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Integrated Approach to Address Future Energy Challenges: An Alternative to Conventional Energy System

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Abstract*: *Hydro power and solar power is an important renewable source of energy. The objective of this study is to develop an integrated approach between hydro power and solar power for power generation. Economic analysis and the feasibility of small hydro power plant and solar system at three canal fall locations on Sakarda branch canal has been carried out. Economical analysis of hydro power plant includes design of hydro power plant, costing, estimation of benefit cost ratio and that of solar power includes estimation of benefit cost ratio considering erection of PV panels. Project life up to 25 years, 25 to 50 years and 50 to75 years is considered for analysis. It is concluded that for project life up to 25 years there is less difference between values of benefit cost ratio of hydro power system and integrated power system but after 25 years it increases, as only replacement cost of PV panels will affect the benefit cost ratio. For the project life 25 to 50 and 50 to 75 years benefit from the integrated power system percentage increase in benefit cost ratio is more than hydro power system hence it is concluded that integrated power system is better compared to only hydro power system on canal.

Key words*: *Benefit Cost Ratio, Solar power, Integrated power system, Small hydro power project

I. INTRODUCTION

Sardar Sarovar is a multipurpose interstate project located in Gujarat state of INDIA. Narmada main canal is a part of Sardar Sarovar project and implemented by government of Gujarat with 1133cumecs capacity at the head regulator and 532km length. Narmada main canal has been distributed in four phases. Phase1 is from 1 to 144.5km, and other phases are distributed from 144.5 to 532km. Sakarda is a branch canal of Narmada main canal, which is a part of Sardar sarovar project [9]. Sakarda branch canal is off taking from Narmada main canal at 102.953km as shown in Figure 1. It is located near savali taluka. At chainages 11214m, 14022 m and 16550 m.. Large potential of energy still untapped in irrigation canals in central and south part of India [12]. Economic analysis of small hydro power project and integrated power (Hydro power and solar power) system has been carried out. Small hydro power stations and solar system constitute remarkable energy production installations with considerably less environmental impacts, since hydro power utilize local water resources without the need of extended infrastructure facilities and construction of huge dams [4] and solar power system utilize solar radiation.. Energy is the basic requirement for economic development of a country [13]. Small hydro power is one of the most efficient and well-elaborated kinds of renewable sources of energy [2]. Figure 1 shows detail map of study area.

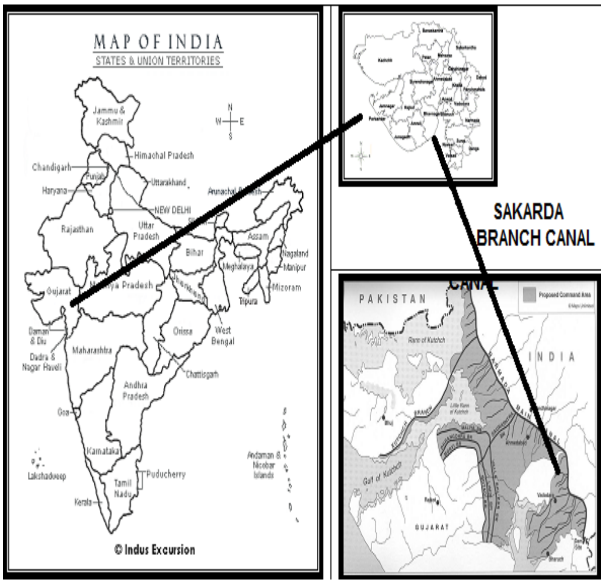

Fig. 1: Map of Narmada main canal indicating location of Sakarda branch canal [9]

II. LITERATURE REVIEW

Adhau, et. al [1] highlighted that energy production has become highly expensive worldwide and its shortage has led to intensified research studies for developing alternate sources of energy.

Nouni, et. al [7] presented the techno-economic feasibility evaluation of few micro-hydropower (MHP) projects being planned and implemented for decentralized power supply for remote locations in India. According to Geraldo et. al [3] hydroelectric power plants help to reduce green house gas emissions, and distribute nation energy generation. The development of small hydro power projects is dependent on the economic and financial feasibility, Evaluation of cost estimates must be done before starting construction. Gagliano, et. al [3]

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emphasized on paying more attentions to small and mini hydro power plants, and also evaluated economic and technical feasibility of the repowering of one of the oldest Sicilian hydropower plant currently abandoned and disused.

