Site Selection & Configuration for Pumped Storage Power Plants

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Abstract

Sri Lanka is currently developing coal fired power plants. Currently one coal power plant is in operation with an installed capacity of 3 units each of 300 MW. The Long Term Generation Plan 2013-2032, indicates that there will be 14 new coal power generating units to be introduced to the power system in future.

In Sri Lanka, the electricity demand rapidly varies with time. The daily load curve shows a minimum of 1,000 MW at off-peak, and 2,150 MW at peak. Such rapid variations cause base load coal power plants to be operated with lower efficiency during low demand hours. Such situations create an opportunity for storage mechanisms. Pumped storage power plants (PSPPs) is one of such storage power plant that could be deployed in Sri Lanka. The country's natural geography is suitable to facilitate nearly 5,000MW of PSPPs and some attractive sites have already been identified. Most importantly, some of them can be designed as the Pumped Storage Power Plant Complexes (PSPPC). A common large upper pond or lower pond can be utilized by two or more lower ponds or upper ponds forms a PSPPC. The economic viability of having PSPPs in Sri Lanka can improve with such PSPP complexes. This paper discusses the basic design principles of proposed PSPPs and PSPPCs in Sri Lanka.

Introduction

Not only that country's economy depends on electricity supply; Sri Lanka has reached the national electrification ratio of 99.5% by now. The maximum demand is around 2164MW while the installed capacity is 3362MW (Statistical Digest 2013, CEB). Sri Lanka has to run expensive thermal power in the peak demand time. At present, Sri Lanka has 900MW coal power plants but cannot run them efficiently at full load during late night off-peak time and some hours during the day, too.

In year 2013, peak demand is around 2,150MW while off peak is around 1,000MW. This off-peak demand is maintained by the utility by giving special off-peak tariffs for medium and large customer. The off-peak tariff is Rs. 5.90 while peak tariff is Rs. 23.50 for Industrial-3 customers. That means peak tariff is four times the off-peak tariff;

both figures do not reflect the actual cost electricity. By reducing the peaks of the load curve using PSPP, Sri Lanka may be able to produce cheap electricity, while giving actual cost reflective, lower tariff to customers.

Attractive sites have been identified for PSPP; along Kiriketi Oya in Haputale; Halgran Oya in Hanguranketha; Maha Oya, Kuda Oya, Mal Oya & Gurugal Oya in Gampola and Dambagastalawa Oya in Nuwara Eliya. Most importantly, some of them can be designed as the Pumped Storage Power Plant Complexes. A common large upper pond or lower pond can be utilized by two or more lower ponds or upper ponds, to form a PSPP complex.

Establishment of Criteria to Locate a Project Site

Table 1 shows the criteria used for determining the sites of PSPPs in a reconnaissance study, and their expected status. For example, the selected site should be suitable for the construction of a power plant of more than 250 MW in capacity and should run for six hours during the period of higher demand each day.

Selecting Sites for PSPPs

The suitable sites were searched using the 1:50,000 scale topographical maps. Basically, natural location for the reservoir and dam with adequate reservoir volume with minimum environment & social effects (avoiding forests, natural parks, historical & cultural heritage sites, areas with high population density) and the locations which has L/H ratio less than 12 were considered. Detailed Analysis comprising basic design and the calculation, was done for the selected sites, using 1:10,000 scale topographical maps. The following table shows the basic details of the selected sites for PSPP.

The locations and design parameters for the four PSPPs each with 500MW capacity, namely Kiriketi I, Kiriketi II, Kiriketi II and Halgran PSPPs were discussed in Planning of Pumped Storage Power Plants for Power Generation in Sri Lanka, SLEMA Journal Volume 14 No.2 September 2011.

This paper discusses the details of locations and design parameters of remaining PSPP sites.

