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Mitigation Techniques for Elimination of Disturbances in Grid Tied Wind Farms

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ABSTRACT: The integration of wind farms with the grid is of utmost importance to harness the benefits of renewable energy sources, reduce costs, meet growing energy demands, and make the Earth more environmentally friendly. Over the last decade there has been significant transformation from conventional generation sources to variable energy resources and proposes areas for future research and innovation. However, integrating such variable energy sources can pose potential challenges that may impact grid stability. Therefore, it is essential to identify technical challenges and develop mitigation plans to overcome them. In this paper, a comprehensive techniques of grid challenges in terms of Wind farm starting, grid voltage profile, active power flow, network power quality, Transient system performance short circuit current calculation is discussed along with their corresponding mitigation plans is presented to ensure that the benefits of natural resources can be fully utilized without compromising the strength and security of the grid system [1]. The paper concludes by highlighting the encountered challenges and suggesting potential areas for future research and innovation. This paper serves as a valuable resource for researchers associated with integrating wind farms with the grid [2-5].

KEYWORDS: Wind turbine generator, short Circuit strength, Voltage stability, PCC, grid Impedance, LVRT Power grid, steady state stability, transient stability, ETAP.

I. INTRODUCTION

Large wind farm usually located in remote areas and are connected through transmission or distribution line. Hence, the grid impedance is increased which lead to voltage fluctuations and easily disconnection of wind farm from the grid [6]. High grid impedance also impacts the protection scheme operation as short circuit current contribution changes with and without grid connection. To measure grid strength, the short-circuit ratio (SCR) is calculated which also represents the voltage stiffness of a grid. A low short-circuit ratio indicate weak grid strength and can potentially impact protection system coordination relay settings.

System short-circuit strength is measured by calculating the short-circuit ratio at a resource's point of interconnection. The SCR is a screening measure to identify weak areas of the grid at a specified point (i.e. bus); therefore, a system consisting of numerous generators and transmission lines will have a different SCR at each bus. [7]. In order to calculate the Short circuit strength & determining the settings of protection devices, the accurate power system modelling is vital. Transient system performance and finally detailed information on Short circuit sources, modeling, an overview of the short-circuit ratio calculation method &model verification.

II. WIND TURBINE MODEL

Wind turbines are divided into five main groups (according to IEC 61400-27) based on machine type, speed control capabilities, and operational characteristics [8].

1) Type I: Squirrel-cage induction generator

Type I wind turbines use an induction generator directly connected to the grid without a power converter. The drop in line voltage in an induction machine following a three-phase fault to ground causes loss of excitation, resulting in supply of substantial transient current into the fault during the sub transient period (first few cycles), eventually leading the ac component to decay to zero.[7]

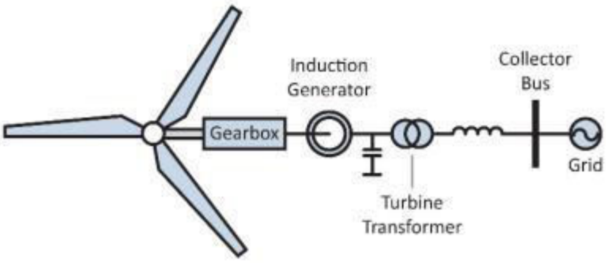

Figure1: Type I Squirrel cage IG

2) Type II: Squirrel-cage wound rotor induction generator with external rotor resistance

Type II wind turbines resemble Type I wind turbines, but they are equipped with variable rotor resistance and utilize avariable rotor resistance non synchronous machine. This modification aims to ensure a more consistent power output from the wind turbines despite fluctuations in wind speed. The short-circuit behavior of Type II machines is similar to Type I machines with different impedances [7].

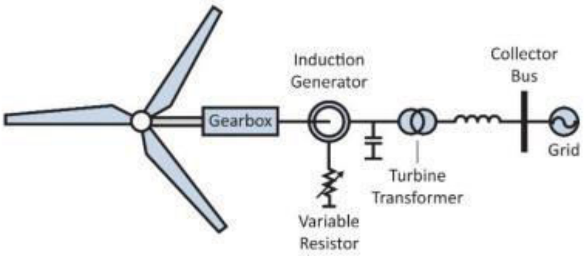

Figure1.2: Type II Squirrel Cage Wound Rotor Induction Generator with External Rotor Resistance Model

3) Type III: Doubly-fed asynchronous generator

Type III wind turbines use double-fed induction machines where the stator is directly connected to the grid and the rotor is connected through a back-to-back power converter. A crowbar system is used for power electronics converter protection (used to divert the induced rotor current protecting the rotor-side converter against over currents and the dc capacitors against over voltages) during faults. The effects of the crowbar resistance can indictate the ac fault contribution [7].

