Comité de Operación Económica del Sistema Interconectado Nacional

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Improving the vRE Forecasting Framework in Peru

Executive Summary

GET.transform is supported by

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Sweden Sverige

Ministry of Foreign Affairs of the Netherlands

Austrian Development Agency

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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Place and date of publication
Lima, September 2023

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energy & meteo systems is an internationally leading provider of sophisticated IT solutions (solar and wind power forecasts, Virtual Power Plants, redispatch platform) for an efficient integration of distributed energy resources into power systems. With its consulting services the German-based company shares its in-depth energy transition expertise on a global level.

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GET.transform is a European programme which offers developing and emerging countries comprehensive advisory services to advance their energy sector transformations. It is hosted on the multi-donor platform GET.pro (Global Energy Transformation Programme), and supported by the European Union, Germany, Sweden, the Netherlands, and Austria.

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Introduction

Over the past decade, Peru has been one of Latin America´s fastest growing economies. The emerging economy, and the significantly increased access of the population to the power network, has spurred the electricity demand. The installed capacity of the power plants increased on average by 9% between 2011 and 2018 which is the highest growth rate in the region. Today, the country's power system ranks as the sixth largest in the region in terms of installed capacity.

Traditionally the electricity sector has been dominated by gas-fired and hydroelectric power plants, which cover more than 90% of the electricity demand. In the past years large scale wind and solar power plants have been connected to the transmission grid system, which allowed the non-conventional renewable share (including wind and solar) to grow and exceed the initial goal of 5%. A growing electricity demand and high potential, especially for solar plants with one of the highest radiations of the planet as well as wind power with high capacity factors in the coastal areas, suggests an increasing participation of renewables in the near future.

Peru´s power system operator, COES (Comité de Operación Económica del Sistema Interconectado Nacional), is already facing the need to introduce operational adjustments to deal with weather dependent production from renewable energies. Its role is to ensure an efficient integration of fluctuating solar and wind power generation and to maintain the stability of the electricity network. In order to meet these challenges and create solutions for a higher share of renewables in the Peruvian power system, COES, in coordination with GET.transform has initiated this study to improve the existing forecasting system of variable renewable electricity injection. Therefore, this study and the presented executive summary intends to contribute to optimise operational processes of the electricity power system, which will also help to grow the participation of renewables according to the national defined goals.

Executive Summary

The efficient system integration of large scale variable Renewable Energy (vRE) requires new operational processes and technologies. A key to managing weather dependent, variable electricity production from solar and wind power plants are accurate power forecasts. With rising vRE shares in the power system, power production forecasts provide crucial forward looking information for an economic, reliable and safe operation of the electricity network.

Based on the COES´ interest on assessing the options to improve vRE forecasting conditions in Peru, a study has been conducted with the support of the global European programme, GET.transform, with energy & meteo systems as the leading expert. The **goal of the study** is to analyse the current vRE forecasting framework in the country and to provide suggestions on how it can be improved to support grid operation to efficiently incorporate solar and wind power production into the power system.

Today, electricity supply in Peru is largely dominated by conventional power plants, in particular gas-fired plants. In 2021, 14 large scale wind and solar parks, with a total capacity of 682 MW, contributed 5% to the national electricity supply. Although vRE is still relatively low, Peru has the ambition to increase the share of solar and wind power production towards 20% by 2030.

When it comes to predicting vRE production, the **forecasting system in Peru** has a decentralised structure, meaning that wind and solar power plant operators must send power forecasts to COES, whose mandate is not to generate or contract from a service provider system-wide centralised power forecasts. The forecasts are sent for the week-ahead and day-ahead schedules and intraday forecast updates can be sent with a three-hours lead time. The predictions provided by the plant operators are used for day-ahead planning and for intraday adjustments. In the intraday, until today with the current vRE penetration level, the flexibility provided by gas-fired plants allows COES to balance forecasting errors. Although forecasting currently does not pose issues, in the mid- to long-term, as the vRE share increases, the need for very short-term balancing and additional ancillary services will also increase. This can result in additional vRE system integration costs, which can increase further when vRE predictions are inaccurate.

