Small-scale hydropower development for rural electrification in South Africa

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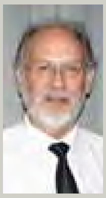

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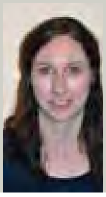

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It is believed that small-scale hydropower is the 'low-hanging fruit' in terms of viable renewable energy which could be developed specifically for rural electrification.

THE TASK

Although the electrification of urban areas and some informal settlements in South Africa has been achieved during recent years, many rural areas still require intervention to provide a reliable and sustainable electricity supply. However, the national electricity grid, managed by Eskom, has for various reasons been experiencing problems, particularly since 2008. Further development of rural electrification is not a high priority at present, due to the shortage in generating capacity available to Eskom. The existing capacity needs to be managed to serve the current users connected to the national grid. However, the primary electricity infrastructure (i.e. coal-fired power stations, major supply lines and distribution of electricity within urban areas) is becoming rapidly insufficient and cannot sustain supply against the demand for electricity from existing (and future) users connected to the national grid.

As a result, supply to the potential electricity demand from rural areas in the Eastern Cape and KwaZulu-Natal now has to be delayed until the national utility's generating capacity is extended. Eskom is currently constructing two new coal-fired power stations, Kusile and Medupi, which will increase their base-load generating capacity.

Although universal access to modern forms of energy is still far from being a reality in many remote parts of South Africa where the population is sparse and the demand low, rural electrification has the potential to greatly improve the standard of living of those people in South Africa who, up till now, have been excluded from the grid.

A new project, supported by the Water Research Commission and the Department of Science and Technology, aims to demonstrate the possibilities of using small hydropower systems for rural electrification in South Africa. It further aims to enhance the uptake of microhydro-technology, making local stakeholders (private sector, financial sector, government entities, etc) aware of the opportunities that this technology brings, and the coordinated efforts required for its successful re-implementation. The project will prove that, under the current legislative and policy framework, small hydropower technology is able to provide 'grid-quality' electricity to rural communities.

THE CRITICAL ROLE OF SMALL HYDROPOWER

Small hydropower can play a critical role in providing energy access to remote areas in South Africa as stand-alone isolated mini-grids.

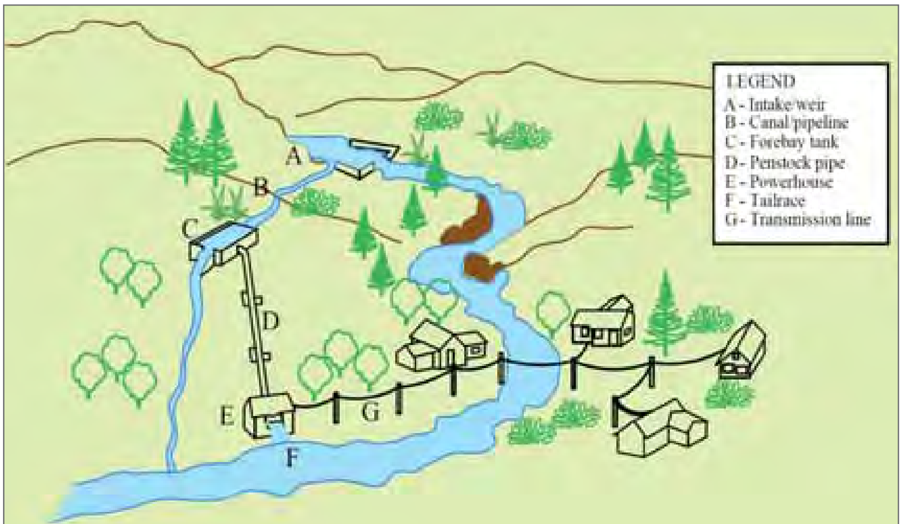

Figure 1: Typical run-of-river hydropower components (Natural Resources Canada 2004)

The reality for many remote communities is that, while they have been uplifted from not having any water supply and/or organised sanitation schemes before 1994, they still do not have access to a sufficient and sustainable power supply.

Small-scale hydropower offers the ability to provide energy access to some remote communities in South Africa. The opportunities that may be available include using existing infrastructure, such as dam releases (typically the release for the natural reserve), irrigation canals, weirs, wastewater treatment plant outflows, or the construction of new run-of-river schemes.

At all of these schemes there is hidden potential for either the installation of pico- (< 20 kW), micro- (up to 100 kW), or even mini- (up to 1 MW) hydropower plants to electrify a clinic and/or school, a village cultural centre or even a whole village.

Decentralised electricity generation options, such as small-scale hydropower, often remain the only viable solutions to supply such areas with electricity. Mini-grids (central generation and a village-wide distribution network) can be a more effective alternative to home power systems, since they can provide capacity for the productive use of electricity (small businesses). Hybrid mini-grids (renewables combined with or replacing diesel generators) are a widely acknowledged technology for rural electrification in developing countries.

