Small Hydropower—An Indian Perspective

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***Abstract*—In view of increasing energy crisis and depleting fossil fuel reserves, hydro power has moved towards one of the top power development options to meet the increasing energy demand. India is blessed with many rivers, canal networks and mountains offering tremendous hydro potential of Small Hydropower (SHP). The potential of SHP in the country is around 15,000 MW, of which only around 13% has been tapped so far. Hence, it is very crucial to explore the balance potential to satisfy the fast growing energy needs.**

Government of India encourages SHP through various promotional schemes and provides subsidy for the installation as well as renovation/modernization of the projects. The aim is the capacity addition of about 2% in the power sector by SHP through participation of government & private sector, central PSUs, state electricity boards, local bodies and NGO's. This paper studies the current SHP scenario in India as well as describes the developments that have taken place so far. An outstanding start has been made in commercializing SHP in India. Government policies/action plans for the development of SHP is presented. Different financing options and manufacturing status are given. The challenges and current trends in SHP are discussed.

***Keywords*—Latest trend, India, power scenario, small hydropower.**

I. INTRODUCTION

In the present scenario of growing, luxurious and developing world the energy demand is continuously increasing and on the other hand the conventional energy resources i.e. fossil fuels are continuously depleting. On account of increased fuel prices due to rising energy needs as well as pollution problems associated with the fossil fuels, the trend has been changed towards the renewable energy sources. In India, there exists enormous potential for the development of various renewable energy sources like solar, wind, small hydro, biomass, etc.

The hydro power is one of the reliable, economical and environmental benign renewable energy sources. Conventional large hydropower is subjected to various economic, social and political problems and hence became unfavorable in the present energy context. Thus, the small, mini, and micro hydropower schemes are considered as the solution for the energy crisis particularly in rural, remote and hilly areas, where extension of grid is uneconomical. Fortunately, India is blessed with many rivers, canal networks and mountains offering tremendous hydro potential of large, small, mini and micro hydropower.

The potential of small hydropower in the country is around 15,000 MW, of which only around 13% has been tapped so far. Hence, it is essential to exploit the balance small hydro potential through various small hydropower (SHP) schemes to satisfy the increasing energy demand of the country. Ministry of New and Renewable Energy (MNRE), Govt. of India promotes SHP through various incentives and provides subsidy for the installation as well as renovation and modernization of the projects. At present, 19 states have declared their policy for private sector participation, with an aggregate potential of over 2500 MW in this sector [1].

In this paper, current energy scenario in India as well as status of SHP is reviewed. Brief introduction of SHP, different layouts and main components are described. Government policies/action plans for the development of SHP is presented. Various National and International Standards relevant to SHP are mentioned. Details of consultancy services, manufacturers as well as financing options available in India are given. At the end, various challenges and latest trends in SHP are presented.

II. POWER SCENARIO IN INDIA

To meet the increasing energy demand and human development goal in the country, power generation capacity would need to be increased to 800 GW in year 2031-32 from the current installed capacity of around 139 GW. Of the total installed capacity share of thermal is 66%, hydro is 26%, nuclear is 3% and other renewable is around 5%. The details of target capacity addition through different sources during 11th Plan (2007-2012) are given in Table I [2].

TABLE I: TARGET CAPACITY ADDITION DURING 2007 – 2012

Source	*Central Sector*	*State Sector*	*Private Sector*	*Total*
Thermal	26,800	24,347	7,497	58,644
Hydro	9,685	3,605	3,263	16,553
Nuclear	3,380	0	0	3,380
Total	39,865	27,952	10,760	78,577

According to Ministry of New and Renewable Energy (MNRE) Guidelines, though large hydro power is also renewable in nature but it has been utilized all over the world for many decades and hence it is generally not included in the term 'New and Renewable Sources of Energy'[3]. In spite of giving highest priority to rural electrification, about 1,00,000 villages remain yet to be electrified in India [2]. Most of these villages are located in remote areas, with very low load densities. In remote areas where transmission of grid power is totally uneconomical, off-grid electrification can be undertaken through renewable energy systems such as Small Hydropower schemes. The details of various renewable energy sources available in India are given in Table II [4].

