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A Novel on Stability and Fault Ride through Analysis of Type-4 Wind Generation System Integrated to VSC-HVDC Link

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ABSTRACT

Now-a-days pollution is increasing due to “Non Renewable Energy Sources”. In order to enhance the efficiency of conventional grid and to generate the electrical power in eco-friendly way, the renewable energy sources are employed. In this paper a type 4 wind generation system is implemented to analyse the system under fault conditions and to analyse the grid stability. In the proposed system type-4 wind generation system integrated to grid through VSC-HVDC link analysis is done by considering a fault on the grid side by the system gets isolated and wind generation system transfers voltage to local load and remote load. When a DC fault is occurred on the VSC-HVDC link then the grid side breaker and wind side breaker gets open, then system gets isolated. This is implemented by considering “Low Voltage Ride Through” (LVRT) conditions, According to the Indian grid code of contact wind generation maintain constant even the voltage collapse is occurred on the grid side. The proposed VSC-HVDC based Type-4 Wind Generation System give more reliable to operate in LVRT condition and can meet the Load demand when the system is under fault condition to some extent; The proposed method is Type –4 Wind generator is of 4.4MW/2.2kV each with a total plant capacity of 110MW operated with VSC based HVDC transmission system with 110kV DC bus voltage connected to 220kV grid. The results obtained shows the Grid is operates under fault ride through conditions stability.

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1. INTRODUCTION

Nowadays, load demand is increasing gradually at the distribution side day by day. To maintain optimal power flow sum of generations must be equal to Load demand. Generation of electrical power by means of Conventional energy sources results in environmental pollution. In response, the Renewable energy sources play a crucial role, especially Wind generating sources. These renewable energy sources can be reserved at the distribution side. The Microgrid involves different DGs and loads at distribution or at sub-level transmission. Microgrid diminishes transmission losses as load demand is nearer to the Power Generation. Microgrid can operate in dual-mode, connected to the grid and Islanded mode. If there is any fault on grid side the MG will operate in islanded mode [1]. One of the main fragments of the wind generating system is wind turbine (WT), which introduces many disturbances like frequency changes, voltage changes and harmonic injections in the system, when integrated [2-4]. The Wind generating system (WGS) includes Turbine blades, hub to hold the blades, Gear-box, Generator and multiple Controlling sub-systems. Basically the generators in WGS are Induction Generators or Synchronous Generators [5-9].

Fundamentally, Wind turbines are of two kinds based on design, Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). The basic speed control of the Wind Turbines are of four types. The first type, Type-1 Wind Turbine is a fixed speed WT which involves Squirrel-cage Induction Generator (IG) where additional Capacitor banks are vital in maintaining reactive power. Second type, Type-2 Wind Turbine is a low variable speed WT which is implemented by Wound rotor type IG where additional capacitor banks are even required [2]. Unlike Type-1 and Type-2 WTs, Doubly-Fed IG (DFIG) is implemented in Type-3 WT where back-to-back converter with generic controllers on both stator and rotor side is considered. DFIG is a partial variable speed WT and has direct contact with grid without any isolation, which results in poor transient stability [6-10]. Now coming to Type-4 WT, a fully variable speed WT has a Full-scale back-to-back converter with generic controllers that can afford greater isolation from grid. This will be improved by using Type-4 WGS. Hence in this proposed scheme, Type-4 Wind Turbine can be as it doesn't take much reactive power from grid, and it provides high speed ranges and improves transient and steady state stability of the system. The main disadvantage of WGS, Wind is available only after dusk and solar is available only after dawn. So in addition to WGS, Solar Photovoltaic generating system is also integrated to MG. Here the proposed model is VSC-HVDC System based Type-4 Wind Generation System, which controls both Active Power and Reactive Power. VSC-HVDC link is used transmit the power to the long distance area and can be connected between two asynchronous power generation systems and can transfer power in both the directions. Low Voltage Ride through (LVRT) system is used to maintain the load demand constantly when there is a fault on the grid side. The proposed method of operating the Type–4 Wind generation system operated with VSC based HVDC transmission system will increase the stability of the Grid. Low Voltage Ride-Through (LVRT) is one of the most significant grid connection requirements to be met by Wind Energy Conversion Systems (WECS). When the voltage dip occurs at the grid side, an imbalance is made between the active power delivered to the grid and generated active power. Which is a challenge for the WECS, here the wind generators are connected local grid under healthy and fault conditions. According to low voltage ride through (LVRT), if any voltage dip is occurred in the wind generation plant must connected to the grid, and it delivers reactive power to the grid to hold the grid voltage [11-16].

