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RECENT INTEGRATION OF A PV-WIND ENERGY SYSTEM WITH ENHANCED EFFICIENCY

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ABSTRACT

A new integration scheme of solar photovoltaic (PV) with a large capacity doubly excited induction generator-based wind energy system is described. In this proposed system uses both the grid- and rotor-side power converters of doubly fed induction generator to inject PV power into the grid. Thus, it renders a cost-effective solution to PV-grid integration by obviating the need for a dedicated converter for PV power processing. The system isable to feed significantly large PV power into the grid compared to an equivalent rating inverter used in the conventional PV-grid system. The proposed scheme prevents circulating power during sub synchronous operation during the availability of solar radiation. All these features enhance system efficiency. System stability is also increased due to turbine inertia, facilitate high PV penetration into the power grid. The alternating but complementary nature of solar PV and wind energy sources considerably improves the converters' utilization. as well, the proposed scheme does not get in the way maximum power point tracking of PV and wind sources except during very rarely occurring environmental glitches, A full system model is presented and used for designing the control strategy. The proposed scheme is supported by analysis, and simulations,

KEYWORDS: Converter Control, DC–AC Converter, Doubly Fed Induction Machine, Hybrid System, Maximum Power Point Tracking (MPPT), Solar Photovoltaic (PV), Wind Generation

The world is facing a major threat of fast depleting of the fossil fuel reserves,the awareness of environmental impact have led the researchers to think of alternate sources of energy for a safer life on this earth. Therefore, the whole world is looking for non-exhaustible energy sources for their future .Most of the present energy demand is met by fossil and nuclear power plants. There will soon be a time when we will face a severe fuel shortage, mankind's attention toward renewable energy sources, such as solar photovoltaic (PV), wind, fuel cell stack, biomass, tidal energy, etc., Out of these, solar PV and wind have as popular sources as they are both clean and cost effective sources that apparently do not require any fuel [J. Carrasco, 2006]–[S. Daniel ,jun2004], electricity generation from wind energy and its integration with power grid is a well-established technology. Wind farms with doubly fed induction generators (DFIGs) are time-tested systems [J. Yao, H. Li, Y. Liao May-2005]. Various control schemes have been developed to enhance the performance of wind-sourced DFIG systems, including those for distorted grid conditions, weak area electric power system, etc.. At the same time, solar PV-based power generation has also emerged as a strong option. It is a pollution free, noise free, and maintenance free source of energy. Significant advancements and refined control strategies have been reported in the recent past for large capacity grid-connected PV systems [A. Yazdani, A. Di Fazio, H. Ghoddami,M. Russo,M. Kazerani, J. Jatskevich, K. Strunz, S. Leva, and J. Martinez Apr. 2011], [Z. Dejia, Z. Zhengming, M. Eltawil Feb2008]. These systems are generally either two power stage or single power stage. The DFIG-based wind energy system, the stator circuit carries the bulk power while the rotor provides the balance power on account of wind speed variation during DFIG's sub-or super synchronous speed operation. This results in the requirement of lower rating power converters for rotor power conditioning, which is especially attractive in the Mega-Watt rangeinstallations of wind energy systems [J. Costa, H. Pinheiro, T. Degner Sep2011]. Unfortunately, the converters used in the rotor circuit are not utilized effectively because of topological and configuration constraints. During operation near the synchronous speed, rotor power is less. Another issue with the conventional wind-DFIG system is that part of the power simply circulates in the machine during its sub synchronous operation, the inverter driven, inertia less PV-grid interfaces result in complex access issues such as poor line voltage profile, reduced dynamic stability, voltage fluctuations, and large injected power variations, etc. [S. Eftekharnejad, V. Vittal, G. Heydt, B. Keel , May 2013]–[M. Bouzguenda and S. Rahman Sep. 1993.] At the same

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time, the PV inverter remains idle during the night or during very low solar radiation. to overcome the issues associated with both PV and wind energy sources by proposing more advanced and refined control schemes, including their hybrid combinations [W. Kellogg, M. Nehrir, G. Venkataramanan ,March 1998], [S. Daniel Jun2004], [Y. Chen, C. Cheng March 2006]– [F. Nejabatkhah, S. Danyali, S. Hosseini, M. Sabahi Feb2014]. system, in which the sources and storage are interfaced at the dc link, through their individual source converters.

