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Implementation of an Energy Management System for Microgrid using Particle Swarm Optimization Technique

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Abstract:

Energy is the most important input for any country's economic progress. Renewable energy sources are currently being deployed to fulfill the rising demand by minimising the consumption of Traditional resources. Distributed Energy Resources are electricity producing resources that are connected to a local distribution system. A microgrid is a local energy grid that may be disconnected from the main grid and operated independently. For optimal functioning, a Microgrid's Energy Management System analyses and regulates dispersed energy resources and loads. Optimization approaches reduce the cost of a Microgrid's investment by ensuring that resources are used efficiently and reliably. Particle Swarm Optimization is a self-tuning control parameter optimization technique inspired by the motion of flocks of birds and schooling fish. The energy management system for Microgrid using Particle Swarm Optimization is implemented with MATLAB Software. The PSO approach is used in Battery Energy Storage Systems to keep the charging and discharging states within limitations in order to avoid load shedding in the Grid.

Index Terms - Energy Management System, Microgrid, PSO, Distributed Energy Resources ,Optimization techniques, Energy Storage Systems.

I. Introduction

The need for electricity is steadily increasing as the world's population grows. Renewable Energy Sources (RES) are widely used on a large scale to meet the requirements of increased energy demand, reducing the consumption of conventional energy sources, achieving socio-economic benefits for sustainable development, and mitigating environmental pollutants. Distributed generation may include emerging technologies such as wind turbines, solar PV, micro hydro power, and other renewable energy sources. Microgrids (MGs) are the next concept for distribution system evolution. MGs are made up of a mix of critical and non-critical loads, as well as distributed energy resources (DERs) and energy storage systems (ESSs). Grid linked and islanded modes were used by MGs. It is cost-effective and dependable to run, and it should be accompanied with a proper monitoring and control system. The control system is responsible for scheduling and controlling all DERs in order to keep the MG stable, reliable, and cost-effective. The Energy Management System (EMS) is responsible for controlling the MGs power generation and/or flow.

During grid-connected and islanded modes of operation in a Microgrid, an EMS is necessary to balance the quantity of generation with the load and govern the flow of electricity. The EMS software enables for real-time monitoring of generation and consumption, as well as determining the best DER operations, including battery storage, in order to increase energy efficiency. To minimise the cost of energy drawn from the grid, generated inside the grid, and consumed by the loads, an optimization method is required. Optimization techniques justify the expense of an MG by allowing for the efficient and dependable use of resources. The Particle Swarm Optimization (PSO) method is based on the social behaviour of flocks of birds and schools of fish. To achieve the best DG integration, Particle Swarm Optimization is utilised to choose the best placement, kind, and size of DG units. The PSO approach is used in BESS to keep the charging and discharging states within limitations in order to avoid grid load shedding.

II. Literature Survey

- The idea of Energy Management System for Microgrid using Particle Swarm Optimization Technique is implemented in reference to the article entitled “Energy Management System of a Microgrid using Particle Swarm Optimization and Wireless Communication System”, IEEE Electric Power and Energy Conference, 2018 by Faizan Khan, Mohammad. Y. Ali, Vijay. K. Sood.

- Implementation of Energy Management System for Microgrid using Particle Swarm Optimization is done based on the entitled “Using Particle Swarm Optimization to find Optimal Sizing of PV-BS and Diesel Generator", Journal of Engineering and Sustainable Develoment, May 2021 by Abbas Q.Mohammed, Kassimal-anbarri, Rafid M.Hannum.

III. Operation of Micro Grid

The transmission and distribution system has traditionally relied on centralised generation from traditional power facilities. Distributed energy resources (DERs), energy storage systems, distribution systems, and communication and control systems make up a microgrid. Distributed Energy Resources (DERs) are a complement to or an alternative to the standard electric power grid. It benefits consumers by lowering costs, increasing service dependability, improving power quality, increasing energy efficiency, and increasing energy independence. During bad weather or grid failures, the microgrid can be connected to the utility grid via a point-of-common connection (PCC), or it can be isolated.

