. However, on large-scale sections where there are high-density operations, the distributed method has its benefits. If passenger guidance systems are going to be utilized (such as automatic announcements and destination displays), the distributed method has advantages. We recommend the distributed method of control.

b) Mimic Panel (MP)

In the past, the MP used folding screen panels, such as mosaic panels, that had LEDs embedded in them and this was used to show the position of trains, the open status of routes and of point machines, the current display status of the signal equipment, codes for existing tracks inside stations and between stations, and numbers for train numbers. With this method, the mosaic board has to be replaced each time the track configuration is changed, which requires changing the electrical wiring and other construction work. By comparison, a more recent method is to use a projector (PRJ) to cast or emit the images of the above-referenced conditions. In this way, changes in the display accompanying the reconfiguration of tracks can be easily performed by software changes. In addition, using a projector makes it easier to increase or decrease the size of the screen area, which means that it can be used more effectively than a mosaic panel or other such hardware-based panels. Hence, use of the PRJ system is recommended.

c) PTC functions

The following shows the basic functions of the PTC:

Train tracking function:	The position of occupied track after the train has passed can be determined based on the train position and open route information
Traffic control function:	Traffic/route control can be managed using train position information and train schedule information.
Time control function and scheduled processing function:	Controls the standard time and operation control time.
Operation display function:	Track circuit information for the entire track system, open route conditions, train numbers and other information needed for train operation are shown on the operation display projector and dispatcher's console.
Operation monitoring function:	This function monitors the operating conditions and gives out

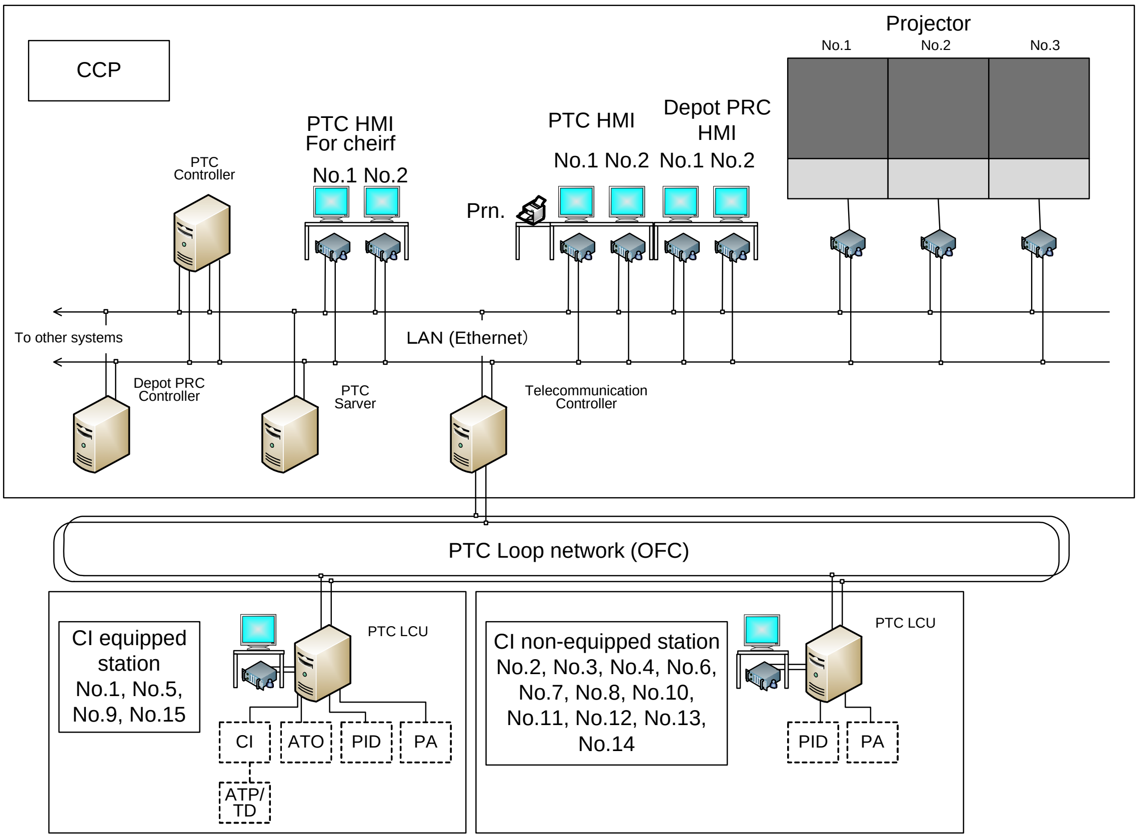
	warnings when delays or other such problems have been detected.
Human-machine-interface (HMI) function:	This function performs changes, command inputs, monitoring and other such activities of the operating information for the train.
Traffic operation arrangement function:	This is the function for changing the train schedule and it provides the operating environment in summary form.
Passenger information display and public address function :	This function controls passenger information display (PID) and automatic public address (PA) system.
Input and output condition I/F function:	This function controls the I/F processing among the other systems (such as interlocking devices, power supply control, and disaster prevention along the track)
Event statistics recording function:	This function records and stores the operating conditions of the trains and the actions taken by the dispatching staff.
Traffic information display (TID) function:	Displays the train route status for the entire track system and delay conditions on the station terminal screen and traffic information display.
Simulation function:	Conditions can be recreated using the stored data and this can be used for training the dispatch staff for simulating operation.
Depot PRC I/F function:	Performs I/F processing with the train depot PRC.

d) Transmission Line

OFC is utilised for the dedicated transmission cable used for transmitting the PTC information, forming a link between the central PTC devices installed at the CCP and the PTC station devices at each station.

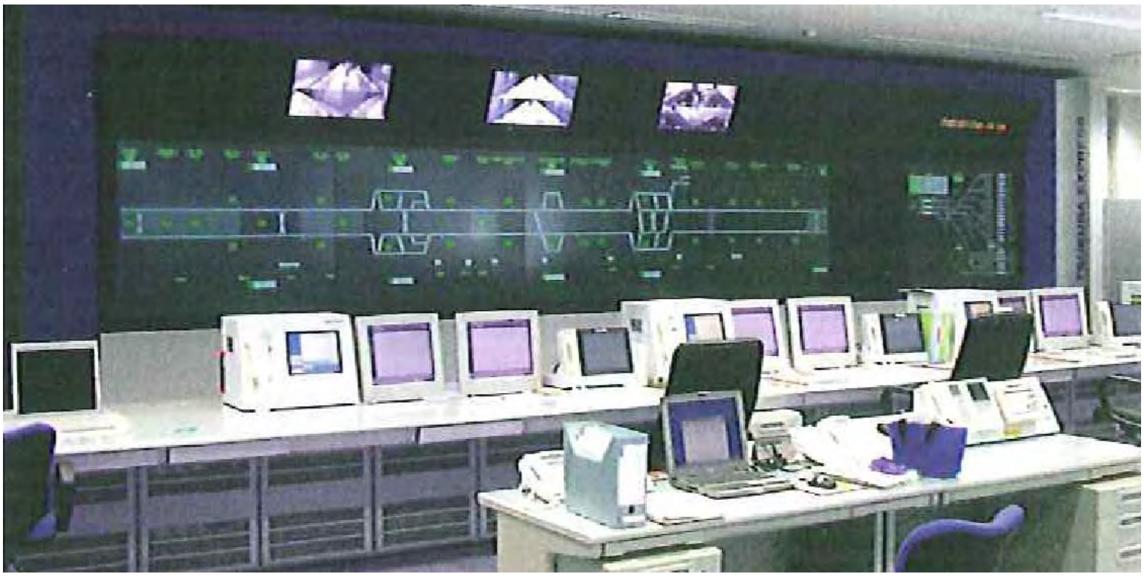
e) PTC and Pjc Systems

The configuration of the PTC system is shown in Figure 4-291 and an example of the application of the Pjc system is shown in Figure 4-292.



Source: JICA Study Team

Figure 4-291 Configuration of PTC System



Source: JICA Study Team

Figure 4-292 Example of the Application of Pjc System (Tsukuba Express in Japan)

(4) Train Interval Control Function

The train interval control function is aimed at controlling train speed in order to prevent a train from colliding with another train operating ahead of it and to prevent trains from entering closed routes. Pulse interval modulation type coding is applied for the existing ATP device. Speedup and minimization of headway of Metro Line 2 are quite difficult to be realized by the code system having fewer than twenty codes.

a) Onboard Signal Equipment Method

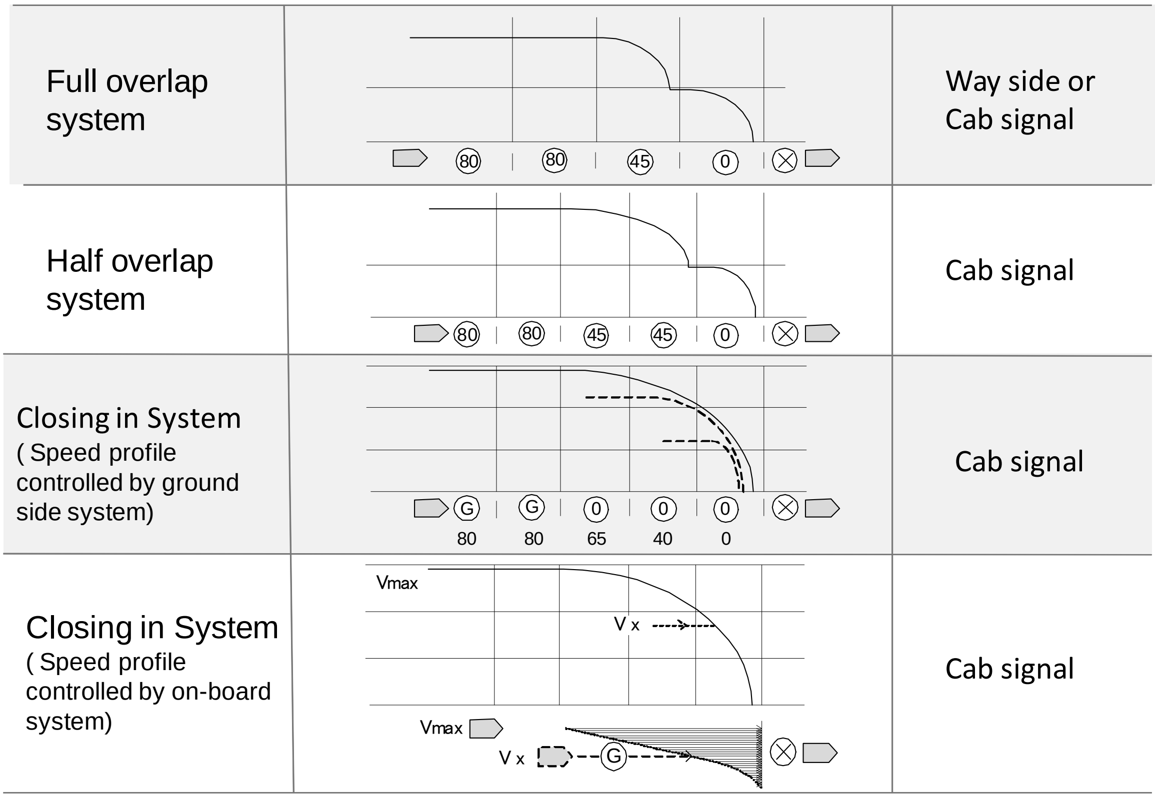
Signal equipment provides operating commands to the operator. With the cab signal system that provides signal equipment on the driver's console inside the train, the track circuit or other methods are used as the transmission route from the wayside equipment to onboard the train. With the onboard receiver, the signal system is controlled by colours and numbers on the driver's console inside the train based on this control information and the driver operates the train by following the display on this signal equipment inside the train. Since the signal equipment is near the driver, it offers better visibility than the wayside signal equipment referred to below. This system is recommended when the route has sections with underground tunnels.

