ENERGY, ENVIRONMENT AND SOCIETY

Chapter - 16

Case Study

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LEARNING OBJECTIVES OF THE LECTURE

- Case study of feasibility study of a micro hydro project of rural nepal

PROJECT SUMMARY

- The proposed power house site is located at Fedi village, ward no. 5 of Salpa Silicho Rural Municipality of Bhojpur district.
- The potential load centres of the project include: Pichhuwa, Tallo Maarel, Siraane, Siraan Tole, Pengche, Bakhuma, Thulo Tendo, Tendo, Baasemlaa etc.
- The design discharge of the project is 210 lps and available gross head is 80 meters.
- The project is designed for the installed capacity of 100 kW, taking overall efficiency of 60.93 %.
- Total length of headrace canal is 1300 meters. Headrace route includes 1300 m long lined headrace canal.

PROJECT SUMMARY

- Settling Basin lies 10 m away from the intake region. The spillway of settling basis consists of 15 m lined canal.
- Penstock pipe and tailrace canal are 214 m & 30 meters respectively. Penstock pipe is proposed of 350 mm diameter and 4 mm thickness.
- The spillway of forebay consists of 32 m lined canal.
- The transmission/ distribution network consists of low-tension and high tension line.
- Seven transformers are proposed at various locations due to very high length of transmission line.
- The total conductor length for the low tension line is 139,907 m and for HT line is 85,120 m.

PROJECT SUMMARY

- The total cost of the project is estimated as Rs. 58,855,870 including VAT.
- Thus, the cost per kW becomes Rs, 588,558.7.
- Similarly, costs of civil, mechanical and electrical works are estimated as Rs. 16,961,165 (28.82%), Rs 3,472,102 (5.90%) and Rs. 27,220,223 (46.25%) respectively.
- The cost of installation including testing commissioning, tools and spare parts is Rs. 600,000 (1.02 %) and Rs. 82,675 (0.14%) respectively.
- The transportation cost is estimated Rs. 3,022,401 (5.14%) and the contingency have been taken as Rs. 2,802,660 (4.76%).
- 13% VAT for non-local cost has been calculated as Rs. 4,694,643 (7.98%).

SALIENT FEATURES OF THE PROJECT

- **General**
- Name of the project : Salpa Community Micro Hydropower Project
- Project Location : Salpa Silicho Rural Municipality
- Name of Source : Salpa River
- Load Centre(s) : Pichhuma, Tallo Matel, Siraane, Siraan Tole, Pengche, Bakhuma,
    - Thulo Tendo, Tendo, Wasemla

SALIENT FEATURES OF THE PROJECT

- **Technical Features**
- GPS Coordinates of Intake : 27°24' 15.1"N, 86° 58'17.3"E, Z = 1646 m
- GPS Coordinates of Forebay : 27°24' 14.5"N, 86° 58' 38.3"E, Z = 1576 m
- Type of Intake : Orifice Type, Side Intake
- Diversion : Temporary Weir, 8 m long on both rivers
- Gross Head : 80 m
- Net Head : 76 m

SALIENT FEATURES OF THE PROJECT

- Measured Flow : 490 lps
- Date of Flow Measurement : 05/15/2022
- Method used for Flow Measurement : Salt Dilution
- Design Flow : 210 lps
- Overall Efficiency : 60.93%
- Design Power : 100 kW
- Length of Headrace : 1300 m lined canal
- Penstock pipe : Mild Steel, 218 m long, 350 mm diameter, 4 mm thick

SALIENT FEATURES OF THE PROJECT

- **Electro Mechanical Features**
- Type of Turbine : Pelton
- Turbine Electrical Power Output : 100 kW
- Mechanical Transmission : Flat Belt (Diameter of Generator Pulley: 175 mm, Diameter of Turbine Pulley: 322 mm)
- Generator : 200 kVA (Synchronous Generator) 50Hz, 400 V, 1500 RPM
- ELC : 100 kW
- Ballast Load : 120 kW, Ballast heaters with Water tank
- Total conductor length of HT line : 85,120 m
- Low conductor length of LT line : 139,907 m

GEOLOGICAL AND ENVIRONMENTAL ASPECTS

- The topographical features of the project were judged to be favorable for the construction work of a Micro-hydropower project.
- The elevation of the power house site is about 1496 meter from the mean sea level. All civil structures are located at the bushy land, barren land and some cultivated land.
- All the civil structures are located at the right bank of the river. According to the surface study, the terrain is stable.
- The terrain along the penstock route is almost steep.

