POWER QUALITY IMPROVEMENT BY INTELLIGENT METHODS IN THE GRID-CONNECTED PV-WIND SYSTEM WITH BACK-TO-BACK VOLTAGE SOURCE CONVERTER

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Abstract- The major objective of this project is to use flow control to connect wind photovoltaic cogeneration utilizing back-to-back voltage converters. The utility grid is interfaced to a permanent magnet with a synchronous full-scale generator (BtB) voltage-source converter (VSCs). The BtB VSC's dc-link condenser comes with a PV solar generator directly. No conversion phases of dc/dc are needed. This means maximizing system performance. The suggested topology includes a separate maximum point tracking system for wind and PV generators for maximum renewable energy extraction by the Fuzzy controller. This paper’s objective is to show the improvement in step response of dc link voltage by artificial neural network (ANN) controller. The control method significantly maintains constant grid voltage ensuring unity power factor even during climatic conditions variation. VSCs are regulated in the rotating reference frame using the vector control approach. To examine overall stability, detailed tiny signal patterns for the system components are produced.

***Keywords*— Back-To-Back Voltage Converters, Voltage-Source Converter (Vscs) Artificial Neural Network (Ann), Vector Control Approach**

1. INTRODUCTION

Wind turbine generating (WTG) and photovoltaic (PV) technologies will play a major role in satisfying future demand among different renewables. The combination of wind and PV is cheaper to operate and more reliable [3]. One system's weakness can be offset by another's strength. Such a combination increases renewable energy production's overall economy and reliability. Renewable sources and electrical storage systems are connected by power electronic converters to the solitary hybrid system through a shared AC bus. The control goal for inverter based, isolated micro Grid is to accurately share power while maintaining an acceptable frequency and voltage of the system. Drop control is an acknowledged technique for accurate load sharing without communication infrastructure between parallel inverters. Droop loops control.

Because wind and solar energy is intermittent and unregulated, power-electronic converters are used as an interface phase on either the load side or the grid, and so distributed generation units are generated[2]-[3]. The majority of distributed systems in literature are dedicated primarily to a form of renewable energy, e.g. solar energy [4]-[5] or wind power [6]-[9], for example. The combination of wind and solar energy in the same area has been considered [9]-[22] in order to optimize the benefits of the available renewable resources. The following features are present in the cogeneration of wind and solar energy:

1) The availability of wind and solar energy are often complementary and hence the combination of both energy types boosts operating efficiency [23] in general.

2) The combination of wind and solar co-generators maximizes the use of resources on land and hence increases expenditures in capital [24].

3) Wind-solar cogeneration systems are more dynamically capable of supporting the utility network in comparison with the static PV generators due to the available time of inertia in the wind power generators mechanics [8].

4) The generation dependability of two energy sources increases [9]-[10].

Wind-PV cogeneration systems connected to the grid are not widely covered [9]-[15]. In contrast, for stand-alone off-grid applications [10], [16]-[22], numerous wind-PV cogeneration systems were developed. In [16]-[17], an independent wind-PV cogeneration system is suggested. A single-phase cogeneration system was proposed at the small-scale stage [18], and a laboratory-scale system [19]-[20] was introduced. The system topology in [16]-[20] usually includes a common dc-bus that interfaces parallel connected renewable energy resources interfacing to converters, which can degrade system efficiencies overall and increase cost [12]. Most notably, strict controller coordination’s are required to prevent induced interactions, resulting in instabilities [25]-[26] in the cascade connection of power converters. The dc-dc converter-interfaced PV generator and an energy storage unit is utilized in a back to back (BtB) power source converter, which is connected to a double-fed inductive generator [21]. In [22], it is proposed that a photovoltaic generator recharge a battery bank and connect to a wind generator via a VSC. In the [21]-[22] wind-power cogeneration systems, the integration of renewable sources of energy with the minimum use of power-electronic conversion step is emphasized. However, for certain off-grid applications these methods are proposed.

