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Real Time Voltage Instability Detection in DFIG Based Wind Integrated Grid with Dynamic Components

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Abstract: Real-time voltage instability detection in the renewable integrated grid is proposed in this work. The present work is the augmented version of preclusive voltage instability detection index (SQLVIDI), in the companionship of the doubly-fed induction generator (DFIG) based wind energy conversion system (WECS). The time-domain simulated results show that the SQLVIDI index has a good capability to sense the impending voltage instability in the presence of a renewable integrated grid. The performance of this index is tested in New England (NE) 39-bus system by considering all the dynamic controls of the synchronous generators and DFIG with different loading conditions. The performance of this index with different load models has also been tested to find the suitable location of DFIG under-voltage stability point of view.

Keywords: Voltage Stability, Voltage Collapse, Reactive Power Losses, Wind Energy Conversion System, Synchro Phasor Measurements, Load Models

1. INTRODUCTION

Increasing pollution levels and depletion of fossil fuel reserves have resulted in intense efforts to get rid of the dependence of the industrial economy on fossil fuels. Rising renewable energy partake in the electrical grid not only address energy security issues but can also take a step for environmental conservation. The thrust for renewable energy sources is due to the following reasons:

- Reduction of carbon emissions from the energy systems.
- Sustained energy security due to reduced dependence on depleting fuel reserves.
- Prospect of widespread access of energy to areas far from conventional sources of energy.

Presently, in the global scenario, renewable-based generation is the utmost priority, due to energy security and environmental concerns. This enforces the transition of the power grid from conventional to renewable grid and thus leads to different instabilities.

As energy production from renewable sources has gone up, the share of wind energy is highest at around 5.6% of the total energy production among renewable sources (excluding large hydropower) [1]. However, unlike conventional energy sources, these renewable Sources are dependent on energy (through sunlight, wind, etc.) whose availability is intermittent. Such stochastic behaviour of supply introduces an appreciable amount of uncertainty in the demand-supply balance. In the case of standalone systems, this is not a pressing issue but for the renewable sources to be integrated into the grid such uncertainty must be taken care of to ensure the stability of the system.

Wind energy has a more important role to play in the area of renewable energy and has reportedly shared a total of 539 GW [1] of power to global energy needs in 2017. India with 34GW (by March 2018) is standing in the fourth position in the world, in the arena of harvesting wind power [2]. Various grid impact studies having a high penetration of wind energy being integrated into the grids show that the security and functioning of both the wind farms and power grid are affected by the voltage stability issues [3]. As the new renewable integrated grids are the future, it is

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important to study their impact on voltage stability. The present paper steps in this direction, which validate real-time voltage stability index SQLVIDI for DFIG based wind integrated grid. Identifying suitable locations to install DFIG with various loading models, viewed from the voltage stability perspective is another key contribution of the present work.

Different methods have been developed in the literature to detect voltage instability with a Wind Energy Conversion System (WECS) based on DFIG. The method in [3], [4] utilize P-V curves and V-Q curves for voltage instability detection. These techniques successfully locate the points of voltage instability but suffer from not being competent enough to identify the voltage instability in real-time as they are framed offline. A probabilistic voltage stability algorithm is proposed in [5] to detect voltage instability and load margin. This algorithm also detects voltage instability through V-Q curves which are static and difficult to apply in real-time operations. The work in [6] demonstrates the effect of high wind energy penetration in the device and the significance of control strategies for improving the voltage stability using the time series power flow technique. A comparative stability study is reported in [7], [8] to achieve a 100% penetration level. This study shows that complete replacement with DFIG deteriorates voltage stability, especially with voltage-dependent loads. The methodology in [9] proposed an evolutionary technique based method for corrective voltage control through load shedding to maintain the desired load margin. These evolutionary techniques and optimization techniques need extensive offline study and may require high computational ability. The influence of DFIG centred wind power generation for voltage stability has been studied in [10], [11] and this work affirms that voltage stability improves with DFIG if the entire load on the system is solely induction motor load. However, the practical system may have a combined load and, therefore, to characterize the voltage stability of the network, combined load models need to be formulated. The methodology proposed in [12] detects voltage instability in the presence of DFIG with reduced duration of time-domain simulation but it needs an extensive offline study to fix the threshold values. Singular value decomposition (SVD) tracking from the load flow matrix is explored in [13] to detect the proximity of voltage instability in a wind integrated grid. This method, however, is computationally burdensome.