b) Wayside Signal System

Wayside signal equipment is installed alongside the track and is a system that shows the inward conditions so that the driver can operate the train by checking the display status of the wayside equipment. However, the signals are difficult to see in underground sections, so this system places a large burden on the driver. However, since a ground-mounted signal for shunting operations in the car depot is less expensive than an onboard signal system, it is still recommended.

c) Continuous Control ATP

This system continuously sends and receives control information between the wayside and onboard systems as the train travels through all sections of the track line. This system is very safe and responsive to changes in information, so it can be used for high-density operations. If the driver should make a mistake in operation, the brakes are applied to avoid collision with another train, provided that the train is travelling at a speed that makes this possible. This is a necessary system if the onboard signal system is used. The comparison of various available continuous control ATP systems are shown in Figure 4-293. Of the systems, the closing in type enables the highest density operation, thus it is the system that is recommended.



Source: JICA Study Team

Figure 4-293 Comparison of Continuous Control ATP Systems

d) Continuous Control ATP Information Transmission System Using Track Circuit

The track circuit, in which the rail is used as the transmission path for sending the ATP information from the wayside equipment to the onboard equipment, is a widely used method. Its use has a long history and has been used in a wide variety of applications. It has been proven to be the most suitable for a large number of subways and urban railways. In general, it is a system that uses 2 to 10 kHz as the carrier wave that is modulated at a frequency of 100 Hz or less. Amplitude modulation (AM) or frequency shift keying (FSK) is used as the modulation method. Unfortunately, these modulation methods can only offer low data volume and transmission speeds, which makes their use for highly precise control quite problematic. However, in recent years, the minimum shift keying (MSK) modulation method, which transmits digital code, has become a practical method for track circuit transmission and is now being introduced into high-speed, high-density commuter track sections. Moreover, this same system is not only being used in commuter rail, it is also being introduced to high-speed rail systems as highly precision ATP system. The introduction of the latest digital code transmission system as the continuous control ATP system using MSK is therefore recommended.

e) Track Circuit System

The track circuits of Metro Line 2 are of an insulated type and the length of each track circuit is from 150 m to 300 m. Failure of an insulator easily causes operation to stop. Therefore, maintenance work for the insulator is necessary. The minimum track circuit length has to be set at about 50 meters to shorten the train headway to 2 minutes or so. However, the insulated track circuit case means an increase in the number of insulated joints and impedance bonds; hence, likewise not only the initial cost but also the maintenance cost. With the track circuit type continuous control ATP, the track circuit is used for train detection and for transmitting data from the wayside to onboard the train. There are two types of track circuits: the insulated system that isolates the tracks by insulating the rails and the non-insulated system that electronically isolates tracks without using rail insulation. There are also two types of rail insulation: conventional insulation where there is an assembly of the insulation plate and rail joint plate and the other is a factory-made part where the insulation section is fastened by a powerful adhesive to create an integrated adhered insulation. The adhesive-fixed insulation is stronger and more reliable than the conventional insulation. The use of the non-insulated track circuits is recommended because it will make maintenance in underground subway tunnels and other such areas easier. The boundaries of non-insulated track circuits are unclear and precision is lost over sections of track covering tens of meters. Because of the risk of inaccurate train detection, the adhesive-affixed insulation is recommended to be introduced for sections of the track that have turnout devices. A comparison of track circuit types is shown in Table 4-84.

Table 4-84 Comparison of Track Circuit Type

Classification	Type	Note
Non-insulated track circuit	Non-resonance	No electric joint Long end-definition
	Resonance	Complex electric joint Long end-definition
Insulated track circuit	Glued-insulated joint	Low maintenance, Short end-definition
	Normal insulated joint	Heavy maintenance, Short end-definition

Source: JICA Study Team

f) Continuous Control Type ATP Using Radio

Compared to the method that uses radio waves, a wireless system is usually called communication-based train control (CBTC). CBTC has been in use for more than 30 years and comes in a variety of types. The major advantage of using a wireless system is that the information can be sent at high speeds. The high-speed transmission enables highly precise ATP to be achieved. However, there are a variety of systems that use frequencies that range from the 100 kHz LF band to the G Hz band of the UHF band. There is a need to use frequency band of 100 MHz or higher in high-density and high-speed operations. In CBTC, the track circuit is needed for detecting broken rails. The economic factors for this system are the same as using the track as a transmission route, previously described in the item above

g) Point Control ATP

This is the system by which information transmission is performed between the wayside and onboard trains in restricted locations of the block section. If the driver should make a mistake in operation, the brakes are applied to avoid collision with another train, providing that the train is travelling at a speed that makes this possible. Unfortunately, its responsiveness to changes in information is not good; if there is a change in transmitted information, the information is not sent and received until the train has travelled to the next transmission point. However, it is more economical than the continuous control system. The point control type ATP is suitable for locations where the operating speed is low, such as in depots where the wayside signal equipment system is being used.

(5) Train Operation Support Device: Automatic Train Operation (ATO) device

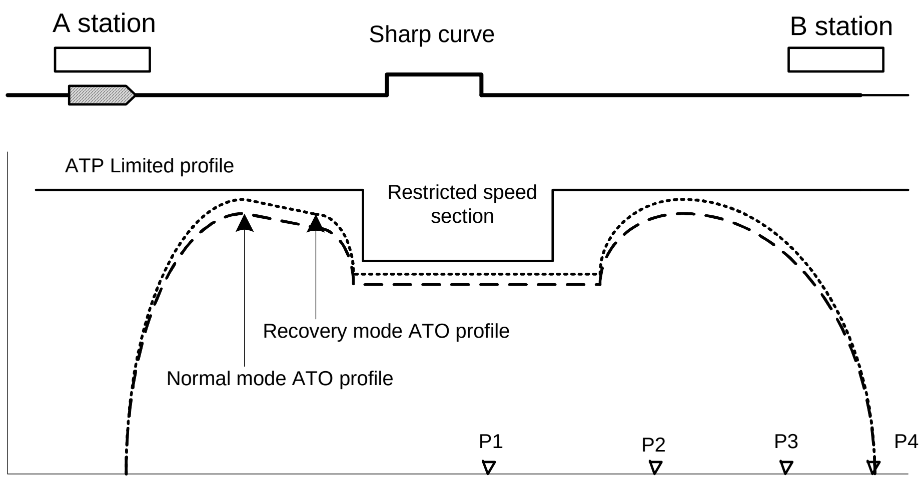
The ATO device is provided with the intention of supporting train operation. The ATO is provided to reduce the burden on the driver, the level of driver experience required, ensure the accuracy of operating time, improve operating speed, save energy through efficient operation and other such objectives. There are various types of ATO systems. Generally speaking, once the doors to the cars have been closed and confirmation has been made, the driver presses the departure button, acceleration and deceleration is performed according to a predetermined travel curve and the train accurately stops at the stop location at the next station. ATO has acceleration commands, constant travel speed commands and train automatic stopping and position control. In summary, the reduction of travel time would enable even more transport capacity without any additional facility investment. There are both wayside and onboard devices.

a) Wayside Equipment

The wayside equipment is comprised of multiple transponders (balises) and control equipment. Transponders P1 is positioned at a ground point located beyond a fixed position from where the transition is made to TASC (approximately 450 meters at the maximum speed of 80 km/h), P2 is located near the start edge point of the platform (180 meters) and transponders P3 and P4 are located at 20 meters and 1 meter, respectively, of the target stop point. The P4 transponder is connected to the ATO control device and exchanges information with the onboard device. The transponders have a fixed number and include information such as its installation position and the distance to the stop point.

b) Onboard Equipment:

The onboard ATO is comprised of the ATO receiver and controller. The ATO receiver receives and deciphers the information from the ATO transponder located on the wayside and sends it to the ATO controller. The ATO controller has the position of each station and the travel speed profiles (ATO pattern). The speed pulse of the speed generator mounted to the axle is inputted into the ATO control unit and the train speed and travel distance are calculated from the speed pulse. The ATO pattern is set at 2 km/h to 5 km/h below the permissible travel speed, and acceleration and brake notching are performed following the ATO pattern, which has been predetermined. With the ATO controller, when there is a deviation from the travel pattern during a trip, deceleration and braking are adjusted and automatic control is performed so that travel will be according to the pattern. The ATO pattern position information is corrected based on the transponder position information. By using this type of control, it is possible to attain a stopping position accuracy of approximately±0.3 meters. If platform screen doors (PSD) are installed, meeting conditions such as the train stop position that are set as the control conditions for opening the door and zero train speed will require that an ATO device be installed. The running profile of the ATO is shown in Figure 4-294.



Source: JICA Study Team

Figure 4-294 Running Profile of the ATO

(6) Maintenance Support Function: Signal Equipment Condition Monitoring Equipment

This signal system is a critical facility that is entrusted with train operation safety, so it will require daily maintenance. Moreover, if even one part of the equipment fails, the railway will not be able to function as a transportation system because failure of the signal equipment will cause the stoppage of train operations. This, in turn will cause disruptions in train services to passengers. Due to this responsibility, and for safe and stable operations, the use of a multiple system arrangement is necessary to ensure reliability. However, this will make the signal system more complex, consequently increasing the places to be maintained. Because of this, it is advantageous to install a system that monitors the condition of the signal equipment as a means of supporting the maintenance operations. In particular, it is strongly recommended that a condition monitoring system be used for equipment such as electric point machines, track circuits and other such devices that cannot be made redundant. Such a system would regularly monitor and record the amperage at the time the electric point machine is rotated, rotation time, torque and other relevant data. This system is effective because if a device being monitored shows signs of deterioration, preventive maintenance can be performed before an actual failure occurs.