To provide well-founded advice on how to improve the forecasting framework, a sound **evaluation of the current forecast quality** was conducted by analysing historic prediction data of the plant operators and comparing them with historic forecasts ('backcasts') created by energy & meteo systems. The analysis covered all of the 14 solar and wind farms the period from 1st June 2020 to 1st June 2021.

The most important findings for the **wind power plants forecast:**

- Rough terrain and vicinity to the coast pose challenges to power forecasting and generally lead to higher error values.
- Mean absolute error (MAE) values of the operator forecast ranges between 16.5% and 22.5% for the day-ahead horizon.

— With the exception of one plant, the forecasts of all the other plants show a negative bias, meaning that the wind farms typically produced more energy than scheduled.
— MAE values for day-ahead benchmark forecasts conducted by energy & meteo systems range between 11.2% and 17.2%.
— On average, the MAE of the benchmark forecast is 4.6% of installed capacity better than the forecast delivered by the operators, representing an improvement of about 25%.
— When non-availabilities of the parks are not considered in the forecasting process, the forecast errors rise significantly.

The most important findings for the **solar power plants forecast:**

— For solar farms, the energy production peaks in the months around December, the lowest general production level is in June.
— Between December and April, drifting clouds cause weak to strong fluctuations in the daily energy production, which naturally leads to higher forecast errors.
— Day-ahead forecasts from the operators show remarkably strong fluctuations on cloudy days which may indicate that the forecast is not based on numerical weather models (exception observed for one of the parks).
— For some solar farms, many day-ahead forecasts from plant operators are missing.
— The operator often sent identical forecasts for several days which is only acceptable on cloud free days, but not with varying weather conditions, again suggesting a lack of a forecast based on weather models.
— Mean absolute error (MAE) values of the operators forecast ranges between 4.4% and 9.3% for the day-ahead horizon.
— On average, the MAE of the benchmark forecast conducted by energy & meteo systems is 2.8% of installed capacity better than the forecast delivered by the operators, representing an improvement of about 40%.
— When non-availabilities of the parks are not considered in the forecasting process, the forecast errors rise significantly.

From the data analysis, and the comparison between operator and benchmark forecast, it can be concluded that there is **significant potential for improving the accuracy of the power predictions**.

It is important for Peru to seize this potential for forecast improvement. Experience and studies show the growing importance of accurate power forecasts with rising shares of vRE production and positive impacts relating to:

— Operational system security
— Improved generation planning
— Reduced operating reserve
— Decreased curtailments of vRE generators

Regarding how forecasts are provided, a review of the international power forecasting markets shows a **trend towards a centralised forecasting system with predictions provided through a forecasting service provider** (sometimes combined with decentralised forecasts provided by plant operators). This ensures high forecast quality and lower costs of developing or sourcing forecasts at a plant operator level. According to the international experience, the following advantages are identified in a centralised forecasting system with a forecasting service provider:

— Aggregated forecasts for all vRE plants
— Reliability of forecast delivery
— Consistent forecasting approach applied for all plants
— Possibility to cover smaller vRE plants as well
— Direct coordination and evaluation of the forecast service provider by the system operator
— Low costs for forecasting services (economies of scale)
— State-of-the-art forecasting practices

Consequently, most transmission system operators in Europe, USA and also an increasing number in Latin America (Chile, Dominican Republic, El Salvador, Uruguay), have introduced a centralised forecasting system along with operational changes.

— **Chile** managed to reduce the forecasting errors from 13% (2017) to 9% (2019).
— Following a pilot project, the system operator of the **Dominican Republic** contracted a forecast service provider. The forecasts show a noticeably higher accuracy.
— In a one-year pilot project in **Mexico**, centralised forecasts proved to be significantly more accurate. A centralised forecast reduced day-ahead MAE values for wind power from 17% to 13%, and for solar power from 9% to 6%. Mexico´s system operator, CENACE, reported that the higher forecast accuracy resulted in substantial savings due to improved scheduling of generator units.

