

Power Flow Optimization of a Hybrid Energy System with Salp Swarm Algorithm

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Abstract

Electric energy has become more essential in the recent year for all human activities. Therefore the demand for electricity is increasing to an extreme. The non-conventional energy generation methods are attracting the energy suppliers as its design and implementation is comparatively simple than the conventional energy generation. However, the non-conventional energy sources are widely dependent to the nature. Hence the power supply regularity has become a questionable one for non-conventional energy systems. The design of hybrid power system allows addressing this issue by connecting more than one non-conventional energy system together for making a reliable power supply. To regulate the power supply generation on connecting more than system several optimization algorithms were implemented in the present hybrid energy systems. The proposed work aims to study the performances of the hybrid energy system connected with 3KW wind power generation with each 1KW power generation with solar system and battery backup of using salp swarm optimization algorithm. The experimental work is also extended to prove the efficiency of the proposed algorithm with the traditional particle swarm optimization and genetic algorithms.

Keywords: Energy optimization, hybrid energy system, renewable energy, swarm optimization, energy flow design

1. Introduction

Hybrid energy systems are designed to meet the required load demand by connecting more than one power generation unit. The hybrid energy systems are widely employed for the renewable energy systems as their primary mover does not be constant all the time. Solar, biogas, wind and water are some of the renewable energy sources that are used to operate the non-conventional energy systems. The renewable energy power systems are widely preferred

by the power makers as it is free from environmental emissions. Figure 1 explores the architectural overview of a general hybrid electric system.

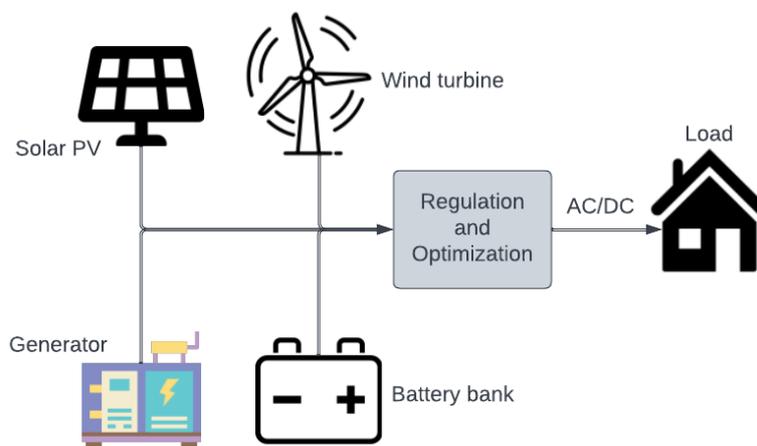


Figure 1. Hybrid power system

A general hybrid power system contains solar photovoltaic cell and wind turbine for its operation. In some cases the large scale hybrid systems are employed with hydraulic power station. The majority of small scale hybrid power systems are equipped with wind and solar power modules alone. Most of the small hybrid systems are connected with either a diesel generator or battery bank to provide supply backup. The renewable energy systems that are employed for industrial applications are connected with both generator and battery bank for meeting their load requirement at the critical state. The major advantages of employing hybrid power system are listed below.

- It regulates the capacity factor of the system with an excellent load curve.
- The possibility of switching from one power unit to another unit makes the system more reliable on heavy load demand.
- Easy for preventive and fault maintenance.
- System allows increasing the capacity of the connected load and as well the power generation load.

The power produced by the energy systems is not in a regular mode and that may have voltage ripples on their outcome and the system can also be observed with irregular frequency. In order to correct those power deviations, a power regulation circuit is placed in between the load and power generation unit. The power regulation circuits are equipped with an optimization algorithm for regulating the power flow in a precise manner. The following

section explores the concepts behind the different optimization algorithms with their attainments.

2. Literature Survey

A 2D dynamic programming optimization algorithm was incorporated to a hybrid power system consists of PV panel, fuel cell and battery bank. An experimental work was performed and found satisfied with the energy cost observation and power generation on both resonant compensation and ripple compensator [1]. A static synchronous compensator was employed to a hybrid power system consists of wind and solar PV panel. A PI controller is also equipped in the work for supporting the whale optimization algorithm for maintaining the power gain. The work provides a better outcome on the system equipped with particle swarm optimization [2]. A hybrid system consists of solar PV and battery bank is optimized with a techno-economic model for minimizing the transmission loss and it found satisfied on the simulation study [3].

