A Review on Optimization of Solar PV and Wind Turbine System

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ABSTRACT: With increasing population, energy demand is also increasing day by day, to meet these energy demands solely dependent on conventional energy sources is not possible as these resources are limited in nature. There is a need to utilize renewable energy resources which are present abundant in nature like solar and wind energy. Renewable energy has become a vital source for generating electricity, mitigating greenhouse gas emissions, and eliminating the reliance on non-renewable forms of energy. This work highlights on the urgent need for clean, efficient, and resilient energy sources through the development of advanced optimization methods. The hybrid solar-wind systems are meant to maximize power generation.

The optimization and simulation of a solar-wind renewable system connected to a nanogrid aims to design an efficient and reliable power generation system that utilizes solar and wind energy sources to meet the energy demand of a localized grid. The first step is to determine the optimal sizing and configuration of the solar and wind components in the renewable system, considering factors such as available space, solar irradiance, wind speed, and local climate conditions. Efficiency, reliability, and component compatibility are taken into account during the selection process. An energy management system (EMS) is developed to monitor and control the operation of the renewable system. The EMS optimizes the energy flow between the solar panels, wind turbines, batteries, and nanogrid, ensuring maximum utilization of renewable energy while meeting the load requirements. Simulation software is employed to model and simulate the system's performance under different scenarios, allowing for analysis, validation, and optimization. Economic analysis is performed to assess the feasibility and cost-effectiveness of the renewable system. Sensitivity analysis helps evaluate the system's performance under various uncertainties.

Overall, the optimization and simulation of a solar-wind renewable system connected to a nano grid involves a comprehensive analysis of resources, component selection, system modelling, optimization algorithms, economic assessment, integration, and performance evaluation. By following these steps, an efficient and sustainable power generation system can be designed for localized grids, contributing to renewable energy utilization and reducing reliance on conventional sources.

Keywords: Nano grid; Photovoltaic; Cost of Energy; Carbon Emission; Hybrid renewable energy system; Power management; Optimal sizing; wind energy.

1. INTRODUCTION

The increasing global demand for clean and sustainable energy has led to a growing interest in renewable energy systems. Solar and wind energy are abundant and widely available sources that can significantly contribute to meeting the energy needs of communities. One effective approach to harnessing these renewable sources is through the optimization and simulation of a solar-wind renewable system connected to a nano grid. A nano grid is a localized power distribution network that operates independently or in parallel with the main grid. It typically serves a smaller area, such as a residential community, a commercial complex, or an industrial facility. By integrating solar and wind energy generation into a nano grid, a self-sustaining and environmentally friendly power supply can be achieved, reducing dependency on traditional fossil fuel-based electricity.

The optimization and simulation of such a renewable system involve designing an energy generation setup that maximizes the utilization of solar and wind resources, minimizes costs, and ensures a reliable power supply. By carefully sizing and configuring the solar and wind components, taking into account factors like available space, climate conditions, and resource availability, an efficient and effective system can be achieved.

Simulating the performance of the solar-wind renewable system using specialized software allows for a detailed analysis of its operation under various scenarios. By considering factors such as energy demand, resource availability, and economic viability, the optimization process aims to achieve the maximum utilization of renewable energy while minimizing costs and ensuring system reliability. Furthermore, economic analysis plays a crucial role in assessing the financial viability of the solar-wind renewable system. By evaluating capital costs, operation and maintenance expenses, and the levelized cost of energy, decision-makers can determine the economic feasibility of the system and compare it with conventional energy sources. The integration of the renewable system with the nanogrid and compliance with grid interconnection requirements are essential considerations. It ensures the seamless exchange of energy between the renewable system and the nanogrid, as well as the ability to leverage the main grid as a backup or supplementary energy source if needed.

In summary, the optimization and simulation of a solar-wind renewable system connected to a nanogrid offers a sustainable and reliable solution for localized power generation. By harnessing the abundant solar and wind resources, optimizing system configurations, and integrating with a nanogrid, this approach contributes to reducing carbon emissions, promoting energy independence, and achieving a greener future.

Nano grids are a smaller-scale version of microgrids that operate at the local level, typically serving a single building, a cluster of buildings, or even a single residential unit. While microgrids can cover larger areas like neighbourhoods or industrial complexes, nano grids focus on providing localized power solutions. Similar to microgrids, nano grids integrate various distributed energy resources (DERs) such as solar panels, small wind turbines, energy storage systems, and localized loads. Nanogrids are particularly suitable for residential communities, commercial buildings, or isolated locations with limited access to the main grid. They provide flexibility, control, and sustainability at a smaller scale, empowering consumers to actively participate in the energy transition and enhance energy resilience at the local level.

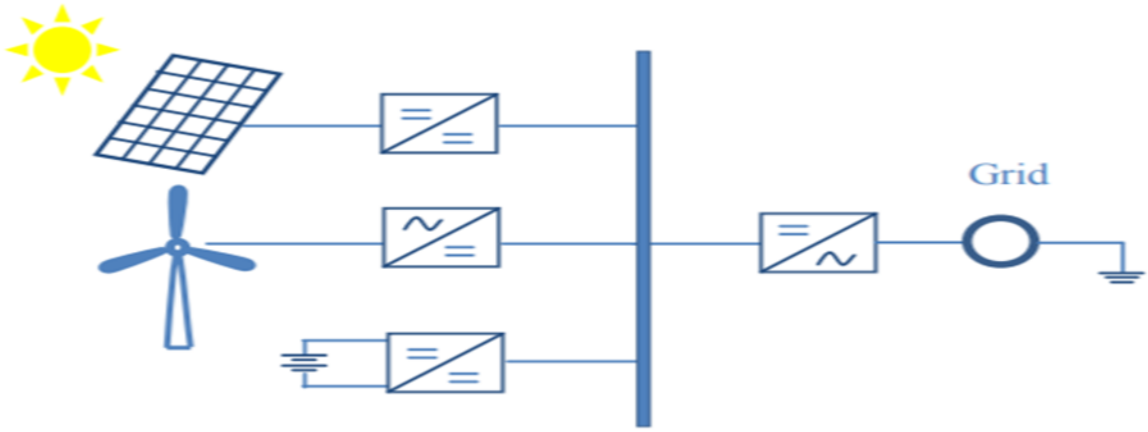

Fig.1 Basic Diagram of Solar Wind Hybrid System.