GEOLOGICAL AND ENVIRONMENTAL ASPECTS

- The project site is located in remote area.
- Very little development infrastructures is observed in this area.
- Since most of the people depend on kerosene for lighting and the forests for their fuel for cooking, the trees/bushes of the forest are being destroyed day by day.
- However, it is believed that after installation of Micro-hydro, the people would be aware about controlled deforestation and improve the sanitation in the area.
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HYDROLOGY AND WATER RIGHT ISSUE

- The river for the source of Salpa Silicho Community MHP is perennial stream.
- The flow of both the stream was measured following salt dilution method using conductivity meter.
- The flow was measured on 15th May, 2022. The flow in the river was 490 lps.
- The hydrological calculation is based on MIP method. The site lies on the MIP region 1. The design discharge was calculated considering about 85% of 11 month exceeding, 5% of water losses and 10% for downstream release of the total flow from both the river.
- 210 LPS is taken as design discharge which is more than sufficient. The average monthly flow using the MIP method

HYDROLOGY AND WATER RIGHT ISSUE

Month	@ river (lps)
January	452
February	339
March	245
April	188
May	490
June	1131
July	2733
August	4712
September	3110
October	1508
November	773
December	584
Annual average	1355.4

ENERGY POTENTIAL AND ENERGY DEMANDS

The proposed Salpa Silicho Micro Hydro Project would supply electricity to the nearby villages. Average power demand per household has been calculated as 96.62 Watts. Moreover, the community is interested to run some end-users within the service area. The expected load demand pattern (Watt) over 24 hours period has been provided in the following table.

ENERGY POTENTIAL AND ENERGY DEMANDS

S.N.	Load	Operating Time				Operating Parameters		Energy Consumption per year (kWh)	Tariff Rs.
		5 pm – 11Pm 5 am – 7 am	7 am –3 pm	8 am –4 pm	9 am – 5 pm	Hours/day	Days/Year		
1	Income from lighting	100 kW				8	330	264,000	Rs. 5 /W/HH
2	Agro Processing Mill		7x3 kW			8	230	38,640	Rs. 25/ kWh
3	Saw Mill/Rural Carpentry				7x3 kW	8	286	48,048	Rs. 25/ kWh
4	Photocopy, Rural Communication Center				7x3 kW	8	286	43,680	Rs. 25/ kWh
	Total							17,160 kWh	

SOCIO ECONOMIC CONDITION AND AFFORDABILITY

The dominant ethnic groups of the project area comprise Brahmin, Janajati and Dalit.

Agriculture and livestock rising are the main occupation of the people. Though, the economic condition of the people varies from poor to medium rich, the living standard of the majority people is average and below-average.

In general, it is observed that most of the people could afford electricity at their required level.

The main crop is maize, millet, wheat, rice and potatoes. Some vegetable crops are also produced in the project area.

AVAILABILITY OF CONSTRUCTION MATERIALS AND LABOR

S.N	Particular	Availability of Materials	Remarks
1	Stone	Service area and Neighbors	
2	Aggregates	Service area and Neighbors	
3	Sand	Service area and Neighbors	
4	Cement	Nearest roadhead	
5	Wood	Service area and Neighbors	
6	Wooden Pole	Service area and Neighbor	
7	Skilled Labour	Nearest roadhead	
8	Unskilled Labour	Service area and Neighbors	

POWER CALCULATION

The proposed size of the Micro Hydropower scheme is 100 kW with 210 LPS design flow and an available gross head of 80 meters with overall efficiency of 60.93% for Pelton Turbine.

