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Pump as turbine for small-hydropower generation a solution to Africa'S energy

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Abstract

Small and mini hydropower systems demonstrate an attractive solution with the help of pump as turbine (PAT) for hydropower generation with lower costs and less impact on the environment. African is having a major challenge in connection with desires for energy. There is the need to increase energy security particularly in the rural areas. The rapid growth of renewable energy capacity in the region contains all the potentials that can answer to quite a lot of these problems. Small-scale hydropower is one of the most cost-effective energy technologies to be considered for electrification in the region since it is economical with other significant benefit if implemented. This paper focuses on the PAT for small-hydropower to Africa since the establishment of widespread small hydropower by the use of PAT can help overcome the current power crisis and play a role in the economic progress of the Region. The paper draws attention on the importance of implementing Pump as turbine for small hydropower development in Africa. It highlights on hydropower potential sites in the region, challenges, the characteristics of pump as turbine has been discussed and draw conclusion on PAT for small scale hydropower development as one of the most cost-effective solution

Keywords: Hydropower, energy, small hydropower, Pump as Turbine, Potential

1. Introduction

Small hydropower systems display an attractive solution with the help of pump as turbine for hydropower generation with lower cost as well as no or minimal environmental impact. The pump-as-turbine (PAT) method is also very good because of low acquisition cost and maintenance cost a swell. The growing demand for energy in Africa is high, this increase demand, coupled with growing awareness of fossil-related negative environmental impacts have sparked new interest in finding alternatives to sustainable energy. Comparable to solar energy, geothermal energy, wind energy, small hydropower has the great potential which can help solve the long-term energy crisis and pollution in Africa. Small hydropower generation does not have a significant impact on large-scale animal and plant as well as human health and leads to the development of large numbers of fish [1]. The cost of construction is minimal. In order to effectively and economically extract small hydropower energy, it is necessary to develop a method suitable for generating small hydropower power in hydraulic presses. As stated by World Bank statistics, over 600 million people In Africa are not connected to modern energy services with Only about 31% out of the entire population having access to electricity access to electricity by rural areas in the continent is very low as can be seen in figure 3. Traditional biomass remains the source of fuel for Most of the people within the rural communities, producing indoor air pollution that causes loss of lives to millions of people every year mostly women and children. The enormous energy resources assets on the continent Africa provide them great opportunities to improve modern energy access. Hydropower especially Small hydropower is anticipated to play a momentous role in the development of

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Africa’s energy sector in future in both urban and rural areas. Small hydropower is perceived as a good choice to increase the contribution of renewable energy in the African energy mix. About 12% of the world’s technically feasible hydropower potential is located in Africa, with the region having the potential to generate over 1,800 TWh of electricity every year. Africa has the lowest electricity consumption in the world for the reason that, the region has poor grid coverage along with a generation deficit. In general, 17 countries in sub-Saharan Africa are the world's top 33 countries. To date, only small portion of Africa's small hydropower potential has been exploited. Renewable energy such as Small hydropower has the potential to meet the energy needs of the entire continent. Quite a lot of African countries, such as South Africa, Egypt, Morocco, Kenya, Senegal, Madagascar, Rwanda and Mali, have adopted national renewable energy targets and imposed tariffs on renewable energy examples include South Africa and Kenya.

