An Impact of Grid Integrated Hybrid Systems under Fault Analysis

Vishnu Murthy K[1], Ashok Kumar L[2]
{drkvm25@gmail.com[1], lak.eee@psgtech.ac.in[2]}

Research Scholar, Department of Electrical and Electronics Engineering, PSG College of Technology, Coimbatore, Tamilnadu[1],Professor, Department of Electrical and Electronics Engineering, PSG College of Technology, Coimbatore, Tamilnadu[2]

Abstract. This study examines how the grid-integrated hybrid system responds to a grid fault caused by a lag in the inverter's closed loop control time. Modeling of the hybrid renewable energy system with solar PV, Doubly Fed Induction Generator incorporated wind power, and the subsequent connection to the AC grid for providing energy to the three-phase load with Closed Loop control scheme of the VSI is presented in detail. This system incorporates solar PV and wind power. An MPPT approach is utilised in conjunction with a DC-DC boost converter in the Solar PV system. The wind power conversion system is combined with VSI's output to produce a hybrid system. The closed-loop controlled VSI's output is evaluated with a delay and while it's running normally. Closed loop control delay has a significant impact on grid output, and an effective real-time control solution for the VSI is therefore required.

Keywords: Solar PV, Voltage source inverter, DFIG, grid integration, Grid fault.

1 Introduction

Population growth and change in the living standards of the people upshot for more electrical power usage. Traditional energy sources, on the other hand, including coal and natural gas, are degrading because they've been primarily used for power generation. Researchers have discovered alternate sources of energy, referred to as renewable sources, that are omnipresent and pollution-free, in order to address these concerns. It's no secret that recent years have seen an increase in the development of renewable energy sources like wind and solar[1][2], owing to their low cost and widespread use. [2] Intelligent computation technique used in renewable energy technology has been discussed woth varied topology/technique for advancement in this domain of research. Wind and solar energy are abundant in nature and are widely used energy sources, each of which has its own set of pros and disadvantages in their own right. Wind power's hindrances include power availability, the initial capital cost of the wind farm, and the remote position of load centres from the wind farm, which makes grid integration difficult. [3]Data sources, size, and grid regulation type are quickly increasing and enriching, and services for enormously multi-sourced data are regulating and administering.

There has been an increase in the need for analytical and processing resources. This data is utilised to improve the quality of the power supply service and cut down on power outage losses.After analysing the common faults in the operation and administration of the power grid

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in Tianjin's Dongli District, this research paper explores the protection and management of power grid faults. The study offered in this research paper may help improve grid operation efficiency and management, as well as system safety and stability.[4]Grid-tied converters may become unstable for a short time during power grid interruptions. In low-voltage outing the Thevenin equivalent grid impedance rises, leaving the converter terminal voltage particularly sensitive to the output current. Due to phase-locking, the converter has a tougher time getting back into sync (PLL). The dynamic synchronisation of the converters in this work is explained using a downsized -order nonlinear model. Convertor resynchronization occurs during LVRT and may be seen by measuring grid impedance and looking at the spatial vector tracking relationship. There are a number of factors that influence converter transient stability, including the relative grid network potential,current and PLL parameters, impedances settings. Computer models and experimental data support the findings.[5]Low voltage ride-through (LVRT) capabilities on an IIDG mean that its fault characteristics cannot be compared to those of a stable supply and power. IIDG control schemes and microgrid fault detection methods need to be studied, hence this is critical Microgrid fault component characteristics were evaluated under various operating conditions, like high and low impedance failures.So, engineers created a completely new method of fault detection that makes use of positive sequence fault components to identify phase mismatches between bus voltage and feeder current.[6]As a result of noise and DG penetration, it might be difficult to locate line to neutral problems in poorly grounded MV distribution networks. These findings suggest the development of a fault locating method that utilises the energy of a transient zero-sequence current in a certain frequency spectrum.Since the distributed networks as well have a issues, while solar energy also has some drawbacks due to seasonal constraints such as solar irradiation level, panel placement, and so on [7]. The intermittent nature of these two sources makes it very evident that their output power is inefficient. As a result of the volatility and scarcity of single energy renewable sources, hybrid energy systems have been developed. Hybrid energy systems, which connect local power generation to non-conventional energy sources, provide specific benefits such as increased reliability, power quality, and system confinement. [8] Diverse groupings of renewable energy sources are conceivable when constructing a hybrid system. Fuel cell and PV hybrid grid-connected systems are examined in detail in [9]. Grid-connected combining the said hybrid technology with the finest distributed power generation design is presented in [10].A hybrid power system, which utilises solar, wind, and tidal power sources, is fully analysed in [11] the report. [12] explored the architecture and financial estimation of intermittent hydrogen production hybrid grid system. A grid-connected hybrid pv and fuel cell power generation performance is optimised in [13].[14][15] provides an overview of contemporary control tactics and direct power control. Additionally, the phase locked loop (PLL) structure is described, as well as grid synchronization strategies for single phase and three phases. A balanced voltage drop, an imbalanced voltage, and a harmonic content variation are all discussed in [16].

