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Hybrid Intelligent Optimization Techniques for Grid Integration with Renewable Systems: Review

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Abstract **– Renewable energy sources are essential in fulfilling the increasing need for electricity. Researchers are actively exploring eco-friendly alternative energy sources and technologies, particularly in the form of micro grids or grid-integrated systems. A hybrid renewable energy system with battery storage in a small-scale industry was optimized using a blend of traditional and cutting-edge models, employing mixed integer linear programming techniques, as demonstrated in a recent study. The proposed optimization algorithm offers improved accuracy and reduced computational burdens. The model considers the intrinsic stochastic nature of hybrid energy systems and integrates fluctuations in load forecasting. By employing an intelligent computational optimization algorithm, the study focuses on optimizing the PV-Wind, Diesel, and battery storage hybrid system. The findings of this research shed light on the impact of load variations on component sizing in small-scale industries. This review holds significant value for researchers who aim to tackle the intricacies of algorithm analysis and power system design in order to drive future enhancements.**

Keywords: intelligent Optimization, Photovoltaic, Wind, Diesel and Battery.

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1. INTRODUCTION

Today, the utilization of fossil fuels as the primary source of electricity in non-renewable power generation systems has become a pressing concern. The rapid depletion of fossil fuel reserves and the subsequent rise in retail prices have necessitated a shift towards alternative energy sources to fulfill our energy needs [1]. This transition is crucial in order to reduce harmful emissions and cater to the growing global demand for electricity. Consequently, renewable energy sources (RESs) are now playing a pivotal role in shaping the future of power generation [2].

Solar and wind energy systems are readily accessible and are being more commonly viewed as the most practical alternative energy sources. Solar and wind energy sources have gained significant importance and proven to be financially advantageous.

The European Union Council has pledged to decrease greenhouse gas emissions to 80 – 95% below 1990 levels by the year 2050. In order to achieve a substantial level of decarbonization, the power generation system would need to undergo significant changes as early as 2013 (57 – 65% reduction by 2030 and 96-99% reduction by 2050). It is crucial to initiate and send out signals that are essential for minimizing investments in carbon-intensive assets in the future generation [4].

Increasing the development of renewable energy generation is one way to achieve this goal. This can be done by implementing more saturated methods, such as the utilization of hybrid energy sources. In Europe, there has been a significant increase in generation from these sources, with the capacity rising from 312GW in 2012 to 350GW in 2014 [5].

Industrial PV systems are commonly linked to the grid, allowing them to supply surplus power to the grid at night and receive power from the grid during the day. Nevertheless, in isolated regions where grid expansion is unfeasible, Hybrid Renewable Energy Systems (HRESs) are employed independently for small-scale industries or within microgrids (MGs) that link multiple industries to create a compact power network. Islands in the Indian and Pacific oceans allocate up to 30% of their gross domestic product towards non-renewable energy sources such as fossil fuels. To ensure a more economically viable and stable electricity supply to a given load, HRESs can integrate energy storage systems (ESS) like battery banks or diesel generators.

In spite of the initial cost, the primary concern lies in the additional maintenance expenses and varying rates of depreciation associated with these hybrid units [7]. The design of HRESs presents a considerable obstacle. Achieving maximum optimization relies on a thorough understanding of energy sources, environmental conditions, technical specifications, and load profiles. In [8], the authors present an analysis of smart grid technologies and standards, while [9] focuses on the multi-criteria optimal sizing of a PV-wind grid-connected system. The article explores the ideal configuration of a self-sufficient hybrid solar PV-Diesel system for providing electricity to a fishing village in Morocco [10]. Moreover, an enhanced optimal sizing technique for a PV-wind-battery hybrid system is presented in [11]. Finally, the focus is on the application of the shuffled frog leaping algorithm for the purpose of long-term generation maintenance scheduling, with the objective of improving the reliability of the units [12]. This paper provides an overview of classical algorithms, artificial intelligent algorithms, and software tools.

