Transient Analysis of Switching the Distributed Generation Units in Distribution Networks

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ABSTRACT

Adding distributed Generators (DGs) to the passive electrical networks causes major changes in the specifications of the network including voltage profile, short circuit level and transient stability. In this paper, the effect of DGs switching transient in network is considered. The DGs location is changed in different buses. Two types of DGs are used (i.e. wind and synchronous DGs). Switching transient signals are time variant. It has a continuous spectrum of frequency. Fast Fourier and Wavelet transform methods are used for transient analysis. The proposed method is applied to IEEE-13 Bus distribution system.

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1. INTRODUCTION

Distributed generators have several merits while connecting to the distribution network. Distributed resources can amend the efficiency of providing electrical power. Also they can generate power locally which is increasing available transmission capacity. Indeed DGs provide reliable power for industries. However, using DGs offer several problems that have to be considered in distribution system. One of this challenges is the penetration of DGs which impact the dynamic behaviour of power system.

In [1] analytical methods for determining the optimal location of a DG in radial systems have been presented in order to minimize the power losses. In [2] an artificial bee colony algorithm has been used for optimal distributed generation sizing and allocation in distribution systems. In [3] the impact of distributed generation technology and penetration levels on the dynamics of a test system has been investigated. In [4] a multi-objective placement and penetration level of Distributed Generators (DGs) has been examined. Both technical and economical parameters of power system have been considered. In [5] Optimal placement of protection devices and distributed generators (DGs) in radial feeders has been considered. In [6] voltage based droop control has been developed for transition from islanded to grid connected mode of microgrids. In [7] many types of common transient analysis in distribution systems including inrush current, load switching, capacitor switching and single phase to ground fault have been classified. In [8] relay logic for islanding detection in active distribution system has been proposed. Several articles have done in the field of optimal placement and sizing of DGs. Few reports are on the effect of DGs switching transient. This paper is aimed at finding the effect of DGs switching transient. The rest of paper is organised as follows, In section 2, the system under study is presented. The simulation results are discussed in section 3. Finally the paper is concluded in section 4.

2. SYSTEM UNDER STUDY

Figure 1 shows single line diagram of the IEEE-13 bus distribution system which is modeled on EMTP-RV [9]. This system consists of 13 buses which are interconnected by means of 10 lines (i.e. overload and underground lines with a variety of phasing), two shunt capacitor banks, unbalanced spot and distributed loads. Two different types of distributed energy resources are considered (i.e. diesel generator and doubly fed induction generator). A 2-MVA, 480-V synchronous DG is located at bus 632. The DG is equipped with automatic voltage regulator in power factor mode. The DG is connected to the distribution system through 4.16-KV/480-V transformers. A 3-MVA, 480-V variable speed wind turbine using doubly fed induction generator is located at bus 692 which is under Pulse Width Modulation (PWM) control. The distribution network is connected to the main supply system through a point of common coupling (PCC). Transient waveforms of DGs switching are obtained by locating DGs in different buses. Fast Fourier Transform (FFT) and Wavelet Transform (WT) are applied to the voltage waveforms.

