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Microgrid Energy Distribution Sizing and Management considering PV/WT/BT Integration under Residential load

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Abstract: This study presented Microgrid (MG) model considering Photovoltaic (PV), Battery (BT), and Wind Turbine (WT) connected through DC/AC inverter and controlled by Energy Management Strategy (EMS). Where the aforementioned components are playing a crucial role in the management and sizing of MG energy distribution. Whereas previous studies have introduced nature-inspired metaheuristic algorithms along with supervisory control algorithms. The sizing algorithm namely Particle Swarm Optimization (PSO) is utilized while the supervisory control is considering a Rule-Based Energy Management Strategy (RB-EMS). In the simulation result, the RES could run the system and overcome the challenges in the proposed system when the PV Produces (5kW) and WT is also estimated to produce 5kW. Furthermore, our results give insight into the effects of different strategies and microgrid configurations.

Keywords: (MG, PV, WT, RB-EMS)

Introduction

Hybrid renewable energy sources are promising systems to address energy barriers that consist of primary sources and batteries and diesel generators [1]. However, hybrid systems face several barrios such as environmental, social, technical, economic, policy, intermittency, and fluctuation. Integrating a proper hybrid system could complement each other and overcome the aforementioned issues when one of the sources experiencing fluctuation or intermittency [2]. Libyan climate is one of the most blessing among African countries [3]. The literature covers numerous Integrating forms of the RESs, the main two integration forms are stand-alone and grid-connected [4]. The former is totally isolated from the grid and suitable for rural and isolated locations. While the latter is the most preferable system due to its flexibility and can be exploited in urban areas [5]. RESs sizing and optimization have been investigated in various studies considering multiple nature sources [6]. The performance of RES. the MG drivers are categorized in terms of deployment and development into three groups, which are energy security, economic benefits, and clean energy integration [7]. The growth was incremental in the examination of PV and WT to get demand satisfaction, meet sustainable goals and environmentally friendly life free of Greenhouse Gas (GHG) [8].

Microgrid energy distribution sizing and management involves the design and control of a localized electrical network that integrates various energy sources and enables efficient distribution within a

specific geographical area [9]. Moreover, the EMS coupled with the sizing techniques to meet the main objectives of gaining a cost-effective system and renewable [10]. Integrate battery storage to address the intermittent nature of renewable energy sources and provide a stable power supply [11]. Size the battery capacity based on the estimated energy deficit during periods of low generation or high demand. Consider factors like depth of discharge, round-trip efficiency, and battery lifespan [12]. Hybrid systems have been evaluated by many scholars because of their flexibility in integrating many sources such as PV, WT, BT, and other generation sources [13]. Furthermore, several merits are provided for integrating MG systems such as enhancing energy efficiency, increased reliability, cost saving, energy resilience, and environmental benefits [14].

The knowledge contribution of this article is addressing the intermittency of the solar and wind turbine by integrating energy storage batteries along with analysis of the climatology collected data for easy understanding from the consumers. Moreover, the main of the RESs to meet the load which mean being renewable system. While the rest structure of the article is organized as follows: the implementing methodology to size and monitor the power flow are discussed in Section 2. The acquired result has been plotted and discussed in Section 3. Eventually, the article is closed with the conclusion and list of literature-cited sources.

Methodology

Based on the load assessment and renewable energy potential, the sizing of the system components will be considered. Microgrids are small-scale, localized power systems that can operate independently or in conjunction with the main power grid. In such systems, energy distribution sizing involves evaluating factors such as load demand, available generation capacity, storage capacity, and the characteristics of the distributed energy sources. The presented components in Figure 1 are the interconnected components of the proposed system that is hybridized and controlled by EMS to manage the flow of power in the system [5]. Furthermore, the system has been connected through DC/AC due to its flexibility, simplicity, and balance of the energy flow to connect PV, WT, BT, and the grid, despite the DC bus bar system that connects DC appliances only. Besides, alternatively integrating more converters that may increase the cost and make the complexity of the circuit.

