BENI HYDROPOWER PROJECT (P.) Ltd

Hadigaun, Kathmandu, Nepal

UPPER SOLUKHOLA HYDROPOWER PROJECT (19.8 MW)

PROJECT COMPLETION REPORT

September, 2023

DEVELOPER:

BENI HYDROPOWER PROJECT Ltd.

Hadigaun, Kathmandu, Nepal.

Phone :01-4511153/01-4523075

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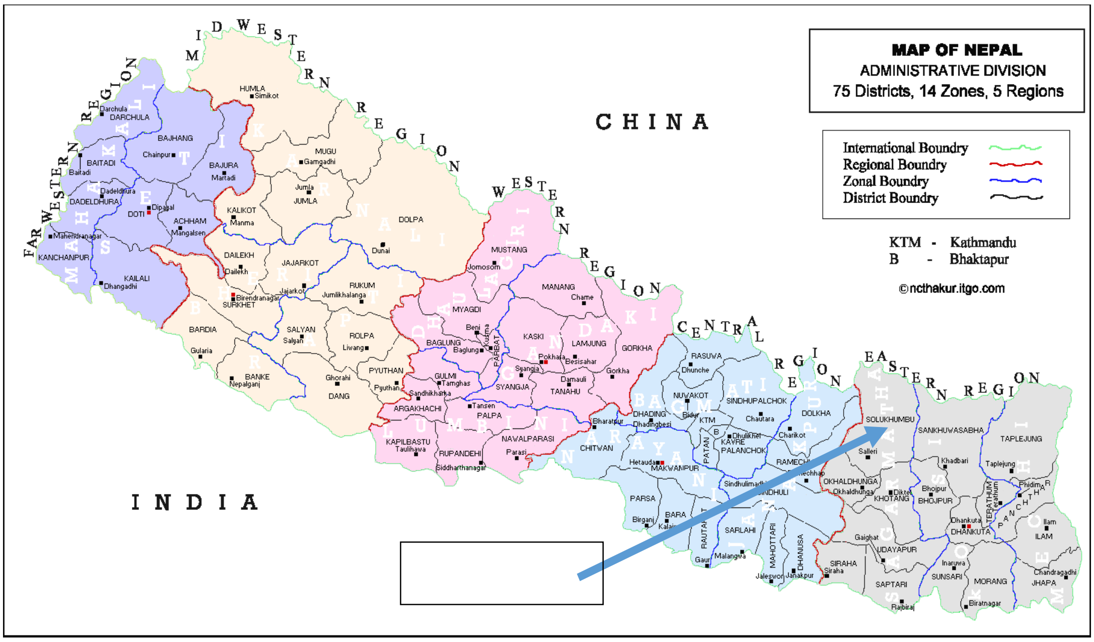
1. PROJECT OVERVIEW AND INSTITUTONAL ARRANGEMENT

Upper Solu Hydropower Project is a Run-of-River scheme located at Beni, previous Salleri VDC now Dudhkunda Municipality of Solukhumbu district in province 1 of Nepal. The headworks area of proposed project is located downstream of the suspension bridge at Beni and the powerhouse area is located at Boldok, about 140 m d/s from the confluence of Tamakhani Khola and Solu River. The approximate distances of powerhouse and headworks of proposed project from Phaplu Bazaar, the nearest Bazaar from the project area are 1.25 and 3.7 km respectively. The project area is shown below in Figure 1-1.

Figure 1.1: Project Location



Geographically the project area lies between the latitudes of 27o 31’ 17” N and 27o 32’ 57” N and the longitudes of 86o 34’ 27” E and 86o 35’ 19” E. The main access from Kathmandu to the project area is via BP Rajmarg-Madhya Pahadi Lokmarg-Sagarmatha Highway with a total distance from Kathmandu of approximately 260 km.

Table I: Company Biography

Name of the Company	Beni Hydropower Project Ltd.
Type of Organization	Private Limited, converted to Public Limited
Registered Address	KMc-05-Hadigaun, Kathmandu
Office Address	Hadigaun, Kathmandu Tel :01-4511153 / 01-4523075
Date of Registration	2063/07/24 (Kartik-07, 2063)
Company Registration No	42320/063-064
PAN Number	302443886
Industry Reg. Certificate	1860/164/069-070

Table II: Board of Directors

Name	Designation
Mr. Pugyelzen Sherpa	Chairman
Mr. Ganesh Karki	Managing Director
Mr. Yam Kumar Shrestha	Director
Mr. Hirendraman Pradhan	Director
Mr. Sonam Sherpa	Director

Table III: Key Activities & Dates

S.No.	Key Activities		Remarks
1	Commercial Operation Date (Completion Date)	Ashad-01, 2080	Completed
2	Connection Agreement Date	Ashoj-18, 2069	Completed
3	Supplementry IEE	Posh-12, 2077	Completed
4	Financial Closure	Magh-17,2073	Completed
5	Generation Licence for 18 MW	Bhadra-23, 2073	Completed
	for 19.8 MW	Sharawan-04, 2079	Completed

2. FINANCING

- Equity: Promoters (PPC) 26.98% of the total Project Cost
- Debt: Consortium of Local Banks 73.02% of the total Project Cost

Table IV: Participating Bank & financing Percentage

S.No.	Participating Banks	Term Loan (Nrs.)	% Financing
1	NMB Bank	1,415,175,000.00	50.270
2	Nepal Bangaladesh Bank Limited (NBBL)	500,000,000.00	17.761
3	Lumbani Bikash Bank Limited (LBBL)	500,000,000.00	17.761
4	Hydroelectricity Investment & Development Company Limited (HIDCL)	200,000,000.00	7.104
5	Glogal IME Bank Limited (GIBL)	200,000,000.00	7.104
	Total	**2,815,175,000.00**	**100.000**

3. Salient features:

1 Project Location		
Development Region	:	Eastern
Zone	:	Sagarmatha
District	:	Solukhumbu
Intake Site	:	Beni
Powerhouse Site	:	Phaplu
Geographical Co-ordinates		
Latitude	:	27º 31′ 17″ to 27º 32′ 57″
Longitude	:	86º 34′ 27″ to 86º 35′ 19″
2 General		
Name of River	:	Solu Khola
Nearest Town	:	Phaplu and Sallari
Type of Scheme	:	Hydropower
Gross Head	:	185.1 m (From Headpond)
Net rated Head	:	177.06 m
Installed Capacity	:	19.8 MW
Average Annual Energy after Outage	:	117.55 GWh, 20.79 GWh Dry and 96.76 GWh Wet
3 Hydrology		
Catchment Area	:	211.288 Km^2
Mean Annual Discharge	:	21.6 m^3/sec
Design Discharge (at 40.0% PoE)	:	13 m^3/sec
Riparian Release	:	0.43 m^3/sec
Design Flood Discharge (100 Yrs)	:	265 m^3/sec at headworks and 475 m^3/sec at Powerhouse
Average Annual Precipitation	:	1600 mm
4 Diversion Weir		**Solu Khola**
Type of Weir	:	Free overflow, Concrete weir
Length of Weir	:	30 m
Crest Elevation	:	2360.6 masl
Undersluice Opening (W X H)	:	2.0 * 2.5 m
Undersluice Crest Level	:	2357 masl

5 Intake Structure cum Gravel Trap		
Type of Intake	:	Orifice Side Intake
Nos of Opening	:	4
Size of Intake (W x H)	:	2.4 m * 1.5 m each (W x H)
Intake Sill Level	:	2358.4 masl
Length of Gravel Trap	:	7 m
Width of Gravel Trap (Avg.)	:	5.7 m
Overall depth	:	3.74 m (Avg.)
Particle size to be trapped	:	5 mm
Flushing Channel	:	0.7 m * 0.9 to 1.5 m (W x H)
6 Settling Basin		
Type	:	Mechanized continuous flushing (By SEDICON AS)
Nos of bay	:	1
Dimension (L x B x H)	:	91 m * 17.4 m * 11.32 m
Inlet Transition Length	:	17.0 m
Particle Size to be settled	:	0.2 mm
Trapping Efficiency	:	90 %
7 Headrace Pipe/Tunnel		Tunnel
Type	:	D Shaped
Internal Diameter	:	3.3 m (Width), 3.45 m (Height to crown), 1.75 m (Height to spring line)
Length	:	2370m
8 Surge Tank		
Type	:	Underground
Depth	:	28.9 m
Diameter (Or size)	:	7.5 m (Finished)
Maximum Water Level	:	2368.7 masl
Minimum Water Level	:	2348.6 masl
9 Steel Penstock Pipe		
Type	:	Mild Steel
Internal Diameter	:	2.2 m, 2.1 m and 2.0 m
Length	:	690 m (Each of 230m)
Steel Thickness	:	12 to 24 mm
Nos. of Anchor Blocks	:	10
10 Powerhouse		

Type	:	Surface
Size (L x W)	:	42 m * 15 m
Height	:	20m
Turbine Axis Level	:	2175 masl
11 Tailrace		
Type	:	Concrete, Box canal
Tailrace Length	:	36 m
Size (W x D)	:	3.5 * 3.5 m
Tailrace Water Level	:	2175 masl (Normal)
12 Turbine		
Type	:	Horizontal Francis
Number	:	3
Rated Output Capacity per Unit	:	6.96 MW
Turbine Axis Level	:	2175 masl
Net Head	:	177.06 m
Discharge per Unit	:	4.33 m^3/sec
Efficiency	:	92.5 %
13 Governor		
Type	:	Electronic with PID flow Adjustment
Adjustment for Speed Drop	:	Between 0 to 5%
14 Generator		
Type	:	Three phase, Horizontal Synchronous
Rated Output Capacity per Unit	:	7.865 MVA
Power Factor	:	0.85
Voltage	:	11kV
Frequency	:	50 Hz
No of Units	:	3
Excitation System	:	Brushless
Efficiency	:	96.00 %
15 Transformer		
Type	:	Three Phase, Oil Immersed, Outdoor
Rated Capacity	:	8.650 MVA
Voltage Ratio	:	132/11 kV
No of Units	:	3

Vector Group	:	Ynd11
Efficiency	:	99.0 %
16 Transmission Line		
Voltage Level	:	132 KV
Length	:	12 Km Approx.
Conductor Type	:	Wolf
From	:	Switchyard
To	:	Lamane, Sub-station

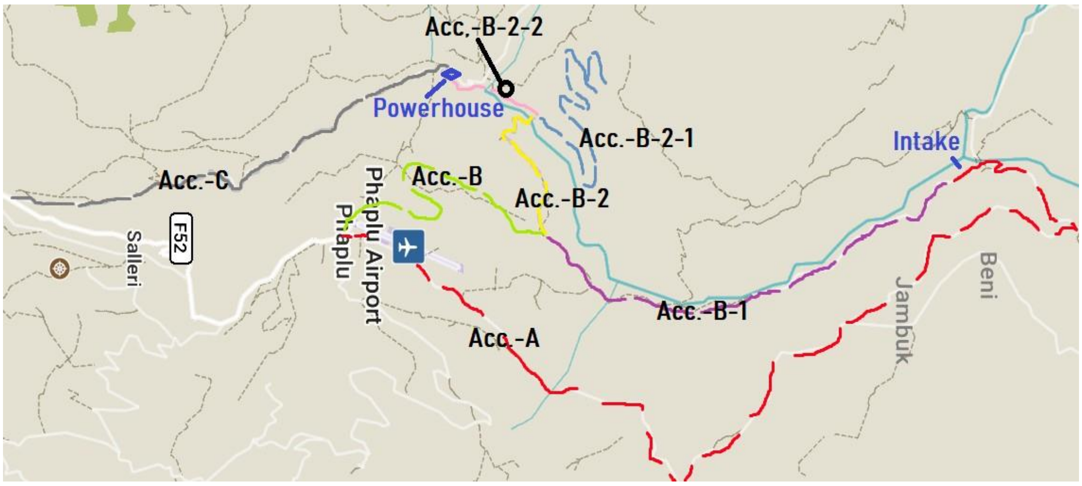
4. BACKGROUND

Upper Solu Hydropower Project (USHP) is a simple Run-of-River scheme located at previous Beni-Salleri VDC, now Dudhkunda Municipality of Solukhumbu district, province 1. USHP has been identified by Beni Hydropower Company Limited (BHCL), who completed the feasibility study and all the legislature requirements for the construction of the project. BHCL is currently constructing the project as per the completed studies.

