Stability and Reliability Improvement in Solar Wind Hybrid Power System with Battery Energy Storage Station

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Abstract: Renewable energy systems, such as photovoltaic (PV) and wind power generation (WPG), are live a more and more important role in energy production. However, the output power of PV are usually strongly fluctuant due to the uncertainty and intermittence of solar and wind energy, which requires a large capacity of energy storage to satisfy the load demand when the system works in stand-alone mode, and results in a strong impact on the utility grid when the system works in grid-connected mode. This paper presents Improvement of Power System Stability and Reliability in Solar Wind hybrid Power systems. The key advantage of the proposed technique is the closed loop Boost control System which has a PI controller that adjusts the Gain value such that the optimal power delivery from Solar is matched with the Wind energy using direct duty cycle control method. The System is employed on a boost converter and tested experimentally using a PV array simulator, DFIG and Battery Storage System.A logical size of PV/WPG/battery can not only improve the power supply reliability, but also reduce the cost of the system. In the established methods, the power supply reliability and system cost are paid more attention to. However, fully utilizing the complementary characteristics of WPG/PV and smoothing the fluctuation of power injected into the grid are also the objectives to be pursued besides ensuring high power supply reliability.

IndexTerms: Hybrid power system, battery energy storage station,Energy conversion process, Doubly fed Induction Generator.

I.INTRODUCTION

The increasing interest in research to improve the performance of Photovoltaic (PV) systems, there is a little work done so far on fault diagnosis of PV arrays. Mismatch, shading and soiling are some of the disturbances that affect the normal operation of the PV panel and reduce its life. Many Maximum Power Point Tracking (MPPT) methods were developed to achieve a maximum power output in real-time[1]-[10].

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The “Perturb and Observe” (P&O) is a well-known method that is widely used in commercial controllers due to its good performance and simple implementation. The principal drawback of this method is the loss of power caused by the oscillations around the maximum power point (MPP) and its limitations at low irradiation. The presence of shading or soiling is another problem that faces the control strategy and can’t be solved by the classical MPPT algorithms. Hence to control the solar efficiency we are here applying the boost methodology to obtain a sustainable reliability[11]-[49].

The Optimal Sizing is used to deal with the different disturbances that can affect the normal operation of the PV panel. The performance of this optimization algorithm is further improved by the introduction of a classical Proportional Integrator (PI) regulator that accelerates the rising time and eliminates the steady state error. The Closed loop system is integrated with the hybrid power system so as to enhance the voltage of the system by conversion and stability systems. In the following Section we present the equivalent model of a PV panel and DFIG based Wind energy system united to supply the power to grid. The Power conversion and boost is done to match the stability current value. The Stabilized DC is now Stored in BESS and Inverted from Storage station to supply the Grid. The Total system of Hybrid power system is simulated and results are found using MATLAB Simulink[50-89].

II. HYBRID POWER SYSTEM (HPS)

A combination of different but complementary energy generation systems based on renewable energies or mixed is known as a hybrid power system. Hybrid systems capture the best features of each energy resource. Hybrid systems can provide a steady community level electricity service, such as marine, village or lighthouse electrification, offering also the possibility to be upgraded through grid connection in the future. Furthermore, due to their high levels of efficiency, reliability and long term performance these systems can also be used as an effective backup solution to the public grid in case of blackouts or weak grids, and for professional energy solutions such as telecommunication stations or emergency rooms in hospitals.

When designing a hybrid system it is important to choose a good combination of components, their dimensions and to determine a good strategy to manage the system that would be reliable and economical for a long time. A large number of resources will result in large investment costs, while a system with a small number of components can