(7) Signal Cables

Signal cables for specific applications are used in each of the subsystems comprising the signal system, such as the ATP transmission cables, signal control cables, and OFCs. The following are the characteristics and intended uses of each of the main types of cables.

a) ATP Transmission Cable

Since the ATP system is a method for centralizing the equipment, the ATP transmission cable is laid between the communication equipment rooms that have been installed for the ATP transceiver devices and the ATP matting transformer (MT) box locations for the track circuit boundaries. Signal quad polyethylene (SQEE) cable is used. SQEE cable has low transmission loss, even in the audio frequency (AF) band, and good equalization while offering both good cross talk characteristics and strength.

b) Signal Control Cables:

Signal polyethylene vinyl pair (SEVP) cable is used as control cable for electric point machines and other equipment. Since control cables use direct current or commercial frequencies, it is best to ensure equalization.

c) Optical Fibre Cable (OFC):

Single mode (SM) OFC is laid between stations to be used for equipment such as operation control and electronic interlocking devices.

d) Conduit Routes:

All signal cables are laid in fire-resistant concrete troughs. It is best to lay the communication cable at the same time. High voltage and low voltage power cables cannot be placed in the same conduit. Conduit is provided for each of the up and down directions.

(8) Power Supply Equipment: Rectifier Equipment (Rf), Uninterruptible Power Supply (UPS) Equipment and Emergency Power Generation Equipment.

Each type of power supply is installed at the CCP and in each interlocking and non-interlocking station signal equipment room. Each power supply device is a redundant system in order to ensure the necessary level of reliability. Uninterrupted power supply systems and emergency generators are installed as countermeasures to a power outage. The power supply receives the low voltage power that has been fed as high voltage from the distribution transformer and then reduced at each power distribution location.

a) CCP Power Supply

Power supply devices are installed to supply the power, both AC and DC, needed by the equipment in the CCP. UPS and emergency generators are installed so that the CCP power supply can respond to both short-term and long-term power outages.

b) Interlocking Station Power Supply

The necessary AC and DC power supply devices are installed at interlocking stations. During a power outage, compensatory power supply for the electronic interlocking and PTC station devices is provided for approximately six hours. The ATP power supply device can provide ten minutes of compensatory power so that a train can travel to the nearest station during a power outage.

c) Power Supply for Non-Interlocking Stations:

The necessary AC and DC power supply devices are installed for the signal equipment located at the non-interlocking stations. It can ensure approximately six hours of power during a power outage.

4.10.2 Telecommunication System

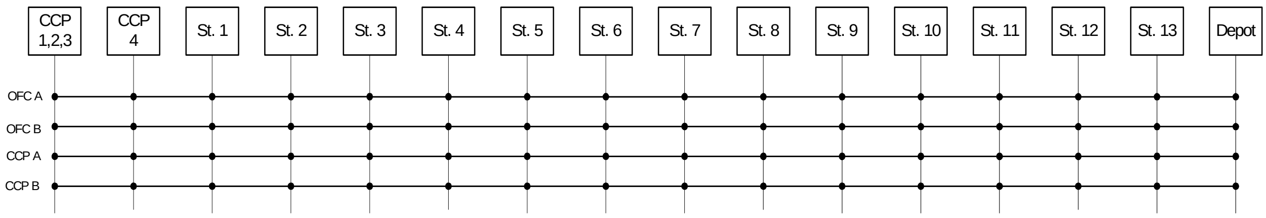
(1) Composition of Communication System

The communication system comprises the following sub-systems:

a. Communication line equipment
b. Optical carrier equipment
c. Train radio equipment
d. Platform monitoring system
e. Video monitoring system
f. Passenger information display (PID) system
g. Station communication equipment
h. Depot communication equipment
i. CCP communication equipment

(2) Communication Trunk System

OFC and CCP are laid as the backbone transmission system throughout all lines. The configuration of the telecommunication lines is shown in Figure 4-295.



Source: JICA Study Team

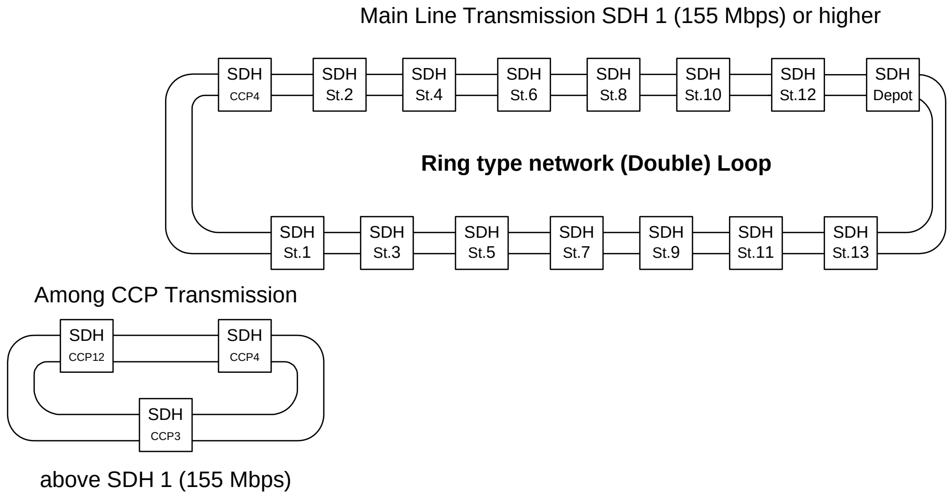
Figure 4-295 Configuration of Telecommunication Lines

a. OFC: Two SM100C cables for OFC are laid for each up and down line. This is pulled into the communication equipment room at each station, depot and CCP. Furthermore, PTC for signal is included in the OFC and various types of core wires are included for electronic interlocking and electric substation system for supervisory control and data acquisition (SCADA).
b. City cables: The CCP will have two city unit cables (CPEE) 0.9mmφ50p each for the up and down lines. This is pulled into the communication equipment room at each station, depot and CCP.
c. Wayside telephone units: Telephone units will be placed at strategic locations along the track, such as at both ends of the platform, at entrances used for maintenance, and every 200 meters along the track. It is possible to directly talk with the staff at the CCP from a wayside telephone as well as call maintenance sections and other places using switched lines.

(3) Optical Carrier System

a. Synchronous digital hierarchy (SDH) system is used as the trunk transmission route. This forms an optical link. Critical lines, such as the train radio and each type of telephone and telephone switching lines, are contained here. Based on the scale of the line sections and the equipment used, the capacity of this system must be capable of ensuring the necessary data volume of approximately STM-1 (155 Mbps). SDH forms the link and ensures redundancy. The configuration of the SDH systems is shown in Figure 4-296.

b. A multimedia transmission route is installed for high-speed, high-capacity transmission. The Gigabit Ethernet optical transmission is used as the transmission standard, which contain ITV image transmissions, command telephone and other similar items.



Source: JICA Study Team

Figure 4-296 Configuration of SDH Systems

(4) Train Radio Equipment

a. Digital radio system is used in the train. This is a time-division multiplexed method system using TDM/TDMA.

b. Since majority of train travel is in tunnels, the transmission method for the train radio is leaky coaxial (LCX) cable, which ensures high transmission quality. This method is also used in the car depot.

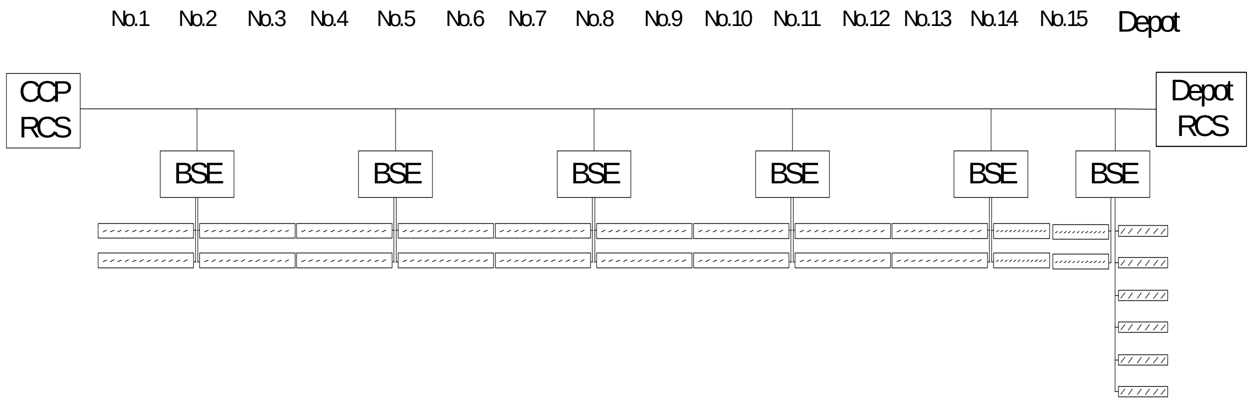
c. Five channels or more are assured for the train radio. These include the operation command channel (CCP-train), data channel (CCP-train), train protection channel (Train itself-CCP-other trains), maintenance audio channel (portable terminals-switching lines, portable terminals-portable terminals) and the control channel.

d. The data channel is used for the command ticket and car information data transmission systems.

e. The use of 150 MHz to 300 MHz as the very high frequency (VHF) band is recommended.

f. There will be more than three hours of compensatory power for the train radio equipment during a power outage.

The configuration of the train radio system using LCX is shown in Figure 4-297.



Source: JICA Study Team

Figure 4-297 Configuration of Train Radio System Using LCX

(5) Platform Monitoring System

a. On a train with two crew members, a driver and a conductor, the monitoring of the platform when the train is departing the station will be performed by the conductor. He/she will have the responsibility of making an emergency stop of the train should it make contact with a passenger on the platform. In order to eliminate the duties of the conductor and have a one-person crew, a system will be installed that gives the driver the responsibility of monitoring the platform. Installing this system ensures the same level of safety as with a two-person crew.

b. The images from the platform are sent to the train and shown on an LCD screen on the operator's console.

c. A transmitting antenna is installed 200 meters in front of the stopping position of the train and there is a receiving antenna on the front of the train.

d. In this system, the centimetre wave band (SHF) or the millimetre wave band (EHF) is the frequency used.

e. The duration of the images shown on the screen on the driver's console will be from the time the train stops until the rear end of the train passes the end of the platform.

(6) Video Monitoring System

a. ITV for monitoring is installed at each station platform, concourse, ticket gate, elevator, escalator and other strategic places.

b. The video images for each station can be monitored in the station master's office.

c. The video images for each station can be sent to the CCP, and dispatchers can observe these video images in the CCP.

(7) PID System

a. The proposed system includes a PID system, which receives the information from the LCU and displays character information of train operation modes (deadhead, test run), destination, departure time, delay situation, etc.