A full survey of several CI applications in diverse power grid scenarios is provided in [11]. Fuzzy logic system is one CI technology that combines regulating algorithms and logical reasoning to enable complicated and uncertain systems to be controlled[12]. The FLC is developed to improve the dynamics of a single wind and diesel hybrid micro grid[13]. In this case, FLC is a flowing logic controller. In this study, the thyristor switches are controlled by FLC for the purpose of frequency control of further sets of three phase resistivity loads connected in the network. In order to reduce the output power fluctuation of the WTG system, the fuzzy pitch angle controller is developed[14] to reduce fluctuations in frequencies of the isolated microgrid. The optimum load share control is achieved in [15] by droop control and fuzzy control systems amongst many inverters connected to smart house. Changing the droop characteristics of each PV system, battery storage and electric vehicle (EV) connected in a smart home will accomplish the ideal load-sharing. The correct load sharing current can be achieved by employing FLC [16] in the low voltage DC microgrid for parallel DC-DC converter operation. In this way the FLC instantaneously calculates the virtual resistance, based on the converters' deviation in voltage of output, provides suitable sharing of load current, improving load tension and reducing flow between conversion machines. In this article, FLC modifies the VSI drop coefficient values for the PV and WTG DC systems of an isolated microgrid connected to each DC battery. As a consequence, the battery load, renewable generation and load profile share VSI connected to the battery system according to SOCs. Here, the FLC calculates the adjustment factor to update the drop value. According to their current drop rates, the connected batteries in each renovable generation share load. This procedure is being evaluated in an isolated microgrid based on the low voltage AC-connected wind and PV. The findings of the simulation demonstrate FLC's advantages and importance in improving the performance of wind and PV isolated microgrid.

2. SYSTEM DESCRIPTION

Fig.1 shows the configuration of a typical medium-scale residential MG used to implement the proposed control scheme. According to Fig. 4.1, the MG includes RESs including the solar and wind sources with 2.3 and 7kW power ratings, respectively, An energy storage system (3.3 kW power rating), and An RLC load with 8 kVA maximum power demand. RLC load is implemented to cover the different variety of residential loads (i.e. thermal load, fan load, and condensers). All sources are connected to the point of common coupling (PCC) using the two stages power electronic interfaces. In addition, all DG units are equipped with ZigBee modules to provide the low bandwidth communication network between units. According to Fig. 1 it is assumed that the line impedances are negligible in comparison with the RLC load values, which is an acceptable assumption in single-phase islanded MGs [18]-[19].