There are also methodologies proposed to maintain and support the grid voltage stability through control mechanisms in DFIG itself. A framework for controlling the DC link voltage with DFIG connected to weak nodes in the system has been formulated in [14]. This controlled DC link voltage may support grid voltage and stability. To improve the grid’s voltage stability, the centralized voltage control scheme [15] maximizes the reactive power reserves in DFIG. DFIG's reactive power support is evaluated in [16] and optimal reactive power allocation was formulated to support voltage stability. In [17], GSC is designed to stabilize reactive power output and DC-link voltage to improve the stability of the grid voltage. Together with other dynamic models such as OXL and OLTC, reactive power capability curves of both GSC and RSC are viewed in [18] to identify how long term voltage stability is affected by DFIG. These studies show that the penetration level of DFIG into the grid has a significant benefit in terms of improving long term voltage stability. To preserve voltage stability, both of these methodologies take into account reactive power regulation in the DFIG. But in the integrated system during a large amount of power flow between the nodes (under stressed condition) from various generating sources, reactive power losses in lines is a major cause for voltage instability.

All the methodologies mentioned above detect or improve voltage stability for both conventional and renewable integrated grids but most of them need either rigorous off-line studies or high computational infrastructure. Besides, they also did not consider the type of load the DFIG has to supply. Load models are very significant in voltage stability studies and therefore in this work, three different load models are considered for detecting voltage instability. The capability of the index suggested in [19] is checked in this paper to diagnose voltage instability in the existence of WECS based on DFIG. The proposed methodology is real-time and covers the shortcoming of the available methodologies. The proposed methodology also comes under the WAMS for long term voltage instability detection. One of the weak nodes has been connected to DFIG based WECS throughout this study. The weak nodes are the nodes that are vulnerable to voltage instability and are obtained through contingency analysis implementation. The performance of the index under spurious noise signals is tested in [20].

The methodology proposed in [21] does not take into account generator reactive power boundaries and in [20] does not account for the effects of OXL and OLTC. However, consideration of them is of utmost importance in a realistic system as they lead to voltage instability such as OXL exceeding its limits or OLTC reverse action, etc. under strong reactive power requirements on the system [22].

In this work, all the synchronous generators and DFIG has been considered with their dynamic models along with OLTC dynamics. The details of the considered models are given in the results section. This ensures the consideration of all the equipment that may cause voltage instability. The output of this index with different load models has been tested to determine the acceptable location of DFIG from the voltage stability point of view.

The proposed index utilizes the reactive power losses in the lines that are occurring at every instant. These losses are computed from the PMUs which can provide data at a fast reporting rate as mentioned in [19]. This faster rate of data is used to calculate the line losses accurately. To measure nodal reactive power losses, this line loss along with the direction of real power flows in the line is used [23]. The time-series variations of the bus reactive power losses characteristics have been studied to develop the index.

2. PROPOSED METHODOLOGY

The methodology proposed here is based on the time-series variations of the reactive power losses in the system [23]. In a power system with different nodes and branches as loading increases the line losses increases. If the loading on the system is very high and is much greater that than the surge impedance loading of the lines, then line reactive power losses increases abruptly. These losses reflect the nodal reactive power losses. The proposed methodology captures when the sudden shoot up of losses going to takes place in the system, as this condition is an indication of impending voltage instability. The sudden shoot up of reactive power losses are calculated by computing the SQLVIDI and the sign of SQLVIDI is a direct indication of the stability status of the system. The directions to compute the SQLVIDI [19], in brief, are as follows.

i. From the PMU measurements compute the time series nodal reactive power losses [23] in the system by observing the branch reactive power losses and direction of real power.

ii. Compute the consecutive reactive power loss (CQL) and reactive power loss deviation from base case loading (CQLB) at all the nodes in the system [21].

iii. Calculate the time series ratio of CQL and CQLB and name it as voltage instability detector (QLVID).

iv. The consecutive change in QLVID is used for the detection of impending voltage instability. This consecutive change in QLVID is called QLVIDI. Apply the smoothening technique as mentioned in [24] to QLVIDI so that it is free from noise and oscillations of PMU measurements. The smoothened QLVIDI is called SQLVIDI.

v. The sign of the SQLVIDI indicates the stability status of the system. If the sign of the index is negative or changes from positive to negative, then the system is stable. Otherwise, if the sign is positive, it is an indication that reactive power losses in the system are increasing excessively which happens usually under high stressed conditions or contingency conditions.

vi. The index is accurate and fast in detection as it explores the system reactive power losses.

