Unbiased Circular Leakage Centered Adaptive Filtering Control for Power Quality Improvement of Wind-Solar PV Energy Conversion System

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***Abstract*— Due to the intermittent and unpredictable nature of solar and wind energy, greater integration of these sources into the existing power grid could pose significant technological difficulties, particularly for weakened grids or standalone systems lacking adequate and sufficient storage. The impact of the fluctuating nature of solar and wind resources can be partially alleviated by integrating the two renewable resources into an optimal combination, and the whole system becomes more reliable and cost-effective to run. In this study, the opportunities and problems of hybrid solar PV and wind energy integration systems are reviewed. Major power quality challenges for both grid-connected and stand-alone systems include harmonics, voltage and frequency fluctuation, and they are more severe in weak grid situations. This can be dealt to a significant extent by having adequate design, improved rapid reaction control capabilities, and good hybrid system optimization. The primary research projects related to optimal size design, power electronics topologies, and control are reviewed in this study. The study provides an overview of the current state of hybrid solar and wind systems that are both grid-connected and stand-alone.**

***Keywords*— Hybrid, Renewable, PV, Wind Energy, Power Electronics.**

I. INTRODUCTION

The conventional energy sources are running out very quickly. A photovoltaic system is a desirable alternative because energy prices are also growing. They are plentiful, free of pollution, dispersed all across the world, and recyclable. Due to its expensive installation and ineffective conversion, it is a barrier. Therefore, our goal is to boost the system's production of power and efficiency. Additionally, the load must get consistent voltage regardless of changes in sun irradiation and temperature. Depending on the meteorological conditions (such as solar irradiation and temperature), PV arrays are made up of parallel and series combinations of PV array and wind systems. Therefore, a boost converter is required to connect the PV array and wind system. Additionally, our system is built in a way that, as load varies, the converter's input voltage and power changes in accordance with the open circuit characteristics of the PV array and wind system. Our technique can be utilised to provide dc loads with steady stepped up voltage.

II. RENEWABLE ENERGY

Renewable energy sources, often known as non-conventional energy sources, are those that are constantly renewed by natural processes. Examples of sustainable energy sources include solar electricity, bio-energy from sustainably generated biofuels, wind and hydropower, etc. A renewable energy system transforms energy from sources such as sunlight, falling water, wind, sea waves, geothermal heat, and biomass into a form that may be used for electricity or heat. Since the majority of renewable energy is generated either directly or indirectly from the sun and wind and never runs out, it is referred to as renewable.[1].

However, fossil fuels like coal, natural gas, and oil made up the majority of the world's traditional energy sources. These sources of energy are frequently referred to as nonrenewable. Despite the fact that there is a very huge amount of these fuels available, it will eventually run out owing to the daily decline in oil and fossil fuel levels. As a result, demand for renewable energy sources rises because they are pollution-free and environmentally benign, which lessens the greenhouse impact [2].

A. *Solar Energy:* Solar energy is a non-conventional source of energy. Humans have used a number of methods to collect solar energy since ancient times. The majority of the world's non-conventional energy sources, including biomass, wave and wind energy, hydroelectricity, and hydrocarbons, are powered by solar radiation. Only a small portion of the solar energy that is accessible to use [3].

Solar-powered heat engines and photovoltaic systems are used to generate electricity. The only limit to the use of solar energy is the human creativity. The most popular method for collecting solar energy is to employ photovoltaic panels, which take in solar photon energy and convert it to electrical energy. Depending on how they capture, transform, and disperse solar energy, solar technologies can be roughly classified as either passive solar or active solar.

B. *Wind Power:* It is possible to turn electric generators with the help of wind power, which uses air flow through wind turbines. As a substitute for burning fossil fuels, wind power is accessible, abundant, renewable, clean, emits no greenhouse gases while in use, uses little water, and occupies minimal land. [4] Comparing the environmental impacts to those of non-renewable power sources, the net effects are much less problematic.