From the abovementioned hybrid systems, it's apparent that solar and wind electricity are the key sources of alternative energy. As a result, in the future, the hybrid power system will predominate, utilising clean renewable energy sources like wind and solar. Here, we'll talk about how to integrate hybrid systems into the power grid. Some magnitude and frequency oscillations arise as a result of the unsteady functioning of alternative energy sources. A consistent output must be maintained via a hybrid system that incorporates wind and solar energy complementary to one another.This is accomplished through the employment of power electronic converter circuits. Increased number of power electronic switches results in increased losses. The purpose of this research is to conduct an analysis of the grid-connected hybrid system under fault conditions. In this case, the fault is deemed to occur at two distinct locations on the grid. On a shared grid, analysis is conducted under two distinct fault circumstances.

2.SPV System Description

A. PV cell

It's a semiconductor diode, and that's what a photovoltaic cell is. With sunlight, the solar cell collects photons and stimulates the separation of electron hole pairs to create emf. Series and parallel resistances make up the ideal PV cell's equivalent circuit.

The voltage, current behaviour of the ideal solar cell can be written as

$$I = I_{pv,cell} - I_{o,cell}\ [\exp\left(\frac{qV}{aKT}\right) - 1] \qquad (1)$$

$I_{pv,\ cell}$ = the light's incident current.
$I_{o\ cell}$= Diode-leakage current
q = electron charge
K=Boltzmann constant
T= temperature of the PN junction.
d = ideality ratio of a diode

B. PV Array Model:

As soon as you have Series and parallel PV cell configurations are used in the PV array modelling to get the required performance. PV modules are made up of series/parallel combinations of PV cells, while PV arrays are made up of series/parallel combinations of PV modules. Series connection is used to increase the irradiation and temperature of the system, while parallel connection is used to increase the current. The V-I characteristic is nonlinear and changes with the weather conditions as well as the actual PV array.

To figure out the PV array's output current, use this formula:,

$$I = n_p I_{ph} - n_p I_{rs}\ [\exp\left(\frac{q}{kTAn_s}\right) - 1] \qquad (2)$$

Where,
I_{ph}: Current Output of Solar Cell
n_s: Cells linked in series sequence, in number
n_p: Cells linked in parallel sequence, in number
q: Electron Charge
k: Boltzmann's constant
A: ideality ratio of a diode
T: Temperature of a Cell
I_{rs}: Reverse saturating current in the cell

I_{ph}, or the photovoltaic current, is dependent on solar radiation and cell temperature, and is given by,

$$I_{ph} = [I_{scr} + k_i(T - T_r)]\frac{S}{100} \qquad (3)$$

Where,

I_{scr}: The cell's short-circuit current and irradiation temperature are measured.
k_i: Coefficient of short-circuit current and temperature
S: Watts per square metre of solar radiation
The following equation can be used to figure out how much power a PV array generates:

$$P = IV = n_p I_{ph} V - n_p I_{rs} V[\exp\left(\frac{q}{kTAn_s}\right) - 1] \qquad (4)$$

Assuming V is the solar array's output voltage, operating the same at its MPP will provide the most available power.

