An Analysis on Integration of Solar and Wind Power into A Single-Phase Grid with an Optimal Parameterized Fractional-Order PID Controller

Abstract: - Because of the complimentary nature of solar and wind electricity, hybrid solar-wind power systems are the most effective renewable energy sources. Weather conditions have a significant impact on the amount of power that can be generated by wind and solar photovoltaic systems. Their intermittent nature causes output fluctuations. The purpose of this research is to offer a technique for a hybrid wind–solar power plant that makes the most efficient contribution of renewable energy resources and is backed by technology that allows batteries to store energy. The fact that solar and wind power display power profiles that are complimentary was the driving force for the construction of the hybrid solar–wind power system.

Keywords: Solar power, wind power, renewable energy, PID controller

I. INTRODUCTION

The main source of inspiration for building renewable energy-powered power plants is the sun. Direct solar energy from the sun or indirect solar energy in the form of wind, hydraulic, or marine energy can serve as the source of inspiration. The method of producing power by harnessing the sun's beams is known as solar energy. Although wind energy has a great deal of potential to make up for the loss of demand responsiveness, controlling wind energy's intermittent nature is one of the most difficult problems to be solved. The total quality of the power that is delivered is reduced by the inconsistent and intermittent development of electrical energy based on renewable energy resources (RES). Alternative energy sources is another name for RES. Furthermore, an abundance of this energy could lead to imbalances and complicate efforts to maintain control over the power system. The excellent quality of the electricity produced by these power plants may be impacted by their connection to any existing electrical system. Network overloading and voltage variations are two external indicators that these changes have occurred.

One of the main ideas underlying the concept of smart grids is the integration of diverse non-traditional power sources into the conventional electrical system. Because of the unpredictable and fluctuating nature of various sources, integration is difficult to plan for and can be difficult. Integration is difficult because of these issues. The strategy presented therein centers on the assimilation of photovoltaic (PV) systems into pre-existing electrical infrastructures. The technology underlying inverters is receiving a lot of attention because power inverters are used to convert solar power panel generated direct current (DC) into alternating current (AC). This is because power inverters are primarily responsible for the harmonisation issue. Even though solar energy is one of the sustainable energy sources, it does have some environmental repercussions, some of which can be rather large. The quantity of environmental harm that is caused can be significantly influenced by a variety of factors, including the particular technology being utilized, the location, and many more. This makes it absolutely necessary to conduct additional research on the effects that the incorporation of solar energy has on the surrounding ecosystem.

II. LITERATURE REVIEW

The writers of [1] talked about the reasons behind, benefits of, and problems with integrating renewable energy sources into the electrical system. They also raised the issue of how these alterations are viewed by final customers.

After examining solar photovoltaic (PV) technologies, Parida [2] concluded that the solar panels PV technology is highly beneficial for the various energy projects like: integrated rooftop building systems for electricity generation point of view, solar pumps for irrigation purpose, water desalination plants, and solar thermal as well as PV collector technology, is due to their growing efficiency, falling cost, and minimal pollution.

The authors of [3] examined the potential outcomes in an urban environment. The study's objectives were to assess the power consumption coverage and financial viability of grid-connected solar systems installed on multi-story building rooftops. The study's conclusions show that the case-study district's load match index was 42.4% when

1 Department of Electrical & Electronics Engineering, Guru Jambheshwar University of Science & Technology, Hisar, India
Corresponding Author: Kalyan Singh  Email: kalyanbaneta@gmail.com

2Department of Electrical & Electronics Engineering, Guru Jambheshwar University of Science & Technology, Hisar, India

3Department of Instrumentation, Kurukshetra University, Kurukshetra, India

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shadowing was not taken into account, but fell to 38.6% when it was believed that the surrounding area blocked 10% of the sun's rays. This study served as an illustration of how solar integration in buildings has historically been used in relation to surrounding activity. In addition to being used to electrical networks, renewable energy sources are currently the subject of numerous integration projects.

The energy fall on earth surface or amount of solar irradiance energy at any given location and time determines how much power photovoltaic, or PV, systems can create, according to the equation shown in [4]. A surplus of power or a deficiency of generation could cause grid instability.

As per reference [5], a distributed system experiences a large-scale burden exceeding 10 MW. The solar power generation plant lie below this range are not technically suitable and eligible for the grid integration and frequently have serious issues with the quality of the power they produce. Nonetheless, large-scale power generation PV systems also encounter power quality issues. Although, they might not be able to generate electricity instantly, for that purpose there is utilization of conventional thermal based system of spinning a turbine for photovoltaic generation nevertheless get complete control over the electrical generation process.

In [6], a building's technological integration was demonstrated through the design of an inventive solar-wind based environmental friendly hybrid electricity generation system and rainwater harvester system for mitigation of peak hour’s urban electricity demand based applications. PV panel manufacturers are also obligated to abide by regulations with a guarantee in which workers are not exposed to harmful chemicals during panel manufacturing and waste material is also disposed of appropriately at the time of manufacturing process.

There is no set capacity level that needs to be taken into account; instead, the unpredictability of solar PV may also be decreased by installing the solar PV based farms into a wide geographic land or by implementing the technology extremely gradually, according to [7].

According to [8], a number of factors such as: the specific technology for PV panel making, location, and others, affects how severe the environmental effects are. Any of the renewable energy, especially solar energy sources, can have its environmental effects successfully prevented or minimized if one is well-informed on present along with potential future issues associated with these energy sources. Depending on where they are located, large solar farms that generate enough electricity for utilities may cause concerns about species extinction and land degradation.

As per reference [9], the depletion of non-renewable energy sources and their adverse consequences are making power generation in power systems more challenging.