In this detailed engineering design and construction phase, the project components were optimized for the location, hydraulic and structural requirements. In this context, the location of the powerhouse is proposed to be shifted 240m d/s of the initial location in order to have large workspace and increment in head. Similarly, the design discharge for the project in DPR corresponds to 42.88 percentile exceedance flow which can be lowered to 40 percentiles of exceedance. In light of these two new conditions, the capacity of the project increased 19.80Mw to 18.00 MW.

5. Access Road/bridges:

All the access road for the construction site area was completed, in total 25.36km road, Two Number Bailey Bridge and numbers of culvert construction is completed.



SN	Access Name	From	To	Status	Length	Remarks
1	Acc-A	Phaplu	Beni	Good	9.8 km	Using
2	Acc-B	Phaplu	Pokhari Danda	Good	1.5 km	Using
3	Acc-B-1	Pokhari Danda	Beni (Headwork)	Good	5.26 km	Using

4	Acc-B-2	Pokhari Danda	Khologhari	Good	1.5 km	Using
5	Acc-B-2-1	Khologhari	Outlet	Good	2.2 km	Using
6	Acc-B-2-2	Khologhari	Powerhouse	Good	0.6 km	Using
7	Acc-C	Chhulyamuha	Powerhouse	Good	4.5 km	Using

6. Infrastructure:

- All the require Infrastructure such as permanent as well well temporary house and champ were constructed at headworks site and Inlet tunnel site at Beni.
- Temporary housing and champ construction for outlet tunnel/surge shaft/power house/penstock tunnel and penstock crew was completed.
- Champ construction for power house champ at power house was completed.
- Plant Manager Camp is completed.

7. Construction Contract and Arrangements for the Project and Present Status:

SN	Packages/Works	Involved on construction	Status	Remarks/ Progress
1	**Civil works**			
	Headworks, Headrace Tunnel, Surge Shaft, Penstock Alignment, Powerhouse, Tailrace & PH Protection Woks and Switchyard	Super Sherpa and Baibhab J/V	Contract Awarded (8th Nov. 2017)	Completed
2	**Hydro-mechanical Works**			
i)	Gates and Hydro-mechanical Specials	Kay Iron Works (Yamuna Nagar) Pvt. Ltd., India	Contract Awarded (21st May 2019)	Completed
ii)	Installation of Penstock Pipe	RK Hydro Engineering &Associates Pvt. Ltd, Nepal	Contract Awarded (22nd Nov. 2019)	Completed
3	**Electro-mechanical Works**			
	Electromechanical/Substation Equipment Fabrication, Installation and Testing (Water to wire)	GEPERT, Austria	Contract Awarded (16thOct. 2019)	Completed
4	**132Kv Transmission Line**			
	132 kV Transmission Line with Tower Foundation	Cosmic Electrical Engineering Associates Pvt. Ltd.	Contract Awarded, (3rd Februry, 2019)	Completed

8. HYDROLOGY

8.1 Basin Characteristics

8.1.1 General

This chapter deals with the pertinent hydrological parameters that are necessary in designing the project.

8.1.2 Basin Physiography and Drainage

Upper Solu Khola is a perennial stream fed mostly by snowmelts and partly by monsoon. Originating from Mount Numbur at an altitude of 6858 and ending at Dudha Koshi confluence at an elevation of 725m and within the latitudes of 27° 30' 31" N and 27° 45' 29" N and the longitudes of 86° 29' 45" E and 86° 37' 55" E, the stream flows through glacier, dense and undisturbed forest and joins Dhudha Koshi River. The proposed intake is located immediately downstream of two major tributaries, namely, Junbeshi Khola and Dudhkunda Khola (also known as Beni Khola) to form Solu Khola (Figure 3-1). Most of the catchment area lies above 3000m elevation, a favourable condition for higher degree of base flow throughout the year and less flood hazards. About one third of the catchment is covered by thin mixed forest. Except some permanent snow lines and glaciers and lakes, the rest of the catchment area is covered with barren hard rock, grass land with scattered vegetation and dense forest. There are several settlements in the project area upstream of the project headworks such as Khamje, Junbesi and Chholin.

The catchment area of the stream is elongated from North to South with trellis pattern of drainage. The catchment area contributing the flow at proposed intake is 211.288 km^2 which can be further divided as in Table 8-1.

Table 8-1: Catchment Area

Elevation, masl	Catchment at Intake	
	Area (Km^2)	Percentage (%)
Above 5000 m	24.737	11.71%
Below 3000 - 5000 m	186.551	88.29%
Below 3000 m	34.259	16.21%
Below 2000 m	0.000	0.00%
Total	211.288	100.00%

According to Table 8-1, nearly 83.79 % of total catchment lies above 3,000 m meaning the catchment is highly influenced by snow contribution. The location map with hydrological and meteorological stations in the vicinity, digitally delineated map and Google map of the project catchment are shown in Figure 8-1, Figure 8-2 and Figure 8-3 respectively.

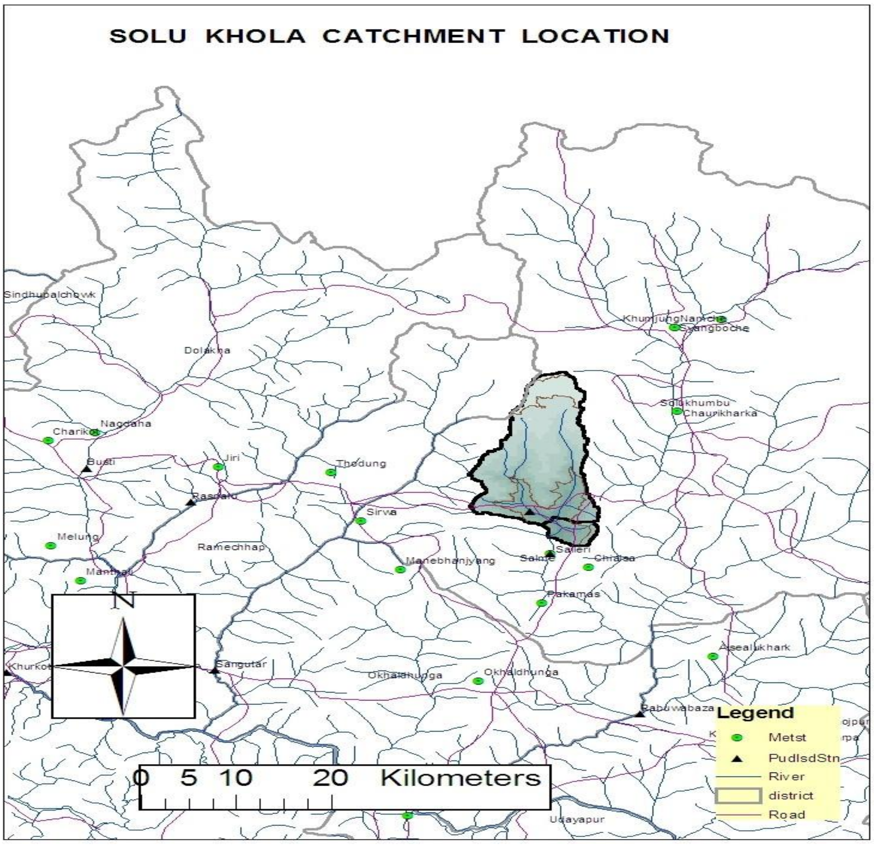


Figure 8-1: USHP catchment area with hydrological & meteorological stations in thevicinity

