Development of soft computing modality for optimization of Renewable Energy Systems

A thesis submitted in part fulfilment of the requirements for the degree of

Doctor of Philosophy

by

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June, 2024

Chapter 6

Conclusion and Future Directions

This chapter provides a concise overview of the main contributions made in this thesis. This is followed by listing the limitations of study and in conclusion we provide a few potential areas of research that might be explored in the future.

6.1 Conclusion

This thesis provides a modality for optimizing different component sizing issues in PV based renewable energy systems. We have explored the role of the optimized DC-DC converter topology as interface for executing MPPT in standalone PV systems. When combined with an MPPT algorithm, the PV system operates at its best when the right load and dc-dc converter interface are properly chosen. The efficacy of the MPPT algorithm to deal with real life variations in atmospheric conditions heavily relies on the design of the DC-DC converter used in PV systems. Non-isolated converters are workable without galvanic isolation due to the straightforward setup and less burden on switching devices. The circuit element must have low power losses subject to fulfilling many design optimization criterion. To select the optimum configuration of power converter interface and tracking algorithm, a simulation based comparative assessment has been made on the combination of an optimized boost converter with established tracking algorithms for varying external conditions. The results indicate that the boost converter utilizing the PSO algorithm consistently performed the better compared to other algorithms across all simulation tests.

The study also outlines the technical considerations involved in design optimization of HRES. The widely utilized algorithms for this purpose include GA and PSO. However, the recent research trends show that utilizing modified algorithms using hybridization and new metaheuristic algorithms for optimization problems yield superior outcomes in computation efficiency, resilience, faster convergence, and handling multiple conflicting objectives. The significant contributions of the research work are classified into three primary subsections, each of which provides a brief summary of the important contributions made in the thesis. The following are the subsections:

6.1.1 DC-DC converter design optimization for MPPT application

This work introduces the optimal design technique for a DC-DC boost converter. The objective is to reduce conduction losses, switching losses, and losses in passive components of the converter to minimize the total power loss in the converter. The study utilized the least power loss in the operation of the converter as the fitness function. Twenty-three metaheuristic optimization algorithms were used to improve the design of the boost dc-dc converter. Among the 23 selected metaheuristics for design optimization, the SCA, DFA, AHA, ASO, EO, FDA, and AOA have not been used before for DC-DC converter design optimization studies. The algorithms were analyzed in three distinct categories: swarm intelligence pattern, physics-based, and other. The WOA, SSA, SCA, and MFO techniques in swarm intelligence algorithms showed comparable results in terms of minimal iteration time and standard deviation. The WOA in the swarm intelligence category outperforms the other 22 algorithms in mean value, best value, highest value, iteration time, filter inductor and capacitor design constraint values, switching frequency, best optimized results for low power loss and convergence curve. With the optimized converter design as a starting point, standalone PV systems integrated with MPPT were tested against changing irradiance profiles using five tracking algorithms. The best tracking response generated was 98.33 % when the optimally designed boost converter was used with PSO as the tracking algorithm.

6.1.2 Optimal Sizing of a Hybrid PV-Hydro based HRES

This study aimed to design a HRES with the lowest LCOE for Hazadisa village in Nagaland's Dimapur district in North East India. It also involved comparing the performance of 23 metaheuristic algorithms to find the most optimal solution. This study involves comparing metaheuristic methods to determine the optimal size of an HRES to meet the seasonal demand variation of 11.1 to 24.61 kW with a base load of 4.8 kW. The GWO algorithm, from the category of swarm intelligence techniques, surpasses other algorithms in achieving optimal objective function values, demonstrating statistically significant results and fast convergence. The overall size of the optimized hybrid system was found to be 31.86 kW in which share of PV and Hydro was 16.12 kW and 15.74 kW respectively. The area for the PV system is found to be 95.58 m^2. The specification of the hydro unit had an effective head equal to 9.0 meters and a flow rate of 0.21 m^3/sec. The optimal value of LOCE was found to be 6.408 INR/kWh.