1.1. Overview of Africa’s energy situation

Africa's hydropower investment channel highlights the potential for renewable energy expansion across the continent. Hydroelectric power is a very attractive investment in Africa due to its huge potential for hydro power generation, of which 60% are located in Guinea, Ethiopia and the Democratic Republic of the Congo [2]. The total highest SHP potential in the African continent is located in The Eastern Africa region with a total potential of 6,759 MW. With only 216 MW installed capacity in the region. SHP development has been relatively slow. So far, Madagascar, Mauritius, Mozambique, Tanzania, Uganda and Zimbabwe have moderately increased their share of SHP in the generation mix. Western Africa has the second-highest SHP potential in the continent, at 3,113 MW. Yet the second lowest in installed capacity in the continent with only 86.1 MW in operation. Representing only 3% of the total potential developed. The Middle Africa region on the other hand has the largest amount of undeveloped SHP potential.in Total, only around 6% of the potentials in the region have been developed. Northern Africa has inadequate potential of only 225 MW, representing one of the lowest in the world, with 112 MW already developed. Affric’s Small Hydro Power can be considered as having a comparatively low level of installed capacity but with substantial potential for development. The total SHP potential is projected as 12,197 MW with an installed capacity of 580 MW. This indicating that roughly 5% of the potential have been developed up to now. Fig. 1 and Fig. 2 below shows the Share of Small Hydro Power installed capacity in Regions (%) and Small Hydropower Potential and Installed Capacity by Regions in Africa respectively as Fig. 3 shows Access to electricity, urban (% of RURAL population.

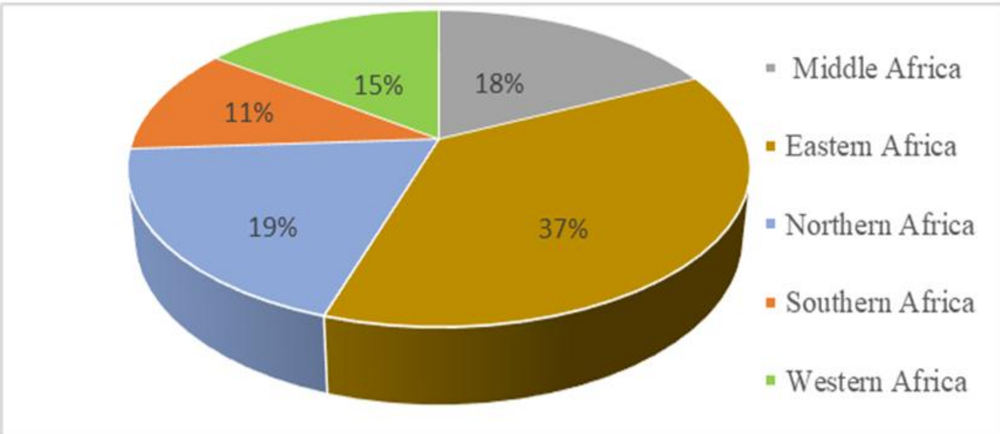

Fig. 1. Share of Small Hydro Power installed capacity in Africa by Regions (%)

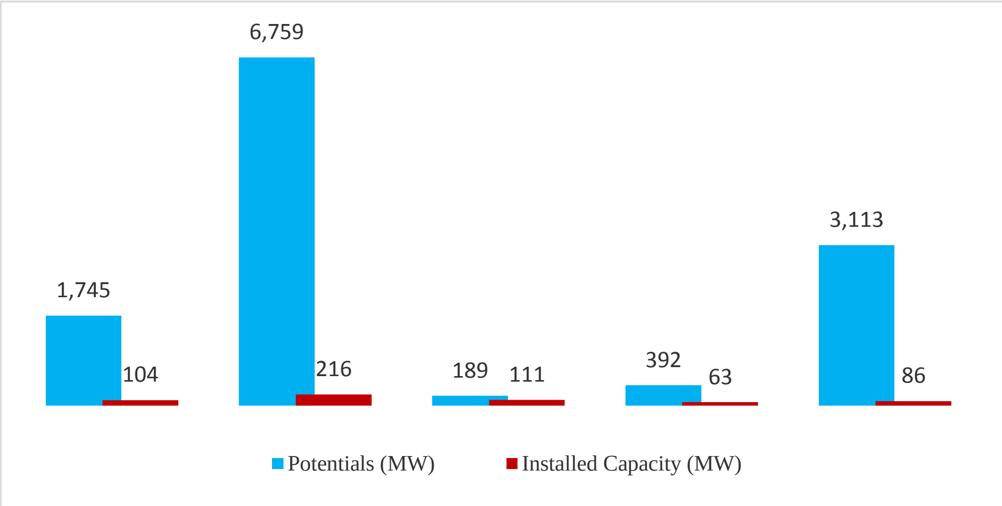

Figure 2 Small Hydropower Potential and Installed Capacity by Regions in Africa (MW)