Power = 9.81ηHQ Where,

η= Overall efficiency of the plant

$$\eta = \eta_t \times \eta_p \times \eta_d \times \eta_g$$

Where,

η_t= Turbine Efficiency = 0.700

η_p= Penstock Pipe Efficiency = 0.950

η_d= Efficiency of drive system = 0.980

η_g= Generator Efficiency = 0.9350

Therefore, η= 0.70 x 0.95 x 0.98 x 0.9350 = 60.93 %

Power = 9.81 X 0.6093 X 80 X 0.210 = **100 kW**

CIVIL COMPONENTS

Weir/Intake/Protection Works

Intake structure is located in the left bank of the river. The flow from the river will be directed to the intake. A temporary weir will be constructed. The weir is proposed to be 0.7 m height and 8 m length which shall be constructed low cost and utilizes locally available materials which could be easily maintained after damaging by the flood during rainy seasons.

Small side intake with orifice system is recommended as the flow in the stream is shallow. The design flow for orifice is 252 lps (1.2 times of design flow for turbine). The size of the orifice is proposed to be 0.4 m x 0.7 m. The proposed size of the trashrack is 1.8 m x 0.7 m. Flood protection wall is recommended to protect the flood entering the headrace canal.

CIVIL COMPONENTS

Settling Basin

The settling basin has been proposed at barren land, which is 35 m far from the intake. The internal size of the basin is proposed 8.0 m x 2.0 m with 1.5 m of depth. The basin is designed to flush at every 12 hours and manually. A flushing gate of size 0.5 m * 0.5 m, 1.7 m height has been proposed to remove the collected particles. Similarly, the spillway canal of same sized as the headrace canal of length 15 meter up to Kholsa is proposed from the settling basin.

Stone masonry wall with 1.3 meter base thickness and 0.30 meter at top is proposed on 1:4 C/S for the construction of the mentioned basin. Plaster of 12.50 mm thick on 1:4 c/m is proposed in wetted area of the structure. The base of the floor will be 30 cm thick stone soling and 10 cm PCC (1:2:4) on top of it.

CIVIL COMPONENTS

Headrace canal alignment

The headrace canal passes through right bank of river. The soil type along the headrace is most of common soil and little gravel mixed soil. Lined canal is proposed throughout the headrace canal alignment. Due to the topography and geological condition stone masonry canal (1:4) c/s plasters are proposed. The length and size of stone masonry canal is 1300m and 0.65 x 0.7 m including the free board of 0.3 m.

CIVIL COMPONENTS

Forebay

The Forebay has been proposed at barren land, which is 1300 m far from the intake. It is located at the end of headrace conveyance. The basin is designed to flush at every 12 hours and manually. A flushing gate of size 0.5 m * 0.5 m and 1.6 m height has been proposed to remove the collected particles. Similarly, the spillway canal of same sized as the headrace canal of length 32 meter up to Kholsa is proposed from the Forebay.

CIVIL COMPONENTS

Forebay

Stone masonry wall with 1.3 meter base thickness and 0.30 meter at top is proposed on 1:4 C/S for the construction of the mentioned basin. Plaster of 12.50 mm thick on 1:4 c/m is proposed in wetted area of the structure. The base of the floor will be 30 cm thick stone soling and 10 cm PCC (1:2:4) on top of it.

CIVIL COMPONENTS

Forebay

The design calculations show the following dimensions.

Particle size to be removed	=	0.3 mm Ø
$V_{vertical}$	=	0.03m/s
Width	=	2.00 m
Inlet transition length	=	3.25 m
Length of the basin	=	8.00 m
Penstock Inlet zone	=	2.3 m x 2.0 m
Settling zone	=	8.0 m x 2.0 m
Length of flushing canal	=	32 m

CIVIL COMPONENTS

Penstock Alignment, Anchor Block and Support Piers

Penstock alignment has been selected on stable ground. The ground slope varies from 7° to 44 ^{0}. As the slope is steep low, the penstock length is 218 m for the gross head of 80 m. There is no single horizontal bends in penstock alignment. Eleven expansion joints have been proposed downwards of each anchor block. The total penstock of is 218 meter long and 350 mm in diameter. The proposed thickness of the penstock pipe is 4 mm for the whole length.

CIVIL COMPONENTS

Anchor Blocks:

Ten anchor blocks have been proposed in order to anchor the Penstock pipe firmly. Anchor blocks are designed as per the simple thumb rule suggested in several Micro Hydro designs manual. The anchor block is constructed with 1:3:6 PCC with 40% plums, applying nominal reinforcement.

