SARBARI I – SARBARI II

length approximating

3,851 m

PARAMETERS

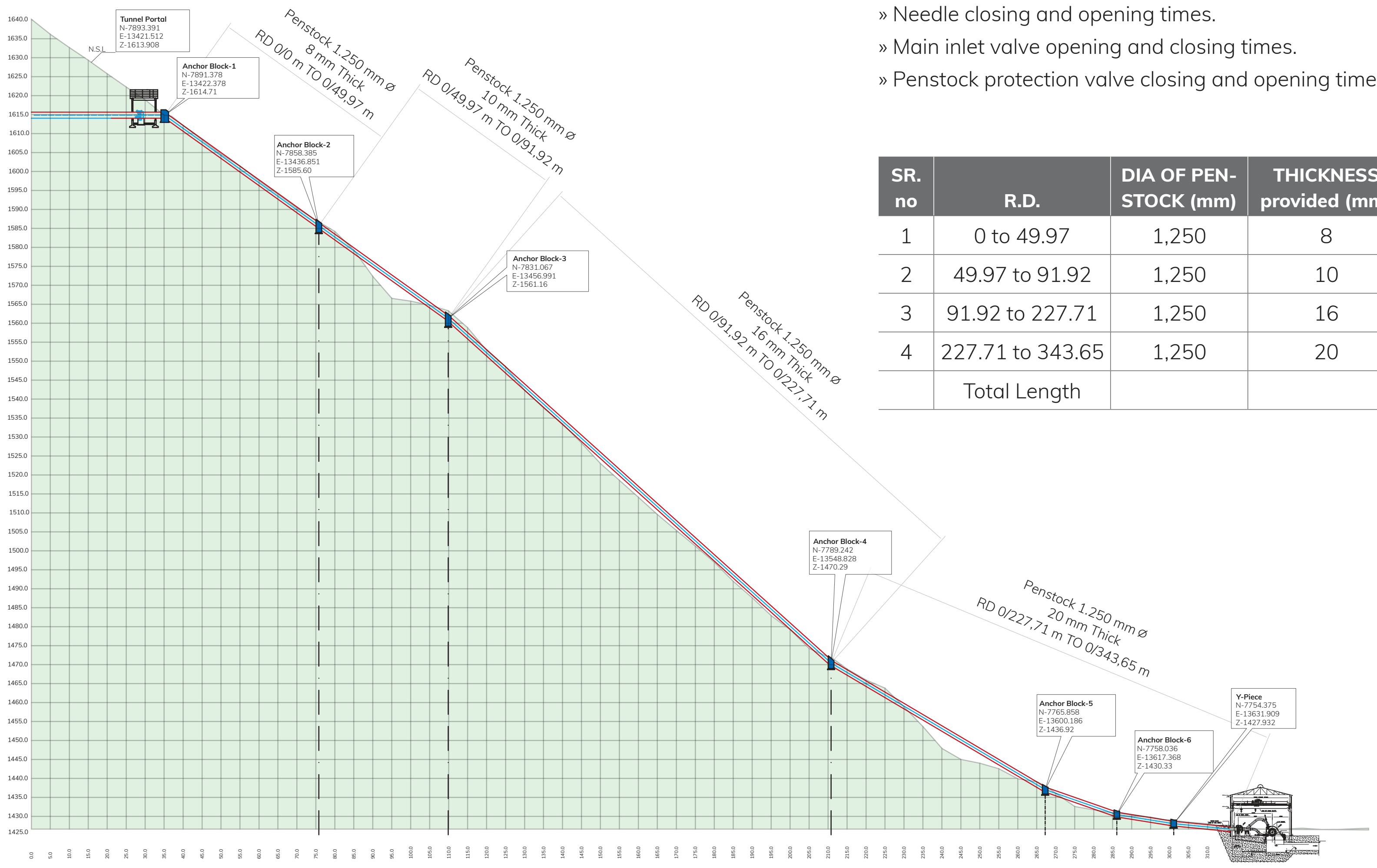
The SARBARI II SHPP is equipped with two (2) units of two (2) jet horizontal Pelton machines running at synchronous speed of 375 rpm, operating under rated head of 189.65 m. Each unit can generate output of 2,700 kW + 25% continuous overload and are capable to give maximum continuous output of 3,575 kW with discharge of 2,275 m³/s. The power house is situated at an elevation of 1,423.00 m above mean sea level with maximum temperature of (+) 30° C and minimum temperature of (-) 5° C.