The computed index using the abovementioned procedure is very accurate and very fast in detection. It is because voltage instability depends on the reactive power support and evolution of the reactive power losses. This index may be used as an early warning index for impending voltage instability detection in the integrated power system.

A. *WECS Modelling*

A WECS comprising of a wind turbine, DFIG, and a controller to control WECS system outcomes, viz., torque, power, etc., is used in this present work. The aerodynamic power from the wind turbine is as follows [25].

$$P_w = \frac{1}{2}\rho A V^3 C_p(\beta, \lambda) \tag{1}$$

Where, ρ - air density factor (1.225 Kg/m^3), P_w - wind turbine output power, V - velocity, A - area swept by the blades and C_P - power coefficient. The typical characteristic of C_P vs λ is shown [25]. The output power w.r.t. wind speed is shown in Fig.1. The wind turbine of this characteristic has been connected to DFIG to extract and inject the power into the grid. The DFIG centred WECS block view is shown in Fig.2.

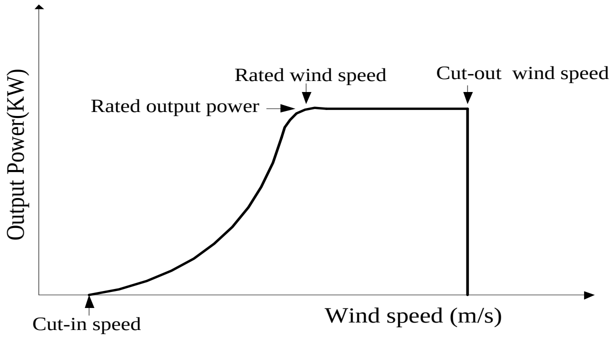

Figure 1. Output power Vs wind speed

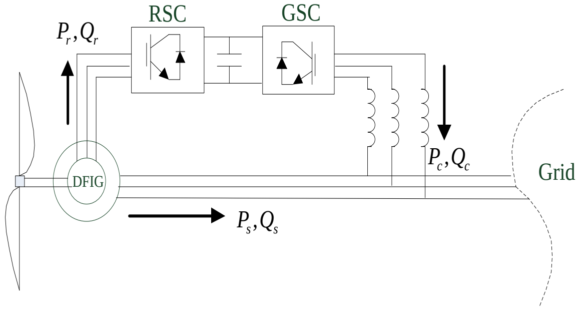

Figure 2. DFIG based WECS connected to the grid

DFIG uses a rotor and stator terminals to get coupled to the grid. From rotor to grid it utilizes two converters and a DC link capacitor. The two converters are, rotor-side converter (RSC) and grid-side converter (GSC), which are used to control the active power and reactive power injection into the grid. RSC's main purpose is to provide optimal positioning of rotor flux and stator flux to set the desired torque by controlling the rotor current and thereby achieve maximum power point tracking (MPPT). Apart from MPPT it also regulates output active power and reactive power at the stator terminals by utilizing a torque controller [26]. On the other hand, the GSC is aimed at regulating the DC link voltage. In the case of DC-link voltage attaining a value larger than the set threshold because of increased wind velocity, GSC makes sure that the DC link voltage increase to the level of threshold voltage by raising the output power. GSC is also allowed to inject or absorb the reactive power to maintain the voltage in the specified limits. The complete details of the functioning of GSC and RSC for controlling active power, reactive power and torque are given in [26], [27]. The real and reactive powers in the arbitrary reference frame shown in Fig.2 are given as follows.