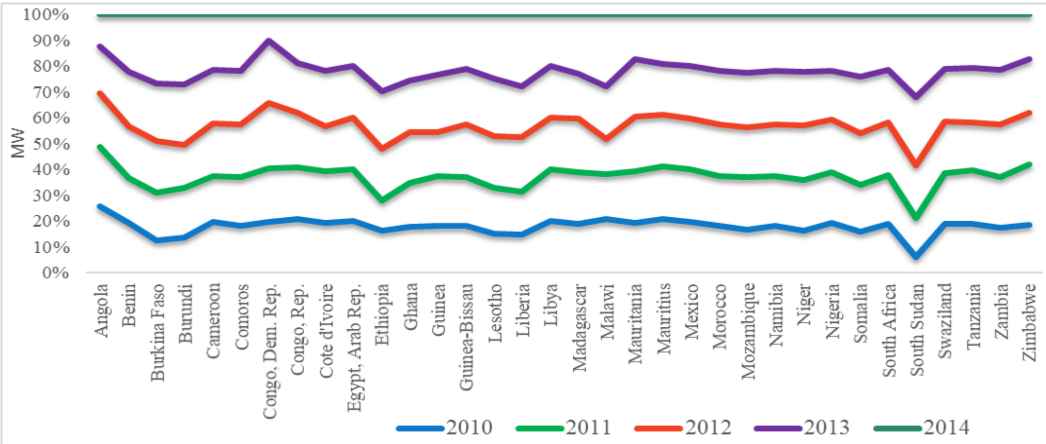

Figure 3 Access to electricity, urban (% of RURAL population [3].

1.2 Existing and projected small hydropower development plants in Africa

As stated by World Bank report, Kenya is recommended as the leader amongst sub-Saharan African countries that has policies in place for energy access, energy efficiency and investment in renewable sources. It also shows in the Regulatory Indicators for Sustainable Energy (RISE) report that progressive measures Kenya in making electricity accessible to about 60% of their population after which Tanzania at 36% and Uganda at 27% [4]. Lesotho Highlands Development Authority appoints Polihali Dam consultant. Highlands Water Project (LHWP) is described as a multi-phased project to provide water to the Gauteng region of South Africa as well as generate Electricity to Lesotho. The Polihali dam is design to take an estimated period of 18 months for construction upon commencement in December 2019. This Phase II will increase the recent supply rate of 780 million cubic meters annually to more than 1 270 million cubic meters per annum. At the same time increase the quantity of electricity generated in Lesotho which is an additional phase in the process of securing an independent electricity source to meet Lesotho's domestic requirements. [5] According to ESI Africa, a new Musanze hydropower plant is to be constructed in Rwanda. This hydropower plant is expected to add about 3.6MW to the national electricity upon completion in 2018, connecting over 100,000 households to the grid [6]. Figure 4 shows Total capacity of Hydro energy generated in selected countries in Africa.

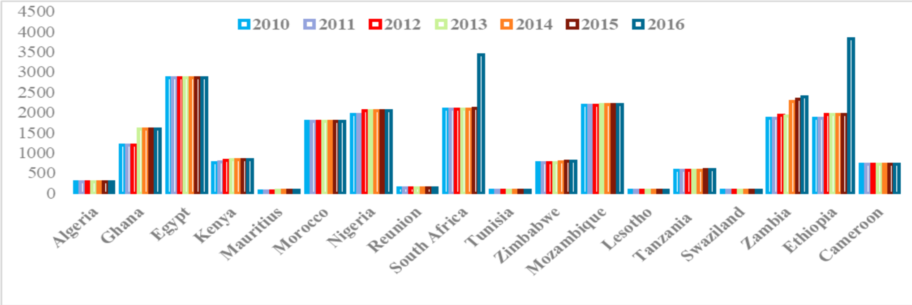

Figure 4 Total capacity of Hydro energy generated in selected countries in the Continent 2010-2016 [3]

