GET FiT ZAMBIA

Research on intermittent renewable energy's impact on hydropower operations

Insights from the MUST Summer Project

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Context of the study

The inclusion of solar power and other intermittent or variable sources of power supply impacts the operation of power systems in general, and hydropower plants in particular. This is becoming a relevant issue in many countries and regions where solar power is rapidly making up an increasing share of the supply mix. However, experience with operating the power system with the entry of variable renewable energy is still relatively limited, in particular in the Southern African context.

The Zambian power system is currently dominated by hydropower, which makes up about 80% of installed generation capacity, with the rest covered by resources such as coal, HFO, solar PV and diesel. Through GET FiT Zambia, with its 120 MW solar PV power project pipeline, as well as other initiatives, the Zambian Government foresees that a total of up to 1 GW of solar power may be added to the system by 2025. In light of potentially higher penetration of variable renewable energy resources, concerns have been raised on the impact that this would have on both the grid stability as well as the operations of existing power plants. Inclusion of new variable sources of power may also have financial and economic impacts on existing sector participants, such as the national utility company ZESCO.

In 2020, GET FiT supported ZESCO in assessing these impacts through the GET FiT Technical Assistance (TA) Facility. A study was conducted to evaluate how introducing variable renewable energy (such as solar and wind) would impact the power system in Zambia. The study was done as part of a summer student programme "MUST" run by the GET FiT Programme Implementation Consultant, Multiconsult. The students undertook the bulk of research and analysis for the study, under close supervision and support by Multiconsult's experts.

Specifically, the study evaluated possible impacts on the power system of including 900 MW of Solar PV, from mechanical, hydrological, environmental and economic perspectives. One of the large hydropower plants was used as a case to develop and analyse different scenarios, by assuming that it would be the main plant to regulate its generation in order to balance the load (so-called load-following plant).

The analyses undertaken show that the overall impact from increased penetration of variable renewable energy in Zambia is likely to be positive. The financial and economic benefits are expected to outweigh, by a solid margin, the technical and operational challenges that implementation of close to 900 MW may represent.

MUST Renewable Energy summer programme

The MUST Renewable Energy summer programme is a highly sought-after summer internship for students. The students are put together in a multi-disciplinary team to solve a real project for a client, under supervision by experts in Multiconsult. The programme offers the students the chance to get an insight into renewable energy challenges and get practical work experience. For the MUST 2020 Renewable Energy summer programme the team consisted of students with backgrounds from electrical, mechanical, hydrological and economic studies. The programme is among one of the most popular summer internships for engineering students in Norway and top students are chosen for the team.

Wear and tear on mechanical equipment is manageable

Based on literature review and operational data from the load-following hydropower plant, the expected lifetime of the equipment is estimated to be reduced by maximum 10% (or an equivalent increase in operating expenses).

More solar PV power generation will imply that a number of generators at the hydropower plant must be shut down during mid-day (when the solar power production is at its highest), depending on the amount of solar power produced. The high-level assessment indicated that mechanical equipment can handle a new operational pattern. While leading to some wear of the equipment, the downtime may be utilised for planned maintenance, which in turn may lead to fewer outages and less unplanned maintenance. Further investigations are required to quantify exactly how much each component may be affected based on its properties and condition, and to take sub-hourly variations in production into account.

The study further found that system stability is not considered to pose a challenge. Because the connected generators are operating at low dispatch levels, the spinning reserves in the system are sufficient to stabilise the system and the power system can be expected to remain stable, even in the most extreme scenario with the highest amount of solar PV produced.

Turbines at the Kafue Gorge Upper power station

Increased solar power may impact the environment in downstream habitats

The study also looked into possible impact on water flow and the environment due to changed hydropower operations.

As the hydropower operations have to adjust to the intermittent solar PV generation, more hydropeaking operations from the dispatchable hydropower units will be required. Hydropeaking is the discontinuous release of turbined water due to peaks of energy demand. Thus, increased fluctuations of downstream river flows may be expected, and cause environmental impacts mainly to be downstream.

There is a lack of studies for tropical regions considering the environmental impacts of hydropeaking and site-specific investigations are required to map impacts and their magnitude. However, the study concluded that hydropeaking likely will cause environmental and social impacts that are different from those occurring at present. The study recommends considering distribution of the required hydropeaking to several power plants and spread the possible (negative) impacts across several river basins. Operational rules must be defined based on site-specific investigations and must ensure sustainability in terms of meeting both national and international regulation and standards.

