Optimized Enhanced Control System for the Unibadan’s Virtual Power Plant Project Using Genetic Algorithm

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ABSTRACT

Pertinent literature arguing on the need for the University of Ibadan Management to decentralize its electricity generation by increasing the penetration of renewable energy sources (RES) in solving its dire energy problems have necessitated similar calls to University Management in incorporating relevant and evolving technologies in its desired efforts to try alternative energy sources. Some of these calls have opined that envisaging a future increase in the amount of distributed generation (DG) schemes, University Management put in place modalities for the incorporation of a virtual power plant (VPP). Leading authors have suggested that despite the proliferation of these DG schemes, their visibility and control would remain a mirage if technologies that could aggregate these distributed energy resources (DERs) in allowing for their participation in displacing part of the University’s load demand are not put in place. As a follow up to such scholarly proposals for the need for a virtual power plant, leading authors have suggested and proposed different schemes from load discrimination to improved load scheduling in the envisaged electricity network of the University. A critical evaluation though of these literatures and upon expert evaluation of existing infrastructure (DG schemes and RES) via modeling, we have discovered that the implementation of the proposed VPP project would be hampered due to existing technical incompatibilities and poor design specifications. Realizing these fundamental problems, we are thus proposing as a follow up to earlier write ups the need for the incorporation of an optimized enhanced control system using genetic algorithm (GA). The ease of arriving at solutions faster by stochastic optimization techniques over classical optimization techniques cannot be overemphasized hinging on the ability of the former not to get stuck in a local optimum solution.

Keywords: renewable energy sources, distributed energy resources, virtual power plant, distributed generation, genetic algorithm, optimization.

1. INTRODUCTION

With epileptic power supply to the University of Ibadan from the national grid as a result of its weakening infrastructure and other sundry reasons, the University Management has been considering alternative energy sources. From the increase in the number of its generating plants to an overhauling of its distribution networks, the replacement of ageing cables and supporting infrastructure, installation of prepaid energy meters etc. Management has stepped up activities in ensuring that there is greater accountability and efficient use of available energy [1][2][3].

As posited by [4], there will continue to be an increase (in the short to medium term) of energy consumption (in the campus community) with increase in the inhabitants within the campus community coupled with an ever increasing demand for consumer electronics and Management’s drive for increased impact of information and communication technology (ICT) in teaching and research [5]. With the heavy operation and maintenance (O&M) costs involved in running these generating plants coupled with their contribution to greenhouse gas (GHG) emissions and climate change, Management has been seeking alternative means of power (electricity) generation on campus.
Such alternative energy sources that are being exploited include solar energy with plans for mini hydro, wind and biomass [1]. The exploitation of solar energy has seen an upsurge in the number of DG schemes on campus powering streetlights to corridor lights in halls of residence and skeletal operations in central admin and other select locations including access points for internet connectivity on campus [1]. The proliferation of these renewable energy sources (RES) however has seen no significant contribution from them to the overall electricity supply on campus. [1] in proposing a VPP for the University of Ibadan, opined that an increased investment in RES should see a concurrent reduction in investments in diesel driven plants as the visibility of these RES is being increased due to their aggregation by the proposed VPP.

With a follow up to such proposal [6] rightly posited that without proper load discrimination, there would be technical difficulties witnessed as the contribution of the DG scheme would not be effectively evaluated. The proposed load discrimination scheme was also to help in the case of faults tripping supply for intentional islanding. This was to see that critical sections were still running even after power interruption from the grid. A subsequent proposal [7] also proposed the involvement of students into the overall growth of the DG scheme as they were expected to finance such expansion locally (on hall basis) through their hall levies. Genetic Algorithm was used in generating different scenarios based on input constraints in showing the respective hall utilization and amount tasked for any combination selected.

[8] further opined that there was a need for stringent voltage control of each contributing DG at the point of common coupling. This was to ensure that at the point of synchronization, voltage and frequency excursions were kept to a bare minimum for the incorporation of future envisaged sensitive electrical equipment.

3. THE PROPOSED SOLUTION

Exhaustively reviewing pertinent literature and proposals by leading authors on the Unibadan’s Virtual Power Plant Project has clearly shown that stochastic optimization techniques are the best tools for effectively and quickly arriving at optimum solutions [6][7].