In Zimbabwe, Honde Hydro Power Consolidated has establish five 74.296MW mini hydro plants located on rivers in the Nyangani massif transmitting electricity into the national grid which includes 1.1MW Nyamingura Scheme on Nyamingura River, 2.2MW Duru scheme on the Duru River, 2.7MW Pungwe A scheme on the Nyamombe River, 15MW Pungwe B scheme on the Pungwe River and 3.8MW Pungwe C scheme on the Chiteme River [7]. Africa's richest water resources, with a hydropower potential of 45,000 MW is located in Ethiopia. In December 2016, Gilgel Gibe III Ethiopia's largest hydropower project in operation was commission presenting the world's tallest RCC dam. Ethiopia is the leader in Africa when it comes to installed hydropower capacity, exceeding 4,000 MW. Hydropower presently constitute 90% of total power generation in Ethiopia, and is at the lead of Growth and Transformation Plan 2 (GTP-II). This aims to increase total installed power capacity to more than 17,000 MW by 2020 [4]. Figure 5 shows the potentials and installed capacity of small hydropower plants in selected African countries.

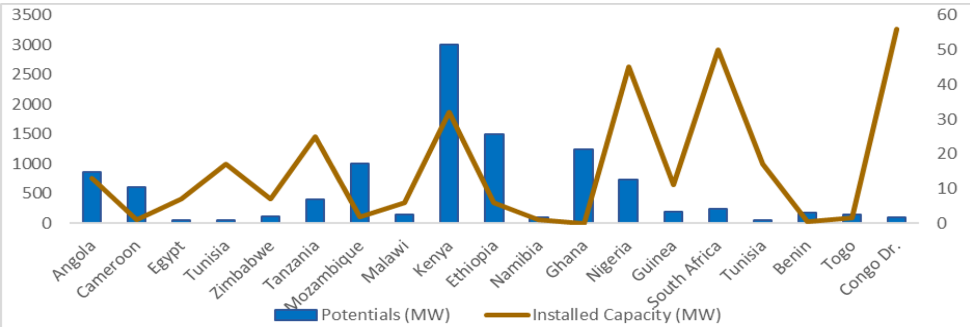

Figure 5 shows the potentials and installed capacity of small hydropower plants in selected African countries.

2. Operation of Pump as Turbine

One of the renewable energy source with a great prospective to economize the sustainable use is Hydropower [8]. As the power plant of pump storage can store energy in addition to power generation, in line with load fluctuations, it performs A very vital role in grid system [9] pump-turbines are moving in the direction higher inflation head, large capacity and high-speed movement, in order to achieve improved economic productivity based on the development of modern technology [10]. Standard pump turbine units when operated in reverse have a number of advantages over conventional turbines for small hydropower generation. Pumps are mass-produced as a result, have advantages for small hydropower as compared to purpose-made turbines. Thus, Integral pump and motor can be purchased for use as a turbine and generator set, it is also available for a wide range of heads and flows in addition to a large number of standard sizes. The cost is Low with Short delivery time. Again, Spare parts like seals and bearings are easily available with Easy installation. The minimalism of the pump turbine means that it has some limitations when compared with the highly expensive types of turbine. The main limitation is that the flow rates range on which a particular unit can operate is much lesser than that of a conventional turbine. The use of combined pump-motor units is suggested for small hydro schemes that are to be used for only electricity generation, then where the simplest installation is required. The use of Pump turbine for small as well as micro hydropower generation is the finest alternate.