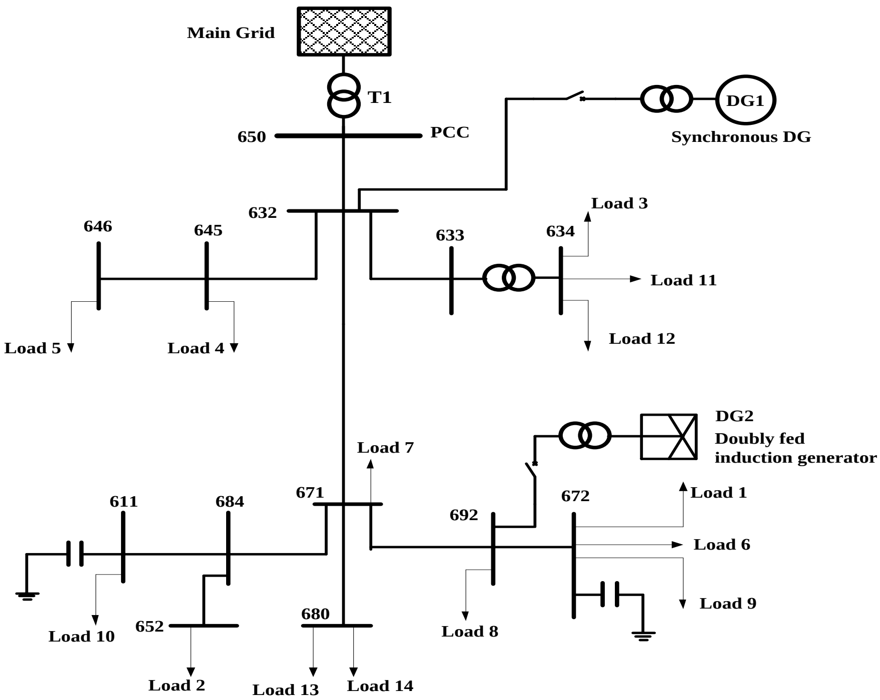

Figure 1. Single line diagram of IEEE-13 bus distribution system

3. SIMULATION RESULTS

This section present the simulation results over a typical distribution system.

3.1. Applying Fast Fourier Transform

A Fast Fourier Transform algorithm computes the Discrete Fourier Transform (DFT) of a sequence, or it's inverse. Fourier analysis converts a signal from its original domain (often time or space) to a representation in the frequency domain and vice versa. The Fourier Transform X(f) of a continuous signals x(t) is given by:

$$X(f) = \int_{-\infty}^{\infty} x(t).e^{-j2\pi ft} dt \tag{1}$$

The continuous function X (f) is the frequency domain representation of x(t) obtained by summation of an infinite number of complex exponentials [10].

The FFT is applied to the measured voltage signals in order to extract the frequency contents in different DGs locations. The transient analysis is done by MATLAB. Figure. 2 shows the voltage waveform and transient signals. Transient signals shown in Figure. 2 are obtained from locating synchronous SDG in bus 632 (no movement from its base place).

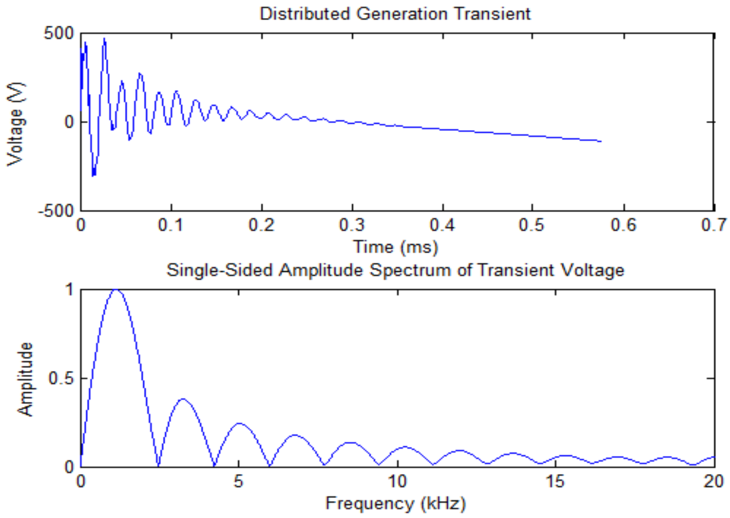

Figure 2. Voltage waveform and transient analysis of SDG switching in bus 632

Figure. 3 shows the transient voltage and frequency contents of SDG switching in bus 634. SDG's frequency waveform shows that its location doesn't affect the frequency content obtained from FFT analysis.

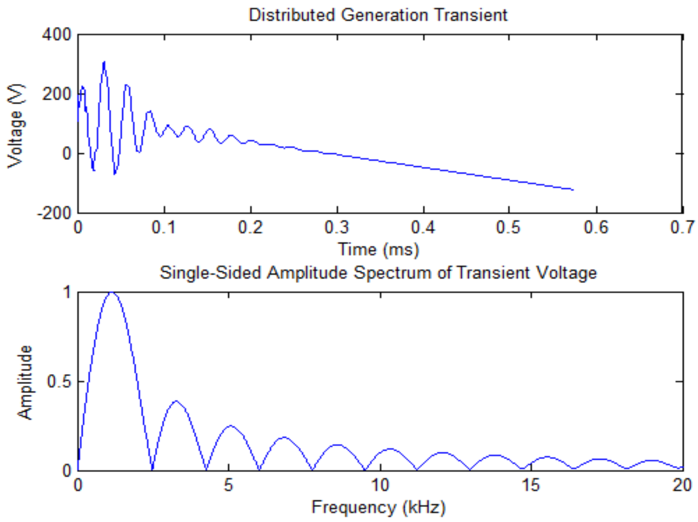

Figure. 3: Voltage waveform and transient analysis of SDG switching in bus 634

Figure. 4 and Figure. 5 shows the effect of changing WPDG's location in buses 633 and 634 respectively. These signals are obtained from FFT analysis and relate to WPDG's switching transient.