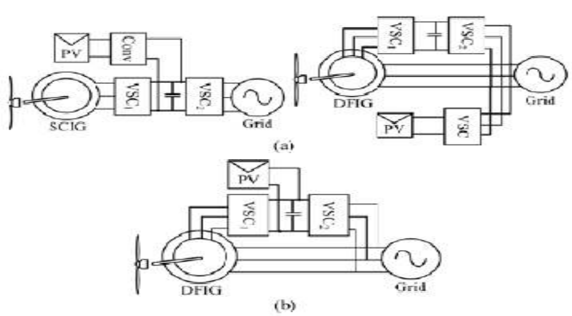

Figure 1: (a) Block diagram of the conventional PV-wind hybrid systems. (b) Proposed PV-wind hybrid system.

A PV-wind hybrid system has a suitable for stand-alone applications, In this paper proposed a multi-input hybrid PV-wind system and improving the dc-link voltage regulation. Here, the power converters are rated for the individual source power rating. have a low capacity multi-input port power converter for a hybrid system to feed the dc loads. There is correlation that exists between the wind and solar energy. Shown in Fig.1(a).. In this system is the reduction in the overall variation in the power output, many attempts have been made to optimize the operation and circuit configuration of such systems that could reduce the cost and increase the efficiency and reliability. In the existing systems, both PV and wind sources are associated with their own power converters [W. Kellogg, M. Nehrir, G. Venkataramanan March1998], [Y. Chen, C. Cheng March1998], [X. Tang,W. Deng Nov 2008] even though these converters are not properly utilized because of highly irregular nature of the two sources. Further, many critical issues high power diffusion of the inverter coupled hybrid sources in to the grid, such as voltage variation, harmonic injection, circulating power, and dynamic stability need to be investigated in more depth [S. Eftekharnejad, V. Vittal, G. Heydt, B. Keel May 2013]–[M. Bouzguenda Sep1993]. Efficiency and cost of the hybrid systems are important parameters that have a significant research potential. Where the dc link of the DFIG is integrated with energy storage (super capacitor) using a separate dc–dc bidirectional converter to address the alternating nature of wind energy they focus on the control and coordination aspects in the presence of multiple DGS, here proposes a cost-effective, efficient, and compact of the solar PV and doubly fed induction generator (PV-DFIG)-based wind turbine system as shown in Fig. 1(b). Thus, the proposed configuration and control scheme provide with neat economical integration of PV source and DFIG-based wind energy source. The proposed hybrid system offers the following advantages:

1) Enhanced power conversion efficiency is realized as a inverter for the PV source

2) Decrease in the overall cost of the system, 3) It facilitates the possible interfacing of a higher conventional interface. 4) It results in increased and optimal utilization of power converters. 5) It reduces the circulating power flow system during low speed operation and high solar radiation. This cuts down the losses of the overall system.

6) Maximum power point tracking (MPPT) of the PV module , to extract optimum power from the PV source. and wind turbine system is controlled with the maximum power extraction with pitch control to avoid overloading in case of high wind velocity.

7) Variation in the grid-injected power over a day is and minimum power delivery from the hybrid system is maintained throughout the day and across the seasons. minimized..

8) The proposed hybrid system has scope for integration of energy storage for enhancing power quality and reliability .

DESCRIPTION OF THE PROPOSED SYSTEM

This section describes the proposed integration of the solar PV and wind-sourced DFIG system and presents

System Description

The proposed system is shown in Fig.2. A wind DFIG system considered along with a PV generation. The stator circuit of the DFIG is coupled to the grid through the circuit breaker, S_2.In this

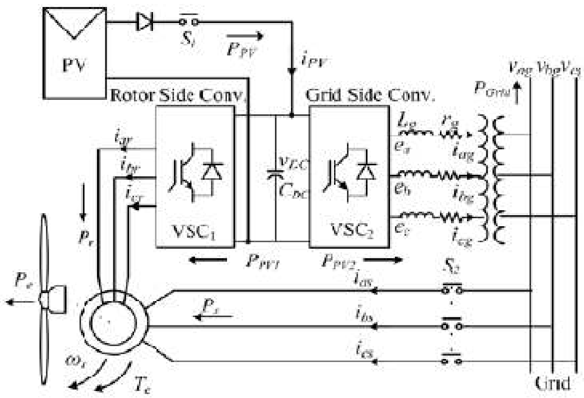

Figure 2: Proposed solar PV-wind DFIG system.

