13 POWER EVACUATION

13.1 INTRODUCTION

Manang Marsyangdi Hydroelctric Project (MMHEP) is a Peaking run-of-the-river type project. The project is located in Chame Rural Municipality, Manang District, Gandaki Zone, Western Development Region of Nepal.

Generation Plant	Installed Capacity (MW)	No. of Units	Location
Manang Marsyangdi Hydroelectric Project (MMHEP)	135	2	Marsyangdi River Basin, Nashong Rural Municipality, Manang District, Nepal

The Project is designed for the domestic consumption of generated power and Power Purchase Agreement (PPA) is expected to be concluded with Nepal Electricity Authority (NEA). The nearest substation in the project area is the proposed 220kV Manang Hub at Dharapani, which lies towards south-east at a distance of about 2 km from the MMHEP power house.

13.1.1 Objective

The overall objective of this Study is to develop the most optimum executable power evacuation proposal for the Project on techno-economic basis. In order to do this, it is necessary to review the existing Integrated Nepal Power System (INPS), its future generation & transmission plans as well as its future load forecast. The feasible power evacuation option has been explored in the study and the most optimum scheme(s) have been identified among all possibilities on technical and economic basis. The study has utilized NEA's latest generation & transmission expansion plans as well as its future load forecast.

13.1.2 Findings

Planned and existing transmission networks in the area around MMHEP are 220 kV and 33 kV respectively. The 33 kV Udipur-Besisahar-Manang transmission line is intended for rural electrification purpose of Chame, headquarter of Manang district. The planned 220 kV Busbar at Manang Hub, Dharapani VDC, has been identified as an appropriate interconnection point of MMHEP. The 220 kV Manang hub will be connected to Khudi hub through a double circuit 220 kV line which will further go down to Udipur hub through 200 KV double circuit line. Udipur hub will be finally connected to New Marsyangdi substation at Marikchowk (Anbhukhaireni) again through a double circuit 220 kV line that will be ultimately linked with Kathmandu and Bharatpur through 220kV transmission schemes. Some other hydropower projects planning to interconnect at Dharapani hub are: Nar Khola (50 MW), Sua Khola (3.65 MW), Dudh Khola (10 MW), Manang Marsyangdi (135 MW), Upper Marsyangdi-2 (250 MW), Chhahare Khola (17.5 MW), Myardi Khola (4 MW), Bumdang Khola (6.85 MW), Marsyangdi-7 (50 MW), Tilicho Pump Storage (50 MW), Humde Marsyangdi (12 MW), Marsyangdi syange (20 MW) etc.

Though the connected power at Dharapani Hub seems to be in the figure mentioned above, but these are the power generation considered during licensing process. The power generation from these hydro projects are basically on the higher side after completing their final phase of study. Hence the total power to be evacuated from Dharapani hub could be nearly twice the power shown in present official document. This justifies the presence of 220kV double circuit transmission line as proposed by NEA replacing the previously planned 132kV transmission along this corridor.

13.2 NEPALESE POWER SYSTEM

13.2.1 Generation System

The peak power demand of INPS in fiscal year 20018/2019 has reached 1102 MW at 18:45 hours on June, 2018 was registered. Total power generation from Nepal is 614 MW, out of which Power generated from NEA is 347 MW and the generator from Independent power Producer is 267 MW. Similarly, 463 MW is being exported from India and the remaining 25 MW is being managed by Tripping.

Apart from Kulekhani I (60 MW), Kulekhani II (32 MW) and under construction Kulekhani III (14 MW), which are storage plants, the rest of the hydropower plants in the country are basically run-of-river types.

Table 13-1 presents the feature of Nepalese generation system.