6.1.3 Hybrid GWOSCAPSO algorithm

This research work was aimed to create a hybrid GWOSCAPSO algorithm. The GWO algorithm is combined with SCA and PSO in this study to create a hybrid technique. This results in the improvement of GWO algorithms exploration and exploitation traits with quicker convergence. The suggested method was compared against PSO, GWO, ALO, WOA, MFO, and SCA meta-heuristics. Twenty-three classical benchmark functions were used to test the accuracy, ideal global solution, and efficiency of the new technique to find the most optimal solution. The simulations show that the hybrid technique is more accurate than GWO, SCA, ALO, MFO, WOA, and PSO. Statistically, the hybrid GWOSCAPSO outperforms the other algorithms against 20 out of 23 benchmark functions, proving it can solve engineering optimization challenges. In the majority of considered benchmark functions the GWOSCAPSO based optimization approach demonstrates superior performance compared to other algorithms in terms of objective function values, statistical significance tests while it also exhibits faster convergence. When applied to three design optimization problems studied in this thesis, the hybrid GWOSCAPSO algorithm produced optimized outcomes that gave better results to existing algorithms in terms of statistical parameters, comparable computational time and fast convergence characteristics.

6.2 Limitations of the current study

This thesis makes a number of investigations into the area of the design optimization of DC-DC converters topologies, optimal design of DC-DC Boost converter for MPPT applications in standalone PV systems, optimal sizing of hybrid renewable energy systems and formulation of a new hybrid metaheuristic optimization algorithm. Nevertheless, the study is not devoid of certain limitations which can be summarized as:

- The optimal designed DC-DC converters have not been constructed physically and in real time. Simulation of their designs and hardware implementation is required to validate the practical applicability of the method developed.
- The simulation of MPPT tracking and the corresponding tests considered to evaluate the performance of the algorithms and converter topologies have not been tested on a hardware platform.
- The hybrid system so designed has not been validated for the real time dynamic load changing scenario.

6.3 Directions for Future works

The work presented in this thesis exhibits competitive performance in terms of application of soft computing techniques in the field of design optimization, but at the same time opens the door for new directions which can be explored in future research. These areas of potential future study can be summed up as follows:

- The various converter topologies detailed in literature used as power interface and their operation in the wide range of external atmospheric conditions can be tested using the irradiance profiles considered in the thesis. A thorough and detailed investigation will provide a clear understanding of their operation and performance limitations.
- The methodology of design optimization of DC-DC converters presented in the thesis can be applied for isolated topologies of power converters. State space models are to be developed and conducting optimal sizing will result in improved and optimal design configurations of these converters. In recent years buck-boost inspired topologies have been reported to find application in PV systems as MPPT interfaces. These configurations can also be optimized using the same techniques.

- Examining the effects of partial shading on MPPT performance offers a valuable direction for future study. Future research may investigate sophisticated tracking algorithms and converter designs specifically aimed at alleviating partial shading effects, hence improving system efficiency across various atmospheric conditions.

- The hybrid system designed has been considered for the minimal objective function of LCOE. The study can be extended to include multiple conflicting objective functions which have realistic operational relevance. Parameters like Loss of Power Supply Probability, Loss of Load probability, etc can be considered as functions to be optimized alongside LCOE to formulate an multi-objective design optimization problem entailing hybrid PV Hydro based systems. Furthermore, the grid integration as a possible variant of the hybrid system as well as testing the optimization approach for HRES with PV, Wind, Hydro as primary sources with and without grid integration for dynamic load demand and energy management is a question that deems a thought and is worth the investigation.

- The developed hybrid GWOSCAPSO algorithm needs to be evaluated against recently proposed metaheuristics. Furthermore, the performance can also be compared with other hybrid algorithms already available in literature. Moreover, based on a similar principle, an approach to further examine the efficacy of the algorithm against opposition based learning, infusion of chaotic elements and hybridization of the GWO with other combinations of GWOSCA and GWOPSO and other algorithms for enhanced performance is another opportune area of research.