TABLE 2: RENEWABL ENERGY SCENARIO IN INDIA

Renewable Energy Source/System	*Estimated Potential (MW)*	*Installed Capacity (MW)*
Wind Power	45195	8757.00
Bio Power (agro residues and plantations)	16881	606.00
Small Hydropower (up to 25 MW)	15000	2180.00
Bagasse cogeneration	5000	800.00
Family-type biogas plants	120 lakh	39.94 lakh
Energy recovery from waste	2700	55.25
Solar water heating system (million m^2 collector area)	140	2.30
Solar photovoltaic system	50 kW/km^2	120 MW_p
Solar cookers	-	6.20 lakh

III. SMALL HYDROPOWER IN INDIA

Introduction

Different countries are following different norms to distinguish between large and small hydro, the range varies between 5 and 50. However, in India hydro projects up to 25 MW station capacity have been categorized as Small Hydropower Projects. Further SHP projects are classified as gives in Table III [5].

TABLE 3: CLASSIFICATION OF SHP PROJECTS

Class	*Station Capacity in kW*
Micro Hydro	Up to 100
Mini Hydro	101 to 2000
Small Hydro	2001 to 25000

Other than dam-toe based layout, *which is most common in conventional large hydropower*, two other layouts namely run-off river and canal based layout are also used in SHP. In run-off-river schemes, water is diverted towards power house as it comes in the river. After power generation, water is again discharged back to the river. Generally, these are high head and low discharge schemes. Canal based small hydropower scheme is planned to generate power by utilizing the head available at the fall in the canal. These schemes may be planned on the main canal itself or in the bypass canal. These are low head and high discharge schemes. Canal based schemes are associated with advantages such as low gestation period, simple layout, no submergence and rehabilitation problems and practically no environmental problems. However, equipment cost is more than that of run-off-river schemes. The typical layouts of different SHP projects are shown in Fig.s 1-3.

In hydropower plant, the main components can be grouped into two categories i.e. electro-mechanical components and civil works components. However, turbine is the most important component because it directly affects the cost of civil works as well as overall performance of the project. Turbines are usually designed according to the site conditions i.e. head and discharge. In small hydro, other than conventional turbines e.g. Pelton, Francis and Kaplan turbine some low cost non-conventional turbines e.g. Turgo-Impulse, Cross flow, Bulb, Stra-flow, PAT (Pump as Turbine) etc. are also used.