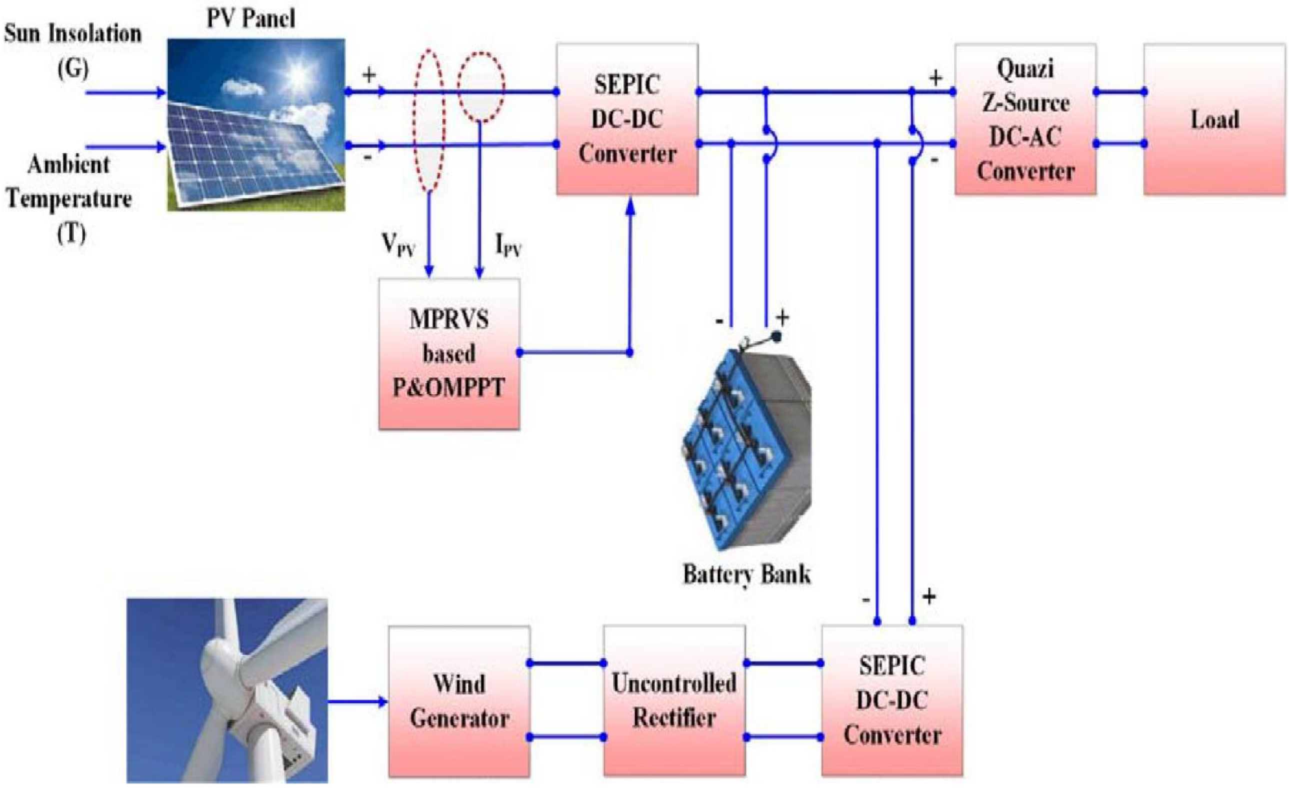

Fig.2 Basic block diagram of solar wind hybrid system.

2. HISTORICAL REVIEW

Citation such as	**Name of journal/ year/Author**	**Research Findings**	**Research scope**
1	2013 International Conference on Alternative Energy in Developing Countries and emerging Economies. ScienceDirect.com R. Nazira, H. D. Laksono a , E. P. Waldi a , E. Ekaputra b , P. Coveria	Renewable Energy Sources Optimization: A Micro-Grid Model Design	The possibility to develop the simple micro-grid model in optimizing the utilization of local renewable energy for on-grid area. The proposed micro-grid model integrates the power plants driven by renewable energy sources employing micro hydro (MHP) and photovoltaic system (PV) which is connected to grid system. This model is analyzed using HOMER and MATLAB software.
2.	Ain Shams Engineering Journal 12 September 2022 ScienceDirect.com Pankaj Sharma, Rani Chinnappa Naidu	Optimization techniques for grid-connected PV with retired EV batteries in centralized charging station with challenges and future possibilities: A review	The usage of Retired Electric Vehicle Batteries (REVB) to support a system with a Centralized Charging Station (CCS) for charging electric vehicle batteries. This paper also focuses on power flow from the Grid to the Centralized Charging Station (G2CCS), power flow from solar PV to the Centralized Charging Station (PV2CCS), PV to the Grid (PV2G), and power flow from Retired Electric Vehicle Batteries to the Centralized Charging Station (REVB2CCS), Retired EV batteries to the Grid (REVB2G), various schemes for EV's in India, and barriers to the adoption of EV respectively.