If alternatives to centralised systems are assessed, examples are seen of a few countries with a decentralised forecasting system which decided to introduce a **penalty scheme** to incentivise plant operators to submit more accurate forecasts. While the effect on the forecast accuracy is not known, the penalty scheme has generated legal disputes and its operation requires substantial effort. Experiences in the Dominican Republic and Chile show that when centralised forecasts were introduced (while decentralised forecasts still had to be carried out), there was enough incentive for the quality of the predictions from the plant operators to improve. This improvement was supported by an increased awareness of the importance of forecasts for power system operation.

Drawing from the data analysis and international experiences and trends, **a set of measures** is identified aimed at **improving the current forecasting system in Peru.** The recommendations distinguish between short-term measures (which could most likely be implemented within a year) and mid- to long-term recommendations (for which preparation and implementation would likely take more than one year). This set of recommendations provides a menu of options from which alternatives can be picked based on the respective current situation. The relevance of each recommendation will vary depending on when it is implemented and on the interdependency it may have with other chosen measures.

Actionable recommendations in the short-term

1) **Enforce the daily submission of power forecasts.** Data analysis showed that plant operators sometimes fail to comply with their obligation to provide daily power forecasts to COES. The respective technical procedure should be enforced.
2) **Introduce a standardised format for power forecasts.** The current framework does not define a data format for the power forecasts provided by the plant operators. The format needs to be standardised to ensure uniformity of the supplied predictions.
3) **Assess power forecasts regularly.** Regularly assess the quality of the power predictions, along with an exchange with the plant operators which serves to share insights on forecasting issues and the benefits of accurate power forecasts for the system.
4) **Establish an automated data exchange between COES and plant operators.** A data transmission platform would help to increase data quality and to inform about events affecting vRE production (e.g. non-availabilities due to maintenance or curtailments of plants).

Actionable recommendations in the mid to long-term

1) **Implement a national plant register.** Establish a national plant register containing detailed technical information on all energy units (renewable, but also conventional generators, storage systems, etc.) installed in Peru. The register is crucial for keeping track of the installation of solar and wind power plants and their technical characteristics, and it is an indispensable database for centralised power forecasts. Furthermore, this will help in the integration of distributed generation when it peaks-up in the future.
2) **Use weather model-based power forecasts.** The forecasting processes of plant operators are unknown. Some characteristics of these forecasts allow the assumption that not all employ weather models for their power forecasts. The technical procedure could be modified to request the forecasting responsible parties, as of today also the plant operators, to provide weather model-based power predictions.
3) **Consider combination forecasts.** On average, an optimal combination of several weather models leads to more accurate power forecasts, and this approach does not seem to be consistently applied by plant operators. The technical procedure could be modified to request the application of combination forecasts.
4) **Switch to centralised power forecasts provided by an external service provider.** International experience shows that higher levels of quality and efficiency are achieved through centralised forecasts provided by a service provider for all vRE plants. It is therefore recommended to change the regulatory framework to enable COES to directly contract a power forecasting service. The

annual costs for the forecast service are estimated to be between 20,000 and 30,000 USD for the current 16 solar and wind power plants in Peru.

5) **Introduce a higher update frequency of power forecasts based on real-time production data.** Currently, only day-ahead forecasts are provided to COES by the plant operators, who can also submit intraday updates with three-hours lead time. However, simulations in this study showed that the consideration of real-time production data in the intraday forecasts can significantly improve forecasting accuracy. Intraday short-term power forecasts (by plant operators, or the centralised forecasting system) could therefore be incorporated into real-time production data.
6) **Work with a higher temporal resolution.** Currently, the operation of the power system and the delivered power forecasts are based on 30 minute intervals. A higher temporal resolution (e.g. **15 minutes**) would better capture the quick production changes of vRE generation, thus leading to higher accuracy.
7) **Incorporate model spreads in power forecasts.** When combination forecasts are used, model spreads can be visualised to indicate possible deviations from the nominal power forecast based on different weather models. They are useful additional information for COES to prepare for more uncertain power forecasts due to challenging meteorological situations.

The above-mentioned measures address the causes of the detected current issues with the solar and wind power forecasts, and aim to increase overall accuracy levels. It is expected that their implementation could effectively support Peru in successfully integrating larger shares of variable renewable energy production in the future, whilst still ensuring system cost-efficiency.

