GRID-INTERFACED WIND-PV COGENERATION USING BACK-TO-BACK VOLTAGE SOURCE CONVERTERS

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ABSTRACT

A permanent magnet synchronous generatorbased full scale breeze turbine is interfaced to the utility-framework via back-to-back (BtB) voltage-source converters (VSCs). A PV solar generator is straightforwardly associated with the dc-interface capacitor of the back to back converters VSCs. No dc/dc change stages are required, and consequently the framework effectiveness is maximized. The proposed geography features an autonomous maximum power point tracking for both the breeze and the PV generators to maximize the extraction of the renewable energy. The regulation of the VSCs is achieved via the vector control plot in the rotating reference frame. The detailed small signal models for the framework parts are created to investigate the overall stability. The simulation results are obtained for various method of smart matrix and nonlinear fault condition and demonstrated proposed control algorithm functions admirably.

I.INTRODUCTION

The expense of the wind and solar energy generation has been rapidly falling since the last decade. Driven by their monetary and technical impetuses, the global installed capacity of photovoltaic (PV) and wind generators has approached 303 Gigawatt (GW) and 487 GW in 2016, as compared to 6 GW and 74 GW in 2006, separately [1]. Because of the irregular and unregulated nature of the wind and solar energy, powerelectronic converters are used as an interfacing stage to the load-side or the utility-lattice, and consequently dispersed generation units are created [2]-[3]. In literature, a large portion of the conveyed generation frameworks are exclusively dedicated for one type of renewable assets, e.g., a solar energy as in [4]-[5] or wind energy as in [6]-[8]. To maximize the advantages of the available renewable assets, the combination of the wind and solar energy in the same area has been considered [9]-[22]. The cogeneration of the wind and solar energy has the accompanying characteristics;1) The availability of the wind and solar energy is generally complementary, and hence combining both forms of energy increases the overall operational efficiency [23].

2) The combination of the wind and solar cogenerators optimizes the utilization of lands resources, and hence improves the capital investments [24].

3) As compared to the static PV generators, the wind-solar cogeneration systems are more dynamically capable to support the utility-grid due to the available moment of inertia in the mechanical system of the wind generators [8].

4) Having two sources of energy increases the generation reliability [9]- [10]. The gridconnected wind-PV cogeneration systems are not widely addressed [9]-[15]. On the contrary, several wind-PV

cogeneration systems are proposed for the standalone offgrid applications . A standalone wind-PV cogeneration system is proposed in [16]-[17]. On the small-scale level, a single-phase cogeneration system has been proposed in [18] whereas a laboratory-scale system is introduced in [19]-[20]. Generally, the system structure in [16]-[20] comprises a common dc-bus that interfaces several parallel connected converters-interfaced renewable energy resources, which might reduce the overall system efficiency and increase the cost . In [12]-[14], the utilityframework integration of the renewable energy assets has been improved by utilizing various information converters. A buck/buck-boost dc converter is proposed in [12]. A dc converter with a current-source interface, and a coupled transformer is proposed in [13] and [14], separately. Nonetheless, the proposed frameworks in [12]-[14] are based on the dc power dispersion which probably won't be the ideal conveyance medium in the ac-dominated power frameworks. Up to the authors' best information, the combination of the gridassociated wind-PV frameworks has been exclusively addressed in [15]. The framework in [15] contains a BtB VSCs to interface the PV and wind generators to the utility-grid. On the machine-side-VSC, the dc-connect voltage is regulated to the maximum power point tracking (MPPT) value of the PV panels by an external circle proportional-and-integral (PI) dc voltage controller. The reference values of the machine-side currents are calculated utilizing the synchronous location strategy, and a hysteresis current controller is used for the regulation. On the grid-side-VSC, a hysteresis grid-current controller is utilized to infuse the total currents into the utility-grid. Regardless of the potential advantages of the proposed framework in [15], the accompanying challenges are noted; 1) the MPPT of either the PV and wind power includes the operation of both VSCs, which at times could decreases the framework reliability and increases the misfortunes. For instance, assuming that the wind speed is lower than the cut-off speed of the wind turbine, i.e., no wind power, the machine-side VSC may be unable to track the solar PV MPPT dc-interface voltage [15]. 2) The currents of the machine and grid-side converters are regulated utilizing hysteresis controllers bringing about a variable exchanging recurrence and higher harmonic items.

