POWER QUALITY ASSESSMENT OF A SINGLE CUSTOMER MICROGRID-CASE STUDY

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ABSTRACT

Mashhad Electric Energy Distribution Company has designed and implemented its first local micro-grid in Mashhad which is called "Mehrsun". This paper presents the results of field measurement of power quality indices and energy flow for a single customer micro grid in Mashhad, Iran. Measurements performed during a week in spring for both grid-connected and islanded mode. Power and energy parameters as well as current and voltage THD, voltage fluctuations, power factor are illustrated and their consistency with power quality standards and limits are investigated.

INTRODUCTION

IEEE defines a microgrid as a power system with distributed resources and energy storage, serving one or more customers that can operate as an independent electrical island from the bulk power system [1]. "Micro-grid may be applied in a broad range of sizes and configurations" [2]. It can be a full distribution substation, full feeder, partial feeder or single costumer microgrid. As it is shown in Fig.1, Mehrsun is a single customer microgrid.

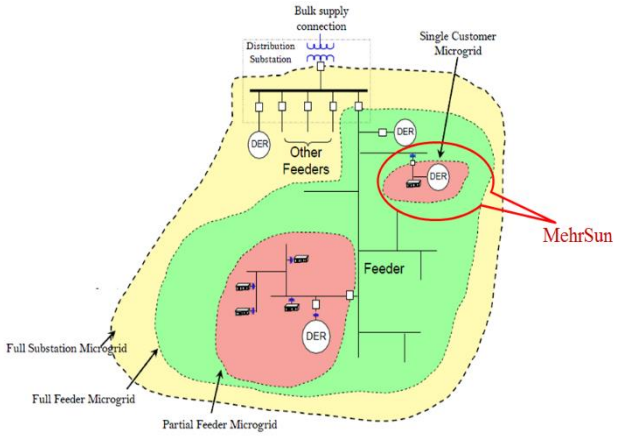

Fig. 1. Micro-grid different sizes and configuration [3].

Nowadays a utility company in field of power distribution not only has to have a reliable power network but also it needs a secure and stable communication network to support IT systems for its power network and its customers. Server computers are critical component of an IT network and providing reliable and uninterruptible electricity which meets power quality standards for these loads is one of the main concerns of the network operators.

Mashhad Electric Energy Distribution Company has implemented a single costumer micro grid to address these needs and provide an uninterruptible green power supply for its critical loads with acceptable power quality indices. Efficiency of the photovoltaic system and its response to the whole distribution grid are two important concern of each photovoltaic system which depends on a number factor like environmental condition as well as system design [4]-[5].

Lots of factors must be considered in installing and connecting photovoltaic systems to a distribution network. IEEE standard 929-2000 “Recommended practice for utility interface of photovoltaic systems” contains guidance regarding equipment and functions necessary to ensure compatible operation of photovoltaic (PV) systems that are connected in parallel with the electric utility including factors personnel safety, equipment protection, power quality, and utility system operation and also information about islanding mode. [6]

The variable power flow due to the fluctuation of solar irradiance, temperature and choice of power semiconductor devices are some of the parameters that affect the power quality of photovoltaic systems [7]. Low power quality indices are not only harmful for micro grid itself but also are often troublesome for distribution grid, because it causes failure of sensitive electronic devices and grid equipment such as transformer and breakers.

The IEEE Standard 519-1992 “Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems” recommends limits of disturbances to the ac power distribution system that affect other equipment and communications [8]. The limit for voltage total harmonic distortion is equal to 5% and the limits for the maximum individual harmonic components are also determined and must be 3 % for voltage lower than 69 kV. The current harmonic limits vary based on the short circuit strength of the system they are being injected into. TDD limits are also presented in this standard.

According to the European standard EN50160 (IEC50160), accommodated by most European Grid Codes, “Voltage characteristics of electricity supplied by public distribution systems”, the limit for total harmonic distortion should not exceed 8 %, including up to the 40th harmonic [7].

The European standard EN 61727 (IEC 61727) “Photovoltaic (PV) systems - Characteristics of utility interface” has established more restrictive limits for voltage and current harmonics. The limits proposed for harmonics are 2 % for total voltage harmonic distortion and 5 % for total current distortion. The maximum for individual voltage harmonics is also limited and must not exceed 1 % [9].

MICROGRID STRUCTURE

Mehrsun is implemented for office building of the

Mashhad electricity distribution company and beside the grid power; it uses a 15kWp photovoltaic system as its source of energy. The photovoltaic system has 66 panels that each one has the capacity of producing 230W electricity. All of these panels are installed on top of the roof using fixed structures as it is illustrated in Fig.2. Two solar inverters with sizes of 5kVA and 10kVA are inverting the DC input voltage to AC voltage.

