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An Overview of Small Hydro Power Generation Scenario in India

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Abstract: This paper presents the scenario of electricity generation in India using various renewable sources especially small hydro. Among various renewable energy sources, small hydro contributes about 15% of the total electricity generation in India. The country is looking for green energy by maximising the harnessing of small hydro power potential available in abundance. About more than 15000MW of small hydropower potential is available in India mostly in Himalayan region. Small hydro power plants (SHPP) are considered as reliable option for both grid and decentralized power generation modes. This paper also presents the technical challenges associated with the development of SHPP like selection of generator and turbine. Various standards related to equipments used in small hydro power plants have also been covered. Different policies of Indian Government related to power generation using renewable energy sources have also been covered in this paper.

Keywords: Small hydro power plant, Hydro generator, Hydro turbine, Watermills.

I. INTRODUCTION

Electricity is the basic need of human beings. Per capita consumption of any country indicates in progressiveness. In India, the demand of electricity is as well as installed capacity is growing steadily. The total power generation increased from 1362MW in 1947 to 309GW in 2016 along with per capita consumption from 16.3 kWh in 1947 to 1075 kWh in 2016. Incipit of this India's has been facing power shortage during peak hour demand because electricity demand is grow at 10% per yearly [1]. By framing various policies, India has created a positive atmosphere for investment in power sector especially in harnessing renewable sources such as solar, wind, small hydro and biomass etc. Among various renewable energy sources, small hydro power generation is considered as a reliable option in grid connected mode or in isolated mode of operation [1]-[2].

In India, 85.6% electricity is generated from conventional sources of energy such as thermal, hydro, nuclear and gas power plants and rest 14.4% is generated by various renewable sources like wind, solar, small hydro, and biomass & waste materials. In renewable power generation, 61.3%, 18%, 10.9%, 9.6% and 0.3% are the share of wind, solar, biomass, small hydro and waste materials respectively [2]. The small hydro power plant has 9.6% share in renewable power generation which is only 22% of the estimated small hydro potential available in India. Small hydro power plants (SHPP) are mostly suitable for providing reliable electricity to rural remote areas especially in remote mountainous regions. SHPP are generally of run off river type with no dam or water storage facilities. These plants are cost-effective and environmental friendly as compared to large hydro and suitable for rural electrification in developing countries [3-5]. In most of the SHPP where reservoir does not exist, the energy availability cannot be considered 100% reliable. There are two distinctive topologies of small hydro power plants in terms of their power ratings. The first one type of SHPPs has MW size of capacity and these are grid connected and usually developed by the state Government or private developer. These SHPPs are influential in increasing the existing installed capacity of power along with providing permanent benefits in remote area in terms of sustainable economic development and employment generation. The second type has size in kW (micro, pico or watermills) and these are operated in isolated or decentralized mode of power generation [8]. These micro/pico projects provide the benefits to village or local community in terms of economic growth along with developing local entrepreneurs.

II. HISTORY OF SMALL HYDRO DEVELOPMENT IN INDIA

Development of SHPPs in India dates back to 1887 when first hydro power plant was set up in Darjeeling (130kW) known as Sidrapong small hydro power station followed by setting up of more hydro power plants in Mysore (2000KW) and Chamba (40kW) in 1902, Jubbal (50kW) in 1911 and Chhaba (1750kW) in 1913 in Shimla. These power plants are still working and providing reliable electricity to small populations in isolated mode. Fig. 1 shows the view of grid connected Gurahan small hydro power plant of 1.5MW capacity in Mandi district of Himachal Pradesh.

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Fig.1. 1.5MW Gurahan Small Power Plant (HIMURJA) in Himachal Pradesh

III. SMALL HYDRO POWER PLANTS

In hydro power plant (HPP), the kinetic energy of water is converted into mechanical energy with help of water turbine and water turbine is further coupled with common shaft to hydro generator for electricity generation. The electrical power generation from hydro power plant is calculated as [4]:

$$P = \Upsilon.Q.H.\eta_T.\eta_G \quad (1)$$

Where

P = Power (Watts)
Υ = Specific weight of water (9810N/m^3)
Q = Water discharge (m^3/sec.)
H = Water fall height (m)
η_T = Efficiency of hydro turbine (%)
η_G = Efficiency of hydro generator (%)

The SHPP without dam are less reliable to supply the power as compare to large scale hydro power plant. The small hydro power plants are classified according to the rating. Different countries have different norms in categorizing small hydro opower plants worldwide [6]. The different countries are following different norms keeping the upper output power limit ranging from 5MW-50MW. The list of capacity of small hydro power plants defined by different countries is shown in Table I.