II.LITERATURE SURVEY

F. Blaabjerg, Z. Chen, and S. B. Kjaer, are proposed The global electrical energy utilization is rising and there is a steady increase of the demand on the power capacity, proficient creation, dissemination and utilization of energy. The traditional power frameworks are changing globally, countless scattered generation (DG) units, including both renewable and nonrenewable energy sources like wind turbines, photovoltaic (PV) generators, energy units, small hydro, wave generators, and gas/steam powered joined heat and power stations, are being integrated into power frameworks at the conveyance level. Power hardware, the innovation of proficiently handling electric power, play an essential part in the integration of the scattered generation units for good productivity and elite performance of the power frameworks. This paper surveys the applications of power hardware in the integration of DG units, in particular, wind power, energy components and PV generators.

A. Yazdani and P. P. Dash, are proposed a control strategy for a single stage, threephase, photovoltaic (PV) framework that is associated with a dissemination organization. The control is based on an inward currentcontrol circle and an external DC-connect voltage regulator. The current-control mechanism decouples the PV framework dynamics from those of the organization and the loads. The DC-interface voltage-control conspire enables control and maximization of the real power yield. Appropriate feed forward actions are proposed for the currentcontrol circle to make its dynamics autonomous of those of the remainder of the framework. Further, a feed forward compensation mechanism is proposed for the DC-connect voltage-control circle, to make the PV framework dynamics invulnerable to the PV array nonlinear characteristic. This, thus, allows the plan and optimization of the PV framework controllers for a great many operating circumstances. A modal/responsiveness analysis is also directed on a linearized model of the overall framework, to characterize dynamic properties of the framework, to evaluate vigor of the controllers, and to recognize the nature of interactions between the PV framework and the organization/loads. The consequences of the modal analysis affirm that under the proposed control strategy, dynamics of the PV framework are decoupled from those of the dispersion organization and, in this way, the PV framework doesn't destabilize the conveyance organization. It is also shown that the PV framework dynamics are not impacted by those of the organization (i.e., the PV framework maintains its stability and dynamic properties in spite of major variations in the line length, line X/R ratio, load type, and load distance from the PV framework).

L. Nousiainen, J. Puukko, A. Maki, T. Messo, J. Huusari, J. Jokipii. J. Viinamaki, D. Lobera, S. Valkealahti, and T. Suntio, are proposed A photovoltaic (PV) generator is internally a power-restricted nonlinear current source having both constant-current-and constant-voltage-like properties relying upon the operating point. This paper investigates the dynamic properties of a PV generator and demonstrates that it has a significant impact on the operation of the interfacing converter. The main properties an information source ought to have to emulate a real PV generator are characterized. These properties are important, since a power electronic substitute is many times utilized in the validation cycle instead of a real PV generator. This paper also qualifies two commercial solar array simulators as an example regarding the characterized properties. Investigations are based on broad practical measurements of real PV generators and the two commercial solar array simulators interfaced with dc as well as three-and single-phase dc-ac converters.

III.PROPOSED SYSTEM:

As shown in Fig. 1, the proposed system consists of a VSR to interface the wind generator, and a VSI to connect the cogeneration system into the utility-grid. The PV generator is directly connected to the dclink capacitor of the BtB VSCs via a dc cable [27]. The VSR and VSI are two-level converters consisting of six cells; each comprises an insulated-gate-bipolar transistor (IGBT) in parallel with a diode. In the following subsections, the complete modeling and control of the proposed system is provided.

