HARMONIC ANALYSIS OF INTEGRATING A DG UNIT TO THE DISTRIBUTION NETWORK – CASE STUDY

Morteza HOSSEIN POURARAB
MEEDC* – Iran
pourarab@aut.ac.ir

Mohammad Hossein MESHKINI
MEEDC* – Iran
mh.meshkini@meedc.net

Ali Yektay
MEEDC* – Iran
a.yektay@meedc.net

* Mashhad Electric Energy Distribution Company

ABSTRACT

In this paper results of a case study in impacts of distributed generation integration on harmonic distortion in medium voltage network are investigated. Comprehensive modelling of MV system and DG units are presented. The results of this study indicate that integration of DG units to the MV network in the case of harmonic distortion is permitted.

INTRODUCTION

Dwindling resources of fossil fuel in one hand and increasing fuel prices on the other hand are changing the context in which power systems are operated and regulated. In particular, concerns about quality of supply and reliability along with the integration of distributed energy resources are presenting new challenges to the system operators. One of the controversial challenges is the connection of significant levels of distributed generation (DG) to the electricity distribution network. This distributed generation is forcing a reexamination of the planning and operation of the distribution system.

The increasing integration of DG is changing the role of distribution network operators. Distribution networks were originally passive networks purely for the delivery of electricity to the customers, are now networks that are being utilized for the energy harvesting from various DG units.

The introduction of DG arise a number of new challenges to electricity distribution companies.

Some technical constraints and limitations arise due to integration of DG which are listed below [1]:

- Equipment Ratings
- Short Circuit Level
- Power flow
- Losses
- Reliability
- Protection
- Power Quality

DG can have a significant impact on power quality. Voltage flicker is a result of dynamic variations in the network voltage. It can be a challenge with wind power, given the variable nature of its energy source [2]. Some kinds of DG may use power electronic devices to interface with the power grid. This can alter the harmonic impedance of the system and care should be taken into account when designing and planning the operation. There are standards, which indicate allowed levels of each of these quantities, which must be considered. On the other hand, DG has the potential to improve the power quality of system [3].

Having considered the selection of publications, it is clear that considerable researches have been carried out into the integration of distributed generation units [4,5,6]. It is also obvious that the integration of DG has a number of considerable impacts on planning and operation of medium voltage networks. As mentioned earlier, one the most controversial issues arising when integrating DG is the harmonic distortion.

It is evident that integration of DG units in the distribution system requires the investigation of both the DG impacts on power quality of distribution system and vice versa. In addition, it is expected to have parts of the distribution system as "micro-grids" in a near future. This will make the system more prone to power quality, in comparison with the on grid operation. Moreover, it is expected that DG will make its way into the distribution systems through power electronics which is very significant with respect to the grid properties, such as frequency, power quality and control of active and reactive power [7].

The main target of this paper is to study the voltage quality and harmonic distortion due to integration of the DG units. Distribution system in the city of Mashhad is taken as a case study. The overall approach adopted attempts to analyze the impact of DG on harmonic pollution in distribution network.

MODELING CASE STUDY

This paper consists of analysis of harmonic distortion injected by distributed generation unit in distribution system with respect to the harmonic current injected by DG into the medium voltage network and harmonic current in the DG substation circuit.

This case study investigates the impact of a distributed generation (DG) unit on the distribution electricity network with respect to the harmonic distortion. DG plant is located 7 kilometers away from Mashhad the capital city of Khorasan Razavi in northeast of Iran and is furnished with 4 gas based generator units with the total capacity of 4100 kVA. The generated power is injected to the distribution network supplying various types of loads, mostly industrial through medium voltage (MV) 20 kV lines.