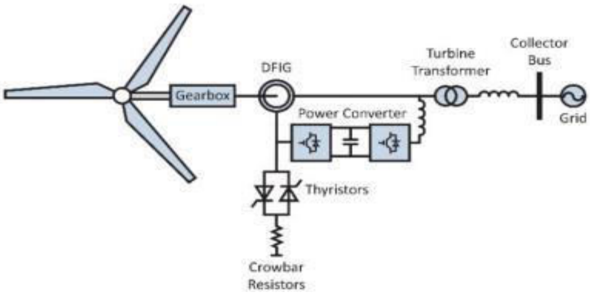

Figure1.3: Type III Double-FedNonsynchronousGenerator Model

4) Type IV: Full power converter generator

For Type I's and Type II's, the short-circuit behavior is dominated by the individual generator characteristics in contrast to Type III and Type IV generators. For Type IV's, a power converter drives the electrical behavior during a fault as the generator is connected to the grid through a full-scale power convertor that is sensitive to excessive currents. In order to protect the power electronics devices during a fault close to the plant, a current limiter is designed into the power converter. Rather than the common voltage source behind an impedance short-circuit equivalent used to model most generators, the Type IV design is represented as a simple current source for maximum short-circuit contribution.

IV machines use different control modes (reactive power control, voltage control, reactive power control with fault-ride- through) that affect the fault current contribution during a disturbance [7].

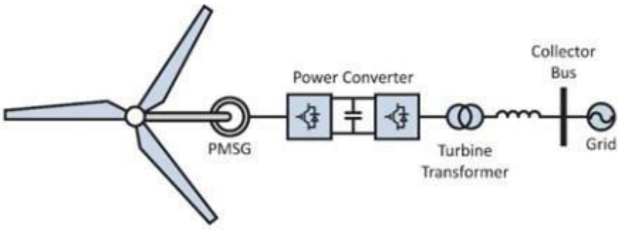

Figure1.4: Type IV Full Power Converter Generator Model

1) Type V: Synchronous generator mechanically connected through a torque converter

The Type V turbine exhibits typical synchronous generator behavior during faults and can be modeled similarly to synchronous generators. Figure 1.5 shows a network diagram model of a type V synchronous generator mechanically connected through a torque converter [7].

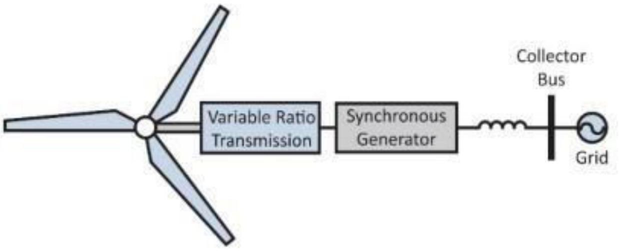

Figure1.5: Type V Synchronous Generator Model

Out of these 5 types, the DFIG is the most preferable one due to its capability of variable speed, grid support, and fault ride-through in a cost effective way. Almost 78% of the total wind installed capacity has employed DFIGs for the generation of electricity [9].

III.WIND FARM AND GRID INTEGRATION CHALLENGES

integration of wind power into the grid presents several challenges that impact system stability, power quality, and overall reliability. Major challenges are:

1. Intermittency: Wind energy generation is inherently variable due to changing wind speeds.
2. Power Quality Issues: Wind turbines can introduce harmonics and transients in to the power system.
3. Angular and Voltage Stability:

Wind farms' dynamic behaviour can affect the grid's angular stability (rotor angle stability) and voltage stability. The impedance path between wind farms and the grid involves transformers, underground cables, and overhead lines. Transformers primarily affect voltage profile through leakage reactance. Overhead line parameters significantly influence voltage profiles, with transmission lines having higher inductive reactance. Real power flow causes in-phase voltage drop, while reactive power flow induces angular shift. Connecting large wind farms to higher voltage networks is crucial for managing reactive power transfer and optimizing performance [1].

