A Study of the Renewable Energy Unit with Uncertainty: Towards Reserve and Energy Capacity Co-Optimization

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Abstract--This study proposed a system model through which reserve and energy capacity could be dispatched. Moderating factors that were considered included unsteady power generation and uncertain load demand. The parameters considered centered on uncertainty in power demand management while considering environmental, user, and utility objectives. The proposed mode also considered day-ahead markets for electricity relative to power demand bid variation. In so doing, the model strived to generate certain amounts of the required energy, as well as reserve capacity. Furthermore, the model predicted any lost opportunity cost before incorporating the expected load that would go unreserved. The investigation culminated into the analysis of the impact of separate and combined energy dispatch and reserve on system outcomes. To address non linear cost curves, robust optimization technique was used to optimize the selected objective function. To conduct and evaluate the numerical outcomes, as well as the feasibility of the proposed framework, case analyses were conducted. From the simulation outcomes, the proposed scheduling model proved effective in such a way that it posed beneficial effects such as improved system stability and reduced cost.

1. Introduction

In power systems, reserve capacity entails the fixed energy amount that could be planned and generated before making demand bids [1]. The role of this energy is to ensure that the dynamic system load is balanced through synchronization [2, 3]. Indeed, the forethought measure is worth considering because it allows room for withstanding any system load fluctuations that would emerge unforeseen, besides sudden outages in power [4]. The outages and system load fluctuations have been documented to arise from renewable energy resource integration [5, 6]. Given energy demand and generation, the frequency and magnitude of imbalances could cause an increase in the cost of the electrical system, especially generation and operation costs [6-8]. On the other hand, the incorporation of renewable energy such as grid to vehicle and vehicle to grid implies that economic benefits could be felt by the power system contingency [9, 10].

Of importance to note is that power demand and renewable energy are dynamic in nature and this trend could cause system inflexibilities [2], hence, increased costs associated with the integration of peak power plants into the system [9]. To ensure that the reserve capacity or extra generation is maintained, actual estimates of the extra generation are required [5], yet this task is difficult. Hence, various approaches have been used in relation to the reserve capacity prediction. Some of these approaches include calculations using stochastic algorithms (such as extreme value distribution, optimal stopping theory, fuzzy logic, Markov’s processes, and neural network) and the percentage of the generated energy or the total generation capacity [1, 4]. In this study, the proposed system is summarized as follows.
2. Methodology

Regarding the implementation of the proposed system, a sample was taken. This sample entailed a connection between an electricity market and an IEEE 6 bus system. Whereas the generation units were three, indicated as P1, P2, P3, the number of loads was n. the function of fuel cost was determined through:

\[ F_i = \alpha P_i^2 + \beta P_i + \gamma_i. \]

Indeed, the quadratic cost function was employed due to its applicability to optimally sized matrices that rely on the coefficients of fuel costs arising from different units of energy generation. Other parameters that were defined included the total energy demand for each hour and the maximum and minimum power generation limits. Regarding the implementation and performance of optimization, well known tools were used. The role of the tools was to produce a numerical solution. For data visualization, optimization, and handling, the study relied on MATLAB 2017a. Also, the trust-region-reflective and interior-point-convex algorithms informed the decision to use the built-in quadprog solver. The role of the solver was to address problems linked to large scale nonlinear optimization.

3. Results and Discussion

Upon establishing the exaggerated peaks for reserve and power, initial findings demonstrated significant optimizing profiles. The inference was obtained after comparing the outcomes with those that had been documented in real-time dispatch. Also, there was not significance in the demand profile trending. Hence, over the selected duration, there were profound fluctuations in the demand for power. Also, the high peaks were obtained during evening hours. This observation could be explained by industrial load. Also, peaks were observed during the early morning. The latter outcome could be linked to power usage in the residential zones. During the rest of the time intervals, the study established medium and low peaks.
Figure 2: Summary of the initial results regarding the power demand and generation profile

Another phase involved dispatching the reserve capacity and energy generation facilities. This process occurred simultaneously. The aim was to predict how the power demand could be met. At this stage, initial moments depicted that the third unit generation did not play a significant role in power provision. This trend was observed because the unit was comparatively expensive, with generation units 1 and 2 playing a leading role in power provision due to their low costs. Hence, the generation units 1 and 2 acted as first choice because they reflected low cost energy generation facilities. The eventuality is that the high cost energy generation plants and reserve capacity only operated due to the need to meet the peak or high demand. For the latter case, fuel rates exhibited upward trends that were exaggerated, hence proving infeasible to utilize when high demanding hours set in.

Therefore, the third case attracted the co-optimization of the reserve and energy. In the stage, power generation units did not work on their expected full rating. Therefore, there was no loss of power. In situations where certain power amounts went unfulfilled because of the condition of overload, the load was under estimated.

In the fourth case analysis, the reserve and energy capacity was co-optimized for the target system constituting variable load. For the load, two stochastic levels were considered. These levels included a low side of 40.00% and a high side of 60.00%. The figure below summarizes the load and energy generation profiles for the fourth case analysis.
4. Conclusion and Future Implications

In this study, the proposed framework pointed to the criticality of wind and reserve energy as avenues through which the cost of energy generation could be curtailed. Given this promising path, the investigation employed a joint optimization algorithm. The algorithm was used to dispatch the reserve capacity and energy simultaneously. The experimental setup involved a day-ahead electricity market. From the results that were obtained, the proposed framework exhibited superior performance in such a way that it handled uncertainty in the loss of power, proving worth adopting for real-time test cases. It is also notable that the effectiveness of the proposed model was validated to determine its feasibility for use in real-world scenarios involving power consumption system. The validation procedure involved the consideration of different test cases. These test cases were characterized by situations with low cost reserve and energy facilities. The cases were co-dispatched with improved economic efficiency. However, a notable attribute is that the perceived benefits were constrained highly because of the moderating role of various parameters. These parameters included process limits, demand, capacity, and generation. However, the integration of the wind power model into the proposed framework saw the aforementioned constraints addressed or alleviated successfully. Hence, the incorporation of the wind power model into the proposed system acted as the maximal cost reduction’s margin. In conclusion, this study’s proposed co-optimizing framework is deemed contributory to practical settings in such a way that it increases the understanding of some of the observations that are likely to be gained if different facilities are developed independently. An example is a case in which the wind and reserve energy facilities are used to form interconnected networks. In such a case, additional benefits can be felt in terms of the generation process shift to low peak hours, having considered high peak hours initially. Overall, the study proved informative through advocacy for the proposed model whereby the findings suggested that renewable and reserve resources play an important role in shaping the nature of the market in day-ahead electricity scenario.

5. References

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