$$P_{s1} = v_{ds1} i_{ds1} + v_{qs1} i_{qs1} \tag{2}$$

$$Q_{s1} = v_{qs1} i_{ds1} - v_{ds1} i_{qs1} \tag{3}$$

$$P_{r1} = v_{dr1} i_{ir1} + v_{qr1} i_{iq1} \tag{4}$$

$$Q_{r1} = v_{qr1} i_{dr1} - v_{dr1} i_{qr1} \tag{5}$$

$$P_{c1} = v_{dc1} i_{dc1} - v_{dc1} i_{qc1} \tag{6}$$

$$Q_{c1} = v_{qc1} i_{dc1} - v_{dc1} i_{qc1} \tag{7}$$

$$T_{e1} = \psi_{ds1} i_{qs1} - \psi_{qs1} i_{ds1} \tag{8}$$

$$\frac{d\omega_{m1}}{dt} = \frac{1}{2H_{m1}} \left(T_{m1} - T_{e1} \right) \tag{9}$$

Where, P_{s1} is the stator real power, v_{ds1} is the d-axis stator voltage, v_{qs1} is the q-axis stator voltage, i_{ds1} is the d-axis stator current, i_{qs1} is the q-axis stator current, Q_{s1} is the stator reactive power, P_{r1} is the rotor real power, v_{dr1} is the d-axis rotor voltage, v_{qr1} is the q-axis rotor voltage, i_{dr1} is the d-axis rotor current, i_{qr1} is the q-axis rotor current, Q_{r1} is the rotor reactive power, P_{c1} is the converter real power, v_{dc1} is the d-axis converter voltage, v_{qc1} is the q-axis converter voltage, i_{dc1} is the d-axis converter current, i_{qc1} is the q-axis converter current, Q_{c1} is the converter reactive power, T_{e1} is the electromagnetic torque, Ψ_{ds1} is the d-axis stator flux linkages, Ψ_{qs1} is the q-axis flux linkages, ω_{m1} is the angular speed, T_{m1} is the mechanical torque, T_{e1} is the electromagnetic torque, H_{m1} the inertia constant of the generator, T_{m1} is the mechanical torque.

3. SIMULATION RESULTS AND DISCUSSION

The proposed methodology is tested and validated using the New England 39-bus test system. This test system contains 10 generator buses and 19 load buses. All the generators are assumed to be synchronous generators. The equations governing the generator (IV order model) and exciter are as follows [28].

$$\dot{\delta} = \Omega_b (\omega - 1) \tag{10}$$

$$\dot{\omega}_i = \frac{P_{mi} - P_{ei} - D_i(\omega_i - 1)}{M_i} \tag{11}$$

$$\dot{e}'_{qi} = \frac{-f_s(e'_{qi}) - (x_d - x'_{di}) i_{di} + v_f^*}{T'_{d0}} \tag{12}$$

$$\dot{e}'_d = \frac{-e'_{di} + (x_{qi} - x'_{qi}) i_{qi}}{T'_{q0}} \tag{13}$$

$$p_e = (v_q + r_a i_q) i_q + (v_d + r_a i_d) i_d \tag{14}$$

$$v_i + r_{ai} i_{qi} - e_{qi}' + (x_{di}' - x_{li}) i_{di} = 0 \tag{15}$$

$$v_{di} + r_{ai} i_{di} - e_{di}' + (x_{qi}' - x_{li}) i_{qi} = 0 \tag{16}$$

$$\dot{V}_m = \frac{V - v_m}{T_r} \tag{17}$$

$$\dot{V}_r = \frac{K_a \left(v_{ref} - v_{mi} - v_{r2} - \frac{k_f}{T_{fi}} v_{fi} \right) - v_{r1}}{T_a} \tag{18}$$

$$v_r = \begin{cases} v_{r1} & if\ v_{r\min i} \le v_{r1} \le v_{r\max i} \\ v_{r\max i} & if\ v_{r1} > v_{r\max i} \\ v_{r\min i} & if\ v_{r1} < v_{r\min i} \end{cases} \tag{19}$$

$$v_{r.} = \frac{-\left(k_f / T_f \right) v_f + v_{r2}}{T_f} \tag{20}$$

$$\dot{v}_f = \frac{-v_{fi} \left(1 + s_e(v_{fi}) \right) - v_{ri}}{T_{ei}} \tag{21}$$

The parameters found in (10) to (21) and their description is given in Table I.