Table 1 - Criteria for Pumped Storage Power Project Locations in Sri Lanka

	Issue	Item	Criteria status
Technical	Generation Plan	-Peak duration time -Installed Capacity	-6 hrs -More than 250 MW
	Limit of manufacturing of power facility	-Design Head -Max. utilizing water depth of pond	-More than 350m of maximum head -Less than 75m
	Location/ Layout	-Catchment area -Dam crest length -Dam height -Length of water way -L/H ratio -Over burden of underground power cavern	-More than 5km ² (total of upper, lower dams diverted) -Less than 500m -Less than 180m -Less than 10 Km -Less than 12 -Less than 1020m
	Geological conditions	-Active fault -Base rock conditions especially for underground power cavern	-Avoid the zone of active faults and those Quaternary Era -Avoid the area of Quaternary Era and weak and unconsolidated strata
Environmental	Natural	-Protected Area (e. g. Nature Reserves) -Endangered species	-Beyond the confines of protected Areas (Natural Parks and reserves) -Avoid the critical habitats of important fauna and flora
	Social	-Mining right	-Avoid the area of mining concession
		-Historical and Cultural heritage -House to be submerged	-Avoid being submerged -Necessary to consider

Table 2 - Summary of Candidate PSPP

No.	Name of the Pumped Storage	Name of the Pumped Storage Plant	Project Feature				1:50,000 Map No
			Capacity	Length	Rough Height	Ratio	
			(MW)	L (m)	H (m)	L/	
1	Maha PSPP	Uduwella PSPP	500	4,110	410	10.0	61
2		Alugolla PSPP	500	3,890	510	7.6	61
3	KMG PSPP	Mul PSPP	250	4,510	400	11.3	61
4		Gurugal PSPP	500	5,320	650	8.2	61
5		Puna-Kotmale PSPP	500	6,570	700	9.4	61
6		Dambagastalawa PSPP	300	2,840	470	6.0	68
7		Agra PSPP	300	3,640	330	11.0	68

Maha Pumped Storage Power Plant Complex

The project is to be situated on the Maha Oya, in the Gampola area, No. 61, 1:50,000 map. There are two options for the Upper Pond.

The two Upper Ponds are in Kandy district, Central Province and Lower Pond is in Kegalla district, Sabaragamuwa Province. Travelling distance is 90 km from Colombo on the Colombo-Kandy road. The principal features of the Project;

Table 3 - Summary of Basic Design Configuration of Maha PSPP Complex

	Maha PSPP Complex	Uduwella PSPP	Alugolla PSPP
Project Specification	Installed Capacity P (MW)	500	500
	Designed Discharge Q (m ³ /s)	152	121
	Effective Head H _e (m)	387.6	485.2
	Peak Duration Hours	6	6
Upper Reservoir	Dam Type	Rock Fill	Concrete Gravity
	Dam Height (m)	32	41
	Crest Length (m)	340	260
	Reservoir Volume at FSL (Mil m3)	3.38	2.6
	H.W.L (m)	714	814
	L.W.L (m)	694.45	785
	Usable Water Depth (m)	19.55	29
Lower Reservoir	Dam Type	Concrete Gravity	
	Dam Height (m)	57	
	Crest Length (m)	350	
	Reservoir Volume at FSL (Mil m3)	5.94	
	H.W.L (m)	300	
	L.W.L (m)	267.2	
	Usable Water Depth (m)	32.8	
Water way	Headrace (m)	1,850	2,350
	Penstock (m)	2,400	1,320
	Tail Race (m)	200	430
Power House	Type	Underground	Underground
L/H		10.64	7.86

Figure 1 - MAHA Pumped Storage Power Plant Complex in 1:50,000 Map

Figure 2 - Waterway Profile of Uduwella Upper Pond to Arama Lower Pond **Figure 3 - Waterway Profile of Alugolla Upper Pond to Arama Lower Pond**

Calculation of Catchment Area

When the dam site is selected, the watershed is checked using the topographic map.

Catchment Area of "Arama" Lower Pond: 17.725 km²; Catchment Area of "Uduwella" Upper Pond: 4.8754 km²;

Catchment Area of "Alugolla" Upper Pond: 2.725 km²

Preparation of Storage Capacity Curve

The reservoir area at each elevation is measured with planimeter on a topographic map, and the water storage capacity curves shown in Figure 6, Figure 7 and Figure 8 were prepared.