(8) Station Communication Equipment

a. Each interlocking station will have a dedicated command telephone for communicating with CCP and a block telephone for communicating with the adjacent interlocking station.
b. At the interlocking station turnout points, there will be a point telephone for contacting the station master’s office and CCP.
c. Each interlocking station will have a dedicated command telephone for communicating with CCP and a block telephone for communicating with the adjacent interlocking station.
d. Each station will have switch line telephones for conducting their own business.
e. Critical locations at each station will have a slave clock for its own time control. The master clock will be in the CCP equipment room.
f. Each station will have a public address system to perform automatic public address broadcasts based on the train schedule information from the PTC station device. Moreover, it is possible to make broadcasts from the station master’s office and CCP.
g. There is an intercom provided at the passenger screen door (PSD) to enable communication between the passengers and the station master's office.

(9) Communication Equipment at Depot

a. Centralized telephone equipment will be installed at the depot station master room. It will include a command telephone for communicating with CCP and a block telephone for communicating with the adjacent interlocking station.
b. The centralized telephone includes a telephone for making contact with every strategic location in the depot. A point telephone will be provided at locations with turnouts. Each wayside signal will have a telephone.
c. There will be a train radio operating device installed at locations handling operations. It will enable communication with trains occupying tracks in the depot.

(10) CCP Communication Equipment

a. Train radio central operation console: There is a train radio central operation console for the operation dispatch staff at the CCP and at the command director’s seat. It is possible to operate all train radio controls from this operation console. There are several consoles for use by the operation dispatch staff, with a total of more than three consoles to ensure redundancy.
b. Centralized telephone equipment: Centralized telephone equipment is installed for the operation dispatch staff, SCADA operation staff and command director. The centralized telephone system makes it possible to connect with each dedicated line for operation, track, substations and signal communication, as well as with switching lines for the railway business.
c. Video selection device: A video selection device enables selective display on the screen display panel built into one part of the operation display panel (mimic panel). Thus, ITV images are possible to be shown from the platforms and others at each station. This enables the operation dispatch staff to use the selection device to directly choose the information about an accident, or other events or locations that can be displayed.

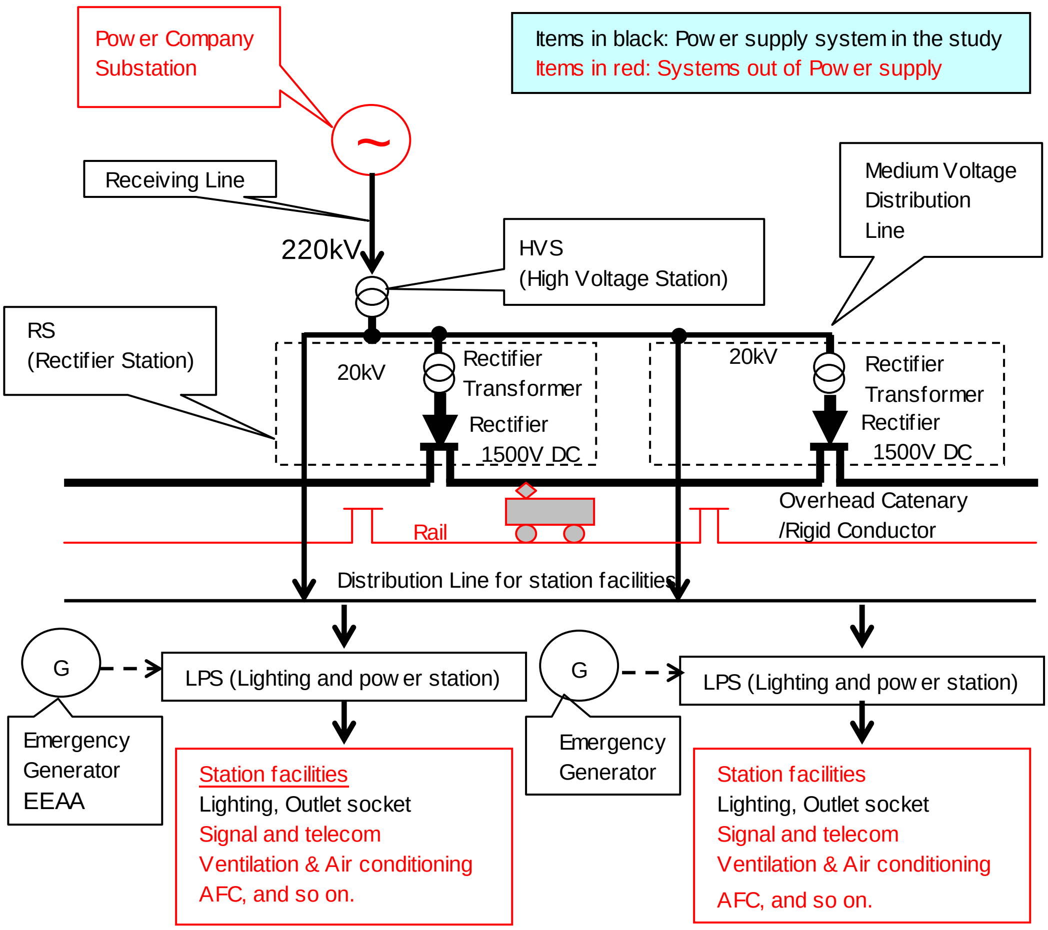
d. Centralized equipment conditions monitoring device: This enables the CCP to regularly monitor the operation conditions of each type of equipment installed between stations, such as in tunnels, including mechanical equipment, lighting and power equipment, communication equipment and signal equipment. If a failure of any one unit of this equipment occurs, an alarm and indication is made to warn the facility dispatch staff. The equipment command staff can assess the extent of the failure and direct response by station staff or dispatch the maintenance staff.

e. Power supply device: The necessary power supply device for the CCP communication equipment is installed. UPS systems are installed as countermeasures to a power outage. Furthermore, emergency power generators are installed as part of the power supply system.

4.10.3 Power Supply

(1) Overall View of the Power Supply System

The power supply system includes all electrical systems for receiving electricity from a power company's substation, and feeding rolling stocks and station facilities. An overall view of the power supply system is as shown in Figure 4-298.



Source: JICA Study Team

Figure 4-298 Overall View of the Power Supply System

(2) Present Condition of the Existing Cairo Metro Lines

The main features of the power supply system in the existing lines are summarised in Table 4-85.

Table 4-85 Main Features of the Power Supply System in the Existing Lines

	Metro Line 1	Metro Line 2	Metro Line 3 Phase 1 (Under construction)
Nominal voltage of contact line	1,500 V DC	750 V DC	750 V DC
Type of contact line	Overhead catenary	Third rail	Third rail
Number and receiving voltage of HVS	Two HVS (220/20 kV and 66/20 kV)	One 220/20 kV HVS	One 220/20 kV HVS
Back-up power supply for traction	Power supply from 11 kV distribution grid		
Back-up power supply for station facility	Emergency generator in each passenger station		

Source: NAT

(3) Design Concept and Proposed System

The design of the power supply system for Metro Line 4 aims to harmonize the following conflicting criteria at a high level of quality.

- High safety and reliability by proven technologies
- Cost reduction through optimization of the whole railway system
- Environmentally friendly and energy saving system by introducing state-of-the-art technologies
- Consistent system with existing lines considering easy operation and maintenance (O&M)

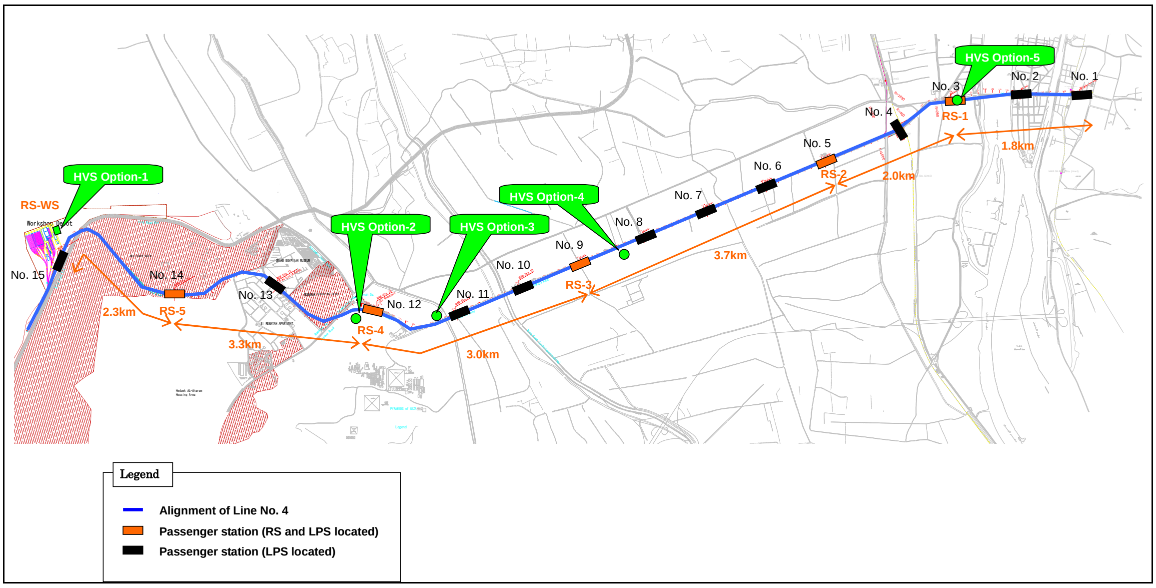
(4) System Function and General Specifications

Main features of the power supply system for Metro Line 4 are summarised in Table 4-86.

Table 4-86 Key Features of the Power Supply System for Metro Line 4

Item		Metro Line 4	
		Phase 1	Phase 2
Nominal voltage of contact line		1,500 V DC	
Type of contact line		Overhead Rigid Conductor	Overhead Rigid Conductor (Tunnel section)/ Overhead catenary (Elevated section)
High Voltage Station (HVS)	Number and receiving voltage	One HVS (220/20kV)	One HVS (220/20 kV)
	Transformer capacity	80[MVA]	80[MVA]
Rectifier Station (RS)	Receiving voltage	20 kV from HVS	
	Number of RS	Five RSs for the main line, one for workshop/depot	Six RSs for main line, one for workshop/depot
	Rectifier capacity	8.0 [MW] for each RS	
	Back-up power supply for RS	Power supply from 11kV distribution grid	
Lighting and Power Station (LPS)	Receiving voltage	20 kV from HVS	
	Number of LPS	One LPS for each passenger station and workshop for power supply to the facilities in low voltage	
	Back-up power supply for station facility	Two 20 kV feeders for each LPS, and emergency generator in each underground passenger station UPS system for signal and telecom and other essential equipment	

Source: JICA Study Team



Source: JICA Study Team

Figure 4-299 Locations of HVS Options, RS, and LPS

(5) High Voltage Station (HVS)

a) Number and Receiving Voltage of HVS

It is common that the rectifier substations in a typical Japanese urban metro line directly receive the power from the grid at multiple substations in 66 kV or 22 kV receiving voltage. On the other hand, the existing lines of Cairo Metro have less number, highly reliable and higher voltage substations called the HVS dedicated to the Metro line power supply due to the less reliable transmission system. Metro Line 1 has one 220 kV HVS (HVS Ramses) and one 66 kV HVS (HVS Tura El Balad), and Metro Line 2 has only one 220 kV (HVS Ramses).