The MPP's immediate output power can be determined using

$$P_{mp} = I_{mp} V_{mp} \qquad (5)$$

C.MPPT Technique

P&O methodology of MPPT technique is utilised in this work. During each perturbation cycle, the P&O operate by disturbing the solar panel array voltage and panel output power. If the operational voltage of the panel changes and the power increases (dP/dVPV>0), the system responds the operational purpose of the panel structure in that direction; otherwise, the operational purpose is rapt in the wrong way.. The formula is repeated in the next perturbation cycle. When the MPP is attained, the output power oscillates the greatest, causing the array terminal voltage to be frazzled, which is the most significant drawback of P&O algorithms. When the region conditions are stable or slowly varying, this holds true. However, under rapidly changing region conditions, it's also true. There are numerous P&O routes to choose from. The standard P&O algorithms are taken into consideration in this study. Using the traditional P&O method (P&Oa), PV operating point perturbations have a predetermined magnitude. According to our calculations, the disturbance has a magnitude of 0.37 percent of the PV array's Vov. PV array voltage VPV and PV array current IPV measurements are necessary for this formula's conductivity.

D.Boost Converter

The MPPT-derived solar array voltage is sent to the boost converter, which changes the duty cycle to obtain the gating signal. There are two operating modes for the boost converter.

Mode 1: The IGBT is turned ON at time t=0 and turned OFF at time t=ton.

When the voltage is applied to the inductor, the inductor current is always larger than zero. A value of Vi is used as an insulator voltage for an inductor.

Mode 2 begins when t equals tonne and finishes when t equals to ts in mode 2. During this cycle, the inductor current decreases, and the inductor voltage goes from Vi-Vo to zero.

The temporal integral of the inductor voltage over a single period must be zero under steady state conditions.

$$V_i t_{on} + (V_i - V_o) t_{off} \qquad (6)$$

Where, Vi= Input Voltage
Vo= Average Voltage Output
ton= IGBTON time
toff = IGBTOFF time.
To simplify, we can divide by Ts and rearrange the terms as follows

$$\frac{V_o}{V_i} = \frac{T_s}{t_{off}} = \frac{1}{1-D} \quad (7)$$

E.Voltage Source Inverter

With the boost converter's enhanced voltage, the voltage source inverter may turn the dc output voltage into an AC voltage, which can then be integrated into the power grid. The constant current controller is used to regulate the solar inverter. The LC filter reduces the harmonic content of the signal after it passes through the VSC. There are two ways to use the VSI. When the converter is connected to the grid, there are two control schemes: one uses active and the other uses reactive power. The active power and voltage approach, which isolates the converter from the grid, is an alternative. The amplitude and frequency modifying indexes ma and medium frequency are provided by the inverter for the PWM control system. Using a phase-locked loop (PLL), the grid voltage point g is determined in order to regulate active power flowing through an electrical converter in synchrony with grid synchronisation. For each DC link, an internal reference voltage is set and tested against that value. A PI controller uses the dc voltage error to calculate the d axis current reference. A comparison is made between the d-axis current reference and the measured value of the d-axis current, and the error is then sent to the PI controller. This compares the q-axis reference to q-axis real current and the difference is supplied to a different PI controller as error information. The control voltages for VSI's three phases are generated using PI controllers and the inaccuracies in the d and q axis currents.

3.Wind Energy System

The components of a wind energy system comprise a wind turbine, gearbox, and back-to-back converter. The kinetic energy of the wind is captured by the wind turbine, and the electrical energy is generated by the generator. As a result of their variable speed operation and other benefits, such as enhanced controllability of both active and reactive power, and the ability to get ride of fault by their uninterruptable operation, double-fed induction generators are employed in the suggested concept. A back-to-back converter connects an induction generator's stator directly to the grid, resulting in a double fed induction system. The stator-to-grid power flow is regulated by the rotor side converter's rotor current monitoring, while the grid side converter controls the power flow from the rotor to the grid. Regulation of rotor- and grid side converter currents using proportional-integral controllers. The mechanical power is provided by the