Lin, et. al [6] highlighted that the cost of China's grid analyze its sharing between different stakeholders.

Ranasinghe, [10] gave a definition of extended benefit-cost analysis. Redpath, et. al [11] investigated the potential of low head hydro power in Northern Ireland for the electricity production.

Purohit, et. al [8] mentioned to create an enabling policy framework for the development of 20,000 MW of solar power by 2022

III. METHODOLOGY

On Sakarda branch canal at selected site locations for the power house, rated power (P) has been estimated using equation 1. Hydraulic designs of the power components like head race, fore bay, trash rack, penstock intake, penstock, air vent are carried out using Indian Standard specifications. Power house dimensions are also calculated. Cost of project is estimated applying current market rates. Cost of transition line is estimated considering actual distance of transition line from the power house location. The cost of the project depends on the physical sizes of civil works and the electro-mechanical equipments [12].

$$P = 9.81 \times Q \times H \times \eta \quad (1)$$

A. Power house dimensions

Super-structure of power house is made of three bays (Machine hall, Erection bay, Control bay). As shown in Figure 4 dimensions of super-structures are calculated using equations 2 to 6. For the power house dimensions, runner diameter (D) of 1.01m. is considered.

$$Lm = (D+2+2) \quad (2)$$

$$Wm = (4D+2.5) \quad (3)$$

$$Hm = 1.5+.75D \quad (4)$$

$$Le = D+1.5 \quad (5)$$

$$We = Wm \quad (6)$$

Where ,
Lm = Length of machine hall
Wm = Width of machine hall
D = Runner diameter
Hm = Height of machine hall
Le = Length of erection bay
We = Width of erection bay

B. Solar Energy

From the standard monthly solar radiation data monthly solar power is calculated considering 100kW capacity of solar panels. Equation 7 is used to calculate solar energy.

$$E = A * r * H * PR \quad (7)$$

Where ,
E= Energy (kWh)
A= Total solar panel Area (m^2)
r = Solar panel efficiency (%)
H= Annual average solar radiation on panels
PR= Performance ratio (Range between 0.5 to 0.9)

C. Integrated Power System

Combine effect of hydro power and solar power is considered as an integrated power system. Economical analysis were carried out for integrated power system and compared with hydro power system.

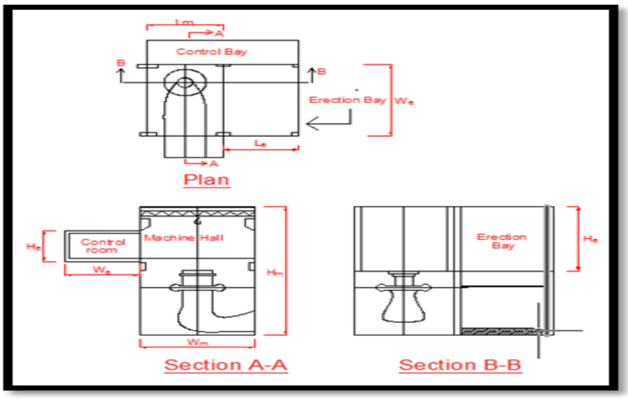

Fig. 2: Power house dimensions

D. Economical Analysis

For both hydro power and integrated power system, benefit cost ratio is estimated using project cost and annual power generation values for project life up to 75 years. Annual Cash is the product of benefit and capital recovery factor. Annual rate of interest of 7 % is considered to find capital recovery factor. Capital Recovery Factor, Annual Cash flow, Total annual cost is estimated using equations 8 To 10.

$$CRF = (i((1+i)^n))/((1+i)^n)-1) \quad (8)$$

$$\text{Annual Cash flow(ACF)} = P*CRF \quad (9)$$

$$\text{Annual Cost} = (ACF) + O\&M \text{ cost} \quad (10)$$

Where,
CRF = Capital Recovery Factor
P = Capital cost of project
i = Annual rate of interest
n = Project life (years)

IV. RESULTS AND DISCUSSION

A. Estimation and Costing

According to the steps mentioned in methodology estimation and costing of the various component of small hydro power project have been done using current markets rates. Fore bay, head race, transitions channel, penstock, air vent, trash rack, machine hall, erection bay and control bay cost have been considered as overall cost of civil work. Cost of electrical and mechanical equipment considered as 52% of total cost, and other cost considered is 8 % of total cost. Transmission line has been calculated considering the actual distance of the transmission line from the power house location. Total project has been estimated as shown in Table 1.