2. WIND GENERATION SYSTEM INTEGRATED TO VSC-HVDC LINK

By using Wind as an input for power generation, Wind turbines play a key role to drive an electrical generator. Basically WT consists of Blades, Hub, Nacelle, Gearbox, Electrical Generator and a control unit. Blades catch wind power, while hub and Nacelle holds the blades. Rotating blades in action move the shaft inside Nacelle. Hence Gearbox is used to increase the speed of the shaft in accordance to synchronize with the Electrical generator speed. Electrical Generator and Control unit serve the MG side parameters. Usually wind energy is trapped, such that if wind flows over blades resulting in rotational force using generating lift. Operated as per these topologies are called Drag lift based machines. The power transfer in wind turbine is nothing but kinetic energy of the flowing air mass per unit time is

$$P_{air} = 0.5\rho A V_{\infty}^2 \quad (1)$$

Where P_{air} is the power in wind (in watts) ρ is the air density (1.225 kg/m3 at 15°C and normal pressure), A is the area cleared in (square meter), and V_{∞} is the wind velocity without rotor interference, i.e., ideally at infinite distance from the rotor (in meter per second). Actually the Equation shows the power in the wind, but the power of the induction turbine rotor is affected by power coefficient, C

$$C_p = \frac{P_{wind\ turbine}}{P_{air}} \quad (2)$$

$$P_{wind\ turbine} = 0.5\rho C_p A V_{\infty}^2 \quad (3)$$

Albert Betz defines the maximum value of C_P limit and the C_P value of turbine can never exceed 59.3% of the power from an air stream of in reality, the maximum value of wind turbine rotors C_P in the range 25% to 45%. Tip speed ratio of a wind turbine (λ) is defined as:

$$\lambda = \frac{\omega R}{V_{\infty}} \quad (4)$$

Where ω is rotating speed of rotor (in rpm), R is the radius of the brushed area (in meter). The tip speed ratio λ and the power coefficient C_P are the dimensionless and so this can be used to describe the performance of any size of wind turbine blade. WTs are basically classified on basis of mechanical power control and speed control. Stall regulation and pitch regulation are the types of mechanical power control, depend on construction of blades. Based on speed control, WTs are fixed speed and variable speed in general. But in actual, four types of WTs are in existence at present are Fixed speed (Type1 WT), Limited Variable speed (Type 2 WT), Doubly Fed Induction Generator (Type 3 WT), Full scale back-to-back converter (Type 4 WT).

High Voltage Direct Current (HVDC) is an effective technology designed to distribute large amount of electricity over long distance with negligible losses. The longest HVDC link in the world is currently in Rio Madeira transmission link, Brazil with an overhead length of 2385Km. The losses at the transmission level can be greatly reduced by HVDC transmission system. The reason for moving towards VSC-HVDC is that the conventional HVDC uses line commutation whereas the VSC HVDC uses self-commutation. Line commutation is used to control active power only while self-commutation is used for control of both active and reactive power. Voltage Source Converters (VSC-HVDC) is effective solution for long distance power transmission system especially for off-shore wind plants and giving power to remote regions. Due to its advantages, VSC-HVDC is one of the most important component of power systems for underground and submarine cable transmission in the future. The AC system has been used for transfer power has been become strong and effective. One main problem with respect to AC power transmission is the difficulties and controllability of the system. This problem may be overcome by using VSC based HVDC transmission system. These converters require a moderately strong synchronous voltage source converter in order to commutate.

2.1. VSC–based HVDC transmission system configurations

The typical system configuration of VSC-based HVDC transmission system is presented in Figure 1.

