Forecasting and risk assessment in MV grids

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***Abstract*— Due to massive increase of distributed energy resources into the electrical grid, Distribution System Operators are facing increased complexity in the distribution system. While flexibility is considered as an alternative and affordable solution, the procurement and dispatching process of flexibility urges for an improvement of monitoring capability from the DSOs. This paper aims to present different network forecasting and risk assessment methods.**

Keywords—forecasting, energy, load forecasting, renewable energy forecasting, DSO, electrical grids.

I. INTRODUCTION

The main component of the emerging energy transition worldwide is the increase in renewable energy sources (RES), including especially solar PV and wind. However, these types of renewable energy are variable depending on the temperature, irradiation, and wind speed. Their integration into the traditional power systems could be a problem to the reliability, stability, and quality of power supply, e.g. power congestion or voltage stability. With the growing of DER, the flexibility from the customer's side becomes more and more important. This enables alternative options for the DSO to control and operate the distribution grids. While reinforcing the network is costly and time-consuming, the flexibility option could help the DSOs for the safe operation of their grid. However, trading energy without a good observability capability to reflect on actual states of the grid will result in the ineffective impact on resolving grid issues. It hinders also possibilities to maximize the utilization of existing assets and circumvent the need of extensive investment for network reinforcement.

II. FORECASTING TECHNIQUES

Energy forecasting is a well-known technique used to forecast the future of energy consumption and production. The rate of growth of energy is estimated at around 1.2% annually. Without the change of normal weather conditions, the peak load for winter periods (e.g. Pacific Northwest) is predicted to grow to 43,000 MW by 2030 [20]. So, energy forecast plays an essential role in distribution networks. In this part, the analysis of different forecast tools will be discussed.

With the integration of RES, the energy network is becoming more and more complex and unpredictable. So, various forecasting techniques are developed around the world to overcome this problem. Depending on the objective of system reliability, efficiency, optimization, etc. different models and approaches are selected.

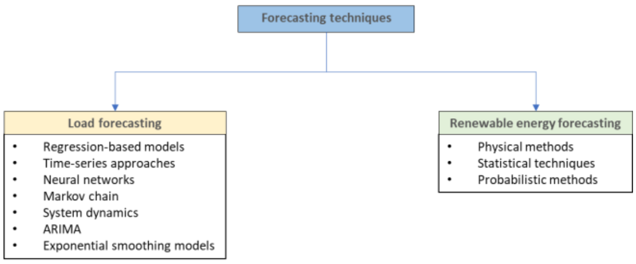

Fig. 1. The most used forecasting techniques

Forecasting errors could cause unbalanced supply-demand, which affects the safe operation, quality of the service, or even lead to local or system power outage. Overestimation of power consumption may lead to unused capacity (wasting the resources). Especially, without or lack of distribution system data, the forecasting model could not give an accurate result. Thus, selecting the right models to accurately predict future energy trends is an essential step for DSOs.

A. Forecasting of load

Load forecasting (LF) is helpful to forecast the energy consumption using historical data, meteo data, and capability of RES. It support the DSOs to balance the generation and consumption of energy. LF forecasts the future load of the energy system for a specific period. The forecast can be for different time intervals, up to 50 years depending on the needs of planning. LF classification can be done in three areas [1], [2]:

- Short term load forecasting is helpful to predict the consumption on an hourly basis up to one week for daily running and also to minimize costs.

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- Medium term load forecast is helpful to forecast consumption weekly, monthly, yearly and is used for proper operational and efficient planning.
- Long term load forecast is helpful to predict load in long periods of time as 50 years ahead and is used for expansion planning.

Load forecasting is an important component of the operation and planning of the power system, and it has a strong impact on reducing utility costs [3]. Assuming inaccuracies in forecasting will lead to an increase in operating costs. The use of a model that takes into account both economic and technical variables is essential, and specific evaluation approaches must be used to determine the parameters of the model. Numerous methods have been proposed in various literature sources. The most common are [4]–[12]:

- Regression-based models:

The best model is difficult to determine due to the nonlinear correlation between electrical loads and influencing factors. They are widely used for their good results and easy simulation by regression analysis. It is assumed that the relationships between the influencing factors are linear, thus achieving good results with minimal errors. This type of model is used to find the connections between the electrical load and the minimum and maximum minimum temperature. Undoubtedly, there are other regression models that help calculate the electric load as a function of temperature.

