Hydrokinetic-Solar Hybrid Floating Renewable Energy Generation System to Explore Hydro and Solar Power Potential Worldwide

Balram Bhardwaj
Director, Research and Development
MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.
New Delhi, India
contact@maclec.com

Narayan Bhardwaj,
Innovative CMD
MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.
New Delhi, India,
bhardwajtheboss.1990@gmail.comk

***Abstract*— Energy is one of the most important building blocks in human development, and as such, acts as a key factor in determining the economic development of all the countries. In an effort to meet the energy demands, non-renewable resources are significantly depleted by human use and use of renewable resources of energy is rapidly increasing worldwide as they can sustain indefinite human exploitation. The Solar power, one of the potential energy sources, is a fast developing industry in India but only through exploiting solar energy, India cannot become energy surplus due to the limitations of Solar Power in terms of availability, technological efficiency and economical feasibility. Therefore it is need of the hour to explore promising sectors of renewable energy and among the promising sectors, Hydro power sector is the most suitable. Surface water Velocity Driven Hydrokinetic Turbine Technology "VARUN-III", Product of MACLEC, generates electricity directly from water velocity, without making dam or any civil structure. VARUN-III is hybrid of Solar PV System and Hydrokinetic Turbine installed in a single floating platform which allow it to harness electricity from running water as well as from sunlight. Installation of Solar on the floating structure of hydrokinetic Turbine VARUN-III save land cost, reduce installation and power transmission cost apart from it easy availability of water facilitate O&M of Solar. First pilot of Solar Hydrokinetic Hybrid have been installed successfully at Upper Ganga Canal in collaboration with Government and results are encouraging.**

Keywords- Energy; economic; hydrokinetic; industry; solar; structures.

I. INTRODUCTION

Non conventional energy resources are numerous and their identification, exploration and exploitation paved the way for their commercialization. Green energy resources such as solar, wind, small hydro, geothermal, biomass, etc technologies which seem promising and efficient; contains various conditions related to their utilization and energy yielding capabilities. To meet the country's target of producing renewable energy of 175 GW by 2022, the hydro power sector can contribute majorly as India have the total potential hydropower is 1,48,704 MW, of which 84% is concentrated in the Himalayan Regions states[1]. But utilization of this Hydro power potential does not possible without making Dam or Reservoir or Head based hydro power plant installation. Building large hydro dams is very costlier as the large hydropower projects include Sardar Sarovar project [2] and Maheshwar Project [3] in Narmada valley in Madhya Pradesh, etc. are witnessing displacement of thousands of people from their ancestral place, destroying their livelihoods and violating human rights in the name of development leaving them with no alternatives. After so many years of the struggle, thousands of displaced people from above projects still waiting for justice in these valleys. Apart from anthropogenic loss, these projects permanently destroyed the local environment and contributed in global warming by engulfing major chunk of forest. The only way forward in order to save rivers and reduce the current rate of ecological degradation is to switch towards alternate hydro energy generation technologies in which without making any civil structure, electricity can be generated through hydro turbines [5].

Many researchers are working in order to explore and exploit waste potential of marine and hydrokinetic (MHK) renewable energy resource as it has the potential to provide a significant contribution to the Global Renewable Energy Demand. Sustainably operate, Scientifically optimize, and develop hydropower in a manner that maximizes opportunities for low-cost, low-carbon renewable energy production, economic feasibility, and environmental stewardship to provide long-term benefits for the whole world are the major goals behind continuous exploration in the field of kinetic hydro [6].

According to Hydro Kinetic Turbines Market Forecasts from 2018 to 2023 report, recoverable potential of hydrokinetic energy resources is about 10% of today's electric consumption in the developing countries. hydrokinetic Turbine Market still in its initial phase, offering early bird advantage to companies with viable & cost-effective technologies[8].

II. Proposed Technology

Canal top Solar Power Plants are one of the most innovative alternatives to harness renewable energy without acquiring additional land. Apart from saving valuable land, canal top Solar have many additional advantages such as reduction in evaporation loss from canal surface, temperature controlling of Solar plats and ease in maintenance due to readily available canal water for rinsing of Solar panel surface. But the low efficiency of Solar power plant is a shortcoming due to which it acquire very large area to install arrays of Solar Plates to produce adequate power. Another shortcoming is the dependency of solar power plant over sunlight to produce electricity [7]. To overcome the above said shortcomings and also to enhance the overall productivity of Canal Top Solar power plant, hybridization with Hydrokinetics, a technology which produces electricity using only surface velocity of flowing water body. Combination of Canal roof top Solar- Canal Surface Hydrokinetic system enable to produce thrice the power produced by any ordinary canal top solar power plant.