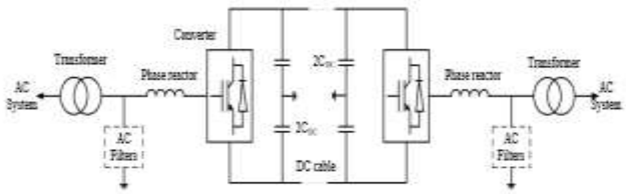

Figure 1. Typical VSC-HVDC system

The above typical system consists of: two voltage source converters, transformers, phase reactors, AC filters, DC-link capacitors and DC cables. The above components will be briefly discussed below. Here the transformers are used to interconnect the Voltage Source Converter (VSC) with ac system, the function of transformer is to implement the voltage level of ac network to a voltage level suitable to particular converter. The main function of ac filters are used to eliminate the harmonics which was created by using Pulse Width Modulation (PWM) technique. The dc-capacitors serves as energy storage and eliminates the harmonic ripples on dc voltage. In off-shore plant we can control AC voltage, active and reactive power. In on-shore plant we can control DC voltage and reactive power.

3. LOW VOLTAGE RIDE THROUGH (LVRT)

According to Grid code of contact the wind generation system has to be synchronized condition even under voltage collapse condition to some extent. To avoid cascading and desynchronizing of wind generation system used improve the stability. LVRT is the one of the biggest challenge towards wind generation system in particular those using synchoronous generators. Low voltage ride through is one of the most important condition for integrating the wind farm with the power system, which has been recently introduced in the grid codes. According to the grid code of contact, it is crucial for the wind generator systems to remain constant even the voltage disturbances occurred on in the system, up to a specified time periods and connected voltage levels. Otherwise, the additional loss of power generation in the system, as a result of the interruption of the WECS, can cause a greater generation imbalance, and therefore the system frequency can be dropped. Also, in the immediate interruption of wind generating units can make a larger voltage dip and eventually failure + voltage stability in the affected area. Low voltage ride through (LVRT) condition in various grid codes for different countries integrated in Europe and shown in Figure 2. According to the German grid code of contact, wind turbines connected to the power system have to operate within the 150 ms after the fault occurrence, even if the voltage at the point of common coupling (PCC) falls to zero. For analyzing the voltage stability during the fault US grid code has been considered as shown in the Figure 3. In United States (US) grid code, according to the low voltage ride through (LVRT) requirement, the wind turbines should connected to the grid and supplying reactive power to the system. When the voltage at the PCC falls in the 'gray color' area, shown in Figure 3. Moreover, the wind farms must be able to obtain continuously at 90% of the rated line voltage, and it is to be measured at the high-voltage side of the wind plant substation transformers. According to recent grid codes wind farms must remain connected and support the system during the fault and after the fault. The system must withstand the voltage dips for a particular percentage of nominal voltage for specified time duration. During the low voltage faults, the system may over speed and become unstable.

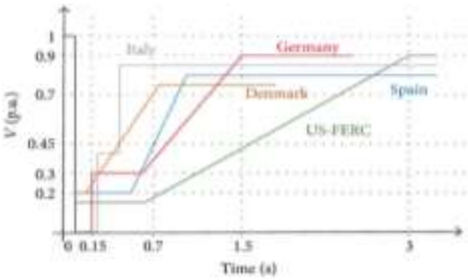

Figure 2. Low voltage ride through (LVRT) requirement in various grid codes in different countries

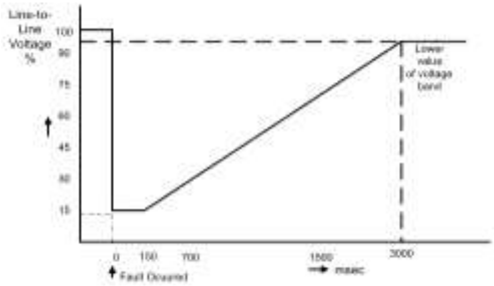

Figure 3. Typical low-voltage ride through requirement

4. SIMULATION AND RESULTS

In this simulation the modelling, frequency analysis and stability analysis of wind generating system and designing of VSC-HVDC System is done by using MATLAB/ Simulink. In Figure 4 the simulation of MG that is integrated to WGS connected to VSC-HVDC link a through a transformer of voltage ratio 750/11kV connected to a transmission line of 30kmand then the voltage level is stepped to a 220kV by a transformers of voltage ratio 11kV/220kV. The designed WGS contains 50 Wind Turbine driven synchronous generators of rating each of 2.2MW connected together to get 110MW. The system parameters for the design of type-4 wind generation system integrated to VSC-HVDC link is mentioned in detail in appendix.