Mehrsun micro-grid feeds only the critical loads of the building including lighting, computers and network servers. In fact, it plays the role of an intelligent UPS for critical loads which is able to feed surplus energy from solar panels to the grid. Because of some security consideration it should provide needed energy for critical loads for 24hrs in case of grid outage and no sun radiation. To address this consideration the battery bank has to be always fully charged. This micro-grid can work in grid-connected mode and islanding mode [3].

The reason for choosing two inverters instead of one inverter was only to prepare a test bed for future researches in field of micro-grid or photovoltaic systems. Schematic diagram of micro-grid basic elements is shown in Fig.3.

Fig. 2. Mehrsun micro-grid solar panels arrangement.

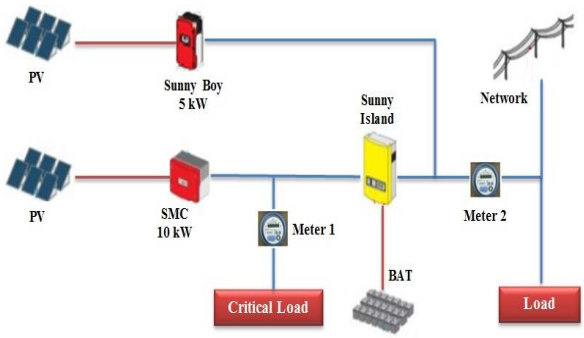

Fig. 3. Mehrsun micro-grid schematic diagram.

To consume energy efficiently, an electric power management system is design and implemented especially for this building which has the ability to monitor and control the electric loads consumption based on solar panel generation and other parameters like battery bank charge status, room occupancy status, temperature, time of the day and so on.

RESULT AND DISCUSSION

To analyse Mehrsun micro-grid power quality parameters, a field measurement is done. All measurements are done at the point of common coupling (PCC). It should be mentioned that in this study the behaviour of micro grid regarding distribution network is considered as a main task. In other words, the impact of micro grid on distribution network is studied from power quality indices. "Fluke 435 Series II power quality and energy analyser" is used for this purpose and power quality parameters are measured for a period of 4 days in March when the sun radiation is like the average of the year and the weather is mild. The power quality parameters recorded are the active power, reactive power, voltage and current, frequency, short term flicker (Pst), Long term flicker (Plt), current and voltage THD and power factor which results are presented below.

As it is shown in Fig.4 the RMS Voltage has a small variation and is in compliance with standard range. The same behavior is observed for frequency and it lies in acceptable range as well. Fig.5.

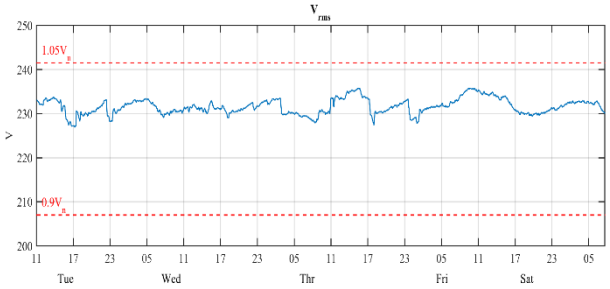

Fig. 4. RMS voltage at PCC

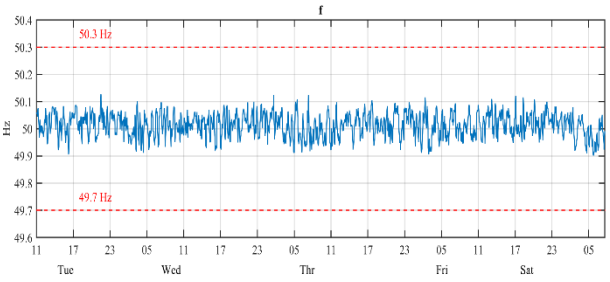

Fig. 5. Voltage Frequency variation graph.

Long-term perception of flicker (Plt) and short-term perception of flicker (Pst) are illustrated in Fig.6 and Fig.7 respectively. As can be seen they are consistence with limits defined in IEEE1453-2004.

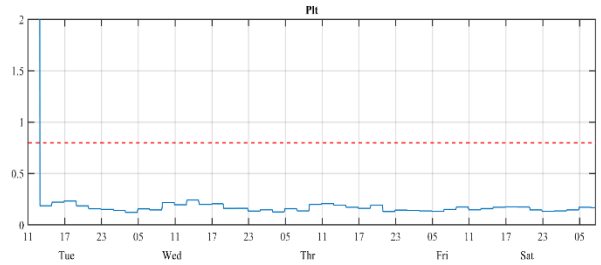

Fig. 6. Long-term perception of flicker graph.

