ROLE OF CANAL BASED SMALL HYDROPOWER IN VIABILITY OF SERVING FAR AND ELEVATED AREAS OF IRRIGATION PROJECTS : CASE STUDY OF SARDAR SAROVAR PROJECT

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ABSTRACT

Any irrigation project should have an aim of serving the thirsty regions to bridge up the socio-economic gaps and then only can it be justified. Far and elevated lands are generally difficult to be included in the command area on techno-economic grounds. But in some cases wherein topography is of saucer shape, a combination of canal falls and lifting points make it possible to provide canal-based hydropower stations and pumping stations to compensate the extra costing of serving elevated lands. The paper discusses how hydropower stations change the cost scenario in such situations with reference to case study of Sardar Sarovar Project and how proper engineering helps serve the societal objectives of an irrigation project.

Keywords : *Sardar Srovar Project, canal-based hydropower, command area, irrigation project*

Features of Sardar Sarovar Project

Sardar Sarovar Project (SSP) – a multi-state, multi-purpose project on River Narmada is taking shape in Gujarat State, India and holds special importance in the light of the fact that the irrigation philosophy it has adopted is to cover the farthest and thirstiest areas of the state. Gujarat State, having geographical area of 19.6 million hectare and current population of about 58 million, is relatively urbanized and is economically progressive a state having its per capita income 31% higher than the national average.

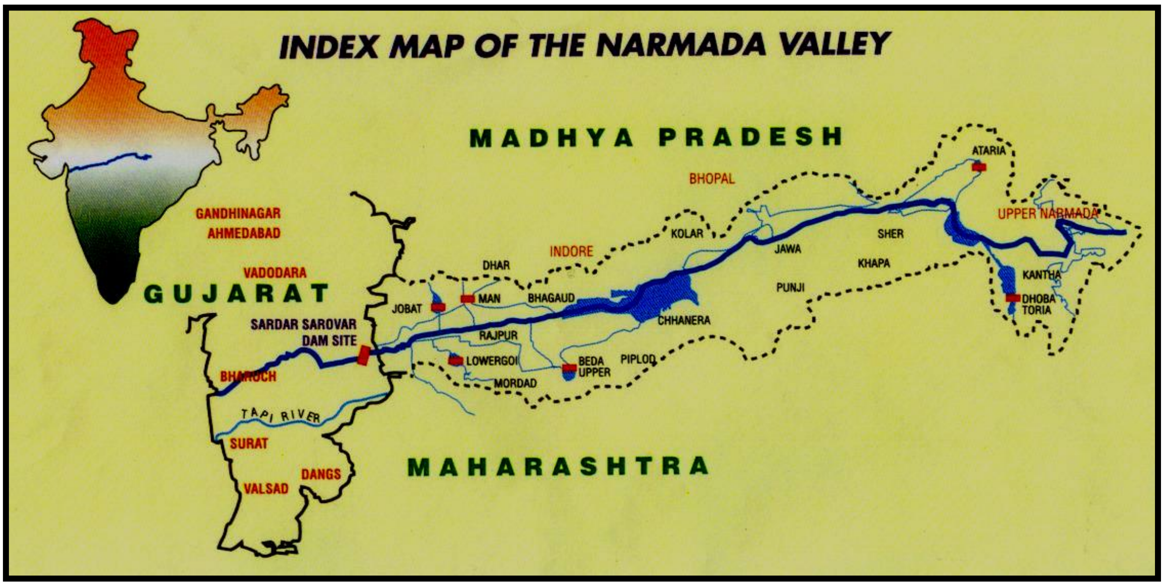

Figure - 1 Index Map of the Narmada Valley

However, having affected by demand-supply gap in both - water and energy, its overall socio-economic development remains well below its potential. It is observed that about 35% electricity consumption of the state which is attributed to irrigation sector (for pumping groundwater), can be considerably reduced with assured canal water supply. Estimate shows that such savings could be awesome - around 3000 MW. The Project, vital for the long term water and energy security of the state, is planned to have one of the largest irrigation canal networks of the world to irrigate 1.8 million ha, that includes 532 km long main canal designed to carry discharge of 1133 cubic meter per second (cumecs), 42 branch canals and a vast distribution network (about 75 thousand km length).

