IJESG International Journal of Energy and Smart Grid Vol 6, Number 1-2, 2021
e-ISSN 2636-7904

Research Article

MEASUREMENT AND EVALUATION OF POWER QUALITY PARAMETERS BATMAN PROVINCE APPLICATION

Naci OBUT [1*], Mehmet Rıda TÜR[2]

[*1] Dicle Electricity Distribution Inc. 72050 Batman, Turkey
[2]Batman University, Faculty of Engineering, Department of Electrical and Electronics Engineering, 72060 Batman,Turkey
[*] Corresponding author; E-mail: naci.obut @dedas.com.tr

Abstract *Energy quality is an important issue that concerns energy producers and consumers. In this regard, having power parameters at certain standards ensures that the energy quality is at a high level, and thus a high quality electrical energy is transmitted to the producer. Measuring power quality parameters is a major factor in preventing problems in electrical power plants and devices connected to electrical power plants. It is important to identify the problems, to reach the solution in a shorter way and to prevent the malfunctions that may occur in the systems. For the determination of technical quality in power plants; Measurement principles, technical quality parameters and limit values, technical quality measurements, evaluation of measurement results and the processes to be done ensure the preservation and continuity of technical quality. Power quality parameters (voltage effective value, voltage unbalance, voltage sag, voltage flicker, voltage harmonics) values must comply with TS EN 50160:2011 standards. As a result of the power parameters measurements made in the transformer center in Batman province, it was seen that some of the measurement values were not in the range of standard values. The power quality has been increased by performing the necessary maintenance and repair works related to these parameters*

Key words: *Power quality, Harmonics, Voltage flicker.*

Received: 06.12.2021 *Accepted:30.12.2021*

1. Introduction

With the development of technology, it is effective in changing the load characteristics of power systems. When we look at these load characteristics, power electronic devices, nonlinear loads, motor drivers etc. loads cause disruptive effects in power systems. Power quality can be explained as the electrical limitations required for a device to work efficiently for its intended use and to operate without any power loss. The presence of nonlinear loads connected to the distribution network causes the current and voltage to diverge from the ideal sinus signal. This situation is called power quality degradation [1-3].

Power quality parameters are directly related to the quality of the power plant, the transmission line and the quality of the electrical energy used by the consumer. The poor quality of power experienced in electrical facilities causes malfunctions and even breakdowns of devices, leading to serious problems in many industrial facilities. The occurrence of harmonics, voltage drops and voltage flickers due to the connection of loads to electrical installations presents power quality problems. In the Regulation on the Supply Continuity and Technical Quality of Electrical Energy published in 2006 (Directions, 2006), Distribution Facilities address the electrical energy needs of consumers; It is defined as the capacity to meet the frequency, amplitude, waveform and three-phase symmetry of the voltage in an uninterrupted and high quality manner within certain standards. In our country, the standard values of power quality parameters EN 50160 and IEC 61000430 (Regulation, 1999; 2003) European Standards apply [4, 5].

One of the purposes of the Electricity Network Regulation published by EMRA is to define the responsibilities of users connected to and affecting power systems and the criteria they must comply with. These criteria are system frequency and variation, system voltages and variation limits, transmission system voltage waveform quality, voltage spikes, voltage oscillations and flickers, phase unbalance, current harmonics [6,7].

Energy quality in power systems is the prevention of negativities in the network and sinusoidal wave disturbances in the current drawn from the network.