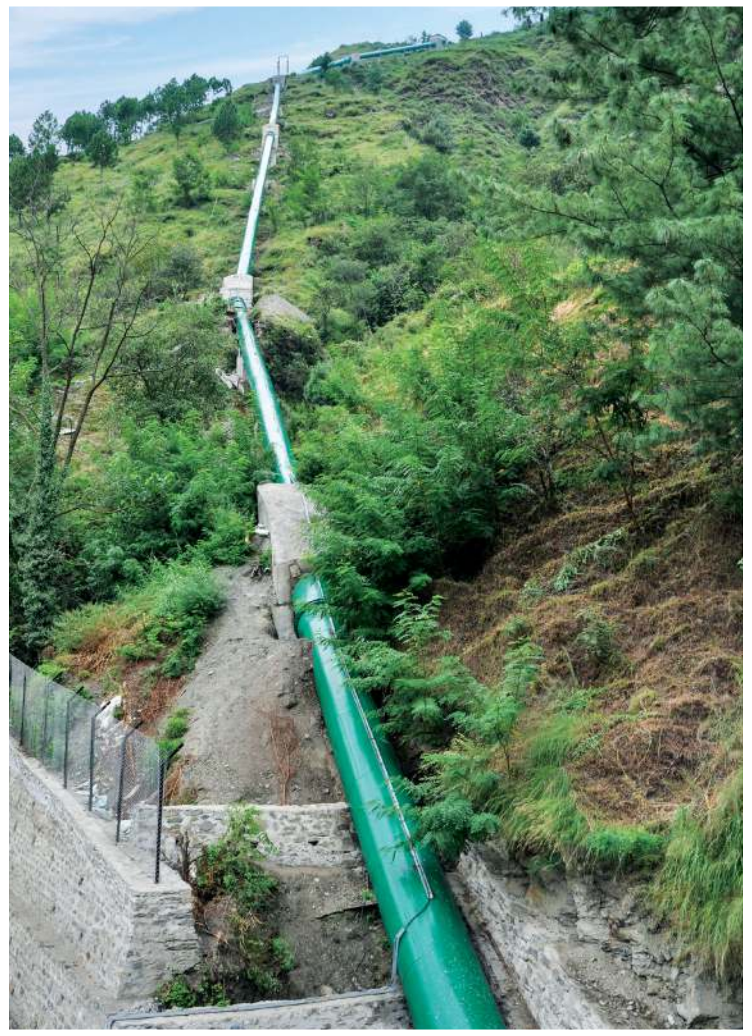
Penstock parameters

SECTION no	LENGTH (m)	DIAMETER (m)	THICKNESS (mm)	DISCHARGE (m³/s)
I	3,500	1.6	6	4.55
II	50	1.25	8	4.55
III	50	1.25	10	4.55
IV	135.8	1.25	16	4.55
V	116	1.25	20	4.55
VI	20	1.0	20	2,275

Plant parameters

Number of units:	2
Type of turbines:	Horizontal Pelton 2 Jets
Maximum Head:	191.65 m
Rated Head:	189.65 m
Minimum Head:	187.65 m
Rated generator output:	2,700 kW
Synchronous speed:	375 rpm
Pressure rise:	25 %





The discharge of Sarbari I is fed to Sarbari II through a pressurized tunnel and penstock of length approximating 3,851 meters.

METHODOLOGY

The following turbine operations produce transient state conditions in the water conductor system of hydroelectric power plant:

» Unit starting.
» Load rejection.

Following methods were used to carry out transient analysis:

» **Arithmetic integration method using Joukowsky's philosophy:** it is based on the principle of Newton's second law which states that Force = Rate of change of momentum. Arithmetical integration method consists of numerically integrating the pressures developed by the successive instantaneous steps during the complete needle closure time. Thus, the total time from the beginning of the closure and total pressure developed up to that time is obtained at the end of each step.
» **Allievis method:** Allievis method for the solution of maximum or minimum water hammer pressures, when the velocity is decreased from zero or is increased from zero to a certain value by uniform gate motion.