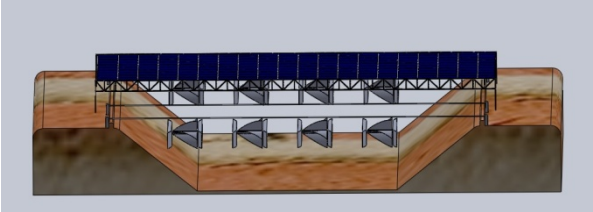

Figure 1, 3D Layout of Solar Hydrokinetic Hybrid Power Plant.

Proposed hybrid solution have following two major components-

A. Surface Water Velocity Driven Hydrokinetic Turbine "VIKALP-I"

The VARUN-IIIprovide most cost effective alternative to generate electricity from running water without civil structure like dams/reservoirs. No environment impact, no harm to aquatic life, no disturbance or changes in natural course of river/canal. Disclosed Technology is fulfill off-grid, on-grid electric need to all lower income group members (farmers, villagers, tribes) living nearby flowing water body to insure overall development and inclusive growth from top till bottom of the social pyramid. All small-medium enterprises and organization's energy need can also be fulfilled through installing VARUN-IIIcaptive power plant .

Proposed Technologies are designed & developed indigenously and tested at numerous sites to evaluate its efficiency and reliability in natural site environments. Conducted tests, simulations, mathematical modeling and efficiency assessment suggested that these state of the art technologies can act as clean & sustainable energy technology without harming the environment and community.

Table - 1, Salient Features of VIKALP-I

S/No.	Feature	Specification
1.	Minimum Required Velocity	0.5 meter/second
2.	Minimum Required Water Depth	0.4 meter
3.	Minimum Required Width of Water body	1 meter
4.	Minimum feasible size	1 kW
5.	Maximum Feasible size of single module	100 kW
6.	Installation mode	Floating type
7.	Compatible water quality	Water with silt, clay, sand, floating garbage, etc.
8.	Power Output	Single Phase/Three Phase
9.	Voltage Output	Customized
10.	Installation Compatibility	Grid-connected & Off-grid
11.	Approx. CAPEX	US$ 1400/kW
12.	Approx. OPEX	US$ 30/kW/Yr.
13.	Working Life	> 35 years
14.	Scheduled Maintenance	In every 5 years
15.	Approx. LCOE	US$ 0.018/Unit
16.	Approx. PLF	> 90%

B. Solar PV Power Plant

Solar Photovoltaic (PV) energy is considered to be one of the most promising renewable energy generation source in the world due to its ubiquity and sustainability[9]. However, installation of solar panels on valuable land can cause some problems, especially in some over populated countries (India, China, etc.) where there is not enough space for installation[11].

Figure 2, Glimpse of India's first Canal Top Solar PV Plant installed in Gujarat.

As sustainable alternative, floating PV and Canal top PV plants emerges with many advantages in terms of efficiency and environment, has attracted attention, particularly with

Identify applicable sponsor/s here. If no sponsors, delete this text box. (sponsors)

regard to installing large-scale floating PV for Canal Top, dam catchments and reservoirs[10].

III. Technical Advantage of VIKALP-I

The novelty of proposed VARUN-IIIHydrokinetic Turbine system for Hybridization with solar is of tapping the surface velocity of the flowing stream and turbine is not submerged in water completely which has been attempted first time. Therefore, it can also be installed on shallow streams. The turbine, generator and other equipment are fitted on a floater and anchored at the banks of the stream through steel ropes. The floater can be adjusted according the water level in the stream without changing its installation. This attempt is the first of its kind in India. Regarding cost of the turbine it has been aimed that the equipment cost may be at par the cost of conventional micro turbines cost after development.

Figure 3, 5 kW Prototype of the Proposed technology installed at upstream of Upper Ganges Canal, Uttarakhand.

The technology disclosed herewith is a type of cross flow turbine module with specially designed blade profile which is specially carved to interact with the flow of water without much disturbance in streamline flow. That is why installation of VARUN-III turbine on the surface of free flowing streams in floating condition does not create much hurdle and allow water stream to cross the turbine after revolving along with the flow.