IV. LITERATURE REVIEW

To improve the voltage stability of wind power grid integration, it is recommended to enhance the fault ride- through capability. Appropriate measures, such as STACOM and SVC, should be implemented to prevent a second trip. A method for sizing STATCOM is proposed to boost the LVRT capability of wind farm grid integration. It is shown that a STATCOM size within the range of 0.8 to 1.0 p.u. strikes an optimal balance between the voltage stability margin and theoverall system cost[10]. On the same topic, a review article published [9] summarized that Voltage stability in wind- integrated power systems is a concern for grid security and reliability. This article provides [9] a detailed analysis of voltage instability complexities and implications for wind power integration. Development and implementation of grid codes are crucial due to wind power's intermittent nature. Integration of wind farms in developed countries has led to voltage instability issues, shifting focus from power quality to stability concerns. Techniques including FACTS devices and WAMS are discussed to address voltage instability challenges. Real-time monitoring systems like WAMS are emphasized for swift action against instability events. Comprehensive Voltage Stability Indices aid in identifying weak buses and assessing overall stability. Advanced forecasting, adaptive control systems, and energy storage solutions are recommended for maximizing wind power benefits. Further research is needed to analyze the integration impacts of other renewable energy resources with wind farms. Challenges in reactive power management in WPPs include limitations in power electronics and turbine distance from substations, affecting the ability to supply reactive power effectively. In both conventional and WPPs, reactive power balance relies on generators, line impedance, and load reactive components, with limitations impacting voltage stability [11].

V. RESULT AND DISCUSSION

In this paper a case study is being analyzed to calculate the maximum 3 phase fault current that can be through on 33 kV Bus Grid of WTG Transformer. For this case a practical 3 MW WTG is connected to 33 kV Utility grid through a 3.8 MVA WTG Step-up transformer. Thelengthof0.69 KV Cable is taken 120 m, length of 33 KV single circuit transmission line is taken 500 m and length of 33 KV double circuit transmission line is taken 2000 m. The block diagram of such has been mentioned. First, the manual calculation is to be performed to check the maximum fault current flow in the event of 3 phase fault & then the result shall be verified with ETAP Simulation soft. For the manual calculation, ohmic and MVA method are adopted for accuracy verification.

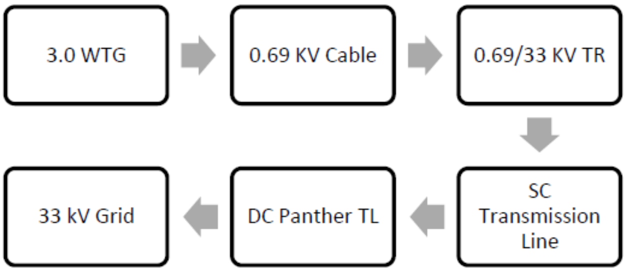

Figure: 1.6: WTG-Grid Interconnection Block Diagram

Table2: Equipment data

Sl. No	ID	Parameters	No
1	WTG	0.69kV,3.0MW,Type-3	01
2	Power Cable	5 R X 500mm2 (cu)Re :0.099Ω/1000m X :0.088Ω/1000 m	120m
3	WTGTR	0.69/33kV, 3.8MVA,%Z 7.5,R/X0.078	01
4	TL-1	Single Ckt	0.5km
5	TL-2	Double Ckt	20km
7	Power Grid	Short Circuit MVA–1503@ 33 kV.	