Although not very well documented, small-scale hydropower used to play an important role in the provision of energy to urban and rural areas in South Africa. The first provision of electricity to cities like Cape Town and Pretoria was based on small-scale hydro, while smaller towns also started local distribution of electricity through isolated grids powered by small hydro stations (Jonker Klunne 2009). However, with the expansion of the national electricity grid, and cheap coal-generated power supplied through this grid, large numbers of small generating facilities were decommissioned.

The South African Renewable Energy Database (Muller 1999), as developed by the CSIR, did investigate the available renewable energy resources in the country, including the potential for hydropower. It was detailed for the Eastern Cape region through a three-year investigative project titled "Renewable energy sources for rural electrification in South Africa". The primary objective of that project was to identify the commercially viable opportunities for rural electrification in the Eastern Cape Province using wind-, hydro- and biomass-powered energy systems. The research indicated that there is potential for small-scale hydropower, with several sites identified and evaluated.

Small hydropower is a proven, mature technology with a long track record, including in Africa. The gold mines at Pilgrim's Rest (South Africa), for example, were powered by two 6 kW hydro turbines as early as 1892, complemented by a 45 kW turbine in 1894 to power the first electrical railway (Eskom 2009 in Jonker Klunne). Many countries in Africa have a rich history of small-scale hydropower, but over time large numbers of these stations have fallen into disrepair. Some were decommissioned because the national grid reached their location, some because of a lack of maintenance or even pure neglect. Recently initiatives in a number of African countries were aimed at reviving the small hydro sector, either through international development agencies or through initiatives led by the private sector.

Particularly in Central Africa (Rwanda) and in East Africa (Kenya, Tanzania and Uganda), as well as in southern Africa (Malawi, Mozambique and Zimbabwe), new initiatives are focusing on implementing small hydropower projects. In South Africa the first new small hydro station in 20 years was opened in 2009, with more under development.

The basic components of a typical small hydropower system are illustrated in Figure 1 (Natural Resources Canada 2004).

Although energy experts reflect that the hydroelectric potential of South Africa is moderate, the establishment of small hydroelectric projects around the country could, in a small way, help provide a sustainable future energy supply.

SOUTH AFRICAN CONTEXT

South Africa, as a member of one of the Non-aligned and Other Developing Countries, was present at an international workshop on the *Role of Micro-hydro for Developing Countries* held in Katmandu, Nepal, in April 2013. It was recognised at the workshop that micro and small hydropower is a mature, viable and clean alternative energy technology, especially for people living in remote and rural areas. The technology brings light into local people's lives, ensures their energy and water security, makes them economically more stable, reduces the physical workload (particularly for women), enables the mechanisation of rural industries, has potential to lessen the use of conventional energy and its negative impacts, and protects the fauna and flora.

At this international workshop, it was resolved that:

- Developing and other countries shall take initiatives to enhance the development of micro and small hydropower plants as an environment-friendly resource through the application of advanced and compatible technologies to meet the demands of a growing population regarding energy and conservation, in order to protect themselves from future energy crises and secure a more sustainable development path.
- Separate, but similar, policies for rural electrification should be formulated in the developing countries by incorporating isolated plants with national grid-connected micro and small hydropower plants.
- The governments of developing countries shall facilitate the possible role that micro and small hydropower plants can play with regard to the reduction of the emission of global greenhouse gases (GHG).
- The governments of the developing countries shall provide financial and technical assistance to the stakeholders of the micro and small hydropower sector through a dedicated body, which also supports capacity building, as well as Research and Development activities.
- Governments shall be involved in the process of development of micro and small hydropower plants in a People-Public-Private Partnership (PPPP) model to facilitate regulatory requirements for the installation of micro-hydro plants, as well as for distribution through mini-grids.
- Development of micro and small hydropower should be linked with burning issues, such as climate change, social inclusion, energy security, sustainability, development of Small- and Medium-Scale Enterprises (SMEs), economic empowerment and poverty alleviation.
- Effective measures shall be taken by the governments of developing countries to ensure the synchronisation of mini-grids and the availability of low-head turbines and appropriate technologies for non-mountainous regions, and to publish standard operative procedures

and guidelines about the micro and small hydropower plants, preferably in local languages.
- For international compatibility, and for the harmonisation of trade in this emerging renewable energy technology, particularly amongst the NAM and other developing countries, standardisation in the designs of the micro and small hydropower systems is desirable. Such attempts should, however, not discourage technological innovation and identification of strategy for up-scaling.

Jonker Klunne (2009) has identified a number of obstacles in the development of renewable energy technologies for rural electrification in South Africa.

Some of the general barriers are the following:

- There are no clear policies on renewable energy.
- There are limited budgets to create an enabling environment for mobilising resources and encouraging private sector investment.
- There are no long-term implementation models that ensure delivery of renewable energy to customers at affordable prices while ensuring that the industry remains sustainable.