The above-mentioned methods were used for determining:

» Needle closing and opening times.
» Main inlet valve opening and closing times.
» Penstock protection valve closing and opening time.

SR. no	R.D.	DIA OF PENSTOCK (mm)	THICKNESS provided (mm)	LENGTH (m)
1	0 to 49.97	1,250	8	49.97
2	49.97 to 91.92	1,250	10	41.95
3	91.92 to 227.71	1,250	16	135.79
4	227.71 to 343.65	1,250	20	115.94
	Total Length			343.65

EQUATIONS AND CALCULATIONS

The total length of penstock is 3851.8 m (neglecting the length of unit penstock as it is very small in comparison to the total length of penstock and hence will not affect the final result).

» Wave propagation speed:

$$a = \frac{\sqrt{\frac{K}{\rho}}}{\sqrt{1 + \frac{K * D * (5 - 4 * \mu)}{4 * t * E}}}$$

» Average water hammer wave velocity:

$$a = \frac{\begin{pmatrix} a_1 * L_1 + a_2 * L_2 \\ + a_3 * L_3 + a_4 * L_4 \\ + a_5 * L_5 \end{pmatrix}}{L}$$

» The wave velocity calculated in the various sections of the penstock is tabulated as follows:

Wave velocity

a_1	752.2 m/s
a_2	898.2 m/s
a_3	957.7 m/s
a_4	1074.6 m/s
a_5	1124.2 m/s
a_{avg}	779.3 m/s

» Parameter $\sum LC_{max}$ based on Li and Di: $\sum LC_{max}$ = 9,224.34 m/s

» Maximum flow velocity is calculated which in case of SARBARI II is 2.39 m/s.

» Allievis constant: $A_c = 0.3685$

» Allowable reduction in flow velocity during water hammer: $\Delta C = 0.4775$ m/s

» Pressure rise at outlet end of tunnel:

$$P_{rt} = 1 + \frac{(\Delta Z * L * a)}{\begin{pmatrix} a_1 * L_1 + a_2 * L_2 \\ + a_3 * L_3 + a_4 * L_4 \\ + a_5 * L_5 \end{pmatrix}}$$

$P_{rt} = 1.1754$

» Increase in pressure at the outlet end of tunnel: $\Delta P = 33.26$ m

» Water hammer reflection time $T_{wr} = 9.88$ s.
This is also known as critical time of closure.

» Allowable reduction in flow during water hammer: $\Delta Q = 0.90$ m³/s.

» Water time inertia constant $T_W = 4.95$ s.

$$T_c = \frac{2 * K * T_W}{\Delta Z}$$

$T_c = 74.25 \approx 75.0$ s

However, some of the parameters varies calculation criteria may vary depending on different project parameters.

RESULTS AND CONCLUSIONS

After the detailed transient analysis for the SARBARI II SHPP, the following results were derived:

» Needle Opening and Closing Time: The setting of the closing speed of needle is of importance in order to avoid excessive pressure rise during shut down. The needle closing and opening time is set to 75 sec. which is much higher than the critical time of closure of needle/ Main inlet valve.
» Main Inlet Valve Opening and Closing Time: The main inlet valve opening and closing time is set higher than the needle closing time of 75 s. The main inlet valve opening and closing time is set to 90 s.
» Penstock Protection valve opening and closing time: The penstock protection valve opening and closing time is set to 110 s which is higher than the critical time of closure and selected needle closing time.
» The actual pressure rise measured at site during field testing conducted by **AHEC Roorkee** is 11% which is less than the permissible pressure rise of 25%.

"OUR MISSION IN DESIGN & ENGINEERING PERFORMING SPECIALIZED ANALYSIS LIKE TRANSIENT FOR SURGE CONTROL IS TO PROTECT THE IMPORTANT INFRASTRUCTURE OF OUR CUSTOMERS."

Luciano Devinar, Chief Technology Officer – D&E, FLOVEL Energy Private Limited