Ground-mounted Solar panels

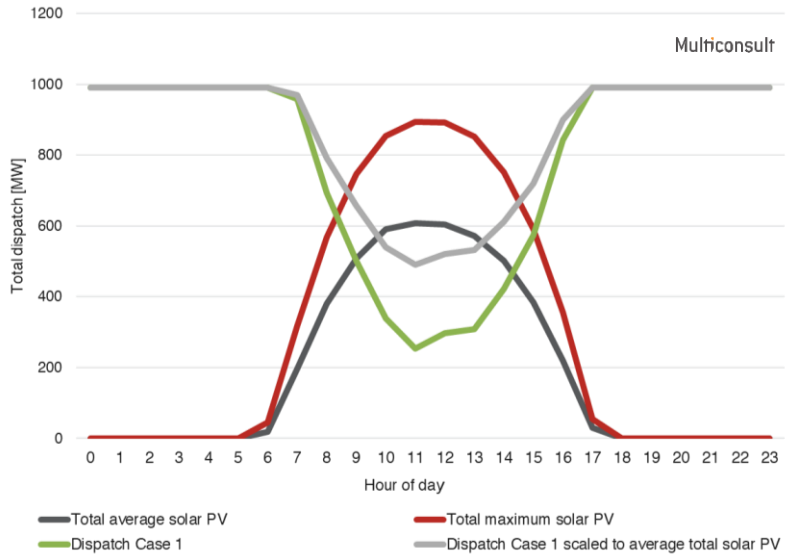
Zambia's role in the regional power system

Regional power trade is the key to harnessing solar power's large potential value. A solid enabling environment for solar power, strong regional transmission capacities, sectoral incentives that promote financial sustainability, and bilateral trade agreements that reflect Zambia's increasing regional importance, will play an important role to this end.

For Zambia, solar and reservoir hydropower could be an exceptionally good fit

The study suggests that new solar power could represent substantial value for ZESCO in terms of cost savings in the power sector cost structure.

Least-cost generation and power purchase between two scenarios were considered: i) without any new solar power and ii) with 895 MW solar in the system, on both a wet day and a dry day. The analysis indicated significant potential annual savings with the solar power. This was particularly significant on dry days when hydropower production is lower and the import prices are high, as power imports may be reduced. This, however, would need to be reviewed and validated in more detailed studies. The potential benefits of trading with flexible hydro, and potential mechanical and environmental impacts due to resulting changed hydropeaking patterns, would also need to be further assessed.



The simulated solar PV profiles and dispatch at the load-following power plant. Dispatch Case 1 is based on the total maximum solar PV profile, while the scaled Dispatch Case 1 is adjusted by the ratio between average and maximum solar profiles. This is to simulate a more moderate case and typical day (based on average) rather than the extreme case.

Net positive impacts of solar power for Zambia

Through the study, the GET FiT TA Facility has provided valuable indications and recommendations for ZESCO, providing a better basis for hydropower operations and planning toward a future with increasing shares of variable renewable energy power generation. Additionally, it shows the possible value and impacts solar power investments may have to the Zambian government from a policy perspective. Most importantly, it provides confirmation that on the overall, solar power is manageable and will have a positive impact for Zambia.

Interview with ZESCO and the MUST students

The study on inclusion of intermittent renewable energy into the Zambian energy system was conducted by Multiconsult students, supervised by in-house Multiconsult experts and experts from ZESCO's transmission and distribution team. The MUST student programme usually involves a field trip in order to conduct interviews, stakeholder meetings, data collection, site visit and more. Due to the COVID-19 pandemic, it was not possible to organise a field trip during the MUST 2020 summer programme.

Interviews about the project have been conducted with the students and ZESCO's technical experts. In this interview, ZESCO's technical experts share their insights from working with the students, as well as key takeaways on the research.

What are the most interesting findings/insights from the study from ZESCO's perspective?

That the introduction of Renewable Energy will be able to translate into benefits such as banking of water during the dry years.

Which aspects of the hydropower operations are ZESCO most concerned about?

Operation of the generation units within the allowable range is one of our concerns. We are also concerned about the frequency of START/STOP of the units due to the integration of Renewable Energy.

