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Centrifugal Pump as Turbine for Micro-Hydro Power Scheme in Rural Areas of India: A Review

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Abstract : In global scenario electrification to rural areas, estimates huge initial capital cost especially in operating turbine. In order to satisfy the needs of power demand, a suitable and attractive alternative of using centrifugal pump as turbine is reviewed in this paper. Micro-hydropower projects are the excellent alternative for electricity generation perceptible effect on environment. The action of centrifugal pumps as centripetal turbines can be useful to yield cheap energy in rural zones of developing nations. This study would be very helpful for the performance calculation and selection of centrifugal pump working as turbine. This review encompass on centrifugal pump acting as turbine has been explained on the literature survey through theoretical, experimental and computational works on pump as turbine.
Keywords : Pump as turbine, Rural areas India, micro-hydro power scheme, turbine.

Introduction

Micro-hydropower applications can provide cost-effective solutions for the energy generation in rural, remote and hilly areas of India. Energy plays an important role in almost all areas of human and commercial activities. From economic point of view, energy is very important input for developing countries like India. Micro-Hydropower is a non-polluting, non-conventional, and being source of energy. Hydropower contributes to around 16 % of the world electricity supply generated from about 20,053 TWh of installed capacity and in many countries; it is the main source of power generation. In India hydro power share decreased from 50 % in 1963 to 26 % in 2005, which has been further reduced to about 18 % in 2015.

In rural areas, generation of electricity through the non-renewable sources is quite common. A large number of thermal power plants are running throughout the world for electricity generation. The fast depleting nature and increasing prices of petroleum products like coal, oil, gas, etc. are the major complications in fulfilling the power demands from these sources. Economic development through renewable energy and sustainable energy sector create more employment, which leads to social development of the nation.In India, there is a huge network of irrigation canals on which number of falls is available where energy is just wasted in the formation of hydraulic jumps. Many of our researchers' was not attracted towards this natural penstock in form of water streams which can be able to operate mini and micro hydro power plants.

The Ministry of Non-Conventional Energy Resources, Government of India has distinguished more than 6000 watercourses in north and north-eastern areas of India, that are not appropriate for installation of large scale hydro power plants but which are promising for electric generation power in the range of 1-100 kW.

The running cost for hydro scale are very low, but the initial capital cost are high especially the cost of turbines. In order to minimize the basic capital cost and the payback period, the pump as turbine (PAT) is often chosen to replace the conventional turbine. Using pump as turbine is an attractive and significant alternative 31. One of the cheap and attractive alternatives in small water power resources is using pumps in reverse operation. Pumps are relatively simple machines, easy to maintain and readily available in most developing countries. Pumps with high technological standards in reverse operation can compete with conventional turbines in respect to maximum efficiency. Hence, the present studies being focussed on the aspects of theoretical, numerical and experimental investigation of pump as turbine and providing modifications, commercial pump i.e. PAT will provide suitable alterative for micro-hydro power schemes in rural areas of India. Nor F. Yah et al., 2017 provided information on small hydro schemes and its application for rural electrification.

History of pump as turbine:

Thoma & Kittredge, 1931 done complete characteristics of pumps-accidentally -pumps could operate very efficiently in the turbine mode. Knapp, 1941 published the complete pump characteristics for a few pump designs based on experimental investigations. Fernandez et al., 2004 contributes in advances of electrical machinery control technologies, rotation sense and torque. Rawal & Kshirsagar, 2007 investigated on water supply networks applications - standard manufactured pumps were studied in turbine mode. Agostinelli & Shafer, 2013 tested many pumps in turbine mode over the years and concluded that when a centrifugal pump operates in a turbine mode; its mechanical action is quiet smooth. P.Vasanthakumar et al., 2014 made review on pump as turbine and reported selection of proper PAT for different sites.

Theoretical PAT:

Williams 1994 predicted a study on comparison of eight different PAT. The test results on 35 pumps of various types and sizes were compared. Derakhshan and Nourbakhsh, 2008 reported a theoretical study to calculate the best efficiency point for centrifugal pump of industrial type running as turbine. Derakhshan et al., 2009 derived a new conversion factors method to predict the BEP of a PAT based on pump‘s hydraulic specifications. Singh and Nestmann, 2010 investigated and developed an optimization routine for the radial flow centrifugal pumps working in turbine-mode operation to improve its reliability. Singh and Nestmann, 2011 reported an analytical model to study the rounding of the sharp edges at the impeller boundary on a combination of mixed flow and radial centrifugal pumps as turbines using experimental method. Also, recommended the standardization of the rounding effects to axial pumps.

