Using Adaptive Safe Experimentation Dynamics Algorithm for Maximizing Wind Farm Power Production

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***Abstract*— This research presents a model-free strategy for increasing wind farm power generation based on the Adaptive Safe Experimentation Dynamics Algorithm (ASEDA). The ASEDA method is an improved version of the Safe Experimentation Dynamics (SED) algorithm that modifies the current tuning variable to respond to the changes in the objective function. The convergence accuracy is predicted to be enhanced further by adding the adaptive element to the modified SED equation. The ASEDA-based technique is used to determine the ideal control parameter for each turbine to maximize a wind farm's total power generation. A single single-row wind farm prototype with turbulence coupling among turbines is employed to validate the proposed approach. Simulation findings show that the ASEDA-based approach provides more total power generation than the original SED technique.**

Keywords*— *wind farm, power generation, safe experimentation dynamics, renewable energy.

I. Introduction

Existing wind turbines could modify control factors such as blade angle, yaw angle, and engine torque to optimize power production. The change in any of the factors in the setting of a wind farm not only affects its own power generation but can also impact the power outputs of downstream turbines. This is owing to the turbulent connections between the turbines. Furthermore, due to the complexities of the turbulence interactions, which are hard to describe increases the difficulty of determining the appropriate control variables. As a result, the work on upgrading the control algorithm of current wind farms is fascinating and has drawn the attention of many control specialists.

Recognizing that turbulence interactions between turbines are complicated and difficult to simulate, a model-free control strategy has emerged as a viable option for maximizing the power output of current wind farms. So far, numerous model-free control techniques have been developed to increase the wind farm energy output. These include cooperative control and game-theoretic (GT) based approaches [1],[2],[3], simultaneous perturbation stochastic approximation [4], [5], maximum power point tracking [6],[7],[8], Bayesian ascent [9],[10], multi-resolution simultaneous perturbation stochastic approximation [11], and random search [12] based approaches.

Furthermore, it is well recognized that the Safe Experimentation Dynamics (SED) approach introduced by [2] is the best way to improve wind farm power generation. It can provide consistent convergence and improve accuracy, and its capacity to maintain the optimized feature value can be obtained by improving the feature. The SED likewise employs a constant step size that is unaffected by the number of iterations. As a result, it is a helpful data-driven optimization technique when perturbations, ambiguities, or stochastic delays arise during the optimization procedure. SED also has the advantage of having fewer coefficients, which makes the optimization strategy more efficient and simpler to execute. The existing SED in [2], on the other hand, had improved the design parameter by randomly perturbing specific design parameters throughout a pre-defined search space. Using an updated technique that is adaptable to changes in the goal function has the potential to increase the accuracy of the performance. Therefore, we introduce the Adaptive Safe Experimentation Dynamics Algorithm (ASEDA) to enhance the effectiveness of the conventional SED approach as a tool for increasing wind farm power generation. If the existing design variable does not enhance the goal function, ASEDA provides additional strength or perturbation to the design variable. Consequently, the algorithm will have a better chance of avoiding the premature convergence problem.

The usefulness of ASEDA as a model-free technique is investigated in this work, and it is evaluated using a single-row wind farm model. The statistical analysis of the overall power generation from wind farms is then shown. Finally, the performance of the ASEDA and SED-based techniques are compared.

II. Problem Formulation

We assume that in a wind farm, N several wind turbines are located, where each turbine's location may be determined randomly. The turbine j control parameter is described as $q_j (j = 1, 2, ..., N)$, a generalized version of the turbine controllers, such as blade pitch angle and turbine rotor speed [13]. The symbol denotes the power generated by a turbine $P_j(q_1, q_2, ..., q_N)(j = 1, 2, ..., N)$. This study considers the entering wind speed with a time-varying speed and randomized orientation. As a result of the turbulence interaction between turbines, we can claim that the control parameters, except for the turbine j , $q_1, q_2, ..., q_{j-1}, q_{j+1}, q_N$, would also impact the turbine j power generation P_j . Therefore, any changes in the control variable q_j influence not just only P_j but also $P_1, P_2, ..., P_{j-1}, P_{j+1}, P_N$. As a result, the turbine's overall power output has a strong influence q_j ,