Table 13-1: Features of Nepalese generation system

S.No.	Particulars	Capacity
1	Total Major Hydro (NEA)- Grid Connected	472.994 MW
2	Total Small Hydro (NEA)- Isolated	4.536 MW
3	Total Hydro (IPP)	166.80 MW
4	Total Hydro (Nepal)	644.336 MW
5	Total Thermal (NEA)	53.410 MW
6	Total Solar (NEA)	100 kW
7	Total Installed Capacity (including private and others)	697.846 MW
8	Under Construction Hydro powers	547.798 MW
9	PPA concluded for new projects in FY 2009/10	126.837 MW

13.2.2 Transmission System

At present, 132 kV is the highest level of transmission voltage in Nepal. This 132 kV transmission level consists of combination of both single circuit and double circuit transmission line extending to 1562.9 km, shown in Table 13-2. East-west 132 kV tie-line runs from Anarmani substation in the east to Lalpur (Mahendranagar) substation in the west. Except for the sections Bardghat S/S - Bharatpur S/S - Hetauda S/S and Duhabi S/S - Anarmani S/S, the entire east-west tie is constructed with double circuit (d/c) towers.

The other level of transmission voltage is 66 kV extending to 354.72 km, as shown in Table 13-3. Kulekhani-I is connected to Kathmandu and Hetauda by 132 kV d/c ACSR Wolf lines. Hetauda connects Birgunj by 66 kV d/c ACSR Wolf line. Chilime is connected to Trishuli by 66 kV s/c ACSR Wolf line. Trishuli is connected to Kathmandu by 66 kV d/c ACSR Wolf line whereas Devighat is connected to Kathmandu by 66 kV d/c ACSR Dog line.

Similarly, NEA has started carrying out 220 kV transmission line construction work between Khimti-Dhalkebar (75 km) and Hetauda-Bharatpur (72 km) adding to the total of 147km long 220kV line and total of 157.5 km long 132 kV transmission line as shown in Table 13-4.

Table 13-2: 132 kV Transmission line

S.No.	Transmission Line	Length (km)	Circuit type
1	Anarmani-Duhabi	85	Single
2	Kusha-Kataiya(India)	19	Single
3	Duhabi-Hetauda	282	Double
4	Hetauda-Kulekhani II	8	Single
5	Bharatpur-Marsyangdi	25	Single
6	Marsyangdi P/S-Suichatar	84	Single
7	Suichatar-Kulekhani II	34	Single
8	Suichatar-New Bhaktapur	26.9	Single
9	New Bhaktapur-Lamoshangu	48	Double
10	Lamoshangu-Khimti	46	Single
11	Hetauda-Gandak	154	Single
12	Bharatpur-Pokhara	97	Single
13	Bardghat- Butwal	43	Double
14	Butwal-Kali Gandaki A	58	Double
15	Kali Gandaki A P/S-Lekhnath	48	Single
16	Pokhara-Modikhola	37	Single
17	Butwal-Tanakpur	407	Single
18	Pathlaiya-New Parwanipur	17	Single
19	Marsyangdi-M.Marsyangdi	44	Single
	Total	**1562.9**	