2. METHODOLOGIES OF HYBRID SYSTEMS

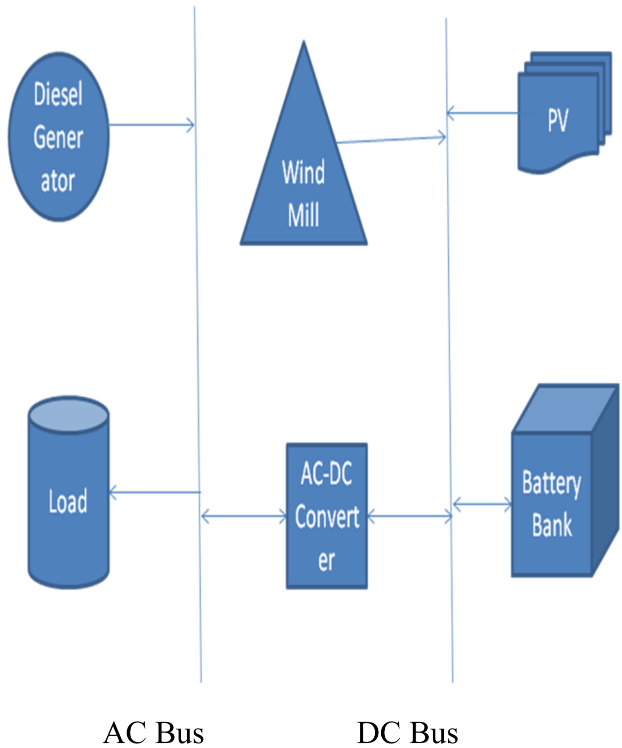

Fig. 1: Hybrid Microgrid.

A PV-Diesel hybrid system comprises solar energy, diesel power, batteries, controllers, and inverters. These components are either connected to the load or integrated with the power grid to optimize system performance. It is of utmost importance to independently model each component in order to guarantee the precision of the entire unit. The efficiency of the hybrid system is directly influenced by the efficiency of its individual components.

A. Metrological data.

The optimization process for a PV-based system and the availability of a diesel power system require the collection of metrological data, specifically solar energy data. It is preferable to have hourly or daily weather data. If there is a lack of measured data, alternative sources such as communication-based data or estimated data can be utilized. Statistical methods can be utilized to fill in missing data if it is not available for the entire duration of the study [12]. If data is available for a neighboring area, it can be extrapolated and adjusted accordingly [13]. The idea of a standard meteorological year, which captures the most typical weather conditions of the chosen area, has been employed. Additionally, a typical day of the month has been identified based on the average hourly power generated.

B. System configuration

The selection of equipment sizing can be determined through the prefeasibility study, which takes into account weather data and load demand. However, it is crucial to ensure that this sizing process aligns with the characteristics of both PV and diesel systems.

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C. Load profile

It is imperative to have a yearly electric load demand profile in order to effectively plan and optimize a hybrid system. Analyzing the real load demand can be challenging and time-consuming, which is why the hourly or daily average of load demand is commonly utilized for design and optimization purposes[15]. The use of artificial neural networks (ANN) and statistical methods is widespread in generating synthetic load profiles and weather data patterns, as well as forecasting industrial energy consumption.

D. Modeling of PV System

Research has been conducted on the modeling of PV systems [16]. The PV generation's output at the maximum power point (MPP) was determined by the model's linear power source, which relied on the ambient temperature, irradiance level, and tilt angle. This approach has simplified the complexity of the system model. The parameters considered in the model include standard test condition (STC), the nominal operating cell temperature (NOCT), rated PV power at the MPP and STC, and the irradiance level at STC. Furthermore, calculations were made to estimate the power temperature coefficient at MPP, cell temperature, and the quantity of modules in series and parallel configurations within the PV array in order to assess the power generation of the PV modules.

E. Modeling of diesel generator

Operation & Maintenance cost = Labour cost plus fuel cost

$OM = L_C + F_C$

The design process takes into account the crucial factor of the diesel generator's capacity. Compared to wind turbines or solar panels, the engine's lifespan is relatively shorter. Therefore, it might be necessary to include an additional diesel generator. The diesel engine operates in conjunction with a synchronous generator (SG), where the electrical frequency of the SG is dependent on the engine's speed. To maintain a constant frequency, the diesel engine's speed governor comes into play. Similarly, the automatic voltage regulation (AVR) ensures a consistent voltage output from the SG [17].

F. Modeling of battery

$Q_B(t+1) = Q_B(t) + \eta r P_{Ch}(t) - P_{DCh}(t)$

The battery is utilized to store surplus energy in order to uphold the system voltage and provide power to the load in the event of insufficient power generation in the hybrid system. The modeling of batteries is based on their charging and discharging states.