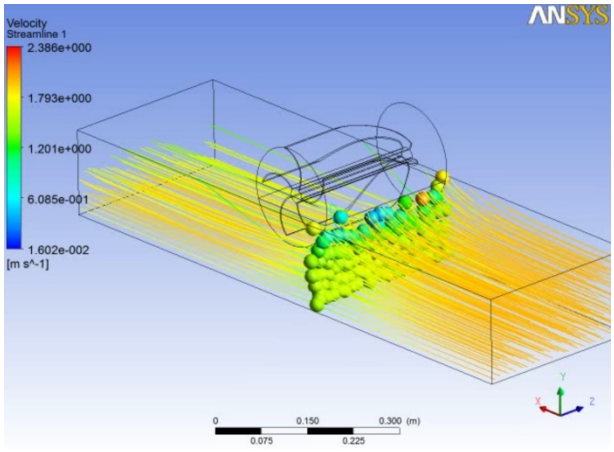

Figure 6, CFD analysis of VARUN-III Turbine in partially submerged state under streamline water velocity range of 1.6 meter/second to 2.5 meter/second.

CFD Analysis of VARUN-III describes that the streamline water flow reacts with the turbine blade at particular angle and transfer fraction of kinetic energy available with the flow to turbine rotor and rotate it. Velocity contours plots predict the variations in velocity in various regions near the turbine blades within the flow domain. Velocity Contours of VIKALP- I turbine are shown in Figs 6. It is seen from velocity contours that the maximum velocity has been noticed at the tip of end blade. Moreover, low speed zone (wake zone) has also been observed in the downstream of channel.

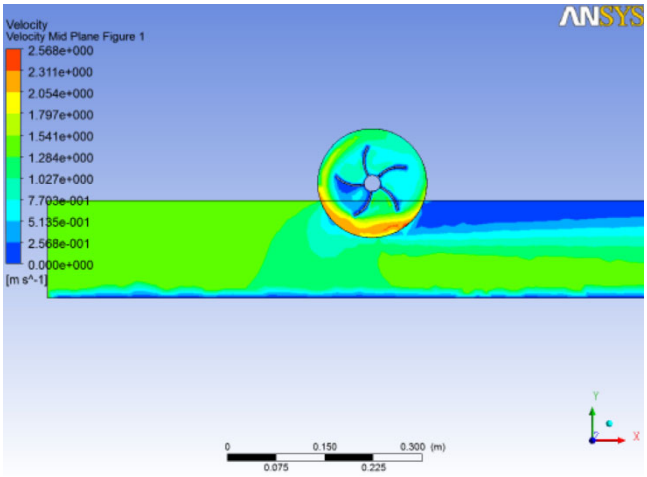

Figure 6, Velocity contours plot of VARUN-IIITurbine,

IV. Effeciency of VARUN-III

VARUN-III Turbine module were tested in various field locations to determine the coefficient of power (Cp) for different velocities and then CFD simulation have been performed to validate the obtained results. Thereafter the results obtained from field trial and CFD analysis both were compared to find out the variation of Cp with TSR for different velocity (Fig. 7) The maximum value of Cp is found to be as 0.462 at V= 0.76 m/s.

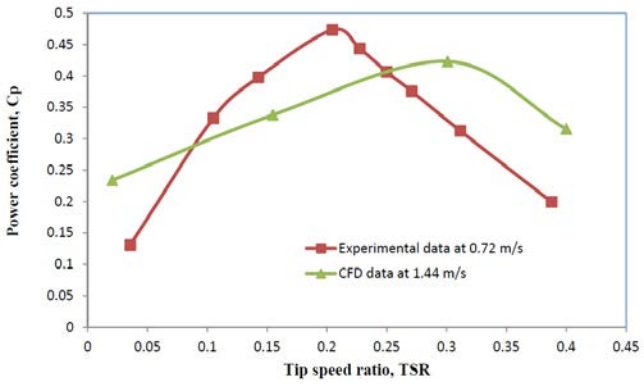

Figure 7, Comparison of CFD and experimental results of VIKALP-I

V. Scope of Solar Hydrokinetic Hybrid

Under favorable conditions any Solar PV plant yield average electricity only in day light hours and rest of the time remain idle but the proposed hydrokinetic power plant can yield electricity throughout the day till the time adequate flow of water is available. There are thousands of kilometer canal stretch available in India where VARUN-III hydrokinetic turbine modules can be installed and the floating platform of the installed module can be utilized as

base to install Solar PV modules. By installing hydrokinetic with solar PV modules will have following advantages