A load increment of 0.2 % pu/sec is provided to all the load buses in tandem, to allow the system to switch to an unstable state from a stable state. Here, three kinds of load models are considered; 1) All the load buses are assumed to be PQ buses, 2) All the load buses are assumed to have constant impedance and 3) All load buses are assumed to comprise ZIP load. In the considered test system contingency analysis is also applied to obtain the weak nodes and the simulation results of these nodes are presented [29]. In one of the weak nodes, a DFIG of 10MW capacity has been connected. This additional capacity of 10MW has been subtracted from one of the generators (Generator31) so that the specified generated power on the considered test system will remain constant. All the synchronous generators are considered with 4th-order flux decay models and IEEE type-1 excitation system with enforced over-excitation limiters (OXL). The time-domain simulations are done in the power system analysis toolbox (PSAT) in the MATLAB environment. The simulation results with different types of load models are discussed in the following section.

TABLE I. PARAMETERS AND THEIR DESCRIPTION

S. No	Parameter	Description
1	δ	Rotor angle
2	Ω_b	Base speed
3	ω	Rotor speed in p.u.,
4	P_{mi}	Mechanical power input
5	P_{ei}	Electrical power output
6	D	Damping coefficient
7	M	Mechanical starting time
8	e_{qi}	q-axis transient voltage
9	e_{di}'	d-axis transient voltage
10	x_{qi}	Synchronous reactance in q-axis
11	x_{qi}'	Transient reactance in q-axis
12	x_{di}	Synchronous reactance in d-axis
13	x_{di}'	Transient reactance in d-axis
14	i_q	Quadrature axis current
15	i_d	Direct axis current
16	T_{d0}'	Open circuit transient time constant in d-
17	T_{q0}'	Open circuit transient time constant in q-
18	v_{qi}	q-axis voltage
19	r_a	Armature resistance
20	v_{di}	d-axis voltage
21	x_{li}	Leakage reactance
22	v_f	Field voltage
23	v_{mi}	Transducer voltage
24	T_r	Transducer time constant
25	K_f	Stabilizer gain
26	T_f	Stabilizer time constant
27	K_a	Amplifier gain
28	v_r	Regulator voltage
29	v_{ref}	Reference voltage
30	v_{rmaxi}	Regulator voltage – maximum
31	v_{rmini}	Regulator voltage – minimum
32	v_{r1}	Saturation voltage point 1
33	v_{r2}	Saturation voltage point 2
34	$s_e(v_f)$	Saturation function
35	T_{ei}	Field circuit time constant
36	V	Terminal voltage

A. PQ-Load

All the load buses are assumed with PQ loads and loads are incremented as mentioned above. The performance of the index without DFIG in [20], [21] obtained time-domain simulations in MATLAB by using repetitive runs of the Newton-Raphson (NR) load flow method and the initial conditions are obtained from PSAT. In this work, the performance of the index is validated with DFIG connected at bus-7 and simulations are done only in PSAT in the MATLAB platform. Time-domain simulations in PSAT are more reliable than repetitive runs of NR load flows. The wind speed considered in this work is shown in Fig.3. Time series voltages in pu which are assumed to be obtained from PMUs are shown in Fig.4, from this, it is evident that voltage instability occurs at 68.7 sec. During this 68.7 sec, the reactive power losses at all the nodes are calculated from assumed PMU measurements are shown in Fig.5.

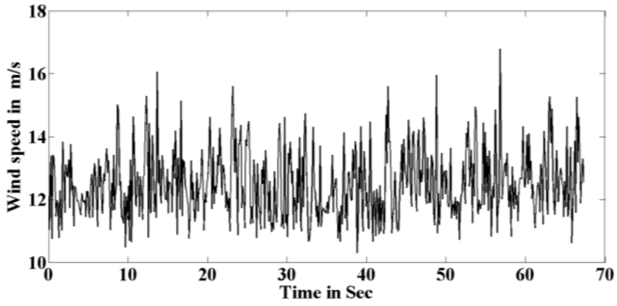

Figure 3. Wind speed in m/s

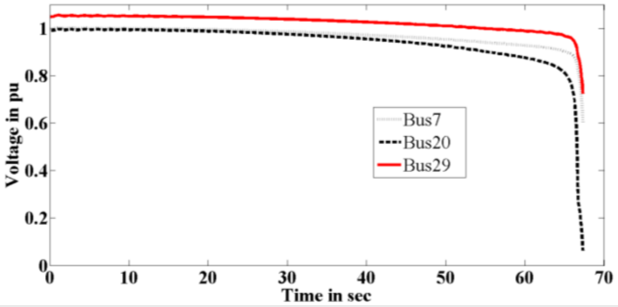

Figure 4. Voltages with continuous load increment using PQ load.