Temporary Fixing of Maximum Plant Discharge

The maximum plant discharge is obtained by the following equation;

$$\text{"Uduwella" Upper Pond: } Q_{max} = \frac{P}{9.8 \times H \times \eta} = \frac{500\,000\text{ kW}}{8.5 \times 410} = 143.5\text{ m}^3/\text{s}$$

$$\text{"Alugolla" Upper Pond: } Q_{max} = \frac{P}{9.8 \times H \times \eta} = \frac{500\,000\text{ kW}}{8.5 \times 510} = 115.3\text{ m}^3/\text{s}$$

where, Q_{max} : Maximum plant discharge (m³/s);
 P : Maximum output (kW); H : Head (Difference in riverbed elevation between upper and lower dams [1650m-880m]); η : Combined efficiency at maximum output

The value $9.8 \times \eta = 8.5$ should be used in the study.

Determination of Storage Capacity of Pond

The peak duration hour is set at 6 hours to obtain the active storage capacity.

“Uduwella” Upper Pond: $Ve = Q_{max} \times T \times 3600$

$$= 143.5 \frac{m^3}{s} \times 6 \text{ hrs} \times 3600 = 3,099,600 \text{ CM}$$

“Alugolla” Upper Pond: $Ve = Q_{max} \times T \times 3600 =$

$$115.3 \frac{m^3}{s} \times 6 \text{ hrs} \times 3600 = 2,491,349 \text{ CM}$$

“Arama” Lower Pond: $Ve = Q_{max} \times T \times 3600 =$

$$5,590,949 \text{ CM}$$

where, Ve = Effective storage capacity (m^3); T = Peak duration hours (hr)

Estimation of Sediment Volume and Determination of Sedimentation Level

(1) Estimation of Sediment Volume

The sedimentation level is determined by estimating sedimentation for 100 years. The sediment volume is estimated as follows provided that q_s is assumed to be $200 m^3/km^2/year$.

$$Vs = q_s \times Ca(d) \times 100$$

$$= 200 m^3/km^2/year \times 0.4.87454 \text{ km}^2 \times 100 \text{ years} = 97,508 m^3 \text{ (Uduwella Upper Pond)}$$

$$= 200 m^3/km^2/year \times 2.725 \text{ km}^2 \times 100 \text{ years} = 54,500 m^3 \text{ (Alugola Upper Pond)}$$

$$= 200 m^3/km^2/year \times 17.725 \text{ km}^2 \times 100 \text{ years} = 354,500 m^3 \text{ (Arama Lower Pond)}$$

where, V_s : Sediment volume for 100 years (m^3);
 q_s : Specific sediment yield ($m^3/km^2/year$); $Ca(d)$: Catchment area at dam site (km^2)

(2) Setting of Sedimentation Level

The sedimentation level is obtained based on the reservoir area and storage capacity curve as shown below.

Uduwella Upper Pond: EL 683.25m; Alugola Upper Pond : EL 775.00m; Arama Lower Pond : EL 256.00m

Figure 4 - Setting of Sedimentation Level

Determination of Water Level (Upper and Lower Ponds)

(1) Low Water Level

The low water level (LWL) is set at a position of about twice the inner diameter (D) of the headrace tunnel above the sedimentation level as shown in Figure 5, to prevent intrusion of air into the tunnel.

Figure 5 - Relation between intake and LWL

$$Q = \pi \times D^2 / 4 \times 6 \text{ m/s}$$

The tunnel inner diameter is obtained as follows by setting the flow velocity at 6 m/s.

Uduwella PSPP:

$$D = (4Q/6\pi)^{0.5} = (4 \times 140/6\pi)^{0.5} = 5.6 \text{ m}$$

Alugolla PSPP:

$$D = (4Q/6\pi)^{0.5} = (4 \times 115/6\pi)^{0.5} = 5.0 \text{ m}$$

Where, Q : Plant Discharge (m^3/s); D : Diameter of Headrace Tunnel (m)

Thus the low water level (LWL) is calculated as below.

$$\text{Uduwella Upper Pond: EL } 683.25\text{m} + 2 \times 5.6 = \text{EL. } 694.45 \text{ m}$$

$$\text{Alugolla Upper Pond : EL } 775.00\text{m} + 2 \times 5.0 = \text{EL. } 785.0 \text{ m}$$

$$\text{Arama Lower Pond : EL } 256.00\text{m} + 2 \times 5.6 = \text{EL. } 267.2 \text{ m}$$

(2) High Water Level

The high water level (HWL) is determined by using the storage capacity curves shown in Figure 6, Figure 7, adding the low water level (LWL) to the available drawdown (ha) corresponding to the effective storage capacities are obtained by Eq. $Ve = Q_{max} \times T \times 3600$

Thus the high water level (HWL) is calculated as below.