- Time series approaches

The advantages of this method is that less historical data is used, there is no need for additional time series for the temperature. This method estimates the uncertainty in short-term forecasting. Disadvantages include the need for human intervention and the possibility of becoming numerically unstable, it is difficult to find and analyze sources of error.

- Neural Networks

This method is based on an algorithm that is trained, including new data, recognizes basic connections in a set of information. The advantages of the method are its ability to process missing data, a large number of parameters, nonlinear models, can predict problems and present a good predictive result, while self-learning. The disadvantage is the need for more resources during training

- Markov Chain

This model is suitable for quantitative analysis, it is good for assessing one quantitative state in another. Allows analysis of consumption as well as reliability, allows for good forecasts using energy price and demand. This method is simplicity, computational speed, and stability. It comprises the forecast of the conditional and unconditional probability distribution.

- System Dynamics

Here we have an interdisciplinary approach. The method is suitable for simulating complex nonlinear systems using causal relationships. Disadvantage is the time required to define each component, as well as system uncertainty. System dynamics can be very complex, with a large number of variables, as in the simulation of real systems. It can simulate only one variant of a situation at a time, although it catches a large selection in the values of its variables.

- Autoregressive integrated moving average (ARIMA)

A model in which an own series history is used as an explanatory variable. Regression uses external factors as an explanatory variable for the dependent value. The method can capture the impact of weather on load. This method also provides a more straightforward model estimation and a more accessible interpretation of the model parameters. However, this is a univariate model. So, it cannot exploit the leading indicators or explanatory variables.

- Exponential Smoothing Models

The easiest model for smoothing uses reducing weights on past observations. In cases where there is a tendency in the information, it is better to use double exponential smoothing, using equations, both general data and the trend. This method is easy to learn and apply. It gives more significance to recent observations. However, it produces prediction that is lagging the real trend. Sometimes this method neglects the ups and downs associated with a random variable. This method is not suitable for long-term forecasts because forecasts are not accurate when data is with cylindrical or seasonal variations.

B. Renewable energy forecasting

RES (i.e., wind, solar) play an essential role in the energy system [12]. At the same time, the uncertainties from these RES are a challenge for the power system, especially for the traditional passive distribution system [13]. The forecast of these RES is an important topic due to the importance of economic and technical parameters and their application in evolving energy markets. [13-19]. The prediction time horizon can be spited into 4 types: ultra-short term, short term, medium term, and long term prediction horizon [26]. The problem has been resolved from different dimensions: meteo (weather forecast), mathematics (probabilistic, statistical), machine learning and the combination of all these methods [13], [15], [16].

- Physical methods

In this subsection, we will discuss the models that use weather forecasting as input data as well as terrain and layout of wind power park to forecast the future parameters [6], [20]. Beneficially, this method skip the training phase with historical data. The result is suitable for the short-term prediction horizon. The inconvenience and difficulty of application is based on the need for data, as well as the need for specialized equipment [4]. These methods are still developed and applied in the real system for wind and solar prediction [4], [21].

- Statistical techniques

Unlike physical methods, statistical methods are purely mathematical. The idea behind these methods is based on historical data; the model will recognize the data's relationship or pattern [36]. The autoregressive, time-series models are mostly used. The periodic curve fitting technique for forecast was presented in [22]. An adaptive autoregressive model is another approach that pre processes the data and renew the output using the cursive least squares curve fitting method. The most popular approach for short term prediction is ARMA (combination of autoregressive, moving average). In [9], the detailed analysis of four models was given; these were used to predict wind direction and speed. A combination of ARMA and wavelet theory result in the forecasting that was generate after preliminary preparation of the wind speed. The ARMA approach is also helpful to upgrade forecasting accuracy. In [23-24], linear models are the basis to forecast wind direction and speed.