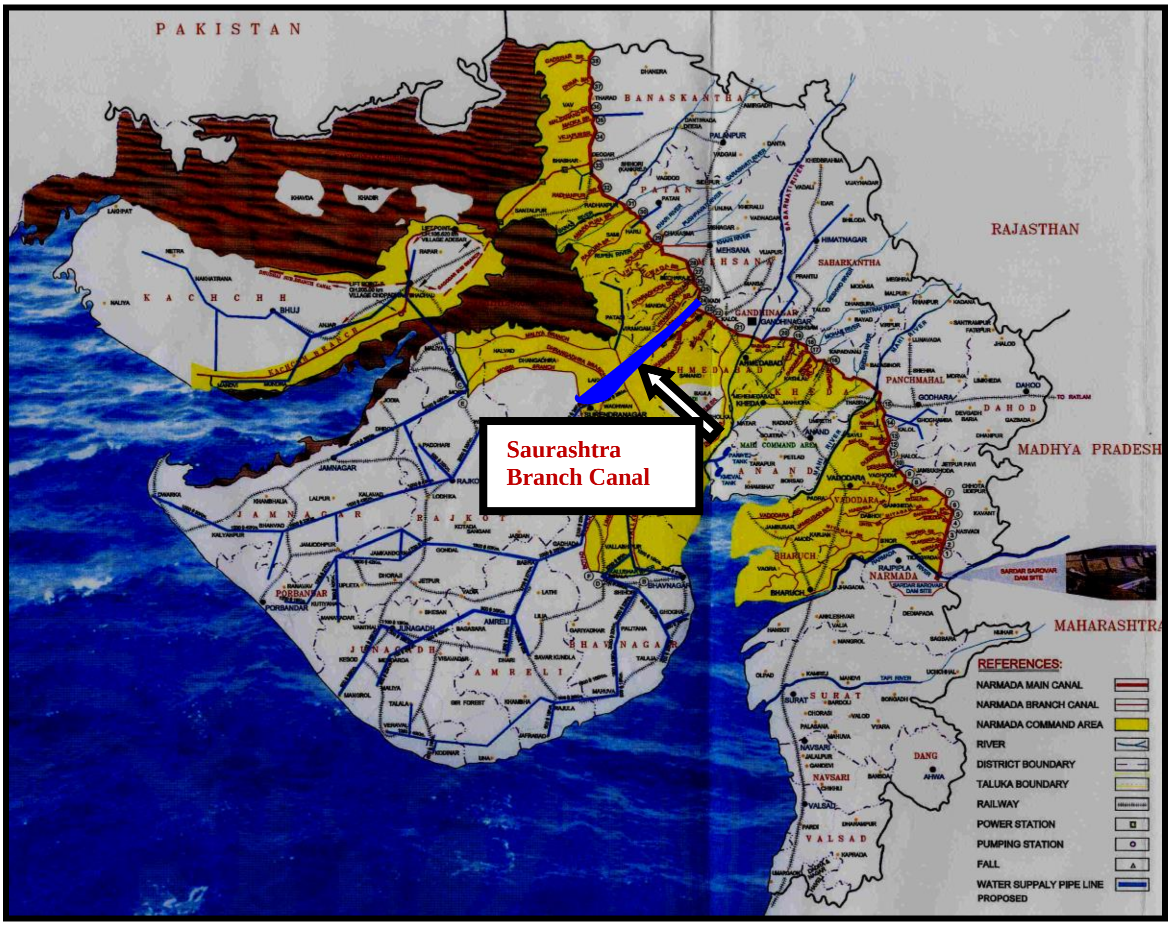

Figure - 2 Command Area of Sardar Sarovar Project in Gujarat State, India

Saurashtra Branch Canal - Topographical Challenge

The Main Canal of Sardar Sarovar Project is a contour canal and hence the command area is only on the left side. It passes through plain land of Ahmedabad Distrcit in which the off-taking point of a canal provided to serve the Saurashtra region is located which is known as Saurashtra Branch Canal and is a ridge canal. The ground level at the off-taking point is about R.L. 62 meter whereas the command to be served is at R.L. 80 meter. In between is the saucer shaped topography with R.L. 14 meter. Thus, there is no direct lift of 18 meter but a fall of 48 meter and a rise of 66 meter. Thus, topography is so uneven in between that serving the command area about 150 Kilometer away from the main canal is a huge challenge. Conventional concepts of irrigation can not be applied here. Even economics do not permit the planning so easily. Recurrent expenses make it even further complicated an issue.