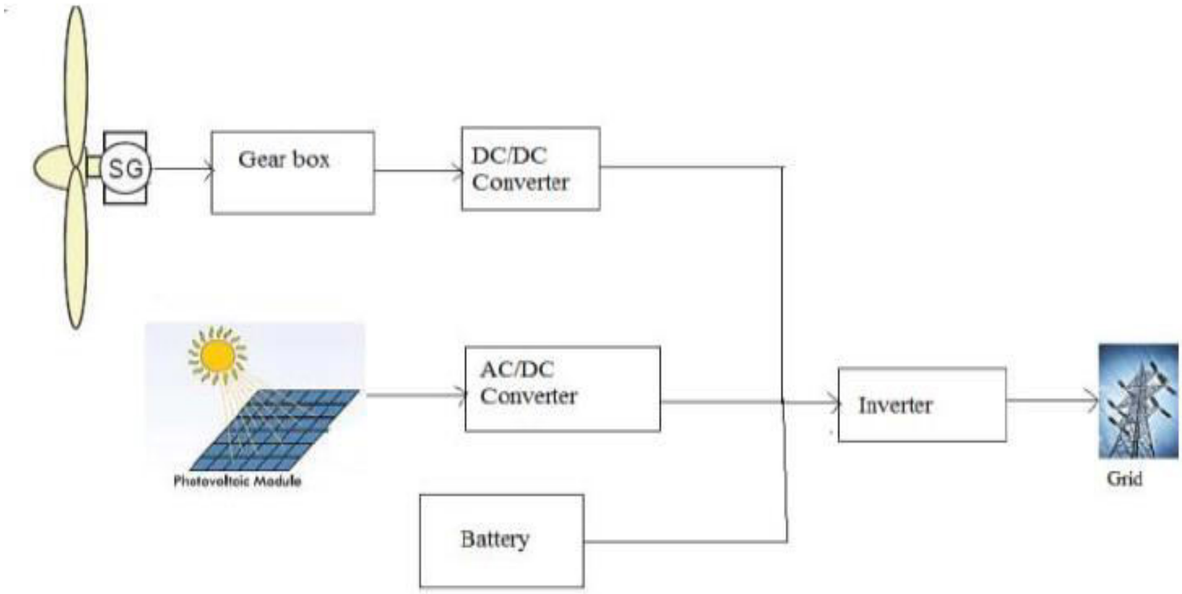


Fig1. Schematic diagram of Proposed Hybrid Energy System

The proposed hybrid energy system consists of a PV array and Induction generator-driven Wind energy conversion system meeting a common load. The PV system consists of PV arrays and corresponding DC/AC converter modules. Generally, according to the sunlight conditions, the maximum power point tracking control mode is adopted for PV system, which aims to maximum utilization of solar energy [4]. An H-Bridge inverter is used to connect the load to the hybrid system. Batteries are used to store the power when the power production exceeds the demand. The supply from the battery is needed during peak hours when power demand is higher than the production.

3. PROPOSED CONTROL SYSTEM TO CONTROL THE FLOW OF POWER IN MICROGRIDS

MODELLING OF VARIOUS RENEWABLE ENERGY SYSTEMS:

This section presents the mathematical models of energy sources namely, Solar PV, Wind and power electronic converters used in the proposed hybrid energy system

A. Modeling *of Photovoltaic System :*

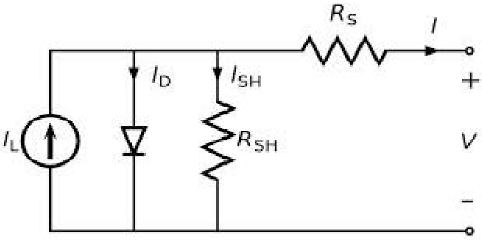


Fig2. Model of Solar PV cell.

The PV system consists of PV arrays and corresponding DC/AC converter modules. When exposed to sunlight, photons which have energy greater than the band gap energy of the semiconductor are absorbed and create some electron hole pair proportional to the incident radiation. The equations of the output current is given by

$$I = I_{PV} - I_D \quad \textbf{(1)}$$

Where

$$I_D = I_0[exp\frac{V}{AV_T} - 1] \quad (2)$$

Then equation (1) becomes

$$I = I_{PV} - I_0[exp\frac{V}{AV_T} - 1] \quad (3)$$

The I-V characteristics of a solar cell is given by

$$I = [\exp\left(\frac{V + I * R_S}{I_{PV - I_0 * V_T}}\right) - 1] \quad (4)$$

$$P = V\ \{I_{sc} - I_0[\exp\left(\frac{V}{AV_T}\right) - 1]\} \quad (5)$$

Ipv is the current generated by the incident of light, I0 is the diode reverse bias saturation current, $V_T = \frac{N_{S*K*T}}{Q}$ is the thermal voltage of PV module having Number of cells (NS) connected in series; Rs starting resistance, Isc is the short circuit current, q is the electron charge; K = 1.38x10^{-23} ^{i}s the Boltzmann constant; T is the temperature of the p-n junction and A = 2 is the diode ideality factor. The output of the current source is directly proportional to light falling on the cell. Naturally PV system exhibits a non-linear Current – Voltage (I-V) and Power - Voltage (P-V) characteristics which vary with the radiant intensity and cell temperature. The dependence of power generated by a PV array with changing atmospheric conditions can readily be seen in the I-V and the P-V characteristics of PV arrays.

B. Modeling of Wind System

The wind turbine rotor consists of two or three blades mechanically coupled to an electric generator. The power captured by the wind turbine is given by the relation

$$P_{\omega}=\frac{1}{2}C_p\rho.A.V_{\omega}{}^3 \quad (6)$$

Where ρ is the air density, which is equal to 1.225 kg/m^3, C_p is the power coefficient, V_w is the wind speed in (m/s) and A is the area swept by the rotor in m^2.