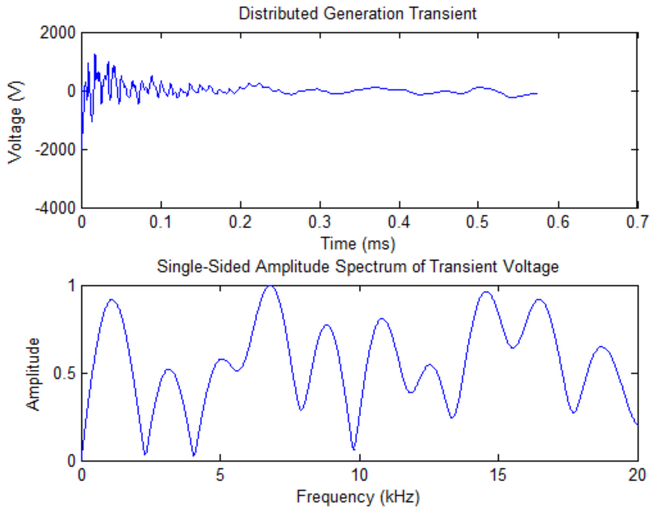

Figure 4. Voltage waveform and transient analysis of WPDG switching in bus 633

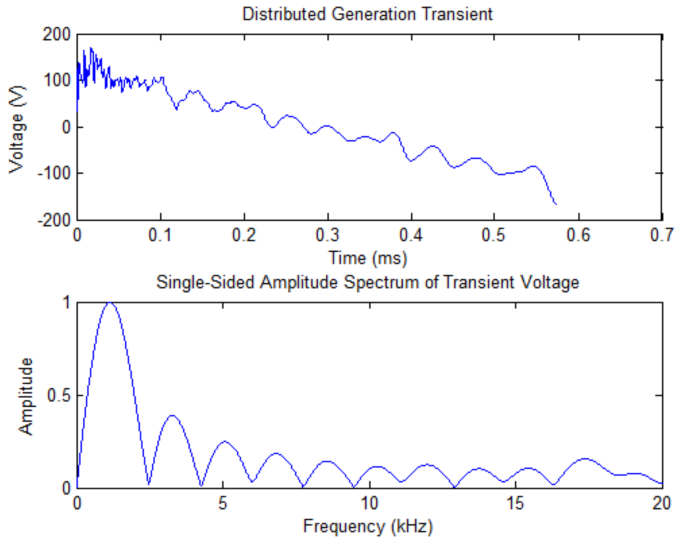

Figure. 5: Voltage waveform and transient analysis of WPDG switching in bus 634

It can be concluded from Figure. 4 and Figure. 5 that the location of WPDG does not affect the frequency contents.

3.2. Applying Wavelet Transform

Wavelets Transform can be used as an aid to detection of features in transient signals. The wavelet transform is used particularly for power system transients since it partitions the frequency spectrum according to identifiable frequencies. Consider a complex valued function ψ satisfying the following conditions [11].

$$\int_{-\infty}^{+\infty} \left|\Psi(t)\right|^2 dt < \infty \tag{2}$$

$$C_\Psi = 2\pi \int_{-\infty}^{\infty} \frac{\left|\Psi(\omega)\right|^2}{\left|\omega\right|} d\omega < \infty \tag{3}$$

where ψ(ω) is the Fourier transform of ψ(t). The first condition implies finite energy of function ψ, and the second condition, the acceptability condition, implies that if ψ (ω) is smooth then ψ (0)=0. The function ψ is the mother wavelet. If ψ satisfies the conditions described above, then the wavelet transform of a continuous signal s (t) with respect to the wavelet function ψ(t) is defined as:

$$X(b,a) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} \Psi'(\frac{t-b}{a}).x(t)dt \tag{4}$$

where the ψ' denotes the complex conjugate of ψ. The parameter b corresponds to the time shift and the parameter a corresponds to the scale of analyzing wavelet. If we define ψa, b (t) as:

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}} \Psi(\frac{t-b}{a}) \tag{5}$$

which means rescaling by a and shifting by b, then equation (4) can be written as a scalar or inner product of the real signal x(t) with the function ψa,b(t):

$$X(b,a) = \int_{-\infty}^{+\infty} \Psi'_{a,b}(t)x(t)dt \tag{6}$$

This study is used Morlet wavelet as an mother function for the construction of continuous wavelet transform. In this section wavelet transform is used for extracting frequency contents of DGs switching transient signal. The following figures show the results of simulation and voltage transient analysis in MATLAB.