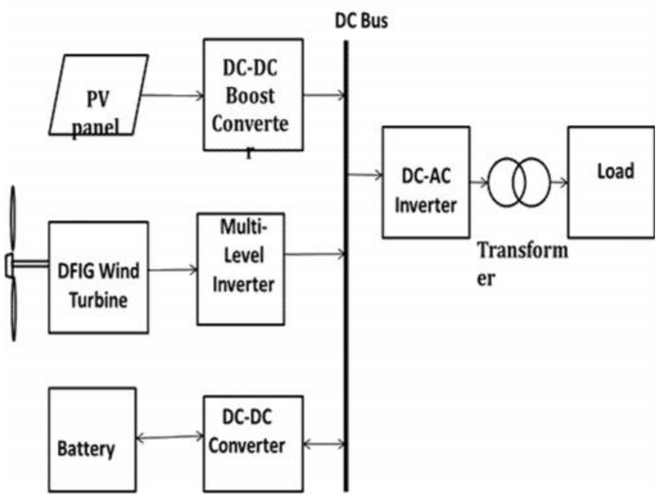

Fig 1 DC bus Connected Wind Solar Hybrid Power System

result in the interruption of electricity supply in the electricity system. Climatic conditions may affect the choice of renewable energy sources. For example, PV hybrid systems are ideal in areas with warm climates and in areas where there is large number of sunny hours.

III. SIMULATION & OPTIMIZATION

The hybrid renewable energy system adopted in this project & it consists of wind turbines and solar PV panels. A battery bank and an inverter are added as part of the back-up and storage system. The main advantage of hybrid PV-Wind systems is that they make use of two different renewable sources of energy. PV panels are able to generate electricity whenever there is solar illumination, while the wind turbines are able to generate electrical power when the wind speed is greater than the cut in speed until furling speed vf is reached, at which point the machine shuts down.

The main task of designing independent power system using renewable energy resources is the correct selection of system components to satisfy the economic demands of consumers.

System components must be determined so as to:

• Reduce the cost of power Transmission

• Optimization of Power Delivery for improving system Stability

• Ensure reliability for power storage and meeting the needs of energy consumers.

A. Open Loop & Closed Loop Systems

Open loop current monitoring systems are characterized by the fact that the measured value is not acted upon immediately. It may, for example, be made available for some other system, usually less time critical. Examples include,

• Current measurement in instrumentation (e.g. bench power supplies, ammeters, current probes).

• Power consumption indication, especially portable battery powered consumer items.

The Closed loop systems are based on the set point value and the gain of the system is adjusted unit the expected output is attained. Here the error correction may be positive or either and the gains are adjusted based on the error feed backs from actual state of the system.

IV. POWER SYSTEM STABILITY

Power system engineering forms a vast and major portion of electrical engineering studies. It is mainly concerned with the production of electrical power and its transmission from the sending end to the receiving end as per consumer requirements, incurring minimum amount of losses. The power at the consumer end is often subjected to changes due to the variation of load or due to disturbances induced within the length of transmission line. For this reason the term power system stability is of utmost importance in this field, and is used to define the ability of the of the system to bring back its operation to steady state condition within minimum possible time after having undergone some sort of transience or disturbance in the line.

Ever since the 20th century, till the recent times all major power generating stations over the globe has mainly relied on A.C. distribution system as the most effective and economical option for the transmission of electrical power. Even the most effective way to produce bulk amount of power has been with the evolution of A.C. machine (i.e. synchronous generator or an alternator).

In the power plants, several synchronous generators with different voltage ratings are connected to the bus terminals having the same frequency and phase sequence as the generators, while the consumer ends are feeder directly from those bus terminals. And ▫ for stable operation it is important for the bus to be well synchronized with the generators over the entire duration of transmission, and for this reason the power system stability is also referred to as synchronous stability and is defined as the ability of the system to return to synchronism after having undergone some disturbance due to switching on and off of load or due to line transience.

The synchronous stability of a power system can be of several types depending upon the

Nature of disturbance and for the purpose of successful analysis it can be classified into the following three types as shown below

- Steady state stability
- Transient stability
- Dynamic stability.