Table 13-3: 66kV Transmission line

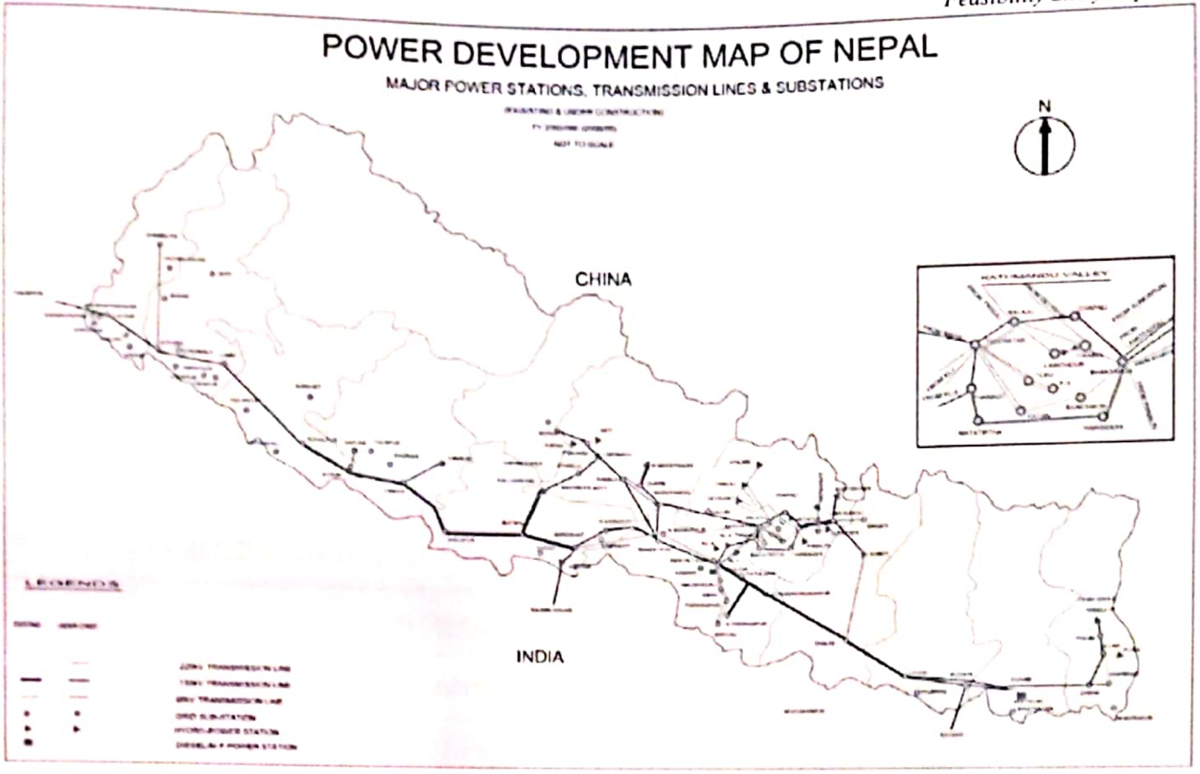
S.No.	Transmission Line	Length (km)	Circuit type
1	Chilime-Devighat	43.56	Single
2	Trishuli-Balaju	26	Double
3	Devighat-Balaju	30	Single
4	Devighat-New Chabel	33	Single

S.No.	Transmission Line	Length (km)	Circuit type
5	Balaju-Lainchor	2.3	Single
6	Balaju-Kulekhani I	36	Double
7	Kulekhani I-Birgunj	72	Double
8	Suichatar-Teku	4.1	Single
9	Suichatar-New Patan	4	Double
10	Teku-K3(Underground)	3.5	Single core
11	Suichatar-K3	6.9	Single
12	New Patan-New Baneswor	2.8	Single
13	Bhaktapur-New Chabel	12	Single
14	New Baneswor-Sunkoshi	61	Single
15	Devighat-Trishuli	4.56	Single
16	Indrawati-Panchkhal	10	Single
	Total	**354.72**	

Table 13-4: Under Construction Transmission line

A. 220 kV Transmission Line			
S.No.	**Transmission Line**	**Length (km)**	**Circuit type**
1	Khimti-Dhalkebar	75	Single with double circuit tower
2	Hetauda-Bharatpur	72	Double
	Total	**147**	
B. 132 kV Transmission Line			
S.No.	**Transmission Line**	**Length (km)**	**Circuit type**
1	Thankot-Chapagaon	28.5	Double
2	Chameliya-Attariya	129	Single
	Total	**157.5**	

Figure 13-1 depicts the present Power development map of Nepal



Source: Nepal Electricity Authority, Transmission and System Operation Year Book 2009/10

Figure 13-1: Present Power development map of INPS

13.2.3 Operation System

The operation of the existing Integrated Nepalese Power System (INPS) is controlled from the Load Dispatch Centre (LDC), which also has the facility of remote control. SCADA facility exists in the entire INPS. On-line active and reactive power, voltage, frequency, etc. data can be observed in real time basis on day to day operation in the LDC. The operation of INPS is conducted / controlled by the LDC. As far as possible demand of system will be managed through available generating plants and imports but when there is no more generation/import left, then load shedding is applied. Since, the system is suffering from power and energy deficit, the available generation facility cannot cope with further increase in energy demand, as it doesn't have any reserve power.

The limited reactive compensation available within the system is a constraining factor in the dispatch. Lack of voltage compensating devices in the system has caused excessive over voltage/under voltage and poor power factors and no flexibility whatsoever in the operation of the system. In order to operate the power system smoothly, when the system grows, reactive as well as active power spinning reserves should be allocated in system so that a certain automatic control capability during contingencies exist. That can easily be done by adding sufficient static compensation and others measure to control the reactive power in the system. An optimum approach would be to run all the plants connected to the system in rated power factor during normal operation.