G. Modeling of Wind Generator

Wind speed measured at the height of an anemometer can be converted to the desired hub height by taking into account the substantial variations in wind speed at different heights.

power law equation.

$$V_2 / V_1 = (h_2 / h_1)^{\alpha}$$

Where v1 represents the velocity at a specified altitude, h1; v2 denotes the velocity at a central altitude, h2; and α symbolizes.

The calculation of the friction coefficient, represented by α, relies on particular factors, including the surface roughness of the terrain.
Various types of terrain often define wind speed, temperature, height above ground, hour of the day, and time of year in technical literature. In accordance with the guidelines set by IEC standards, extreme wind conditions are assigned a friction coefficient value of 0.11, whereas normal wind conditions are assigned a value of 0.20.

3. OPTIMIZATION METHODOLOGY

The hybrid energy system's development is witnessing a steady increase with each passing day. This progress is being achieved through the utilization of diverse optimal sizing techniques and optimization algorithms. These algorithms can be categorized into two primary methods: the traditional method and the new generation method.

B. Traditional method for optimization

At the onset of hybrid renewable energy research, an iterative approach was implemented to facilitate the design and optimization process. An iterative method, a mathematical procedure, was employed to generate an approximate solution for the problem at hand [18]. The objective of this approach was to ascertain the most suitable dimensions for a battery bank and PV array in a self-sufficient hybrid wind-PV system. It was discovered that the optimal mix of components depended on the specific site, reliability, and load profile of the hybrid system. However, it is important to note that the iterative optimization method necessitates additional computational efforts.

C. Probabilistic approach

This method enables the calculation of abnormalities and uncertainties by utilizing distributions of predetermined values. In their study, [19] conducted a probabilistic analysis of an autonomous solar-wind energy conversion system that supplies power to a load. However, this approach does not take into account the charging/discharging cycles of the batteries and the dynamic performance changes of the hybrid system, making it impractical.

D. Linear programming techniques

The linear programming approach has been widely employed for the sizing and optimization of renewable systems. It has been utilized in the sizing and simulation of PV-wind-battery hybrid energy systems, aiming to achieve minimum cost and enhanced reliability [20]. Compared to other techniques, LP offers superior performance, improving quality and flexibility, while also providing easy problem-solving capabilities.

E. Trade off method

This hybrid system [21] employs a method that is not widely recognized. The results of this method do not yield a singular, optimal solution, but rather a limited yet influential range of designs.

4. NEW GENERATION METHOD

This method adequately tackles optimization design issues, providing a wider range of solutions beyond local optimal setups and a more straightforward option compared to conventional optimization techniques.

A. Swarm-Nelder-Mead for optimization method

The Nelder-Mead simplex algorithm, developed by John Nelder and Roger Mead in 1965, is specifically tailored to tackle unconstrained classical optimization problems. The goal is to reduce an objective function within an N-dimensional space without depending on gradient information.

B. Genetic Algorithm

John Holland developed a genetic algorithm (GA) between 1960 and 1970[23]. This algorithm is a flexible optimization method that is influenced by the principles of natural selection and genetics. GA functions by operating on a group of potential solutions, evaluating the fitness of each individual according to the objective function of the problem[24]. Consequently, GA-based optimization aims to determine the optimal values for the generator's active power output and the angle of a two-phase shifting transformer.

C. Simulated annealing

Annealing is a technique that involves heating a solid to a high temperature and then gradually cooling it down by reducing the temperature of the surrounding environment in a stepwise manner. This process follows a specific set of rules and a sequence of configurations that form a Markov chain [1].

D. Tabu Search

TS is an effective optimization method that has demonstrated successful applications in various combinatorial problems. It can be regarded as an iterative approach that generates a set of problem solutions by continuously transitioning from one solution to another [1].

5. CONCLUSION

This paper provides an explanation of various types of optimization and analysis techniques for hybrid PV-Wind and Diesel-based systems. These sustainable energy sources, known as hybrid renewable energy sources, are extensively utilized across the globe. The importance of meteorological data, load profiles, and modeling different components within the system is emphasized in the paper. Additionally, a new artificial intelligent computational optimization algorithm is proposed. This method is considered more favorable compared to other methods due to its accuracy, efficiency, and ability to optimize both domestically and globally. Furthermore, this technique proves to be highly effective in optimizing hybrid PV-Wind/Diesel energy systems and integrating them with the grid.

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