A. Three Phase Power as Source from DFIG

It is found that generation of three phase power is more economical than generation of single phase power. In three phases system the three voltages and current waveform are 120* offset in time in each cycle of power. That means each voltage waveform has phase difference of 120* to other voltage waveforms and each electric current waveform has phase difference of 120* to other electric current waveforms. Three phase power definition states that in an electrical system, three individual single phase powers are carried out by three separate power circuits. The voltages of these three powers are ideally 120o apart from each other in time – phase. Similarly, the currents of these three powers are also ideally 120o apart from each other. Ideal three phase power system implies balanced system. A three phase system is said to be unbalanced when either at least one of the three phase voltages is not equal to other or the phase angle between these phases is not exactly equal to 120*.

B. PID Controller

PID controller is a generic name for a controller containing a linear combination of

- Proportional (P)
- Integral (I)
- Derivative (D)

The Combination of the Controllers like P, PI, or PD controller

It has been estimated that of all controllers in the world 95 % are PID controllers PID (proportional integral derivative) control is one of the earlier control strategies. Its early implementation was in pneumatic devices, followed by vacuum and solid state Analog electronics, before arriving at today's digital implementation of microprocessors. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. Since many control systems using PID control have proved Satisfactory, it still has a wide range of applications in industrial control. According to a Survey for process control systems conducted in 1989, more than 90 of the control loops were of the PID type

PID control has been an active research topic for many years. Since many process plants controlled by PID controllers have similar dynamics it has been found possible to set satisfactory controller parameters from less plant information than a complete mathematical model. These techniques came about because of the desire to adjust controller parameters in situ with a minimum of effort, and also because of the possible difficulty and poor cost benefit of obtaining mathematical models. The most popular PID techniques were the step reaction curve experiment, and a closed-loop "cycling" experiment under proportional control around the nominal operating point.

V. TRANSFORMER

A transformer is a static machine used for transforming power from one circuit to another without changing frequency. This is very basic definition of transformer. Transformers can be categorized in different ways, depending upon their purpose, use, construction etc.

The types of transformer are as follows, generally used for stepping up and down the voltage level of power in transmission and distribution power network.

Three Phase Transformer & Single Phase Transformer Former is generally used in three phase power system as it is cost effective than later but when size matters it is preferable to use bank of three Single Phase Transformer as it is easier to transport three single phase unit separately than one single three phase unit. Transformer generally used in transmission network is normally known as Power Transformer, distribution transformer is used in distribution network and this is lower rating transformer and current transformer & potential transformer, we use for relay and protection purpose in electrical power system and in different instruments in industries are called Transformer. Former is generally used where ratio between High Voltage and Low Voltage is greater than 2. It is cost effective to use later where the ratio between High Voltage and Low Voltage is less than Transformers designed for installing at outdoor is Outdoor Transformer and Transformers designed for installing at indoor is Indoor Transformer.

VI. COORDINATED CONTROL OF AC AND DC MICRO GRIDS

Traditional utility grids have always been ac due to its relative ease of transmission, distribution, protection, and transformation. This preference for ac networks, to a great extent, has migrated to micro grid development, but the incentives for a full ac micro grid might not be as strong now. Some obvious reasons are the lower power level found in a micro grid, shorter distance of distribution, and a higher portion of sources and storages that are dc by nature. The main contributing dc sources would undeniably be solar energy and fuel cells, and for storages, it would be different types of batteries and capacitive storage mediums.

For an ac micro grid, the thought of grouping these dc entities together to form a dc micro grid for powering localized dc (mostly electronic) loads might equally be feasible with a significant reduction in power conversion stages expected. The coexistence of an ac and a dc micro grid with an interfacing converter, like in fig, is therefore likely, inferring that methods for coordinating them should be discussed. Probably, the simplest approach is to treat each micro grid as an independent network with either dc sources supplying only dc loads or ac sources supplying ac loads. That certainly defeats the purpose of linking the two micro grids and would require much higher source ratings in order to always meet supply and demand within each micro grid. To better coordinate the micro grids and to hence lower the source ratings, some

Forms of energy sharing between them must be introduced with preferably no or only slow communication link. That would certainly require some means of droop control, which is already reviewed, but more for sharing power among the sources in the ac micro grid. The extension to the dc micro grid is possible and would simply involve replacing the active power versus frequency droop (P − f) for the ac micro grid by the active power versus dc voltage droop (P − Vdc) for the dc micro grid. Upon implementation, power sharing among sources in the dc micro grid would be realized with some minor errors expected. This slight sharing inaccuracy is no different from that experienced by reactive power sharing in the ac micro grid.