System, the rotor-side converter (VSC_1), is major advantage of this system is PV source is considered which is significantly higher than the grid-side converter rating (VSC_2) can be integrated with the wind-DFIG system without an inverter. Though the rotor-side converter (VSC_1) can support system operation over a wide speed range, pitch control is provided to security optimal energy extraction and protection against excessive wind turbulence and overloading. The PV source is protected with an anti blocking diode and dc circuit breaker S_1 whose operation is integrated into the overall control strategy. This protects VSC_2 from overloading. Both rotor- and grid-side control are crucial for the successful operation of the proposed system. Fig.2 also shows the parameter descriptions of the proposed system, which have been considered for modeling and controller design.

System Modeling of DFIG

Vector control is powerful tool for controlling the 3−ϕ system with transformation technique is used for DFIG, rotor start rotates at a synchronous speed . The stator and rotor fluxes are relative motion between them, to obtain the of rotor speed and terminal voltage which is controlled by VSC_1, the stator and rotor current control by the rotor speed according to transformation technique facilitates, independent control of the stator's active and reactive power by the rotor current. Further, In this model dc values to be control under steady state condition. Hence, they are easy to control with traditional PI-PID controllers with a sufficiently large bandwidth and minimum steady-state error and replacing all stator current components with rotor current components using phase locked loop (PLL) with the grid supply voltage and rotor position In steady state, frequency of the rotor current is equal to the slip frequency. The electromagnetic torque generated by the rotor speed. Thus, throughout the generation mode a very important point is made during sub synchronous operation.

DFIG Control

DFIG rotor current model is nonlinear in nature and is coupled with both rotor currents, the rotor terminal voltages are controlled by VSC1 through thepulse width modulation (PWM) technique is used for both VSC1 and VSC2 . Decoupling and feed-forward compensation are invoked to independently control the rotor current components by using the decoupled model. The dc-link voltage is considered to be constant during the current control operation as it is supported by a large capacitor bank and also controlled by VSC2 with relatively less bandwidth of the dc-link voltage control. During the entire operation, the stator flux is tightly held by grid supply voltage, and its magnitude remains constant except during starting.This results in a first-order transfer function of the closed-loop current control system with time constant and is designed to achieve desired bandwidth (1/10th of the switching frequency of VSC1). The wind turbine-driven DFIG can be controlled over a considerable speed range to achieve maximum power

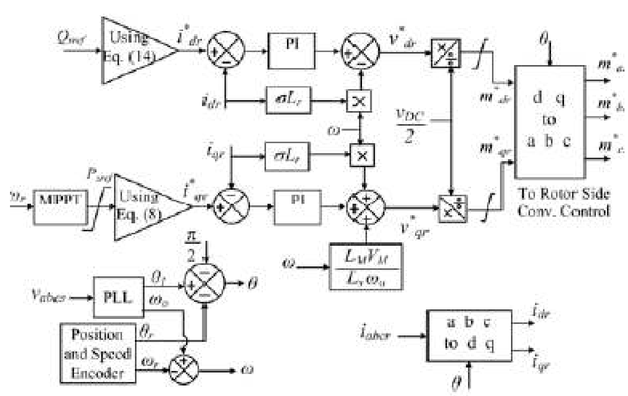

Figure 3: Rotor-side converter, VSC1 control

DFIG can be controlled to improve line voltage profile or for reactive power support. In the proposed scheme, PV power is controlled by regulating and ensuring that the operation does not shift to the over modulation range with. Conventional MPPT control can be used