- There is no civil engineering intervention or diversion of flow from the mainstream to separate channel. In that sense, this form of hydro power development is the least interference with the nature.
- Utilization of VARUN-III turbine module's Floating structure eliminate additional land required to install any other major civil structure as earlier required for Solar PV Plants.
- Only the upper part of the flow of the canal participates in the rotating motion of the turbine. Therefore, the flow depth requirement is quit less say 0.5 to 1 m depth which made VARUN-IIITurbine module useful to harness electricity even from shallow streams

VI. Opportunity

Worldwide as well as in India itself, approximately 85% of total energy production is from Non Renewable Resources, approximately 10% is from renewable energy sources, and the remainder is from nuclear sources [16]. Because of emerging concerns and global consciousness about the diminishing reserves of fossil fuels, increasing atmospheric Green House Gases concentration, global warming, ocean acidification, and other effects from fossil fuel consumption, non-fossil-fuel sources are increasingly of interest—renewable sources in particular. The kinetic energy in moving waters along with Solar Energy, available abundantly in sunlight are such renewable energy source which can fulfill energy requirements of billions. Perennial rivers, Irrigation Canal Networks and hilly streams contain most of the world's kinetic hydro energy, and the flow speeds of these water bodies are sufficiently high in many locations that some fraction of this energy could be extracted for electrical power production.

Figure 8, Area View of VARUN-III Turbine Module installed in floating condition.

Hydrokinetic energy is currently being harnessed from ocean waves and simultaneous tidal currents in certain locations throughout the oceans [12], but commercial-size power plants have yet to be engineered and installed in any large-scale ocean currents[13][14], even though the available potential for generating hydro kinetic power from the Gulf Streams has a long history of study[15].

The proposed concept of surface turbines in hybridization with Solar PV Modules is need of hour in view of its application to harness power at community level as well as Megawatt Scale provide nonpolluting energy security to remote areas where grid power is not available making Renewable Energy More Affordable, Sustainable, Technically feasible even in running waters and viable even as off-grid/micro grid/ decentralized stand alone power plant. Enhancing the existing Renewable power generation capacity without compromising with environment, ecology and social issues is the biggest problem. Conventional dam based hydro power plant development need to construct dam/reservoir and installation of Mega Solar PV Plants also required the huge land mass which forced the authorities to acquire valuable land at the cost of rehabilitation of thousands of families, permanent destruction of forest and wildlife. That is why now government have imposed many policies, laws and regulations which ultimately make it tough to build any Renewable Energy Power plant.

VII. Conclusion

Hydrokinetic power is clean, green, sustainable and also a cheap source of power in the long run amongst all other alternatives to generate renewable energy. Implementation of hydrokinetic Turbine installation along with Solar PV in hybridized form could bring revolution in renewable energy market due to its inherent benefits described in this research paper. Conventional thermal Energy generation units are dependent on fossil fuel supplies, which are limited and may not last long, whereas hydro power, precisely hydrokinetics in this context, is a renewable source of energy with no any environmental impact because conventional hydro power has a long gestation period and needs huge upfront capital cost, but proposed Hydrokinetic hybrid power plant can be installed as quickly as possible and can have much longer life and is free from fuel cost which significantly makes it cheapest in the long run.

According to India’s Nationally Determined Contribution (NDC) commitments at COP-21 held at Paris in 2015, India has to reduce the emissions intensity of its GDP by 33 to 35% by 2030 from 2005 level. mainly through achieving 40% share of renewable in the total electricity generation mix and creating additional carbon sinks of 2.5 to 3 billion tonnes of CO2 equivalent by replacing environment friendly means of transportation, etc. that is why the proposed hybrid model can bring a significant change in current renewable energy installation scenario through making it possible to explore and exploit huge hydrokinetic potential lying unexploited till today because of unavailability of Economically Profitable, Technically Feasible, Environmentally Sustainable and Socially Acceptable technology.

Acknowledgment

The authors would like to thank Prof. R. P. Saini, Hydro and Renewable Energy Department, Indian Institute of Technology for their technical support and mentoring.