In the case study, vector group in DG transformers is grounded Why- Delta. Hence, third harmonics injected by

each DG unit into the 20 kV network would be circulating in the Delta side of the transformers and would not inject into grid. As a result, integrating DG units into the distribution network is allowed considering the effects of harmonic currents circulating in DG transformer circuits. On the other hand, harmonic currents generated by each DG unit are important in the study and can lead to changes in protecting device settings and neutral wire cross section.
So, Analysis and simulation of harmonic currents before integrating a DG unit is strongly recommended. Gas-based DG units are the most commonly applied DG technology and the least expensive one in Iran. The most common interface of the engine is a synchronous or an induction generator. This type of DG unit can be integrated directly to the grid without any power electronic interface [8].
The generators in the case study are produced by Leroy Somer and according to the data sheet of the company, harmonic currents generated by each generation set is 1.5 up to 5 percent. In the current study, harmonic level is assumed 5 percent, which is the worst.
Increased proliferation of these generators has lead to changes in network characteristics, along with the two-way flow of active and reactive power which is variable. These generators change the technical characteristics of the network and push them closer to their limits of reliable and safe operation.
There are several simulation tools such as PSCAD, DIgSILENT, PSS/E, etc. In order to simulate harmonic currents of generating units we used a tool in DIgSILENT called Fourier source. It should be noted that injected current of Fourier source in the fundamental frequency (50 Hz) is set to zero.
In this paper, each generator as the source of harmonic current is modelled as a current source in DIgSILENT Simulation Language (DSL). Figure 1 shows harmonic current sources in DSL. As it can be obviously seen three current waveforms, I_A, I_B and I_C are injected into the current source, ElmIac, through three Fourier sources. In addition, there should be one harmonic current source for each DG unit in the simulation. Figure 2 illustrates modelling of harmonic sources along with the generators.
According to IEEE 519 standard shown in table 1 the permissible Total Harmonic Distortion (THD) injected by distributed generation units into distribution network is 5 percent.

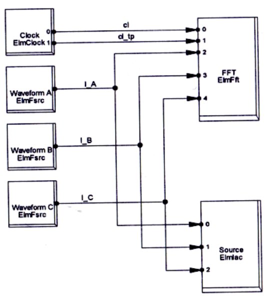

Figure 1. Block diagrams in DSL for simulating harmonic current sources

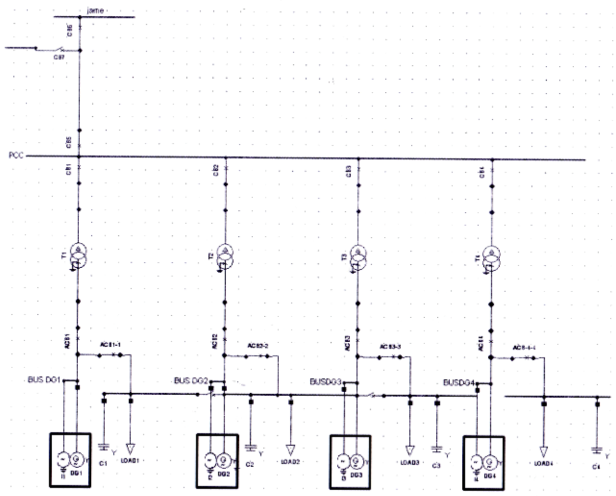

Figure 2. Harmonic sources modeling in DSL

Table 1. Harmonic current limits in MV network injected by DG

Harmonic order	Allowed level relative to fundamental (Odd harmonics)
<11th	4%
<11th to <17th	2%
<17th to 23rd	1.5%
<23rd to 35th	0.6%
35th or greater	0.3%
Total Harmonic Distortion	5%

HARMONIC DISTORTION ANALYSIS

The increasing applications for DG connections present a significant challenge to the existing connection policies of distribution network operators. With the connection of DG units to the distribution systems, they are expected to face a number of problems in power quality. One of the main issues arising with respect to DG is the harmonic distortion injected to the power grid. The DG integration policy employed by the distribution companies will affect the impact of DG on power quality.
Harmonic voltage distortion in distribution systems is due to the interaction of harmonic currents from a variety of sources and the impedance of the distribution system [9].
The well known sources are nonlinear loads and recently DG units which are fully or partially connected to the network through power electronic converters. Harmonic distortion levels are compared to the limits determined by standards such as IEEE and IEC [10,11].
Harmonic distortion analysis of integrating DG units includes harmonic current injected into the MV system by DG units and harmonic currents circulating in transformers. Since the connection of DG units to the MV network medium voltage is via grounded wye-delta transformers, consequently 3rd harmonics by DG units will circulate in the delta side of transformer and would not inject to the 20

kV network. Thus, the connection of DG units in this respect is permitted. However, harmonic injection by DG units in transformers would circulate due to vector groups of the transformers and could affect the protection settings and cross section of neutral wires.