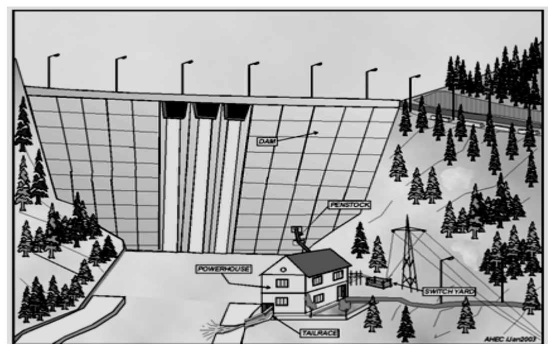

Fig.1: Typical arrangement of dam-toe based scheme

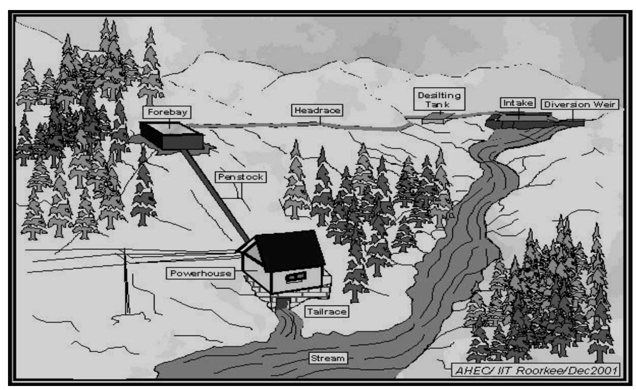

Fig. 2: Typical arrangement of run-off-river scheme

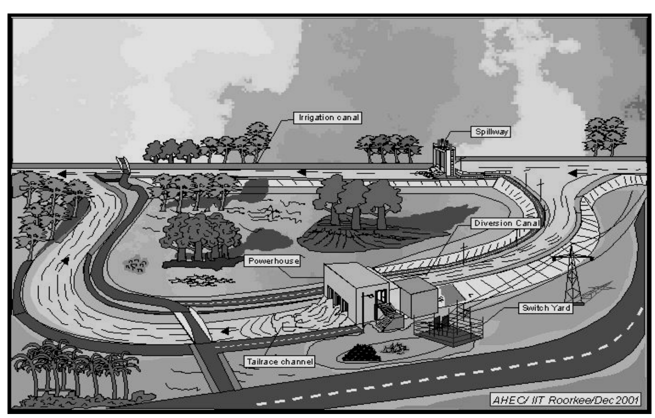

Fig. 3: Typical arrangement of canal based scheme

Small Hydro Potential

The potential of small hydropower in the country is around 15,000 MW. Of this, 1976 MW from 602 sites have been tapped so far. The capacity addition through SHP during 10th Plan (2002-2007) was over 500 MW and target capacity addition during 11th Plan (2007-2012) is 1400 MW. The state wise details of SHP status are given in Table IV [6]:

TABLE 4: STATE WISE DETAILS OF SHP

State	*Identified Projects*		*Installed Projects*		*Projects under Implementation*	
	No.	Capacity (MW)	No.	Capacity (MW)	No.	Capacity (MW)
Andhra Pradesh	377	250.50	57	178.850	11	17.50
Arunachal Pradesh	452	1243.47	68	45.240	56	41.82
Assam	40	119.54	3	2.110	4	15.00
Bihar	74	149.35	7	50.400	9	7.60
Chattisgarh	132	482.82	5	18.050	1	1.00
Goa	4	4.60	1	0.050	-	-
Gujarat	287	186.37	2	7.000	-	-
Haryana	23	36.55	5	62.700	1	6.00
Himachal Pradesh	457	2019.03	61	141.615	13	64.00
J&K	208	1294.43	32	111.830	5	5.91
Jharkhand	89	170.05	6	4.050	8	34.85
Karnataka	468	1940.31	69	416.500	17	103.50
Kerala	207	455.53	16	98.120	5	39.55
Madhya Pradesh	85	336.33	9	51.160	5	39.90
Maharashtra	221	484.50	29	209.330	3	13.50
Manipur	99	91.75	8	5.450	3	2.75
Meghalaya	90	197.32	3	30.710	3	1.70
Mizoram	53	135.93	16	17.470	3	15.50
Nagaland	84	149.31	9	20.670	5	12.20
Orissa	206	217.99	6	7.300	8	60.93
Punjab	204	270.18	29	123.900	-	-
Rajasthan	55	27.82	10	23.850	-	-
Sikkim	70	214.33	14	39.110	4	13.20
Tamil Nadu	155	373.46	14	89.700	4	13.00
Tripura	10	30.85	3	16.010	-	-
Uttar Pradesh	211	267.06	9	25.100	-	-
Uttarakhand	354	1478.24	87	75.670	35	61.25
West Bengal	141	213.50	23	98.400	16	79.25
A&N Islands	5	1.15	1	5.250	-	-
Total	4861	12,841.81	602	1975.59	219	649.91

SHP Promotional Schemes

Government of India has declared Hydro Policy in 1998 to encourage the Hydropower sector. State Nodal Agencies for Renewable Energy provides assistance for obtaining necessary clearances, in allotment of land and potential sites to private entrepreneurs. According to Electricity Act 2003, the State Electricity Regulatoty Commission (SERC) would promote generation of electricity from non-conventional sources which includes SHP. The aim is the capacity addition of about 2% in the power sector by SHP through participation of government & private sector, central PSUs, state electricity boards, local bodies and NGO's.

The Ministry of New and Renewable Energy (MNRE), Government of India is responsible for the development and deployment of SHP in the country. In early 90s, most of the SHP projects were set up in the public sector only. However, to promote small hydropower in private sector 19 states have declared policies for private sector participation with an aggregate capacity of over 2500 MW. So far, over 120 projects with a total capacity of about 500 MW have been set up by the private sector mainly in Andhra Pradesh, Karnataka, Punjab, Uttarakhand and Maharashtra [1].