As an outcome of the recommendations presented in this study, the Peruvian stakeholders have indicatively prioritised measures to be implemented for improving the national power forecasting system. The following table represents a preliminary status of discussions at the time of writing and may be subject to further changes.

Recommendation		Current situation	Type of measure	Responsible for measure: proposal and enactment	Responsible for measure: execution, implementation and supervision	Implications for COES (and its interaction with plant operators)	Effort and costs	Relevance for forecast quality
Time horizon	Action for change							
Short-term (< 1 year)	**Enforce the daily forecast submission**	Regulation requires plant operators to send day-ahead schedules, but vRE operators sometimes fail to comply	Existing Technical Procedure needs to be enforced	Proposal: operational measure, no proposal required	COES: Notify Osinergmin if there are compliance issues with the regular submission of forecasts Osinergmin: take action to enforce regulation	Communicate directly with plant operators (or request Osinergmin do this) to comply with regulation, in order not to face penalties	COES: little effort and costs Osinergmin: little effort and costs	High
Short-term (< 1 year)	**Introduce standardised format for power forecast**	No standardised format established	Operational measure not requiring any regulatory change	Proposal: operational measure, no proposal required. COES instructs plant operators on the standardised format	COES: control compliance with standardised format	Organise meeting with plant operators to explain the standardised format	COES: little effort and minimal costs	Medium
Short-term (< 1 year)	**Regular forecast quality assessment**	COES does not carry out assessment	Informative events to share insights into the issues and benefits of forecast accuracy	Proposal: no regulatory proposal necessary	COES: establish frequent dialogue with plant operators on forecasting issues	Organise meetings with plant operators to discuss vRE forecasting issues and raise awareness of the importance of accurate power forecasts	COES: little to medium effort and costs	Medium (impact depends significantly on responsiveness of plant operators)
Short-term (< 1 year)	**Automated mutual exchange of data between COES and plant operators to increase data quality and to inform about events (curtailments/non-availabilities) affecting vRE production**	There is no automatic exchange on non-availabilities between COES and the operators No automated data transmission platform implemented	Technical Norm needs to be modified by MINEM to require plant operators to enable bi-directional communication	Proposal: COES presents proposal to MINEM Approval: MINEM approves modification to the Technical Norm	COES: adjustment of processes required, identify lack of compliance and notify Osinergmin Osinergmin: impose penalties if plant operators do not comply with Technical Norm Plant operators: must have IT equipment for data exchange	Make/have IT system capable of exchanging data, automatic identification and notification in case plant operators do not comply	MINEM: medium effort to issue modification to Technical Norm COES: medium effort, low costs for IT infrastructure Plant operators: little effort and costs Osinergmin: little effort (depending on compliance)	High

Recommendation		Current situation	Type of measure	Responsible for measure: proposal and enactment	Responsible for measure: execution, implementation and supervision	Implications for COES (and its interaction with plant operators)	Effort and costs	Relevance for forecast quality
Time horizon	Action for change							
Long-term (> 1 year)	**Implementation of a national plant register**	There is no complete national plant register	Modification of Electricity Concession Law	Proposal: COES presents importance of national plant register to MINEM Approval: MINEM approves new legal norm, with contributions from COES, Osinergmin and distributors require the operator of any energy unit (plant, storage system, etc.) to submit plant data to the national plant register	MINEM: implement national plant register Osinergmin: supervise compliance by plant operators to register	Participate in process and ensure that requirements are fully met	MINEM: Medium to high effort to pass legal norm and to implement national plant register COES: little effort/cost to participate in legislative process Osinergmin: medium effort and costs	High
Long-term (> 1 year)	**Require weather model-based forecasting approach**	Some park operators do not seem to use weather models for power forecasting	Existing Technical Procedure is modified so that it requires existing and future plant operators to submit a weather model-based forecast	Proposal: COES presents a report on the benefits of weather model-based forecasts in comparison to the current status. Approval: Osinergmin after a public consultation ('Proceso de audiencia pública')	Plant operators: implementation of weather based forecasting system Osinergmin: validate that weather models are in use and audit compliance	Review forecasts and notify Osinergmin in case of indications that no weather model is applied	COES: medium effort (proposal), low costs Osinergmin: little to medium effort Plant operators: at least two global models available free of charge; costs may be incurred for those who do not yet use a weather model.	High
Long-term (> 1 year)	**Require combination forecast which optimally combines several weather models**	Combination forecast is not consistently applied by plant operators	Existing Technical Procedure is modified so that it requires plant operators to submit a combination forecast based on at least two weather models	Proposal: COES presents a report on the benefits of the combination forecast, in comparison to the current status. Approval: Osinergmin after a public consultation ('Proceso de audiencia pública')	Plant operators: implementation of combination forecast Osinergmin: validate existence of a combination forecast and audit compliance	Review forecasts and notify Osinergmin in case of indications that no combination forecast is applied	COES: medium effort (proposal), low costs Osinergmin: little to medium effort Plant operators: no extra cost if combination forecasts are already in place, otherwise medium costs for implementation	Medium