Wind farms are made up of a number of separate wind turbines that are linked to an electric power transmission network. Onshore wind is a low-cost source of electricity that can sometimes be found to be less expensive than coal or gas-fired power stations. [4][5][6] Offshore wind is more consistent and powerful than on land, and offshore farms have less of an aesthetic impact, but the expenses of development and upkeep are significantly greater. Small onshore wind farms have the potential to provide energy to the grid or supply remote, off-grid locations with electricity. [7]

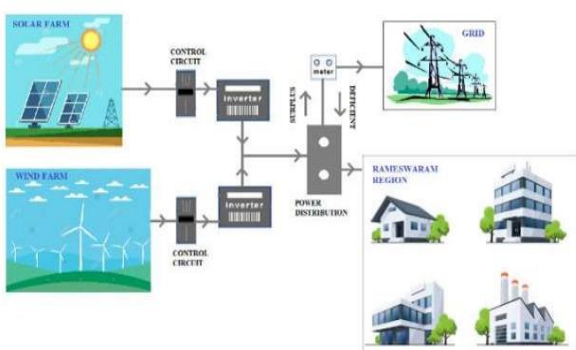

Fig 1. Block Diagram of wind solar hybrid system.

Fig 2. General Block Diagram of wind + solar system.

III. LITERATURE SURVEY

[1] Qiuyan Zhang, "A Short-Term Optimal Scheduling Model for Wind-Solar-Hydro-Thermal Complementary Generation System Considering Dynamic Frequency Response": This paper proposes a model to realize the coordinated optimal dispatch of windsolar-hydro-thermal hybrid power generation system, aiming at minimizing the power generation cost of thermal generators and maximizing the water storage value of hydropower stations at the end of the scheduling periods, while considering the dynamic frequency response of wind/solar/hydro/thermal generators. Considering the virtual inertia and droop control of wind farms and PV stations, the dynamic frequency response model of wind-solar-hydro-thermal multi-energy complementary system is derived and the metrics that evaluate the frequency dynamic characteristics of the generation system are presented. Then the dynamic frequency response constraints are incorporated into the traditional optimal scheduling model and the Mixed Integer Linear Programming (MILP) method is used to solve it. Finally, the validity and applicability of the proposed model are verified by simulation examples.

[2] Miswar A. Syed, "Moving Regression Filtering With Battery State of Charge Feedback Control for Solar PV Firming and Ramp Rate Curtailment": The surge in energy demand needs to be met with environmentally pleasant resources to reduce the production of greenhouse gases. Solar Photovoltaic (PV) power is a widespread choice as it is accessible in plenty and is comparatively inexpensive. However, the large-scale penetration of intermittent PV power causes multiple variabilities in the grid such as frequency issues and voltage deviations. To

counteract these instabilities, Battery Energy Storage System (BESS) is integrated into the grid as it reduces the PV fluctuations and promotes optimal operation.

[3] Jun Xie, "A Short-Term Optimal Scheduling Model for Wind-Solar-Hydro Hybrid Generation System With Cascade Hydropower Considering Regulation Reserve and Spinning Reserve Requirements": In order to meet the challenges brought by the high penetration of intermittent and fluctuating wind and solar power, a short-term optimal scheduling model for wind-solar-hydro hybrid generation system with cascade hydropower is established with the objective of minimizing the amount of abandoned wind, solar and hydro power and maximizing the stored energy of hydro stations. Cascade hydropower is considered to provide spinning reserve and regulation reserve to ensure the security of system. Mixed Integer Linear Programming (MILP) method is used for the short-term optimal schedule of wind-solar-hydro hybrid generation system. The case studies show that spinning reserve and regulation reserve are beneficial to the hybrid generation system, and verify the practical applicability of the proposed model.

[4] Shakti Singh, "Feasibility of Grid-connected Solar-wind Hybrid System with Electric Vehicle Charging Station": Recently, renewable power generation and electric vehicles (EVs) have been attracting more and more attention in smart grid. This paper presents a grid connected solar-wind hybrid system to supply the electrical load demand of a small shopping complex located in a university campus in India. Further. an EV charging station is incorporated in the system. Economic analysis is performed for the proposed setup to satisfy the charging demand of EVs as well as the electrical load demand of the shopping complex. The proposed system is designed by considering the cost of the purchased energy, which is sold to the utility grid, while the power exchange is ensured between the utility grid and other components of the system. The sizing of the component is performed to obtain the least leveled cost of electricity (LCOE) while minimizing the loss of power supply probability (LPSP) by using recent optimization techniques. The results demonstrate that the LCOE and LPSP for the proposed system are measured at 0.038 $/kWh and 0.19% with a renewable fraction of 0.87, respectively. It is determined that a cost-effective and reliable system can be designed by the proper management of renewable power generation and load demands. The proposed system may be helpful in reducing the reliance on the over-burdened grid, particularly in developing countries.