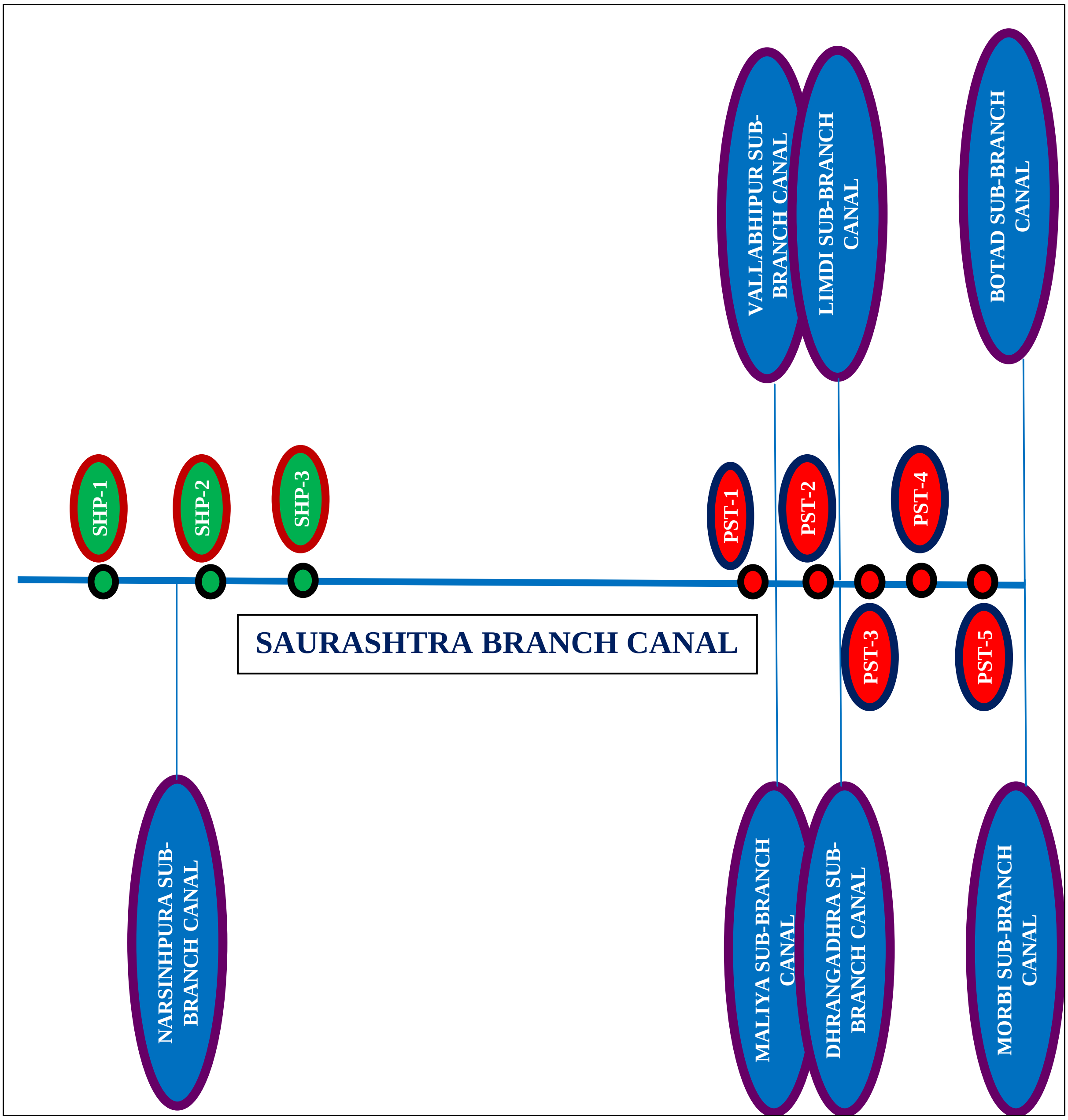

Figure - 3 Line Diagram of Saurashtra Branch Canal

Average heads at three falls are given in Table - 1. It is evident that in between three falls there is no canal off-taking.