The term "power quality" refers to the reliability of the generated electrical energy and the ideal characteristics of the voltage and current magnitudes measured in electrical transmission and distribution networks. This term also includes any undesirable deviations and adverse effects on the customer and connected equipment as a result of malfunctions that may arise. Another problem of power quality is prolonged voltage interruptions. Total interruption or reduction in current, which is about a few milliseconds, directly causes an error in the data processing process. Also, another common problem with systems is their distortion, which is described as distortion. This problem is defined as high frequency signals that conflict with the main waveform of the power system and cause data loss in the system [8]. Another problem defined as flicker is the voltage fluctuations between 90-110% of the nominal value from the power supply and usually damages the load side of the system [9]. Interruptions in power systems are, in any case, long-running and zero-voltage situations. This is because in an electrical system, the circuit is de-energized and the power distribution is interrupted or the mains electricity is interrupted. It is inevitable that an outage situation will directly lead to data loss, quality degradation and damage to the equipment used in the system [10]. These interruptions are generally divided into two groups; short interruptions and long interruptions. Short interruptions occur if the energy source fails for a few milliseconds to a second or two. This is usually due to situations such as opening protection devices and disabling a faulty part of the network. However, large interruptions cause more serious errors, which are; insulation failure, lightning and insulator deterioration [11, 12]. On the other hand, if the power supply lasts longer than 1 to 2 seconds, the equipment in the system can be completely stopped if interruption occurs due to power system network hardware disruption, storms and/or other environmental factors [13].

2. Power Quality Measurements and Evaluation

In order to detect power quality problems, measurements are taken at regular intervals. After the measurements, the problem type is determined and the problems in the system are eliminated. Faults that may occur in the system are listed below. At the same time, in this section, the results of power quality measurements made in Batman Transformer Centers and the evaluation of the results will be made [14].

- Voltage Effective Value
- Voltage Imbalance
- Voltage Slump
- Voltage Flicker (Fliker)
- Voltage Harmonics – Total Harmonic Distortion

2.1. Voltage Effective Value

Overvoltages occur in power plants due to atmospheric and switching events. With the surge arrester or fixed capacitors connected at the supply point, overvoltages at certain levels can be damped and protect the network from overvoltages. Voltage drops can occur as well as overvoltages in the network.

Voltage drops may occur in power systems due to short-circuit events occurring at a remote point of the network. Short-term voltage drops damage the electrical devices, and it can take a long time to restart the devices (for example, PLCs used in industrial facilities are disabled when the voltage drops to 80-85% of the nominal value). By connecting appropriate surge arresters to overhead lines, the possibility of short-circuit faults is reduced. By doing these processes, the quality of power systems is increased [15].

The voltage level measured in power systems should be between +-10% of the declared nominal voltage value.

2.2. Voltage Unbalance

The absence of a 120 degree phase difference between the voltage phase angles, and the 3-phase voltage difference being more than 7V creates voltage imbalance and this problem is one of the power quality problems. Single-phase loads connected to power systems are the main cause of voltage imbalance. At the same time, problems such as not performing the necessary transposition processes due to the long overhead lines, and the voltage regulators not working properly are other causes of voltage imbalance. If the single-phase loads are distributed towards the phases and transposed operations are performed, the possibility of voltage unbalance is reduced [16].

2.3. Voltage Slump

Voltage sag is the short-term decrease of the effective value of the mains voltage (0.1 pu – 0.9 pu) at the rated frequency. It occurs due to the activation of high-powered motors in networks with low short-circuit power or as a result of late detection of short-circuit faults in the network by the switching elements. Due to voltage collapse, electrical devices may malfunction and if this situation becomes more frequent, it may cause the device to malfunction. Figure 1 shows the decrease in the sinus signal, which is the voltage sag event [17].

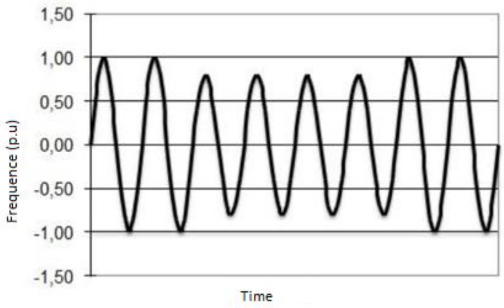

Figure 1. Voltage sag (Voltage Right)

2.4. Voltage Flicker (Fliker)

Flicker event is a sudden increase and decrease of loads in the network depending on time. This effect is mostly due to non-linear variable loads (eg arc furnaces). The luminous intensity or spectral distribution is manifested by the irregularity in visual perception caused by a light stimulus that fluctuates over time. There are two types of flicker as long-term flicker and short-term flicker [18].