The amount of aerodynamic torque T_w in (N-m) is given by the ratio between the power extracted from the wind P_w and turbine rotor speed W_w in (rad /s) as follows

$$T_w = P_{\omega w_{\omega}} \quad (7)$$

C. Modeling of Battery:

The storage capacity of the battery at any given time (t) is expressed as

$$C_{bat\,(t)} = C_{bat(t-1)} + P_{pv(t)} + P_{wg\,(t)} - P_{load(t\,)}.\eta_{cad}\,\Delta t.\eta_b \quad (8)$$

Where $C_{bat\,(t)}$ and $C_{bat(t-1)}$ is the available battery capacity at time (t) and (t-1).P_{pv} is power generated by Photovoltaic system, P_{wg} is power generated by wind turbine generator, $P_{load\,(t)}$ is power consumed by load t, t is simulation step $(\Delta t = 1\text{hrs})$, η_{cad} is efficiency of AC/DC converter and η_b is battery charging efficiency which depends upon charging current and may vary from 0.65 - 0.85. When wind alone cannot meet the power demand but combining with PV can, i.e., $\eta_{inv}P_{wg}(t) + Ppv(t) \geq P_{load\,(t)}$. The excess power if available is used in charging the battery.

Battery storage capacity in such case is given by:

$$C_{bat}(t)\;C_{bat}\;(t-1)\left(P_{pv}(t)\;\left(\frac{P_{load}(t)-P_{\omega g}(t)}{\eta_{inv}}\right)\right)\Delta t.\eta_b \quad (9)$$

D. DC-DC Boost Converter:

DC-DC boost converter is a most efficient topology which ensures good efficiency along with low cost. A DC-DC boost converter is connected next to full-wave bridge rectifier to raise the voltage of the diode rectifier. Figure 3 shows the arrangement of the DC-DC boost converter circuit. A capacitor C1 is connected across rectifier to lessen the variation the rectified AC output voltage waveform from the bridge.

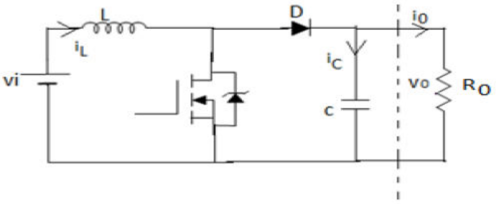


Figure: 3 . DC-DC Boost converter circuit

The model of the boost converter is needed to simulate and analyze the behavior. The input and output voltage of the boost converter under an ideal condition can be written as

$$V_{i=}\;V_0 * (1 - D) \quad (10)$$

where Vi is the input voltage, Vo is the output voltage and D is duty cycle . Given the value of D, it is possible to find the minimum values of inductance and capacitance using the equations given below:

$$L_{min} = \frac{(1-D)D\,R_0}{2f}$$

$$C_{min} = \frac{DV_0}{V_r R_0 f}$$

Where, Vr is the ripple voltage, R0 is the output resistance and f is the switching frequency. An important consideration in DC-DC converters is the use of synchronous switching which replaces the flywheel diode with a power IGBT with low "on" resistance, thereby reducing switching losses. This is achieved by using a Pulse Width Modulation (PWM) switched mode control design or PWM. The PWM performs the control and regulation of the total output voltage. If the semiconductor device is in the off-state, its current is zero, and hence, its power dissipation is zero. If the device is in the on-state, the voltage drop across it will be close to zero, and hence, the dissipated power will be very small.

4. CONTROL SYSTEM DESIGN

Photovoltaic, Wind Turbine, Grid System Modelling

This step is modelling small scale PV and Wind Turbine and its DC/DC converter to show the characteristic of power at different solar irradiation and wind speed in grid interconnecting system.

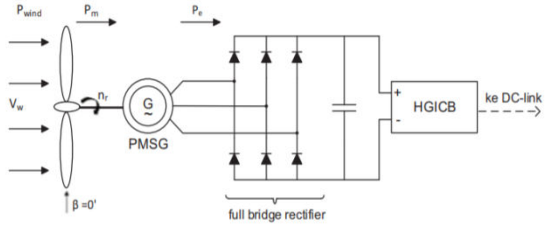


Fig. 4. Equivalent circuit of wind PV system

Figure 2 shows the schematic diagram of hybrid PV/Wind that connects to the grid through a common DC bus at the inverter. The solar PV and PMSG Wind Turbine with the capacity connects to the DC-DC converter that have a MPPT function. The inverter, so the DC-DC converter use a VSC topology which have a high ratio to bring the output voltage of PV and WT to DC common bus voltage. The MPPT was applied to these HGICB converter using fuzzy logic controller (FLC) that achieve the maximum power from any irradiation and wind speed condition. The DC bus voltage is controlled by the inverter that it can in stable value. The inverter is VSC and use a fast decoupled current control to get synchronization with the utility grid. LC filter is use to damp the harmonic output voltage and current so its value must not exceed from the grid requirement.