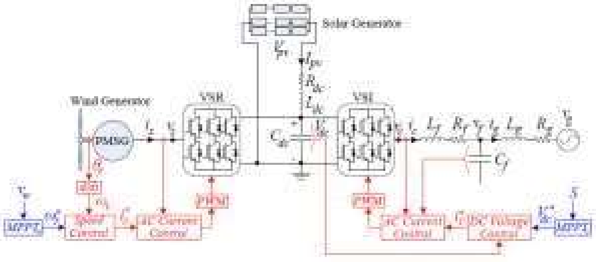


Fig. 1. The proposed wind-PV cogeneration system.

As shown in Fig. 1, this role can be achieved at the VSR-side using the MPPT for the wind generator (MPPTw) that utilizes the wind speed (vw) to generate the reference value of PMSG rotor speed (ω∗ r) .

A. Machine-Side Voltage Source Rectifier (VSR) The VSR is utilized to capture the maximum wind power by regulating the mechanical rotor speed of the PMSG to follow the MPPTw characteristics in Fig. 2, using the PI speed controller (Gs(s)) in (4).

$$I^*_{sq} = (\omega^*_r - \omega_r)\, G_s(s)\,,\ I^*_{sd} = 0$$

The PI speed controller (Gs (s) = gps + gis/s) is implemented in the outer loop, where s represents the differential operator and the superscript "∗" denotes the reference values of the variable. The speed controller regulates the PMSG speed to the optimal value (ω∗ r) and dictates the q- component of stator current reference (I∗ sq), whereas I∗ sd is set to zero to operate at maximum produced torque.

B.Grid-Side Voltage Source Inverter (VSI)

As shown in Fig. 1, the ac-side of the VSI is terminated by an inductive filter (Lf) with an internal resistance (Rf) and a shunt capacitor (Cf). The rms value of the three-phase terminal voltage and currents of the VSI are vc and ic , respectively. The utility-grid-impedance comprises an inductive part (Lg) in series with the equivalent resistance of the line (Rg); vg and ig are the utility-grid three-phase rms voltage and currents, respectively.

1) Generation of the Maximum PV Power: This can be achieved by regulating the dc-link voltage of the BtB VSCs (Vdc) to the reference value V ∗ dc that corresponds to the generation of the maximum PV power under different solar irradiance levels.

2) Transferring the the DC Power to the UtilityGrid: Referring to Fig. 1, the rate of change of the energy in Cdc is governed by the balance between the delivered dc power(Pwind + Psolar) and the injected active power to the utility-grid (Pvsi), assuming a lossless converter

IV.SIMULATION RESULTS

A time-domain simulation model for the hybrid system in Fig. 1 is developed under the Matlab/Simulink environment to evaluate the validity and the performance of the system. The wind and solar generators are rated at 2.0 and 0.9 MVA, respectively. The complete model entities are built using the SimPowerSystem toolbox. The VSCs are simulated using average-model-based blocks. The simulation type is discrete with a sample time of 50 μs. In the following subsections, the proposed hybrid system is subjected to theoretical challenging operating conditions which might not occur in the realty, e.g., large step variations in the wind speed and the solar irradiance levels, and three-phase-to ground (3PG) faults conditions. The external disturbances have been applied in the worst case to challenge the system stability and show the effectiveness of the designed controllers.

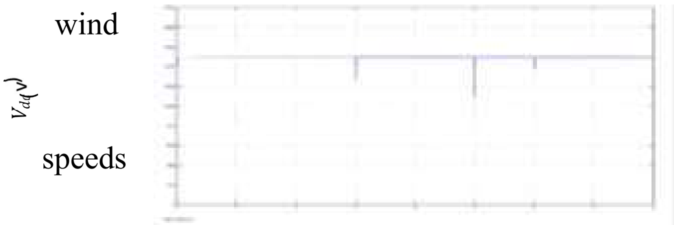
Wind and Solar Co-Generation

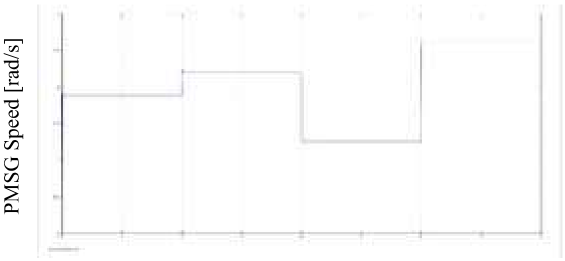
Grid current[kA]