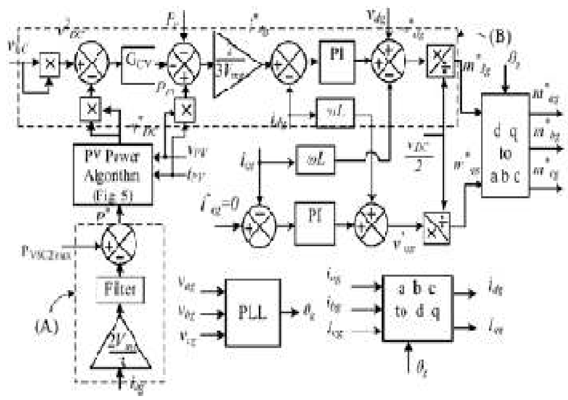

Figure 4: Proposed control strategy for the grid-side inverter, VSC2.

POWER CONVERSION ANALYSIS OF THE PROPOSED SYSTEM

In this section, power conversion analysis is presented to highlight the relation between P_{PV} and PV $_{SC2}$ and to conclude about their ratings. Fig. 4 shows the power conversion process in various stages of the proposed hybrid system, shown as per actual power flow direction. Complementary nature of solar radiation and wind enables the interfacing of a large PV installation in the proposed system with a capacity significantly higher than the grid-side converter (VSC_2) rating.

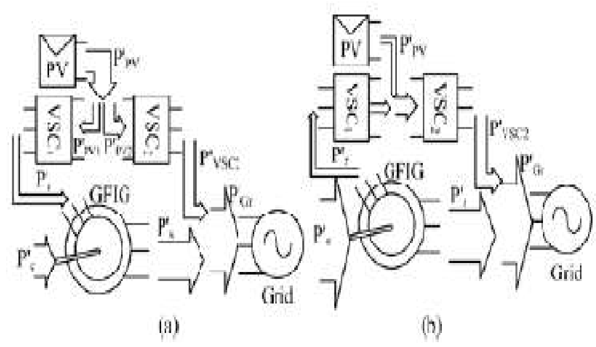

Figure 4: Power conversion process in various segments of the proposed hybrid PV-wind-energy system during most of the (a) High solar radiation, low wind speed. (b) Low solar radiation high wind speed.

The steady-state power balance equation of a DFIG is a function of rotor speed,during the day time, wind velocity is generally low and solar radiation level is high. Under these conditions, the wind turbine system is controlled with MPPT and operates below the synchronous speed Hence, during the generating mode of operation, i.e.Pe, Power is −ve, which results in the following power flow in the various stages:

1) Pr becomes +ve: machine receives power through the rotor it is proportional to the slip speed;

2) Ps becomes −ve: machine delivers power through stat or to the grid

3) P_{PV} is +ve: the solar PV generated power splits into two components; one goes toward rotor circuit and the other toward the grid-side converter;

4) PV SC2 is +ve: it is the differential power flow through VSC2 ,The PV generated power can be bifurcated into two parts , the component P_{PV1} is directed to the rotor circuit of the machine through VSC1 during the sub synchronous operation and may be considered as compensation power of the rotor circuit. The P_{PV2} component corresponds to the bulk surplus power injected into the grid through VSC2 . In turbine power versus speed characteristic,between the region of constant low speed to the synchronous speed, the maximum power extraction region, is clear that the solar PV power is injected into the grid via two paths. In this region, the machine receives power through VSC1 and it is finite. Also, as $P_{PV1} = P_{VSC1.}$ From this relation it may be concluded that the PV capacity can be more than VSC2 rating. In other words, if VSC2 is considered as the PV inverter of the conventional PV-grid system, then with the proposed hybrid integration, the installed PV capacity can be increased beyond the inverter rating. In the conventional grid tied system, the VSC regulates the dc-link voltage by incorporating power balance between the ac and dc ports. However, in the proposed hybrid system configuration, the PV power not only compensates the dc-link losses to regulate its voltage indirectly throughVSC2 , but also the PV power is bifurcated into two parts depending upon the mode of operation, unlike a conventional DFIG system. One part of the PV power flows through the rotor circuit (VSC1) and the other part is injected into the grid through VSC2 . This provides an opportunity

to install a PV source with power capacity more than the VSC2 rating. The proposed configuration drastically reduces the circulating power that is common in conventional DFIG systems and hence enhances the overall efficiency. During low radiation and high wind velocity phase, the turbine operates at super synchronous speed and the PV power is not significant to overload VSC2 even though rotor power Pr is also routed through VSC2 . Though rare, both wind and solar radiation may be high simultaneously is capable of optimally utilizing VSC2 by reducing the PV power generation. The proposed hybrid system also provides scope for incorporating energy storage for further enhancing the power quality and reliability to improve the continuity and availability of the power supply.