Uduwella Upper Pond: $LWL\ 694.45\ m + ha\ 19.55m = HWL\ 714m$

Alugolla Upper Pond : $LWL\ 785.0\ m + 29ha = HWL\ 814m$

Arama Lower Pond : $LWL\ 267.2\ m + ha\ 32.8m = HWL\ 300m$

Where, ha : Available drawdown (m) = 19.55m..... (Uduwella Upper Pond)

= 29m ..... (Alugolla Upper Pond)

= 32.8m ..... (Arama Lower Pond)

Figure 6 - Uduwella Upper Pond - Capacity Curve

Figure 7 - Alugolla Upper Pond - Capacity Curve

Figure 8 - Arama Lower Pond - Capacity Curve

Determination of Normal Intake Water Level and Tailwater Level

The normal intake water level and tailwater level which correspond to mean water levels of both reservoirs are determined by the following equation.

$$MWL(U) = HWL(U) - ha(U)/3$$

$$\dots\dots\dots (Uduwella\ Upper\ Pond) \\ = 714\ m - 19.55\ m/3 = 707.5\ m$$

$$MWL(U) = HWL(U) - ha(U)/3 \dots\dots\dots (Alugolla\ Upper\ Pond) \\ = 814\ m - 29\ m/3 = 804.3\ m$$

$$TWL(L) = HWL(L) - ha(L)/3 \dots\dots\dots (Arama\ Lower\ Pond) \\ = 300\ m - 32.8\ m/3 = 289.1\ m$$

where, HWL, LWL, ha : High water level, low water level and available drawdown (m) of upper pond (U) and lower pond (L), (m); MWL : Normal intake water level (m); TWL : Normal tailwater level (m); ha : Available drawdown (m)

Preparation of Waterway Profile

- (1) Setting the elevation of turbine center

The turbine center is set at the elevation corresponding to the draft head below the low water level of the lower pond as described in the following formula.

For Uduwella PSPP

$$\text{Elevation of Turbine Center} = LWL\ (Lower\ Pond) - \text{Draft Head (m)} \\ = LWL\ 267.2m - 56m = EL\ 211.2m$$

For Alugolla PSPP

$$\text{Elevation of Turbine Center} = LWL\ (Lower\ Pond) - \text{Draft Head (m)} \\ = LWL\ 267.2m - 64m = EL\ 203.2m$$

Where

For Uduwella PSPP - (Head Loss ignored)

$$\text{Maximum Pumping Head (m): } HWL\ (Upper\ Pond) - LWL\ (Lower\ Pond) + \text{Head Loss} = 714m - 267.2m = 446.8m$$

For Alugolla PSPP - (Head Loss ignored)

$$\text{Maximum Pumping Head (m): } HWL\ (Upper\ Pond) - LWL\ (Lower\ Pond) + \text{Head Loss} = 814m - 267.2m = 546.8m$$

Draft Head is obtained from the relation between the maximum pumping head and draft head as shown in Figure 9.

Figure 9 - Relation between the Maximum Pumping Head and Draft Head

(2) Dam specification and turbine center
Dam specifications (HWL and LWL) and the elevation of turbine centre of the power plants are determined as below.