Figure 6 and Figure 7 show the transient signals of SDG in different bus locations (i.e. 633 and 634 respectively). The instantaneous voltages are measured from phase a.

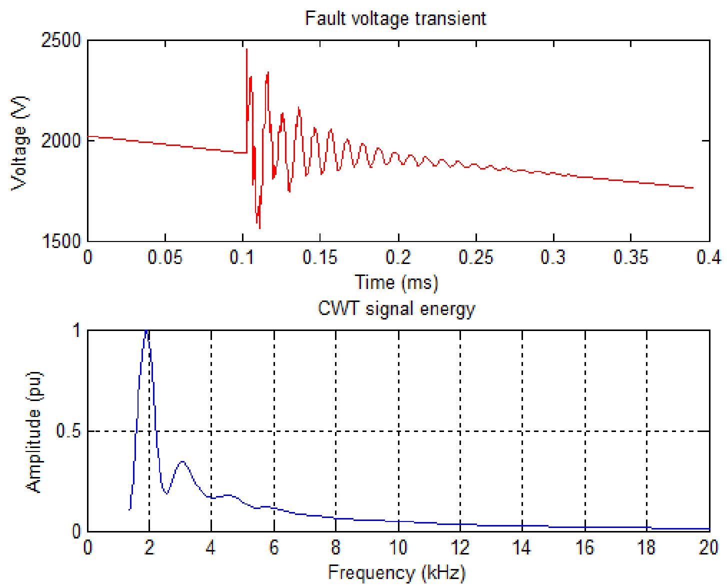

Figure 6. Voltage transient signal and frequency contents of switching SDG in bus 633

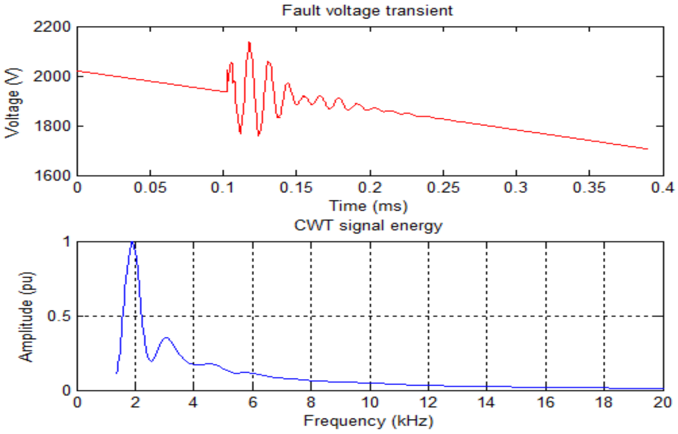

Figure 7. Voltage transient signal and frequency contents of switching SDG in bus 634

Similarly Figure. 8 and Figure. 9 shows the voltage transient signal of WPDG in buses 632 and 634 respectively. The energy signals in per unit are obtained from WT.

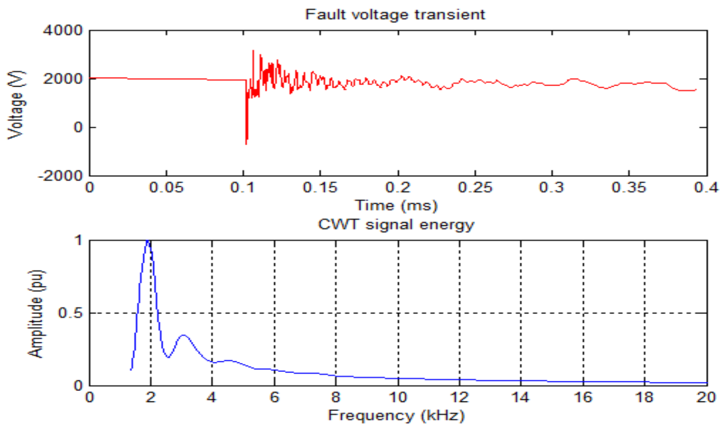

Figure. 8: Voltage transient signal and frequency contents of switching WPDG in bus 632