In addition there are some hydro-specific barriers (Jonker Klunne 2009):

- Policy and regulatory framework: Unclear or non-existence of policies and regulations that govern the development of (small) hydropower.
- Financing: Hydropower developments are faced, even more than other sources of renewable energy, with high up-front costs and low O&M costs, something most available financing models do not favour. Nearly all of the new village hydro developments on the continent are relying on one form or the other of donor financing. The lack of policymakers' familiarity with the technology, despite the existence of success stories, results in no best practice information being available.
- Capacity to plan, build and operate hydropower plants: National and regional knowledge and awareness regarding the potential of small hydro in rural electrification is non-existent or minimal.
- Data on hydro resources: Linked to the limited knowledge about the technology is the lack of proper resource data on water availability and flow, which is the information on which hydro developments are based.

RESEARCH AIMS AND OUTCOMES

It is believed that the untapped energy from water resources and existing water infrastructure can be utilised to the benefit of rural communities. The aims of the planned research are as follows:

1. To prove that it is feasible and technically possible to provide small hydropower installations for rural electrification in the current South African legal and policy environment.
2. Development of manuals/training material to assist prospective small hydropower developers/proponents for rural electrification in dealing with the technical, site evaluation, financial and regulatory aspects of such developments.
3. Evaluating the various dimensions of sustainability (technical, economic,

social, environmental and institutional) of micro-hydropower plants used for rural electrification.
4. Demonstration of technology by means of full-scale pilot plant installations, using various technologies available.
5. Ensuring that successful, working, sustainable small-scale hydro power plants are constructed.

The proposed projects should demonstrate the possibilities of using small hydropower systems for rural electrification in South Africa. The aim of this project would be to enhance the uptake of micro-hydro technology, making local stakeholders (private sector, financial sector, government entities, etc) aware of the opportunities that this technology offers, and the coordinated efforts required for its successful reinstatement. The research will aim to prove that, under the current legislative and policy framework, small hydropower technology is able to provide 'grid-quality' electricity to rural communities.

A number of hydropower pilot plants will be constructed in some of the 23 identified prioritised district municipalities in South Africa. These will be full-scale pilot plants showcasing the technologies and various components that make up such a system. A set of small-scale hydropower development manuals/guidelines are also envisaged:

1. Manual for Design, Implementation and Management of Micro-hydropower
2. Guideline for Selection of Potential Sites for Micro-hydropower Installations
3. Project Evaluation Guideline for Micro-hydropower Development
4. Micro-hydropower Operator Training Manual.

EXAMPLE OF RUN-OF-RIVER SCHEME (NEPAL)

Throughout the world there are numerous examples of small-scale hydropower plants being utilised for rural electrification. China, to mention just one country, has more than 100 000 small-scale hydropower plants. An example of a small-scale hydropower plant in Nepal used for rural electrification is shown in Figures 2–6. This plant, the Karamdanda Micro-hydro Project, has a capacity of 17 kW and benefits 179 households. The electricity is mainly used for lighting and battery-charging in the evenings.

What cannot be seen in Figure 6 is the operator's bed to the left! This plant is his pride and joy, as it is his responsibility to ensure that the community has electricity available every night from 18:00 to 23:30.

IN CONCLUSION

Due to the low cost and high availability of coal, electricity generation in South Africa is heavily dependent on fossil-fuel power generation, with the majority of the country's electricity generated at coal-fired power stations. Worldwide, alternative methods involving the use of inexhaustible natural flows of energy to generate electricity are being investigated.

The expansion of the national grid to supply rural areas is thus not a priority at the moment. Small-, mini-, micro- and pico-hydropower are particular types of small-scale hydropower where the installed capacity is less than 1 MW. As with other small-scale hydropower schemes, these schemes have the potential to be a long-term form of renewable electricity generation, because such projects have shorter lead times than large-scale projects and can last for up to 50 years.

Access to electricity serves a vital role in empowering community development by expanding opportunities for education, fostering the growth of local businesses, and improving quality of life. Where electricity is not available, rural areas rely on traditional fuel sources that are poor sources of lighting, and are detrimental to the environment and users' personal health. Hydropower is less expensive and less polluting than traditional fuel sources such as kerosene or diesel. This research project looks at ways in which small-, mini-, micro- and pico-hydropower can be used in the generation of electricity for rural applications in South Africa.

There are numerous benefits for developing small-scale hydropower for rural electrification (Van Vuuren *et al* 2013):

- Hydroelectric energy is a continuously renewable energy source.
- Hydroelectric energy technology is

Figure 2: Turbine room, Karamdanda project, Nepal

Figure 3: Intake collecting water from stream

proven technology offering reliable and flexible operations.

- Hydroelectric stations have a long life – many existing stations have been in operation for more than half a century and are still operating efficiently (an example of this is in Cape Town).
- Hydropower stations achieve high efficiencies.
- Existing water infrastructure could be used, thus reducing expensive capital works, for example retrofitting the reserve outflow from an existing dam.
- Hydropower schemes have very low operating and maintenance costs, as well as reliable and flexible operation.
- The preliminary feasibility studies indicate short payback periods.

ACKNOWLEDGEMENTS

This research will be funded by the Water Research Commission and the Department of Science and Technology, whose support is acknowledged with gratitude.

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Figure 4: Penstock supplying water to turbine room

Figure 5: Cross-flow turbine and generator

Figure 6: All the components of the hydropower plant in the turbine room (turbine, generator, electrical control panel and dumb load)