Uduwella Upper Pond: HWL: 714m; LWL: 694.45 m; Available drawdown: 19.55 m

Alugolla Upper Pond: HWL: 814 m; LWL: 785 m; Available drawdown: 29 m

Arama Lower Pond: HWL: 300 m; LWL: 267.2 m; Available drawdown: 32.8 m

Turbine Center for Uduwella PSPP: EL: 211.2 m

Turbine Center for Alugolla PSPP: EL: 203.2 m

Calculation of Head Loss and Effective Head for Uduwella PSPP

The effective head is calculated on the basis of the following equation;

$$H_g = MWL - TWL = HWL - \frac{ha}{3} - TWL$$

$$= 707.5m - 289.1m = 418.4m$$

$$H_l = axL_1 + bxL_2 + cxL_3 + \Delta h$$

$$= 1/300 \times 1850 + 1/100 \times 2400 + 1/300 \times 200 + 3.5 = 30.8m$$

$$H_e = H_g - H_l = 418.4 - 30.8 = 387.6 m$$

where,

MWL : Normal intake water level (m) = 707.5 m;
TWL : Tailwater level (m) = 289.1 m; H_g : Gross head (m) = 418.4 m; H_l : Head loss (m) = 30.8 m;
H_e : Effective head (m) = 387.6 m; L₁ : Length of headrace (m) = 1850 m

L₂ : Length of penstock (m) = 2400 m; L₃ : Length of tailrace (m) = 200 m; Δh : Other head losses (m) = 3.5 m

a, b and c : Coefficients to obtain losses; a : Pressure headrace tunnel 1/300; b: Penstock 1/100;

c : Pressure tailrace tunnel 1/300

Calculation of Head Loss and Effective Head for Alugolla PSPP

The effective head is calculated on the basis of the following equation;

$$H_g = MWL - TWL = HWL - \frac{ha}{3} - TWL$$

$$= 804.3m - 289.1m = 515.2m$$

$$H_l = axL_1 + bxL_2 + cxL_3 + \Delta h$$

$$= 1/300 \times 2350 + 1/100 \times 1320 + 1/300 \times 430 + 3.5 = 30m$$

$$H_e = H_g - H_l = 515.2 - 30 = 485.2 m$$

where,

MWL: Normal intake water level (m) = 804.3 m;

TWL: Tailwater level (m) = 289.1 m; H_g : Gross head (m) = 515.2 m; H_l : Head loss (m) = 30 m; H_e :

Effective head (m) = 485.2 m; L₁ : Length of headrace (m) = 2350 m;

L₂: Length of penstock (m) = 1320 m; L₃ : Length of tailrace (m) = 430 m; Δh : Other head losses (m) = 3.5 m

Re-Calculation of Maximum Plant Discharge-Uduwella PSPP

The normal effective head (H_e) 387.6 m is determined and the maximum plant discharge is then determined from the following equation;

$$Q_{max} = \frac{P}{9.8 \times H \times \eta} = 500,000kW / (8.5 \times 387.6m) = 152m^3/s$$

Re-calculation of Maximum Plant Discharge-Alugolla PSPP

The normal effective head (H_e) 485.2 m is determined and the maximum plant discharge is then determined from the following equation;

$$Q_{max} = \frac{P}{9.8 \times H \times \eta} = 500,000kW / (8.5 \times 485.2m) = 121m^3/s$$

Calculation of Annual Energy Generation-Uduwella PSPP

The annual energy generation is obtained by the following equation.

$$E = P \times T = 500,000 kW \times 2190 \text{ hours} = 1,095 \text{ GWh kWh}$$

Calculation of Annual Energy Generation-Uduwella PSPP

The annual energy generation is obtained by the following equation.

$$E = P \times T = 500,000 kW \times 2190 \text{ hours} = 1,095 \text{ GWh}$$

Where, E: Annual energy generation (kWh); T: Annual generating hours (hrs)

Calculation of Reservoir Volume-Uduwella PSPP

$$V_e = Q_{max} \times T \times 3600 = 152 \frac{m^3}{s} \times 6 \text{ hrs} \times 3600 = 3,282,200 \text{ CM}$$

Calculation of Reservoir Volume-Alugolla PSPP

$$Ve = Q_{max} \times T \times 3600 = 121 \frac{m^3}{s} \times 6 \text{ hrs} \times 3600 = 2,613,600 \text{ CM}$$

KMG Pumped Storage Power Plant Complex

The project is to be situated on three streams namely Kuda Oya, Mul Oya and Gurugal Oya, in

the Gampola area, No. 61, 1:50,000 map. The upper ponds are in Mul Oya and Gurugal Oya. All the three ponds are in Nuwara Eliya district, Central Province of the Sri Lanka. The principal features of the Project will be;