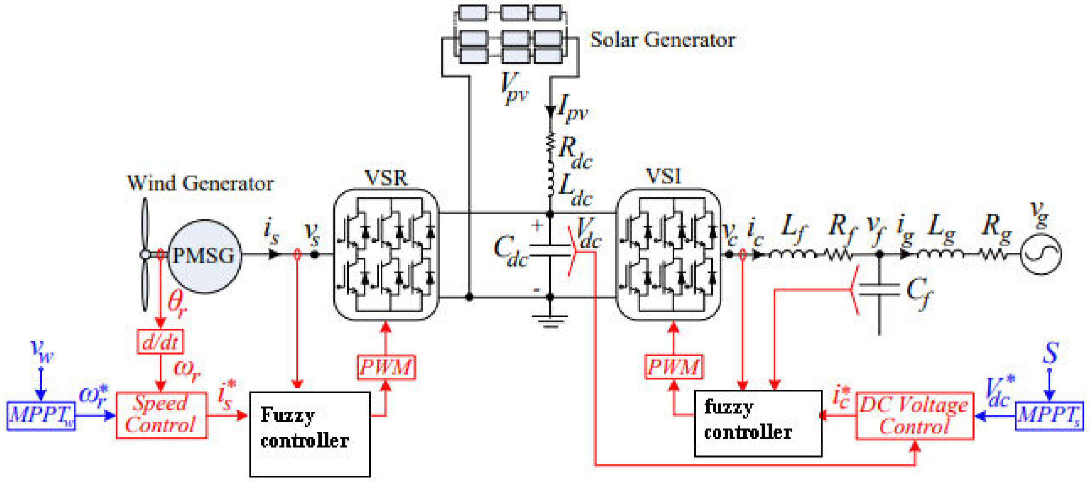


Fig5. The proposed wind-PV cogeneration system with fuzzy logic controller

5. FUZZY LOGIC RULES

The quantity and range of uses of fluctuating logic have increased dramatically in recent years. The applications include consumer products like camera, washer and microwave, industrial process control, medical devices, decision-making systems and portfolio selection. Comprehension of what the application of futile logic means through foggy logic is growing. Two alternative definitions have been given to fuzzy logic. Fuzzy Logic is in a narrow sense a logical system which is a multivalve logic extension. Nevertheless, in an overall sense of Fuzzy Logic (FL), the theory of Fuzzy sets is virtually synonymous, a theory that concerns classes of objects with sharp limits where membership is an issue. In this context, in its narrow sense, fugitive logic is a branch of fugitive logic. Construct a furious system of inference Fuzzy inference is a way to understand input vector values and assign output vector values depending on user provided rules. Using the Fuzzy Logic toolbox's GUI editors and viewers, you may establish the rules, set the membership features, and analyse how the inference system performs (FIS). The fuzzy controller has the following characteristics: 1. Five fuzzy inputs: NB (negative large), NS (negative small), Z (zero), PS (positive small), PB (negative small) 1. (positive big). 2. Simplicity functions of triangular membership. 3. Fuzzing via the continuous discourse universe (COD). 4. Implication with the 'min' operator of Mamdani 5. Defluence by the method "high."