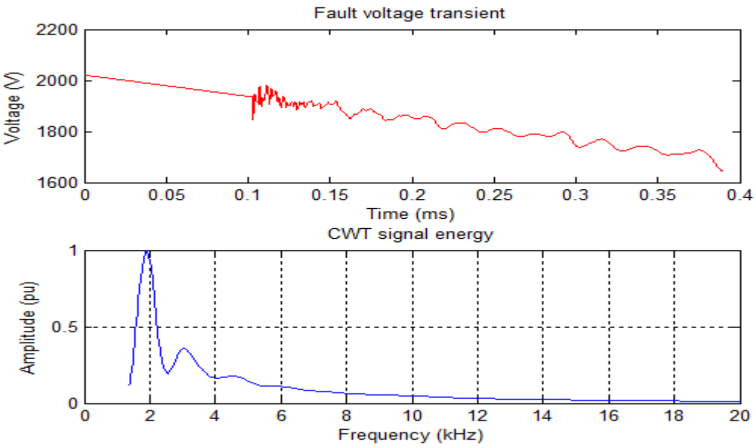

Figure 9. Voltage transient signal and frequency contents of switching WPDG in bus 634.

The amplitude of emerged transient voltage is important. It must be restricted in its allowed range by surge arresters.

4. CONCLUSION

This paper showed the transient effect of DGs switching in distribution systems performance. Two different kinds of distributed generation resources were considered (i.e. diesel generator and wind turbine generator). For transient analysis discussion, determining system voltage in small intervals are required. On the other hand, this type of signal is time variant and has continuous spectrum in the frequency domain. The frequency spectrum must be extracted. Thus the conventional FFT and WT methods were used.

The proposed approach was implemented in a typical IEEE-13 bus distribution system. The test system contained combination of over head lines and underground cables. Also the effects of reactive power compensators are considered in simulation studies. Location of DGs were changed. The voltage transient signals and their frequency spectrum were obtained from FFT and WT. The obtained results clearly showed that the displacement of DGs in different buses (independent of the types of DGs) had no significant effect on transient analysis and did not threaten power system transient stability.

5. ACKNOWLEDGEMENTS

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REFERENCES

[1] C. Wang, M. H. Nehri. "Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems". *IEEE Transaction on Power System, vol. 19, NO. 4, 2004.*
[2] F. S. Abu- Mouti and M. E. El-Hawary. *"Modified artificial bee colony algorithm for optimal DG sizing and allocation in distribution systems"*. IEEE Electrical Power & Energy Conference, 2009.
[3] Slootweg, J. G., and W. L. Kling. "Impacts of distributed generation on power system transient stability". Power Engineering Society Summer Meeting, 2002, *IEEE.* Vol. 2.
[4] Kamalinia, S., Afsharinia. S, Khodayar. M. E., Rahimikian. A & Sharbafi, M. A. *"A combination of MADM and genetic algorithm for optimal DG allocation in power systems"*. Universities Power Engineering Conference, UPEC 2007. 42nd International. IEEE.
[5] Wang. L, and Singh. C. "Reliability-constrained optimum placement of reclosers and distributed generators in distribution networks using an ant colony system algorithm". *IEEE* Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) 38.6, 2008, 757-764.
[6] Vandoorn, T. L., Meersman, B., De Kooning, J. D., & Vandevelde, L, "Transition from islanded to grid-connected mode of microgrids with voltage-based droop control". *IEEE* transactions on power systems, 28(3), 2545-2553, 2013.
[7] Smeets, R., Van der Sluis, L., Kapetanovic, M., Peelo, D. F., & Janssen, A. "Switching in electrical transmission and distribution systems". John Wiley & Sons, 2014.
[8] Vatani, M., Amraee, T., Ranjbar, A. M., & Mozafari, B. "Relay logic for islanding detection in active distribution systems". IET Generation, Transmission & Distribution, 2015, 9(12), 1254-1263.
[9] Afifi, S. N., H. Wang, G. A. Taylor, and M. R. Irving. *"Impact of DFIG wind turbines on short circuit levels in distribution networks using ETAP"*. InPower Engineering Conference (UPEC), 48th International Universities, 2013, pp. 1-4. IEEE.
[10] Robertson, David C., Octavia I. Camps, Jeffrey S. Mayer, and William B. Gish. "Wavelets and electromagnetic power system transients". *IEEE* Transactions on Power Delivery 11, 1996, no. 2, 1050-1058.
[11] Lee, D. T., & Yamamoto, A.. "Wavelet analysis: theory and applications. Hewlett Packard journal", 1996, 45, 44-52.

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Mehrnoosh vatani was born in Iran, in 1983. She received the B.E and M.S degrees in power electrical engineering from Babol Nooshirvani university of technology, Iran, Ph.D degree in power electrical engineering from Islamic Azad uinversity, science and research branch in 2016.
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