Support Piers:

Fifty (50) numbers of support piers have been proposed at an interval of about 3 meters in average. The support piers are to be constructed with 1:3:6 PCC and stone masonry works in 1:6 cement sand mortar.

CIVIL COMPONENTS

Powerhouse:

The powerhouse is proposed at the left Bank of River. The outside dimension of the powerhouse building including operator's quarter is 8.85 m x 5.40 m. The powerhouse has been proposed to construct in mud mortar. 1:2:4 PCC has been proposed for flooring and 26 gauges CGI sheet for roofing. The powerhouse would be strong and sufficiently waterproof to prevent ingress of rainwater into electrical equipment.

Machine Foundation:

Machine foundation has to make in reinforced cement concrete (1:1.5:3 RCC). Although the exact size and type of machine foundation is depend on the size of the base frame provided by the turbine manufacturer, the size of the base is estimated as 3.6 meter long and 3.6 meter wide for turbine and generator.

CIVIL COMPONENTS

Tailrace Canal:

The cross section of the tailrace canal inside the power house is 0.75 m x 0.7 m and outside the power house also 0.65m x 0.70 m with 30 m length has been proposed. Tailrace canal is proposed to be rectangular in section and would be constructed in stone masonry in 1:4 c/m. The tailrace canal inside the powerhouse has been proposed with pre-cast slabs cover. The water of tailrace is discharged into the same parent stream.

MECHANICAL COMPONENTS

Penstock Pipe

The penstock pipe consists of MS pipe of 350 mm internal diameter in throughout the total length of 218 m. The proposed thickness of the penstock pipe is 4 mm for the whole length. Each length of the MS penstock pipe is proposed to be of 2.5 m lengths with 9 mm thick and 420 mm wide flange at both sides. The MS penstock pipe pieces are proposed to join with 12 mm diameter bolts. The size of the proposed bolt pieces is 12 mm x 50 mm. In every joint 8 numbers of bolts with nuts are proposed with 12 mm diameter "O" ring gasket for sealing water. The penstock should be erected from bottom to top. Air vent pipe of 50 mm diameter is proposed to be installed in penstock pipe just after the Forebay.

MECHANICAL COMPONENTS

Valves:

A butterfly valve of 350 mm diameter size with adopter ahead of the turbine is proposed to regulate the flow of water in penstock pipe.

Expansion Joints:

Eleven expansion joints of diameter 350 mm are proposed to be installed just below the each anchor blocks for adjustment of the penstock pipe from expansion and contraction due to change in temperature. Each expansion joint is capable of accommodating 50 mm change in penstock length.

MECHANICAL COMPONENTS

Turbine and Base Frame

Turbine is sized to at a design discharge and gross head of 0.210 m^3/s and 80.00m respectively, when the reservoir is at normal operation level which results in the turbine shaft power of 120 kW. Based on the preliminary design, the turbines will have a speed of 700 rpm. So for these constraints we select Pelton Turbine.

Type: Pelton, Single Jet

Runner diameter/PCD (mm) - 415

Turbine RPM - 815

Efficiency: 70 %

Discharge: 210.00 LPS

Gross head: 80.00 m

No. of buckets: 17

MECHANICAL COMPONENTS

Drive System

Flat belt drive with transmission ratio 1:1.84 power transmission system has been proposed for this scheme.

The proposed diameter of generator pulley is 175 mm and of turbine pulley is 322 mm.

ELECTRICAL COMPONENTS

Generator

A generator rated to continuously deliver 100 kW power at the given site condition with the following specification is proposed.

Size, Types & Rating - 200 kVA, Synchronous, 3 Phase, Brushless
Voltage - 400/230 Volt
Frequency - 50 HZ
RPM of Generator - 1500 rpm
Power factor - 0.8
Generator Efficiency – 93.5 %
No of Pole of Generator – 4
Maximum Temperature - 19ºC

The generator size and type is compatible with the electronic regulation system. The construction and bearings are rated to withstand runaway speed of the turbine.