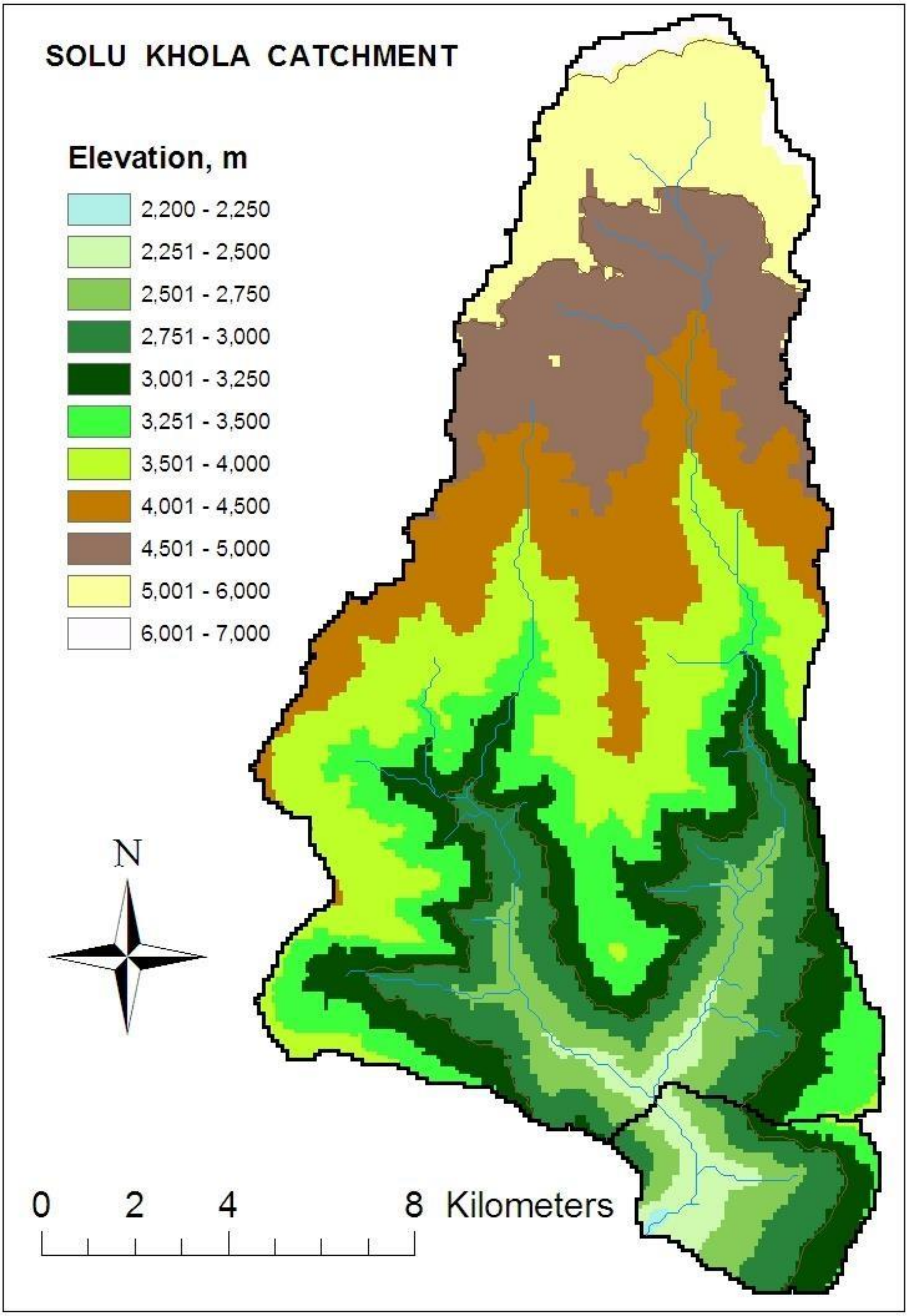


Figure 8-2: Digitally delineated Solu khola river basin at USHP headworks

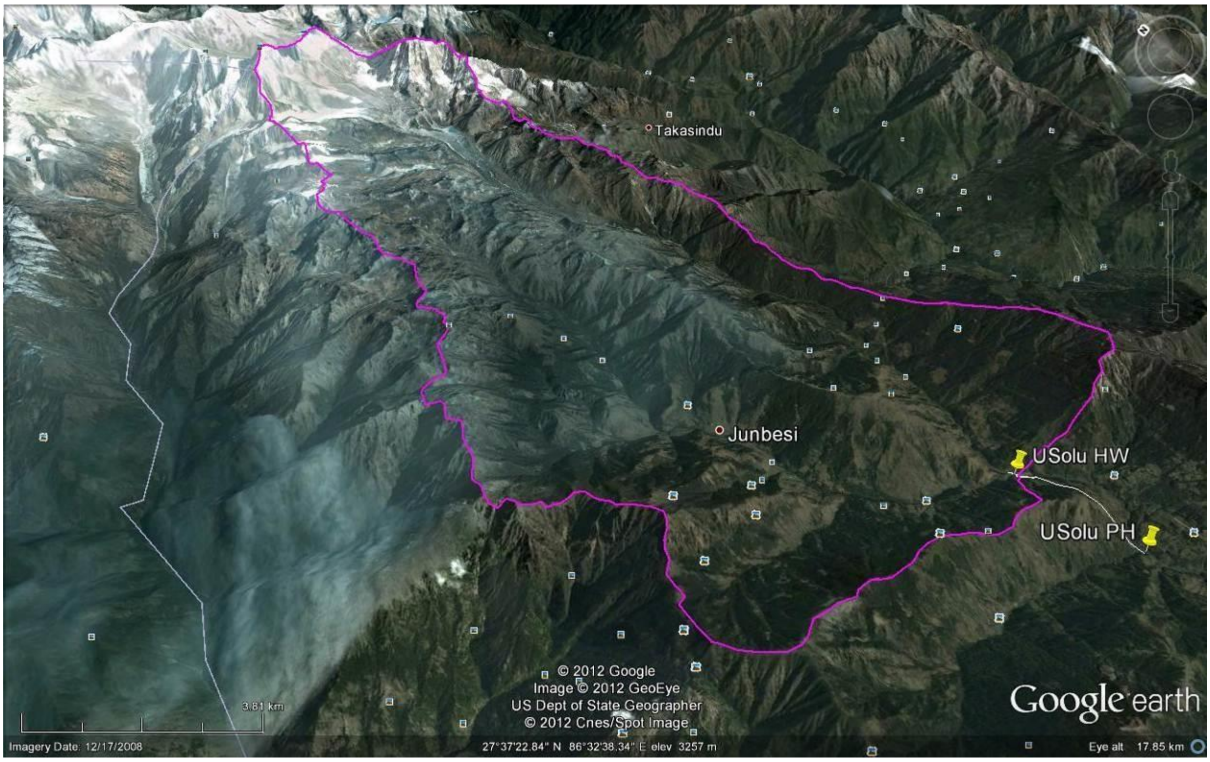


Figure 8-3: USHP catchment area by Google Earth

8.1.3 River System and Gradient

Upper Solu Khola flows from the north and finally turns to the east to merge with Dudh KoshiRiver. The total length of the stream from its origin to proposed intake and confluence at DudhKoshi River are nearly 25 km and 60 km respectively. Its width varies between 4 m to 50 m along its course. The average gradient of the stream up to proposed intake and confluence at Dudh Koshi River are 1 in 10 and 1 in 22 respectively.

9. PROJECT COMPONENT DESCRIPTION

A summary of layout, design criteria and concept for the major components of Upper Solu Hydropower Project are presented in this chapter. The major components of the project are: Diversion weir, side intake, gravel trap, settling basin, headrace tunnel, surge tank, penstock, powerhouse and tailrace, electro-mechanical equipment, and 132 kV transmission line and switchyard. The whole of the components of the project are proposed on the right bank of theSolu River. The project's civil structures has been broadly classified into three groups, namely, headworks, water conveyance system and powerhouse complex.

9.1 General Arrangement of Project Components

The overall layout of the project is prepared for the installed capacity of 19800 kW with the design discharge of 13.0m^3/s. The main civil components of the project are: diversion weir, side intake, gravel trap, settling basin, headrace tunnel, surge tank, steel penstock pipe, powerhouse and tailrace structure respectively.

A 30m long free overflow weir with a sluice on the right bank shall divert the design flow. A side intake having four orifices 2.4 m x 1.5 m is proposed. Gravel trap is proposed immediatelyafter the intake. A single bay settling basin is proposed with 91 m length, 17.4 m width and

11.32 m depth at the right bank of the river.

A low-pressure headrace tunnel runs inside the hills on the right bank of the river. The lengthof the inverted D shaped tunnel is 2370 m and is proposed with the cross-sectional area of

10.25 m^2. At the end of the tunnel, a surge shaft with internal diameter 7.5 m is provided.

The penstock starts from the end of the tunnel and is proposed to be buried and exposed. Thediameter of the pipe is 2.2 m, 2.1 m and 2.0 m and the length is 690 m before bifurcation.

The powerhouse and the tailrace structures are placed on the right bank of the Solu River. A powerhouse of 42 m x 15 m size will be constructed in the plain area at an elevation of 2175masl. Three units of horizontal axis Francis Turbine is proposed in the powerhouse. The tailracewater level after turbine is fixed at 2175 masl.

10. Civil Construction Progress at Site:

Super Sherpa and Baibhav JV have been awarded as Civil Contractor for construction of USKHEP. All the civil works has been completed.

10.1 Headworks

10.1.1 Weir body/divide wall and stilling pool

The weir is located about 120 m d/s of the confluence of Solu River and Junbeshi Khola. A free flow concrete gravity weir is constructed as the suitable diversion structure for this purpose.

The weir crest is 30 m in length and 3.6 m above the river bed level. The crest is designed to elevation of 2360.6 masl. The section of the weir is designed to have a trapezoidal section with the weir crest width of 2m and base width of 12.9 m. The d/s face of the weir is with the slope of 1 in 1.5 (V:H).

Although a sloping glacis weir is constructed, the depth of water above the weir crest is determined considering the weir to be a broad crested weir. This consideration is due to the fact that the upstream bed will be filled with sediments almost till the crest elevation in the future. The weir and side walls have been designed to pass flood of 100 years return period. The flood considered in the design is 265 m^3/sec. The water elevation during the design flood thus estimated is 2363.3 masl. Hence, the elevation of the operation platform for intake and sluice is proposed at 2364.4 masl.

The stability of the weir has been checked with the water elevation of the design flood. The weir shall be constructed completely with concrete; however, to reduce cost the core is proposed to have low grade concrete with plum. Similarly, the d/s slope of the weir is proposed to have high strength concrete of at least M50 with steel fiber to protect from scour.

A stilling basin of length 20m is provided d/s of the weir to dissipate the energy during the flood. The depth of the stilling basin is 1.5m from the river bed. Drainage holes are provided in the floor to dissipate uplift pressure.

Key works executed:

- All the structural and civil works has been completed of weir, divide wall and stilling portion all completed.

10.1.2 Intake and Gravel-trap

Side intake with four orifices. The dimensions of the orifice are 2.4m length and 1.5m height. The orifices are designed to have flow velocity of 1.1m/s at the design flow. Coarse trash rack is proposed in front of the intake orifices to avoid trashes during the high flows.

Four vertical sliding gates are proposed for the flow control. The operation platform is proposedat 2364.4 masl above the designed flood elevation. The intake sill is at an elevation of 2358.4 masl.

Intake gate will be closed and plant operation is stopped if the flood at river exceeds elevationof 2361.9 masl corresponding to 1 in 10 years return period operation flood (125 m^3/s).

A conventional gravel trap is proposed immediately after the intake to settle particle size greater than 5mm. Gravel trap is divided into two bays. The dimensions of each bay of the gravel trap are 7.0m length, 5.7m width and average depth of 3.74m.
The flushing gates are proposed at the end of the gravel trap. The opening of the gravel trap flushing is proposed to be 0.7m width and 0.9m to 1.5m height.
The flushing canals are closed canals with avg length of 23.2 m, width of 1 m and height of 1.5 m. The longitudinal slope is provided at 1:25 (V:H).

- All the works is completed

10.1.3 under- sluice and Floodwall

A single opening side sluice is at the right end of the weir with the dimensions 2.0mwidth and 2.5m height. The sluice is designed to pass about 30m^3/sec flow during monsoon with water elevation at the weir crest. The purpose of the sluice is only to flush the bed load deposited in front of the intake. The sill elevation of the sluice gate is proposed at 2357 masl.
A hydraulically operated radial gates and stoplog are for the regulation of the flow.

Flood protection (flood wall) on left bank and right bank both at headworks is completed.