Simulation Results

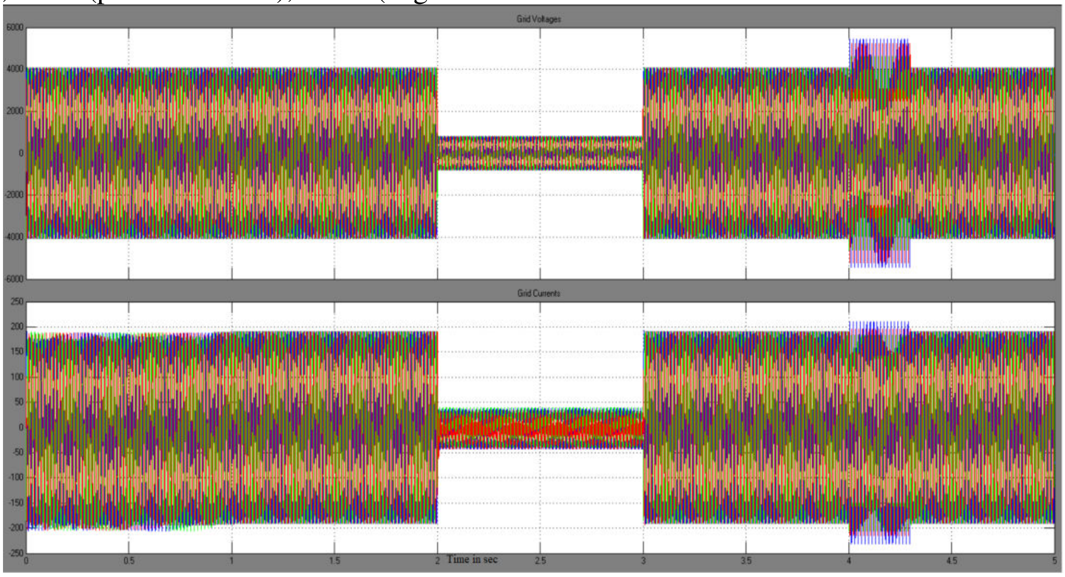


Fig6. Grid Voltages and Grid Currents

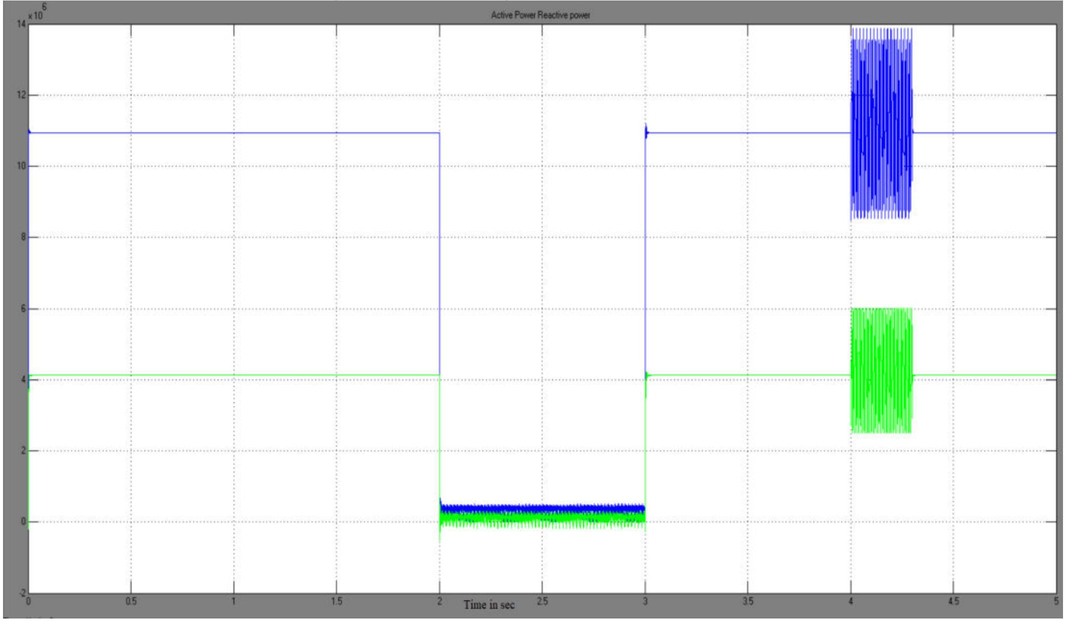
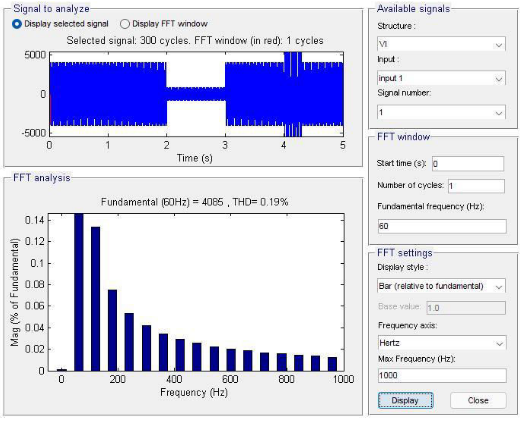


Fig7. Grid Active power and Grid Reactive Power.