13.3 POWER EVACUATION THROUGH MMHEP

Currently 132 kV high voltage network is limited up to switchyard of Middle Marsyangdi Hydroelectric Power Plant at Tadikuna. A double circuit, single strung 132 kV transmission line joins Middle Marsyangdi HEP with Marsyangdi HEP. There are two outgoing 132 kV feeders from 132 kV bus bars of Marsyangdi to Bharatpur and Suichatar 132 kV substation, through single circuit 132 kV lines. The second circuit from Middle Marsyangdi is being strung up to Dumre that will loop in loop out Damauli substation through a double circuit 132 kV transmission lines from Dumre to Damauli and finally connect Damauli with Marsyangdi HEP. To increase the reliability, this will create a single circuit loop around Middle Marsyangdi, Damauli and Marsyangdi and back to Middle Marsyangdi. In the next stage of development, it is planned to establish a 220/132 kV substation at Markichowk between Marsyangdi and Dumre (Abukhaireni). This substation is supposed to connect Marsynagdi corridor with the Kathmandu valley network directly as well as with southern trunk line at Bharatpur directly or through proposed Upper Seti Project. Existing 132 kV trunk lines will then terminate at this Markichowk substation.

Power evacuation through Lower Manang can be achieved through connecting the transmission line of Lower Manang Marsyangdi with either of the following gird substations mentioned in Table 13-5.

Table 13-5: Grid Interconnection possibilities

Option	Description	Line length	Transmission voltage
1	MMHEP to Tadi Kuna Hub	26 km	132 kV
2	MMHEP to Middle Marsyangdi	57 km	132 kV
3	MMHEP to Manang SS	10.8 km	132 kV
4	MMHEP to Upper Seti Storage HEP	82 km	220 kV
5	MMHEP to proposed Dharapani Hub	2 kM	220 kV

From the above mentioned options, 220 kV busbar at Manang Hub, Dharapani, has been identified as an appropriate interconnection point of MMHEP. The approximate distance of Manang Hub from the MMHEP power house is about 2 km. Power Transformers steps up the generation voltage of Manang Marsyangdi Plant to the 220 kV voltage level. 220 kV GIS (Gas Insulated Substation) through double circuit 220kV transmission line then evacuates the power of MMHEP to the nearest Manang hub.

Udipur hub will be connected to New Marsyangdi at Markichowk through a double circuit 220 kV line. The 220 kV double circuit transmission line further goes through Marsyangdi corridor to connect at Manang hub.

The details of Marsyangdi Corridor transmission line project is shown in Appendix-A of this report.

13.3.1 Technical Considerations

Voltage Selection

Selection of economic transmission voltage is performed by using the empirical formula:

Voltage (V) = $5.5*\sqrt{\frac{L}{1.6}+\frac{kVA}{150}}$ V = Transmission voltage (kV), Line to Line

L = Distance of transmission line i.e., 2 km

KVA = 169412 kVA

The above equation produces 145.05 kV as the economic voltage for the transmission of power. The nearest standard transmission voltage for this economic voltage level is 220 kV. Hence, Double circuit 220kV transmission line is selected for transmitting the power of MMHEP which will also satisfy the N-1 Criteria for NEA with capacity above 50 MW.

Conductor Optimization

Selection of optimum conductor size and number of circuits for power transmission up to the interconnection point are major tasks of transmission line design. With the above described basic formulas, the design team performed conductor optimization on per kilometer (capital cost + operation and maintenance cost + cost of losses) capitalized cost basis, employing the values of plant factor, energy cost, power factor, discount rate and project life among the following listed options. The considered options have voltage regulation and line losses below 5%. Following options have been considered:

1. 132 kV single circuit transmission line, Bear conductor,
2. 132 kV single circuit transmission line, Duck conductor
3. 132 kV single circuit transmission line, Goat conductor
4. 132 kV double circuit transmission line, Bear conductor
5. 132 kV double circuit transmission line, Duck conductor
6. 132 kV double circuit transmission line, Goat conductor
7. 220 kV single circuit transmission line, Twin Bison conductor,
8. 220 kV single circuit transmission line, Twin Moose conductor,
9. 220 kV double circuit transmission line, Twin Bison conductor,
10. 220 kV double circuit transmission line, Twin Moose conductor.