Table – 1 Average Head at Falls

Chainage in Kilometer	Average Head in meter
5.150	11.76
17.760	12.05
32.940	11.61

Lifting height and pump configurations at different locations are given in Table – 2. At each location Pumping Station (PST) has been commissioned with detailed calculation of quantity of water to be lifted to serve the respective part of the command area.

Table – 2 Average Head for Lifting and Pump Configuration

Chainage in Kilometer	Average Head for Lifting in meter	Pump Configuration (Cumecs X No.)	
		Concrete Volute Pumps	Vertical Turbine Pumps
69.000	11.200	20 X 10	5 X 6
78.000	15.900	20 X 5	5 X 4
90.000	15.800	20 X 5	5 X 4
93.000	12.150	20 X 3	5 X 4
102.000	17.400	20 X 3	5 X 4

Details of branch canals off-taking from Saurashtra Branch Canal are given in Table – 3. It is clear that two sub-branch canals off-take from between PST – 1 and PST – 2, two off-take from between PST – 3 and PST – 4 and two from PST – 3 and PST – 4.

Table – 3 Details of Sub-Branch Canals Off-taking from Saurashtra Branch Canal

Name of Branch	Off-taking Chainage of SBC	Length in km	Discharge at Head in Cumecs	Discharge at Tail in Cumecs	Culturable Command Area hectare
Narsingpura	15.465	32.01	20.053	7.674	36173
Maliya	69.490	137.73	28.420	8.460	41561
Vallabhipur	70.680	118.75	69.96	6.39	137529
Dhrangadhra	88.870	126.60	59.50	9.07	81502
Limbdi	89.14	117.74	73.86	9.88	109648
Botad	104.46	109.20	70.70	2.81	65465
Morbi	104.46	116.81	49.91	8.52	61757

Discharge Variations in Saurashtra Branch Canal

Two scenarios are considered in the design of Saurashtra Branch Canal. In the first scenario only irrigation requirement is considered i.e. the monsoon is normal and there is no extra demand for domestic or industrial purposes.

Table -4 Discharge Variations in Saurashtra Branch Canal

Month	Fortnight	Discharge in Cumecs Scenario I (Irrigation Requirement)	Discharge in Cumecs Scenario II (During Draught Full Requirement)
May	I	60.742	65.551
	II	94.722	133.803
June	I	113.302	169.399
	II	117.082	157.900
July	I	70.182	69.901
	II	110.572	96.364
August	I	158.852	188.124
	II	171.292	276.095
Sept	I	173.750	319.153
	II	146.710	275.264
Oct	I	143.932	230.342

	II	134.102	209.459
Nov	I	146.762	235.424
	II	148.442	238.323
Dec	I	95.012	136.363
	II	91.532	122.238
Jan	I	104.792	149.876
	II	106.743	155.454
Feb	I	122.142	187.606
	II	111.842	165.874
Mar	I	80.832	101.804
	II	0.000	0.000
April	I	0.000	0.000
	II	0.000	0.000

During draught year, not only greater would be the irrigation requirements but domestic and industrial requirements would also be greater and hence there would be more discharge in the Saurashtra Branch Canal. Because Narmada river has relatively definite monsoon pattern, reliability of water availability is high and accordingly the water distribution pattern is designed. Without having an idea of fortnightly variations in the canal, potential of hydropower generation and variations therein can not be understood. Table - 4 provides the summery of fortnightly discharge variations in the Saurashtra Branch Canal. Irrigation requirements would be for every year and drought requirements in addition to irrigation requirements would be for 4 years in 10 years.

Determining Installation Capacity and Unit Size

Installation capacity and unit size of turbines can be decided on the bases of potential available, fluctuations in discharge, capital investment, recurrent expenses, production scenario, etc. Figure – 4 provides estimated annual hydropower generation (MU) at each fall with respect to total capacity of turbines there.