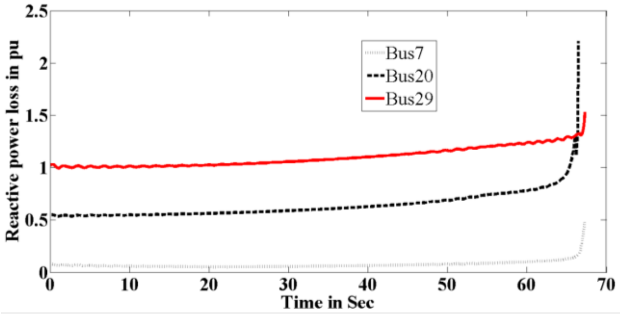

Figure 5. Nodal reactive power losses with continuous load increment using PQ load

A careful inspection of the nodal reactive power losses shows that for smaller increments in load, there is a linear and a minor change in nodal reactive power loss. But as the system is stressed, then the change in losses between two consecutive instants increases in an exponential fashion and near the voltage collapse point these losses increases abruptly. The index SQLVIDI computes the sharp rise in nodal reactive power losses and reports a positive value if the nodal reactive power losses start increasing exponentially. Fig.6 shows the plot of SQLVIDI and it has become positive at 48.6 sec. At bus 29 (Fig.6) the index begins from a positive value. This is because the nodal reactive power losses initially decrease from the baseload condition due to system dynamics. Voltage instability detection time is the time at which the index becomes positive (changes from negative to positive) and sustains that positive value. Voltage instability detection has been done at 48.6 sec and giving a window of 18.7 sec for the power system operator to respond and to take remedial actions.

The DFIG considered in bus-7 is operating under voltage control mode. To show the efficacy of the DFIG in the power system, simulation is also done without using the DFIG in the same test system, and the voltage instability has occurred at 67 sec as shown in Fig.7. From this, it is observed that the voltage profile has been maintained close to the nominal value even at time t=65.5 sec, which is near to collapse time. At this time, the load on the system is so high and the system demands a high amount of reactive power to maintain the voltage stability. This shows that the DFIG in the test system is acting as a reactive power reserve and is supporting the voltage and thereby improves the voltage stability. But, this may not be appealing if DFIG replaces the synchronous generator because of the lower power handling capability of DFIG in contrast to a synchronous generator. DFIG can support voltage stability in parallel with synchronous generators in the system.

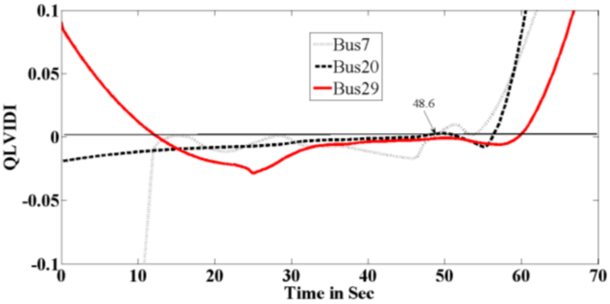

Figure 6. SQLVIDI plot with continuous load increment using PQ load

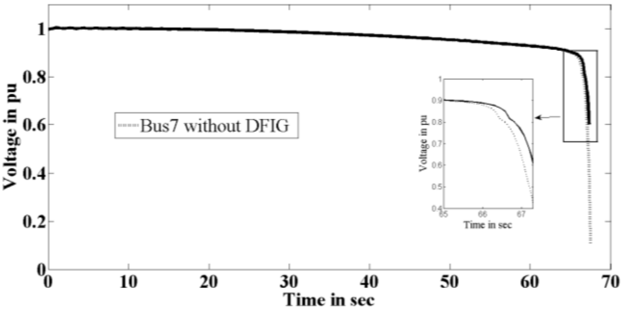

Figure 7. Comparison of voltages at bus 7 with and without DFIG and with continuous load increment using PQ load.