The next concern is to introduce power sharing between the ac and dc micro grids, treated as two separate entities. The droop representation of each entity can be rightfully determined by summing the individual source characteristics in each micro grid, leading to an overall P − f droop for the ac Micro grid and an overall P − Vdc droop for the dc micro grid.

Information from these two droop characteristics should be properly merged, before using it to decide on the amount of power to transfer across the interfacing converter. For that, the recommendation written in the following equation is to normalize the frequency in the ac micro grid

and the voltage in the dc micro grid, so that their respective ranges of variation commonly span from −1 to 1 [48], i.e.,

$$f_{pu} = \frac{f - 0.5(f_{max} + f_{min})}{0.5(f_{max} - f_{min})} \quad (1)$$

$$V_{dc,max} = \frac{V_{dc} - 0.5(V_{dc,max} + V_{dc,min})}{0.5(V_{dc,max} - V_{dc,min})} \quad (2)$$

where subscripts max and min represent the respective maximum and minimum limits of f and Vdc, and subscript pu represents their normalized per-unit values. These normalized variables should be next forced equal by feeding their error to a proportional-integral (PI) controller, followed by an inner current controller. Upon being equalized, the two micro grids would share active power based on their respective overall ratings. This thought is no different from enforcing a common frequency in the popularly discussed ac micro grid, upon which the ac sources would share power proportionally based on their respective ratings.

One simple method to keep fpu and Vdc,pu equal is to feed their error (fpu − Vdc,pu) to a PI controller, whose output is the active power reference PIk that must be transferred from the dc to ac micro grids through the interfacing converter when positive and vice versa.

Certainly, the power sharing principle reviewed here is only a possible method of control. Other management principles with different objectives could be defined for future investigation.

General advantages of the Distributed Power Systems are

- Redundancy
- Modularity
- Fault tolerance
- Efficiency
- Reliability
- Easy maintenance
- Smaller size
- Lower design cost

VII. BOOST (STEP-UP) CONVERTER

The output voltage is of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor and the boost inductor.

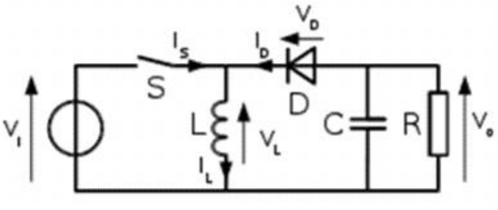

Fig 2 Boost Converter

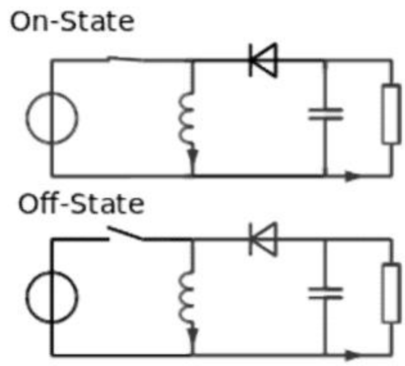

Fig 3 ON and OFF State of Boost Converter

The basic principle of the buck–boost converters are

• During in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.

• During in the Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R.

Compared to the buck and boost converters, the characteristics of the buck–boost converter are mainly

• Polarity of the output voltage is opposite to that of the input.

• The output voltage can vary continuously from 0 to (for an ideal converter). The output voltage ranges for a buck and a boost converter are respectively 0 to and to.

Like the buck and boost converters, the operation of the buck-boost is best understood in terms of the inductor's "reluctance" to allow rapid change in current. From the initial state in which nothing is charged and the switch is open, the current through the inductor is zero. When the switch is first closed, the blocking diode prevents current from flowing into the right hand side of the circuit, so it must all flow through the inductor. However, since the inductor doesn't like rapid current change, it will initially keep the current low by dropping most of the voltage provided by the source. Over time, the inductor will allow the current to slowly increase by decreasing its voltage drop. Also during this time, the inductor will store energy in the form of a magnetic field.