What would have been interesting to look further into?

We would be interested in knowing the limit of intermitted Renewable Energy integration into the ZESCO grid for each of the years between 2021 and 2040 (taking into consideration the dynamic response of the network).

Small hydropower plant

What does ZESCO plan to investigate further?

We plan to undertake further studies into the hydrological conditions of various river basins for the next 20 years in order to estimate how much energy deficit we are likely to incur. We would be interested in knowing the limit of intermitted Renewable Energy integration into the ZESCO grid for each of the years between 2021 and 2040 (taking into consideration the dynamic response of the network).

What was ZESCO's experience of using a student team for this type of study?

Our experience was very good. We were able to contribute with our experience in areas where the students were lacking insight, and the students were able to use time and their theoretical knowledge to assess the research questions. It must be emphasised that most of the findings were consistent with what various consultants have done.

The summer students were Håvard Næss, Guido Cimadamore-Werthein, Lars Falsen Habostad and Helga Løset Skodjereite. Lars Falsen Habostad is currently working on his master thesis on the Zambian power system. He is studying electrical engineering with major in energy and environmental engineering at the Norwegian University of Science and Technology (NTNU). In this interview, he shares some thoughts on working with ZESCO on this project.

The client and stakeholders were located in Zambia, while you were working from Oslo. How were you able to communicate and coordinate with them?

It worked surprisingly well to communicate with the client virtually, through Zoom. However, processes took more time than they probably would if we could meet the persons face to face. It was also challenging sometimes to coordinate who is responsible from the client's side for different inputs and data. Once we had worked that out, it was easier to know who to approach. Everyone being in the same new situation meant that everyone has adjusted to make cooperation possible.

How could the study have been enhanced through a field visit?

As most of the study was done through literature review, desktop research and analysis, I think we were able to get almost as good results as if we had conducted a field trip. However, it would have been possible to take a closer look at the water basins to consider environmental and social impacts, and also take a closer look at the mechanical components. And of course, we would have very much liked to visit Zambia and meet the client and stakeholders, which would also have improved the coordination as mentioned.

What delimitations in the scope did you have to make? What aspects would you have liked to research further if time and budget had allowed?

We had to use one generic day as the scenario for analysis. It would have been interesting to look at more scenarios to evaluate the sensitivity and robustness of the results. For instance, to consider one whole year, or even several years with varying weather conditions. ZESCO would ideally have liked even more detailed results on the impact on the mechanical equipment. Our findings were mostly based on the literature review, it could be interesting to analyse the impacts based on the actual equipment.

How do you think study can be of use for managing Zambia's power system?

I think the study was able to provide some comfort that the technical challenges are not too great. However, in order to harvest the potential economic benefits, the regulatory and financial aspects need to be in place. Although it is not directly transferable, the study could also be used to give indications for other countries with hydropower-based power systems.