TABLE I DEFINITION OF SHPP IN DIFFERENT COUNTRIES

Country	Capacity of Plant
USA	≤ 5MW
UK	≤ 5MW
Sweden	≤ 15MW
Colombia	≤ 20MW
Australia	≤ 20MW
Canada	≤ 20MW
India	≤ 25MW
China	≤ 25MW
Phillipines	≤ 50MW
New Zealand	≤ 50MW

In India, hydro power plant (HPP) up to 25MW capacities are consider under small hydro power plant (SHPP). Pico, micro and mini hydro power plants come under the category of small hydro power plants.

TABLE II CLASSIFICATION OF SHPP ON THE BASIS OF POWER CAPACITY

Types of SHPP	Power Capacity (kW)	Applications
Small Hydro	2001-25000kW	Feeding the electricity to nearby regional grid
Mini Hydro	101-2000kW	Suitable for electricity generation in isolated operation, stand-alone operation , often feeding the local grid, small factory and isolated communities
Micro Hydro	10- 100kW	Feeding the electricity for rural electrification in remote area which are away from the grid, small isolated communities
Pico Hydro	up to 10kW	Feeding the electricity for few houses which are away from the grid.

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Most of the SHPP in India are located in the Himalayan states having vast hydro potential in the forms of small water streams along with the large rivers. The brief classification of SHPP and their applications in India are given in Table II.

Further, SHPP are classified on the basis of availability of water head such as high head, medium head, low head and ultra low head hydro power plant. The brief classification of SHPP on basis of head in India is given in Table III.

TABLE III CLASSIFICATION OF SHPP ON THE BASIS OF AVAILABLE HEAD

Type of SHPP	Available Head(m)
High head	>50
Medium head	10-50
Low head	3-10
Ultra low head	<3

A. Small Hydro Power Potential in India

The estimated potential of SHPP in India is of about 20,000MW. The identified potential of SHPP is 19,749MW at 6454 sites, out of which 4320 has been harnessed at 1075 sites (as on 31.01.2017). The bulk potential of small hydro is in the states of Karnataka, Himachal Pradesh, Uttrakhand, Jammu & Kashmir, Arunachal Pradesh and Chattisgarh [1]-[5].

TABLE IV STATE WISE POTENTIAL & INSTALLED CAPACITY OF SHPP AS ON 31-12-2016

State	Potential		Project Installed		Project Under Implementation	
	Nos.	Capacity (MW)	Nos.	Capacity (MW)	No.	Capacity (MW)
Karnataka	834	4141.12	166	1220.73	13	70.75
Himachal Pradesh	531	2397.91	180	796.81	21	33.5
Uttarakhand	448	1707.87	101	209.32	44	139.54
J&K	245	1430.67	40	158.03	32	35.3
Arunachal Pradesh	677	1341.38	152	104.605	13	10.45
Chattisgarh	200	1107.15	10	76	04	91.25
A P & Telengana	367	978.4	71	232.98	14	40.94
Madhya Pradesh	299	820.44	11	86.16	03	4.9
Maharashtra	274	794.33	64	346.175	05	30.35
Kerala	245	704.1	31	205.2	12	72.75
Tamil Nadu	197	659.51	21	123.05	0	0
Uttar Pradesh	251	460.75	09	25.1	1	1.5
Punjab	259	441.38	54	170.9	4	4.75
West Bengal	203	396.11	24	95.5	17	84.25
Orissa	222	295.47	10	64.626	04	3.6
Sikkim	88	266.64	17	52.11	01	1.5
Assam	119	238.69	06	34.11	03	12
Meghalaya	97	230.05	04	31.03	03	24.2
Bihar	93	223.05	29	70.7	13	26.9
Jharkhand	103	208.95	06	4.05	08	34.85
Gujarat	292	201.97	06	16.6	09	57
Nagaland	99	196.98	12	30.67	02	2.2
Mizoram	72	168.9	19	41.47	02	04
Haryana	33	110.05	09	73.5	00	00
Manipur	114	109.13	08	5.45	03	2.75
Rajasthan	66	57.17	10	23.85	00	00
Tripura	13	46.86	03	16.01	00	00
A&N Islands	7	7.91	01	5.25	00	00
Goa	6	6.5	01	0.05	00	00
Total	**6454**	**19749.44**	**1075**	**4320.036**	**231**	**789.23**

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Small hydro power plants play the crucial role in meeting power requirements of the people living in remote mountainous regions where providing electricity through conventional grid is difficult. In India, the present scenario of small hydro potential, installed capacity and the project under implementation is given in Table IV.