$$P = \frac{1}{2}(\rho \pi R^2 v_t^3 C_P(\gamma, \beta)) \qquad (8)$$

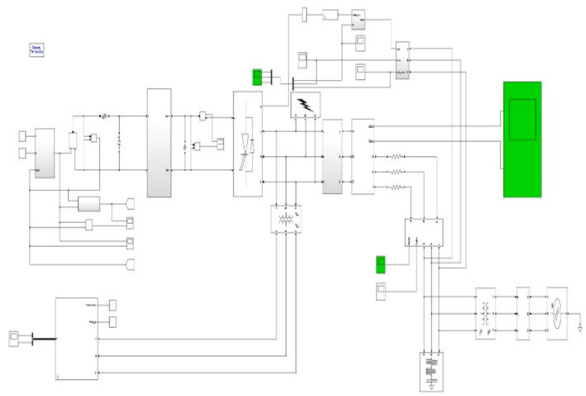

Fig: 1 Simulation of grid integrated hybrid system

Where R= turbine radius (m), V_t=wind velocity (m/s), C_p=power coefficient

Zrot is connected in series with a Pulse Width Modulator rotor-side converter by DFIG to further expand the induction generator. The PWM rotor converter in the DFIG comparable model adds an extra circuit to the design compared to the SCIG. By varying the generator voltage's magnitude and phase angle, the PWM enables for quick and flexible control of the machine.

Below are the DFIG stator and rotor voltage equations explained in more detail.

$$U_s = R_s I_s + \frac{j\omega_0\varphi_s}{\omega_n} + \frac{1}{\omega_n} + \frac{d\varphi_s}{dt} \qquad (9)$$

$$U_r e^{-j(\omega_0-\omega_r)} = R_r I_r + j\frac{(\omega_0-\omega_r)\varphi_r}{\omega_n} + \frac{1}{\omega_n}\frac{d\varphi_r}{dt} \qquad (10)$$

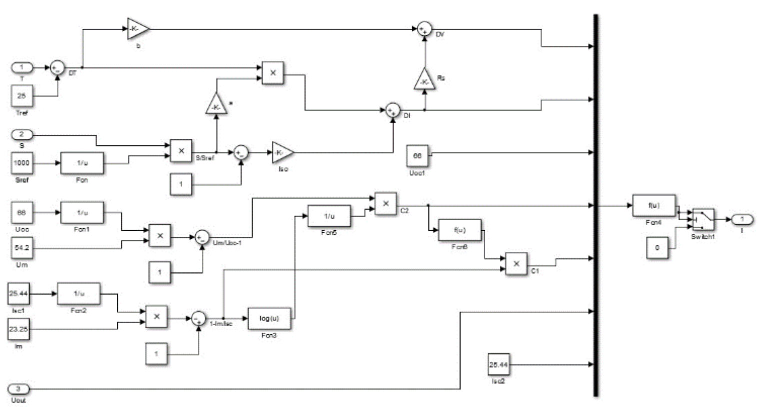

Fig:2 MPPT Technique

Where U_S and U_r are the stator and rotor voltages. ω_n and $\omega_r$are the system frequency and angular speed of the rotor.

4.Hybrid System Integration and Simulation Result with Fault Analysis

The AC output from the wind energy system is integrated with the PV system. For the integration purpose, wind power generated from the wind energy conversion system is given to the three-phase transformer as shown in Fig 1.Similarly, the PV system employs converter topologies for the integration. The combination of wind power system and PV system is brought out to a common AC bus. Fig.2 represents the MPPT technique exercised in the solar PV system. The closed loop control of VSI is displayed in the Fig.3. The output voltage and current of the VSI without delay in the closed loop control is revealed in Fig.4. Similarly, the output voltage and current of the VSI with delay in the closed loop control is shown in Fig.5. From Fig.5, it is clearly inferred that due to the delay in the control of the VSI voltage and current becomes zero over a period of time which in directly represents the fault occurred in the grid. The RMS voltage with and without fault is shown in Fig 6 and Fig 7 respectively. The RMS voltage reaches zero at the fault which shows the impact of unstable operation of the closed loop control of VSI.