Time(s)

5(b)

The co-generation of the wind and solar energy is investigated following different weather conditions. As shown in Fig. 5(a), the wind speeds increases from 8.4 to 10.8, then drops to 7.2, and finally increases to 12 m/s at t = 2, 4, and 6 s, respectively. Along with the wind speed variations, the solar irradiance level decreases from 1 to 0.8, and then 0.4, and finally increases to 0.6 kW/m2, at t = 3, 5, and 6 s, respectively. Following Figs. 2 and 3, the MPPT$_w$ and MPPTs generate the optimal ω^*_r and V^*_{dc}. As shown in Figs. 5(b) and (c), both ω_r and V_{dc} have a well damped performance which is reflected on the generated wind and solar power as depicted in Figs. 5(d) and (e), respectively, and the injected current to the utility-grid as in Fig. 5(f).

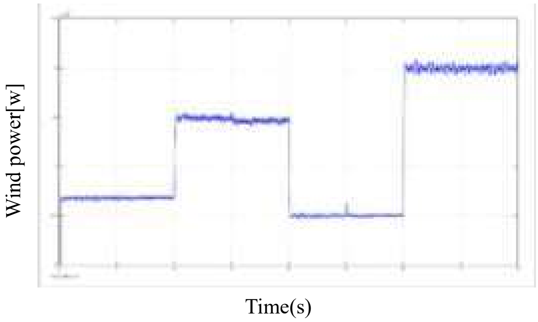




PCC Voltage[p.u.]

Time(s)

5(c)



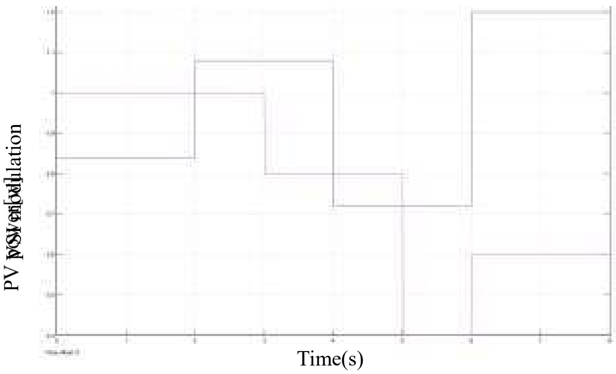
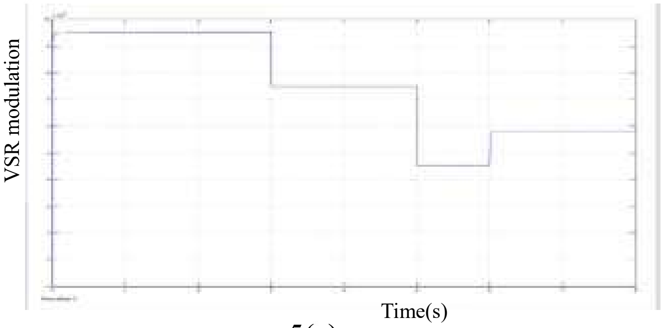


Fig.5(a)

5(d)



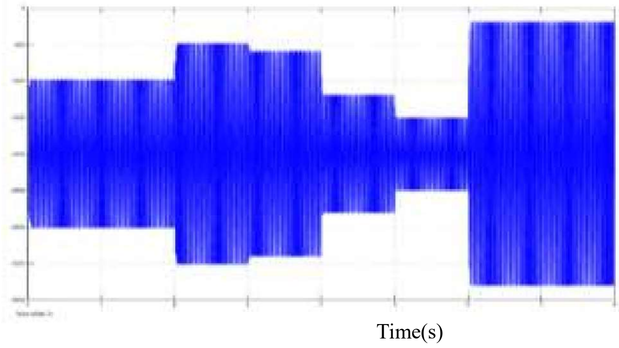
5(e)