[5] Silvia Sekander, "Statistical Performance Modeling of Solar and Wind-Powered UAV Communications": We develop novel statistical models of the harvested energy from renewable energy sources considering harvest-storeconsume (HSC) architecture. We consider three renewable energy harvesting scenarios, i.e., (i) harvesting from the solar power, (ii) harvesting from the wind power, and (iii) hybrid solar and wind power. In this context, we first derive the closed-form expressions for the density functions and moments of the harvested power solar and wind power. Then, we calculate the probability of energy outage at UAVs and signal-to-noise ratio (SNR) outage at ground cellular users. The energy outage occurs when the UAV is unable to support the flight consumption and transmission consumption from its battery power and the harvested power. Due to the intricate distribution of the hybrid solar and wind power, we derive novel closed-form expressions for the moment generating function (MGF) of the harvested solar power and wind power. Then, we apply Gil-Pelaez inversion to evaluate the energy outage at the UAV and SNR outage at the ground users. In addition, we formulate the SNR outage minimization problem and obtain closed-form solutions for the transmit power and flight time of the UAV.

[6] Pranoy Roy, "Cost Minimization of Battery Super Capacitor Hybrid Energy Storage for Hourly Dispatching Wind-Solar Hybrid Power System": This study demonstrates a dispatching scheme of wind-solar hybrid power system (WSHPS) for a one-hour dispatching period for an entire day utilizing battery and super capacitor hybrid energy storage subsystem (HESS). A frequency management approach is deployed to extend the longevity of the batteries through extensively utilizing the high energy density property of batteries and the high power density property of super capacitors in the HESS framework. A low-pass filter (LPF) is employed to decouple the power between a battery and a super capacitor (SC). The cost optimization of the HESS is computed based on the time constant of the LPF through extensive simulations in MATLAB/SIMULINK platform. The curve fitting and Particle Swarm Optimization approaches are applied to seek the optimum value of the LPF time constant. Several control

algorithms as a function of the battery state of charge are developed to achieve accurate estimation of the grid reference power for each one-hour dispatching period.

[7] Hongming Yang, “Optimal Wind-Solar Capacity Allocation with Coordination of Dynamic Regulation of Hydropower and Energy Intensive Controllable Load”: With the increasing penetration of renewable energy, it becomes challenging to smoothen highly fluctuant and intermittent power output only through the conventional thermal units. In this paper, by exploiting the dynamic regulating ability of hydropower and energy intensive controllable load to reduce the power output uncertainties, an optimal wind-solar capacity allocation method is proposed. The power regulation characteristics of hydropower stations based on hydraulic head and energy intensive controllable load based on complex production process are modelled. A bi-level (including planning and operation layers) optimization model for wind-solar capacity allocation is proposed, which is subject to the system dynamic regulation constraints.

[8] Ahmad F. Tazay, “Modeling, Control, and Performance Evaluation of Grid-Tied Hybrid PV/Wind Power Generation System: Case Study of Gabel El-Zeit Region, Egypt”: The potential for utilizing clean energy technologies in Egypt is excellent given the abundant solar irradiation and wind resources. This paper provides detailed design, control strategy, and performance evaluation of a grid-connected large-scale PV/wind hybrid power system in Gabel El-Zeit region located along the coast of the Red Sea, Egypt. The proposed hybrid power system consists of 50 MW PV station and 200 MW wind farm and interconnected with the electrical grid through the main Point of Common Coupling (PCC) busbar to enhance the system performance. The hybrid power system is controlled to operate at the unity power factor and also the Maximum Power Point Tracking (MPPT) technique is applied to extract the maximum power during the climatic conditions changes. Modeling and simulation of the hybrid power system have been performed using Matlab/Simulink environment. Moreover, the paper presented a comprehensive case study about the realistic monthly variations of solar irradiance and wind speed in the study region to validate the effectiveness of the proposed MPPT techniques and the used control strategy. The simulation results illustrate that the total annual electricity generation from the hybrid power system is 1509.85 GWh/year, where 118.15 GWh/year (7.83 %) generates from the PV station and 1391.7 GWh/year (92.17%) comes from the wind farm. Furthermore, the hybrid power system successfully operates at the unity power factor since the injected reactive power is kept at zero.