SIMULATION VERIFICATION

Dynamic performance of the complete control scheme for various stages of the proposed hybrid PV/DFIG system is evaluated in this section. The complete system described in Section II is modeled in MATLAB-Simulink software for validation of the proposed PV-wind hybrid system. To evaluate the important aspects of the proposed system, wind velocity and hence turbine speed are varied in the regions of sub synchronous and super synchronous speed by keeping turbine-machine combined inertia very low and directly controlling the speed parameter of the inbuilt MATLAB model. Similarly, solar radiation is also varied so as to cover most frequently occurring events .dc link is regulated at a nominal value 0f votage. A rotor-side converter is activated. When machine is operating in sub synchronous mode, the PV power is routed through both rotor-side and grid-side converters. Hence, in spite of large power flow, the PV source still operates at MPP and adjusts the dc-link voltage during time intervals. However, during super synchronous operation, responsible for the extraction of maximum turbine power using stator power control. It brings out a very important observation that during low wind speed, the rotor power is positive and flowing into the rotor circuit through VSC1 . During the day time when the solar radiation is high, part of PV power is shared and only remaining PV power is fed by VSC2. The reactive power support is to achieve unity p.f. operation on the stator side. The current feedback of VSC2 is also used to determine the PV power reference. But during high wind velocity and high radiation occurring simultaneously limits the VSC2 power at its maximum rated capacity shows the PV generated power. The complete system injects considerable amount of power into the grid from both wind and PV sources . Clearly, the total PV-wind hybrid system power is enhanced due to the contribution of the PV power. MPPT has been assumed for both PV and wind sources unless the power flow through VSC2 reaches its rated capacity. VSC2 power, turbine generated power Pe , and PV power PP V Their complementary nature helps to achieve optimum power yield from both the sources without overloading any of the converters in the proposed system. Further, there are very few operating points, which need to be clamped at the rated capacity of VSC2 to avoid its overloading. This results in an overall reduction in power loss The efficiency performance of the proposed PV/wind system is evaluated and compared with the conventional distributed PV and wind sources (with DFIG) of similar capacity. have been the analysis and comparison of the two cases:

1) conventional PV-inverter and wind-DFIG system

2) proposed hybrid system of PV/wind sources.

CONCLUSION

Nature has provided ample opportunities to mankind to make best use of its resources and still maintain its beauty. In this context, the proposed hybrid PV-wind system provides an elegant integration of the wind turbine and solar PV to extract optimum energy from the two sources. It yields a compact converter system, while incurring reduced cost. The PV generated power can be routed to the grid using both the rotor and grid-side converters of the wind-DFIG system, during its sub synchronous operation. It has been verified that unlike the conventional wind-DFIG system, the circulating power is significantly reduced with PV-DFIG integration at the dc link. Enhanced efficiency is observed compared to existing PV/wind hybrid systems. It is demonstrated that the proposed hybrid system provides an opportunity to integrate a higher capacity PV source than can be done through a dedicated converter as in a conventional solar PV system. In Simulations -have shown that the proposed system optimally uses the daily available energy from solar and wind sources making the best possible utilization of its converters. Will be more pronounced for high-power PV-wind farm systems. There is also a scope of designing the DFIG-wind turbine more optimally for the hybrid solution presented. The proposed hybrid combination can also render a neat stand-alone energy solution with minimum storage and can, in fact, be developed as a dispatchable source Overall, the proposed system makes good use of the nature's complementary behavior for wind velocity and solar radiation. Sometimes this complementary trend may break down, in which case the proposed control scheme is well equipped to prevent converters' overloading at the cost of momentary loss of PV power. Such instances, however, are expected to be rare.

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