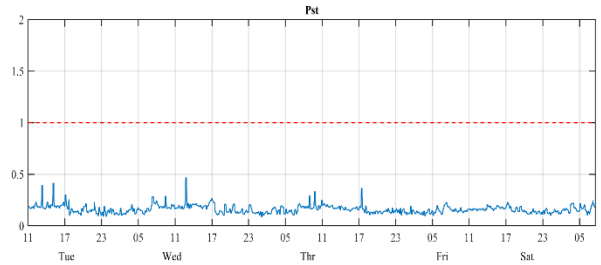

Fig. 7. Short-term perception of flicker graph.

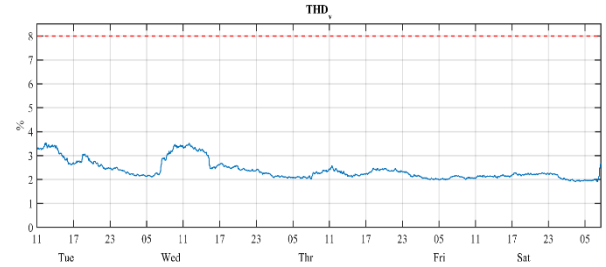

Fig. 8. Voltage THD graph.

Individual and total voltage distortion are also measured and as seen from Fig.8 voltage THD is always less than 4% and has very low dependency on solar irradiance. The worth case for individual harmonic voltage distortion is related to 5th order that is less that 3% and for other frequencies they are less than 1%. Despite acceptable situation for voltage, current THD is inconsistence with standards. Fig.9 and Fing.10 are shown RMS current and current THD results. It is observed that current THD is significantly depend on solar irradiance and in low solar radiation condition, current THD is more than when solar radiation is high. In period of time between 6a.m to 5p.m micro grid production is more than its consumption and surplus energy is fed to grid and it shows that critical loads have significant impact on THD current because they are computer servers and lighting loads which are non-linear loads. As soon as there is enough energy to feed the critical loads the THD current at PCC is low but when the flow of energy is from grid to micro grid it is high and at sunrise and sunset micro grid injects a significant distorted current to the distribution network reaching up to 60% at some instances. Individual harmonic orders (odd orders) have same trend with less peak amplitude. The worth case is related to harmonic of 5th order.

Despite the THD current which is significantly over standard limits, TDD current has an acceptable range (Fig. 11). TDD gives us better insight about how big is impact of harmonic distortion on grid. In this case study, high THD current is not a concern because the magnitude of harmonic current is low compare to full load current, even though its relative current distortion is quite high. Based on IEEE Standard 519-1992, TDD current can be between 5% to 20% according to

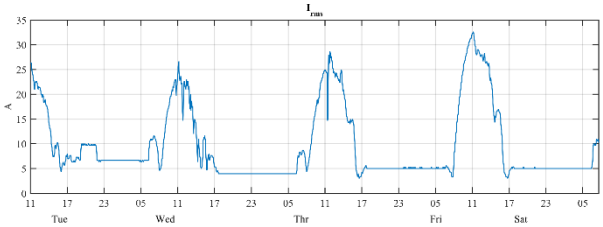

Fig. 9. RMS current graph.

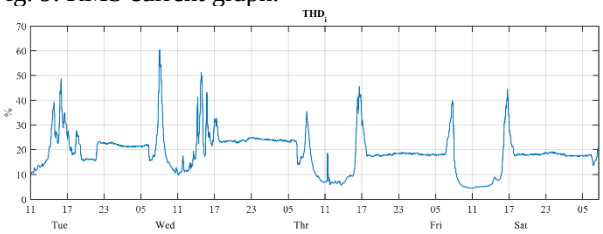

Fig. 10. Current THD graph.

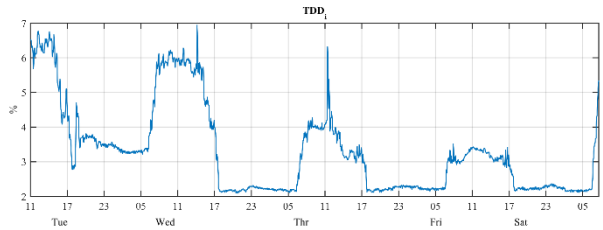

Fig. 11. Current TDD graph.