There is significant potential for the development and up-gradation of watermills and micro/pico HPP (upto100kW) in India. There are large numbers of watermills in hilly areas. These traditional watermills are operating at very low efficiency around 15-20%. At present, total installed capacity of SHPP in India is around5000 MW which is around 22% of the total available capacity. Work on around 1000 MW capacity of small hydro power projects is underway which amounts to 4% of the total capacity and rest 74% small hydro potential is unutilized till date. So, favourable policies and technologies are required to converts vast small hydro potential into useful electricity. The Fig. 2 shows the current status of development of SHPP in India.

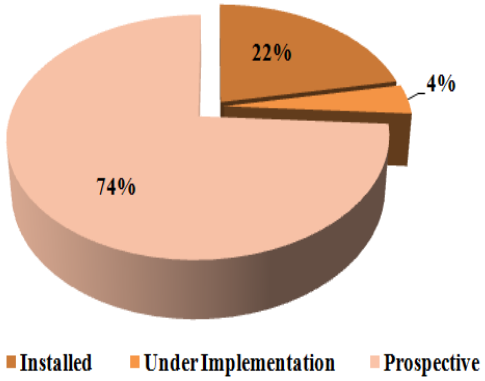

Fig.2. Current Status of SHPP in India

A. Growth of Small Hydro Power Development in India

In India, there is rapid growth in power generation through SHPP. In year 2010 additional 395MW highest SHPP power was installed in last ten years The Fig.3 shows the year-wise and cumulative installed growth of SHPP power generation in India.

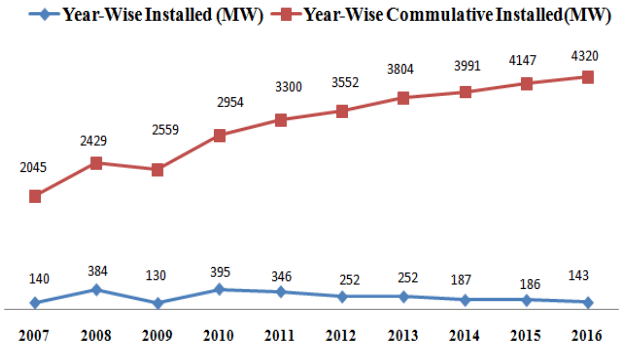

Fig. 3. Year-wise and Cumulative Installed Capacity of SHPP in India

A number of mini/micro HPPs are set up in remote and isolated areas many in Himalayan region. These projects are developed and maintained with local community participation along with the support from various state agencies

IV. TECHNICAL CHALLENGES ASSOCIATED WITH SMALL HYDRO POWER PLANTS

The main technical challenges associated with SHPP power generation are selection of small hydro turbine (SHT), hydro generator (HG) i.e. synchronous generator (SG) or induction generator (IG), grid connectivity, quality and reliability of SHPP to deliver the electricity to consumer at economical rates.

A. Selection of Small Hydro Turbine

Small hydro turbine (SHT) is selected on the basis of techno-economic considerations of generating equipment, powerhouse cost and relative advantages of power generation of SHPP. The SHT manufactures have developed

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standard turbine designs, which may be effectively employed in SHPP. Factors like head, discharge variations, load variations, efficiency, turbine setting, pressure rise& speed regulations considerations and maintenance considerations determine the type of turbine [10]-[16].

On the basis of available head, the SHPP are of three type; high head (>50m), medium head (10-50m) and low head (<10m). Another classification is based on the type of control used in turbines. These are uncontrolled hydro turbines as used in constant power input hydro turbine or controlled hydro turbines. In case of uncontrolled hydro turbine, the input power to the turbine is fixed due to constant water discharge and head.
The brief classification of small hydro turbine on basis of head and specific speed is given in Table V.