- Short-term flicker (Pst): It expresses the flicker severity index measured in 10-minute periods.

- Long-term Flicker (Plt): It refers to the flicker severity index calculated according to the formula below from the Pst values measured during the two-hour time interval (12 consecutive measurements).

Table 1. Limit values for flicker severity.

Voltage Level	Flicker Intensity	
	Pst	Plt
V > 154 Kv	0,85	0,63
34,5 Kv < V < 154 kV	0,97	0,72
1 kV < V < 34,5 kV	**1,15**	**0,85**
V < 1 kV	1,15	0,85

2.5. Voltage Harmonics – Total Harmonic Distortion

When a zero source impedance voltage is applied to a non-linear load, the waveform of the resulting current will be different from the waveform of the voltage. This distorted current; located on its path only, such as transformers, conductors, and circuit breakers.

affect the elements. But zero source impedance is an ideal situation. In fact, the distorted current produces a voltage drop across the source impedance, which causes a distorted voltage to be applied to all loads after the source impedance.

It is possible to collect the effects of current and voltage harmonics in the power system under four main groups;

- Harmonic levels increase due to parallel and series resonance.
- Reduced efficiency in electricity generation, transmission and consumption.
- Reduction of the life of the plant elements as it weakens the insulation in electrical installations.
- Failures in facilities.

The sub-items of these groups are mainly problems such as:

- Formation of additional losses and increase in voltage drop
- Distortion of generator and network voltage waveform
- Damage of capacitors by exposure to excessive current
- Overheating and noisy operation in asynchronous and synchronous machines
- Faulty operation of measurement, protection and control systems
- Exposure of power system elements to overcurrent or overvoltage due to resonance events [19].

Harmonic currents and voltages are formed as a result of the distortion of the current-voltage sinusoidal wave, which is distorted due to non-linear loads (arc furnaces, regulators, switch-mode power supplies and devices such as inverters) or non-ideal generators connected to the system. With the formation of harmonics, transformer and neutral conductors heat up due to harmonic currents. Therefore, in order to avoid overheating, the neutral conductor cross-section and transformer power should be chosen in such a way that they are not affected by these harmonic currents. At the same time, it is necessary to use appropriate filters in order to absorb the harmonics created by the devices in industrial facilities that consume large power. Table 1.2 shows the acceptable harmonic voltage levels in the transmission system between 20 and 154 kV according to the Electricity Market Grid Code.

The intensity of distortion caused by current and voltage waves is expressed as 'Total Harmonic Distortion'.

- Total Harmonic Distortion expresses waveform distortion as a percentage, which is the ratio of the square root of the sum of the squares of the effective values of the voltage harmonic components to the effective value of the main component. Formula Equivalent (1) is given below

$$THB_V = \frac{\sqrt{\sum_{h=2}^{40} (U_h)^2}}{U_1} \times 100 \quad (1)$$

Table 2 Acceptable harmonic voltage levels in the transmission system between 20 and 154 kV according to the Electricity Market Grid Code.

Single Harmonics (Not Solid of 3)		**Single Harmonics (Solid Of 3)**		**Even Harmonics**	
Harmonic No "h"	Harmonic Voltage (%)	Harmonic No "h"	Harmonic Voltage (%)	Harmonic No "h"	Harmonic Voltage (%)
5	1,50	3	1,5	2	1
7	1,50	9	0,75	4	0,8
11	1,00	15	0,3	6	0,5
13	1,00	21	0,2	8	0,4
17	0,75	>21	0,2	10	0,4
19	0,75			12	0,2
23	0,50			>12	0,2
25	0,50				
>25	0,2+0,3(25/h)				
Total Harmonic DistortionLevel %3					

3. Measurement and Evaluation of Power Parameters at Batman Transformer Centers

The change in the resistance of the conductor as a result of the fact that the current passing through a conductor is not distributed homogeneously on the surface of the conductor due to the frequency, and the tendency of the current to pass through the parts close to the outer surface of the conductor as the frequency increases, is defined as the "skin effect". As the level of harmonic components increases, the frequency value increases at the same rate. As the frequency increases, the current tends to flow from areas close to the outer surface of the conductor. The resistance of the conductor in alternating current is greater than its resistance in direct current increases with harmonics.