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Table I: Canal fall locations

Chainage	Over All Cost of Civil Works	Cost of Electrical and Mechanical Equipments	Other Cost	Transmission line Cost	Project Cost
m	Rs.	Rs.	Rs.	Rs.	Rs.
11214	2249894	2924862.2	449978.80	1692450	7317185
14022	2233194	2903152.2	446638.8	733395	6316380
16550	1900677	2470880.1	380135.4	1692450	6444143

B. Economical Analysis

Sample calculation of benefit cost ratio for Sakarda canal at chainage11214m (25 year project life) is given below.

Cost of civil works	=	Rs. 2249894.00	
Cost of electrical and mechanical equipments	=	Rs. 2924862.2	
Other cost	=	Rs. 449978.8	
Transmission line cost	=	Rs. 1692450	
Total Capital cost of Project (P)	=	Cost of Civil Works + Cost f Electrical and Mechanical Equipments + Other Cost + Transmission Cost	(11)
	=	Rs. 7317185.00	
Energy generation	=	316542.59kW	(12)
Transmission losses (@ 1 % to be deducted)	=	316542.59 X 0.01	(13)
	=	3165.43kW	
Total Energy Generation Per Annum (Kw)	=	Energy generation - Transmission losses	(14)
	=	316542.59- 3165.43	
	=	313377.16	
Benefit from generation	=	313377.16X 4 (considering 4 Rs./unit)	(15)
	=	Rs. 1253508.66	
Capital Recovery Factor (CRF)	=	[i×(1+i)〗^n/((1+i)^n-1)	(16)
Where i	=	Annual interest rate (7%).	(17)
n	=	Project life (25 Years)	(18)
	=	0.0858	
Annual Cash flow	=	P X CRF	(19)
p	=	Total Capital cost of Project	(20)
	=	1253508.66x 0.0858	
	=	Rs. 627891.43	
Operation And Maintenance Charges (3% of Total Capital Cost)	=	Rs. 219515.55	(21)
Total annual cost	=	Annual Cash Flow + Operation And Maintenance Cost	(22)
	=	627891.43+ 219515.55	
	=	Rs. 847406.98	
Benefit Cost ratio	=	Benefit/Annual cost	(23)
	=	1253508.66/847406.98	
		1.48	

As shown in Table 2 benefit cost analysis of hydro power project for Sakarda branch canal has been analyzed considering project life of 25 years.

Table II : Benefit Cost analysis of hydro power project (25 year project life)

Sr. No.	Parameter	Chainage (m)		
		11214	14022	16550
1	Cost of Civil Works (Rs.)	2249894	2233194	1900677
2	Cost of Electrical And Mechanical Equipments (Rs.)	2924862.20	2903152.20	2470880.10
3	Other Cost (Rs.)	449978.80	446638.80	380135.40
4	Transmission Line Cost (Rs.)	1692450	733395	1692450
5	Total Capital Cost of Project (Initial Cost) (P)	7317185.00	6316380.00	6444142.50
6	Energy Generation	316542.59	340955.55	251128.67
7	Transmission Losses	3165.43	3409.56	2511.29
8	Total Energy Generation Per Annum (kW)	313377.16	337546.00	248617.39
9	Benefit From Generation (Rs.)	1253508.65	1350183.99	994469.55
10	Capital Recovery Factor (CRF)	0.0858	0.0858	0.0858
11	Annual Cash Flow	627891.43	542011.83	552975.20
12	Operation And Maintenance Charges (Rs.)	219515.55	189491.40	193324.28
13	Total Annual Cost (Rs.)	847406.98	731503.23	746299.48
14	Benefit Cost Ratio	1.48	1.85	1.33

A. Solar Energy

From the standard values of monthly solar radiation using equation 7 solar energy has been calculated.