When the switch is then opened, the inductor will be cut off from the input voltage supply, so the current will tend to drop to zero. Again, the inductor will fight such an abrupt change in current. To do so, it must now act like a voltage source to the rest of the circuit, which it can do using the energy it stored while charging. Since current was previously flowing "down" the inductor, it will want to maintain this direction, and so the voltage that it provides will be inverted relative to input supply. During this time, the inductor will discharge through the load and the rest of the circuit, which will cause its voltage to decrease over time. Also during this time, the capacitor in parallel with the load will charge up to the voltage presented by the inductor.

When the switch is once again closed, the diode is reversing biased by the input supply, cutting the load off from the left hand side of the circuit. During this time, the capacitor will discharge into the load, providing energy and voltage to it. By cycling the switch fast enough, the inductor can be allowed to charge and discharge only slightly in each cycle, maintaining a relatively steady voltage to the load. Similarly, the capacitor will only need to discharge slightly while the switch is closed before it has a chance to recharge again while the switch is open.

VIII. PI- CONTROLLER

- Basic proportional and integral feedback control (PI)
- How to tune the PI-controller

The process to controlThe model used in b) P-control will be used again. The only thing to be changed is the content of the controller block i.e. the block "Controller - PI-controller".

PI control - definition

The definition of proportional feedback control is

$$U = K_p e \qquad (3)$$

Where

e = is the "error"

K_P = Proportional gain

The definition of the integral feedback is

$$U = K_I \int e\,d\tau \qquad (4)$$

Where KI is the integration gain factor

In the PI controller we have a combination of P and I control,
ie.

$$U = K_p e + K_I \int e\,d\tau \qquad (5)$$

$$U = K_p e + \frac{1}{\tau_I} \int e\,d\tau \qquad (6)$$

$$U = K_p \left(e + \frac{1}{\tau_n} \int e\,d\tau\right) \qquad (7)$$

Where

τ_I = "Integration time" [s]

τ_N = "Reset time" [s]

IX. IMPLEMENTATION

This Project has Wind and Solar Energy Systems. These two Energy stations are interlinked to Supply power to the load. The process is executed by storing the Energy in a battery Station and converting the DC to AC and transmitting to the Load. Solar power is drawn and converted from DC to DC by adding Single Switch IGBT based closed loop DC to DC boost convertor and the Voltage is monitored such that a closed loop system follows the output voltage variation of solar power because of variation in sun light intensity will cause power fluctuations from solar. This variation is controlled by boosting the output accordingly by monitoring with closed loop control system.The renewable energy from Wind Energy station is obtained as an Alternating source. The Source voltage is converted to DC by rectification process and fed to Battery Station for Power Storage. This is done by a three phase full wave rectifier bridge. The storage energy is again converted to sinusoidal form and distributed top Load sides. The above Topology is studied and simulated and output results are obtained using MATLAB.

