Wind Power Forecasting Uncertainty and Unit Commitment

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Abstract — In this work we evaluate the impact of considering a stochastic approach on the day-ahead basis Unit Commitment (UC). Comparisons between stochastic and deterministic Unit Commitment solutions are provided. The generation of Unit Commitment solution is guaranteed by DEEPSO, which is a hybrid DE-EA-PSO algorithm, where DE stands for Differential Evolution, EA for Evolutionary Algorithms and PSO for Particle Swarm Optimization. For the calculation of the optimal economic dispatch an algorithm based on the Benders Decomposition, combining the Dual Dynamic Programming, was developed. Results show that the stochastic approach leads to more robust Unit Commitment solutions than the deterministic one.

Index Terms — Stochastic, Unit Commitment, Uncertainty, Wind Power.

I. INTRODUCTION

The increasing use of renewable energies, namely wind power, for economic and environmental motives have reduce the commitment of conventional generation units. The uncertainty and variability in the wind power requires that the unit commitment solutions are flexible. The deterministic methods do not guarantee this flexibility, and so, stochastic methods need to be developed and tested. The stochastic approaches developed take into consideration several wind power scenarios and their probability of occurrence. These scenarios were constructed based on the technique presented in [1]. Results comparisons were made and the stochastic advantage proved.

II. STATE OF THE ART

The impacts that the increasing use of renewable energy has on the UC have been studied for the last years. Studies on the integration of wind power into the unit commitment problem have been made [2]–[4], namely on the reserve requirement [5], [6] and on novel unit commitment algorithms [7]–[10]. The overall opinion is in favor of considering stochastic methods on the unit commitment problem. The computational time and effort associated to the stochastic methods can be overcome by the use of techniques like Benders Decomposition.

III. MODELING

A. Unit Commitment

The unit commitment model adopted considers constraints like the power balance, and ramping rate, minimum and maximum output, and minimum up and down times of generation units. Reserve levels are also included as constraints. The objective function is the minimization of total operational costs, considering units’ production costs and start-up costs.

B. DEEPSO

The metaheuristic adopted, DEEPSO, was adapted to our problem considering that the UC solutions are binary. The population is of 10 particles, each one with a dimension of 240, for the 10 generation units and the 24 operational periods. The fitness function includes the routine that calculates the optimal economic dispatch through Benders Decomposition – Dual Dynamic Programming. A commercial optimization tool box was considered for time efficiency [11].

IV. RESULTS

Result comparisons were made, considering wind power conditions in 2 different operational days. 2 stochastic approaches were considered, one using the top 5 probable scenarios and the other considering the point forecast plus 4 extreme scenarios. Result analysis from the stochastic and deterministic methods considered the actual wind power generation on the operational days and all the possible scenarios, making a risk analysis. The expected operational costs, and the expected levels of load shedding, wind spilling and generation surplus were evaluated.

Figure 1 presents a chart that compares the probability that each one of the 3 approaches has of producing operational costs under the determined values, for one of the days studied.
More exhaustive studies are expected in future works. A medium-term collaboration with systems operators would be of great value, permitting the access of real operational data and assessing in a more realistic manner the benefit of considering a stochastic Unit Commitment. A more profound study that considers the electrical grid and the respective power flow constraints could help to expose and confirm the supremacy of the stochastic method over the deterministic. More detailed reserve constraints should be considered in future works.

REFERENCES


The chart presented makes clear the supremacy of the stochastic approaches against the deterministic one. For all the operational costs considered the stochastic methods have a higher probability of being above that value. The stochastic approach that considers the top 5 probable scenarios produces the best results.

Table 1 presents the results on the expected levels of load shedding, spilled wind and generation surplus for the same operational day in the analysis before.

<table>
<thead>
<tr>
<th></th>
<th>Deterministic</th>
<th>Stochastic Top 5</th>
<th>Stochastic Extremes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load Shedding</strong></td>
<td>40,10</td>
<td>10,47</td>
<td>11,30</td>
</tr>
<tr>
<td>(MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spilled Wind</strong></td>
<td>117,18</td>
<td>16,05</td>
<td>97,98</td>
</tr>
<tr>
<td>(MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Generation Surplus</strong></td>
<td>14,48</td>
<td>0,68</td>
<td>8,99</td>
</tr>
<tr>
<td>(MWh)</td>
<td></td>
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Once again the stochastic approaches led to preferable results, mainly the one using the top 5 probable scenarios.

V. CONCLUSION

With the study carried out and with the obtained results the advantage of adopting a stochastic method of calculating the Unit Commitment was clearly demonstrated. A stochastic UC solution adapts better to extreme and unseen wind power scenarios, which facilitates the system operation and leads to lower operational costs. As levels of load shedding, spilled wind, and generation surplus are inferior in a stochastic approach, along with less costly system operation, we conclude that the systems operators should embrace a stochastic method of calculating the units schedule.

The developed UC calculation tool, combining the DEEPSO with the Benders decomposition, showed its viability. This combination is expected to present great performances with the increasing of the complexity of the power systems analyzed. Benders Decomposition technique is recognized to be much faster than the conventional simplex formulations, especially for large scale problems.