● Display selected signal ○ Display FFT window

Selected signal: 300 cycles. FFT window (in red): 1 cycles

Fundamental (60Hz) = 4085 , THD= 0.19%

Structure : VI

Input : input 1

Signal number: 1

Start time (s): 0

Number of cycles: 1

Fundamental frequency (Hz): 60

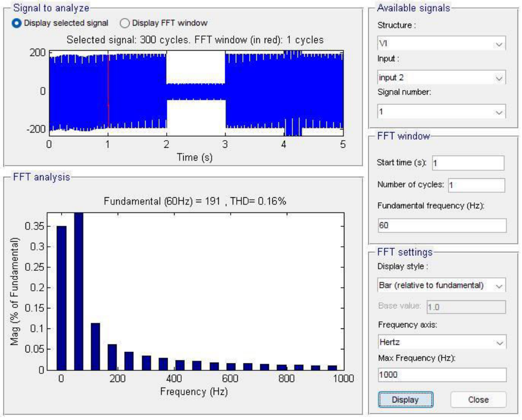
Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Grid Voltage FFT analysis



● Display selected signal ○ Display FFT window

Selected signal: 300 cycles. FFT window (in red): 1 cycles

Fundamental (60Hz) = 191 , THD= 0.16%

Structure : VI

Input : input 2

Signal number: 1

Start time (s): 1

Number of cycles: 1

Fundamental frequency (Hz): 60

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Grid Current FFT analysis.

Fig 8. THD of the Grid Voltage and Grid Currents.

At 1.0 p.u. wind and PV power generation, and following the clearance of the 3PG fault, the dc-link voltage stability is violated whereas the quality of the injected ac Voltage and Current is degraded to a total-harmonic-distortion of 0.19% and 0.16%. On the contrary, the response with the 0.5 and 1.0 p.u. wind and PV power generation, respectively. This implies that the wind generator is associated with the system instabilities under the utility-grid faults conditions. The fault conditions are associated with a sudden drop in the PCC voltage that hinders the maximum power transfer from the dc-link to the grid. As the input wind power is driven by a relatively slow mechanical system, the wind generator keeps injecting the maximum wind power into the dc-link capacitor during the fault conditions. Therefore, the dc-link input power becomes significantly higher than the output power and so the dc-link voltage increases, as shown in Fig. 9(a) [at 1 p.u. wind power]. On the contrary, the PV generator does not contribute to the dc-link voltage instabilities under the fault conditions. The increased dc-link voltage pushes the operating point of the PV array beyond the maximum power point. As shown in Fig. 3, as the PV array voltage exceeds the MPPT operating point, the generated PV power is naturally decreased, and so the PV array does not contribute to the fault currents. The PV generator has self-healing capabilities under the utility-grid faults conditions.

CONCLUSION

This research introduced the BtB vector-controlled grid-connected BtB VSCs in wind PV cogeneration systems. The VSR is responsible for obtaining the greatest wind power once the wind speed changes on the wind generator side. On the utility grid side, the VSI's duties are to extract maximum PV power from the PV generator, strike a balance between input power across the DC link condenser, and maintain a unit PCC voltage with different operating modes. Different types of PV packing systems are available on the system with time for grid-linked operation. The different configurations have discussed these systems in detail. One can use any configuration with the suggested fuzzy system and source converter. The DC-link voltage controller of the VSI is successfully controlled by both PI and ANN controllers. The simulations results showed a better step response of dc-link voltage by ANN controller than the existing PI controller. Among these setups. In the domain analysis of the Laplace domain is also considered an impedance source converter with the benefit over the voltage source and current source.

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