The basic component ohmic resistance value (R1) in the sinusoidal current of the conductor is added to the (RH) resistance that occurs due to harmonics in case of nonsinusoidal current flow. Thus, the ohmic resistance value shown to the harmonic current becomes R = R1+RH. While most of the analyzes ignore the additional resistance (RH) from harmonic components, its effect is also included in academic and more detailed analyses. The increase in conductor resistance due to the skin effect is calculated by various empirical formulas based on experimental studies and practical applications. One of them is the following equation 2.

$$x = 1{,}585.10^{-4}ç\sqrt{\frac{f}{R_0}} \quad (2)$$

Table 3 shows the power parameters measurements made in 10 transformer centers in Batman province for a week and whether the transformer systems qualities are suitable according to TS EN

50160:2011 standards as a result of these measurements. Among the standard values given in the measurement results, the transformer center quality has successfully passed the tests in the measurements made. If the measurements are not within the given standard value ranges, they are considered unsuccessful in the tests [20].

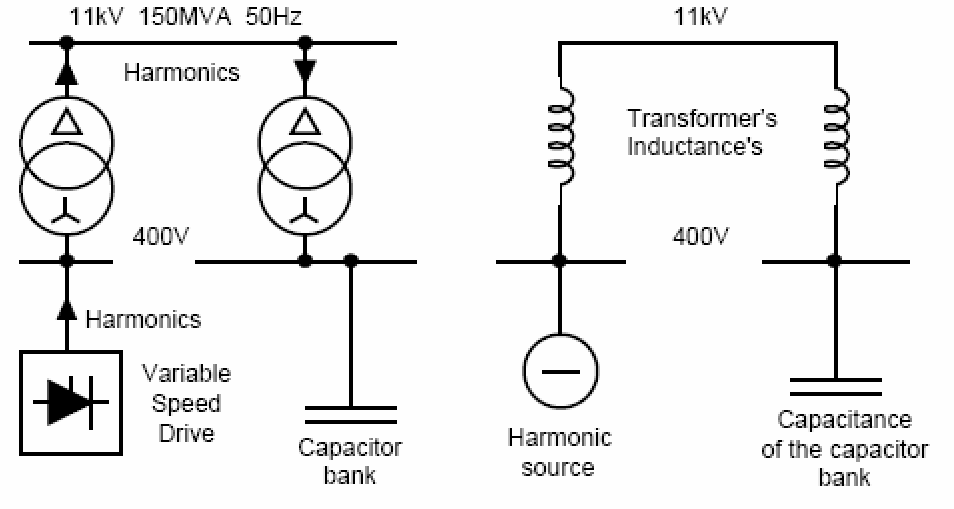

Figure 2 The formation of series resonance in the energy system due to harmonics and its equivalent circuit

Harmonic currents have two important effects on electrical circuits. Since harmonic currents increase the effective value of the total current, power losses will occur in the transmission medium. In addition to power transmission lines, machines and transformers also get hot due to harmonic currents. In addition, while the depreciation windings of the generators act to reduce and eliminate the harmonics that occur in one-phase or two-phase short circuits, they also get very hot and cause additional losses in the generators.

Another effect of harmonic current is to create harmonic voltage drops on circuit impedances. In other words, high impedance systems cause greater voltage disturbance effects than low impedance systems. Since the frequencies of the harmonic currents are equal to multiples of the normal network frequency of 50 Hz, the voltage drops that occur on the generator, transformer and line reactances against these currents increase in proportion to the harmonic frequencies, and as a result, the waveform of the voltage is distorted [21-24].