TABLE V CLASSIFICATION OF SMALL HYDRO TURBINES

Turbine Type	Turbine Name	Head (m)	Specific Speed (RPM)
Impulse	Pelton	50-1770	8.5-47
	Turgo	50-250	30-85
	Multi-Jet-Pelton	40-450	15-40
	Cross flow	3-250	20-200
Reaction	Francis	10-300	85-188
	Propeller	2-40	15-200
	Kaplan	2-40	12-400

B. Selection of Hydro Generator
Small/mini hydro power plant (HPP) uses the synchronous generator (SG) for electrical power generation which is coupled with small hydro turbine. The power is transmitted nearby substation by changing the level of voltage of grid. The schematic representation of Small/Mini hydro power plant with grid-connected scheme is shown in Fig.4

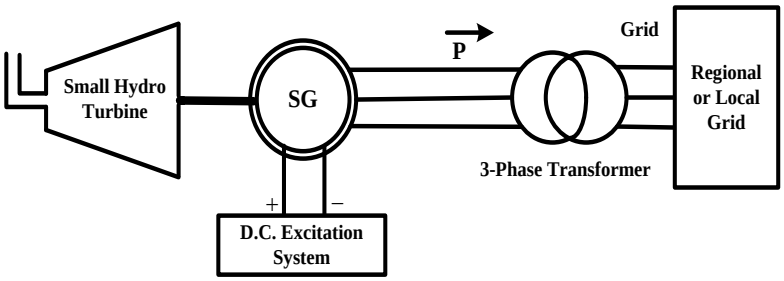

Fig.4. Schematic Diagram of Grid- Connected Small/Mini HPP

Another option in hydro power plants especially the micro/pico hydro power plant (HPP) is of induction generator (IG) for power generation [10]-[12]. Induction generators are preferred where there is a constant input power available with fixed head and uncontrolled hydro turbine with fixed water discharge. The frequency of induction generator is function of consumer load. This type of scheme is also known as isolated SHPP scheme which requires intelligent controller to control voltage and frequency of IG. The schematic representation of isolated Micro/Pico hydro power plant is shown in Fig.5.

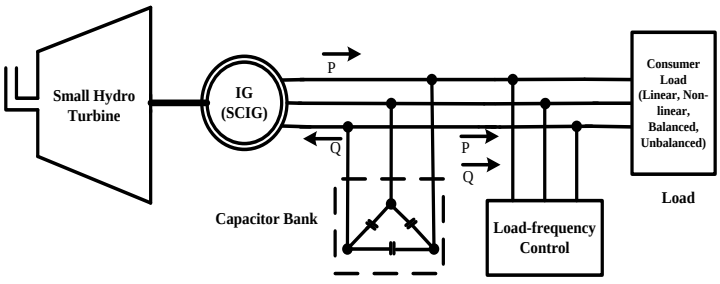

Fig.5. Schematic Diagram of Isolated Micro/Pico HPP with Load-frequency Control

This type of scheme is generally used for electrification of remote rural area. For isolated operation of SHPP load forecast is necessary.

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C. Standard of Various Equipments for SHPP

In order to ensure SHPP quality and performance, the MNRE has been insisting to adhere to IEC/International standards for equipments and civil works. It is essential for all the SHPP developer to conform the following IEC standards during the developing stage of project.

The various standards used for SHHP equipments is given in Table VI.

TABLE VI STANDARDS FOR VARIOUS EQUIPMENTS USED IN SHPP

Equipment	Standard
Turbine and Generator (Rotating Electrical Machine)	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 for Hydraulic Turbine	IEC 60308
Transformer	IS 3156-1992 IS 2705-1992 IS 2026-1983
Inlet Valves for Hydro Power Stations & Systems	IS 7326-1902

V. POLICIES RELATED TO SMALL HYDRO POWER DEVELOPMENT IN INDIA

The ministry of renewable energy (MNRE) has established Alternative Hydro Energy Centre (AHEC) at IIT Roorkee in 1982 to promote power generation through development of SHPP in hilly as well as in plain area and for undertaking various research and development (R&D) work for SHPP development. A Real Time Digital Simulator for SHPP has been developed and installed at AHEC, IIT Rookree under the GOI/UNDP-CCF-II RERL programme with objective of providing training to operators and technical staff of various SHPP.

The present focus of the SHPP programme is lower the cost of equipment, increases its reliability and set up projects in the area that gives the maximum advantages in terms of capacity utilization. The SHPP are being setup both in public and private mode. In consent of Government of India, 24 states have announced their policy for inviting private sector to setup SHPP about 2389MW out of 4320MW capacity was installed by 416 private sectors (as on 31.01.2017). The MNRE has taken the various steps to promote development of SHPP in the planned manner and improve reliability & quality of projects.