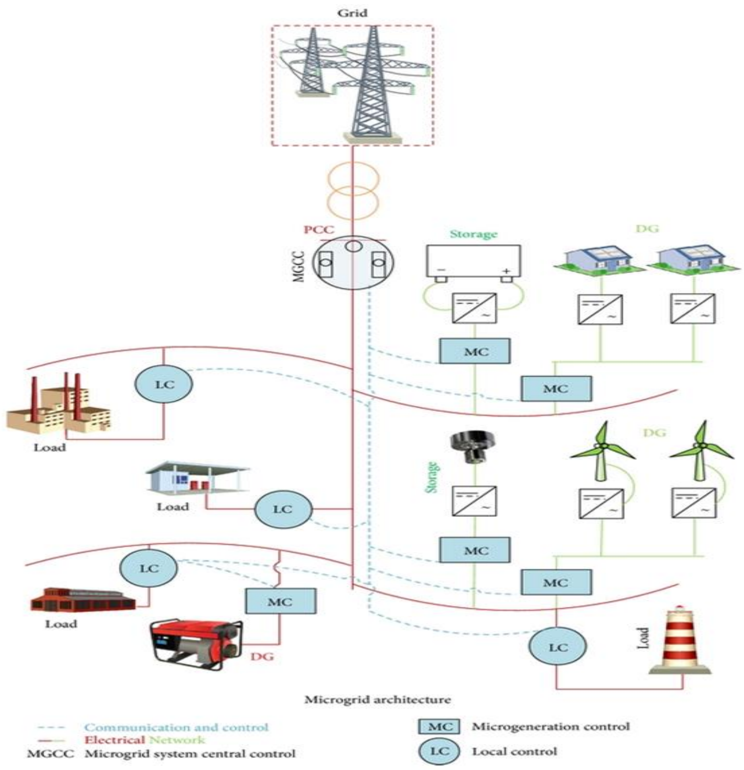

Fig 1: Architecture of a Micro-grid

IV. Significance of an Energy Management System in Micro grid

The integration of dispersed energy resources and controllable loads in a power distribution network customises a microgrid. When opposed to typical power systems, this integration poses a number of issues for Microgrid administration. If energy generation sources are insufficient to feed the desired load in Microgrids, the system will be unable to meet supply demand. To avoid this problem, a suitable Energy Management System (EMS) is required. EMS for Microgrid integrates supply and demand side management while meeting system limits, allowing for optimal implementation with distributed energy sources.

Fig 2: Energy Management System in a Microgrid

If the overall demand exceeds the maximum capacity of the generation sources, these systems may fail in load feeding. To address these issues, the traditional Energy Management System (EMS) must be redesigned to accommodate the inherent characteristics of Microgrids. An energy management system (EMS) is a set of computer-assisted tools used by electric utility grid managers to track, control, and improve the performance of their generating and transmission systems.

It can be created by considering all of the Microgrid EMS's functional requirements (e.g., optimization, forecasting, human–machine interface, and data analysis) as well as engineering constraints (i.e., interoperability, extensibility and flexibility). The major functions of an Energy Management System are to **determine how much energy is created or consumed, how it is utilised, and when it is consumed.** It is built a mathematical model of an Energy Management System based on optimal generation and load scheduling.

V. Microgrid Energy Management System Using Particle Swarm Optimization:

The first step toward integrated electricity is adequate planning and design. Optimization approaches justify the cost of a Microgrid by allowing for the efficient and dependable use of resources.
Traditional optimization methods may only be appropriate for a specific type of problem. In the event that standard optimization methods fail, natural processes such as biological, physical, and chemical processes are artificially represented to produce optimization tools for solving complex optimization problems. Different optimization considerations are made for different demand response and power/energy scheduling applications that are frequently used. Demand response and power/energy scheduling are often written as non-linear optimization problems with multiple objective functions, and different optimization decisions are made for different applications.