3.	http://www.researchgate.net/ publication/305285542 Badwawi1,*, Mohammad Abusara1 and Tapas Mallick1	A Review of Hybrid Solar PV and Wind Energy System	Due to the fact that solar and wind power is intermittent and unpredictable in nature, higher penetration of their types in existing power system could cause and create high technical challenges especially to weak grids or stand-alone systems without proper and enough storage capacity. By integrating the two renewable resources into an optimum combination, the impact of the variable nature of solar and wind resources can be partially resolved and the overall system becomes more reliable and economical to run. This paper provides a review of challenges and opportunities / solutions of hybrid solar PV and wind energy integration systems.
4.	Journal of King Saud University – Engineering Sciences sciencedirect.com	A simple control strategy and dynamic energy management for the operation of combined grid-connected and standalone solar photovoltaic applications	There is an increased focus on energy savings in low-voltage DC (LVDC) loads for home appliances. Use of LVDC for the local distribution system enables easier integration with renewable sources. This work presents the control and management of power flow to DC loads in grid-tied photovoltaic (GPV) systems. This system provides bi-directional flow of power from DC load to AC grid, using a pulse width modulation (PWM) technique, employing a voltage source inverter between the DC nano grid and the AC main grid. The bidirectional converter controls the active power transferred in both directions while operating at unity power factor (UPF).

R. Nazir et al (2013) analyzed the possibility to develop the simple micro-grid model in optimizing the utilization of local renewable energy for on-grid area. The proposed micro-grid model integrates the power plants driven by renewable energy sources employing micro hydro (MHP) and photovoltaic system (PV) which is connected to grid system. The model is analyzed using HOMER and MATLAB software. Based on the load profiles and the availability of water resources, the HOMER simulates the proposed micro-grid model with three options of MHP capacity. The simulation results show that the micro-grid model with the largest capacity MHP produced the lowest energy cost, greatest reduction of CO2 emission, and largest fraction of renewable energy. However, the result required the expensive initial capital cost. In addition to this PV power generation was always recommended with a minimum capacity. Hence, MATLAB results show the performances of the power plants with renewable energy sources were used maximally.

Pankaj Sharma, Rani Chinnappa Naidu et al (2022) emphasized the usage of Retired Electric Vehicle Batteries (REVB) to support a system with a Centralized Charging Station (CCS) for charging electric vehicle batteries. This paper also focused on power flow from the Grid to the Centralized Charging Station (G2CCS), power flow from solar PV to the Centralized Charging Station (PV2CCS), PV to the Grid (PV2G), and power flow from Retired Electric Vehicle Batteries to the Centralized Charging Station (REVB2CCS), Retired EV batteries to the Grid (REVB2G), various schemes for EV's in India, and barriers to the adoption of EV respectively. The review of the modelling and optimization was mainly based on retired EV batteries for EVs charging with recent trends, and future possibilities of retired EV batteries are also discussed. This review paper provides valuable references for researchers and assists them in continuous improvement in this field. In developing countries, rural and urban areas suffer from the charging infrastructure. But the demand of the EV's increasing day by day in developing countries as well as developed countries. To reduce the carbon footprint, all countries around the globe focus on renewable energy. The demand for EVs increases day by day in the global market and hence the battery consumption.

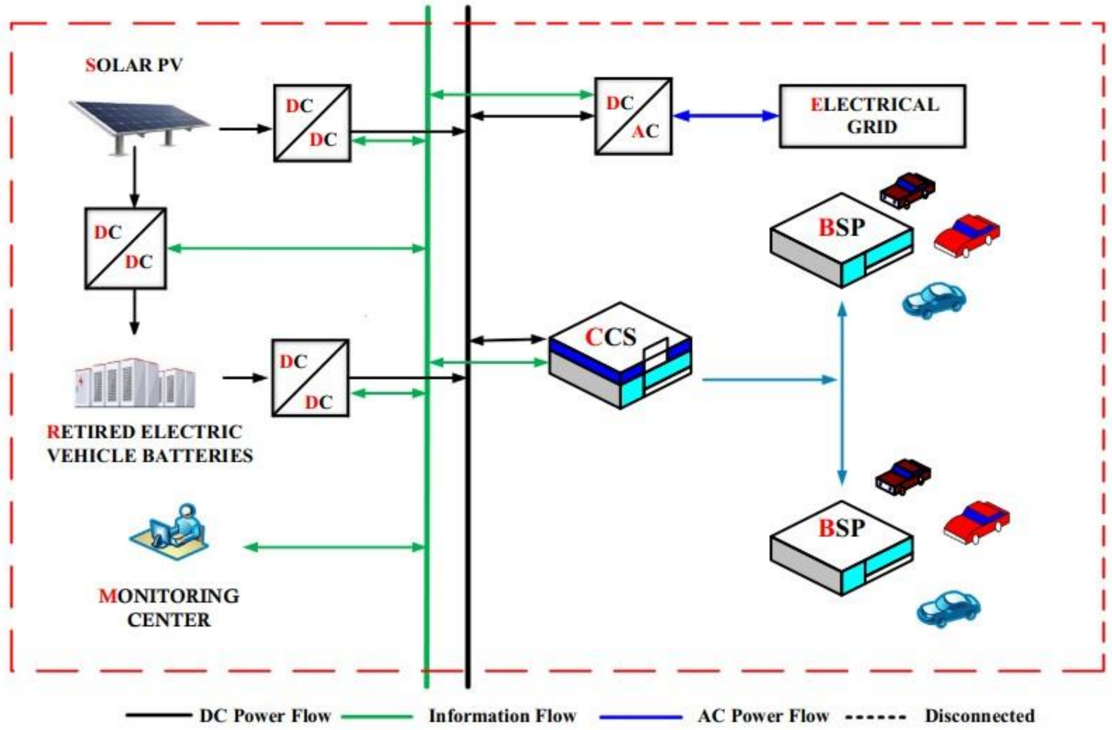

Fig.3 Power Flow of Grid-Connected Solar PV/Centralized Charging Station / Retired Electric Vehicle Battery.