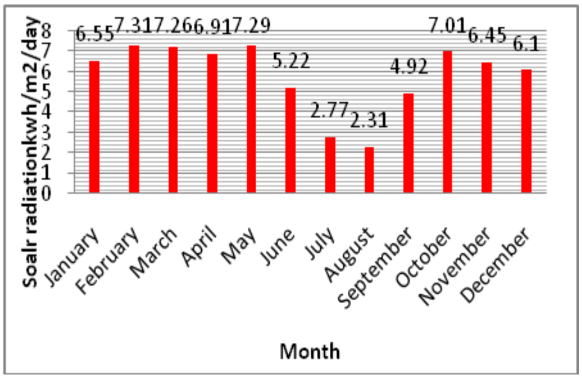


Fig.: 3 Month wise solar radiation chart

life. Analysis is done considering integrated power system various chainages of Sakarda branch canal. Here for the analysis as the solar panel life is up to 25 years, project life of 25 years is considered.

100 kW capacity of solar system need 918.3 m^2 area. Performance ratio .5 and solar panel efficiency 56 % has been considered. Figure 3 shows monthly solar radiation chart.

D. Integrated Power System (Hydro and Solar)

Table 3 shows the benefit cost analysis for 0-25years period project

Similarly benefit cost analysis has been done for 25 to 50 year life and 50 to 75 years project life.

Table III: Economical Analysis of Integrated Power System up to 25 year project life

Sr. No.	Parameter	Chainage (m)		
		11214	14022	16550
1	Cost of Civil Works (Rs.)	2249894	2233194	1900677
2	Cost of Electrical And Mecha1nical Equipments (Rs.)	2924862.20	2903152.20	2470880.10
3	Other Cost (Rs.)	449978.80	446638.80	380135.40
4	Solar Cost (Rs.)	3000000	3000000	3000000
5	Transmission Line Cost (Rs.)	1692450	733395	1692450
6	Total Capital Cost of Project (Initial Cost) (P) (Rs.)	10317185.00	9316380.00	9444142.50
7	Solar Energy /Year (Kw)	150000.00	150000.00	150000.00
8	Energy Generation (Kw)	316542.59	340955.55	251128.67
9	Total Energy Generation Per Annum (Kw)	466542.59	490955.55	401128.67
10	Transmission Losses (@ 1 % To Be Deducted)	4665.43	4909.56	4011.29
11	Total Energy Generation Per Annum (Kw)	461877.16	486046.00	397117.39
12	Benefit From Generation (Rs.)	1847508.65	1944183.99	1588469.55
13	Capital Recovery Factor (CRF)	0.0858	0.0858	0.0858
14	Annual Cash Flow	885322.98	799443.39	810406.75
15	Operation And Maintenance Charges Hydro Power (Rs.)	219515.55	189491.40	193324.28
16	Operation And Maintenance Charges Integrated System (Rs.)	50000.00	50000.00	50000.00
17	Total Operation And Maintenance Cost (Rs.)	269515.55	239491.40	243324.28
18	Total Annual Cost	1154838.53	1038934.79	1053731.03
19	Benefit Cost Ratio	1.60	1.87	1.51

Table IV: Economical Analysis of Integrated Power System 25 to 50 year project life

Sr. No.	Parameter	Chainage (m)		
		11214	14022	16550
1	Total Capital Cost of Hydro Project (Rs.)	7317185.00	6316380.00	6444142.50
2	Operation And Maintenance Charges (3% Of Total Capital Cost) (Rs.)	219515.55	189491.4	193324.275
3	Operation And Maintenance Charges (After 25 Years) (Rs.)	455494.766	393194.655	401147.871
4	Panel Price Per Number (Rs.)	13500		