VI. Flowchart and Algorithm of Particle Swarm Optimization:

Kennedy, Eberhart, and Shiand proposed PSO in 1995, and it is based on particle movements in the search space. The current location and velocity of each particle are displayed. In order to refine the final solution, the particles assess their positions based on their fitness level at each iteration, while nearby particles show the history of their "best" places. Fast convergence, escape from local optimum, and ease of implementation are all features of the PSO method.Each particle in a PSO moves around in the search space with an adaptive velocity that is dynamically adjusted based on its own and other particles' flight experiences. As each particle attempts to enhance itself by replicating qualities from successful peers, it takes use of their advantages. Furthermore, each particle has the ability to recall the best point in the search space that it has ever visited.
PSO employs a swarm, which is a collection of candidate solutions. The vector $x_i(t)$ represents the particle's position for particle i. Each particle has a velocity that is indicated by $v_i(t)$ in addition to its position . Both x and v have the same dimensions. The direction of particle i movement is described by its velocity. To find the solution, particles interact with one another, learn from one another, and follow a few simple laws. Aside from location and velocity, each particle has a recollection of its own best position thus far, which is expressed by personal best (p_i), as well as a shared best experience across the swarm members, which is marked by global best (p_g).
Both r_1 and r_2 are are uniform random numbers within the range [0, 1]. . The position and velocity of each particle are updated at each iteration At each iteration, position and velocity of each particle are updated.

The entire procedure is outlined in the Algorithm section below.

1: Start Procedure

Inputs**:**

c_1: Cognitive coefficient

c_2: Social coefficient

NP: Population size

w: inertia weight

2. Initialize whole swarm using randomly uniformly distributed and evaluate fitness

3. While ($i_{te} \leq i_{temax}$)

4. Evaluate each particle $f(x_i)$

5. For (i=1, i ≤ NP, i++)Do

6. //Update particle velocity:

7. $v_i(t) = w * v_i(t-1) + c_1 * r_1 * (p_i - x_i(t-1)) + c_2 * r_2 * (p_g - x_i(t-1))$

8. //Move to new position:

9. $X_i(t) = X_i(t-1) + v_i(t)$

10. If $(f(x_i) \leq f(Pbest_i))$ then $Pbest_i = x_i$

11. If $(f(x_i) \leq f(gbest_i))$ then $gbest_i = x_i$

12. Update (x_i, v_i);

13. End For

14. End While

15. Output: Best Solution

16. End Procedure

The flow chart in Figure depicts the system's core procedure

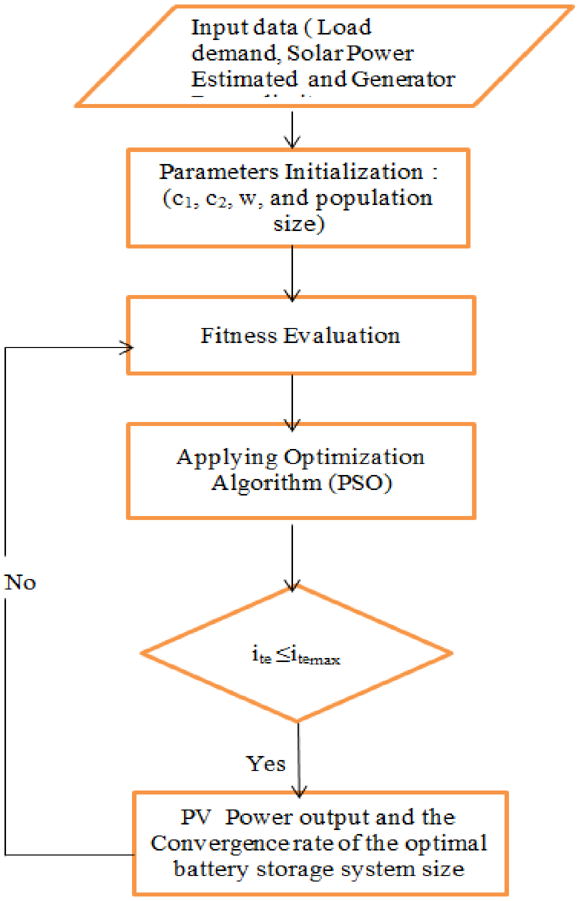

Fig 3: Flowchart for the PSO process in Microgrid

The following are the steps in the procedure:

Step 1: Forecasted data such as load demand, solar power, and generator power limits are entered into the system.
Step 2: The starting population is formed when the optimization parameters (c1, c2, w, and population size) have been specified.
Step 3: The PSO algorithm is used to optimise the battery storage system in order to save costs.
Step 4: If the termination condition is met, the system will reflect the PV system's power output and the Convergence rate of the optimal battery storage system size. The system will return to Step 3 if the termination condition is not satisfied.