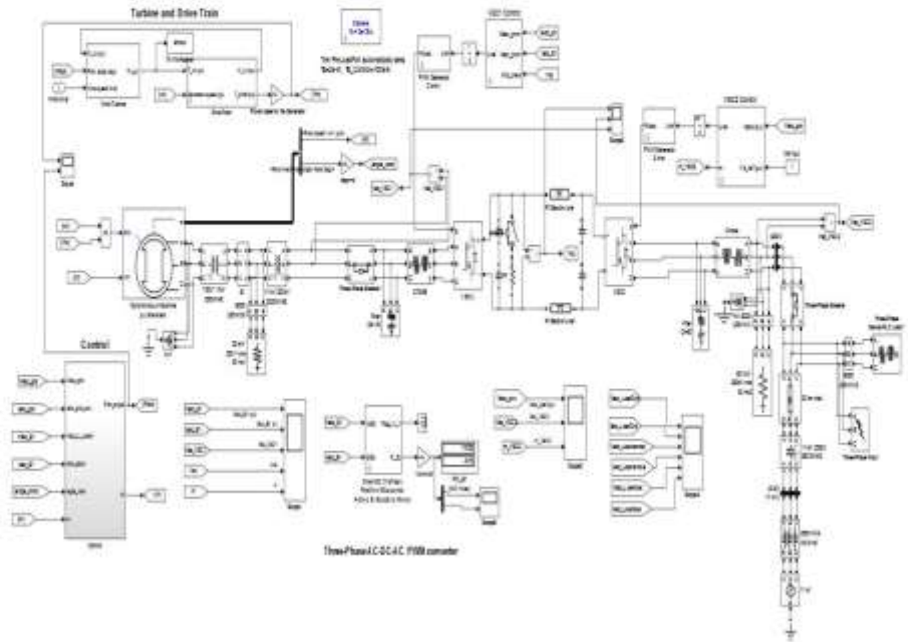

Figure 4. Simulation model of type-4 wind generation system integrated to VSC-HVDC link

Figure 5 shows grid side load voltage=220kV (rms), load phase current=927A (Peak to Peak). Figure 6 shows remote load voltage=220kV current=222.5A. Figure 7 shows local load voltage=11kV;

current=1485.5A (peak to peak). Figure 8 shows grid side voltages. Figure 9 shows line voltage of transformer primary, wind generation load current and line voltage of transformer secondary. Figure 10 shows torque and mechanical power.

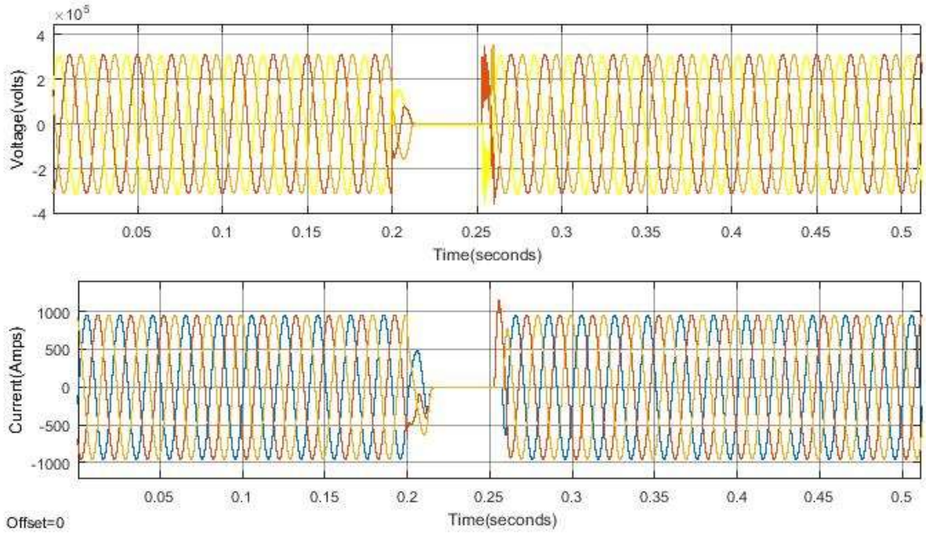

Figure 5. Grid side load voltage=220kV (rms), load phase current=927A (Peak to Peak)