Numerical PAT:

Rodrigues et al., 2003 worked on CFD- pump casing, inlet and outlet zone, impeller diameter and draft tube - variation 10 % for part load condition. Natanasabapathi & Kshirsagar., 2004 predicted the results on structured grid interface provide a good resolution to minimize errors. Rawal & Kshirsagar., 2007 made numerical analysis on axial type pump. The numerical system was quite supportive on impeller, casing, draft tube and flow pattern. Derakhshan & Nourbakhsh., 2008 simulated on centrifugal pump (NS = 23.5 (m, m3/s)) using CFD in direct and reverse modes. Nautiyal et al., 2010 noted that CFD study was an efficient simulation tool for calculating the performance of centrifugal pumps in turbine mode and to categorize the losses in turbo components like casing, draft tube and impeller.

Barrio et al., 2010 suggested that CFD- commercial centrifugal pump working in forward and reverse direction mode. The outcomes of mathematical simulation were good and agreed with the experimental results. Fecarotta et al., 2011 Concluded, CFD study was reliable tool for better understanding the interaction between hydro-mechanical components and flow performance irrespective of complex computation. Agarwal, 2012 CFD is an efficient design tool for predicting the performance of centrifugal pumps operating in turbine mode. The results from numerical and experimental investigation do not match exactly in case of PAT. It was recommended that the variation can be minimized through development in computational study by using fine grid, numerical methods and turbulence models. P.Vasanthakumar and A.Arulmurgu., 2015 provided complete numerical details for selection of centrifugal pump as turbine for micro-hydropower plants. When the centrifugal pump was operated in reverse mode, the efficiency of turbine is attained up to 35.45% and maximum power output of 17.78KW in the radial flow pump. The BEP of centrifugal pump operated in pump mode was observed as 70% that to turbine mode was 35.45%.

Experimental PAT:

Chapallaz et al., 1992 experimented on conversion factors involved in PAT. Based on the pump specific speed, conversion factor graphs were generated. Fernandez et al., 2004 experimented on turbine characteristics can be predicted from the pump behaviour. The operating curves were obtained for PAT mode with same head and speed. Joshi et al., 2005 summarize the case study of a micro hydro power plant capacity of 25 kW with 5.5m of gross head. The derived correlation equation between pump specific speeds and turbine helps in selection of pump. Derakhshan & Nourbakhsh .,2008 derived correlations to compute the best efficiency point of a PAT based on hydraulic pump. An industrial type centrifugal pump of specific speed ranges from 14-56 (m, m3/s) were experimentally tested. Suarda., 2009 noted implementation of PAT was successful one and best replacement for conventional hydraulic turbine. Singh & Nestmann.,2010 experimented study on pumps with different specific speeds. And the errors in the pump head at maximum load were considerably reduced, in particular at PAT low specific speed.

Nautiyal et al., 2011 investigated on centrifugal pump experimentally whose specific speed of 18. The best efficiency in PAT mode was set upto 8.5 % inferior than pump mode best efficiency. The outcome of experiment on the test pump and other pumps were used to attain a new correlation in PAT mode. N. Raman et al., 2013in end suction type pump of 15.3 (m, m3/s) specific speed was tested experimentally, the efficacy of 39 % in turbine mode operation with head and flow of 30 m and 13.52 lps respectively. P.Vasanthakumar et al., 2015 worked on Optimization through electricity generation of pump in turbine mode operation for pico hydropower plants. Ashish Doshi et al., 2017 experimented with different specific speed pumps and three stage impeller rounding in pumps as turbines. Joon-Hyung Kim et al., 2017 provide design technique to improve the energy efficiency of a reversed pump as turbine.

Conclusion:

The current review will provide complete details for selection of centrifugal pump as turbine for micro-hydropower plants in India. The improved performance in PAT through low cost modifications in the impeller and volute casing.Improvement in material properties provides better fluid interaction with casing, impeller, shaft and bearing, to enhance its hydraulic efficiency.With the above modifications, Commercial centrifugal pump ie. PAT will provide suitable alternative for micro-hydro power schemes in rural areas of India.

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