Modeling of Windmills for Improving Voltage Stability in Distribution Network

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***Abstract*— The most important factor in the power system is to provide stable and smooth electricity to the consumers in front of the big increase in the usage of the renewable energy, especially, wind power farms. This paper will study the effects of wind energy units on voltage stability in distribution networks. We will consider that the wind farms are connected to different locations of the unit to see how far the contribution of wind farms on the voltage stability is.**

***Keywords*— voltage stability, distribution system, penetration level, buses**

I. Introduction

Nowadays, power systems are extremely huge, and contain hundreds of generators, transmission lines, transformers, and loads. All of those components are connected through thousand of bus bars. The more increase of loads, the more electric power need to be generated.

The voltage instability issue might be occurred in distribution or transmission systems or in both. For that, the problem of voltage instability in distribution units is considered very important [1, 2].

In some Distribution systems there might be small generators connected directly to these networks to generate low level voltage. Electrical engineers call these small generators the distribution generators. Usually, the wind turbines, thermal, and photovoltaic plants are called distribution generators[4,5].

When distribution generators are Connected to a distribution network, that could effect the system's performance regarding to the location and rating of the generators, and there are tow sides of the affects[6], good affects distribution generators can drop the power losses, improve power quality, and voltage magnitude[7,8]. Bad side, distribution generators or some types of it might cause voltage stability problems due to their variable output, such as solar energy converters and wind farms[9,10]. Wind farms effects sudden changes in the injected power into the system, because the power output from its generators can change rapidly on time. If the generation were low, there would be a voltage drop at the end of the distribution feeder. While the high generation would cause over voltage. All of that means voltage instability problems[11].

This paper aims to provide explanations of the impact of wind farms on distribution networks' voltage stability. A radial distribution network were suggested, and wind farms were connected to different nodes at different buses. A voltage collapse proximity indicator M, based on network load ability is used to find out the affect of wind farms on voltage stability. Powerworld® simulator was used to study the case.

II. Voltage Stability Index

In this paper the voltage stability index L was created using a simple power system as shown in Fig. 1. [12]. From Figure (1). P, and Q can be written as for single phase:

$$P_{source} = (P_s^2 + Q_s^2) \cdot \frac{R}{V_s^2} + P_{load} \quad (1)$$

$$Q_{source} = (P_s^2 + Q_s^2) \cdot \frac{X}{V_s^2} + P_{load} \quad (2)$$

Regarding to the above equations:

Let assume that P.source and Q.source as variables, the above equations are quadratic in form and for Ps and Qs have real roots, given by:

$$[(X \cdot P_L - R \cdot Q_L)^2 + X \cdot Q_L + R \cdot P_L] \cdot 4 < 1 \quad (3)$$

From equation number (3) :

$$[(X \cdot P_L - R \cdot Q_L)^2 + X \cdot Q_L + R \cdot P_L] = L \quad (4)$$

Where L can be defined as the voltage stability index. The closer the L to the unity 1.0 the closer the system to the voltage drop off point. The authors [13] in found that the single phase representation did not represent the actual system, and to solve this problem the L should be:

$$[(X \cdot P_L - R \cdot Q_L)^2 + (X \cdot Q_L + R \cdot P_L) \cdot V_s^2] \cdot \frac{4}{V_s^4} = L \quad (5)$$

Where this equation can defined the L at any node. [14] The voltage stability index L also can be defined as the following ratio (7):

$$L = \frac{Z_{SEQ}}{Z_{LEQ}} \quad (6)$$

Z.SEQ: Equivalent impedance for the system.

Z.LEQ: Equivalent load impedance for the load.

If the stability index approaches 1 p.u, that means the system is closer to the voltage collapse point or the system will be unstable.