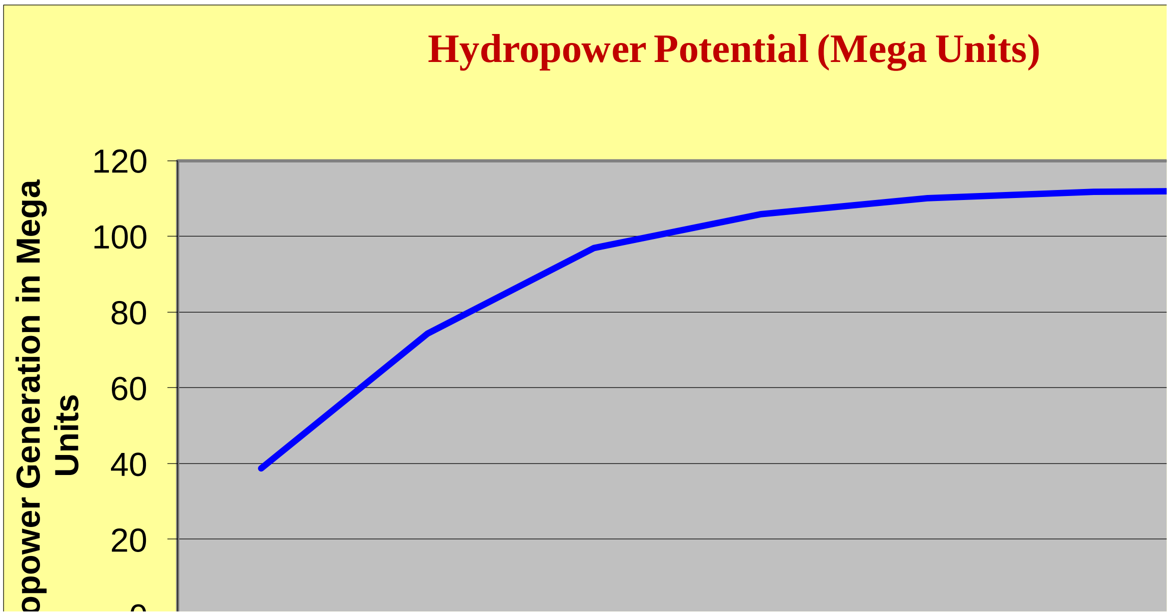

Figure – 4 Estimation of Annual Hydropower Potential (Mega Units) At Each Fall

Because there is no canal off-taking between these falls, any one fall can be studied to get an idea of all the three falls. In 10 years, 6 years as per normal irrigation requirements and 4 years as per drought requirements for irrigation and domestic and industrial use have been considered and weighted average for annual hydropower generation has been estimated. Because of meager difference in head, turbines of identical size at each of the three falls would be beneficial in long run is assumed here. It can be derived from Figure -1 that about 20 MW is the capacity at each fall that could fully utilize the generation potential. However, 16 MW onwards the rise in hydropower generation is quite flat and hence by inputting much only little can be gained. Therefore, 16 MW as the most suitable installed capacity is deduced. Average annual energy generation at fall is estimated to be 99.69 MU. Thus, on three falls in total there would be 48 MW of installed capacity and about 300 MU of average annual energy generation.

Main parameters for selection of number of units and unit size are following.

(1) Pattern of flow and its variation
(2) Maintenance and outage considerations
(3) Power evacuation (stand alone or grid connected system)
(4) Redundancy

Values of Main parameters are given in Table – 5.

Table – 5 Main Parameters for Selection of Number of Units and Unit Size

Description	Value
Pattern of flow and its variations	Minimum flow – 60.74 cumecs Maximum flow – 173.75 cumecs (Scenario – I) 319.15 cumecs (Scenario – II) Average flow – 104.31 cumecs (Scenario – I) 153.51 cumecs (Scenario – II)
Maintenance Consideration	3 fortnights every year – Canal is closed for maintenance 3 to 5 fortnights every year – Flow in the Canal is equivalent to one unit full load generation
Stand Alone/ Grid Connected	Power is proposed to be near by Gujarat Energy Transmission Company grid

Following are general points that should be considered.

(1) Plant cost increases with increase in number of units.
(2) Efficiency of turbine decreases at part load.
(3) Variations in discharge may require running of varying number of turbines
(4) Larger turbines in small hydro have production and maintenance limitations.

With consideration of 16 MW installed capacity at each fall, sizing of turbines could be worked out. The trade-off between number of units and size of turbines calls for detailed consideration on many aspects. Considering low head and high discharge, Kaplan or Bulb type turbines could be suitable. Various options could be thought of – 16 MW single turbine, 8 MW two turbines and 5.33 MW three turbines at each fall could be taken for comparison.