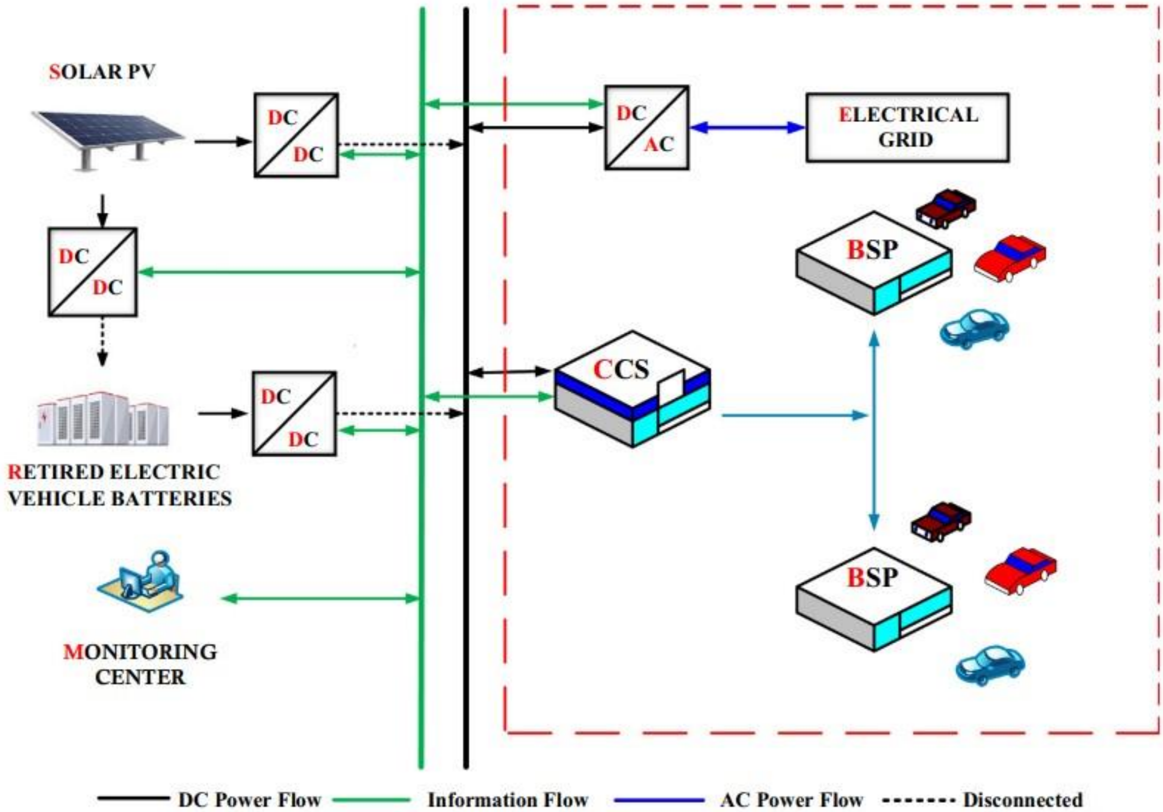

Fig.4 Flow from the Grid to the Centralized Charging Station

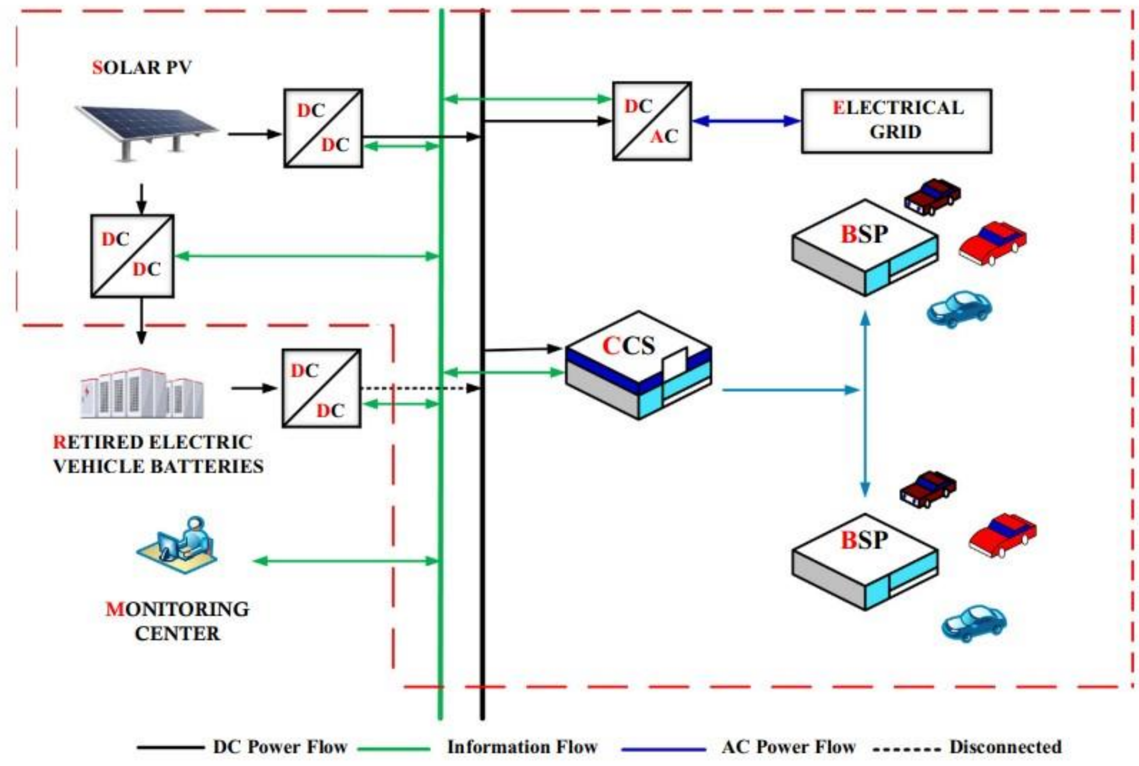

Fig.5 Power Flow from Solar PV to the Centralized Charging Station, Retired Electric Vehicle Battery, and Grid.