50 kVA, self-excited, self-regulated, compounding excitation system, 50Hz, power factor: 0.8 (lag), Ingress protection: IP 23 and 93.5 % Efficiency at Full Load Condition

ELECTRICAL COMPONENTS

Electronic Load Controller (ELC)

Electronic Load Controller (ELC) of 100 kW is proposed for regulation of speed/frequency of electricity generated from the plant. ELC with ballast unit is proposed to control the system load such that the generator is always operating at full load. The locally made Thyrister type ELC and locally available ballast load of 120 kW is proposed.

ELECTRICAL COMPONENTS

Ballast Heater

Size (kW) : 120 kW

Phase : Three phase

Minimum thickness of tank : 3 mm

Hose pipe, hose clamps-2 nos., GI nipples 3 inch long 3 nos., 1/2-inch gate Valve, with 40 kW heaters in each phase and necessary bracings at place.

ELECTRICAL COMPONENTS

Power Cables/MCCBs/Distribution Boxes

240 mm^2, 4-Core Copper Cable for interconnecting generator, control panel, ELC, Ballast, Sensors etc, all complete set.

300 mm^2, 4-Core Aluminum Cable from control panel feeder terminals (main switch) to the first pole, all complete set.

300 A, MCCB, Three Phases Connected at Generator Side.

200 A, MCCB, Three Phases Connected at Load Side.

ELECTRICAL COMPONENTS

Earthing /Lightening Arrestors

Copper Plate Earthing:

No. of Earthings in powerhouse (system and equipment Earthing) (A) : 2 Sets

No. of Earthings for T&D line including first pole (B) : 105 Sets

Total Earthings (A+B) : 107 Sets

Specification:

8 SWG Copper earth wire, 600 mm x 600 mm x 3 mm copper plate (each plate 9.65 kg) as earth electrode with necessary coal, lime, salt, nut, bolts, washer, 160 mm polythene pipe etc. all complete set. Generally, place for every 500 meter length in transmission and distribution line.

ELECTRICAL COMPONENTS

Lightening Arrestor

0.5 kV, 50 HZ, ISO 9001 Certified Manufacturer

Total 53 nos. of 0.5 kV lightening arrestor are required

Total 25 nos. of 9 kV lightening arrestor are required

Generally proposed in every 500 m length in transmission and distribution line.

In three phases line there will be three numbers and in single line there will be a single lightening arrestor used.

Earthing is done in each place where lightning arrestors are used

TRANSMISSION AND DISTRIBUTION SYSTEM

ACSR Conductors

For the transmission/distribution of the generated power, the following Aluminum Conductor Steel Reinforced (ACSR) has been proposed. Conductor sizing has been done with the consideration of anticipated peak load demand in each of the branch. The line material has been designed in such a way that maximum voltage drop at peak hours at the end of each distribution line will not exceed by 10 percent.

Total ACSR in (m)			**With Sag 10%**
1	Squirrel	171.63	188.7919
2	Weasel	25.74	28.3151
3	Rabbit	7.20	7.92
Total ACSR in km		205	225.027

TRANSMISSION AND DISTRIBUTION SYSTEM

Service line

All together 36,225 meter of 6 mm^2 concentric Aluminum cable (@ 35m/HH) has been proposed for the service connection to the households. The internal wiring of each household should be connected through a suitable sized load-limiting switch (MCB).

TRANSMISSION AND DISTRIBUTION SYSTEM

Transformers

1 step up transformer of 160 kVA is proposed for powerhouse.

7 step down transformer are proposed at various locations.

Insulators

Small Size Shackle Insulators: 5394 numbers, Dimension (55 mm x 55 mm); Weight 200 gm; applicable in Squirrel and Service wire

Medium Size Shackle Insulators: 1035 numbers, Dimension (75 mm x 90 mm); Weight 600 gm; applicable in Gopher, Weasel and Rabbit Conductors

TRANSMISSION AND DISTRIBUTION SYSTEM

Poles

- 416 numbers of 6-meter long wooden poles for single phase in the scheme and 382 numbers of 7-meter long wooden poles for three phase are proposed for the scheme.
- The lower 1.5 m of the wooden poles should be coated with bitumen paint and buried 1 meter for wooden pole.
- The poles are to be erected instable soil at must be cable stayed in bends.
- Concrete foundation should be provided where loose/sandy soil is encountered.