Table 4 - Summary of Basic Design Configuration of KMG PSPP Complex

	KMG PSPP COMPLEX	KM PSPP	KG PSPP
Project Specification	Installed Capacity P (MW)	250	500
	Designed Discharge Q (m ³ /s)	80.2	98.25
	Effective Head H _e (m)	366.7	598.7
	Peak Duration Hours	6	6
Upper Reservoir	Dam Type	Concrete Gravity	Rock Fill
	Dam Height (m)	53	64
	Crest Length (m)	220	420
	Reservoir Volume at FSL (Mil m ³)	1.732	2.122
	H.W.L (m)	1,114	1,348
	L.W.L (m)	1,086	1,305.8
	Usable Water Depth (m)	28	42.2
Lower Reservoir	Dam Type	Rock Fill	
	Dam Height (m)	24	
	Crest Length (m)	260	
	Reservoir Volume at FSL (Mil m ³)	3.854	
	H.W.L (m)	708	
	L.W.L (m)	694.3	
	Usable Water Depth (m)	13.7	
Water way	Headrace (m)	1,120	3,280
	Penstock (m)	2,320	1,220
	Tail Race (m)	1,260	1,560
Power House	Type	Underground	Underground
L/H		11.6	9.0

Puna-Kotmale Pumped Storage Power Plant

The project is to be situated on the Puna Oya and Kotmale Oya which are connected to

Kotmale Oya reservoir in the N' Eliya district, Central Region of Sri Lanka. The principal features of the Project will be;

Table 5 - Summary of Basic Design Configuration of Puna-Kotmale PSPP

Puna-Kotmale PSPP		
Project	Installed Capacity P (MW)	500
Specification	Designed Discharge Q (m ³ /s)	88
	Effective Head H _e (m)	666.5
	Peak Duration Hours	6
Upper Reservoir	Dam Type	Concrete Gravity
	Dam Height (m)	49
	Crest Length (m)	270
	Reservoir Volume at FSL (Mil m ³)	1.9
	H.W.L (m)	1,503
	L.W.L (m)	1,471.4
	Usable Water Depth (m)	31.6
Lower Reservoir	Dam Type	Concrete Gravity
	Dam Height (m)	57
	Crest Length (m)	220
	Reservoir Volume at FSL (Mil m ³)	1.9
	H.W.L (m)	790
	L.W.L (m)	775.4
Water way	Usable Water Depth (m)	14.6
	Headrace (m)	4,110

	Penstock (m)	2,230
	Tail Race (m)	430
Power House	Type	Underground
L/H		9.4

Dambagastalawa Pumped Storage Power Plant

The project is to be situated on the Dambagastalawa Oya, near Ambewela, Pattipola fields in the Nuwara Eliya district, Central Region

of the Sri Lanka. The principal features of the Project will be;

Table 6 - Summary of Basic Design Configuration of Dambagastalawa PSPP

Dambagastalawa PSPP		
Project Specification	Installed Capacity P (MW)	300
	Designed Discharge Q (m ³ /s)	79
	Effective Head H _e (m)	445.8
	Peak Duration Hours	6
Upper Reservoir	Dam Type	Rock Fill
	Dam Height (m)	26
	Crest Length (m)	440
	Reservoir Volume at FSL (Mil m ³)	1.7
	H.W.L (m)	1,831
	L.W.L (m)	1,813
	Usable Water Depth (m)	18
Lower Reservoir	Dam Type	Rock Fill
	Dam Height (m)	28
	Crest Length (m)	280
	Reservoir Volume at FSL (Mil m ³)	1.7
	H.W.L (m)	1,363
	L.W.L (m)	1,351.5
	Usable Water Depth (m)	11.5
Water way	Headrace (m)	1,760
	Penstock (m)	850
	Tail Race (m)	690
Power House	Type	Underground
L/H		6.0

Agra Pumped Storage Power Plant

The project is to be situated on the Agra Oya, near Pattipola field in the Nuwara Eliya district, Central Region of the Sri Lanka.