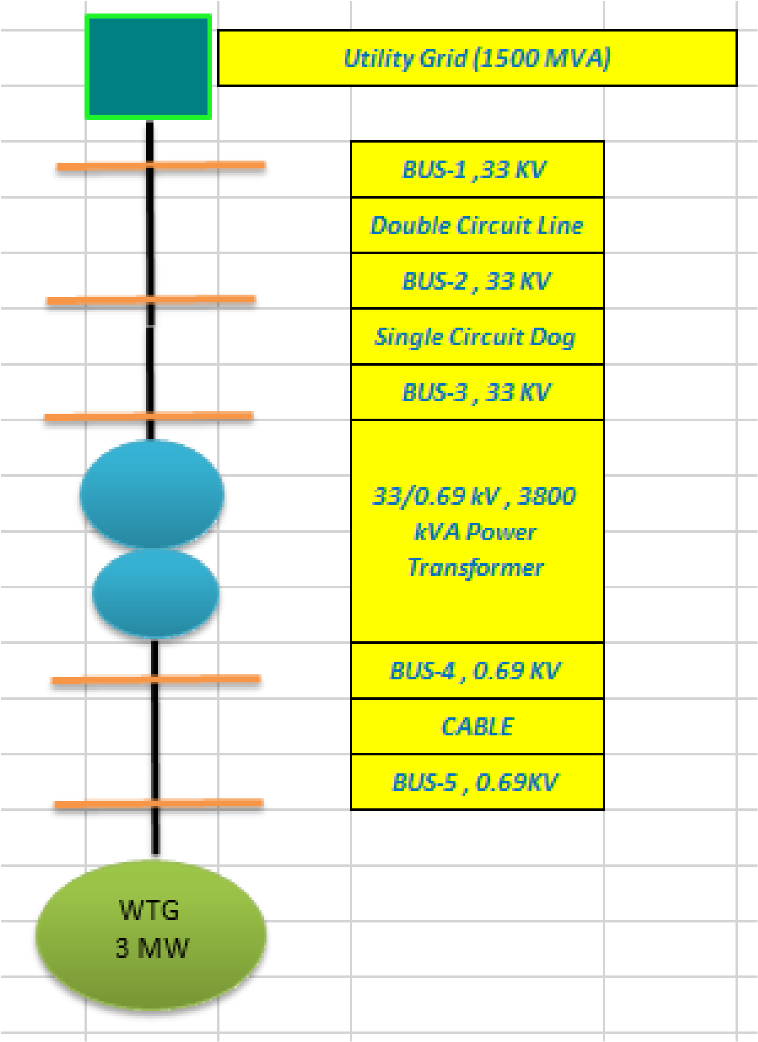

Figure: 1.7: Single Line Diagram

Total Single Circuit Transmission Line Impedance is 0.34 Ω, double circuit line impedance is 0.18 Ω & cable impedance 0.019 Ω at @ 75 Degree Celsius.

a) Table 3: Fault calculation using MVA Method

Source (Grid)	Source	=	1503	MVA
Transmission Line-1	TL-1	=	3178.26	MVA
Transmission Line-2	TL-2	=	5979.53	MVA
WTG Transformer	TR	=	50.67	MVA
WTG Cable	Cable	=	334.39	MVA
WTG	WTG	=	52.63	MVA
Fault Calculation- MVA Method-Fault @ BUS-1				

Source (Grid)	Source	=	1503	MVA
Network Reduction Technique: TL-1 in series with TL-2	TL_{New}	=	2075.23	MVA
TL new in series with Transformer	Tr_{New}	=	49.46	MVA
Tr New in series with Cable	$Cable_{New}$	=	43.09	MVA
Cable in series with WTG	WTG_{New}	=	23.69	MVA
Net MVA feeding to Bus-1 by WTG & System		=	23.69	MVA
Total MVA @ GridBus-1(WTG new II Grid Bus Old)		=	1526.89	MVA
Symmetrical Fault Current to be fed @33 KV Voltage @ Bus-1		**=**	**26.715**	**KA**
Fault Calculation- MVA Method-Fault @ BUS-3				
Source (Grid)	Source	=	1503	MVA
Network Reduction Technique: Source(Grid) in Series with TL)	TL_{New}	=	871.75	MVA
Cable in series with WTG	$Cable_{New}$	=	45.47	MVA
Cable New is series with Transformer	Tr_{New}	=	23.97	MVA
Total MVA from Source Side (Tr Series with Cable & with WTG))	Tr_{New1}	=	895.71	MVA
Symmetrical Fault Current to be fed @ 33 KV Side on Transformer Bus-3)		**=**	**15.671**	**KA**

b) Result Comparison & Discussion

The manual calculation using MVA method, Ohmic method and simulated through ETAP software for the Symmetrical Fault Current to be fed @33 KV Side on Transformer Bus-3) are summarized in the below table.

Table 4: Result

Sl.No	MVA method	Ohmic method	ETAP
1.	15.671 kA	15.252kA	18.026 kA

The results obtained indicate a 2% error in both the MVA and Ohmic methods, which is acceptable. However, the error marginally increases when comparing manual calculations to simulations. Therefore, the accuracy of all three methods could be further evaluated using field data. Moreover, the results obtained in this study can serve as a reference for the selection and sizing of equipment ratings, particularly circuit breakers, and for further studies on the topic.