For Metro Line 4, the construction of HVS similar to the existing lines is recommended following the electric company's recommendation and considering the difference in the reliability of the transmission systems in Japan and Egypt.

As for the number of HVS, two HVS are recommended for higher reliability, although it is possible to supply power to the whole line with only one HVS from the view point of supply capacity.

b) Location of HVS for Phase-1

The locations of HVS have to meet the following conditions:

- Accessible from the metro route
- Easy land acquisition
- The area of around 3,000m^2 is necessary for the HVS building

- Grid connection from two independent substations is available
- Low grid connection cost

The following five options for HVS location were studied. The location for each option is shown in Figure 4-299.

- Option-1: Inside the workshop/depot area
- Option-2: Inside the land owned by the Haidelco company next to Remayah Square
- Option-3: Land without buildings currently used as a bus station for tourism owned by the Ministry of Agriculture
- Option-4: Agricultural fields and greenhouses owned by the Ministry of Agriculture
- Option-5: B2 floor of El-Nile station (M4W-Sta. 3 passenger station of Metro Line No. 4)

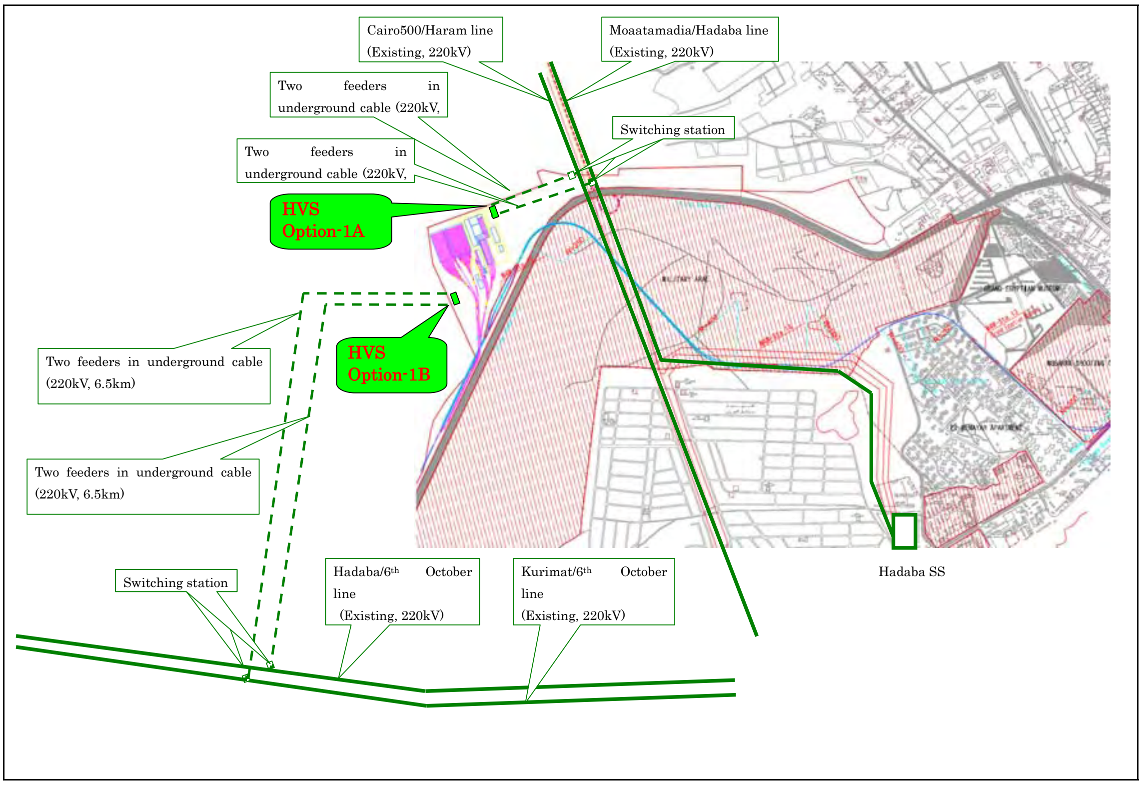
As a conclusion, Option-1 is recommended for HVS location, due to the following reasons:

Option-2 is a land owned by the Haidelco company, which is related to a power company, thus is easy to acquire. It is, however, not feasible because GOPP and SCA have a construction plan of a pedestrian walkway to connect GEM and the Pyramids in this location. The construction of HVS is therefore not preferred from the aesthetic point of view.

Unlike Option-2, the aesthetic problem can be avoided in Option-3 and 4. These lands are owned by the Ministry of Agriculture, and acquisition will be easier than private sector land. For these options, connections to the grid are through underground cables since these are located in built-up areas, and grid connection through overhead transmission lines is not allowed. The grid connection needs construction of more than 3 km-long underground cables to the nearest substations, with high construction cost. The locations are far away from the CCP located in the workshop/depot area at the end of the Phase 1 route, and therefore have a disadvantage from the view point of O&M.

In the built-up area with limited space for HVS construction, an underground HVS is one of the solutions to reserve the space for construction. Option-5 adopts an underground HVS inside of a passenger station. It is, however, not feasible because the EEHC rejects an underground HVS for safety, operational, and cost reasons.

Option-1 is the most favourable option because it meets all the conditions; the area where the workshop will be located is in a desert area out of urban area, and is easy to ensure a piece of large land enough for HVS construction. In addition, this location is close to the CCP, and has the advantage of O&M convenience. The grid connection is available in two alternative routes: Option-1A and Option-1B as shown in Figure 4-300. Option-1A has the shorter feeding route than Option-1B, and this will lead to savings in the construction cost of feeding cables.



Source: JICA Study Team

Figure 4-300 Options for Feeding Route from Transmission Line to HVS in Option-1

c) Capacity of HVS

The HVS capacity is estimated as the summation of the total power consumption, including traction power and the power for station facilities. This is based on assumptions of minimum head way, number of cars and passenger density by operation periods, as shown in Table 4-87. For Phase 1, the power demand was estimated based on the estimation of traction power mentioned in Section 4.4.7. The estimation includes 120% of reserve factor for the HVS transformer. For Phase 2, the traction power was estimated assuming proportionality to the route length with reference to the power demand of Phase 1, while the distribution power was estimated in proportion to the number of stations.

The results of the estimation are summarised in Table 4-88.

Table 4-87 Major Assumptions for the Estimation of Power Consumption

Year	2020- 2022	2023 – 2026	2027 - 2050	After 2050
Phase in operation	Phase 1	Phase 1 and 2		
Minimum Headway	4:00	2:18	2:13	2:09
No. of cars	8			
Passenger density (person/m2)	7			

Source: JICA Study Team

Table 4-88 Estimated Power Demand and Transformer Capacity

Year	2020-2022	2023-2026	2027-2050	After 2050
Phase 1 [MVA]	63	72	73	74
Phase 2 (Northern route) [MVA]	–	78	79	79
Total power demand for whole line [MVA]	63	150	152	153
Transformer capacity for HVS 1 [MVA]	80	80	80	80
Transformer capacity for HVS 2 [MVA]	–	80	80	80

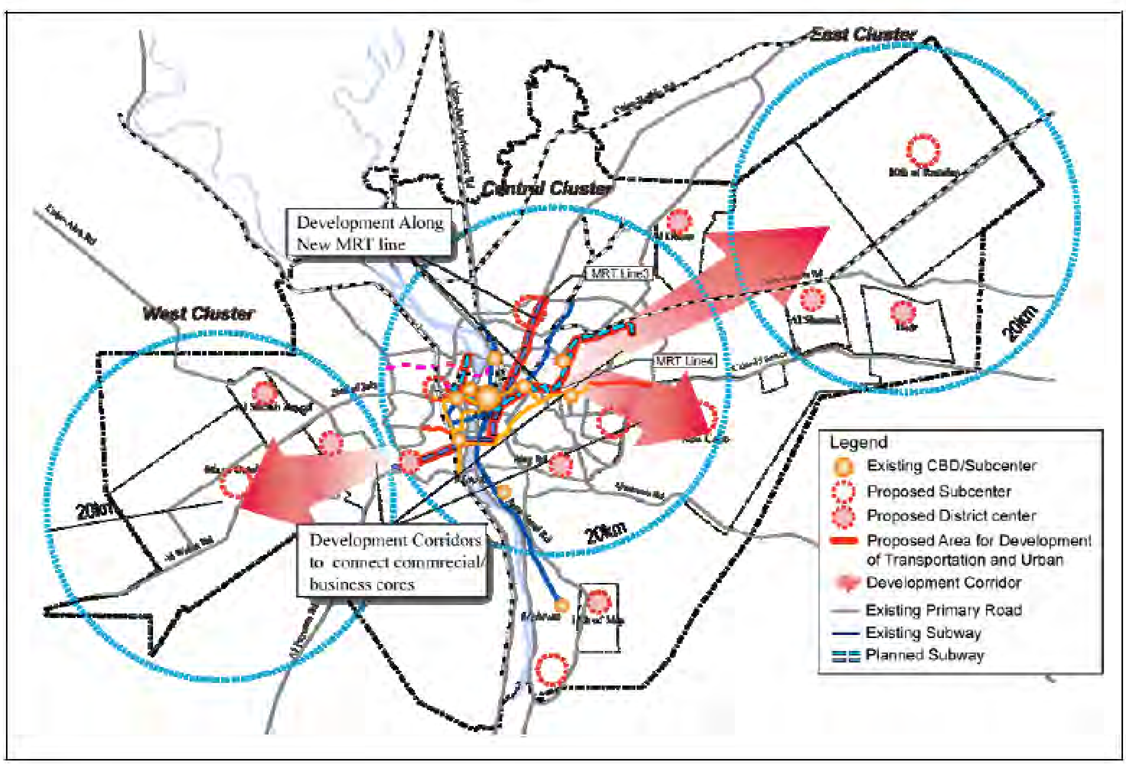
Source: JICA Study Team

(6) Traction System

a) Basic Concept

In the transportation system development in the Greater Cairo Region, Metro Line 4 is characterized as a connection line between the central urban area and suburban developing areas as shown in Figure 4-301.

In selecting the most suitable traction system, the line extension from the urban area to suburban areas was thus considered.



Source: SDMP

Figure 4-301 Proposed Development Corridors in Greater Cairo Region in SDMP

As a result of the comparison to be discussed in the following sections, a 1,500 V DC Overhead Contact System (OCS) is selected as the traction system for Metro Line 4, especially focusing on the following advantages in the operation in suburban areas.