PMSG Speed[rad/s]

Power[w]

Wind solar references:

Wind and solar both:



5(f)

Wind only

Grid current[A]

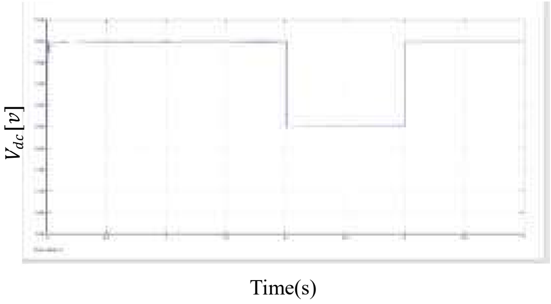
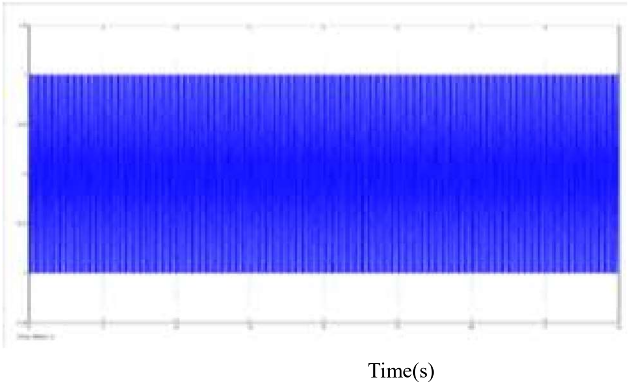
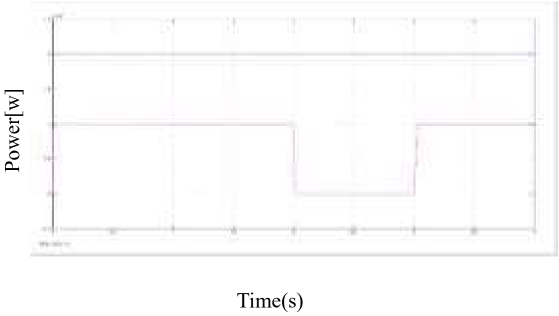


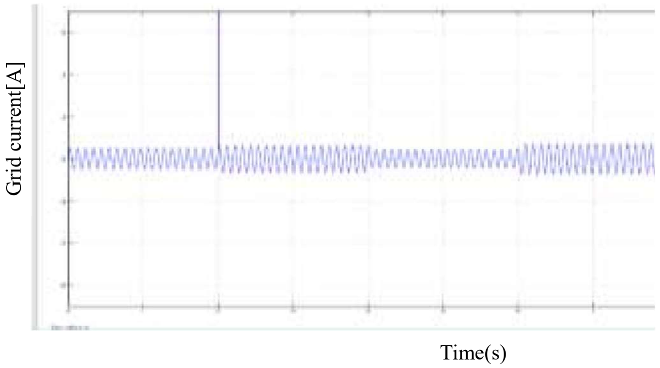
Fig:6(a): DC-link voltage



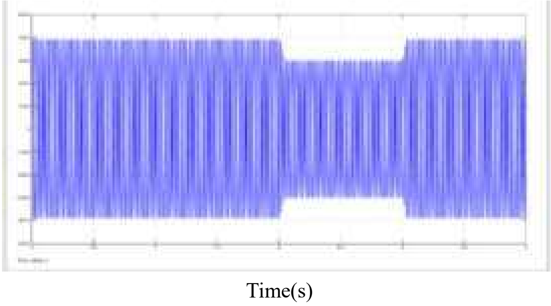
5(g)



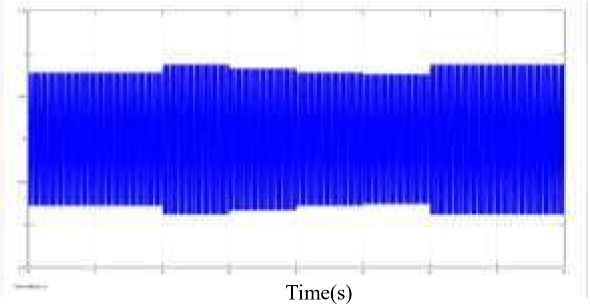
6(b): Wind and solar generated powers.