The speed and ease provided by programming software tools such as MatLab has led to the improvement of such stochastic optimization tools from the classical optimization techniques. Evolved stochastic optimization techniques like Genetic Algorithms (GAs), Particle Swarm Colony Optimization (PSCO) Techniques, Ant Colony Optimization (ACO) Techniques, Simulated Annealing (SA) and other Evolutionary Algorithms (EAs) have all been used in optimizing varied design problems.

In providing an encompassing solution to that seeks to harness and incorporate the varied suggestions for the Unibadan’s VPP Project, an Optimized Enhanced Control System (OECS) is being proposed. In designing this proposed OECS, GA would be used. The proposed OECS scheme incorporates the allocation of students into a hall of residence while generating their respective contributions and also accommodates load discrimination and voltage and frequency control. The OECS in accommodating these does not compromise on the safety and integrity of the VPP project.

As a single platform, it also provides for future incorporation of upgrades in form of software. Its advantage over other proposed models including the Enhanced Auto Control System (EACS) is in the number of parameters it optimizes and its flexible nature.

4. GENETIC ALGORITHM

Genetic algorithms (gas) as an optimization tool was evolved due to the inefficiency of traditional techniques in solving complex nature problems [9], as opined by [10], optimization is the process of making something better. In providing an apt definition therefore for GA, [11] posits GA as an optimization and search technique based on the principles of genetics and natural selection. This view is further rectified by [10] who further opines that GA is an optimization algorithm intended to mimic some of the processes observed in natural selection.
The flow chart and algorithm are therefore described as posited by [7]. In designing a GA code therefore, a population needs to be defined (fig.2). In defining the sample population, different methods could be used depending on the problem formulation and choice of the designer – binary, continuous, steady-state and multi-objective [11]. For the problem at hand, the binary GA method is used because of its ease of programming and ability to constrain its values to be within limits while generating a sample population. Thereafter, a fitness function is defined. This fitness function provides the GA intelligence in screening out unfit chromosome strings from the population (fig.4) or in the eventual selection process. Each chromosome string (fig.3) corresponding to a solution is tested using the fitness function as a discriminant and their results are collated.

Those with values coalescing around zero (optimal result) are considered better answers while those with values further dispersed from zero are considered poorer solutions (fig.5). Elitism as used in the flowchart (fig.1) means the selection of the top best results, those with results closest to zero. In filling the now depleted population, cross-over operation (fig.6) is performed between the elitist solutions to generate off-springs who are going to compete with their parents in the next generation. Mutation operation is performed (fig.7) to alter the gene construct of selected chromosomes in order to prevent the program from getting stuck in a local minimum.

5. THE OPTIMIZED ENHANCED CONTROL SYSTEM (OECS)

As earlier explained, the OECS incorporates most of the solutions being proposed by leading authors on the Unibadan’s Virtual Power Plant Project. The allocation of students into a hall of residence, load discrimination, frequency and voltage control etc. are some of the parameters being optimized by the OECS.

Strongly argued and supported is the fact that the throughput of the proposed system, system’s efficiency, output and reliability are not in any case compromised.

6. RESULTS

The results displayed in figures 8, 9 and 10 give a combined graphical representation of the results of employing the proposed OECS. As can be surmised from the figures an attempt by the frequency curve to mimic the voltage curve is in an attempt to maintain system stability. These adjustments by the frequency curve are within a limited range and on defined levels thus preventing frequent fluctuations and excursions.

The voltage limit is also observed to be constrained to a very limited span and with fewer fluctuations (as the voltage output can only exist within certain levels) compared to the EACS. Also, as can be observed from the figures 8, 9 and 10, the number of parameters being optimized by the OECS is more than those being optimized by the EACS and every other proposed model.
Fig.1: flow chart of proposed GA

Fig.2: Chromosome string

Fig.3: M x N population matrix

Fig.4: Initial population matrix with corresponding penalty

Fig.5: Elitist chromosomes with the lowest penalty

Fig.6: Chromosomes with penalty ranked

Fig.7: Cross-over point

Elitist parents and off-springs
Elitist parents in new matrix
New off-springs after elitist parents have mated

Fig.8: Mutated bit of chromosome
7. CONCLUSION

From the foregoing therefore, incorporating the OECS into the design of the VPP Project for the University of Ibadan is advised as not only does it reduce the complexity in designing the proposed system, as previously opined, but also allows for a better and seamless integration of other supporting structures. Also, it provides an opportunity to better learn and come up with pragmatic and feasible solutions during the testing stage.

REFERENCES


**Authors’ Brief**

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