Key works executed:

- All the concrete works at Under-sluice and flood wall is completed. All the Gabion Protection works at D/S flood wall is completed.

10.2 Settling Basin, Head pond, Spillway and Sediment Flushing Canal:

The settling basin is designed to remove suspended sediments of particle size greater than 0.2mm is diameter. The efficiency is estimated to be 90% removal of the above mentioned particle size. A single basin is provided for settling the fine particles owing to the installation of mechanized continuous flushing system designed and provided by SEDICON AS.

The total length of the settling zone is 91 m with width of basin as 17.4 m. The average flow velocity is designed to be below 0.17 m/s for the design discharge. The inlet transition is designed to have an inlet angle of 9° with a divide wall at the center. The length of the inlet transition zone is 17.0m.
The outlet is designed as orifice. Four orifices are provided with the dimensions 3.6m length and 1.4m height.

The flushing of the basin is a continuous type using the Slotted Pipe flushing system installedby SEDICON AS, Norway.

A conventional forebay is proposed at the end of the settling basin with the dimensions 7.5m length and 17.4m width.
Key works executed:

- All the concrete works on settling basin is competed.
- All the concrete works on Head pond is completed.

10.3 Headrace Tunnel/Surge Shaft

The proposed 2410 m long headrace tunnel passes entirely through the Augen gneisses alongthe right bank of the Solu Khola. The headrace tunnel runs almost parallel to the strike of foliation plane. The dip amount of foliation ranges from 20 to 40 degree hence the tunnel driving conditions are fair. Based on the surface rock mass classification, entire tunnel will passthrough augen gneiss with schist. Shear zones may encountered in some sections. The characteristics of rock are grey to light grey, massive to blocky, strong augen gneisses with schist partings. Generally, there are three discontinuity sets including foliation in slightly weathered conditions. The orientation (direction) of foliation in the headrace tunnel varies from 280º to 320º with dips ranging between 20º to 40º.

A surge shaft is at the end of the headrace tunnel inside the hills above the Lodhing Khola. The surge shaft is located on the side to the tunnel so that parallel construction is possible. The surge shaft is circular with necessary rock supports and concrete lining.

Analysis of the surges were accomplished by Finite Difference Method and using software HYTRAN. For the worst-case scenario, the load rejection and acceptance conditions were referred from IS 7396 Part I.

Key works executed:

- Tunnel Excavation works is completed.
- Final Shotcrete work is completed.
- Invert Concrete Lining works is all completed.
- Concrete Lining works at Surge Shaft is completed.

10.4 Penstock Tunnel

Key works executed:

- Excavation of Penstock tunnel is completed, final support works is completed on tunnel.

10.5Anchor Block/Penstock/Power House/Tailrace

10.5.1 Anchor blocks in penstock alignment and saddle

The most of the penstock is exposed. The pipe is supported by anchor blocks at the bends and by saddle supports in between the anchor blocks at the exposed portion.
Anchor blocks are designed to stabilize the hydraulic forces at the pipe bends. There are altogether 10 anchor blocks in the penstock pipe alignment.
The anchor block foundation soil will be well compacted and well covered by backfill.
The shape of the blocks has been governed by the topography and the bend angle. All the blocks will be constructed of plum concrete with C20 grade. Anchorage bars will be provided around the bend and temperature and shrinkage bars will be provided on the surface of the blocks.
All the blocks will be stable regarding sliding, overturning and bearing of the foundation.

Saddle support piers will be provided along the straight sections of exposed penstock between anchor blocks to avoid overstressing in the pipe. The spacing of the piers will be 8.0 m alongits true length. The piers will be constructed of concrete.

Saddle plates will be placed in the saddle along with 4 mm thick HDP liner to minimize the frictional effects and increase the useful life of the pipe.

All the saddle support will be stable regarding sliding, overturning and bearing of the foundation.

Key works executed:

- All civil works at Anchor Block and penstock alignments all completed.

10.5.2 Powerhouse and Tailrace Canal

In the DPR, the powerhouse was at the confluence of the Lodhing Khola and Solu River. The area available at the location will not be sufficient to construct the powerhouse comfortably. Hence, the location of the powerhouse is shifted further d/s of the Lodhing Khola.

The surface powerhouse is constructed on the terrace of the right bank of theSolu River, about 140m d/s of the Solu-Lodhng confluence. The location is about 85m u/s of the recently completed concrete bridge on Solu River.

The powerhouse consists of building containing turbines, generators and accessories, and tailrace conduit. A switchyard is constructed outside the powerhouse for stepping up transmission voltage.

The powerhouse consists of a reinforced cement concrete (RCC) structure that houses the machine floor, control section and all the mechanical and electrical equipment. The size of the powerhouse is 42.0 m x 15.0 m x 20.0 m. Three generating units, each of 6682 kW installed capacity, will be accommodated in the powerhouse. There will be provision for the auxiliary plants and service area. A concrete raft foundation is provided for the machine foundation in the powerhouse.

A rectangular concrete conduit of 3.5 m x 3.5 m has been proposed to convey water from powerhouse to Solu River.

Key works executed:

- All the civil work at power house/ control room all completed.
- Concrete works at the power house Periphery all completed.
- All the civil works at Tailrace completed.

10.6 Switch Yard Civil works

- All the civil structures on power house outgoing switch yard and receiving end Lammane Tingla Sub-station is completed.

Table 10.1.1: Status of Civil works

Item No.	Item and Short Description Packages	Work Status	Remarks
A	**General Items**	**All Completed**	**100%**
B	**Civil Works**		
B1	Headworks		
1	River diversion works	All Completed	100%
2	Diversion Wier and Undersluice	All Completed	100%
3	Intake, Gravel Trap, Spillway & Flushing Duct	All Completed	100%
4	Flood Protection Wall	All Completed	100%
5	Hillside Protection Wall	All Completed	100%
6	Bypass Canal	All Completed	100%
7	DeSettling Basin	All Completed	100%
B2	**Underground tunnel works**		
8	Headrace Tunnel and Portals	All Completed	100%
8.1	Headrace Tunnel	All Completed	100%
8.2	Headrace Tunnel Inlet and Outlet Portals	All Completed	100%
9	Surge Tank and Areation Tunnel	All Completed	100%
9.1	Surge Tank	All Completed	100%
9.2	Aeration Tunnel Inlet Portal	All Completed	100%
9.3	Aeration Tunnel	All Completed	100%
10	Penstock Tunnel	All Completed	100%
10.1	Penstock Tunnel Inlet Portal	All Completed	100%
10.2	Penstock Tunnel	All Completed	100%
10.3	Penstock Tunnel Outlet Portal	All Completed	100%
B3	**Penstock Alignment**		
11.1	Anchor Blocks	All Completed	100%
11.2	Alignment E/W Excavation, Backfilling and Structure	All Completed	100%
11.3	Saddle Supports and river crossing	All Completed	100%
B4	**Powerhouse, Tailracce, River Protection/Hill Side Protection works**		
12.1	Powerhouse	All Completed	100%
12.2	Tailrace	All Completed	100%
12.3	Flood protection works and village road/Loading Crossing Bridge	All Completed	100%
B5	**Switchyard Civil Cost**	**All Completed**	**100%**
B6	**Powerhouse Staff Camp**	**All Completed**	**100%**

11. Hydromechanical

Key works executed: All Hydro-mechanical gates works was completed.

Table 11.1: Progress Table of Hydro mechanical (Gates works):

S.N.	**Item**	**Nos. of Items**	**Status of Works Progress**			**Remarks**
			Vertical Frame	**Leaf**	**Super structure**	
1	Intake Gate	4	Completed	Completed	Completed	
2	Undersluice Gate	1	Completed	Completed	Completed	
3	Undersluice Stoplog	1	Completed	Completed	Completed	
4	Trash Passage Gate	1	Completed	Completed	Completed	
5	Gravel Trap Flushing Gate	2	Completed	Completed	Completed	
6	Gravel Trap Flushing Stoplog	2	Completed	Completed	Completed	
7	Desander inlet gate	4	Completed	Completed	Completed	
8	Desander inlet Stoplog	4	Completed	Completed	Completed	
9	Desander Outlet Gate	8	Completed	Completed	Completed	
10	Tailrace Gate	2	Completed	Completed	Completed	
11	Draft tube gate	3	Completed	Completed	Completed	

Penstock Pipe

Key works executed: All the Penstock Pipes works was completed.

Table 11.2: Progress Table of Hydro-mechanical (Penstock Pipe works):

S.Nos.	From	To	Length (m)	Completed Length (m)	Remarks
1	Bellmouth	Bellmouth End	2.75	2.75	
2	Bellmouth End	Outlet Portal	40.15	40.15	
3	Outlet Portal	AB#01	14.74	14.74	
4	AB#01	AB#02	60.4	60.4	
5	AB#02	AB#03	102.8	102.8	
6	AB#03	AB#04	59	59	
7	AB#04	AB#05	42.7	42.7	
8	AB#05	AB#06	65.4	65.4	
9	AB#06	AB#07	56.7	56.7	
10	AB#07	PS Portal	33.72	33.72	
11	PS Portal	AB#08	142.18	142.18	
12	AB#08	Y#01	55.51	55.51	
13	Y#01	T#01	13.4	13.4	
14	Y#01	Y#02	11.58	11.58	
15	Y#02	T#02	8.87	8.87	
16	Y#02	T#03	14.7	14.70	
	Total		**724.6**	**724.60**	

12. Electromechanical

12.1 GENERATING EQUIPMENT

This chapter deals with detail design and study of Electro-mechanical equipment along with required switchgear materials to be installed for Upper Solu Khola Hydropower Project.

The generating equipment proposed to be housed inside power house is broadly differentiated into (i) mechanical equipment comprising of main inlet valves, turbines, governors, pressure oil supply system, cooling water supply system, and water drainage & dewatering system , (ii) electrical equipment comprising of generators, excitation system, neutral grounding devices, control & protection panels, SCADA system, MV/LV indoor switchgears, station service/auxiliary transformers (dry type), and battery & battery charger (iii) ancillary equipment comprising of overhead travelling crane, diesel generating set, oil handling and purifying equipment, firefighting system, ventilation and air conditioning system, and compressed air supply system, and (iv) miscellaneous materials comprising of power cables, control and instrumentation cables. Power transformers, high voltage switchgears, steel structures, etc. are also major parts of generating equipment located at outdoor switchyard.

12.2 Turbine Type Selection

The selection of type of turbine primarily depends upon the net head available and design discharge. For the rated net head of 177.06 m and design discharge of 4.33 m3/s, Vertical Francis Turbine is the suitable choice of the turbine as presented in Figure: Turbine Selection Chart. At this rated discharge of 4.33 m^3/s and net head of 177.06, Vertical Francis turbine is the suitable option for the generating power as provided in Section 5.3.1.2 but in accordance with the detail provided by the reputed manufacturer, Horizontal Francis Turbine with rated speed of 600 rpm is selected. Thus, we have selected Horizontal Francis Turbine for water to wire purpose in association with the Synchronous Generator with rated speed of 600 rpm.