B. *ZIP-Load*

ZIP load is considered the most practical load, as the power system usually contains a combination of loads. The ZIP load models can be mathematically formulated as follows [30].

$$P_i = P_0\left[a_1\left(\frac{V_i}{V_0}\right)+a_2\left(\frac{V_i}{V_0}\right)+a_3\right] \tag{22}$$

$$Q_i = Q_0\left[a_4\left(\frac{V_i}{V_0}\right)+a_5\left(\frac{V_i}{V_0}\right)+a_6\right] \tag{23}$$

Where, Q_0 and P_0 are the base loads, P is the real power and Q is the reactive power at an operating voltage V, V_0 is the nominal voltage. In this work a = 0.2, b = 0.2 and c = 0.6 are considered.

In this simulation also all the load buses are simultaneously loaded and the voltage plot in Fig. 8 shows that voltage instability has occurred at 89.7 sec. Fig. 9 shows the computed nodal reactive power losses. It shows that, for a system working in a highly stressed condition, nodal reactive power losses rise sharply. From the index plot shown in Fig. 10, it is observed that the imminent voltage instability is at 74.19 sec. It gives a time margin of 15.51 sec to respond for activating the reactive power reserves or initiation of load shedding to stop further decline in voltage that causes voltage instability. Comparison of voltages at bus-7 with and without connecting DFIG is also done and is shown in Fig.11, which clearly shows that both voltage profile and voltage stability are improved with the DFIG.

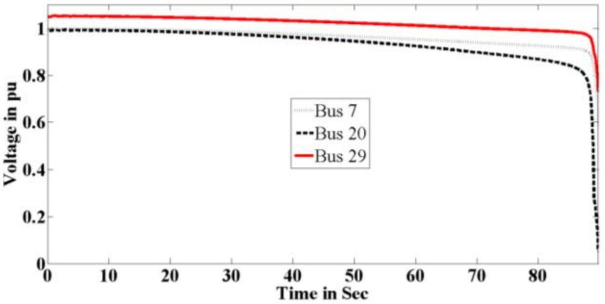

Figure 8. Voltages in pu with continuous load increment considering ZIP load.

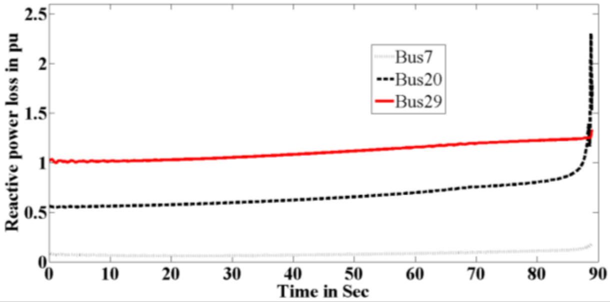

Figure 9. Nodal reactive power losses in pu with continuous load increment considering ZIP load.

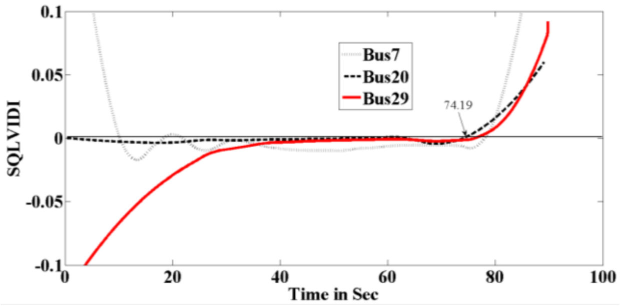

Figure 10 SQLVIDI plot with continuous load increment considering ZIP load.

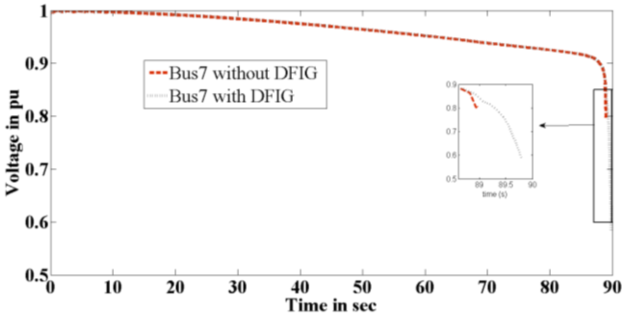

Figure 11. Comparison of voltages at bus-7 with and without DFIG with continuous load increment considering ZIP load.