- High speed operation
- Less construction cost considering the line extension to suburban city

b) Summary of Comparison of Traction System

The following two kinds of traction system, OCS (Overhead Catenary (OHC) for above-ground section and Overhead Rigid Conductor (ORC) for underground section) and third rail system, were studied.

Table 4-89 Comparison of Traction System

Criteria	Overhead Contact System (OHC/ORC) (1,500 V DC)	Third rail system (750 V DC)
1. Maximum distance between RS (frequent train services in urban area)	Approx. 3.7km	Approx. 2.3km
(Less frequent train services in suburban area)	Approx. 7.0km	Approx. 4.0km
Number of RS required for Metro Line 4 Phase 1	4 or 5	7 or 8
2. Max. Operation Speed in existing lines	100km/h	80km/h
3. Transportation capacity (No. of passengers/train)	2,304	2,150
4. Characteristics of contact line	1. No wire disconnection (ORC) 2. Long life (20 years or more)(ORC) 3. Shorter life (OHC)	1. No wire disconnection 2. Long life (20 years or more)
5. Safety for O&M workers	Higher	Lower (Conductor at ground level increases the risk of accidental contact for O&M workers and persons to fall into the tracks)
6. Aesthetic aspect	OHC may spoil the beauty of the scenery in above-ground section	Good appearance because there is no overhead equipment
7. Line extension to suburban area	1. Higher operation speed 2. RS can be located inside of passenger stations.	RS construction is required in additional places other than passenger stations.
8. Construction cost	1. Max. 1% higher than third rail system for Phase 1 2. Lower cost in extended line to suburban area	

Source: JICA Study Team

c) Item 1: Number of and Average Distance between RS

The larger distance between RSs, the fewer number of RSs are required to be constructed. This contributes to the cost reduction of construction of RS and for easy O&M.

A major factor determining the distance between RSs is the voltage drop in the contact line under the same train O&M conditions. Voltage drop in the contact line is proportional to the distance from the RS, and a higher traction voltage has a larger reserve of permissive minimum voltage: the differences between the nominal voltage and the lowest voltage are 250 V in 750 V DC system and 500 V in 1,500 V DC system.

Table 4-90 Permissive Lowest and Highest, and Nominal Voltage in IEC

Electrification System	Lowest Permanent Voltage	Nominal Voltage	Highest Permanent Voltage
750 V DC	500 V	750 V	900 V
1,500 V DC	1,000 V	1,500 V	1,800 V

Source: IEC 60850

The average distance of RS based on the experience in Japanese railway systems is approximately 3.5 km in the 1,500 V DC system, and 2.3 km in the 750 V DC system.

Therefore, the 1,500 V DC system has an advantage for this criterion.

d) Item 2: Maximum Operation Speed

The maximum operation speeds in existing lines are 100 km/h in 1,500 V DC OCS, and 80 km/h in 750 V DC third rail system. The difference in maximum operation speed is derived from the difference in the structure of the current collecting device used in the two systems. In the third rail system, the end ramps of the conductor rail, where they are interrupted, limits the maximum speed due to the mechanical impact on the shoes (current collecting device).

The difference in the maximum operation speed, however, does not affect the actual operation speed in urban areas because the actual cannot reach the maximum operation speed in the area where the distance between passenger stations is not so far between.

On the other hand, the 1,500 V DC OCS will enable a higher speed operation in the suburban area, where the distance between passenger stations tends to be longer.

e) Item 3 Characteristics of Contact Line

The OHC has a possibility of wire disconnection. On the other hand, ORC and third rail hardly have any possibility of disconnection.

The life span of the contact lines of ORC and third rail is at least 20 years, and comparatively longer than that of OHC

f) Item 4 Safety for O&M workers

In the case of third rail system, the contact conductor is mounted at ground level. This increases the risk of accidental contact for O&M workers and of persons falling into the tracks. Therefore, the OCS, in which the contact line is mounted at a higher level, has an advantage at this point. In addition, the ORC has almost no possibility of disconnection, thus is safer for O&M workers and lower risk of persons to fall into the tracks.

g) Item 5 Aesthetic Aspect

From the aesthetic viewpoint, the third rail system has an advantage over OCS because it has no overhead equipment that could be eyesores. This issue, however, matters only in the above-ground section.

h) Item 6 Line Extension to Suburban Area

The OCS has an advantage when the line extension to suburban area is considered. In the suburban areas, the distance between passenger stations will be longer than in the urban areas, and the OHC that has a higher maximum operation speed will enable a higher speed operation compared to the third rail system.

From the view point of RS construction cost and its O&M, OCS has an advantage over the third rail system. The RS in the third rail system may need additional places other than inside the passenger stations for its construction because the distance between RSs may be shorter than the passenger station interval.

i) Item 7 Construction Cost

Compared with the third rail, the construction cost of OCS will be higher, but the increase will be less than 1% of the total project cost. The cost increase is mainly caused by the higher civil works cost associated with the increase in the tunnel diameter. When the line is extended to the suburban areas, it is highly possible that the civil works for the line will be an elevated structure. Although it is difficult to assess the accurate cost difference because the line extension plan is not yet known, there will be little difference in the construction cost between the OCS and third rail system.

The rough estimation of the difference of the cost between OCS and third rail system for Phase 1 is described as follows.

Civil cost

In general, one of the major advantages of the third rail system compared to the OHC system is that its tunnel diameter will be smaller, and third rail system is able to reduce the civil cost for shield tunnel construction.

Comparing between the ORC and third rail, the tunnel diameter of ORC can be equivalent to that of the third rail as shown in Figure 4-302, and the cost increase caused by the increase in diameter will be about 9.5%.

Civil works cost estimation for Phase 1 in the case of OCS compared to third rail system

Cost increase by larger shield tunnel diameter: 120 [million EGP/km] x (109.5-100)/109.5 x 13 [km] = 135 [million EGP]

Where, unit cost of shield tunnel construction in case of OCS: 120 [million EGP/km]
Line length: 13 [km]
Proportion of cost increase: 9.5 [%]

Cost reduction by reduction of RS: 25 [million EGP/km] x 3 [RS] = 75 [million EGP]
Where, assumed unit civil cost of RS: 25 [million EGP/km]
Reduced number of RSs: 3 [RS]

Total cost increase in civil works: +60 [million EGP]

Contact Line Cost

The construction cost of ORC will be 30%-40% higher than that of the third rail system.

Contact line cost estimation for Phase 1 in case of OCS compared to third rail system

Cost increase by ORC: 1.0 [million EGP/km] x 40 [%] x 16 [km] = 6.4 [million EGP]

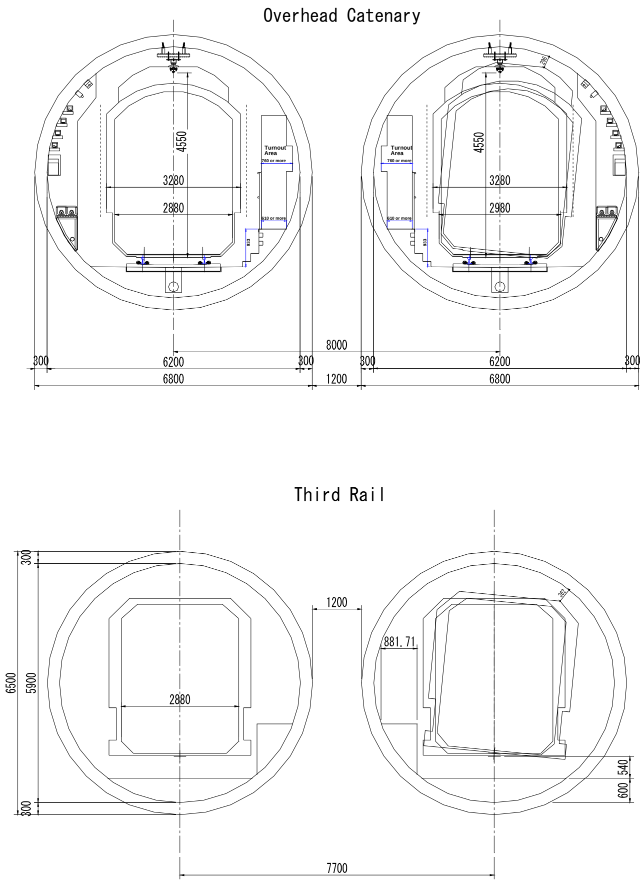
Where, assumption of unit cost of third rail: 1.0 [million EGP/km]
Line length: 16 [km]
Proportion of cost increase compared to third rail: 40 [%]

Total cost increase in contact line: +6.4 [million EGP]

Total Cost Increase for Phase 1

The total cost increase in civil and contact line is equivalent to 66.4 [million EGP]. The increase will be less than 1% of the total construction cost of approximately 11,000 [million EGP]

Note that the above rough estimation of the cost does not include the station civil structure cost for RS. Therefore, cost reduction by reducing number of RS will be much higher than that as mentioned above. In other words, the selection of ORC or third rail will not affect the total construction cost for Metro Line 4.



Source: JICA Study Team

Figure 4-302 Standard Section of Shield Tunnel

(7) Rectifier Station (RS)

a) Design Criteria

The criteria for RS design, i.e., deciding on the interval between RSs and the capacity of rectifiers, are as follows.

- One RS failure can be compensated by the neighbouring RSs
- The voltage of the contact line should not be under 1,000 V, in compliance with the IEC standard
- The distance between RSs should be longer as possible while meeting the above-mentioned requirements in order to decrease the number of RSs and reduce the construction cost.
- RSs should be located inside of the underground passenger stations.

b) Calculation of Voltage Drop

The maximum interval distance between RSs was determined by calculating the contact line voltage to meet the above-mentioned criteria. The minimum headway of 2:13 in the target year 2027-2050 is assumed for the calculation of voltage drop. This design of the RS in the most severe condition in operation headway is reasonable since the life span of the RS equipment is longer than 20 years.

The details of the calculation and the assumptions such current flow is described in *Annex 4-1.* Although the permissive lowest voltage of the contact line is 1,000 V in the design criteria, the calculation of the voltage drop is made to secure more than 1,100 V of contact line for allowing leeway.

As a result of the calculation, the voltage of the contact line exceeds the permissive lowest voltage (1,000 V) even in case of one RS failure. Therefore, the 3.7-km RS interval is feasible.

c) Location of RS

As a result of the calculation of the voltage drop in the contact line, the average interval distance between RSs must be shorter than 3.7 km. (The details of the process of the calculation are described in *Annex 4-1*.) The location of RS is also affected by the station structure design, and the interval distance varies according to the station conditions.

Based on the result and requirements from the station architectural design, five RSs are required for Phase 1. The locations of RSs and relation between RS and passenger stations are determined as shown in Figure 4-299.

