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Optimising the power generation cost of microgrids using genetic algorithms - An analysis of the impact of crossover and mutation rates

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This study focuses on optimising microgrid costs, with a particular emphasis on the influence of crossover and mutation rates by applying genetic algorithms. As the demand for decentralised energy solutions in isolated and underserved areas grows, microgrids have gained popularity for their ability to incorporate renewable energy sources efficiently. However, their benefits over conventional power generation systems can diminish if not configured properly. The primary objective of this research is to identify the optimal operational conditions for harnessing genetic algorithms to optimise microgrid costs, with a specific focus on the Sri Lankan energy market. This endeavour aims to promote decentralised microgrid technologies and enhance the reliability of the energy service sector. Our methodology employs a Python-based genetic algorithm that iterates through 100 generations to identify the most cost-effective operational settings for microgrids. The cost optimisation equation considers operational expenses for each unit, carbon dioxide emissions costs, and the present value of future running expenses. The future running expense involves a summation over all power generation units, where the present value of the future cost of owning and operating each unit is calculated based on the discount rate and unit lifetime. Elitism is incorporated in the algorithm to preserve the best-performing individuals in each generation and increase the likelihood of converging towards the global optimum. To evaluate the impact of crossover and mutation rates on fitness, a series of experiments were conducted. The null hypothesis stated no significant effect on the fitness of a generation, while the alternative hypothesis considered a significant effect. For the crossover rate experiment, values ranging from 1% to 50% were tested by switching specific bits in the gene representation. The experiment was repeated 100 times to obtain average values and minimise outliers. Similarly, the mutation rate experiment included values from 1% to 50%, with random bit flips according to the specified probabilities. The experiment was also repeated 100 times for accurate evaluation. Statistical analysis relied on the Kruskal-Wallis H-test, with a subsequent Dunn post hoc test to identify significant pairwise differences in mutation rates. The Dunn post hoc test, using Holm's method for multiple comparisons, revealed significant differences in mutation rates at various levels of significance. Notably, no significant differences were found between mutation rates at the 50%, 25%, and 20% levels of significance. However, at the 10%, 5%, and 1% levels of significance, there were significant differences between certain pairs of mutation rates. It is important to consider that while a higher mutation rate tends to correlate with better fitness values, it can also lead to inconsistent results, potentially affecting the final output of the algorithm. Our study finds that crossover rates have minimal impact on microgrid cost optimisation using genetic algorithms. However, extreme values affect convergence and speed. Mutation rates significantly influence outcomes, with the ideal range being 1% to 10%. This insight aids energy professionals in optimising power generation strategies in Sri Lanka, driving the nation towards a sustainable and resilient energy market.

Keywords: Genetic Algorithm, Cost Optimisation, Microgrid Optimisation, Energy Management