12.3 Unit Capacity

The selection of unit capacity is based on the assumption that minimum number of units could be installed for the more economic development of the project, reliability of generation, and minimum loss of power during maintenance and operation at different stage of time. Unit capacity is generally determined by considering the available discharge throughout the seasons, load demand, type of operations, efficiency of the machine, etc. Single unit is not preferred due to the fact that total generation loss will occur in the time of the unit breakdown and hence two or three units will be suitable for the Project. Considering the above factors, three (3) units arrangement is the best option for the Project. Therefore, the study of Upper Solu Hydropower Project reveals that the installation of three (3) power units will be more economical for the following reasons:

12.3.1 With three (3) turbines, the peak power is the same as with two (2) turbines andpartial load efficiency will also be good.

12.3.2 In dry season, one unit will run at nearly full load and hence the turbine performanceand efficiency will be high.

12.3.3 The required repair and maintenance work of the power units (which are in idle condition) can be performed in the yearly dry season in such a way that with the exception of a temporary reduction of the plant power, no energy loss will occur.

12.4 Turbine-Generator arrangement

The turbine runner will be directly mounted on the extended shaft of the generator. For smaller sized machine, this type of arrangement is usually adopted and has benefits like easy installation, lesser space for turbine-generator and is economical.

12.5 Electrical Equipment

12.5.1.1 General

The purpose of the study pertaining to electrical equipment is to identify and dimension the principal components of the powerhouse electrical equipment for safe and economic plant operation of Upper Solu Khola Hydropower Project. The powerhouse electrical equipment of the project includes generators, transformers, switchgears, protection schemes, control systems, earthing systems, lighting systems, communication systems, etc. The ratings of the equipment are designed safely to cope with all normal and fault conditions, avoiding any overstressing of material and equipment. Also, equipment will be of standard design (IEC/IEEE/IS/BS whichever is applicable), providing highest degree of safety, reliability, availability and ease in operation.

12.5.1.2 Generator

Self-excited, self-regulated, Horizontal axis, three phase, cylindrical pole synchronous generators built in accordance with IEC standard are proposed to be used. The generators will have capacity to incorporate sufficient flywheel inertia to achieve stable frequency control when running in isolated mode. The generator shall have anti-friction / sleeve bearing.

The stator core of the generator will be constituted of stacking of laminations made of silicon alloy steel sheets. In the axial direction the stator core is subdivided into a number of partial stacks separated by spacers. These spacers form radial cooling ducts allowing the cooling air to pass. Stator winding of the generator is a double layer, multi-turn lap type coil winding. The stator winding is short pitched to suppress harmonics and to obtain nearly sine wave curve. It will be made of individually insulated stranded copper conductors, stacked and form-pressed to constitute coils or half coils with the design cross section. Each coil will be insulated for the full generator voltage.

The rotor will be of the cylindrical pole type and built in accordance with the best practice and designed to withstand safely all overloads and other stresses encountered during abnormal operating or runaway speed conditions. The poles will be built of thin steel laminations, bolted under high pressure and furnished with dovetails for fastening to the rotor rim. Rotor will be designed so as to allow dismantling of the poles without excessive disassembly of the stator or rotor.

The damper winding will be installed on pole faces with interconnecting type windings in order to maintain the stable operation of the generator. The generator will be capable of withstanding, without damage, a 30-second, 3-phase short circuit at its terminal when operating at rated MVA, at rated power factor and at 5% over voltage with fixed excitation. The generator shaft will adopt single shaft structure. It will have maximum rigidity and strength so as to guarantee no abnormal deformation and vibration at various speeds (including maximum runaway speed) when run together with the turbine. The generator shaft shall be made of a high-quality medium carbon steel, properly heat treated and accurately machined all over and polished at the bearing surfaces and at all accessible points for alignment checks. A complete set of test reports covering metallurgical strength & ultrasonic tests performed on each shaft shall be furnished.

The generators will have enough electric heaters and de-humidifiers and arranged in fan shield of generator to protect them from moisture during shut down and to enable a start up at any time without drying procedure. Insulation and other parts of the generators will not be damaged when electric heater runs.

Resistance type temperature detectors of PT-100 simplex / duplex type shall be installed between the upper and the lower layer of the same phase and are symmetrically distributed in the stator winding over all three phases to indicate the temperature obtained during operation. An auxiliary terminal box having suitable terminal blocks shall be mounted on the generator frame to terminate the resistor element connections. The temperature detector leads shall be kept flexible to facilitate disconnecting them without breakage.

Table 12-1: - Generator Data

S.N.	Description	Parameters
1	Type	Cylindrical pole, synchronous
2	Arrangement	Horizontal
3	Capacity	7,865 kVA + 10% IOL
4	Number	3
5	Power Factor	0.85
6	Generator Voltage	11 kV
6	Generator Current	412.80 A
7	Frequency	50 Hz
8	Class of Insulation	F
9	Protection	IP54
10	Excitation System Type	Brushless
11	Efficiency	96%
12	Heating class	B
13	Number of Poles	10
14	Synchronous Speed	750 rpm

Generator fire protection will be provided by CO2. The activation of the CO2 fire protection system will be conditional to the operation of the flame or smoke detectors in the generator hall combined with the operation of the generator differential protection or a manual push button instruction. Upon receipt of a signal from the fire detectors and of the generator differential relays, an alarm will be initiated. The CO2 release will only be initiated after a preset time delay in order to allow evacuation of the personnel in the hall at that moment unless the operation is aborted by manual interruption instruction.

The generator shall have following major protection systems:

a) Reverse power Relay,
b) Loss of field relay,
c) High speed trip relay,
d) Generator differential protection relay,
e) Under and over frequency relay,
f) Loss of synchronization relay,
g) Field ground detect relay,
h) Negative phase sequence relay,
i) Overvoltage/Undervoltage relay, and
j) Stator earth fault relay.

12.5.1.3 Generation Voltage Level

The generated voltage for Upper Solu Khola Hydropower Project is 11 kV. Switchgear panels will be located inside the control room together with switchgear components (like VCBs, CTs, PTs, etc.). These switchgear panels will have in-built bus bar cabinets housed in its back. Each generator's output terminals will be connected to this 11-kV bus bar system with XLPE power cable of adequate size. The switchgear and other protection and control components will accompany them in the switchgear panel to complete the incoming generation power circuit.

The switchgears will be provided with housing to install the required set of current transformers and potential transformers for metering and protection.

Each generator will be synchronized on 11 kV vacuum circuit breaker. All the generator circuit breakers and fuse switches will be arranged in one continuous row accessible from the front side with sufficient space on both side of the switchgear assembly for safe operations. Individual switchgear panels for each generator incomer and outgoing feeder will be provided to complete the generation level switchgear system.

This switchgear system will work in co-ordination with the control panels accommodated in the control room.

This switchgear system will work in co-ordination with the control panels accommodated in the control room.

12.5.1.4 Generator Braking

Generator shall be provided with hydraulic operated brakes of sufficient capacity to bring rotating parts of generator and turbine to stop from 30 % of rated speed.

12.5.1.5 Generator Grounding

The principle objective of grounding synchronous generator system is the protection of the generator and associated equipment against damage caused by abnormal electrical conditions. Grounding in Upper Solu Khola Hydropower Project is achieved by the intentional insertion of resistance on the secondary of Neutral Grounding Transformer as shown in SLD. Each generator unit will be equipped with transformer, self-ventilated, dry, resistive type grounding system. The rated voltage of the resistor shall be 110 V and shall be made up of alloy of Chrome, Aluminum and Iron.

12.5.1.6 Excitation and Automatic Voltage Regulator (AVR)

Each generator of Upper Solu Khola Hydropower Project will be equipped with brushless excitation system consisting of a 3-phase AC exciter and silicon diode type rotating Rectifier Bridge mounted on the generator shaft extension. The system shall be complete along with surge suppressor, automatic voltage regulator of solid-state type with Thyristor Bridge and field suppression equipment, etc.

The protection against voltage spikes shall be provided. The AVR shall have fast response and anti-hunting features. The AVR shall be provided with cross compensating devices for parallel operation of generators.

The excitation transformer of sufficient size, with 11 kV on primary side shall be used. The Transformer shall be of dry type.

The excitation shall be suitable for maintaining the voltage for a grid voltage variation of ± 10% & for a frequency variation of ± 3%. The AVR shall be sensitive enough to track and respond the changes up to +/- 0.5% of normal voltage (average of 3 phases) of the Generator when operating under steady load conditions (for any load) or excitation within operating range and shall initiate corrective action without hunting. The response time of excitation system shall be less than 20 ms.

After the initial maximum voltage following any load rejection up to 100% of rated load, the AVR shall restore the terminal voltage to a value not more than 5% above or below the voltage being held before load rejection and shall maintain the voltage within these limits throughout the period of generator over speed.

The AVR shall have the following features:

a. Two auto channels with one manual mode for voltage control
b. Voltage / frequency during accelerating and decelerating of machine
c. Power factor / KVAR control mode
d. Reactive power shedding
e. KVAR limit
f. Short circuit limit
g. Diode failure indication

Besides these, equipment for limiting and regulating (both automatic/manual mode) on generator rotor current shall be included. Voltage setting devices and necessary control switches shall be included. This equipment shall be of a tropical design and shall work satisfactorily at a temperature of maximum 40°C.

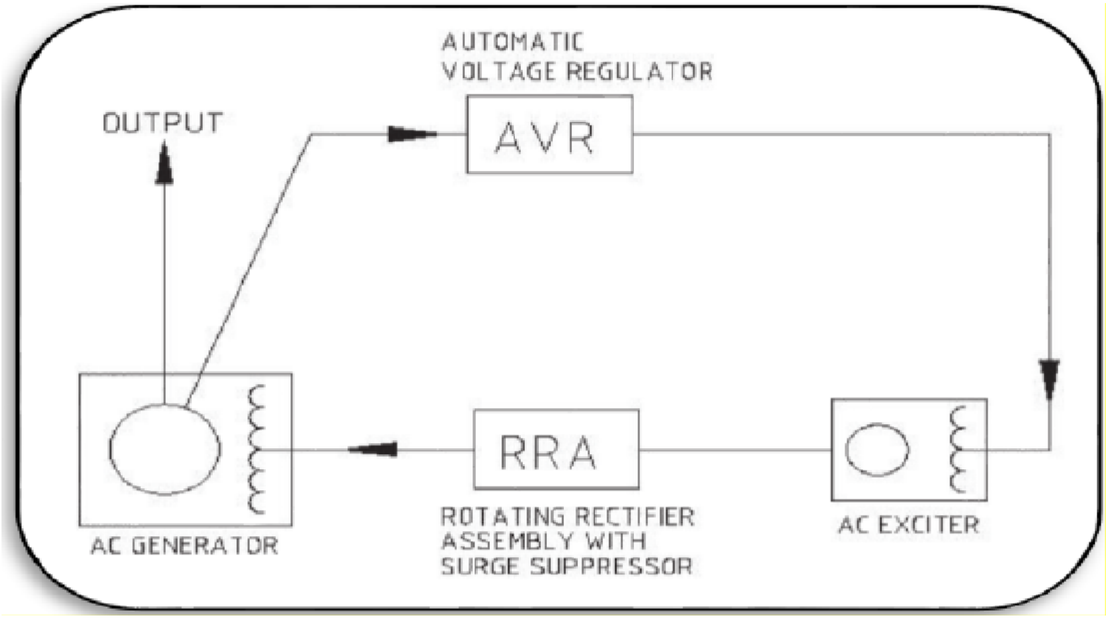


Figure 12-3: Excitation System

12.5.1.7 Power Transformers

Power transformers are used to step-up the generated power so as to evacuate the generated power to the nearest substation. The main transformer in Upper Solu Khola Hydropower Project shall have three (3) numbers of 3-phase, outdoor, oil immersed, and ONAN type, each of 8.650 MVA, for stepping up the voltage from 11 kV to 132 kV.