Because of the many advantages of the solar energy system's operations, ref. [10] claims that it will become the primary source of electricity on Earth in the future. These advantages include the ease of upkeep, the lack of noise, and the environmental friendliness.

The production of fossil fuels and the negative impacts of greenhouse gasses have led to a significant increase in the use of renewable energy in [11]. According to the World Energy Outlook, 2018 forecasts, solar power generation will surpass all other forms of energy generation in terms of global capacity by 2040. It will be able to produce more electricity than any other energy source thanks to this capacity.

As per reference [12], there are numerous disadvantages and challenges linked to the utilization of this energy source. A few of these are the solar system's non-linear design, poor energy efficiency, higher cost at the time of installation, and dependency on certain weather conditions like: temperature, pressure, wind and solar irradiance.

A range of models, such as: single diode technology, double diode, and three diode technology based models, as outlined in ref. [13], can be used to characterize the behavior of any PV module. The reference contains these models.

According to [14], meta-heuristics offer optimisation strategies that have gained significant traction over the past 20 years by providing suitable answers in a reasonable amount of time to tackle challenging problems in a range of industries. This is because meta-heuristics are capable of solving complex issues in a range of domains.

III. SOLAR-GRID SYSTEM

Significant amounts of solar electricity produced by PV or CSP systems can be integrated into the existing power infrastructure thanks to a technology known as solar-grid integration. The manufacturing of solar components, the installation of solar systems, and the operation of solar systems are just a few of the areas where this technology demands careful consideration and attention. The different degrees of solar energy penetration onto the transmission system must be effectively integrated. A thorough understanding of the effects that various grid positions have is necessary to successfully connect these levels.
There are many distinct parts that make up a photovoltaic plant that integrates PV modules into the grid, but the most important part for the integration process is the inverter. A PV generator, sometimes referred to as solar modules, meters, a generator junction box (GJB), a grid connection, and both DC and AC wiring are additional parts.

![Diagram of a PV power station](image)

**Figure 1:** Diagram of a PV power station

Because of their crucial role, inverters are sometimes referred to as the “brains” of a project and are an integral part of any solar energy system. An inverter's primary function is to “invert” the direct current (DC) output into alternating current (AC), which powers all commercial equipment. Regardless of the load conditions, inverters have to keep a constant voltage and frequency, and they have to supply or absorb reactive power as needed [22]. To fulfill these needs, inverters are required. Apart from inverting, the main purpose of inverters is to synchronize the different systems and make sure that solar energy is sent into the grid as efficiently as possible. Consequently, the orientation, connectivity, and quality of the PV modules, as well as the inverter's dependability and efficiency, have a significant impact on a photovoltaic system's yield [21], [12], [6], and [18].

### IV. WIND SOLAR HYBRID MODEL

The hybrid wind and solar energy system, or HWSES for short, is a solar integrated wind energy conversion system that has been designed. As shown in the photo, this system uses a DFIG to convert wind energy into electrical energy. The electrical energy is then combined with a solar PV system and connected to the DC link of back-to-back converters.

![Diagram of DFIG](image)

Kinetic energy is produced by wind power and can be put to use. The actuator disc hypothesis, which uses the wind as a driving force, can be used to explain how this energy was taken from it. It is based on energy balance theory equations along with the Bernoulli’s theory equation. Prior to delving into the theory of momentum of wind turbines behaviour, a few presumptions must be made. The below figure depicts these presumptions.
The amount of solar radiation that is available depends on the position of the earth's surface, the time of day, and the date. The right amount of radiation exposure will be determined after taking these traits into account. The amount of radiation below the optimal level is influenced by various factors, including height above sea level, the amount of water vapor or contaminants in the atmosphere, and cloud cover. Short-term variations in solar radiation may occur even though it is not subject to the same level of turbulence as wind. These are often associated with cloud movement in the sky. Solar photovoltaic systems (PVS) offer several benefits over wind energy systems. Among the most significant are lower maintenance requirements, the absence of moving parts, and easier installation.

V. RESULT AND ANALYSIS

The hybrid system is simulated to operate at a wind speed of 4 metres per second, which mimics the system to operate at speeds that are below synchronous. During this simulation, a Trina Solar module was employed. Table 1 is a detailed listing of the parameters for the solar device in question.
By keeping all of the parameters of the standalone solar energy system at their initial values and only modifying the MPPT algorithms, we were able to obtain the graphs depicted in the figure. The efficiency graphs in the image show significant spikes at 0.5 second and 3.5 second to 4 second intervals. This implies that the system is unsteady as it searches for the greatest power output point. This also implies that the system is highly sensitive to all kinds of noises, which could lead to the creation of local maxima points and, thus, a delay in the expected output. Therefore, it is abundantly obvious from the graphs that the proposed technique has been validated by making use of real data. The actually recorded wind power profile from the chosen location is given in the picture for 500 different samples so that the presentation may be as clear as possible.
The performance of the model is assessed in terms of how closely it matches the real power demand, and the outcome of this evaluation can be seen up above. It is essential to keep in mind that the power profile for the hybrid wind and solar system is scaled to correspond with the specified demand.

VI. CONCLUSION

Photovoltaic (PV) systems can reduce losses occurred on transmission and distribution system, increase grid stability, reduce generation running & installation costs, and minimize the need for utilities to invest in more generation capacity by being integrated into national networks. It has been shown how well the combined wind and solar power output can match the demand profile over the course of the designated amount of time based on the study’s findings. This includes moments when there is more power than needs to be produced and moments when the generation is unable to meet the demand and the BESS needs to make up the difference.

REFERENCES