The principal features of the Project will be;

Table 7 - Summary of Basic Design Configuration of Agra PSPP

AGRA PSPP		
Project Specification	Installed Capacity P (MW)	300
	Designed Discharge Q (m ³ /s)	86.9
	Effective Head H _e (m)	406
	Peak Duration Hours	6
Upper Reservoir	Dam Type	Rock Fill
	Dam Height (m)	22
	Crest Length (m)	440
	Reservoir Volume at FSL (Mil m ³)	1.9
	H.W.L (m)	1,827
	L.W.L (m)	1,813.2
	Usable Water Depth (m)	13.8
Lower Reservoir	Dam Type	Rock Fill
	Dam Height (m)	36
	Crest Length (m)	250
	Reservoir Volume at FSL (Mil m ³)	1.9
	H.W.L (m)	1,401

	L.W.L (m)	1,389.2
	Usable Water Depth (m)	11.8
Water way	Headrace (m)	120
	Penstock (m)	630
	Tail Race (m)	2,730
Power House	Type	Underground
L/H		11.0

Conclusion

The nature has blessed with several natural locations which are suitable for developing Pumped Storage Power Plants. A few sites can be developed as Pumped Storage Power Plant Complexes which further improves their economic viability.

The calculated basic project design parameters will be used to calculate the cost of the particular project in pre-feasibility level. Thereby, these basic

design parameters will be used for the detailed design work of the best selected candidate sites.

The summary of the basic design parameter of the sites which were considered in this paper are given in the Table 8.

Note: This paper was presented in the Energy Symposium Sri Lanka 2015.

Table 8 - The Summary of the Basic Design Configuration of the Sites

Project Specification	Design Configurations	MAHA PSPPC		KMG PSPPC		Puna-Kothmale PSPP	Dambagastalawa PSPP	Agra PSPP
		Uduwella PSPP	Alugolla PSPP	KM PSPP	KG PSPP			
Project Specification	Installed	500	500	250	500	500	300	300
	Design	152	121	80.2	98.25	88	79	86.9
	Effective head	387.6	485.2	366.7	598.7	666.5	445.8	406
	Peak Duration	6	6	6	6	6	6	6
Upper Reservoir	Dam Type	Rock fill	Conc.	Conc.	Rock fill	Conc.	Rock fill	Rock fill
	Dam Height	32	41	53	64	49	26	22
	Crest Length	340	260	220	420	270	440	440
	Reservoir	3.38	2.6	1.732	2.122	1.9	1.7	1.9
	HW (m)	714	814	1,114	1,348	1,503	1,831	1,827
	LWL (m)	694.45	785	1,086	1,305.8	1,471.4	1,813	1,813.2
	Usable Water	19.55	29	28	42.2	31.6	18	13.8
Lower Reservoir	Dam Type	Concrete Gravity		Rock fill		Conc.	Rock fill	Rock fill
	Dam Height (m)	57		24		57	28	36
	Crest Length	350		260		220	280	250
	Reservoir	5.94		3.854		1.9	1.7	1.9
	HWL (m)	300		708		790	1363	1401
	LWL (m)	267.2		694.3		775.4	1,351.5	1,389.2
	Usable Water	32.8		13.7		14.6	11.5	11.8
Water way	Headrace (m)	1,850	2,350	1,120	3,280	4,110	1,760	120
	Penstock (m)	2,400	1,320	2,320	1,220	2,230	850	630
	Tail Race (m)	200	430	1,260	1,560	430	690	2,730
L/H		10.64	7.86	11.6	9	9.4	6	11
Power House Type		Underground	Underground	Underground	Underground	Underground	Underground	Underground
Construction Period		6	6	6	6	6	6	6
Average Rainfall (mm)		1,450	1,450	1,450	1,450	1,450	1,450	1,450

References

1. Guide manual for Development Aid Programs and Studies of Hydro Electric Power Projects, New Energy Foundation, Tokyo, Japan 1996.
2. Planning of Pumped Storage Power Plants in Sri Lanka, M.T.A.P. Wickramaratna, SLEMA Journal, Volume 14-No.2, September 2011.