MNRE also provides subsidy for the installation of the projects to both public as well as private sector. The project is required to be tested after commissioning for its performance by Alternate Hydro Energy Center (AHEC), Indian Institute of Technology, Roorkee. The subsidy is released after project attaining 80 percent of the envisaged generation, as per DPR for three consecutive months.

Renovation and Modernization (R&M) of existing/old SHP projects is considered to be the most economic way of adding generation from the project. MNRE has a scheme for providing financial assistance for R&M and capacity up rating of small hydropower stations. The main aim of the scheme is to extend the life of these stations with improved performance and reliability. This scheme is only for government sector projects. The same level of subsidy is given to languishing SHP projects in the government sector with a view to get them completed at the earliest. The details of financial assistance given by MNRE are given in Table V [6]:

TABLE 5: FINANCIAL ASSISTANCE GIVEN BY MNRE FOR SHP

Purpose of subsidy	*Special Category States (NE Region, Sikkim, J&K, HP & Uttarakhand)*	*Other States*
For installation	Rs 2.25 crores X (Capacity in MW)$^{0.646}$	Rs 1.50 crores X (Capacity in MW)$^{0.646}$
For Renovation & Modernization	Rs 1.125 crores X (Capacity in MW)$^{0.646}$	Rs 0.75 crores X (Capacity in MW)$^{0.646}$

Standards for Small Hydropower

The quality of equipments utilized is important for the reliability and attainment of project performance parameters.

MNRE has been insisting to follow stipulated standards for receiving subsidy for the project. SHP equipments must confirm to the standards laid down by the International Electro-technical Commission (IEC) and the Bureaus of Indian Standards (BIS). List of some of the standards relevant to SHP is given in Table VI [7]. Recently, MNRE has given an assignment to AHEC, IIT Roorkee to revise the existing standards and come out with standards/manuals/guidelines for improving reliability and quality of SHP projects in the country.

TABLE 6: STANDARDS RELEVANT TO SMALL HYDRO

Name of Equipment/Component	*Standard*
Turbines and Generator	IEC 60034 -1:1983 IEC 61366 -1:1998 IEC 61116: 1992 IS 4722 :2001 IS 12800 (Part 3):1991
Field Acceptance test for hydraulic performance of turbine	IEC 60041:1991
Governing system, Transformers	IEC 60308 IS 3156:1992 IS 2705:1992 IS 2026:1983
Power house, surge tanks, cross regulator, penstocks	IS 4247:1992 IS 7396:1986 IS 7114:1987 IS 11625:1986

Performance Testing and Consultancy Services

Performance testing of hydropower station is becoming a necessity in view of global competition and long-term benefits. Currently, it is mandatory for all SHP developers to carry out performance testing after commissioning at the site with the objective of quality control and achieving higher efficiency of the system. SHP projects are required to be tested by the AHEC, IIT Roorkee to check whether the projects have attained performance parameters during trials; whether the equipments used meets the stipulated standards; and to verify project cost, capacity utilization and cost of electricity generation.

Consultancy services of SHP projects are available through many government/ private consultancy organizations. The MNRE is strengthening technical institutions to provide such services. AHEC, IIT Roorkee is providing a full range of technical services in the field of small hydro including survey and investigations, DPR preparation, project design, availing subsidy, modification in existing projects, performance testing etc.

Cost Aspects

Cost of civil works is higher for the run-off-river projects but cost of equipments is more in case of canal based schemes. The cost distribution for different types of project is given in Table VII [8]. Generally, the overall cost of SHP project varies from Rs. 5 to 7 crores per MW, depending on the location and topography of the site. The payback period is around 5-7 years depending upon the capacity utilization factor [3].

TABLE 7: COST DISTRIBUTION FOR DIFFERENT SHP PROJECTS

Component	*Cost Distribution (%)*		
	Low Head	Medium Head	High Head
Civil construction	40	50	60
Civil design supervision	10	10	10
Electrical components	10	15	15
Turbine and valves	35	15	5
Penstock	5	10	10

Financing Small Hydropower Projects

Realizing the need for financial input for the organized development of the renewable energy sector including SHP, the Government of India established an independent specialized public sector undertaking, called IREDA (Indian Renewable Energy Development Agency Ltd). IREDA started financing SHP projects up to 25 MW in late 80's and the projects sanctioned were for government sector along with subsidy from MNRE. In line with the government's policy of privatization of power sector in 1990/91, IREDA started financing private sector SHP from its own resources. Till the end of 2004, IREDA has financed 124 SHP projects with loan assistance of around Rs. 1,22,863 lakh for installation of aggregate capacity of nearly 466 MW, which also includes 114 private sector projects. Financing norms of IREDA are given in Table VIII [7].