Recommendation		Current situation	Type of measure	Responsible for measure: proposal and enactment	Responsible for measure: execution, implementation and supervision	Implications for COES (and its interaction with plant operators)	Effort and costs	Relevance for forecast quality
Time horizon	Action for change							
Long-term (> 1 year)	**Implement centralised forecasts with external service provider**	No centralised forecasting system in place	Change of the Electricity Law 28832 and Regulation for COES. Modification of the Technical Norm for the Co-ordination of the Real-Time Operation. Existing Technical Procedure is modified, or a new regulation for COES introduced.	Proposal: COES presents report on the benefits of centralised power forecasts to MINEM and Osinergmin Approval: MINEM changes Electricity Law 28832 and Regulation for COES to implement centralised forecasts. Osinergmin approves modification of Technical Procedure after a public consultation	COES: prepare and carry out a tender to contract a forecast provider	1-2 experts to monitor and assess forecasts and to co-ordinate service provider	COES: medium effort to prepare tender and co-ordinate the forecast provider; yearly cost estimation for a service provider is between $2,000 USD (one single plant) and $600 per plant (in a larger portfolio of about 100 plants) also depending on the specific forecast requirements. For the current 16 farms, the estimated cost is 20,000 to 30,000 USD. Osinergmin: little to medium effort	High
Long-term (> 1 year)	**Higher forecast update frequency based on real-time data**	Currently only day-ahead forecasts and intraday three-hours ahead updates provided	Modification of the Technical Norm for the Co-ordination of the Real-Time Operation. Existing Technical Procedure is modified requiring intraday short-term forecasts from plant operators and service providers	Proposal: COES presents a report on the benefits of intraday short-term power forecasts. Approval: Osinergmin approves modification of Technical Procedure after a public consultation	Plant operators/service providers: implementation of more forecast updates using real-time data Osinergmin: validate delivery of short-term forecasts	Consider short-term forecasts in operation, provide real-time data to forecast provider	Plant operators: low to medium costs for setting up short-term forecasts	High
Long-term (> 1 year)	**Higher temporal resolution (15 minutes)**	Currently, 30 minute values			Plant operators/service providers: provide forecasts in 15 minute resolution COES: consider 15 minute values in operation	Adjust processes to enable use of 15 minute values	Plant operators/service providers: no or very little effort and costs COES: little effort to adjust processes and formats to incorporate/require 15 minute values	High

Recommendation		Current situation	Type of measure	Responsible for measure: proposal and enactment	Responsible for measure: execution, implementation and supervision	Implications for COES (and its interaction with plant operators)	Effort and costs	Relevance for forecast quality
Time horizon	Action for change							
Long-term (> 1 year)	**Incorporation of model spreads in power forecasts**	Plant operators do not provide model spreads with their power forecasts	Modification of the Technical Norm for the Co-ordination of the Real-Time Operation. Existing Technical Procedure is modified so that it requires plant operators to submit a model spread with their forecast	Proposal: COES presents a report on the benefits of the model spread for system operation, and the proposal for the modification of the Technical Procedures Approval: Osinergmin after a public consultation ('Proceso de audiencia pública')	Plant operators/service providers: provide power forecasts with model spreads	Consider model spreads in day-ahead planning and operation	Plant operators/service providers: no or very little effort and costs	Medium

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