VI. CONCLUSION

In Conclusion, the study found that though there is a small 2% error in both the MVA and Ohmic methods, when we compare manual calculations to simulations, the error goes up slightly. So, it's a good idea to check the accuracy of all three methods using real-world data and can guide future research. Further, to make wind power grids more stable, available FACTS device like STATCOM and SVC should be implemented to prevent problems like secondary trips. It's important to choose the right size for STATCOM, somewhere between 0.8 to 1.0 p.u., to balance stability and cost. We can also use advanced technology like forecasting and energy storage to make wind power more reliable, even when it's not always windy. It's a good idea to study how other renewable energy sources can work together with wind farms.

We need to create better ways to measure voltagestability and to monitor the system in real-time so we can fix problems quickly. And we should make sure that all the rules for connecting wind power to the grid are followed, so the system stays stable and reliable.

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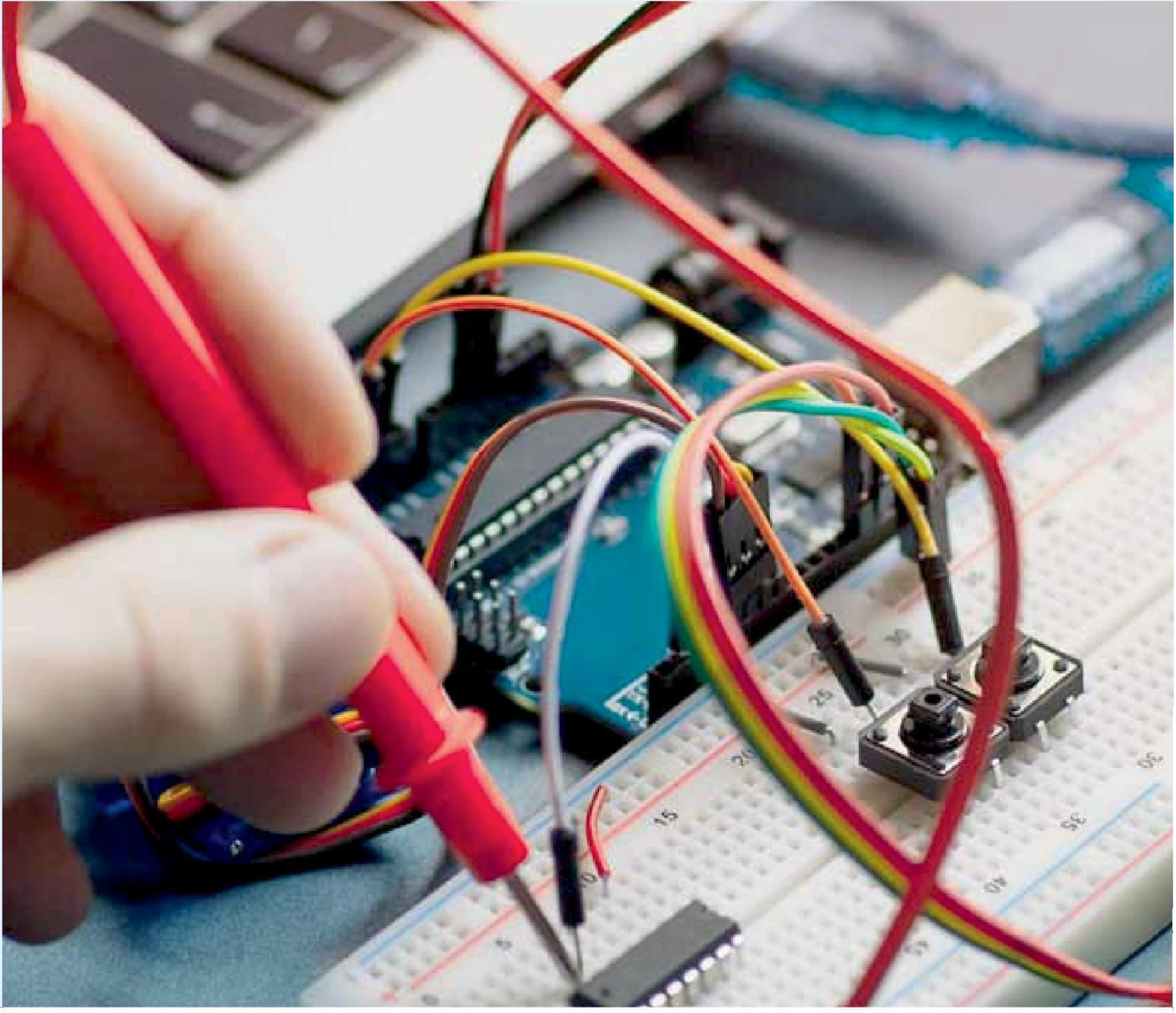

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