In Himachal Pradesh, the state Government has taken the several initiatives to encourage private sector participation in SHPP development. State Government continuously refining the various procedures/ processes to minimize the bottlenecks and state stared the process of exploitation of small hydro potential through private sector participation began during 1995-96. The all the SHPP up to 5MW are handled by HIMURJA in two modes viz: project identified by HIMURJA and IPPs designated (Self identified projects). SHPP up to 2MW capacity shall be exclusively reserved for the Himachalis, whereas while allotting the SHPP up to 5MW capacity, additional 30% marks shall be given to Himachalis. Maximum SHPP of Himachal Pradesh in private sector is commissioned under UNDP-GEF programme. The watermills have the potential to meet the power requirements of remote area in isolated mode.

The MNRE revised the scheme to support micro HPP and watermills in July, 2014 by relaxing terms and conditions, as a result of which some states like Uttrakhand, J&K and Karnataka show considerable interest to take up this activity. About 2460 upgraded watermills (upto5kW) have been installed in Kerela, Karnataka, J&K, Tamil Nadu and Uttarakand. Isolated operated micro/ pico hydro power plants directly benefiting in remote and hilly areas of Himalayan & sub-Himalayan region of India. About 200 micro hydro projects are also installed by the state nodal departments/agencies mainly Uttarakand and Arunachal Pradesh [17]-[18].

A. Incentives for Small Hydro Power Development in India

MNRE is providing financial supports to states of India for development of SHPP. There is incentive for different activities such R&D capacity building, recourse survey (RS), details survey & investigation (DSI) and renovation & modernization of SHPP in state Govt. sector to develop SHPP sector in India are given in Table VII.

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TABLE VII INCENTIVES/SUBSIDIES SCHEMES TO DEVELOP SMALL HYDRO POWER

Type of Activities	States	Capacity of SHPP	Incentives
DSI & Preparation of DPR	All States	Up to 1MW	Rs. 6.00lakh
		Above 1MW	Rs. 10.00 lakh
New SHPP in State Govt. Sector	Special Categories States (N.E. States, J&K, H.P. and Uttarakhand)	100kW – 1000kW	Rs. 75,000 per kW
		1MW-25MW	Rs.7.5 Crores/MW limited to Rs. 20.00 Crore per SHPP
	Others States	100kW – 1000kW	Rs. 35,000 per kW
		1MW-25MW	Rs. 3.5 Crores/MW limited to Rs. 20 Crore per SHPP
New SHPP in Private/Co-operative Mode	Special Categories States (N.E. States, J&K, H.P. and Uttarakhand)	0.1MW-25MW	Rs. 1.5 Crores/MW limited to Rs. 5.00 Crore per SHPP
	Others States		Rs. 1.00 Crores/MW limited to Rs. 5.00 crore per SHPP
Renovation & modernization of old SHPP in Public Sector	All States	Up to 1000kW	Rs. 10,000 per kW
		Above 1MW-25MW	Rs. 1.00 Crore/MW limited to Rs. 10.00 Crore per SHPP

VI. CONCLUSION

Harnessing of renewable energy sources is essential to meet the ever increasing electricity demand and also to minimize the impact on environment by reducing the use of conventional sources of energy. Among various renewable energy sources, small hydro power plants play a crucial role in meeting power requirements of people living in remote mountainous regions in isolated mode. This paper has highlighted the various technical aspects of small hydropower plants. An overview of the small hydro power potential and its harnessing in India has been presented in this paper. The various policies and agencies enacted by Govt. of India to boost the small hydro power sector have been presented in this paper and as per these policies, Govt. of India along with various state governments are providing lot of incentives to boost the harnessing of vast small hydro power potential available across the country.

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Before joining the teaching profession, he has an industrial experience of about 5 years in leading MNC as an Electrical Engineer. During his tenure in industry, he handled installation, operation and maintenance of Electrical and Instrumentation Systems in the process industry. There he also had a working experience on PLC, SCADA and DCS based automation systems. Presently he is working as Head of Department (Electrical) in the Department of Technical Education, Government of Himachal Pradesh. For the last 18 years; he has been teaching the Electrical, Electronics and Instrumentation related subjects in the Departments of Electrical, Electronics & Communication; and Computer Engineering. He is also having published many research papers in reputed international journals & conferences. He has also authored four books in electrical & instrumentation engineering subjects.
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