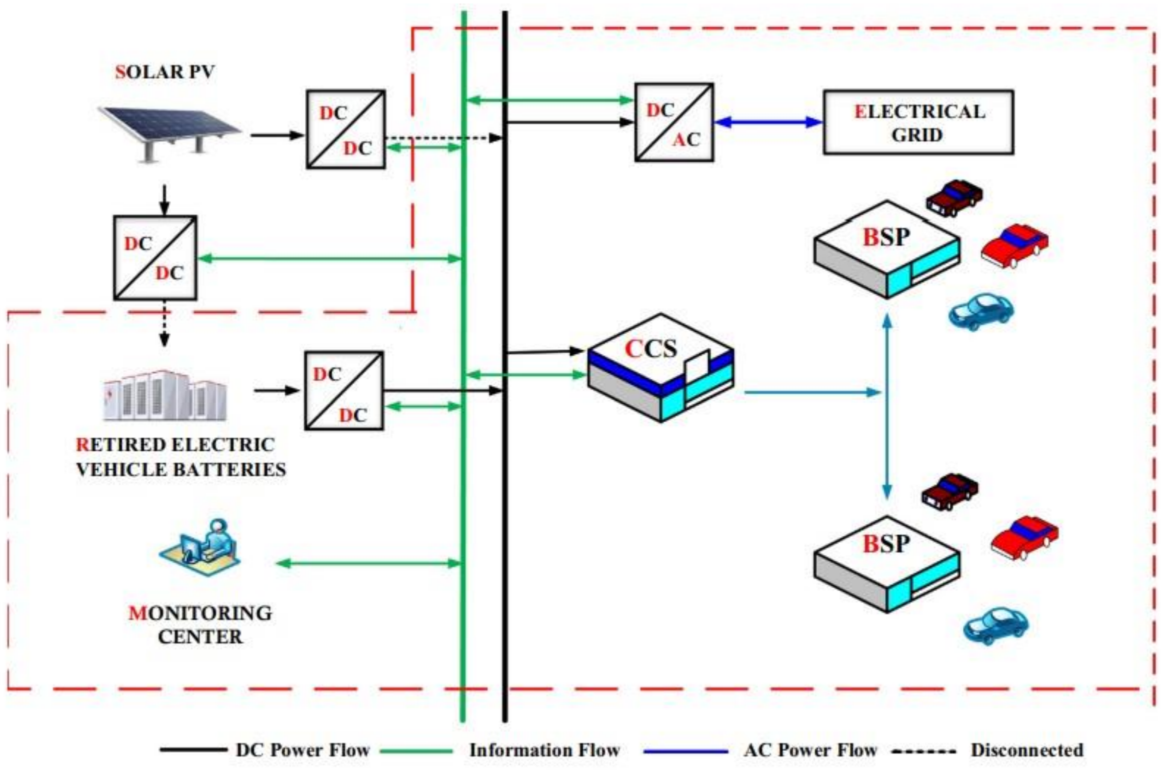

Fig.6 Power flow from retired Electric Vehicle batteries to the Centralized charging stations and Grid

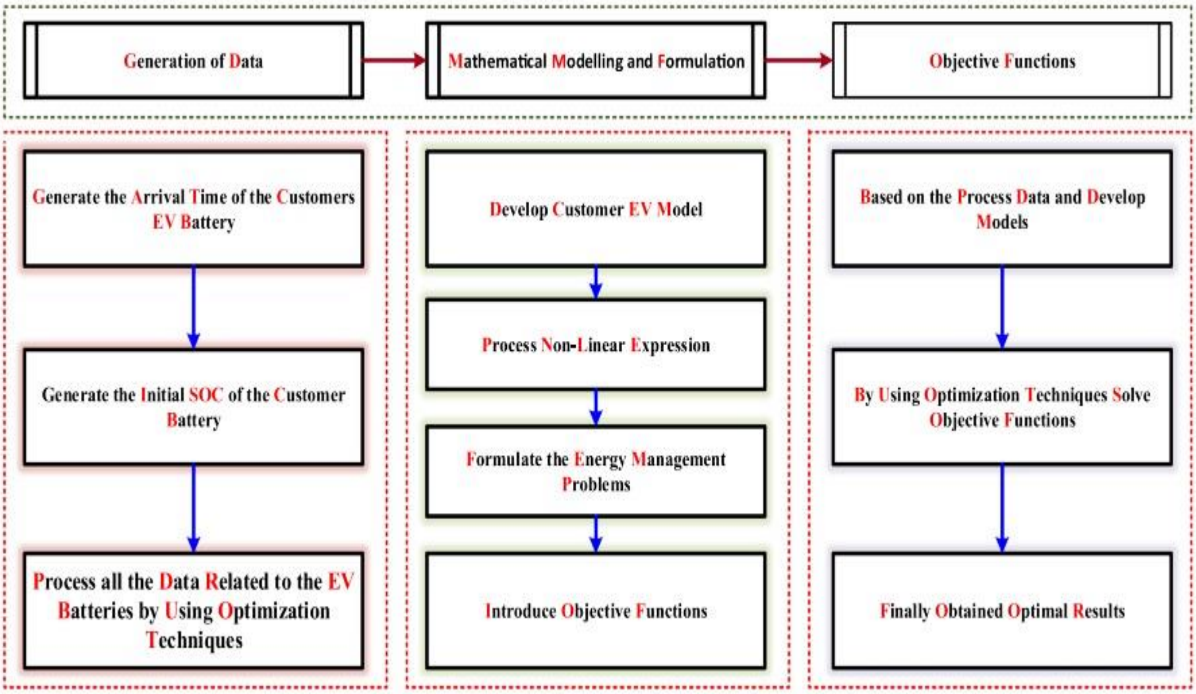

Fig.7 Typical Optimization process flow chart.