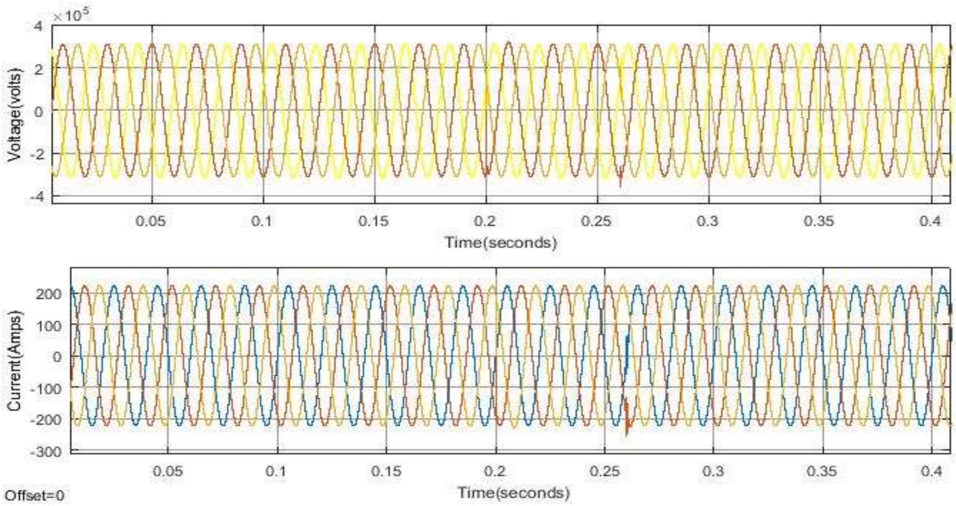

Figure 6. Remote load voltage=220kV current=222.5A

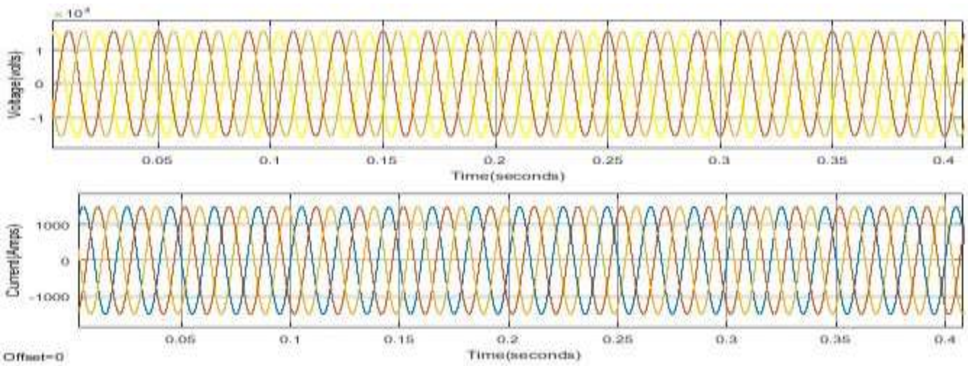

Figure 7. Local load voltage=11kV; current=1485.5A (peak to peak)