Table 12-3: Data for Power Transformer

S.N.	Description	Parameters
1	Number of Transformers	3
2	Type	3-phase, outdoor, oil immersed
3	Cooling	ONAN
4	Rating	8.650 MVA
5	Rated Voltage	Primary side – 11 kV and Secondary Side -132 kV
6	Maximum Voltage (Line to Line)	Primary side – 12 kV and Secondary Side -145 kV
7	Current on HV side and LV side	HV side 37.834 A and LV side 454.00 A
7	Type of Tap changing	Off Load on High Voltage side
8	Tap Changing Range	±10% in Steps of 2.5
9	Principal tapping	132 kV
10	Vector Group reference	YNd11
11	Efficiency	≥ 99 %

The transformer will be installed outdoor. The transformer will be oil immersed and designed for the cooling system as specified. The transformer will be capable of operating continuously at its rated output at all tap positions without exceeding the temperature rise limits.

The incoming side (low voltage side) will be suitable for terminating appropriately sized XLPE cables inside the cable terminating chamber. The termination arrangement will include cable terminations for delta connection of the transformer windings besides the phase cable termination. The outgoing side high voltage terminals will be brought out through high voltage bushing for connecting to other high voltage apparatus of the switchyard. The neutral points will be brought out on suitable bushings installed and will be solidly grounded via appropriate conductors. Following Protections are implemented in Power Transformers at Upper Solu Khola Hydropower Project.

a) Transformer differential Protection (87T)
b) Restricted Earth fault Protection (64T)
c) Thermal Protection (49)
d) Pressure Relief device (63)
e) Buchholz (gas operated relays) protection
f) Low Oil level alarm
g) Over voltage/Under voltage protection
h) Over Frequency/Under Frequency protection
i) Rate of Change of Frequency Protection

Station Transformer

Auxiliary transformer or station supply transformers provide electrical supply to the power house electrical equipment. The auxiliary transformer, used for station power supply, shall be three phase, indoor, dry epoxy resin moulded type of 250 kVA.

Table 12-4: Details of station transformer

S.N.	Description	Parameters
1	Number of Transformers	1 x 3-Phase
2	Type	Indoor
3	Cooling	dry type
4	Rating	250 kVA
5	Rated Voltage (Line to Line)	Primary side – 11 kV and Secondary side -0.4 kV
6	Type of Tap changing	Off Circuit Tap Changer (OCTC)
7	Tap Changing Range	±5% in Steps of 2.5
8	Principal tapping	0.4 kV
9	Vector Group reference	Dyn11

12.5.1.8 Switchgears

Upper Solu Khola Hydropower Project consists of three (3) numbers of AC generators each rated 11 kV, 50 Hz, 7,865 kVA, 0.85 power factor (lag) and connected to 132 kV system outdoor switchyard through three (3) numbers of 3-phase power transformers each rated at 8.650 MVA. Each generator output is connected to the 11 kV busbar through a 11 kV switchgear consisting of vacuum circuit breaker (VCB).
Each generator shall be synchronized with 11 kV Vacuum Circuit Breaker (VCB). All the generator circuit breakers and fuse switches will be arranged in one row accessible from the front side with sufficient space on both sides of the switchgear assembly for safe operations. There will be following number of switchgears in PH.

- 3 No. of 11 kV Generator output switchgears
- 3 No. of 11 KV Transformer incoming switchgears
- 1 No. of 11 kV switchgear for auxiliary transformer
- 1 No. of 11 kV switchgear for dam-site distribution transformer
- NGT & LAVT panels with LA, PTs and surge protection capacitor of appropriate ratings.

Each switchgear comprises of

- Vacuum Circuit Breaker
- Cable box for incoming and outgoing XLPE insulated copper cables
- Current transformers
- One unit of voltage transformer sets for synchronization for each generating unit.
- NGT & LAVT panels with LA, PTs and surge protection capacitor of appropriate ratings
- Air insulated three phase bus-bar system, extensible to make connection with the bus-bars of other adjacent panels

Table 12-5: Data for Generator Circuit Breaker

S.N.	Description	Parameters
1	Type	Vacuum, Metal Enclosed, Cubicle Indoor Type
2	Rated Voltage	12 kV
3	Rated Current	630 A
4	Frequency	50 Hz
5	Insulation level	28 kV/75 kVpK
6	Short Circuit Breaking Current	25 kA rms
7	Short Circuit current Duration	3 secs
8	Operating Sequence	O-0.3 sec-CO-3 min-CO
9	Closing Coil & Opening Coil Supply Voltage	110 VDC
10	Motor Supply Voltage	230 VAC

Table 12-6: Data for Transformer incomer Circuit Breaker

S.N.	Description	Parameters
1	Type	Vacuum, Metal Enclosed, Cubicle Indoor Type
2	Rated Voltage	12 kV
3	Rated Current	1,600 A
4	Frequency	50 Hz
5	Insulation level	28 kV/75 kVpK
6	Short Circuit Breaking Current	25 kA rms
7	Short Circuit current Duration	3 secs
8	Operating Sequence	O-0.3 sec-CO-3 min-CO
9	Closing Coil & Opening Coil Supply Voltage	110 VDC
10	Motor Supply Voltage	230 V AC

12.5.1.9 Current Transformer (CT)

The current transformers will be of dry, synthetic resin insulated type. All secondary connections will be connected to a terminal block which will be located in a dust-proof and watertight terminal box and will be clearly labeled. An earth connection to the housing will be provided.

The indoor current transformers will be designed to carry continuously a current of 120% of the rated current. The rated current of the secondary windings will be 1 A.

The core for measuring purposes will have the following characteristics:

Accuracy class 0.5

Cores for protection purposes will have the following characteristics:

Accuracy class 5P20

The rating, burden and location of current transformers shall be as specified in Single Line Diagram (SLD).

12.5.1.10 Voltage Transformer (PT)

The indoor voltage transformers will be of the single-phase dry synthetic resin type. All primary and secondary connections will be clearly marked. An earth connection to the housing will be provided. Earthing of the cores and the neutrals will be done on the transformers and not on the terminal boxes. The windings for measuring purposes will be designed for accuracy according to class 0.5. The voltage transformers will have an additional secondary winding for earth fault protection, connected in open delta with a resistive burden. The accuracy class will be 5P20.The secondary will be provided with miniature circuit breakers with alarm contacts and primary will be protected with a fuse.

The burdens of all windings will not be less than 125% of the overall computed (design) burden of the connected apparatus including cables.

Table 12-7: Details of 11kV Potential Transformer

S.N.	Particular	Specifications
1	Type	Indoor, dry synthetic resin type
2	Rated primary voltage	11 kV/√3
3	Rated secondary voltage	0.11 kV/√3
4	Impulse withstand voltage (peak)	75 kV
5	Frequency	50 Hz
6	Burden	As specified in SLD
7	Accuracy	As specified in SLD

12.5.1.11 Lightning Arrestors

The lightning arresters will be of the gapless metal oxide type. The generator will be protected against incoming voltage surges by means of lightning arresters connected between phases and earth.

The outdoor lightning arresters will be mounted on steel structures and will be fitted with a pressure relief device. Surge counters shall be supplied. The earth conductor from the arrester to the counter, as well as the terminal of the counter, will be suitably insulated or screen protected against accidental touching.

The Lightning Arrestors for the protection of generator will be of rated arrestor voltage of 10 kV.

Table 12-8: Details of 11 kV Lightning Arrestor

S.N.	Particular	Specifications
1	Type	Indoor, gapless Zno arrestor
2	Frequency	50 Hz
3	System voltage	11 kV
4	Rated voltage	10 kV
5	Impulse withstand voltage (peak)	75 kV
6	Power frequency withstand voltage	25 kV
7	Nominal discharge current	10 kA

12.5.1.12 Governor

Each turbine is controlled by a microprocessor controlled proportional integral derivative (PID) governor in combination with the oil pressure unit to operate the turbine guide vanes for regulation of the unit. The main features of the governor include:

a. Programming capabilities for automatic control of guide vane openings to regulate maximum output of turbine

b. Shutdown of the unit in case of emergency.

Governors are provided for the automatic control of the turbines during load variation. The electronic governors in combination with the oil pressure unit acts on the turbine guide vanes for regulating the turbine flow. Each electronic governor has its own oil pressure unit/system. The oil pressure unit consists of a sump tank, N2 filed accumulator pressure tank, and gear pumps.

For maintaining oil pressure in the system, a jockey pump is supplied. Essential controls and piping connections to the governor relay valve and servomotors of the turbine guide vane is also provided. The capacity of governor pumps and servomotors for wicket gate and inlet valve shall be suitably selected. Further discussions on oil pressure unit are provided on succeeding sections.

The governor panel and oil pressure unit will be located on the turbine floor near to the turbine.