- Probabilistic methods

These methods used, solar irradiation and wind speed are used as a probability density function. The Weibull distribution is a helpful for predicting wind speed [25], [26]. Several methods were proposed to improve the forecast accuracy by estimating the Weibull parameters. The most used method is maximum and modified maximum probability, as well as energy and graphical model [27-28]. Besides the wind profile, there are some different probabilistic methods which are used to predict the uncertainty, such as Quantile regression and kernel density estimation.

III. State Estimation to Enable Flexibility Procurement

The first research works on the distribution SE were carried out in [29]–[34]. The distribution system state estimation is construct on node voltage rectangular and polar in [34], [35]. The DSSE base is on current rectangular and polar in [36]. In [37], the performance of the branch current and node voltage state estimator is analysed. The accuracy of the two methods is reported as the same.

Most of the methods try to minimize the quadratic error. But, other methods like quadratic-constant, quadratic-linear, least measurement rejected, least median of square are applied to minimize the state error [37], [38]. For the non-normal distribution measurement errors, the probabilistic SE methods are used [31]. In this case, the PDF can be presented based on Gaussian distributions equivalent [11], Beta - distribution [14], [39], Gaussian mixture models [40], or via their own PDF [41]. Artificial Neural Network SE techniques are presented in [42]–[44]. Fuzzy logic state estimation techniques are presented in [45], [46]. Furthermore, the weighted least square approach is choosed for the distribution system state estimation application. SE, when used to the distribution system, implies to the system with many state variables, which can be thousands. Where such cases exist, it would be useful to divide the SE's problems into different areas, as proposed in [47]–[49].

State prediction for risk assessment

Risk assessment on distribution networks has gained much attention in last years due to the energy transformation that results in high penetration of distributed resources and renewables in distribution grids. The uncertainties associated with renewable generation as well as with loads that are dependent on end-users behavior such as EVs and heat pumps (HPs) have deteriorated the prognosis of the distribution level operation. Figure 2 shows some of risk assessment method and security indicators. New techniques are proposed to comprehensively determine the level of the potential risk that the operation of a given distribution grid faces considering multiple risk factors [50]. In [50], probabilistic models are established to determine the uncertainties, includes several indicators, as well as the risk of overvoltage, overload, voltage change, voltage drop, are calculated using the sensitivity method taking into account the probabilistic load flow.

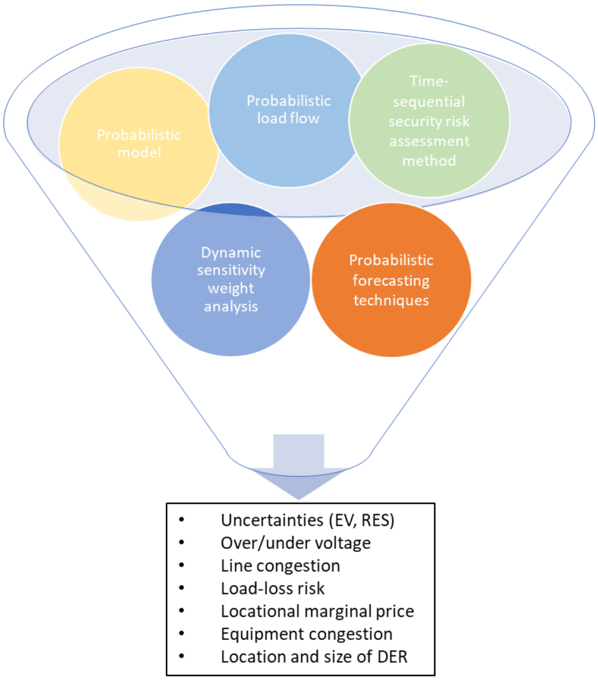

Fig. 2. Some of risk assessment methods and security indicators.