A mixed-integer linear programming method was designed to optimize the hybrid model consists of battery and hydrogen storage unit. The experimental analysis projects the outcome of the method with better energy utilization [4]. A grey wolf optimization algorithm was employed to obtain a maximum output from an IEEE 30 and IEEE 57 bus systems. An experimental work was performed to prove the efficacy of the work with five regular optimization algorithms and found better in terms of power handling and bus voltage maximization [5]. A levy whale optimization algorithm is merged with a modified crow search optimizer for providing a good power flow management in the hybrid system consists of super capacitor, battery, PV and fuel cell [6].

A multi target optimization and sizing technique was developed to regulate the load on hybrid system made with solar PV and wind energy system. However, a diesel generator is included in the system for backup and the system gives a better outcome when it is combined with solar PV [7]. Zero sequence current injection based power control strategy was proposed to stabilize the grid inverter connected with renewable systems. A maximum power point tracking is also included in the work on energy system and found satisfied with its outcome over other conventional methods [8]. A particle swarm optimization technique was improved by adding a ϵ -greedy algorithm in combination with pareto archive algorithm for improving the performances of multi-objective reactive power optimization. It is achieved by analyzing the mean difference between various objective functions with their optimal

solution. An experimental work was performed to find the betterment of the work over the traditional PSO and an improved genetic algorithm and found satisfied in terms of node voltage observations [9].

An improved chicken swarm optimization technique was designed to estimate the power of a photovoltaic system for a short term condition. The experimental outcome of the work provides an average mean square error of 5.54% and it is comparatively better than the other existing models like support vector machine [10]. A two-stage robust optimization algorithm was incorporated in a work to meet power generation and load demand activity on a microgrid. The simulation analysis indicates a betterment of the work in terms of operational efficiency [11]. A perceptron neural network model was incorporated with two hidden layer architecture to optimize power generation in a solar chimney system. The performance of the work is satisfied with a power generation of 719kW from $14.28\text{kg}\cdot\text{s}^{-1}$ amount of water [12]. The literature section indicates a plenty of optimization algorithms was developed so far to improve the power quality in various applications. However, there is no standard methodology is structured for such application as a scenario is getting differ from design to design. The following section represents the concept and methodology of the proposed work on power optimization in a hybrid power station.

3. Proposed Method

The optimization algorithms are struggled with its slow convergence process on its solution. Therefore the work utilizes the Salp Swarm Optimization (SSO) algorithm for providing a multiple solution towards the power optimization problem. The optimization technique was structured in the year 2017 [13] basically salps are jelly kind of barrel shaped marine organism that moves using a jet action propulsion technique in the water.

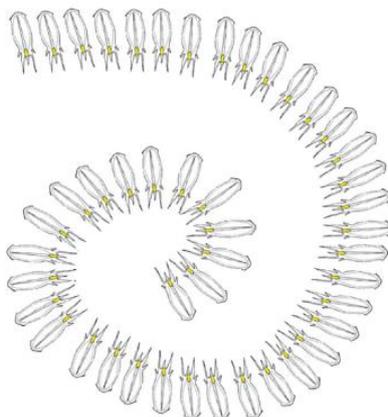


Figure 2. Salp chain [14]