Conceptual governing system architecture is presented as below:

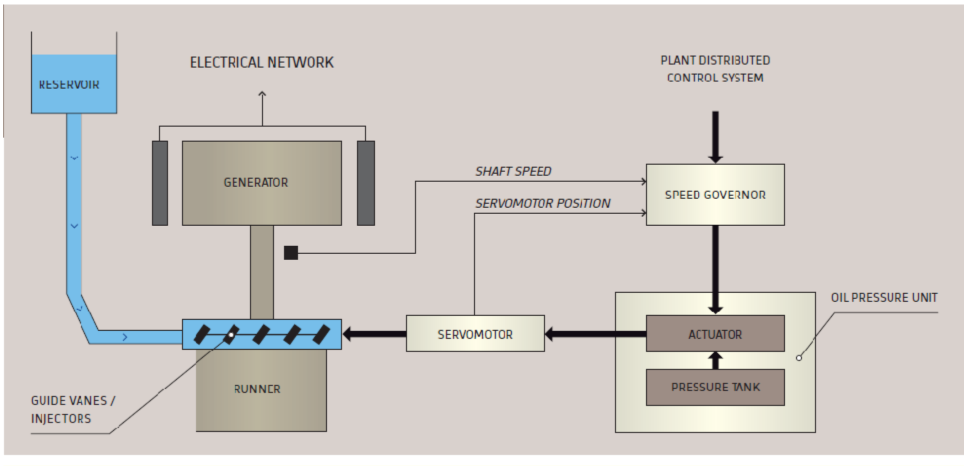


Figure 5-4: Governing System Architect

12.5.1.13 Powerhouse Overhead Travelling Crane

One Powerhouse Electric Overhead Travelling Crane of 10/35T capacity to handle the equipment inside the powerhouse will be installed. The capacity of main hoist (35 ton) is determined considering a single piece generator. The auxiliary hoist of 10 ton will be used for lifting smaller loads inside the powerhouse during installation as well as operation period.

The crane will be complete with drives for cross travel, long travel and lifting motion, runaway rails of adequate size, end carriages & gantry rail. All motions operated from a pendant, operated by an operator on the machine hall floor.

The gears will be helical type and all bearing and other wearing surface will be splash oil lubricated. The DC Electromagnetic shoe with EHT braking system will be provided.

S.N.	Description	Notation	Values
1	Turbine Capacity	P_t	6,860 kW
2	Generator Efficiency	n_g	96%
3	Generator Capacity	P_g	7,865 kVA
4	Synchronous Speed	N_s	600 RPM
5	Lifting Capacity of Main Crane		35 Ton
6	Lifting Capacity of Auxiliary Crane		10 Ton

12.5.1.14 Control and SCADA System

The computer supervisory and control system at Upper Solu Hydropower Project shall adopt the full distributed mode in open environment in accordance with international open system concepts so that compatibility of selection of various computers, translatability of system expanding and renewal of equipment shall be assured. The open environment shall include application development environment, user interface environment and interlink of system environment, which shall comply with the specifications of the open environment recommended by international open system organizations.

The computer supervisory and control system shall have station control level and local control unit level.

The station control level, real time supervisor and control center of the plant shall be responsible for automatic functions of the whole plant (AGC, AVC, generating optimization control etc.), historical data process (various operation tables, operation archives of important equipment and various operating parameters etc.) and man machine dialogue of whole plant (operation monitor of plant equipment, accident and failure alarm, manual intervention of operating equipment, modifying and setting of various parameters for the Computer Supervisory and Control System). Station control level shall be made up of the relevant equipment located at computer room and central control room. The computer will adopt dual computers for redundancy and hot standby. At normal condition a computer works and the other is backing-up. When master computer receives failure, the computer is changed-over by back-up.

The local Control unit (LCU) shall have turbine-generator local control unit. Each LCU shall manipulate production procedures and accomplish the supervision and control functions under controlling. LCUs will be connected with the production procedures by means of input and output interface, with the network by communication interface and exchanging information with control level through network. The information shall be exchanged among LCUs. LCUs may be independent from control level relatively. They shall directly finish real time data acquisition and pre-processing, supervision, adjustment and control etc. of unit equipment conditions with station control level divorced.

The operator's console in the central control room shall be equipped with CRT display that displays operation conditions of the power station. When the power station is under normal operation, the operator can monitor the conditions of each equipment in the power station. The major monitoring items shall be as follow:

- Operating conditions and output of generating units
- Operating conditions of auxiliary equipment of the generating units
- Operating conditions of the transformers
- Status of circuit breakers, disconnectors and earthing switches.
- Operating conditions and transmission power of power lines
- Opening level of gates, inlet valves, etc.
- Operation mode of station service power, and
- Other important parameters

When the system receives any fault or the equipment has abnormality during operation, the supervisory control system shall automatically give alarm in both sound and picture striking to the eye to indicate nature, location, time and abnormal parameter values of the event.

13. Switchyard and Transmission Line

13.1 132 kV Switchyard at Power House

132 kV outdoor type switchyard shall be constructed near the powerhouse to evacuate the generated power. The switchyard components shall be suitable for hot, humid and moderately polluted environment. The switchgear system for this switchyard shall be equipped with circuit breakers, current transformers, potential transformers, disconnecting switches with/without earthing and lightning arrestors and synchronous check relay, etc. for 132 kV incoming and outgoing circuits. The switchgear system here will work in coordination with the associated control panels accommodated in the control room and shall ensure the overall protection of the switchyard.

Table 13-1: Data for 132 kV Circuit Breaker

S.N.	Description	Parameters
1	Type	SF6, Metal Enclosed, Cubicle Outdoor Type
2	Rated Voltage	145 kV
3	Rated Current	1,250 A
4	Frequency	50 Hz
5	Insulation level	275 kV/650 kVpK
6	Short Circuit Breaking Current	40 kA rms
7	Short Circuit current Duration	3 secs
8	Operating Sequence	O-0.3 sec-CO-3 min-CO
9	Closing Coil & Opening Coil Supply Voltage	110 V DC
10	Motor Supply Voltage	230 V AC

Table 13-2 : Data for 132 kV Isolator

S.N.	Description	Parameters
1	Applicable standard	IEC
2	Type	3 pole, single throw, outdoor, Center Break
3	Frequency	50 Hz
4	Rated voltage	132 kV
5	Rated current	
	a) Continuous at 40-degree C ambient	1,250 A
	b) Short time current for 3 sec	40 kA
6	Insulation level	
	a) Impulse withstand voltage	650 kV
	b) Power frequency withstand voltage (1 min, rms)	275 kV
7	Main contacts	

	- Material of fixed contacts	copper alloy
	- Coating of fixed contacts	Silver plated
	- Material of moving contacts	
	- Coating of moving contacts	Silver plated
	- Material of the contacts of the earthing switch	copper alloy
	- Coating of the contacts of the earthing switch	silver plated
8	Operating mechanism	Motor and Manual operated
9	No of operations switch can withstand without deterioration of contacts	Minimum 1000
10	Auxiliary power supply	
	a) Space heater and cubicle	230 V, 1-Ph
	b) Control circuit	110 V DC
	c) Operating motor	400/230 V AC
11	Local operating device provided	Yes
12	Insulator	
	a) Reference standard	IEC
	b) Creepage distance in air	900 mm
	c) Number of Stacked/type	1/Solid Core Post Type
13	Enclosure protection	IP-55W
	Thickness of sheet (minimum)	2 (for steel) mm 3 (for Al. alloy) mm
14	Earthing switch	
	a) Operating mechanism	Manual
	b) Type of interlocks furnished	Electrical & Mechanical

Table 13-3: Details of 132 kV Potential Transformer

S.N.	Particular	Specifications
1	Type	Outdoor
2	Rated primary voltage	132 kV/√3
3	Rated secondary voltage	0.11 kV/√3
4	Insulation Level	275 kV/650 kV
5	Frequency	50 Hz
6	Burden	30 VA
7	Accuracy Class	3P, 0.5, 0.2

Table 13-4: Details of 132 kV Current Transformer

S.N.	Description	Parameters
1	Type	Outdoor
2	Rated current ratio	As specified inSLD
3	Burden	30 VA
4	Accuracy Class	5P20, 0.5, 0.2
5	Insulation Level:	
6	Impulse withstand voltage (Peak)	650 kV
7	Power frequency withstand voltage (1min, rms)	275 kV

Table 13-5: Details of 132 kV Lightning Arrestor

S.N.	Particular	Specifications
1	Type	Outdoor, gapless Zno arrestor
2	Frequency	50 Hz
3	System voltage	132 kV
4	Rated voltage	110 kV/phase
5	Insulation Level	275 kV/650 kV
6	Nominal discharge current	40 kA

13.1.1.1 Interconnection Point

132 kV outdoor type switchyard shall be constructed at NEA Lamane Substation to evacuate the generated power. The switchyard components shall be suitable for hot, humid and moderately polluted environment. The switchgear system for this switchyard shall be equipped with circuit breakers, current transformers, potential transformers, disconnecting switches with/without earthing and lightning arrestors, metering units, etc. for 132 kV outgoing circuits. The switchgear system here will work in coordination with the associated control panels accommodated in the control room and shall ensure the overall protection of the switchyard.

Metering Scheme at Interconnection Substation

To measure import and export of energy between User and Owner's system, Bi-directional (Import and Export) Energy Meters (Main and Check Meters) shall be installed at proposed substation as shown in SLD. The Main and Check Meters shall be able to record the followings:

- Voltage (KV)
- Current (A)
- Power Factor (Lead and Lag)
- Frequency (Hz)

- MW or KW
- MWh or KWh (import and export)
- MVAr or KVAr (import and export)

In addition, KW meter, KVAr meter, PF meter, Ammeter and Voltmeter shall be installed at control panel inside control building of substation for 132 kV system to measure respective quantities.

13.1.1.2 Power evacuation and Transmission Line

Upper Solu Khola Hydropower Project shall construct 132 kV single circuit ACSR WOLF conductor transmission line (approximately 12 km) up to the switchyard of proposed Lamane substation. Main and Check meters of accuracy class 0.1 shall be installed at NEA's Lamane Substation.

Key works executed: All the Transmission Line works was completed.

Table 13.1.1.1: Progress Table for Transmission Line:

S.No	Tower Number	Land Purchasing	Excavation works	Foundation works	Tower Erection works	Conductor Stringing works	Remarks
1	T1	yes	Complete	Complete	Complete	Complete	
2	T2	yes	Complete	Complete	Complete	Complete	
3	T3	yes	Complete	Complete	Complete	Complete	
4	T4	yes	Complete	Complete	Complete	Complete	
5	T5	yes	Complete	Complete	Complete	Complete	
6	T6	yes	Complete	Complete	Complete	Complete	
7	T7	yes	Complete	Complete	Complete	Complete	
8	T8	yes	Complete	Complete	Complete	Complete	Leo-Tower
9	T9	yes	Complete	Complete	Complete	Complete	
10	T10	yes	Complete	Complete	Complete	Complete	
11	T11	yes	Complete	Complete	Complete	Complete	
12	T12	yes	Complete	Complete	Complete	Complete	
13	T13	yes	Complete	Complete	Complete	Complete	
14	T14	yes	Complete	Complete	Complete	Complete	
15	T15	yes	Complete	Complete	Complete	Complete	
16	T16	yes	Complete	Complete	Complete	Complete	
17	T17	yes	Complete	Complete	Complete	Complete	
18	T18	yes	Complete	Complete	Complete	Complete	
19	T19	yes	Complete	Complete	Complete	Complete	
20	T20	yes	Complete	Complete	Complete	Complete	
21	T21	yes	Complete	Complete	Complete	Complete	
22	T22	yes	Complete	Complete	Complete	Complete	
23	T23	yes	Complete	Complete	Complete	Complete	
24	T24	yes	Complete	Complete	Complete	Complete	
25	T25	yes	Complete	Complete	Complete	Complete	
26	T26	yes	Complete	Complete	Complete	Complete	
27	T27	yes	Complete	Complete	Complete	Complete	
28	T28	yes	Complete	Complete	Complete	Complete	
29	T29	yes	Complete	Complete	Complete	Complete	
30	T30	yes	Complete	Complete	Complete	Complete	