I_A, I_B and I_C (shown previously in figure 1) will make harmonic current of each DG unit, which is depicted in figure 3. Meanwhile, it is clear that generator reactance is relative to frequency, linearly.

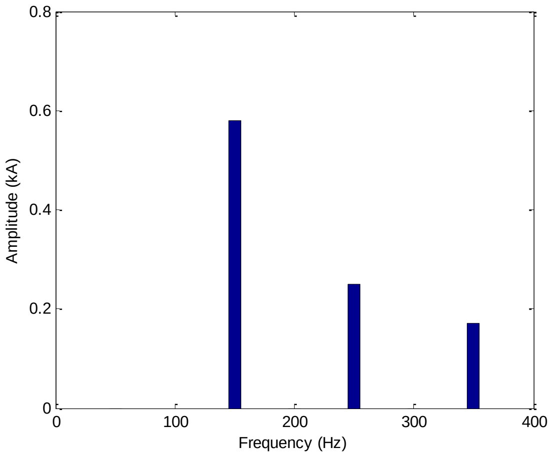

Figure 3. Harmonic spectrum of DG

Figure 4 shows simulation results of harmonic distortion injected by DG units. As it can be seen, current THD injected by each generation unit is set to 4.99 percent (the worst). Results show that total harmonic distortion injection in PCC is 2.81%.

NEUTRAL CURRENT ANALYSIS

For the analysis of harmonic distortion when integrating a DG unit, we need to simulate neutral current of DG units with different grounding systems of other DG units.

If each DG has the grounded neutral connection with a 2 Ω resistance, then maximum neutral current would be 4 A. When only neutral in one of the units is disconnected, the maximum neutral current in other units would be around 2.88 A. neutral current waveform in this situation is shown in figure 5. The worst case is when only one of the grounding systems in DG units is connected in which simulation results shows this case is the same as the situation two.