In last part, measured data for active power, reactive power and power factor are shown in Fig. 12, Fig. 13 and Fig. 14, respectively. In period of time between 8 AM to 4 PM surplus energy from the micro grid is fed to grid and other times of the day the flow of energy is vice versa, from grid to micro grid. Active power graph in a time period from 11AM to 4PM has small fluctuation which is related to shading effect for a number of solar panels. Reactive power measured data show that micro grid always injects reactive power to grid and the reason is the critical loads which are more capacitive loads rather than inductive loads. As can be seen from Fig. 14, except a number of points, power factor of the micro grid in PCC is about 1 when there is sun shine and is -1 for night time.

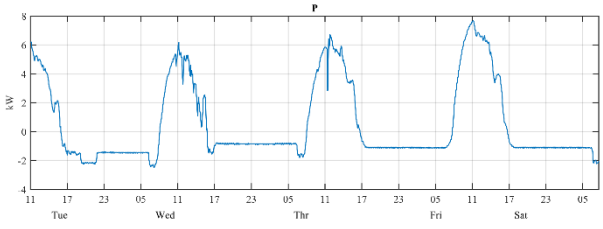

Fig. 12. Active power measured at PCC.

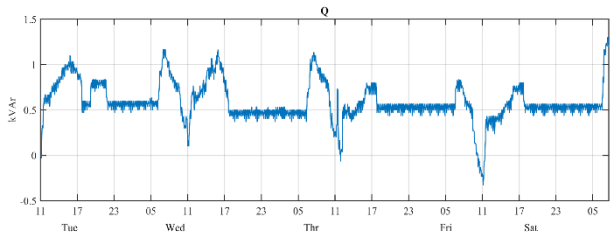

Fig. 13. Reactive power measured at PCC.

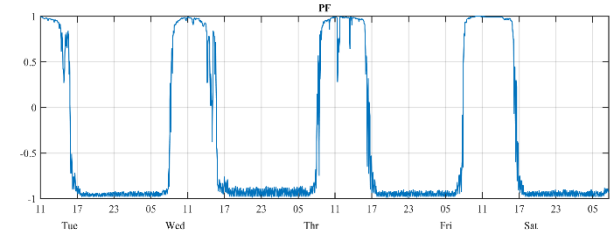

Fig. 14. Power factor measured on PCC.

CONCLUSION

Mehrsun micro-grid which is a single costumer micro-grid introduced with its basic elements and its power quality responses into the distribution grid including current and voltage THD, current TDD, voltage fluctuations, power factor, active and reactive power and log-term and short-term flicker indices are measured. Based on IEEE Standard 519-1992, all measured data were in acceptable range and it shows that this UPS operated micro grid has no power quality issue for distribution grid during one week measurements. It should be mentioned that the results are based on one week measurement data and in order to draw a generalized conclusion, more data would be needed.

REFERENCES

[1] IEEE Standard 1547.4-2011, "*IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*", 2011

[2] D. Herman, *"Investigation of the Technical and Economic Feasibility of Micro-Grid Based Power Systems", EPRI, PaloAlto, CA:2001.1003973.*

[3] N. Nakhodchi, S. Alishahi, M. H. Pourarab and G. Wu, 2015, "*Result assessment of the first local micro-grid in Mashhad, Iran*" IEEE International Telecommunications Energy Conference (INTELEC), Osaka, , pp. 1-5.

[4] P. Boulanger, P. Malbranche, "Photovoltaic system performance statistical analysis", 3rd World Conference on Photovoltaic Energy Conversion, Vol. 2, pp. 2098 – 2101, May 2003.

[5] R. Gonzalez, H. R. J imenez, J. M. Huacuz, "Voltage and Power Ratio Effects of Grid-Connected PV Plant's Operation on the Performance Ratio and Total System Efficiency", 3rd International Conference on Electrical and Electronics Engineering, pp. 1 – 4, September 2006.

[6] IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems," in IEEE Std 929-2000 , vol., no., pp.i-, 2000.

[7] Patsalides, M., Evagorou, D., Makrides, G., Achillides, Z., Georghiou, G.E., Stavrou, A., Efthymiou, V., Zinsser, B., Schmitt, W. and Werner, J.H. "The effect of solar irradiance on the power quality behaviour of grid connected photovoltaic systems." International Conference on Renewable energies and Power Quality, ICREPQ, La Coruña, ES, 25 - 27 Mar 2007.

[8] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems," in IEEE Std 519-1992 , vol., no., pp.1-112, April 9 1993.

[9] EN 50160 "Voltage characteristics of electricity supplied by public distribution systems".