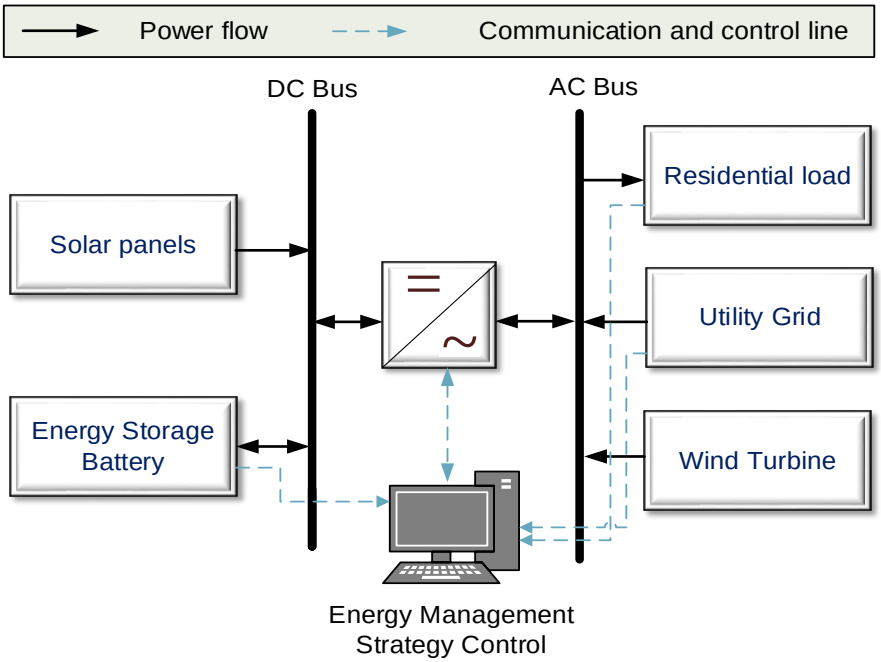

Fig. 1 Proposed microgrid hybrid diagram.

Based on International Energy Agency (IEA), the generation cost of electricity from the RESs (PV and WT) is decreasing throughout the years from 2010-2021 as demonstrated in Figure 2.

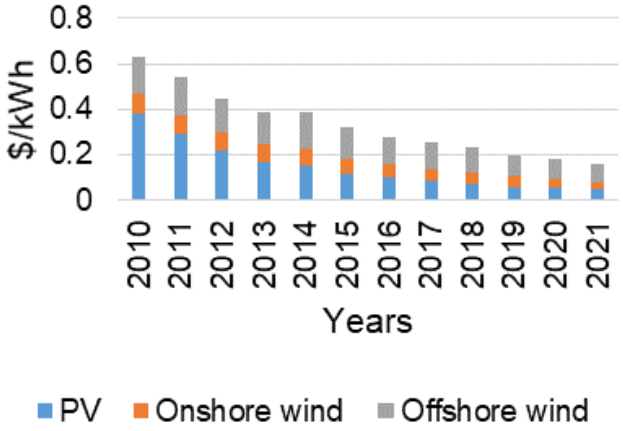

Fig. 2 Global PV and wind turbine generation costs (2010-2021) based on IEA.

According to the collected climatology data for the considered site of the study that recorded by the PVWatt web page [15], while the hourly recorded data of solar irradiance and wind speed data have presented in Figure 3 and Figure 4, respectively.

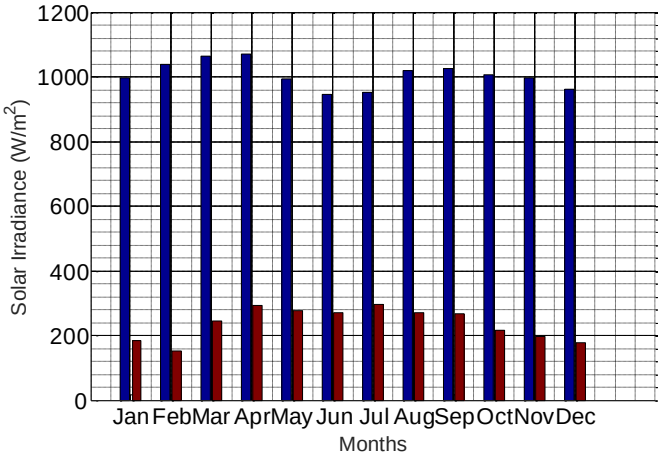

Fig. 3 Annual solar irradiance.