5(h)



6(c): Injected ac current to the utility-grid



5(i)

Solar only

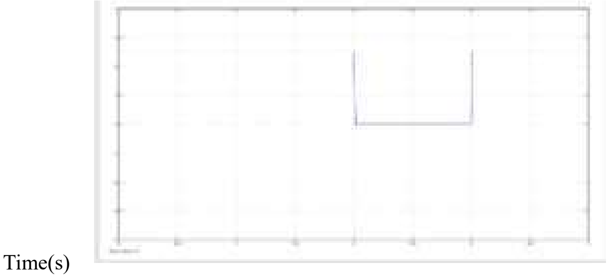
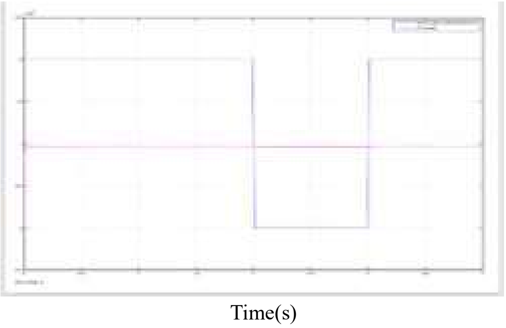
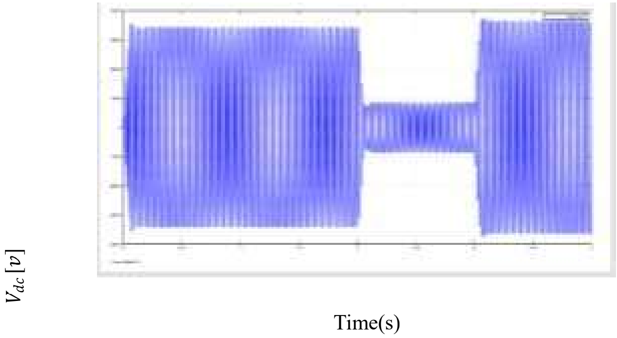


Fig:7(a): DC-link voltage.



7(b): Wind and solar generated powers.



7(c): Injected ac current to the utility-grid

3phase ground

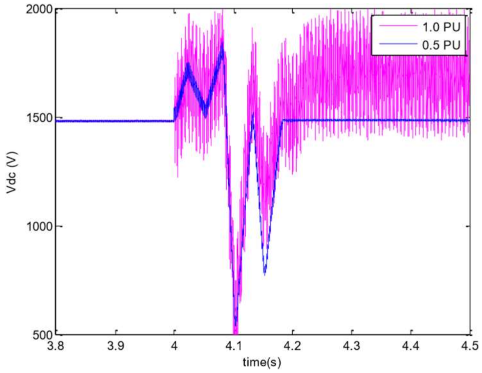
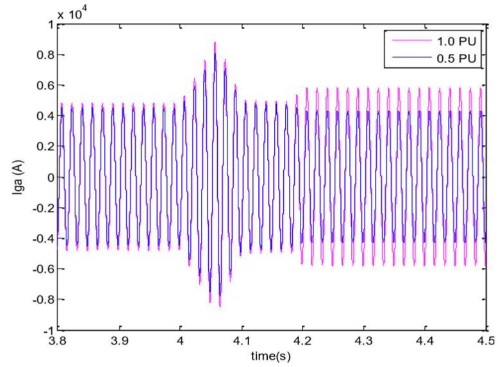
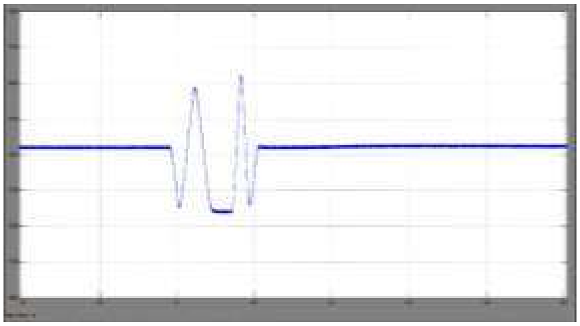