Conductor optimization is given in **Figure 13-2**. As seen from the figure, "220 kV D-C, 520 mm^2 Twin Moose" line exhibits the least capitalized cost for evacuation of 135 MW power at 0.623 capacity factor. Moreover, this option will be economical for power evacuation of higher plant capacity hence, ASCR "Moose" conductor with double circuit will be used for the power transmission. The capital cost of the various conductors under study can be shown in figure 3.1 above and table 3.2 below:

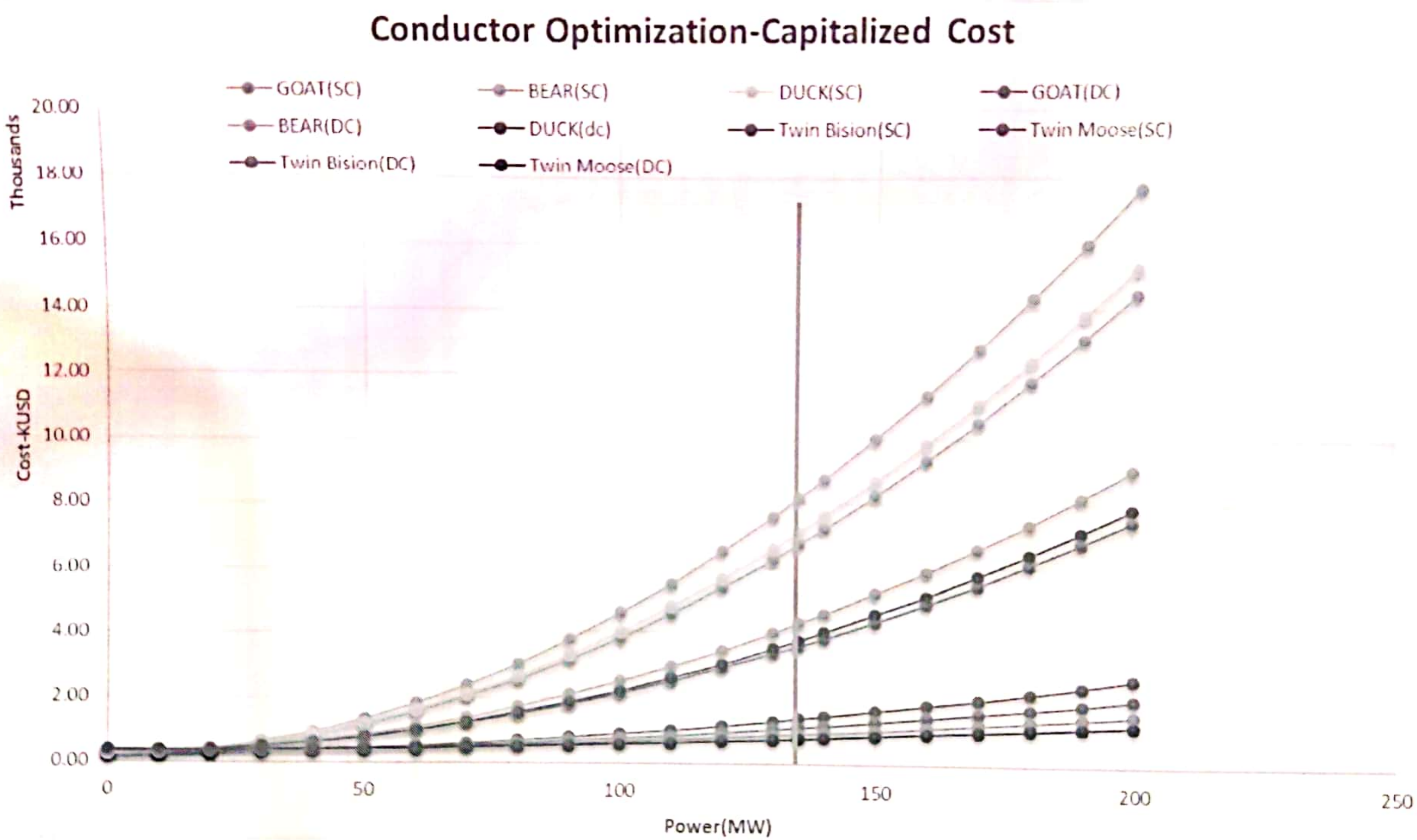


Figure 13-2: Conductor optimization

Table 13-6 Transmission line Capitalized cost Option

S.No	*Transmission Line*	*Capitalized Cost (kUSD/km) [for evacuation of 135 MW power at .623 Plant factor]*
1.	132 kV single circuit transmission line, Bear conductor	8168.39
2.	132 kV single circuit transmission line, Duck conductor	7085.93
3.	132 kV single circuit transmission line, Goat conductor	6729.56
4.	132 kV double circuit transmission line, Bear conductor	4277.00
5.	132 kV double circuit transmission line, Duck conductor	3745.95
6.	132 kV double circuit transmission line, Goat conductor	3578.59
7.	220 kV single circuit transmission line, Twin Bison conductor	1357.71
8.	220 kV single circuit transmission line, Twin Moose conductor	1087.05
9.	220 kV double circuit transmission line, Twin Bison conductor	882.49
10.	220 kV double circuit transmission line, Twin Moose conductor	757.93

The existing down-time i.e. average annual outage in Nepal is 0.28 hours per km and the Energy Not Supplied (ENS) cost due to such forced outage is 29.2 USc/kWh. Hence, the reliability cost of not constructing a double circuit line is,

Cost of ENS = 292 USD/MWh * 0.28 Hr/km/year * 135 MW * 0.623
= 6876.42 USD/km/year

Discount factor = 8.514

Capitalized cost of ENS = 6876.42 USD/km * 8.514 *2 km
= 117.09 kUSD/km

The capitalized ENS cost (reliability cost) of not constructing double circuit 220 kV transmission system is 117.09 kUSD/km, whereas the extra capitalized cost involved in transmitting 135 MW power through *"220 kV d/c Moose transmission line"* instead of *"220 kV s/c Moose transmission line"* is 329.12 kUSD/km.