X. RESULTS

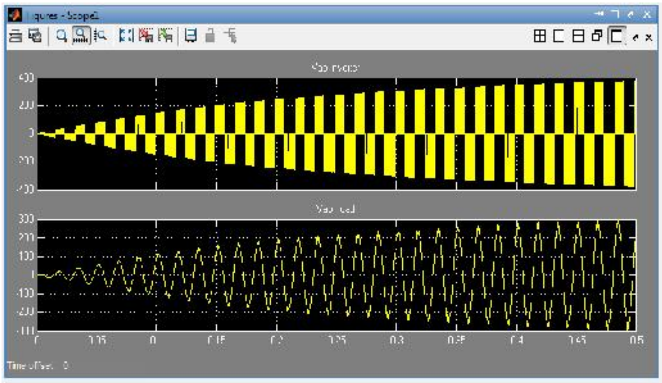

Fig 4. Wave form for Three Phase Load and Inverter output

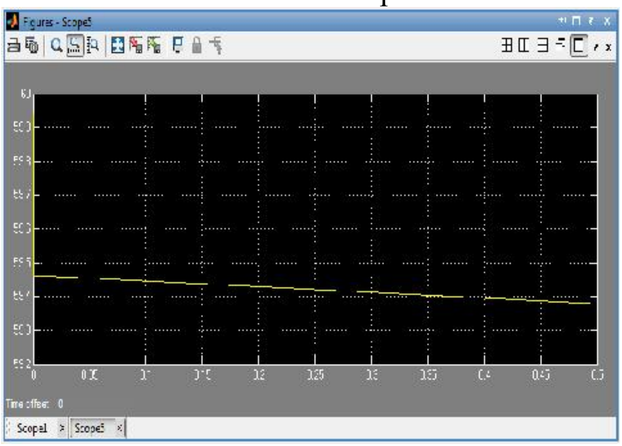

Fig 5 Solar Power output from Module before Boosting

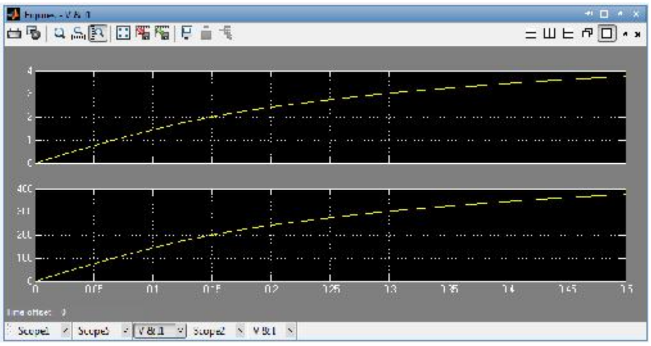

Fig 6 Solar DC Voltage after Closed Loop Boost Conversion

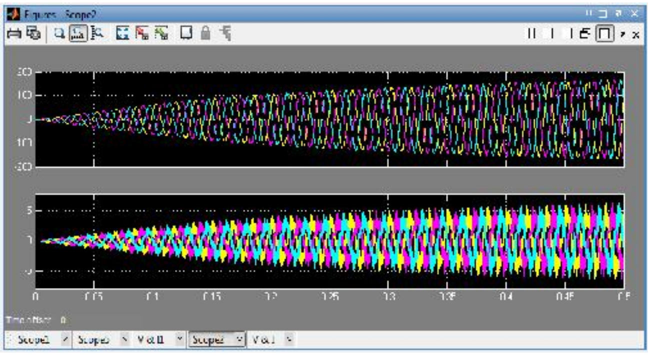

Fig. 7 Three Phase Volatge and Current after Inversion

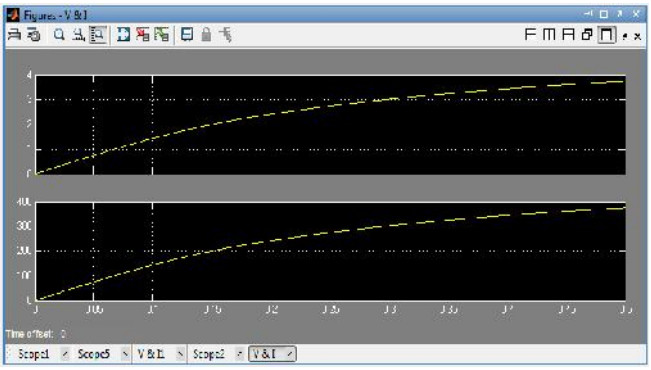

Fig 8 DC Power from Wind anergy after Rectification

XI. CONCLUSION

The Solar and Wind is important tool for the study of the Hybrid power system and their efficient purpose during peak loads. In this study we proposed a method based Closed Loop PI controller method to sustain the voltage of Hybrid Power system with Stability and reliability on loading conditions. The PI controller is tuned to attain a constant phase matching current so as to charge the battery station and economize the power delivery. And eliminate the steady state error. The simulation results show the effectiveness of the closed loop PI boost control strategy in the case of the presence of the partial shading effect. The proposed method is useful in Stability and Reliability of the Power system.

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