[9] Farheen Chishti, “Unbiased Circular Leakage Centered Adaptive Filtering Control For Power Quality Improvement of Wind–Solar PV Energy Conversion System”: The hybrid renewable energy conversion systems and their increased penetration into the utility grid are intensifying the power quality (PQ) issues especially in the form of increased total harmonic distortion of voltages and currents at point of common coupling. The objective of the proposed grid-tied windsolar photovoltaic (PV) energy conversion system is to analyze PQ issues and to mitigate them by utilizing the unbiased circular leakage centered (UCLC) adaptive filtering control. An implementation of UCLC adaptive control improves the PQ indices and system performance by overcoming the intermittency issues associated with solar and wind energies. UCLC adaptive control effectively extracts the fundamental load current component and mitigates the grid current harmonics. It has simple structure, enhanced convergence rate, and better performance with noise corrupted input and output signals. It effectively resolves the weight drift problem depicted by the conventional least mean square (LMS) control and leaky LMS control algorithm by avoiding biased estimates. The averaging theory and the deterministic stability analysis provide the relying facts of the performance of UCLC adaptive control. The extraction of maximum power from solar PV array energy and wind generation is carried out by perturb and observe scheme. A prototype is made in the laboratory and verified for environmental variations of solar insolation level, wind speed, and perturbing load demand. The PQ issues are effectively alleviated. Test results confirm the effective performance of the proposed system.

IV. MOTIVATION

In the past, typical distribution generation applications used reciprocating engines or modest hydro plants with reasonably steady AC power injection. The intermittent resource characteristics of the wind/PV hybrid power system need the conversion of DC-AC power through inverters and have higher power ratings with sophisticated control. The power production varies throughout the day. Due to its unique properties, the expansion of wind/PV hybrid power systems is a less common challenge for distribution utilities and has a variety of effects that are distinct from those of conventional DGs. Therefore, a thorough analysis of the potential dynamic impact of PV systems on the distribution network under a variety of load and generating situations is necessary. The main goal of the paper is to pinpoint the oscillations in the grid-connected wind/PV hybrid power system. must create a method for dampening these oscillations and supplying a stable power system. Despite the demand, there is no industry-accepted benchmark model of a large-scale wind/PV hybrid generation plant.

V. PROBLEM STATEMENT

Solar emission fluctuates over time and is influenced by the environment (irradiance, temperature, etc.). As a result, finding a typical production all the way through is difficult. Additionally, the solar power supply is not available at night, therefore we must look for alternative sources of energy. The wind power system is another way to produce electricity at night with a typical wind speed of 12 metres per second. For a microgrid system, the voltage generated by solar and wind is insufficient. We must connect the converter and inverter components to the system in order to solve this issue. Different converters have been used in this thesis, and the outcomes are contrasted. The most appropriate converter is selected using the simulation results, and more groups of hybrid renewable energy system connected microgrid will be added in the future.

VI. PROPOSED METHODOLOGY

A. Wind Speed and Solar Irradiance Predictions

Models for forecasting wind speed and solar irradiance are created independently in order to create a hybrid model for the area. The Artificial Neural Network (ANN) was chosen to be used for prediction after training and testing the wind and solar factors using various machine learning methods. This was because the results of all the other algorithms did not significantly differ from one another. First, a model for forecasting wind speed is created. After exploring every parameter that is related to wind speed, the following parameters are chosen for this work's investigation. The wind characteristics that are taken into account during training include the following: temperature in °C, pressure in hPa, humidity in %, rainfall in mm, and visibility in kilometers. The wind velocity, expressed in km/h, is the goal.

The aforementioned information was gathered over a five-year period (2012-2016). The network is trained for wind speed prediction using the MATLAB neural network toolkit. Network type, input/target data, training algorithm, performance measure, number of layers, number of neurons per layer, and activation functions must all be chosen by the user. The network is trained until the performance metric is met or the predetermined number of iterations is reached after the user has chosen every parameter. If the network object model performs satisfactorily, it is tested using the test data set; if not, it must be tested using various training procedures, transfer functions, layer counts, and neuron counts. At this point, any fresh data set can be used to replicate the network object. Next, using MATLAB's ANN toolbox, a model for solar irradiance prediction is created. Elevation and azimuth angles, air temperature in °C, humidity in percentage, and pressure in hPa are the solar characteristics that are taken into account for training. The aim is the hourly total of the Global Horizontal Irradiance (GHI), given in W/m2.

B. Power Calculation

The optimal times to operate wind turbines in a given area are determined based on the results gathered. The following categories of wind speeds are used to operate wind turbines:

- The initial rotational speed of tiny wind turbines is approximately 8 km/h (2 m/s).
- At a speed of 12.6 km/h (3.5 m/s), wind turbines begin to produce electricity.
- At a speed of 36–54 km/h (10–15 m/s), a turbine reaches its optimum efficiency.
- A turbine is brought to a stop at its cut-out speed of 90 km/h (25 m/s).