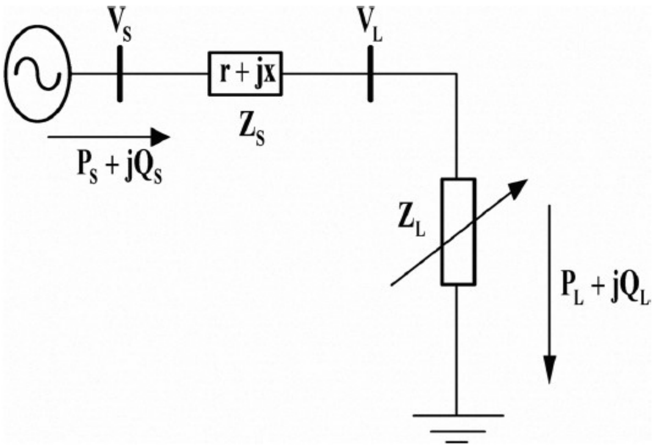

Fig. 1. A single-line system

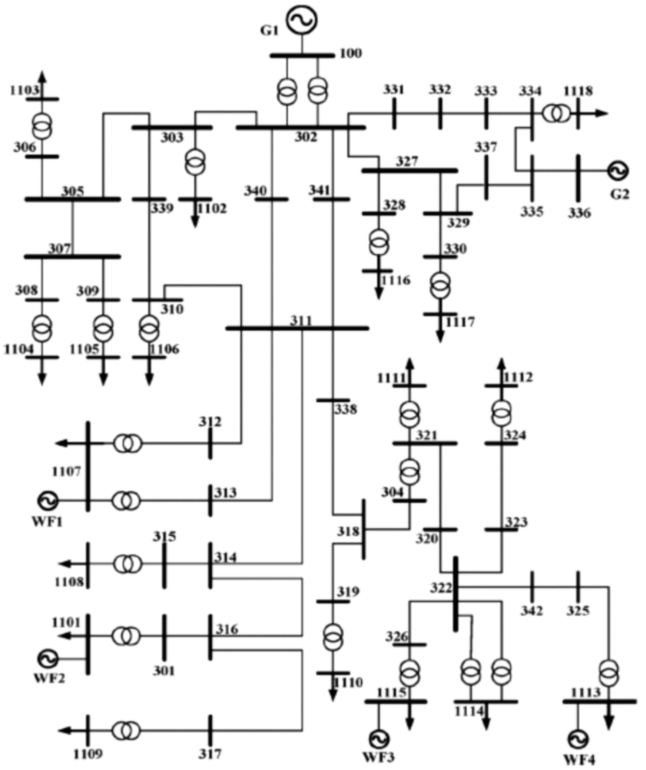

Fig. 2. A 61-bus radial sidtribution network with connecting 4 wind farms

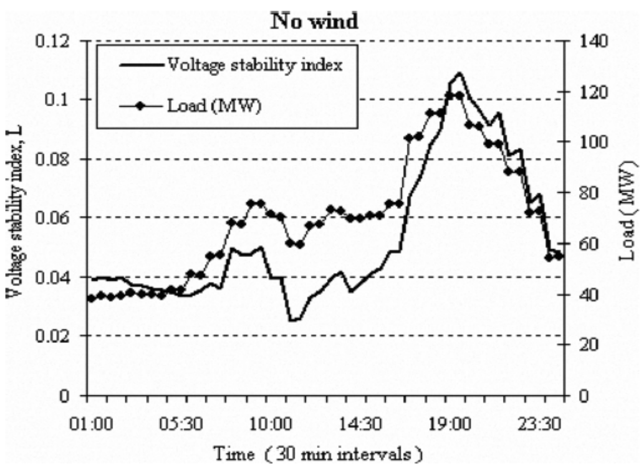

Fig. 3. Voltage stability idex of 61-bus network without wind generation

III. Testing the Radial Bus Distrubution System

A bus radial distribution network was simulated in Powerworld®, and it was used as the test system [15]. The (Fig. 2) shows bus radial distribution system with two thermal generators which supply power to the 18 load points through 132/33/ kV substation. The voltage level at the loads is 11 kV and the total load is 118 MW. The total generation capacity is 185 MW and the sending end voltage at Bus 100 and at Bus 336 is set to be 1.0 p.u. The Wind stations were connected at different buses at different penetration levels of wind generation with different scenarios, and the capacity of each wind farm was 65 MW.

IV. The Simulation Model

The simulation was done using Powerworld® utilizing with time-stop simulation option, where inputs can be varied at any time of the simulation window. Wind turbines were connected to the distribution system at different locations and at different MW outputs. The different wind generation are:

S1: 1 wind farm connected at bus 1107.

S2: 2 wind farms connected at bus 1107 and 1115.

S3: 4 wind farms connected at bus 1101, 1107, 1113 and

1115 respectively.

All wind farms' outputs were varied every 30 minutes to behave exactly like real wind farm under variable speed of wind, and the generation was varied between 15% and 30% of the total connected load. The voltage stability index L is calculated for each time step.