TABLE 8: NORMS OF IREDA FOR FINANCING SHP PROJECTS

Particulars	*Value*
Interest rate (%) p.a.	10.00
Maximum repayment period (years)	10
Minimum promoter's contribution (%)	30
Term loan/ lending norms of IREDA	Up to 70% of total project cost

Challenges in SHP

Development of SHP is subjected to some of the policy matters as well as technical challenges as mentioned below:

- Technical issues like hydrology and geology of the site: The hydrology issues could be non-availability of long term data to ascertain the water availability and pattern, change in course of river, drying of canals etc. Geology issues could be soil quality and assessment, silting etc.
- Water may not be available round the year hence seasonality in power generation and revenue earned.
- State Electricity Regulatory Commission's (SERC's) need to treat every projects differently as the hydrology and geology of each site varies, which is difficult to implement in practice.
- Involvement of irrigation ministry in case of canal based projects.

Latest Trends in Small Hydro

To meet the fast growing techno-economic demand of developing SHP projects, the recent trend is as follows [9]:

- Optimize the unit in terms of turbine /generator / civil works so that overall project cost can be reduced.
- Go for standardized units, which helps in reducing initial as well as maintenance cost. Turbines can be standardized based on the runner diameter, generators on the basis of rating & generation voltage.
- As far as possible Siphon type turbines or Open flume turbines shall be used. Siphon machine allows the turbine to be kept at a higher elevation and thus reduces excavation cost. Also, these machines eliminate the need for intake gates as the machine can be stopped by breaking the siphon. Open flume machines simplify the civil works to a great extent.
- Francis turbine is having relatively poor part load efficiency due to fixed pitch runner blades. Also, it is subjected to undesirable effects like variation in power output, pressure fluctuation, vibration of shaft, damage to runner blades at partial discharge. Research is going on to improve the part load performance of Francis turbine.
- Design of environmental friendly turbines e.g. Fish friendly turbines, oil free turbines.
- Increased use of Computational Fluid Dynamics (CFD) software to carry out the flow analysis of turbine.
- Use of PLC based system instead of conventional electronic governor.
- Attempts are made to reduce project cycle time.

TABLE 9: LEADING MANUFACTURERS IN INDIA

Manufacturers	*Collaboration*	*Type*
Alstom Power India Ltd, Baroda	Alstom, France	Joint venture
BHEL, Haridwar and Bhopal	Fuji, Japan	Technical
Boving Fouress Pvt Ltd, Bangalore	GE, UK/Norway	Joint venture
Jyoti Ltd., Baroda	Turbo Institute of Slovenia	Technical
Kirloskar Brothers Ltd., Pune	Ebara Corporation, Japan	Technical
VA Tech Escher Wyss Flovel Ltd, Faridabad	VA Tech, Austria	Joint venture

Manufacturing Status

In India there are more than 10 manufacturers who fabricate almost entire range and type of SHP equipments. The estimated capacity of the manufacturers is around 250 MW per year. The list of leading manufacturers is given in Table IX [10].

IV. CONCLUSION

In India, rural, hilly and remote areas suffer from inadequate and unreliable supply of energy. Small hydropower schemes can be considered as the solution for the energy crisis in these areas, where extension of grid is uneconomical. Very large amount of energy is wasted in the flowing water in rivers as well as at the canal falls. The need is to tap this energy and utilize for the sustainable development in such areas. Government of India promotes SHP through various promotional schemes in terms of financial as well as policy matters. The target capacity addition during 11^{th} Plan (2007-2012) through SHP is 1400 MW. To achieve this, it is essential to create awareness and increase the share of private sectors & local bodies by simplifying allotment & clearance procedure, minimizing procedural delay and maximizing financial incentives.

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