Wind power is calculated on days where wind speeds are greater than the cut-in speed and lower than the cut-out speed, based on the average wind speed prediction for each day. Using the conventional formula, the amount of wind power generated each day is determined. Air density, wind turbine swept area, and velocity are the factors used to calculate wind power. The formula that is currently in the literature is used to determine the total solar power gathered daily once solar irradiance is predicted.

C. Optimal Use of Wind, Solar and Grid Power

The area under consideration was picked for this study because it has the potential to be used for the combined use of solar and wind energy. The two main sources of income for people living in Rameswaram are tourism and fishing. The primary industries in the region include hotels, sea food processing, seashell craftsmanship, and coral and handicrafts. The aforementioned industries are quite common in. For research purposes, we therefore only take into account the household, commercial, and industry loads. Inverters are used to change the DC to AC power from wind and solar farms. In order to meet the demands of the town's cottage industries, businesses, and households, power is created and distributed. The grid receives any excess energy from renewable sources, and it also receives any power needed to fulfill peak demand. The goal is to create a self-sufficient model for the area, therefore data is gathered on the day when the region's daily peak demand is the highest out of 365 days in a year. It was decided to maintain fixed solar power while adjusting the wind turbines' operations to suit demand, shutting down the remaining turbines when necessary, following a tour of several solar and wind farms throughout Tamil Nadu and careful consideration of input from the operators of these power plants.

A recently developed algorithm called Operationi_Decision_Algorithm () has two primary functions, which are

i. Hybrid_Operation ()
ii. Only_Solar_Operation (),

is developed. Depending on the wind speed, the algorithm will decide whether to use Only_Solar_Operation () or Hybrid_Operation (). Solar and wind turbine power can be used together if the wind speed exceeds the cut-in speed of 3.5 m/s. Solar panel power is used if the wind speed is less than the cut-in speed. In the event that no solar nor wind energy is available, grid electricity alone must provide the entire demand. It is necessary to assess the combinations of energy sources—solar, wind, and grid supplies—that can be used in the area to fulfill peak demand at specific times of the day. With the exception of two brief months (October and November) each year, all three energy sources are available during the day on the majority of days of the year. Sunlight, which is present for practically all 365 days of the year, is necessary for the solar panels. It is also feasible to harvest enough solar energy from this area on overcast daytime. The energy that is available from the three sources as well as the hourly peak demand at different times of the day must be considered in the constructed model. In order to minimize costs overall, energy must be distributed properly such that power requirements are satisfied with the least amount of grid energy.

D. Cost Analysis

The main goal of the study being suggested is to create a model that can choose the energy resource combination that will give enough electricity at the right moment for the least amount of money. Any power shortfall can be supplied by the grid. Solar electricity costs INR 3.11 per unit, wind energy costs INR 2.86, grid power costs INR 7.00, and power returned to the grid costs INR 3.00. The energy produced by the solar panels is initially tailored to satisfy the hourly peak consumption. Wind turbine energy will be added to the demand if the peak demand exceeds the amount of electricity provided by solar power. Only the necessary amount of power is taken from the grid source to meet the hourly maximum demands when solar and wind energy are not available at any one moment. The backup storage devices in this analysis are not taken into account for storing any extra electricity produced by the wind turbines and solar panels. A cost analysis was conducted and estimates for the costs of using energy from renewable sources and the grid alone were made separately. An appropriate model that is comparable to the suggested model could not be discovered for a precise comparison because there are no models available for such a type of setup that has been utilized or adopted. The suggested algorithm and its various functions provide justifications for demonstrating that, under the specified parameters (power availability, power type, usage pattern, and cost of using various energy sources), the cost of power utilization is negligible.

VII.CONCLUSIONS

This study has presented an overview of the problems and opportunities associated with merging solar PV and wind energy sources for power generation. The intermittent nature of solar PV and wind sources presents the main problem for grid-connected systems as well as stand-alone systems. The impact of the fluctuating nature of the solar and wind resources can be partially mitigated by combining the two resources into an ideal combination, and the total system becomes more dependable and cost-effective to operate. The stand-alone generation is undoubtedly more affected by this. A more affordable option for stand-alone type is the integration of renewable energy generation with battery storage and diesel generator backup systems. The wind battery-diesel hybrid combination has the capacity to handle peak system loads. Energy management solutions should assure high system efficiency, reliability, and low cost. Good planning, including accurate forecasts of weather patterns, solar radiation, and wind speed, can assist in mitigating the impact of intermittent energy.

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