Rashid Al Badwawi1et al (2015) provides a review of challenges and opportunities as well as solutions of hybrid solar PV and wind energy integration systems. Voltage and frequency fluctuation, and harmonics are major power quality issues for both grid-connected and stand-alone systems with bigger impact in case of weak grid. This can be resolved to a large extent by having proper design, advanced fast response control facilities, and good optimization of the hybrid systems. The paper gives a review of the main research work reported in the literature with regard to optimal sizing design, power electronics topologies and control. The paper presents a review of the state of the art of both grid-connected and stand-alone hybrid solar and wind systems.

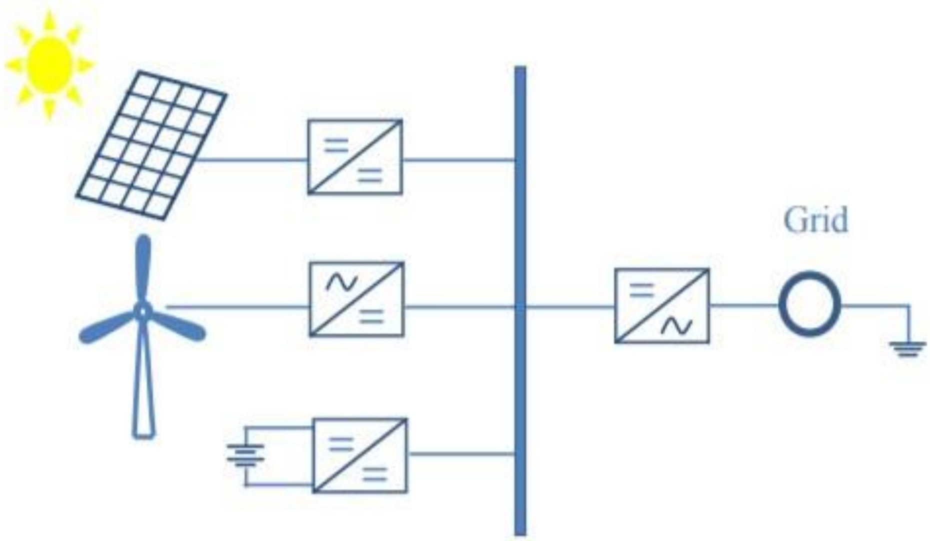

Fig. 8 Grid-connected hybrid system at common DC bus

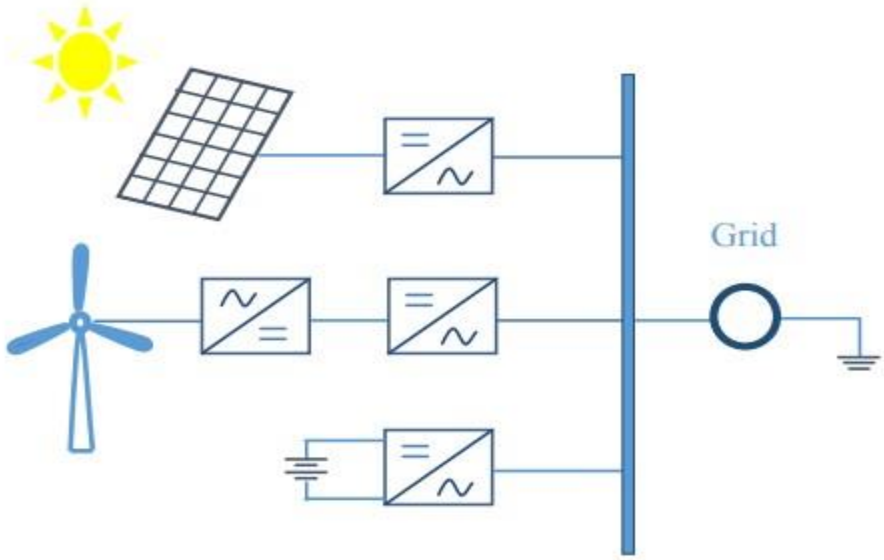

Fig. 9 Grid-connected hybrid system at common AC bus

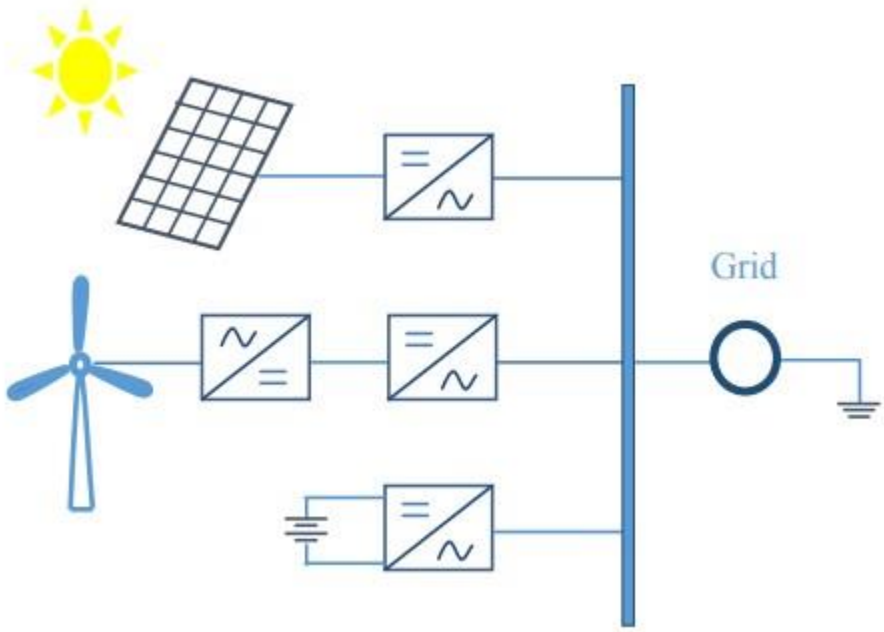

Fig. 10 Stand-alone hybrid system at common DC bus

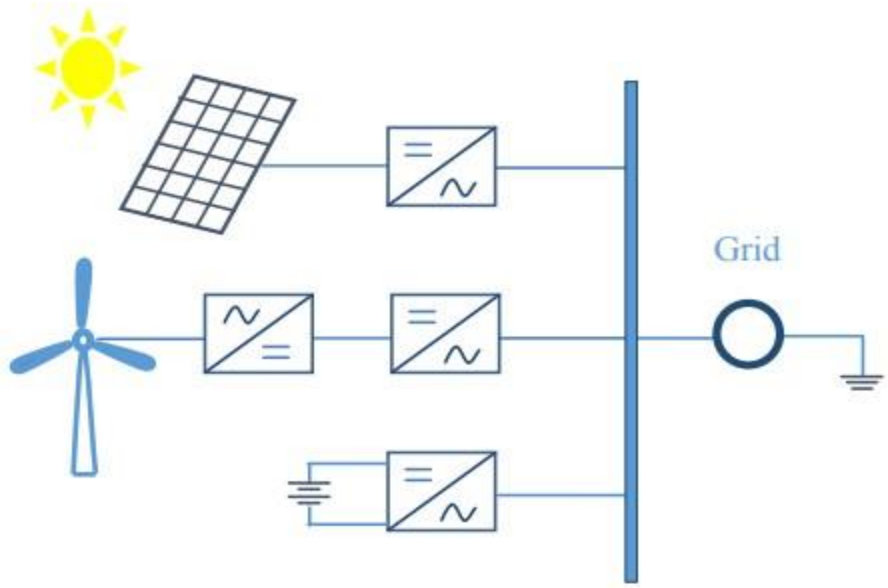

Fig. 11 Stand-alone hybrid system at common AC bus

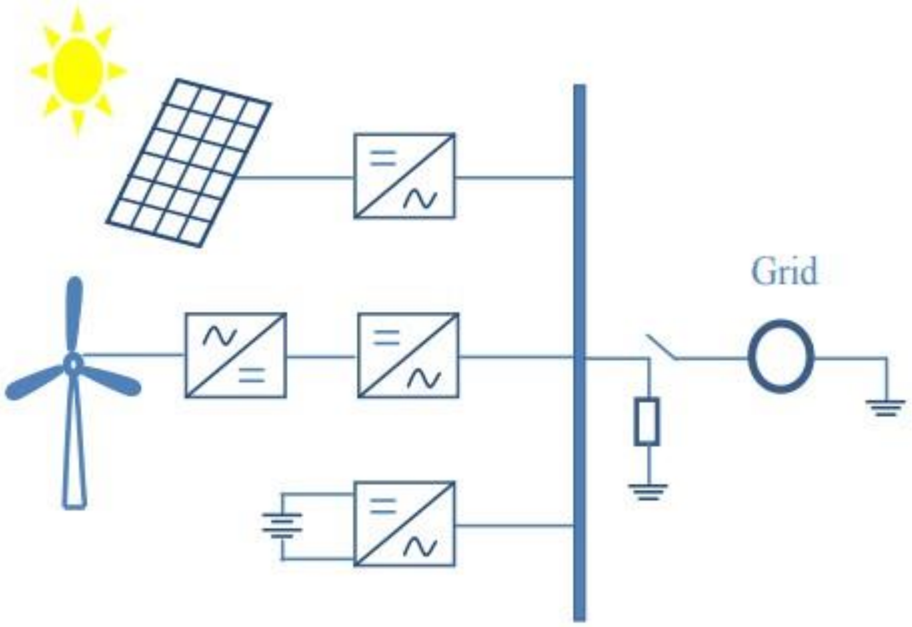

Fig. 12 Hybrid system with AC Microgrid

Bilawal A. Bhayoa Hussain H. Al-Kayiema et al (2020) hybrid renewable energy systems (HRES) are fascinating solutions for standalone power generation and have great future to supply reliable power and keep the environment clean. Tang et al. suggested and optimized a HRES as a power supply to ships as an auxiliary source after ship berths in port. In general, when a ship begins to enter the port, the primary engine is slowed down. As the ship docks, the primary engine is switched off and auxiliary generator is switched on for backup power supply to hotel and other amenities. HRES are influenced by various factors such as energy potential, site dependency, technical and social constraints. Each one of the above constraints is affecting the power yield and further can lead to increase in the cost of the system. The influence of location, area and shape on electric energy generation from small-scale solar and wind power in Brazil, Ribeiro et al. concluded that it is needed to optimize the design and operational strategy for achieving the high reliability with low cost of power production.