C. *Contingency Analysis*

To test the performance of the index and voltage support capability of the DFIG, a branch connecting nodes 1 and 2 have been removed at time t=15 sec with the ZIP load along with the same load increments pattern mentioned above. Fig.12 depicts time series voltages under contingency conditions, it shows that voltage instability occurs at 90.13 sec. The index for detecting the voltage instability (Fig.13) detects at time t=72 sec allowing 18.13 sec for the power system operator to respond. Without DFIG voltage instability occurred at 89.11 sec. For this type of load, DFIG has improved voltage stability by 1.02 sec.

For the other two kinds of load models (PQ and constant impedance) branch contingency is applied and it is found that voltage stability is improved with PQ load by 0.5 sec and voltage stability has not been improved with constant impedance load. These results show that DFIG is capable to perform better with PQ load even in the case of contingency. The performance of the index for detecting instability and DFIG for improving voltage stability is shown in Table II. The performance of both index (SQLVIDI) and DFIG in the presence of various load models shows SQLVIDI can sense the upcoming voltage instability early for taking the remedial actions, and DFIG can improve the voltage stability.

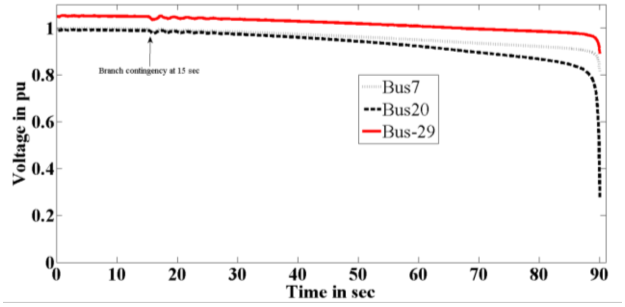

Figure 12. Voltages in pu with continuous load increment considering ZIP load with contingency.

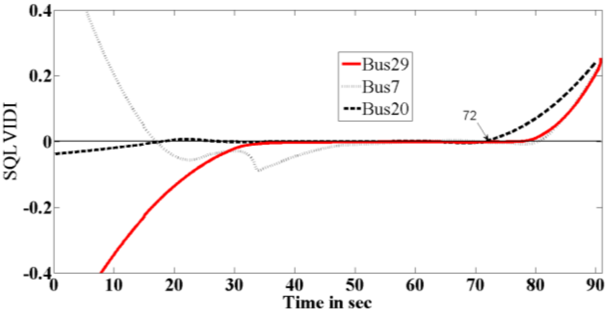

Figure 13. Voltages in pu with continuous load increment considering ZIP load with contingency.

TABLE II. QLVIDI AND DFIG'S PERFORMANCE WITH DIFFERENT LOAD MODELS

S. No.	Type of Load	Collapse Time (s)	Detection Time (s)	Time Margin (s)	Voltage Collapse Time Without Connecting DFIG (s)	Voltage Improvement in Time With DFIG (s)
1	PQ	68.7	48.6	20.1	67	1.7
2	ZIP	89.7	74.19	15.51	88.9	0.8
3	Constant Impedance (Z)	167	97	70	167	Nil

4. CONCLUSIONS

The energy security and environmental concerns enforce the compulsory incorporation of renewable energy power sources into the existing grid at a larger scale. The transition of the conventional grid to a renewable grid leads to stability issues. Voltage instability detection for the renewable integrated grid is validated by connecting a DFIG at one of the weak nodes in the considered test system (NE 39 Bus System). The proposed voltage instability detection index (SQLVIDI) algorithm has been applied to various load models to find the suitability of the DFIG installations for voltage stability improvement. The simulation results show that DFIG can act as a good source of reactive power support in the system, especially at weak nodes. The simulation results also reveal that voltage stability has been improved with PQ and ZIP loads. This indicates DFIG installations to achieve voltage stability improvement. The performance of both index (SQLVIDI) and DFIG in the presence of various load models shows SQLVIDI has the competence to sense the approaching of voltage instability in an early time for taking the remedial actions, and DFIG can improve the voltage stability.

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