V. Simulation Results

Simulation results were concluded through two steps :

A. *No windmills were connected*

The presented results in Fig.3. were for a 24-hour period. The voltage stability index L of the network was calculated for every 30 minutes of the simulation by the equation (7). Figure 3 shows a plot of the load (MW) and the voltage stability index L when no wind generation was connected to the network. The maximum value (0.109) of L was recorded at peak load.

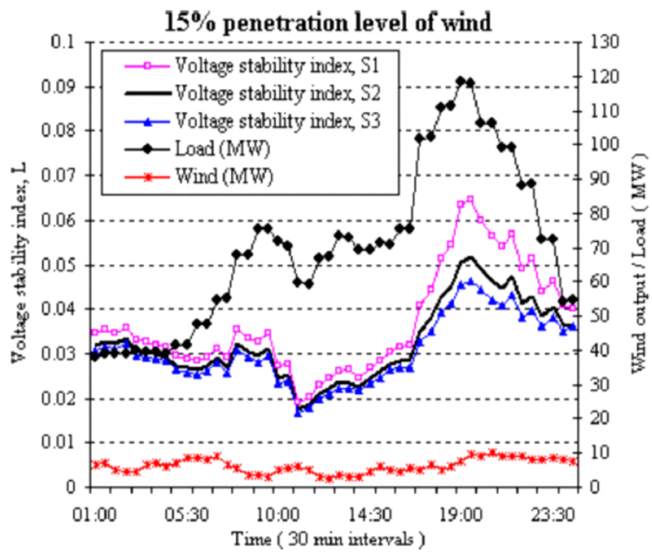

Fig. 4. Effects of wind generation on voltage stability index at a 15% penetration level of wind generation

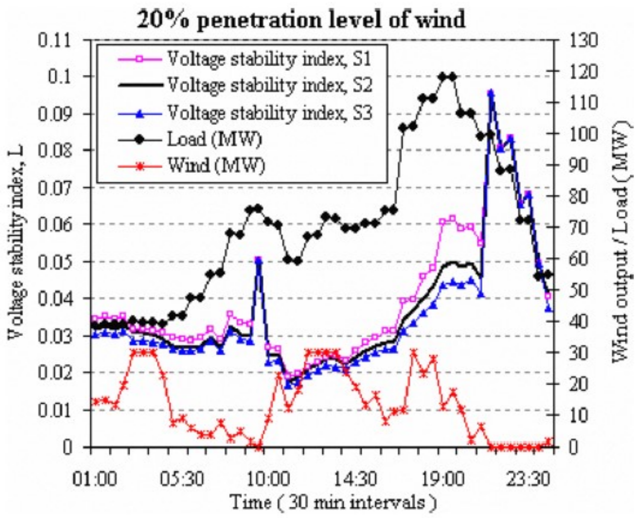

Fig. 5. Effects of wind generation on voltage stability index at a 20% penetration level

B. The windmills were connected in two different penetration levels at (15% and 20%)

The first wind generation was connected to bus 1107 (Sl) at penetration level (15%). Also wind generation was connected to bus 1115 1107 (S2) at the same penetration level. In the third scenario, wind generations were connected to buses 1101, 1107, 1113 and 1115 respectively (S3) with penetration levels at 15%. The corresponding voltage stability index L was recorded for S1, S2, and S3. The computed values of L for the scenarios S1, S2, and S3 are shown in Fig.4. for a 15% penetration level. The aim of connecting windmills at different " points and penetration levels " was to find out the effect on the voltage stability of the system. The value L dropped down with connecting the wind farm from (0.1) for no wind generation to (0.046) for case S3, (0.051) for S2 and (0.063) for Sl as shown in Fig. 4. Fig. 5. shows the index L for penetration level of 20%, and the plots for the voltage stability index L at a 20% wind penetration level was shown. It can be noticed that the voltage stability value was more stable for higher wind penetration levels. At 20% penetration level the index L went down to (0.043) for case S3, (0.049) for S2 and (0.061) for Sl as shown in Fig.4.

The results showed that for both penetration levels of wind generation the highest value of the index L was not related to the penetration level directly of wind generation; although, the voltage stability might be improved by connecting windmills by comparing L in Figure.4. to corresponding values for the 20% penetration level.

VI. Conclusion

The index, of the voltage stability (L), for both penetration levels were analyzed, and the results did show an improvement in the voltage stability of the radial distribution system for higher penetration levels of wind generation. Although, the improvement did not show a direct relation to either the penetration level or the location of the wind generation. As the distribution network is expanding, this method that been showed could be used to ensure compliance with voltage stability limits in the network.

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