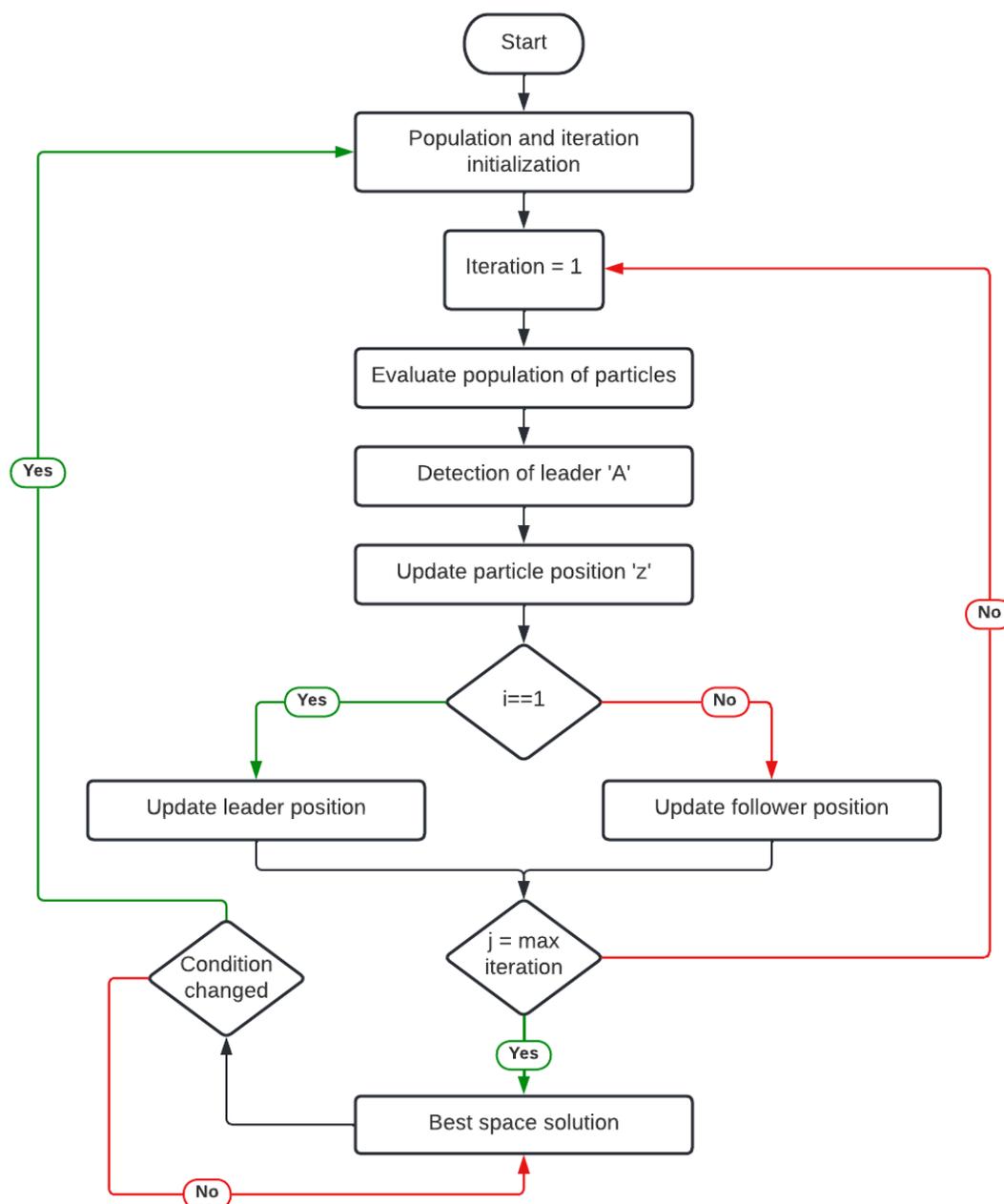


Figure 3. Flowchart of the proposed work

It makes a spiral kind for formation with other salps to ensure its sustainability and food safety. The spiral chain contains a leader for commanding the followers to make a path according to its movement. This is achieved by making a balanced understanding between the leader and the follower and that reduces the time for searching the food in a free space. Figure 2 represents an overview of a salp chain and figure 3 explores the graphical overview of the proposed model.

The proposed work is structured with a wind turbine and solar PV system and its motive is to take instant solution on power optimization between the solar PV and wind

turbine at load fluctuations. The solution is identified by making the particle that is closer to the solution as leader, following the algorithm makes a move on other particles. The change in position of a salp algorithm can be represented as follows.

$$A_j^1 = \begin{cases} X_i + z_i ((af_j - bf_j)) z_2 + bf_j) z_3 \geq 0 \\ X_i + z_i ((af_j - bf_j)) z_2 + bf_j) z_3 \leq 0 \end{cases}$$

Where,

- A_j^1 = Leader location
- X_i = Food location
- af_j = Initial bound
- bf_j = Final bound
- z = Constraint of particle motion

The better essential part found from the constraint acts like a leader. The exploration and exploitation of the leader improves the convergence speed and a power loss in the circuit.