Table - 6 given below provides an idea as to how various sizes of turbines perform at different levels of part load.

Table – 6 Discharge Requirements of Turbines of Different Sizes

	Turbine Size 16 MW	Turbine Size 8 MW	Turbine Size 5.33 MW
Discharge (Cumecs) Required at 100 % Load	156.09	78.05	52.00
Discharge (Cumecs) Required at 60 % Load	93.65	46.83	31.20
Discharge (Cumecs) Required at 40 % Load	61.05	30.52	20.34

Considering the flow variations given in Table – 1 it is clear that 16 MW single unit at each fall is highly uneconomical as it can not run on full load for most of the year. 8 MW 2 turbines and 5 MW three turbines at each fall are better propositions as they can be run on higher levels of part loads as compared to 16 MW single turbine even with less discharge for a long duration in a year. It is a fact that part load below 40 % significantly affects the efficiency and therefore effort should be made to ensure that turbines run on higher part loads. For part load running 8 MW two turbines and 5.33 MW three turbines have little difference but still latter option offers better choice.

5.33 MW turbine is lighter in weight and hence while maintenance it is easier to handle. Redundancy is obviously more with 5.33 MW three turbines at each fall which ensures more reliability. Moreover, with given head and discharge as per preliminary design, 8 MW turbines require diameter of about 4 m whereas 5.33 MW turbines require diameter of about 3.3 m. Considering production limitations of the primary manufacturers of small hydropower turbines in India, up to 3.5 m diameter is O.K. and hence 5.33 MW three turbines is a preferable option by all considerations.

Economics of Command Area

Economics of command area can be evaluated on the basis of two scenarios – without utilizing hydropower and with using hydropower so as to appreciate the contribution of canal based hydropower in real sense. For the latter scenario, contribution of hydropower in terms of electricity units has been divided on the basis of cumec-lift-pump combination basis, i.e. discharge, height of lift and pump combination used for lifting which would require different denomination of electricity consumption. Table-7 gives a fair idea of cost of lifting water with and without contribution of hydropower with consideration of all losses and rational computations based on actual data as far as possible.

Table – 7 Lifting Cost of Canal Water in Terms of Electricity Units

Name of Sub-Branch Canal	Lift in Meter	Lifting Cost of Canal Water in Units per Cumecs	
		(Without Hydropower)	(With Hydropower)
Narsingpura	0.0	0.00	0.000
Maliya	11.2	0.04	0.031
Vallabhipur	11.2	0.04	0.031
Dhrangadhra	27.1	0.11	0.088
Limbdi	27.1	0.11	0.088
Botad	42.9	0.17	0.128
Morbi	42.9	0.17	0.128

Electricity consumption in pumping and electricity generation from hydropower stations are considered while working out the lifting cost of water in the canal. Maintenance cost of pumping stations and hydropower stations and interest on capital investment are not considered. This is because how electricity is compensated is the interest of discussion and not the net monetary advantage. However, looking to future requirement of energy, every bit of energy saved would benefit the state multifold which may lead to a better scenario for perceiving the overall planning. It is clear that because of hydropower cost of canal water in units/ cumec has come down to some extent. In the estimate all losses are considered. Total fall height is less than half of the total lift and yet we get sizable compensation. The saving of energy in long run is projected to be worth Rs. 1500 million per year and cost of hydropower station is likely to be recovered in less than three years.

It is worth noting here that because six sub-branch canals off-take after all the three falls and no canal off-takes in between the falls, simultaneous operation of hydropower stations and one or more pumping stations is obvious.

Conclusion

Topography of Saurashtra Branch Canal is such that total fall is about two-third the total lift. Cost of lifting in terms of electricity units, i.e. KWH shows that because of hydropower that the command areas on higher contours could be served with lesser cost which otherwise would have become economically unviable. Catering to the requirements of irrigation water to far and elevated areas is the real achievement of the project planning and that is because of canal-based hydropower generation. Compensation in power consumption is about 25 % which is a big achievement in itself as power crisis is likely to be more stringent in future and hence cost benefit in monetary terms may become secondary.

Disclaimer

Views expressed in this paper are the individual views of the author and not necessarily of the organization he works for.

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