Fig:8(a)



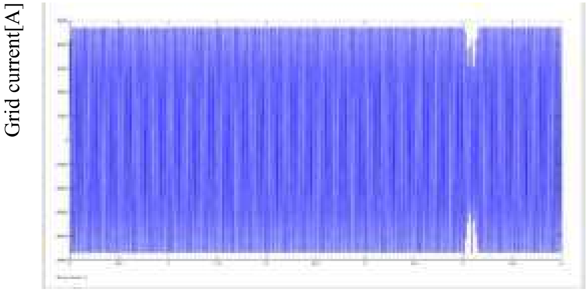
8(b)

Fig.8: Response to a 3PG fault at t=4s for 4 cycles - 1 and 0.5 p.u. wind power generation with 1 p.u. solar power



Time(s)

Fig:9(a)



Time(s)

Fig.9(b)

Fig. 9. Response to a 3PG fault at t = 4s for 4 cycles – 1p.u. wind and solar power generation with implemented fault protection schemes.

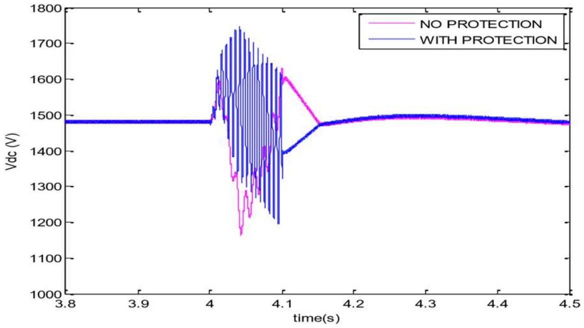


Fig.10. Response to a 1PG fault at t=4s for 4cycles-1p.u. wind and solar power generation with and without the fault protection schemes.

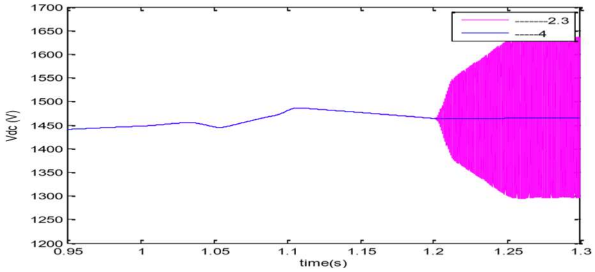


Fig.11 DC-link voltage response at different values of SCR-1 p.u. solar power and a step change of the wind power from 0.5 to 1 p.u. at t=1s

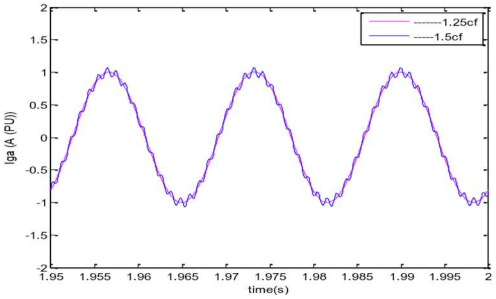


Fig.12. PCC voltage response at different values of C_f

V.CONCLUSION

An efficient control based smart grid to enhance power quality is investigated in this paper. The VSR at the wind generatorside is responsible for extracting the maximum wind power following the wind speed variations. On the utility-grid side, the roles of the VSI are to extract the maximum PV power from the PV generator, achieve the balance between the input-output powers across the dc-link capacitor, and to maintain a unity PCC voltage under different modes of operation. Proposed ANFIS control-based technique suppresses the fault tolerance of the network and enhances the power quality.

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