5	Number of Panels To Cover 10000 Sq Ft Area	308		
6	Panel Cost As on 2018 (Rs.)	4408000		
7	Yearly Average Inflation Rate (%)	4.3		
8	Panel Cost After 25 Years (Rs.)	9170447.28		
9	Solar Panel Replacement Cost After 25years (P) (Rs.)	9170447.28	9170447.28	9170447.28
10	Solar Energy /Year (Kw)	150000.00	150000.00	150000.00
11	Energy Generation For Hydro Power (Kw)	316542.59	340955.55	251128.67
12	Total Energy Generation Per Annum (Kw)	466542.59	490955.55	401128.67
13	Transmission Losses (@ 1 % To Be Deducted)	4665.43	4909.56	4011.29
14	Total Energy Generation Per Annum (Kw)	461877.16	486045.99	397117.38
15	Benefit From Generation (Rs.)	3842818.01	4043902.67	3304016.63
16	Capital Recovery Factor (Crf)	0.0858	0.0858	0.0858
17	Annual Cash Flow (Rs.)	786920.82	786920.82	786920.82
18	Operation And Maintenance Charges (3% Of Total Capital Cost)(Rs.)	219515.55	189491.40	193324.28
19	Operation & Maintenance Cost of Solar System As On 2018 (Rs.)	50000.00	50000.00	50000.00
20	Operation & Maintenance Cost of Integrated System (After 25 Years)	103750.00	103750.00	103750.00
21	Total Operation & Maintenance Cost (Rs.)	323265.55	293241.40	297074.28
22	Total Annual Cost=Annual Cash Flow + Operation And Maintenance Cost) (Rs.)	1110186.37	1080162.22	1083995.10
23	Benefit Cost Ratio	3.46	3.74	3.05

E. Comparison Between Hydro Power and Integrated (Hydro Cum Solar) System

Figure 8 shows monthly hydro power and solar power generation at three chainages. Figure 4 to 6 shows comparison of benefit cost ratio between hydro power and integrated power system. A1, A2 and A3 representing the chinage at 11214 m, 14022 m and 16550 m respectively on Sakarda branch canal.

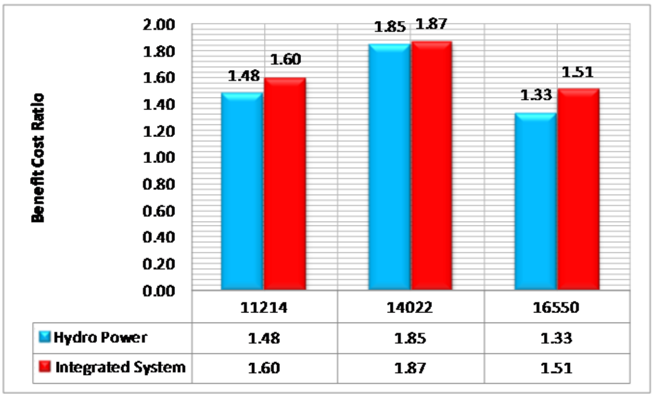


Fig. 4: HP and IPS Benefit Cost Ratio Comparison (0 To 25 Year Project Life)

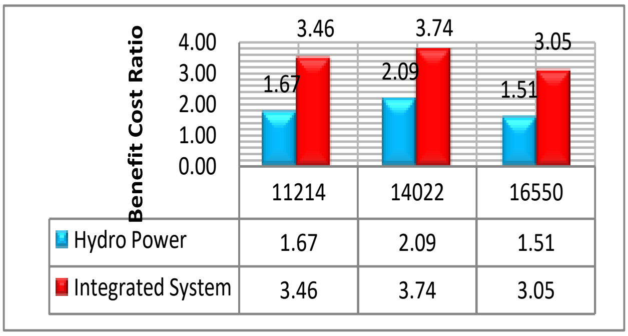


Fig. 5: HP and IPS Benefit Cost Ratio Comparison (25 to 50 year project life)

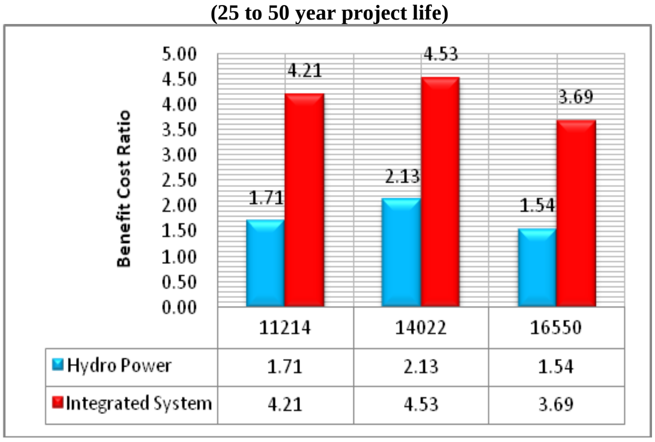
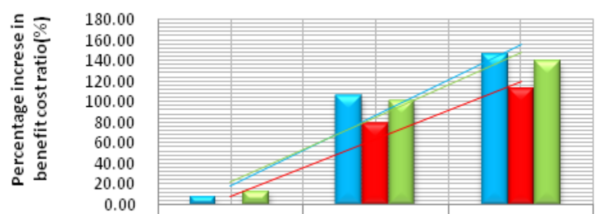