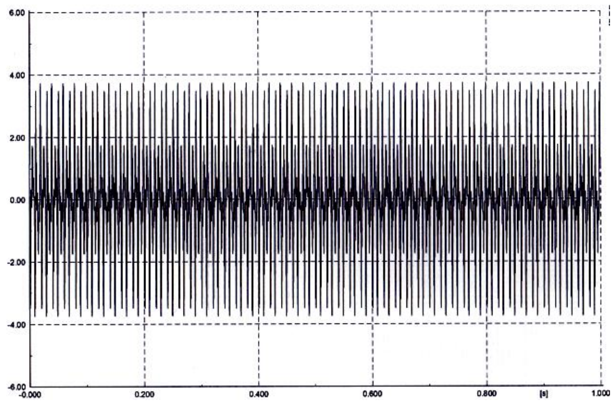

Figure 5. Neutral current of DG

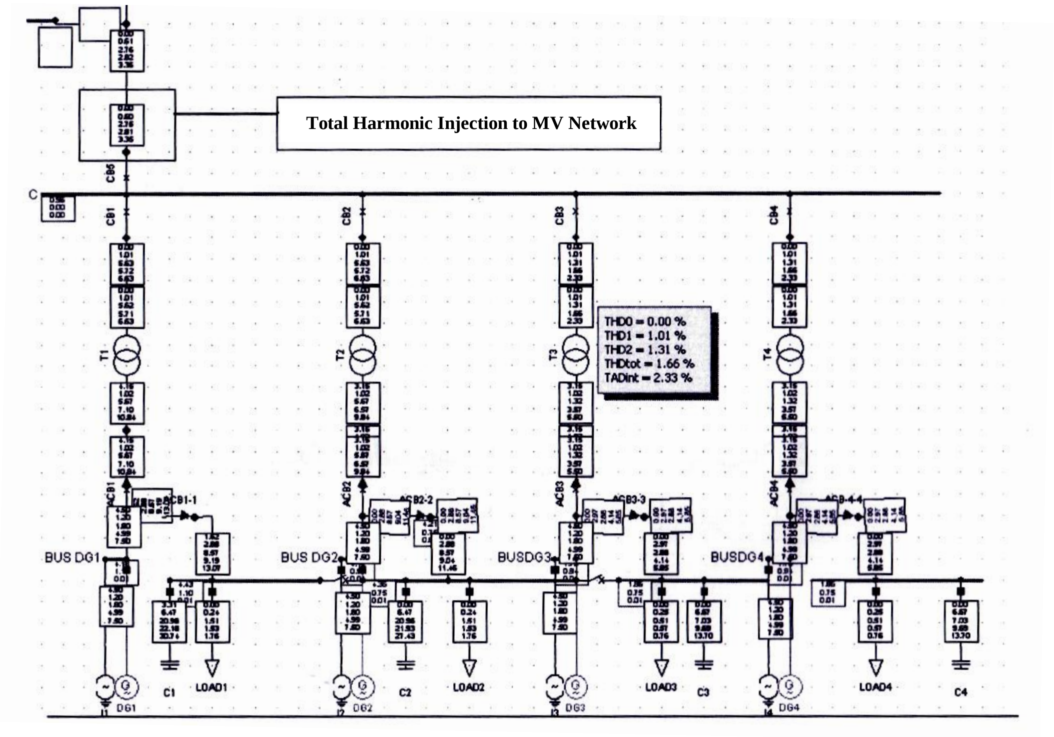

Figure 4. Results of simulation tool

CONCLUSION

In this paper results of a case study in impacts of distributed generation integration on harmonic distortion in medium voltage network are investigated. Comprehensive modelling of MV feeder and DG units are presented. The results of this study indicate that integration of DG units to the MV network in the case of harmonic distortion is permitted. It can be concluded that the installation of DG unit in the case study is allowed so that the harmonic distortion level in medium voltage system is not exceed the limitations. However, it is recommended that further research be undertaken in this area.

REFERENCES

[1] T. Ackermann, G. Andersson, and L. Sd er, 2001, "Distributed generation: a definition," Electric Power Systems Research, vol. 57, pp. 195-204.

[2] A. Papathanassiou and M. P. Papadopoulos, 2006, "Harmonic analysis in a power system with wind generation," IEEE Transactions on Power Delivery, vol. 21, pp. 2006-2016.

[3] R. C. Dugan and M. F. McGranaghan, Electrical Power Systems Quality, 2nd ed. New York: McGraw-Hill, 2002.

[4] N. Hadjsaid, J. F. Canard, and F. Dumas, "Dispersed generation impact on distribution networks," IEEE Comput. Appl. Power, vol. 12, pp. 22-28, 1999.

[5] H. E. Farag and E. F. El-Saadany, "Voltage regulation in distribution feeders with high DG penetration: From traditional to smart," in Proc. IEEE PES General Meeting, 2011S.

[6] T. McDermott, R. Dugan, “Distributed generation impact on reliability and power quality indices,” IEEE Rural Electric Power Conference, 2002.

[7] A. Keane "Integration of Distributed Generation" Ph.D. Thesis, University College Dublin, Ireland, February 2007.

[8] “Distributed power generation: A strategy for a competitive energy industry Chicago, USA” Gas Research Institute, 1998.

[9] M.H. Pourarab, S. Alishahi, M. Hakkak Sadeghi, “Analysis of Harmonic Distortion in Distribution Networks Injected by Nonlinear Loads” in Proceedings of the 21st International Conference and Exhibition on Electricity Distribution, CIRED 2011, Frankfurt, Germany, June 2011.

[10] IEC 61000-3-2, Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current missions (Equipment input current ≤16 per phase) ed. 2.1, 2001.

[11] IEEE Std 1547-2003, "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems", 2003.