4. Experimental Work

The performance of the proposed work salp swarm optimization (SSO) is compared with the traditional particle swarm optimization (PSO) and genetic algorithm (GA). The performance of generated power and its loss are compared over the different techniques on same scenario. Table 1 represents the outcome of the simulated work. Figure 4 indicates the power loss observation on raising the supply on even load ratio. The proposed model is generated in a MATLAB tool that consists of 3KW wind turbine, 1KW of solar PV system and battery backup for the analysis.

Table 1. Comparative analysis of the optimization algorithms

Scenario	Generated Power (P_{gen} in KW)			Power Loss (P_{loss} in KW)		
	SSO	PSO	GA	SSO	PSO	GA
1	3.2	2.8	2.1	0.8	1.2	1.9
2	2.9	2.7	2.6	1.1	1.3	1.4
3	1.5	1.2	1.3	2.5	2.8	2.7
4	3.8	3.1	3	0.2	0.9	1
5	3.1	2.5	2.2	0.9	1.5	1.8

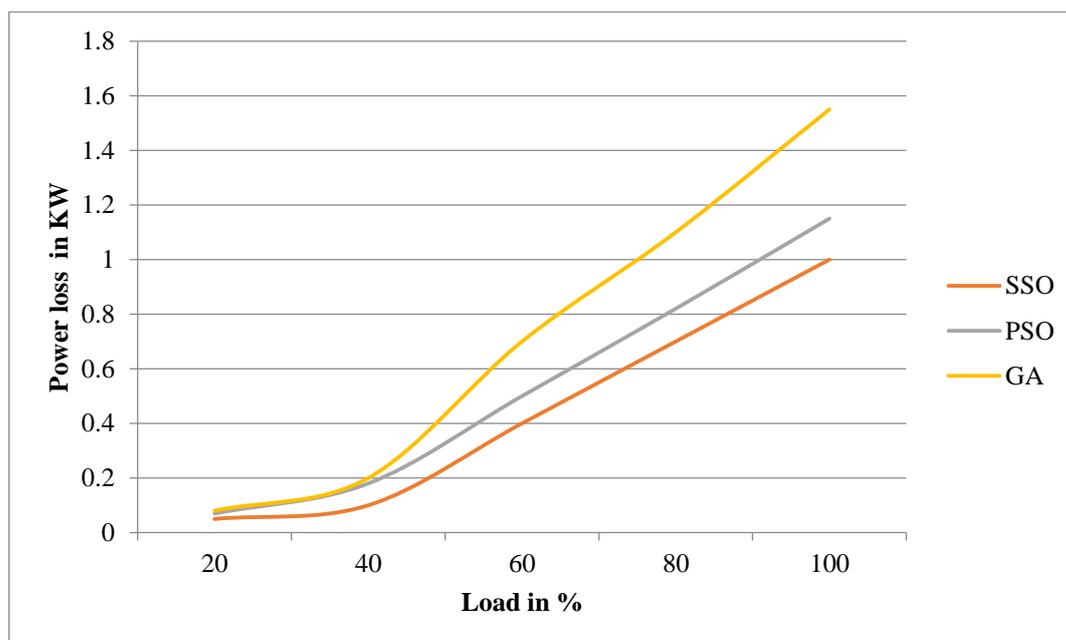


Figure 4. Power loss curve on the comparative method

The experimental outcome of the work indicates betterment on the SSO algorithm over the PSO and GA algorithm in terms power loss and generated power. Table 1 represents are major deviation on generated power between the GA and SSO. The work also indicates that the performance of PSO stands in between the GA and SSO with a quit higher betterment. Similarly the power loss curve shown in figure 4 indicates a smooth variation on SSO and PSO whereas in GA the power loss is not smooth as seen in other two algorithms. In order to maintain a smooth power transmission the work suggests the either SSO or PSO for the optimization.

5. Conclusion

Generating electric power without loss is one of the hardest tasks on energy modelling. There are many ways followed to make a reliable power transmission system that includes power optimization, load estimation and transmission smoothing techniques. The proposed work implemented a salp swarm optimization technique for enhancing the power regulation between the solar PV and wind turbine. An experimental work was conducted to observe its performance with a simulation study on estimating the power loss in various scenarios. The experimental analysis indicates the performance of the work found satisfied over the traditional optimization algorithms. The work will be further extended in future with a customized salp swarm optimization algorithm for obtaining an improved outcome.

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Author's biography

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