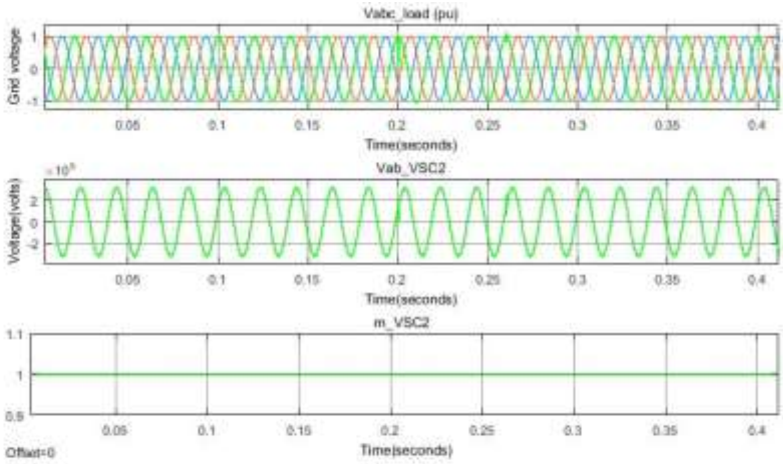

Figure 8. Grid side voltages

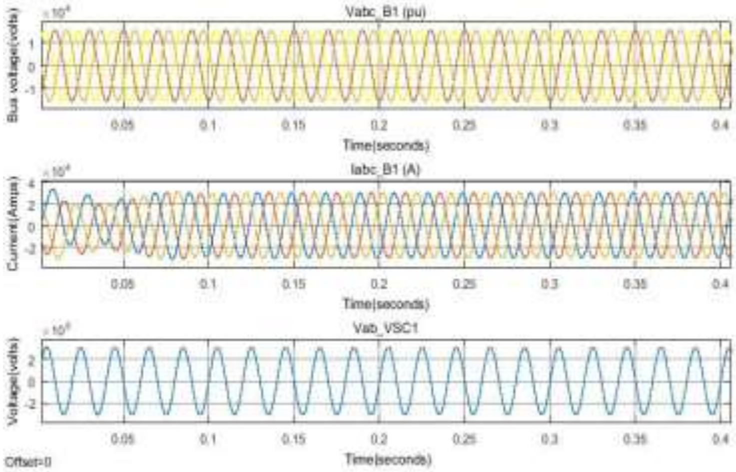

Figure 9. Line voltage of transformer primary, wind generation load current and line voltage of transformer secondary

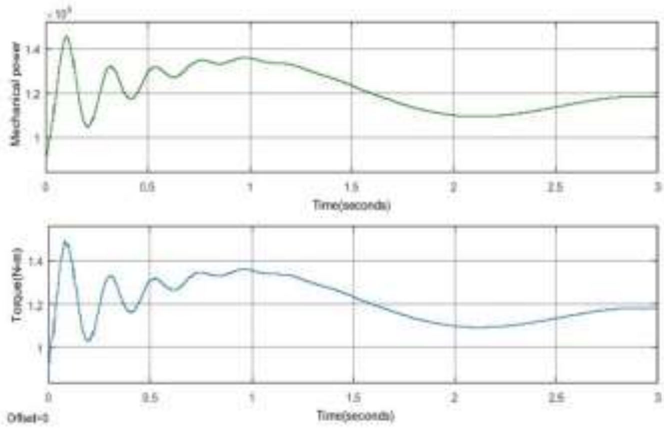

Figure 10. Torque and mechanical power

5. CONCLUSION

The designing of Type-4 Wind generation integrated to VSC-HVDC Link 2.2V SG, which is integrated to MG of 11kV at 220kV level and the base load of rating 220kV, 110 MW at 0.96 pf is simulated.

Generic Controllers like Inverter pulse control, Pitch angle control and Voltage source converter control are implemented to enhance the stability of MG, this can be clearly observed by the results shown above. The proposed 110MW Type-4 WGS is analyzed with VSC based HVDC link with 110kV DC link voltage, the simulation results shows that the grid is stable with active and reactive power flows and further analysis is required for a fault ride through conditions.

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APPENDIX

S.NO	PARAMETERS	RATING
1.	Wind turbine	110MW/2.2kV
2.	DC-bus bar voltage	110kV
3.	Grid voltage	220kV
4.	Generation	11kV-Swing/Slack bus
5.	Transmission line	160km
6.	Frequency	50Hz
7.	No of wind turbines	25
8.	Converter transformer	750/220kV
9.	Inverter transformer	11kV/220kV