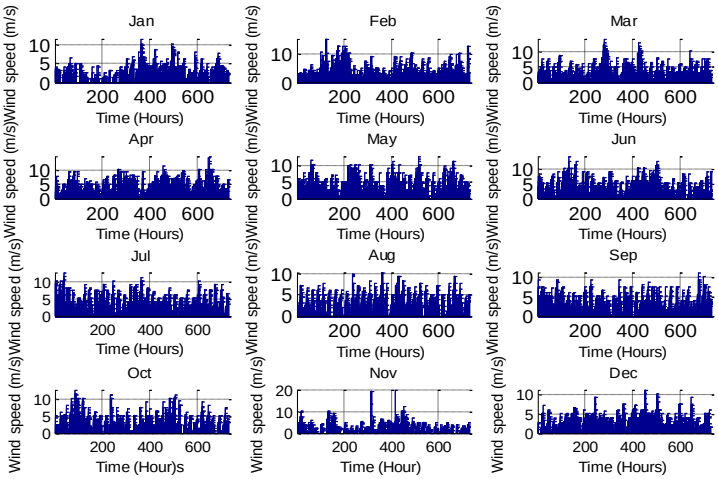

Fig. 4 Annual wind speed.

The aforementioned data has been implemented with the help of mathematical equations that presented in the literature [9]. To size the system components, nature-inspired metaheuristic algorithms as part of Artificial Intelligent (AI) tools are exploited [16]. The PSO is originally introduced in 1995 by Kennedy and Eberhart to address various problems in several fields [17]. The EMS is based on IF-THEN statements and considered due to its simplicity as human knowledge based rules and does not have a complex mathematical equations [18]. Additionally, classified into three main groups, Rule-Based, Optimization-Based, and Learning-Based [19], [20]. The EMS proposed rules can be as listed:

1. RESs power home appliance (the priority to run with RESs).
2. Battery to run home appliance.
3. Grid supply the home appliances.