For Phase 2, at least six RSs will be required assuming the required number of RSs is proportional to the route length with reference to Phase 1.

d) Capacity of Rectifier

The capacity of the rectifier in RS was calculated based on the condition mentioned in the previous section and assumptions as shown in Table 4-91 and Table 4-92.

Table 4-91 Key Assumptions for Determining Capacity of Rectifier (1)

Item	Value
Acceleration current of rolling stock	2,474[1] [A]
Current of auxiliary circuit of rolling stock	168[1] [A]
Rate of power consumption	48[1] [kWh per 1000 t·km]
Weight of train (rolling stock + passenger)	406.6[2] [t]

Source: [1] Specifications of commuter train in JR East, [2] JICA Study Team

Table 4-92 Key Assumptions for Determining Capacity of Rectifier (2)

Year	2020- 2022	2023 - 2027	2028 - 2050	After 2050
Number of trains per hour (both directions)	30	52	54	56

Source: JICA Study Team

Table 4-93 shows the estimated maximum power per hour for one RS. The table shows the required power for one RS in normal operation and in the situation that the next RS does not work due to a failure. The required rated capacity of the rectifier is derived from the required power in year 2028-2050 for the situation that the next RS experiences failure.

Table 4-93 Estimated Maximum Power per Hour for One RS and Rated Capacity of Rectifier

Year		2020- 2022	2023 - 2027	2028 - 2050	After 2050	Rated Rectifier Capacity [MW]
Required power for a RS in Phase 1 [MW]	Normal operation	3.5	5.1	5.2	5.3	8.0
	Next RS failure	5.2	7.6	7.9	8.0	

Source: JICA Study Team

e) Measures against Harmonics Problem

According to NAT engineers, the harmonics from rectifiers in RSs usually cause malfunctions in the lighting equipment of Metro Line 1 and 2.

From experience, all the electrical facilities in Japan, including the railway power supply system and rolling stock, comply with the “Guideline for Harmonics Control Measure” published by the Ministry of International Trade and Industry of Japan in 1994. This guideline aims to maintain the harmonics level of less than 5% in 6.6kV grid and 3% in more than 7.0 kV grid. After the implementation of the guideline, any noticeable harmonics problem has never occurred in the railway system.

IEEE Std 519-1992 is an internationally employed standard for regulating harmonics in transmission systems. The power supply system in Metro Line 4 should also comply with this standard.

As shown in Annex 4-2, a special circuit configuration that separates the traction and distribution current flow from each other for avoiding harmonics is employed in existing lines. In Metro Line 4 design, harmonics problems can be overcome by installing the electrical equipment that can comply with the standard without any special circuit configuration.

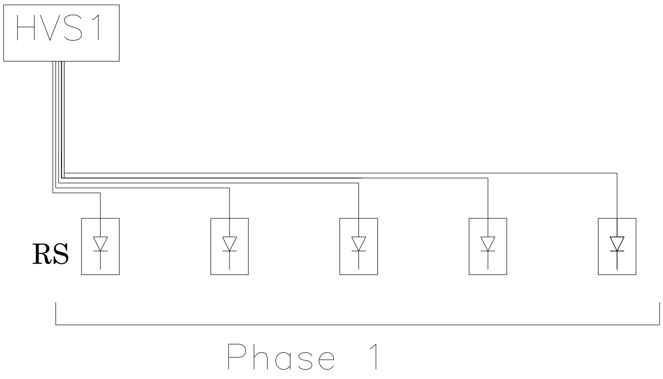
Nevertheless, contractors shall assess the harmonics level after the installation of the power supply system during the construction phase. If harmonics exceeding the constraint is detected, the countermeasures taken in the existing lines should be considered.

(8) Distribution System for Traction Power Supply

The power received at HVS is converted by transformers from 220 kV into 20 kV in order to supply RS for feeding rolling stocks.

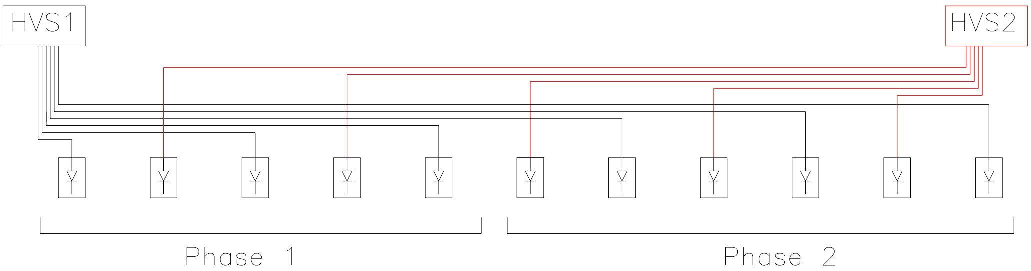
The conceptual diagram of the distribution systems between HVS and RS for each phase is shown in Figure 4-303 and Figure 4-304. Due to the request from NAT, the radial cabling method, similar to the existing lines, will be adopted for the connection between HVS and each RS.

The major feature of the distribution system for Phase 1 and 2 is that one HVS feeds every other RS. In case power failure occurs in one HVS, this configuration enables another HVS to feed the remaining RSs and train operation could continue in a degraded mode.



Source: JICA Study Team

Figure 4-303 Cabling between HVS and RSs for Phase 1 Only



Source: JICA Study Team

Figure 4-304 Cabling between HVS and RSs for Phase 1 and 2

(9) Overhead Contact System (OCS)

The type of OCS should be studied considering that the whole route will be a tunnel section. The selected contact line has to be suitable for it.

In the 1,500 V DC OCS, there are mainly two types of contact line: one is the overhead catenary and another is the overhead rigid catenary.

a) Overhead Catenary

This type of OCS is widely used in railway systems all over the world. The OCS used in Metro Line 1 of Cairo Metro is also of this type. Overhead catenary has a long technical history over the years and is known for high performance in high speed operation.

The main features of the two kinds of overhead catenary suitable for urban railway system are described in Table 4-94.

Feeder messenger system has a wire that functions both as a messenger and a feeder, enables easy construction and O&M, and has a simple appearance preferable from the aesthetic point of view. This type of catenary is recommended for the elevated section of Metro Line 4.

A simple catenary is the most basic structure of overhead catenary. This has a cost advantage and is recommended for use in the workshop/depot track where high speed operation is not required.

Overhead catenary has, however, some disadvantages in durability and possibilities of disconnection from the contact line compare to Overhead Rigid Conductor described in next section.

b) Overhead Rigid Conductor (ORC)

The catenary type of contact wire installed in underground metro has the possibility of disconnection defect, and this may cause problems from the viewpoint of safety and maintenance workability in small spaces.

The ORC, which has no disconnecting defect, has been developed as a new type of overhead contact line suitable to be installed inside tunnels.

Catenary has mechanical elasticity, in which the catenary lifts up against the upward force of a pantograph. On the other hand, in an ORC, the contact wire is completely integrated with the moulding compound conductor.

Main features of ORC are as follows:

- ORC can prevent the contact wire from a disconnection fault because the contact wire is integrated with the moulding compound conductor.
- Tunnel cross-section can be smaller because the height of uplift of contact wire is so small.
- Pull-off equipment and steady equipment is unnecessary.
- ORC enables through operation to the line the catenary is installed.

In 1961, the ORC was introduced in the Hibiya-Metro Line in Tokyo for the first time. It has been installed into not only metro lines but also a part of above ground lines that has small cross-section tunnels. The detailed technical characteristics of ORC are shown in Annex 4-3.

ORC is recommended for the contact line in the tunnel section of Metro Line 4 due to the above-mentioned advantages in its use in tunnel sections.

The main characteristics of the two types of catenary are summarised in Table 4-95.

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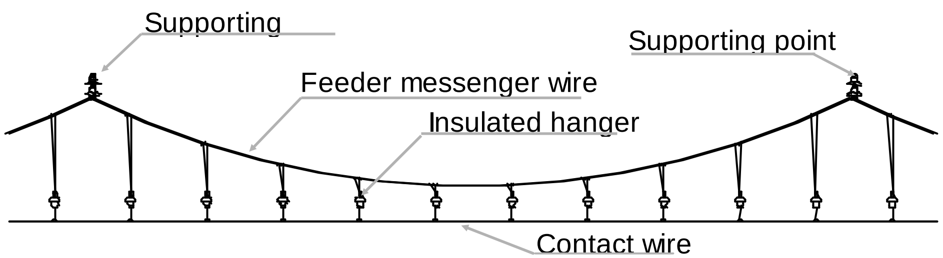
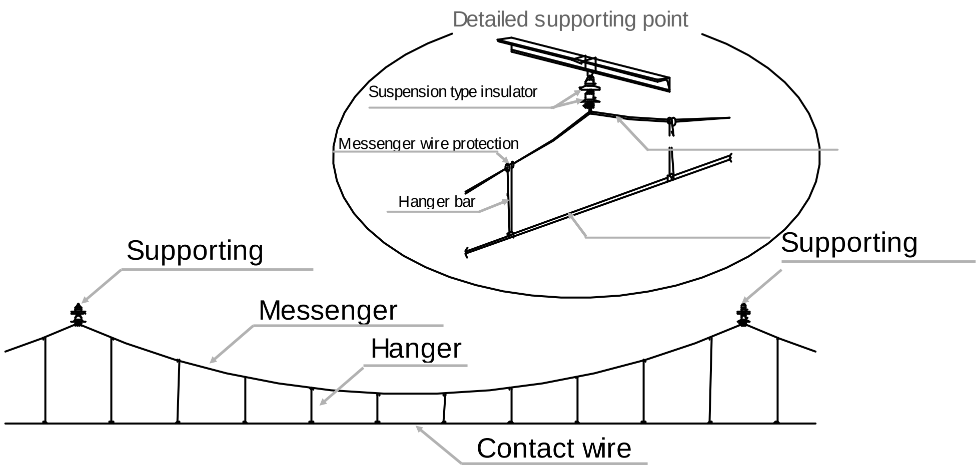
Table 4-94 Outline of the Two Types of Overhead Catenary System

Type	Feature	Application
- 	It is one of the overhead catenary systems which uses a large cross-section in order to supply current easier with messenger wire, also has the function of feeder wire. This system does not require the additional feeder wire, and it is harmonized to the surrounding scene and facilities. For high speed (Under 130km/h)	Elevated section
	This is the simplest catenary suspension system and is widely used. For medium speed (Under 100km/h level)	Workshop/depot