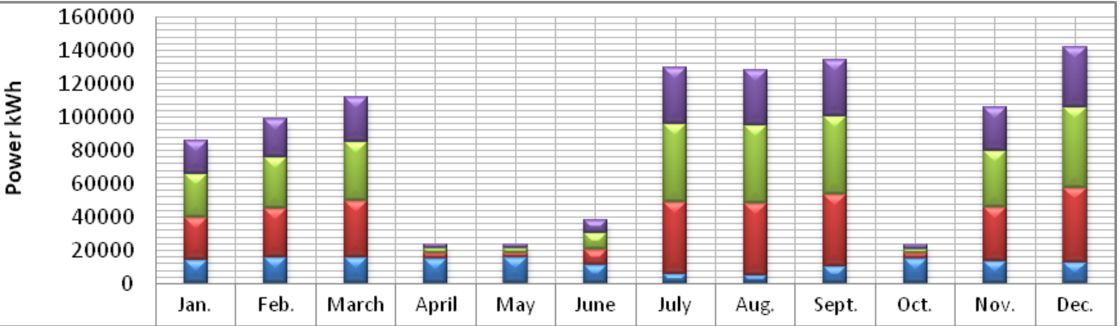
Fig. 6: HP and IPS Benefit Cost Ratio Comparison (50 to 75 year project life)



Project life (Years)	up to 25	25 TO 50	50 to 75
A1	8.00	107.00	146.00
A2	1.00	78.95	113.00
A3	13.53	102.00	140.00

Fig. 7: Alternative wise Percentage Increase In Benefit Cost Ratio

Figure 7 shows alternative wise percentage increase in benefit cost ratio with increase in project life.



	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hydro Power at A3	20050.15	22866.42	26691.5	2585.08	2332.88	7923.38	33360	33360	33360	2594.09	25913.87	36128.1
Hydro power at A2	26724.53	30912.9	35614.69	3323.68	2999.42	10187.21	46800	46800	46800	2594.09	34290.62	48071.72
Hydro Power at A1	25244.33	29495.76	33891.3	2954.38	2666.15	9055.29	43200	43200	43200	3062.47	31585.44	44555.89
Solar Power At All alternatives	14034.68	15663.13	15556.00	14806.05	15620.28	11184.89	5935.279	4949.637	10542.08	15020.32	13820.41	13070.47

Fig. 8: Month wise hydro power and solar power generation comparison

V. CONCLUSIONS

Out of three alternatives, at first alternative (A1) percentage increase in benefit cost ratio from hydro power project to an integrated power system up to project life of 25 year is 8%, for project life 25 to 50 year is 107% and for 50 to 75 year is 146%. At second alternatives (A2) percentage increase in benefit cost ratio from hydro power project to an integrated power system up to project life of 25 year is 1%, for project life 25 to 50 year is 78.95% and for 50 to 75 year is 113%. At third alternatives (A3) percentage increase in benefit cost ratio from hydro power project to an integrated power system up to project life of 25 year is 13.5%, for project life 25 to 50 year is 102% and for 50 to 75 year is 140%.

Considering results of all three alternatives it is concluded that there is small amount of percentages increases in benefit cost ratio for project life up to 25 years because of the reason that for solar power system up to 25 years of project life total cost of solar system is higher, where in 25 to 50 years and 50 to 75 years of project life percentage increase in benefit cost ration is more because only solar panel replacement cost and maintenance cost will affect the project cost.

It is also concluded that the benefit from the integrated power system if more than that of only hydro power system hence if feasible it is recommended to provide integrated system instead of only hydro power system.

Benefit cost ratio at chainage 11214m is 1.48, at 14022m chainage is 1.85 and at 16550m chainage is 1.33 for hydro power project, which are more than 1 for project life up to 25 years hence the hydro power project is feasible. As benefit cost ratio at 14022m is higher than at other two locations first propriety for the hydro power and integrated power project is at chainage 14022m followed by 11214m and 16550m chainages.

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