TRANSMISSION AND DISTRIBUTION SYSTEM

Stay Sets

159 numbers of low tension stay sets and 126 numbers of high tension stay sets are proposed. Length of Stay rod (1.8 m), dia. (16 mm), Ultimate Tensile Strength (4500 kg/Sq.mm.), Minimum Breaking Load (7272 kg),Length of Threaded Portion (300 mm), Thimble Shape (Suitable for 7/22 SWG Stay Wire), Minimum Thimble Section (18 SWG), Stay Plate Section (600 mm x 600 mm x 3 mm MS Plate), Eyebolt Length mm/1 (300 mm), Stay Wire (7/12 SWG Steel Wire, 700 Grade, 45 ton Steel Quality, 2.64 mm dia. Minimum Wt. /km (300 kg), Applicable Standard (B.S. 183 1972/(1983))

TRANSMISSION AND DISTRIBUTION SYSTEM

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ENVIRONMENTAL SAFEGUARD

Environmental Safeguard

10 % of low flow was considered for downstream release during hydrological calculation

Structures of MHP do not lie on conservation/ Protected area.

During the transmission line survey, key plan was designed and drawn to exclude the area of community forest. For this local community assisted the study team during the survey.

SOCIAL SAFEGUARD

Social Safeguard

1035 beneficiary households have been identified during socio-economic survey. Some of these households are eligible for GESI subsidy. Moreover, MHP components do not lie on private land and hence cause not threat to the community.

During the social economic survey community with least monthly income have also been identified. End Uses proposed for Salpa Silicho Community MHP are focused to address these marginalized groups. It is recommended that the concerned local authority and the government also provide valuable input to uplift their living standard via these endues.

SOCIAL SAFEGUARD

Social Safeguard

It is also recommended that the community itself play a lead role in understanding the financial status of the beneficiary household and collect the required cash for the project accordingly. If the financially weak are not able to contribute cash, special considerations are to be made but it is not recommended to exclude these households from electricity.

To address the issues of women in the community, they have been encouraged to take part in User committee.

COST ESTIMATES

S.N.	Description of works	Local Cost	Non local Cost	Amount (NRs.)	% of total cost
A	Civil Works	10,634,529	6,326,637	16,961,165	28.82%
B	Mechanical Works	0	3,472,102	3,472,102	5.90%
C	Electrical Works	989,000	26,231,223	27,220,223	46.25%
D	Tools	0	43,675	43,675	0.07%
E	Spareparts	0	39,000	39,000	0.07%
F	Transportation and Packaging	979,419	2,042,982	3,022,401	5.14%
G	Civil Work Supervision, Installation Work, Testing and Commissioning	0	600,000	600,000	1.02%
H	**Sub-Total (A+B+C+D+E) -VAT Applicable Items**	**11,623,529**	**36,112,637**	**47,736,165**	
I	Sub-Total (F+G) -VAT Non-Applicable Items	979,419	2,642,982	3,622,401	
J	VAT 13%	0	4,694,643	4,694,643	7.98%
K	Sub-Total Project Cost (H+I+J)	12,602,948	43,450,262	56,053,209	
L	Contigencies (5%)	630,147	2,172,513	2,802,660	4.76%
M	**Total Project Cost (K+L)**	**13,233,095**	**45,622,775**	**58,855,870**	**100.00%**
N	**Cost per kW**	**778,417**	**2,683,693**	**588,559**	
O	% of Local Contribution	22.48%			
P	% of Non Local Contribution	77.52%			

END USES

S. N.	Type of Business	No	Capacity (kW)	Operating Hours	Total Energy Consumption (kWh)	Tariff (Rs.) per kWh	Total Income (Rs.)
1	Agro Processing Mill	7	3	8	38640	25.00	966,000
2	Saw Mill/Rural Carpentry	7	3	8	48048	25.00	1,201,200
3	Rural Communication Center	7	3	8	43680	25.00	1,092,000

SITE PHOTOS

Community

SITE PHOTOS

Proposed Settling Basin Location

SITE PHOTOS

Weir measurement

SITE PHOTOS

Weir measurement

SITE PHOTOS

Proposed Forebay Location

SITE PHOTOS

Headrace alignment

SITE PHOTOS

Headrace alignment

SITE PHOTOS

Headrace alignment

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THANK YOU