REFERENCES

[1] FORTY THIRD REPORT, STANDING COMMITTEE ON ENERGY (2018-19) (SIXTEENTH LOK SABHA) MINISTRY OF POWER, Hydro Power, *Presented to Lok Sabha on 04.01.2019, Laid in Rajya Sabha on 04.01.2019*

[2] H. Upadhyay, J. Goyal, "PERFORMANCE AND DEVELOPMENT EFFECTIVENESS OF THE SARDAR SAROVAR PROJECT", a report by TATA INSTITUTE OF SOCIAL SCIENCES (A Deemed University), 2008

[3] R. K. Grover, R. K. Tripathi, R. Chandak, H. K. Mishra, "Probabilistic Seismic Hazard Assessment at Maheshwar Hydel Project Dam Site", Journal of Engineering Research and Application www.ijera.com ISSN : 2248-9622, Vol. 7, Issue 8, (Part -1) August 2017, pp.30-37

[4] Marcus W. Beck, Andrea H. Claassen & Peter J. Hundt (2012): Environmental and livelihood impacts of dams: common lessons across development gradients that challenge sustainability, International Journal of River Basin Management, DOI:10.1080/15715124.2012.656133G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. (references)

[5] Badger, Andréa René, "Technology assessment of hydrokinetic energy: Run-of-river and in-stream tidal systems" (2011). Masters Theses. 141

[6] Ayodele, T. R., A. A. Jimoh, J. L. Munda, J. T. Agee, and G. M'boungui. "Economic analysis of a small scale wind turbine for power generation in Johannesburg." In Industrial Technology (ICIT), 2013 IEEE International Conference on, pp. 1728-1732. IEEE, 2013.

[7]

[8] Fundamental Properties of Solar Cells, Principles and Varieties of Solar Energy, January 10, 2012 The University of Toledo, Department of Physics and Astronomy SSARE, PVIC

[9] Global Hydrokinetic Converters Market Report 2019 Latest Trends, Market Overview, Growth and Analysis Research Report, 2019

[10] Galdino, M.; de Almeida Olivieri, M.M. Some Remarks about the Deployment of Floating PV Systems in Brazil. J. Elec. Eng. 2017, 5, 10–19.

[11] Oh, M.; Park, H.D. A new algorithm using a pyramid dataset for calculating shadowing in solar potential mapping. Renew. Energy 2018, 126, 465–474.

[12] Patil, S.S.; Wagh, M.M.; Shinde, N.N. A Review on Floating Solar Photovoltaic Power Plants. Int. J. Sci. Eng. Res. 2017, 8, 789–794.

[13] Doran C. 2015. Power from the sea. *J. Homel. Def. Secur. Inf. Anal. Cent.* 2:3–6

[14] Neary V, Lawson M, Previsic M, Copping A, Hallett KC, et al. 2014a. Methodology for design and economic analysis of marine energy conversion (MEC) technologies. In Proceedings of the 2nd Marine Energy Technology Symposium, April 15–18, 2014, Seattle, WA. http://www.globalmarinerenewable.com/images/pdf/METS_PAPERS_VII/90-Neary.pdf

[15] BOEM (Bur. Ocean Energy Manag.). 2016. Ocean current energy. http://www.boem.gov/Renewable- Energy-Program/Renewable-Energy-Guide/Ocean-Current-Energy.aspx

[16] Hanson HP, Bozek A, Duerr A. 2011. The Florida current: a clean but challenging energy resource. Eos Trans. AGU 92:29–36

[17] EIA (Energy Inf. Admin.). 2016. Frequently asked questions. http://www.eia.gov/tools/faqs

BIOGRAPHICAL INFORMATION

Mr. Narayan Bhardwaj & BalRam Bhardwaj

Mr. Narayan and BalRam Bhardwaj are the founders of MACLEC Laboratory with a vision to innovate the present technology scenario. They are the pioneers of surface water velocity driven hydrokinetic turbine technology in India. Since last 10 years they both are working as a freelance engineer service providers and R&D guide for many Government and private institutes, individuals and students. Their research spanning over 6 years has been on engineering behavior of non-conventional energy technologies particularly in hydrokinetics, Microbial Fuel Cells, mono crystalline/polycrystalline Solar PV Technology, Robotics, Kinematics, prototype manufacturing, etc. They have been the Associate investigators of 3 sponsored research projects and carried out more than 1300 consultancies in the areas of green energy, robotics, kinematics, solar incinerator and Embedded Technologies.