VII. EMS Implementation In a DC Microgrid using PSO Technique with MATLAB Software:

To complete the code ,two MATLAB script files (*.m file) are needed. The Objective function is defined in the first file, while the the main PSO programme is written in the Second file. The objective function is called multiple times in the main programme file as needed.

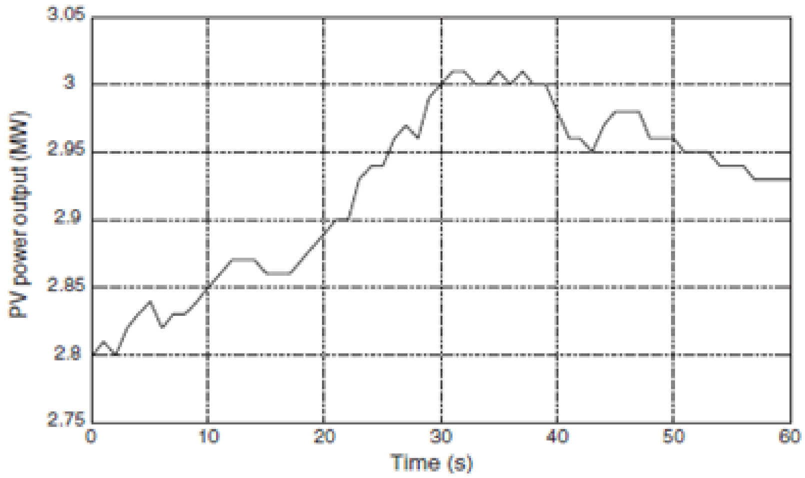

Fig 4: Power output of PV System

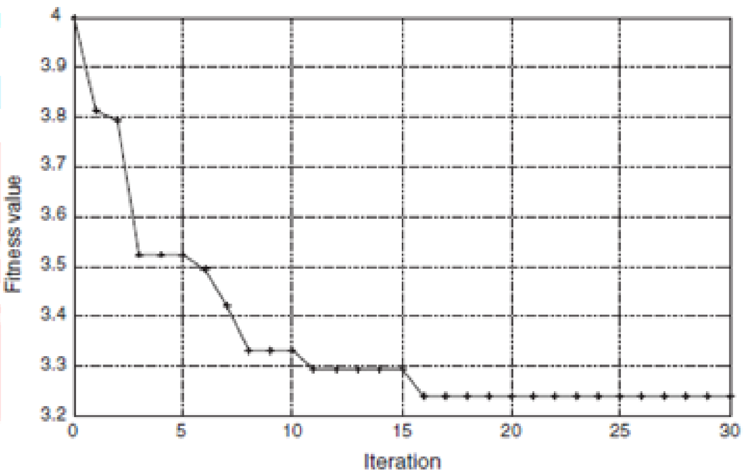

Fig 5: Convergence rate of the optimal size of Battery Storage System based Particle Swarm Optimization

The PSO approach is used in Battery Energy Storage Systems to keep the State of Charging (SoC) within acceptable bounds, and it is supplemented with solar energy if it is not. It is unable to send power to the grid if SoC falls below a certain threshold. It will not be able to absorb the power if SoC exceeds the maximum limit. The PSO approach is used in BESS to keep the charging and discharging states within limitations in order to avoid grid load shedding.

VIII.Conclusion:

Energy Management System was implemented Microgrid using PSO technique in the most optimal way while minimizing the operational cost in islanded mode of operation. The proposed project, Energy Management System for Microgrid using PSO Technique, optimizes the Battery Energy Storage Systems to keep the state of charging and state of discharging within the constraints to avoid load shedding in the grid.

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