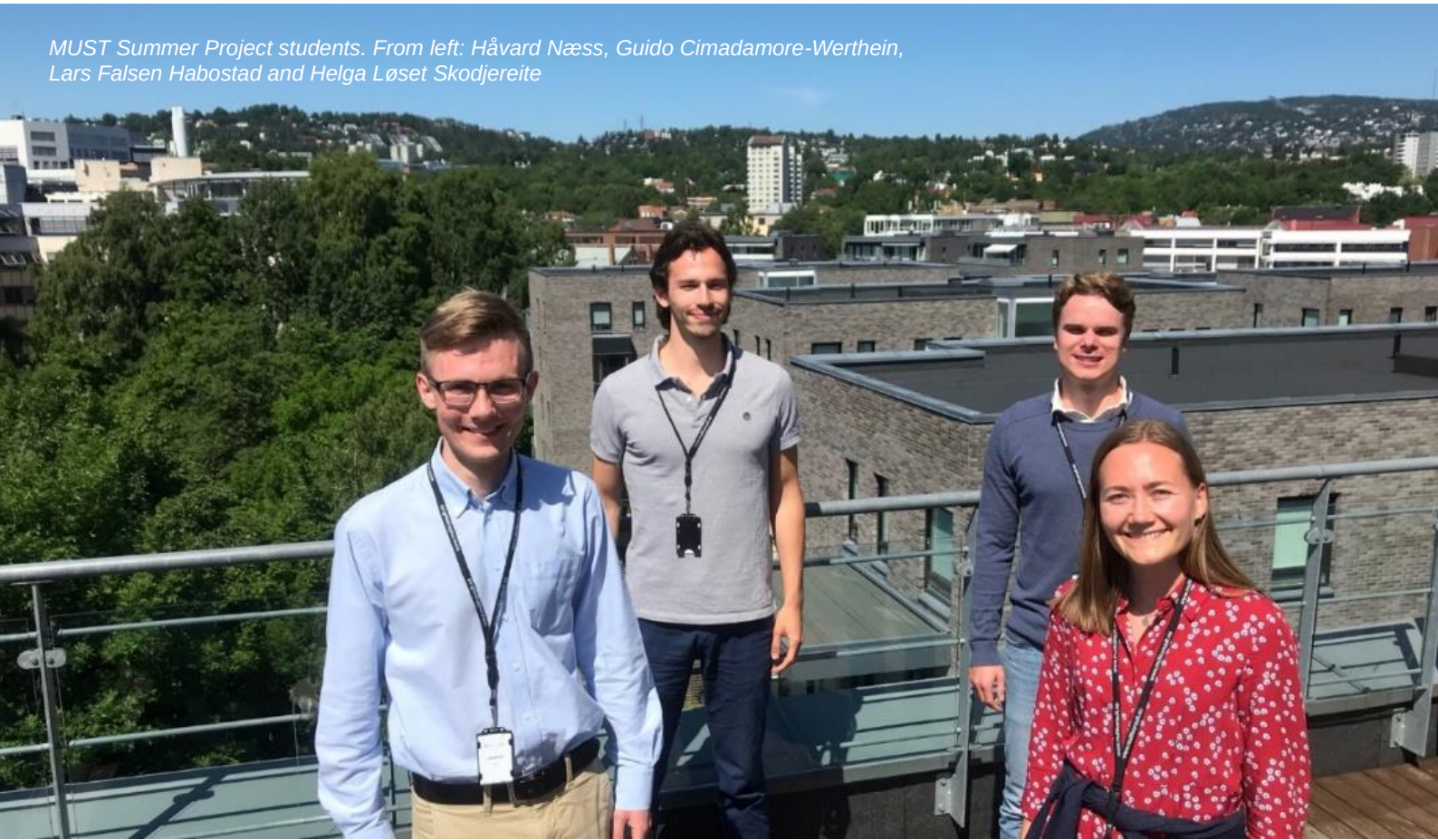
You will continue to focus on Zambia in your master thesis – what is the topic?

Yes, I found Zambia as a case very interesting through the MUST project, so I have chosen to continue to study the Zambian power system. The aim of my thesis is to evaluate what the optimal portfolio of renewable energy will be for Zambia. I will build a technical-economic optimisation model to analyse the mix of hydropower, solar and wind power. Some interesting reflections will be the role of hydropower going forward, as risk increases with climate change that leads to more drought and less predictable supply of water. I would also like to investigate whether the grid will be able to manage the optimal level of renewable variable energy.

"We would like to wish Lars Falsen Habostad well as he undertakes his Master Thesis study on the Zambian power system. We are hopeful that the study will provide us with more information on the impact of VRES integration on the national grid. This information, which will complement results from other studies that have been undertaken by respective consultants, will support the decision-making processes with the electricity supply industry in Zambia."

– Dr. John Kunda, ZESCO

MUST Summer Project students. From left: Håvard Næss, Guido Cimadamore-Werthein, Lars Falsen Habostad and Helga Løset Skodjereite



GET FiT Zambia is the Government of the Republic of Zambia's Programme to facilitate private sector investment in small- and medium-scale Renewable Energy Independent Power Projects (IPPs) in Zambia. The Programme is a partnership between the Department of Energy and the German Development Bank, KfW, and is implemented by the GET FiT Secretariat. GET FiT Zambia was officially launched in 7th February 2018.

Implementing Agency: Ministry of Energy (Department of Energy
Main Financing Institution: KfW (Germany)
Target: 100 MW Solar PV and 100 MW Small Hydropower Capacity
Timeline: Programme Period is from 2018-2024

Cover Picture:
Turbines at Kafue Gorge Upper Power Station

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