31	T31	yes	Complete	Complete	Complete	Complete	
32	T32	yes	Complete	Complete	Complete	Complete	
33	T33	yes	Complete	Complete	Complete	Complete	
34	T34	yes	Complete	Complete	Complete	Complete	
35	T35	yes	Complete	Complete	Complete	Complete	
36	T36	yes	Complete	Complete	Complete	Complete	
37	T37	yes	Complete	Complete	Complete	Complete	
38	T38	yes	Complete	Complete	Complete	Complete	
39	T39	yes	Complete	Complete	Complete	Complete	
40	T40	yes	Complete	Continue	Complete	Complete	
41	T41	yes	Complete	Complete	Complete	Complete	
Completed			**41 complete**	**41 Complete**	**41 complete**		

Site Progress Photographs:

Photo: Headworks View

Photo: Settling Basin View

Photo: Tunnel shotcrete works during construction

Photo: Penstock Alignments AB#06 to AB#07

Photo: Settling Basin and Penstock Alignments

Photo: PPV House View

Photo: Power House & Switchyard View

Photo: Power house Switchyard View

Photo: Photography during the NEA Testing Team

Photo: BOD members with testing & commissioning team

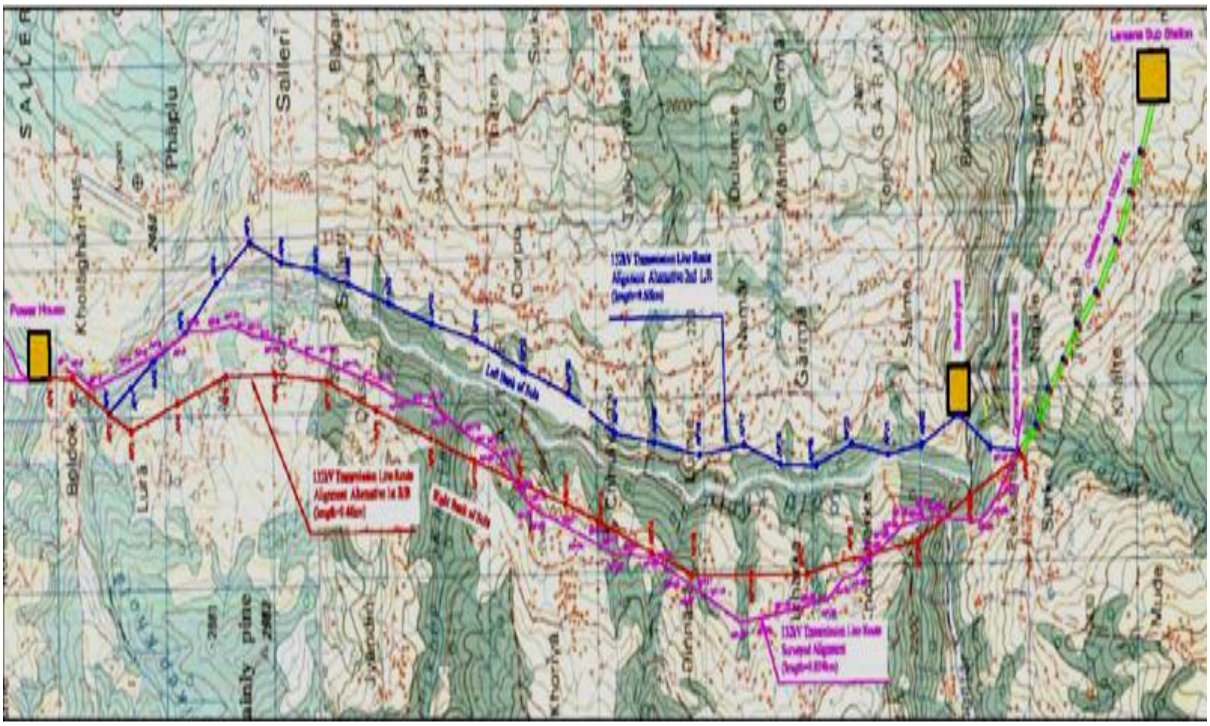


Photo: Transmission Line Route

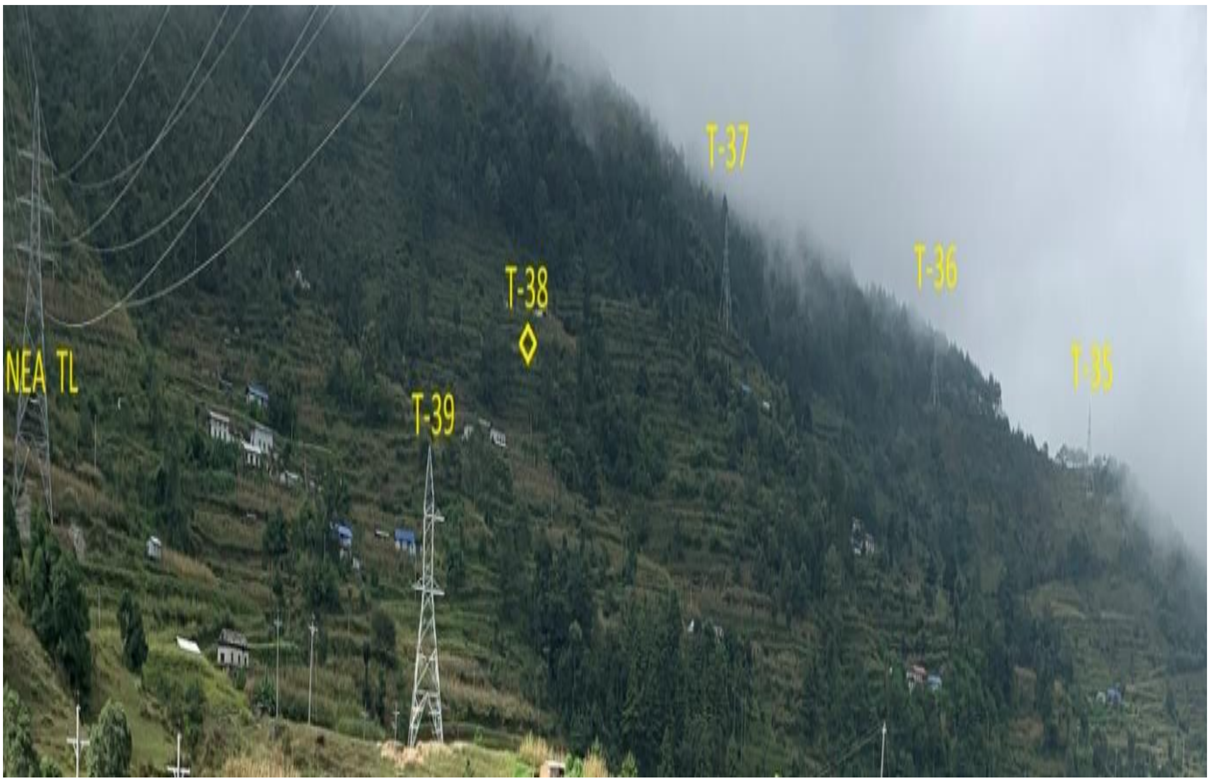


Photo: Transmission Line Route at Tingla Area

Photo: Transportation and fitting works at Tingla Sub-station during working time

Photo: Receiving End Tingla Sub-station

Photo: Transmission Line

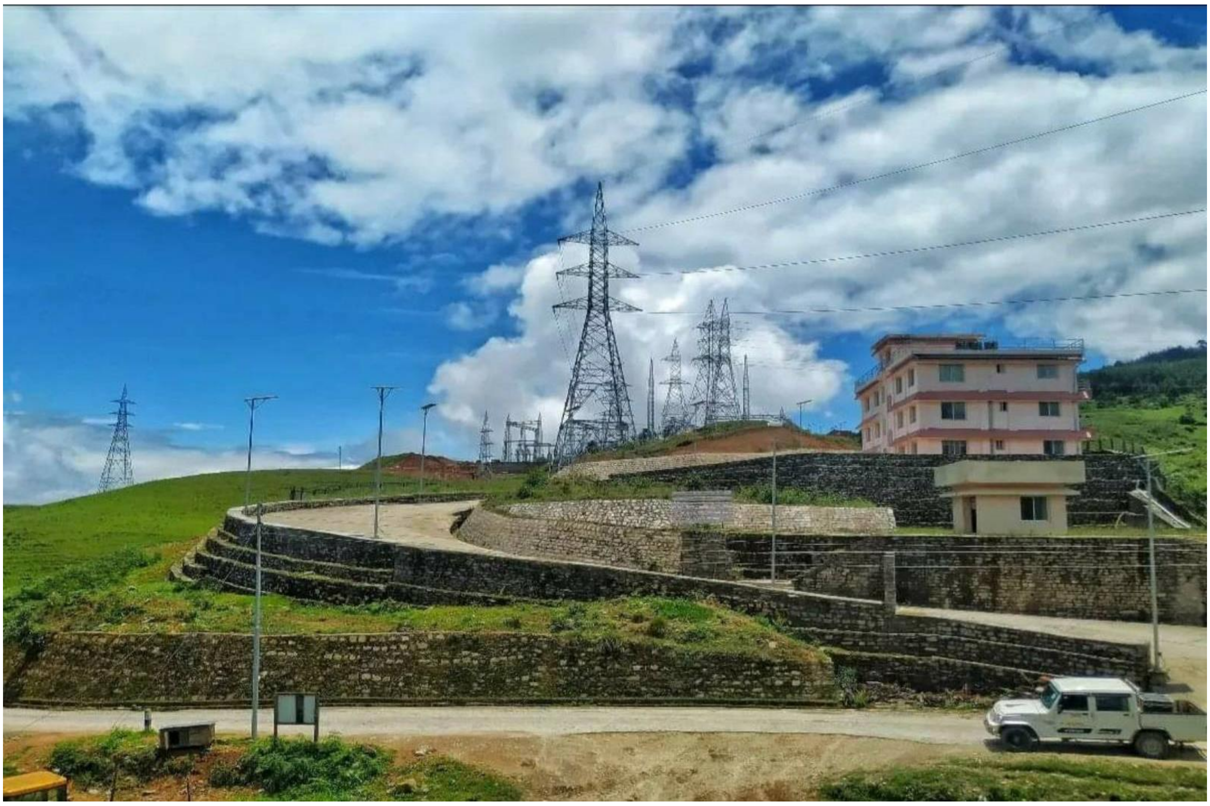


Photo: View Lammane (Tingla) Sub-station area