Source: JICA Study Team

Table 4-95 Major Characteristics of Catenary Used in Line 1 and ORC

Type of Overhead Conductor Line		Material		Weight [kg/m]	Tensile strength	Life time of contact wire/conductive rail	Max. Operation speed (Actual max. [km/h]	Possibility of conductor disconnection	Material cost [LE/km]
		Feeder	Contact conductor						
OHC in Line No. 1		Hard-drawn electrolyte copper E-Cu 57 alloy with 0.1 % silver (107mm2)		0.95		More than to 30 years (in good condition)		Possible	3,800
Rigid Conductor	T-section feeder with contact wire	Al (1,900-2,230mm2)	Cu (110mm2 or, 2×110mm^2 or 150mm2)	9.4 - 9.6	0 (No tension)	5 to 7 years	108 (90)	Very rare because of no tension to contact wire	4,200
	Conductive rail (Al feeder)	Al (1400mm2),	Fe (15.2mm2)	19.1	0 (No tension)	More than 20 years	75 (75)	Non	5,000
	Conductive rail (Cu feeder)	Cu (480mm2)	Fe (15.2mm2)	18.6	0 (No tension)	More than 20 years		Non	Data not available

Source: JICA Study Team

(10) Distribution System for Station Facilities

Low-voltage (220 V AC for single-phase and 380 V AC for three-phase) power supply for all station electrical facilities will be fed from LPS similar to the existing lines. Likewise, the design policy for emergency power supply will basically follow the idea in existing lines.

a) Lighting and Power Station (LPS)

All passenger stations will be equipped with the LPS, which receives 20 kV power from the HVS and convert it into low voltage power to feed the station facilities, similar to the existing lines. Each LPS should have two feeders from HVS and one stand-by transformer for reliable power supply. LPSs will be located inside each underground station as shown in Figure 4-299.

b) Emergency Power Supply

An emergency generator, which feeds the station facilities, is critical for passengers' evacuation and safety in case of power failure in regular power supply. Hence, similar to the existing lines, all passenger stations have to be equipped with generators. From the view point of O&M and fuel supply, the diesel generator, which is also adopted for existing lines, is recommended for emergency power.

(11) Power SCADA

Power SCADA, which controls and monitors electrical equipment in all related facilities, HVS, RS, and LPS, is an essential system for managing the power supply system in Metro Line 4.

The power SCADA system will be managed and controlled in the power control point (PCP). The PCP should be located in the same room in the workshop/depot where the CCP will be located for better cooperation and coordination on train operation.

Examples of control and monitoring items for the power supply system are presented in Table 4-96.

Table 4-96 Examples of control and monitoring items

Electrical facilities	Control and Monitoring Items
HVS, RS and LPS	Voltage of all 220kV, 20kV, 380 V AC and 1,500 V DC bus bars Current of all 220kV, 20kV, 380 V AC and 1,500 V DC bus bars Status of circuit breakers and disconnecting switches Status of all protection equipment Operation of alarm and protection devices Rectifier current

Source: JICA Study Team

(12) Building Automation System (BAS)

BAS should be provided in each station and workshop to control and monitor the E&M system, including building services, elevators and escalators.

(13) Electromagnetic Interference (EMI)

a) General

Generally speaking, EMI is a disturbance that affects an electrical circuit due to either electromagnetic conduction or radiation emitted from a power supply system.

The effect of EMI on other equipment in external systems depends not only on the emission level of the EMI source but also the distance to the objective external systems and these systems' immunity. Therefore, it is impossible to accurately assess the influence of the EMI without knowledge about the objective systems.

In railway power supply systems, the causes of the electrical disturbance are classified by two kinds of physical phenomena, electro-magnetic induction and electrostatic induction. Basic principles of the theoretical assessment of the emission level of the power supply system are described in Annex 4-4.

b) Experiences in Japanese Projects

In railway system projects in Japan, EMI can be a problem mainly in AC electrification systems. Only some cases of DC systems affecting electron microscopes used in research institutes such as a university or laboratory were found in past projects in Japan. In these cases, the influence could be prevented by physically isolating the RS and contact lines from research institutes. An actual measurement is necessary to know the accurate intensity of EMI, and it is difficult to assess quantitatively the distance of the isolation before the construction of the line. It is, however, widely known from the experiences in past projects that the distance of 400 m to 500 m between a railway system and an electron microscope is enough to eliminate the influence of EMI.

In Metro Line 4, it would appear that research institutes using electron microscopes are not found in the area close to the alignment. If it is expected that there will be facilities that needs some countermeasures against EMI, then the problem will be prevented by the above-mentioned countermeasure.

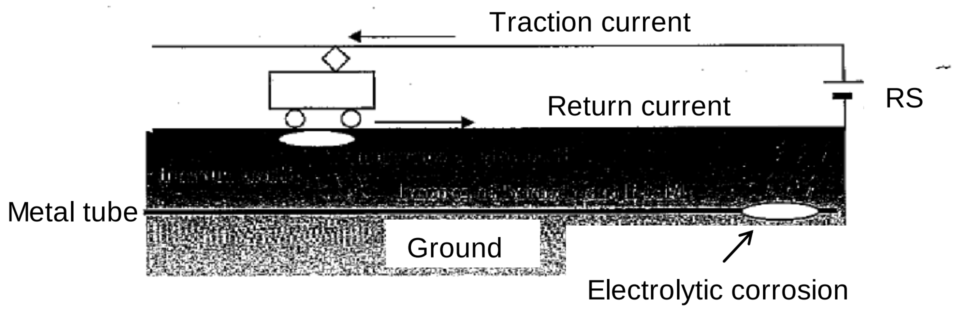
(14) Stray Current

Stray current is leakage current from rails to ground. Stray current that flows in the ground instead of through rails, may cause electrolytic corrosion of underground metal tubes buried in the vicinity of the rails. In addition, rail current tends to flow from the main line toward the workshop/depot, where the combined electric resistance of rails is lower than the mainline since a lot of rails lie in parallel. This could lead to electrocution hazard to workers in the tracks for inspection and repair.

a) Electrolytic Corrosion Caused by Stray Current

Electrolytic corrosion is a kind of galvanic corrosion that is an electrochemical process in which one metal corrodes when in electrical contact with a different type of metal and both metals are immersed in an electrolyte.

As shown in Figure 4-305, electrolytic corrosion is caused generally around the metal tube near a RS where return current flows into it. Stray current tends to flow toward the rails in the workshop/depot from the main line because the parallel connection of congested rails in the workshop/depot makes a lower combined ground resistance. Consequently, corrosion problems tend to happen especially in workshops/depots.



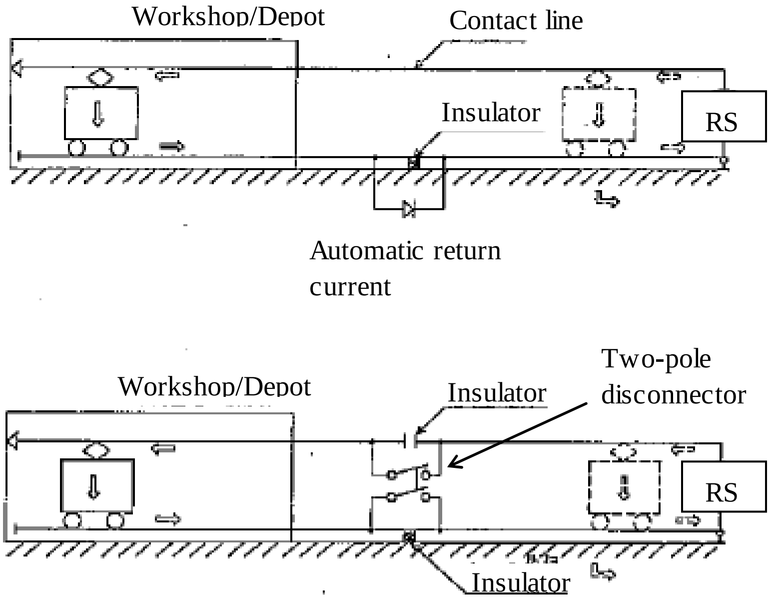
Source: JICA Study Team

Figure 4-305 Electrolytic Corrosion Caused by Return Current

b) Mitigation Measures against Influence of Stray Current

Reduction of stray current is the most basic mitigation measure to prevent electrolytic corrosion. It becomes possible by decreasing the traction current, return conductor (rail) resistance and leakage time.

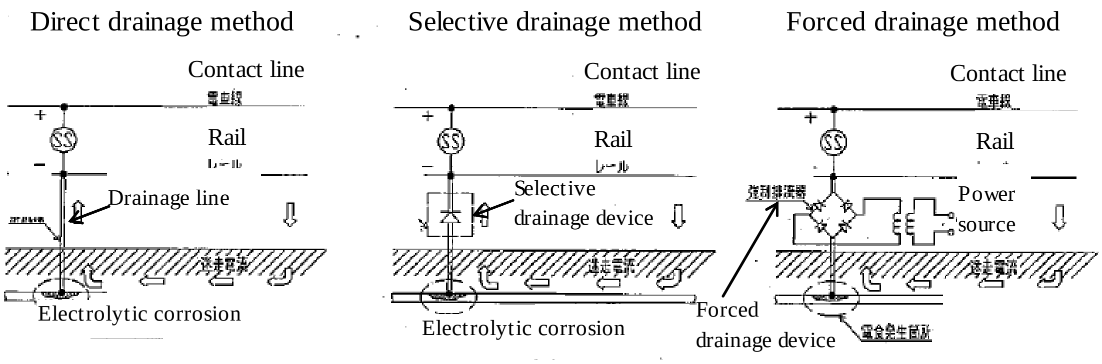
- Traction current: Average traction current will be decreased by the installation of a regenerating system.
- Return conductor (rail) resistance: Installation of thicker and longer rails, and appropriate maintenance of rail bonds will decrease the return conductor (rail) resistance.
- Leakage time: It is difficult to decrease the leakage time from rails in the main line because of the constraint of the operation schedule. However, it is possible to decrease the leakage time in a workshop/depot, where the rail voltage is affected by the one in the main line, by insulation of the rail in an appropriate point and installation of automatic return current switchgear that enables one-way flow of return current. A two-pole disconnector also makes it possible to decrease the leakage time by insulating both contact lines and rails and opening isolator when no rolling stocks are in the workshop/depot.



Source: JICA Study Team

Figure 4-306 Decrease by Automatic Return Current Switchgear and Two-pole Disconnector

Electrolytic corrosion can also be reduced by the installation of appropriate devices to control the stray current flow. Stray current may cause electrolytic corrosion on metal tubes in the vicinity of RSs. The equipment for the prevention of corrosion by electrically connecting buried tubes and rails is called drainage device. The three major types of drainage methods are direct, selective and forced, as shown in Figure 4-307.



Source: JICA Study Team

Figure 4-307 Drainage Methods

In a lot of experiences in Japanese projects, the installation of these types of mitigation equipment for corrosion is already after an actual occurrence of corrosion phenomenon. It is therefore recommended that the mitigation measures by drainage methods should be implemented after, or if, corrosion problems are found.