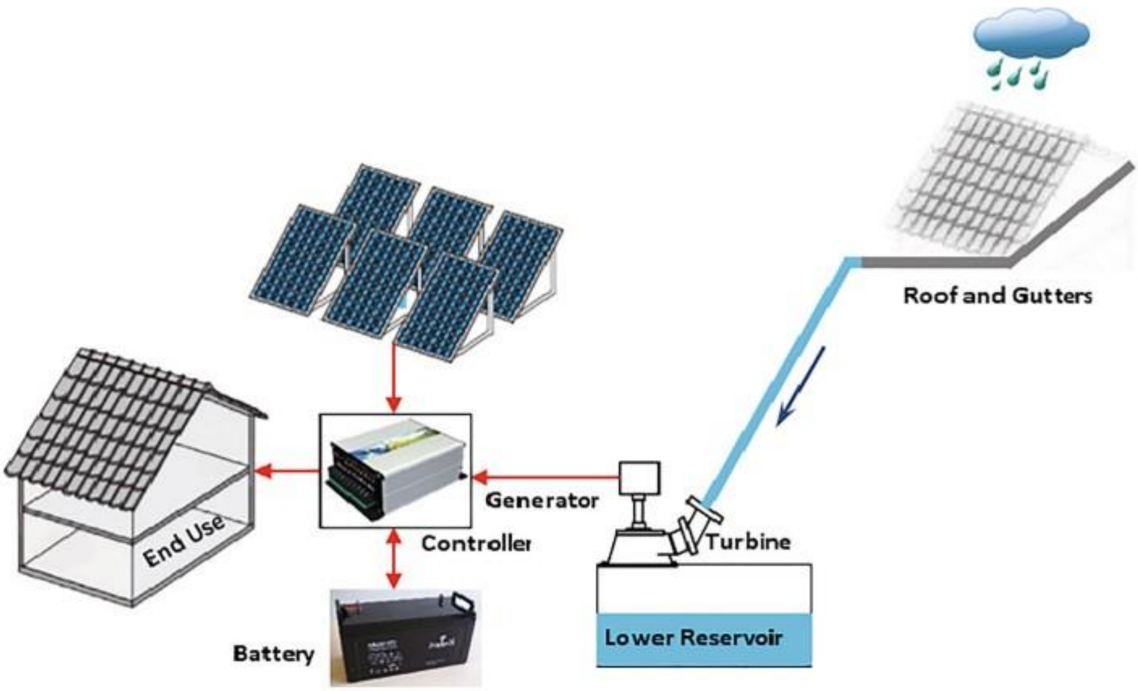

Fig.13 Schematic layout of configuration-1: hybrid PV-battery-hydro system to harvest rainfall for power generation

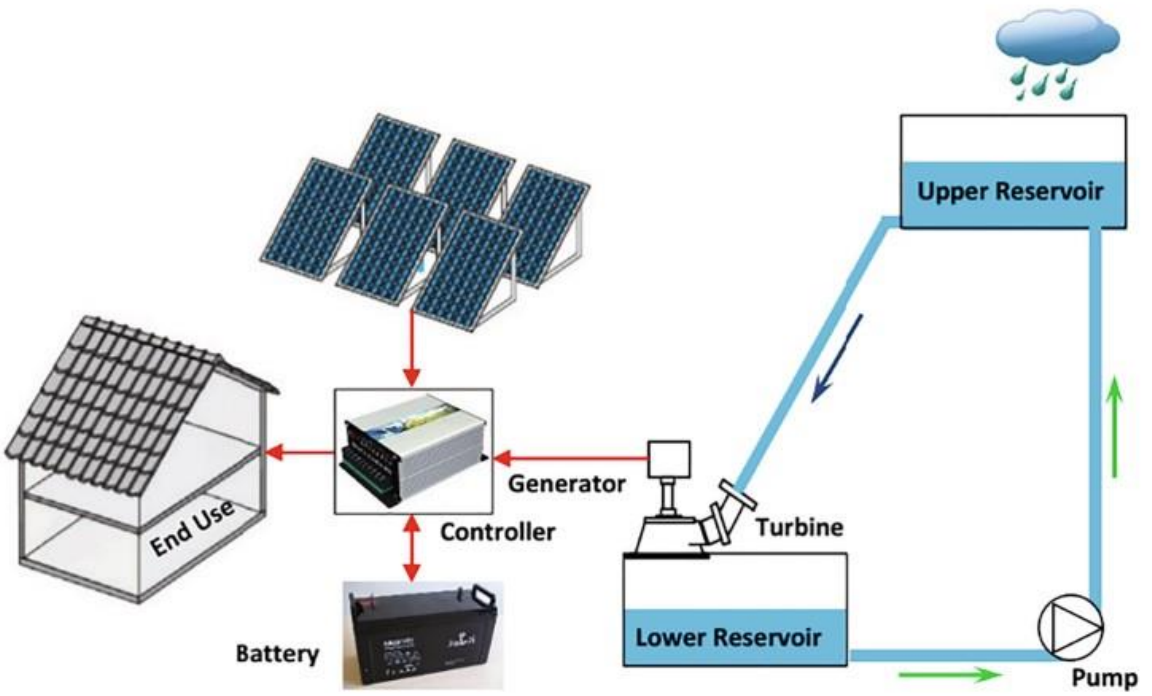

Fig.14 Schematic layout of configuration-2: PV-Battery-PHSS system to harvest rainfall for power generation

J.L. Marquez, M.G. Molina et al (2009) described a small-scale hydropower station is usually a run-of-river plant that uses a fixed speed drive with mechanical regulation of the turbine water flow rate for controlling the active power generation. This design enables to reach high efficiency over a wide range of water flows but using a complex operating mechanism, which is in consequence expensive and tend to be more affordable for large systems. This paper proposes an advanced structure of a micro-hydro power plant (MHPP) based on a smaller, lighter, more robust and more efficient higher-speed turbine. The suggested design is much simpler and eliminates all mechanical adjustments through a novel electronic power conditioning system for connection to the electric grid. In this way, it allows obtaining higher reliability and lower cost of the power plant. A full detailed model of the MHPP is derived and a new three-level control scheme is designed. The dynamic performance of the proposed MHPP is validated through digital simulations and employing a small-scale experimental set-up.

Yijie Zhanga, Tao Ma et al (2023) states that the fluctuation and intermittency of distributed PV generation, battery energy storage is required with higher renewable installation towards carbon neutrality. Thus, the photovoltaic battery (PVB) system receives increasing attention. The study provides a critical review on PVB system design optimization, including system component sizing and strategy improvement studies, from mathematical modeling, evaluation system establishment to feasibility and optimization studies. Several PVB simulation software packages are compared and evaluated, and acknowledged system models are presented. The evaluation indicators are summarized from various aspects with cases of various evaluation systems combining different indicators or using the Pareto front for multi-criteria system designing. The PVB system feasibility study is analyzed from system configuration variation, critical technical and economic parameter analyses, rule-based operation strategies to future expectations like large-scale energy storage profitability, grid parity, and energy community trading platform. This study could provide guidance and references to distributed PVB system future design and optimization studies.

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