Hence the *"220 kV d/c Moose transmission line" to proposed Manang Hub is economical after consideration of reliability compared to "220 kV s/c Moose transmission line". The selected transmission System also incorporates (N-1) reliability level for the evacuation of power of Lower*

Manang Marsyangdi HEP. The (N-1) criteira is a standard way of describing a single component outage in transmission line system planning.

CONDUCTOR SELECTION

As the distance is very less, double circuit 220 kV transmission line with Moose conductor will be enough for the evacuation of Power from MMHEP. However, to satisfy the NEA's N-1 criteria for the capacity above 100 MW and as shown in preceding Sub-clause, Double Circuit 220 kV transmission line with MOOSE Conductor is selected for the connection. The transmission line loss and voltage regulation for transmitting 135 MW power in a distance of 2 km with this conductor is 0.05% and 0.13% respectively. Table 13-7 presents the characteristics of conductor selected for MMHEP transmission line.

Table 13-7: Characteristics of Conductor

Specification	Conductor
Material	ACSR
Conductor Designation	MOOSE
Cross section (mm^2)	500
Overall diameter (mm)	31.77
Current Rating 75 Degree (Amp)	836
Maximum dc resistance at 20˚C (Ω/km)	0.05596

Earth Wire (Fibre Optic Earth Wire)

Earth wire with embedded fiber optic cable (OPGW) for telecommunication is recommended. The fibre design should preferably be based on the loose tube method of fibre protection, whereby the fibre tubes and interstices could be filled with water repellent compound. The fibre must be protected from vibration and other mechanical loads, during installation and operation and from strain and extreme temperature exposure caused by short circuit currents through the wire. The fibres must remain strain free throughout installation, operation and service.