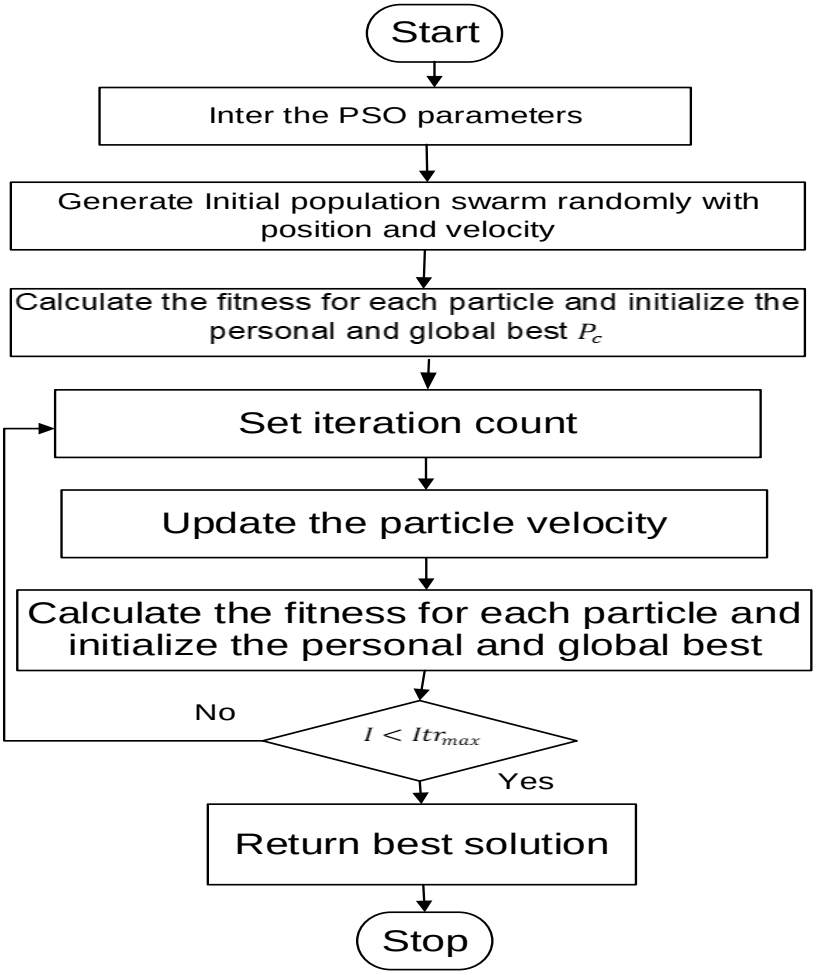

Fig. 5 Particle Swarm Optimization flowchart [17].

Results and Discussion

Based on the proposed modal system in Figure 1, the acquired result for the iteration number that refers to the annual cost that equals to USD 0.03/kWh during 1000 times of iteration. The comparison result of the output generated power from the sources is demonstrated in Figure 7. The operation shows the charge, discharge, PV output, WT output, and the main load. The integrated sources produced power during the year based on the main factor which is the climate changes. When the sources are not sufficient to meet the demand, the battery as backup system will run the system appliances.

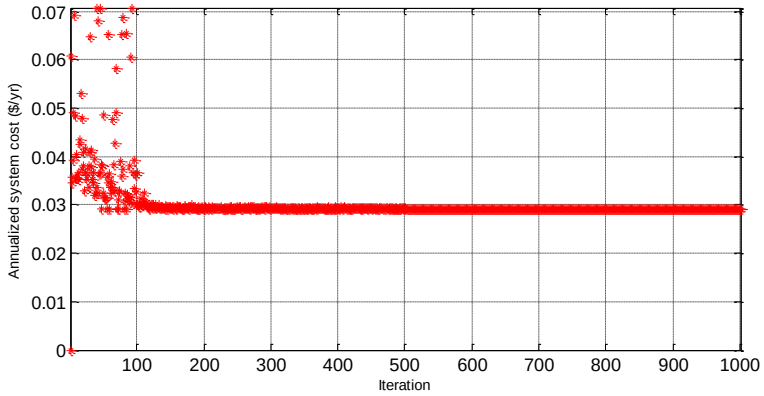

Fig. 6 convergence

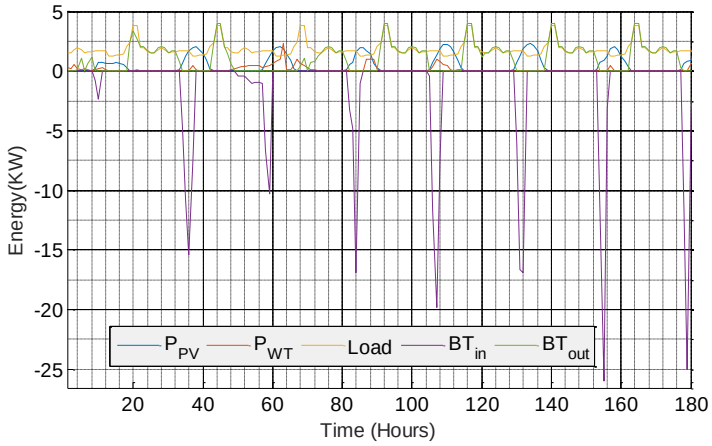

Fig. 7 Comparison result of the generated output power.

Conclusion

In conclusion, microgrid distributed systems are preferable generation systems because they hold great potential for promoting sustainable energy optimizing resource utilization and achieving reliable and cost-effective energy supply systems. Nature-inspired methos coupled with EMS to meet the objectives with smoothly flow the power in the proposed system based on if-them statements. Based on the collected data and obtained result, the study area is rich with sources to generate electricity using nature sources instead of conventional sources. For future studies direction by considering smart systems acquire decarbonization systems to improve the power and environmental systems which integrated more RESs.

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