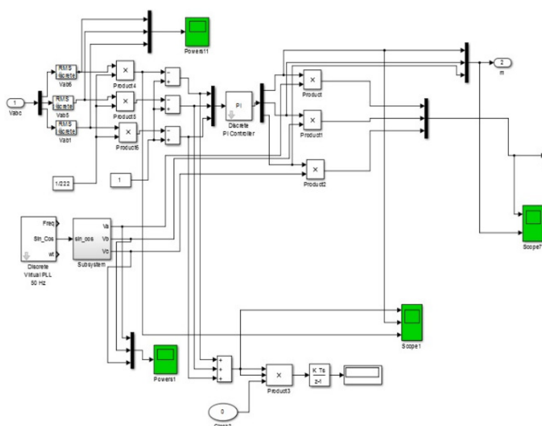

Fig:3 Closed Loop control of VSI

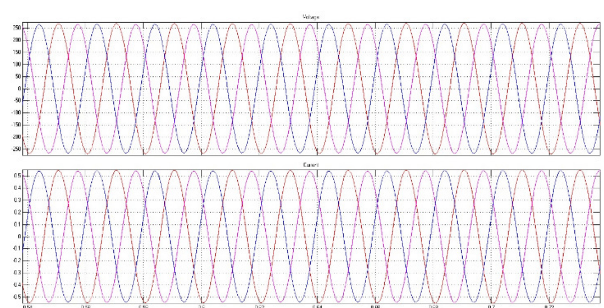

Fig:4 VSI output voltage and current without delay

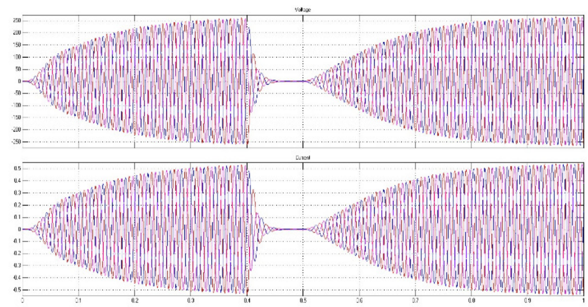

Fig:5 VSI output voltage and current with delay

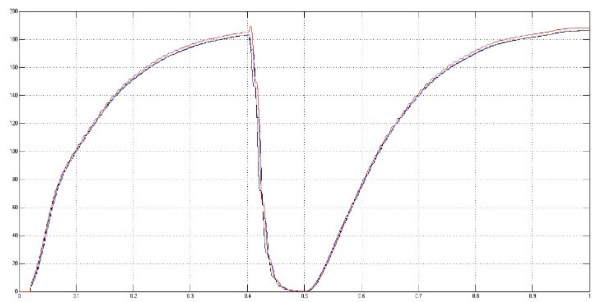

Fig:6 RMS voltage waveform with fault

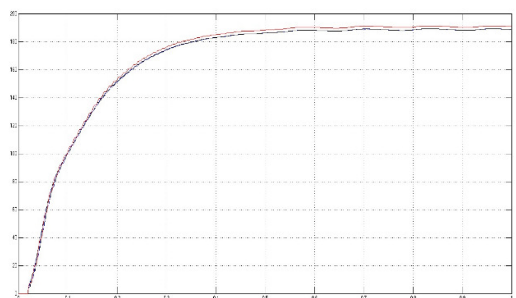

Fig:7 RMS voltage waveform without fault

5.Conclusion

To research the influence of inefficient operation of the closed loop controlled VSI, this paper analyzed the effect of the fault that occurred because of the delayed control of VSI. From the investigation of the response of the VSI it has been shown that the effect of fault outcomes with the voltage dip over a period of delay which illustrates the unbalanced operation of closed loop controlled grid integrated system. This clearly denotes the need of efficient real-time control of VSI without any delay. Meanwhile it is also necessary to isolate the system if the hybrid renewable energy system does not produce sufficient energy due to these types of faults.

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