Design Standards

High altitudes influence on both the thermal rating and the insulation co-ordination are likely due to the change in air density. Accordingly, a correction factor has to be assumed for the impulse and withstand voltages at altitudes above 1,000 m. The line route is considered as light polluted corresponding to level 1 of IEC 815 with a creepage distance of 16 mm/kV. The line electrical characteristics will be as follows:

- Nominal voltage of a three-phase system: 220 kV
- Highest voltage of a three-phase system: 245 kV
- Rated short duration power frequency withstand voltage: 460 kV
- Rated lightning impulse withstand voltage (peak): 1050 kV
- Rated frequency: 50 Hz
- Minimum insulator creepage distance: 16 mm/kV
- Maximum shielding angle to outer phase conductor, in towers: 20˚C
- Maximum operating conductor temperature: 80˚C
- Maximum air temperature: 35˚C
- Average air temperature: 20˚C
- Minimum air temperature: -5˚C

Conductor Clearances

Minimum vertical and horizontal conductor clearances as given by

Table 13-8 will be maintained at a maximum conductor temperature in still air and final sag, i.e. tower spotting temperature of 80°C:

Table 13-8: 220kV Transmission line clearance

Objects	Vertical Clearance (m)	Horizontal Clearance (m)
Roads	9.0	-
Lands that may be traversed by vehicles	9.0	-
Land accessible to pedestrians only	7.5	-
Rivers	7.5	-
Buildings roofs not accessible to people	6.0	5.2
Buildings roofs accessible to people	7.5	5.2
Signs, chimneys and antennas	6.4	5.2
Lighting support	4.5	3.7
Communication lines	4.2	7.5
Transmission line 66kV and below	3.5	8.5
Transmssion lines 132 kV	3.8	9.5
Transmission lines 220 kV	4.4	12.0

The conductor clearance with the towers to be maintained under the specified swing of insulator sets and jumpers are:

- Minimum clearance phase to earth: normal 20^{o} (altitude up to 2000 m): 2150 mm
- Minimum clearance phase to earth: full wind 55^{o} (altitude up to 2000 m): 1250 mm

Tower

Conventional lattice steel self-supporting Double circuit towers with conductors in Vertical formation and one overrunning optical earth-wire have been considered.

In hilly terrain, or even mountainous terrain, solid rock suitable for bolt anchor foundations is seldom encountered. Mostly the rock is decomposed and can very often be excavated manually with pick and shovel. Thus, in most cases blasting or heavy machinery is not needed, and conventional soil foundations are installed.

On the Khimti-Lamosangu line, steel grillage foundations were installed at tower sites with difficult access. This is mainly due to easier handling and lighter transport weights compared to concrete foundations.

These practices are generally accepted and widely used. However, the following should be taken into account:

- Steel grillage foundations should not be used where foundations are, or can be, submerged.

- Steel grillage foundations normally have a shorter life span than concrete foundations and the steel structure above ground, depending on soil corrosiveness, quality of galvanising and application of bituminous paint.
- The area most sensitive to corrosion damage is normally a zone from ground level to about 0.4 m below the surface. It may delay corrosion if tower legs are properly encased in concrete in this zone and to 0.3 - 0.4 m above the ground line. Such encasing may also be necessary for distribution of shear forces in the region of the ground line.
- Generally, concrete foundations will be used wherever possible for all voltage levels.

With the topography and geology in northern Nepal it is of utmost importance to execute foundation and earthing works in a way that minimize the risk of erosion damage.

13.4 POWER HOUSE SWITCHYARD

MMHEP houses two number of hydro-generator units generating total of 135 MW salable power. Conventional Air Insulated Switchyard (AIS) will be replaced by GIS type, in case of MMHEP, because of the constraint in switchyard area.

The GIS will comprise 5 bays, of which 2 for connecting to the main transformers, 2 for the outgoing transmission lines, and one for distribution transformer with single bus bar scheme. The rating of GIS adopted in MMHEP is shown in Table 13-9.

Table 13-9: Typical ratings of GIS

Rated Current (A)	1250
CB breaking capacity (kA)	40
50Hz withstand voltage (kV)	460
Impulse withstand voltage (kV)	1050
SF_6 gas pressure (20°C)	6 bar

13.4.1 220 kV Cables

The cable system consists of:

i. 220kV dry insulated XLPE cables from the SF_6 switchgear to the outdoor transmission line take off gantry.
ii. Outdoor sealing ends and terminal bushings for connection to overhead lines.
iii. 220kV dry insulated XLPE cables from the HV transformer bushing to the SF_6 switchgear.
iv. Cables SF_6 sealing ends at the GIS
v. Cable sheath earthing wire.