Moreover, risk assessment methods based on probabilistic forecasting techniques can be used to predict congestion set network. As, in [51] a forecasting model is shown, which uses the division of the uncertainty parameters into critical areas, as a result of which we calculate the real-time probability distribution and the presence of equipment overload. The method involves production forecasts, available constraints and possible unforeseen situations [51]. To this extent, risk assessment techniques (i.e., congestion forecasting methods) can be utilized to forecast the changes of the LMPs in a network and, thus, determine the future energy price and define a suitable market strategy [52-53].

The use of standard risk assessment provides information on the security of the system in which it is, but cannot determine the level of risk. A significant problem can arise when assessing the risk of new RES in electricity distribution networks, this happens if probabilistic methods are used, such as those used that include basic reliability indicators, such as SAIDI and SAIFI. This can be essential when forecasting the availability of RES connected to the electricity grid [54]. The results presented in [54] show that the risk assessment for distribution networks with significant renewable generation when using probabilistic methods, underestimation may occur if these methods are used for large energy systems. In [55-56] a proposed method determines the risk, where it will occur, its level and what protection to include in the self-recovery of the electrical network. To implement it, a multi-segment method is used, which includes estimating the risk of congestion, using historical data as well as real-time data as well as forecast data. Furthermore, in [57], an algorithm for the evaluation of the operational risk for electricity networks with PV, the effective calculation of risk indices is extremely useful in dispatching and undertaking an optimal management strategy, thus minimizing the risk to the electricity distribution system. Between the operational risk and the level of distribution, the protection and operation is determined to obtain the probable problems and to determine which elements may lead to damage.

Risk assessment methods can also be implemented to determine the suitable location and size of the distributed generation that should be connected to a given network, either in the distribution or in transmission level, in order to prevent the congestion of the power lines [58]. Furthermore, risk assessment methods can be implemented for maintenance purposes and for the inspection of the health of the equipment of a given distribution network. Due to the large amount of items included in a typical distribution network, risk assessment methods can be implemented to improve the effectiveness of the sample inspection efficiency while reducing the cost of the sample inspection [59]. In [59], based on the assessment of the condition of the equipment, a risk assessment method was used. An assessment of the condition of the technical equipment, the probability of damage is used, facilitating the assessment of the condition of the distribution network. Multi-purpose optimization is used, taking into account the assessment of the degree of risk. This strategy brings the sample inspection work of equipment into the assets management system and makes the sample inspection work more reasonable and economical. Furthermore, in [60], a method for the state maintenance decision-making is developed, based on the evaluation of the real-time health status and the results of the risk assessment of the equipment of a distribution network. The results obtained from the exponential model are for failures, and the health index is calculated from the condition of the equipment. The feeder separation method is used for calculation of rate of the average real time failure of all technical equipment. The cost of damage, equipment and environmental damage is determined. In conclusion, the risk for each device is calculated using the cost of risk loss for each individual device. Depending on the value of the indicator, the maintenance and the mode of operation are determined, as well as in what sequence to perform. [60]

IV. CONCLUSION

DSOs need to build a future intelligent distribution system for monitoring and control the system. It aims to realize high quality and high velocity near real-time information stream on customers' energy consumptions and prosumers' generation while providing accessibility to metering data. Also to create an framework based to an open data of managing flexibility of prosumer demand and generation while utilizing cloud computing for power grid management. This approach would be relevant to facilitate the transition towards future intelligent distribution grids with DSO's role as a market facilitator. Especially, a cross-platform for data sharing and grid monitoring from H2020 project UNITED-GRID is an important development to integrate data measurement gathered from both grid and DER's owners. Flexigrid will adopt and strengthen this development with focuses on advanced physics-aware network structure for state estimation and an integration of stochastic assessment framework for risk assessment. This enables control functionalities at the grid edges by leveraging the enriched energy data while addressing thoroughly security and privacy issues. The ultimate goal is to enable optimal solutions for operating different local demands and allocating flexibility when and where it is needed. The involvement of DERs' owners is important provide relevant data as well as flexibility options, e.g., power curtailment or load shifting.

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