2.1. The need to use pump as turbine (PAT) for small Hydro power generation in Africa

The cost of the equipment for centrifugal pump operated in reverse mode is just reduced and could be used as conventional turbines alternate [11]. Manufacturers of Pumps generally do not make available pumps in their reverse mode characteristic curves. Thus, the establishment of a correlation that allows the passageway form characteristics of "pump" towards the "turbine" characteristics is the utmost important dispute in the use of the pump as a turbine. As it's rotating as turbine, hydraulic pump efficiency is changed. On the whole, the operation of pump in turbine mode occurs with higher head and discharge in the same rotational speed. Many researchers have proposed some theoretical and experimental relationships to envisage characteristics of PAT at the best efficiency point (BEP) [12]. Small hydropower may be one of the most important choices in remote rural communities, the benefits of electrification and related progress, and will help in the enhancement of quality of life [13]

3. Challenges to PAT for Small Hydropower Development in Africa

While small hydropower development offers great opportunities, it also comes with complex challenges and risks that vary significantly by the type, place, and scale of projects. Below are the challenges preventing Africa's small hydropower development using Pump as Turbine.

Lack of Finance: One of the biggest challenges facing Africa on small hydropower development is financing. Funds are not available for the feasibility studies on these potential site as well as construction and maintenance PAT machinery even though cheaper. Almost all the new developments on the continent are relying in one Way or the other on donor financing. Development of alternative financing models, such as tapping into alternative funding sources are required to facilitate small hydro developments.

Ability to plan, build and operate hydropower plants: there are very low or no knowledge on the awareness of the small hydro power potential for rural electrification at both national and regional levels in Most Countries as well as PAT development. Such as knowledge at political, government and regulatory units, along with knowledge on local production of parts and components.

Lack of Data on hydro resources: Information on the potential sites where small hydropower can be develop in these countries such as water availability flow rate head and production capacity are not available in most of these countries with those having being minimal. As politicians and the power utility often lack interest in SHP development and also lack the appropriate capacities and budgets, public data on potential SHP sites is often not available. Such as lack of sound basic data (e.g. on mid-to long-term hydrological, geographic, geologic data and figures on the current and future demand for electricity and social infrastructure, but especially on effects of seasonal and long-term river flow variations), poses a major barrier for private investors in SHP. Increasing climate variability and the destruction of rainfall catchment areas are making investment in hydropower systems a risky venture

Another challenge is that in some countries the developers are expected to have finished a feasibility study before getting the right to a site. In other countries, a site can be allotted to a developer on condition that the appropriate fees are paid, irrespective of their technical or financial capability to develop the scheme. Therefore, one may identify a good site, but the rights are being held by someone else who wants a significant, and unrealistic in most cases, payment to hand over their site. Good examples comprise of Uganda and Kenya who are far advanced in the incorporation of small hydropower their regulations which has encouraged their small hydropower potential development.

4. Conclusion

African's demand for energy, as well as a large number of substantial and unexploited small hydropower resources indicates where the continent should be heading to in the development of its energy sector and infrastructure. The immediate development of small hydropower potential capacity in the continent encompasses all the potentials requires in solving quite a lot of problems such as, speedily increasing electricity saturation, including remote areas detached from the grid infrastructures has the greatest answer to the rural electrification increment, which carries access to consistent and clean energy to individuals as well as assisting in reduce poverty, both of which are very fundamental in Africa. Pumps are accessible in the wide range of head and discharge and widely used in industries, commercial and domestic areas. They are subjected to various advantages com- pared to conventional hydro turbines i.e. low cost, less complexity, mass production availability for a wide range of heads and flows, short delivery time, availability in a large number of standard sizes, easy accessibility of spare parts and installation. It has technically been observed that, any type of pump i.e. axial flow, mixed flow, radial flow, double suction and multistage pumps can be used in turbine mode for power generation. The review of literature revealed that lots of theoretical, experimental and numerical work has been done by many researchers on P AT use. Conclusions are drawn on pump as turbine for small hydropower development as one of the most cost-effective energy technologies to be considered in Africa for electrification, stresses on the need to identify potential risks and also proposes guidelines to help future implementation of this technology in a better way.

Acknowledgements

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