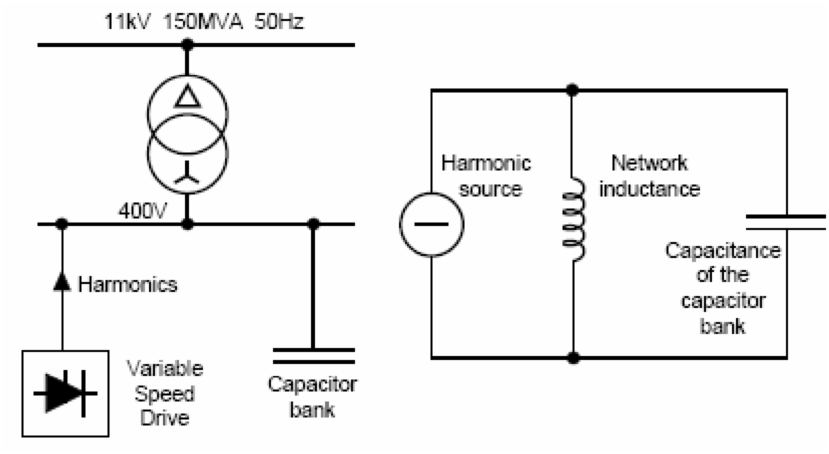

Figure 3. Parallel resonance formation and equivalent circuit in electrical installations

Table 3. 1-week measurements and evaluation results at Batman Transformer Centers

Transformer Center	Hour-Date	Voltage Change	Voltage Imbalance	Total Harmonic Distortion	Harmonic Voltage	Long Time Flicker	Voltage Slump
Batman DM13	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	25
Batman DM22	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	15
Batman DM3	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	18
Batman DM42	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	21
Batman DM53	16.10.2021	Passed	Passed	Passed	Passed	Passed	0
Beşiri DM8	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	32
Hasankeyf DM6	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	24
Batman DM30	16.10.2021	Passed	Passed	Passed	Passed	Passed	8
Batman DM17	16.10.2021	Passed	Passed	Passed	Passed	Passed	14
Batman DM18	16.10.2021	Passed	Passed	Passed	Passed	Not Passed	17

- Transformer substations are among the standard values given in voltage variation, voltage imbalance and total harmonic values and have passed all tests successfully.
- Considering the voltage harmonics, it is seen that the BATMAN DM42 transformer substation measurement values are not suitable because of the nonlinear loads (six-pulse rectifiers and other converters). By using the necessary filtering circuits, the power quality problem can be eliminated by damping the harmonics.
- It has been observed that the measurements of 6 transformer centers in voltage flicker are above the standard values. It has been observed that the high power motors in the industrial facilities connected to these transformer centers are in the majority.

4. Conclusion

Power quality problems are increasing day by day and we encounter power losses. Measuring parameters related to power quality is important to eliminate the problem. Nonlinear loads connected to power systems, arc furnaces, high power motors used in industrial plants and control systems are the factors that cause power quality problems with the increase. By using appropriate filtering circuits, making compensation in the facilities where high power motors are used, and performing maintenance and repair works in the facilities increase the power quality. Thus, quality energy is provided to the consumer by keeping the power quality parameters in accordance with TS EN 50160:2011 standards.

When we examine the power quality parameters measurements made in Batman Transformer Centers, we obtain the following results.

- In the power quality measurements, it is seen that flicker values and voltage events in Batman Substations sometimes exceed the limit value allowed in the standards. It was observed that a large number of power quality events occurred in the measurements lasting 24 weeks, which started in April 2021. The loads that produce harmonics on power systems are increasing day by day. Therefore, it indicates that power quality problems will increase in the future. Considering this situation, necessary precautions should be taken.
- When the measurements made at Batman Distribution Substations are examined, it is seen that the long-term flicker intensities in the 3 substations do not exceed the standard value in the voltage measurements at the measurement points, while the remaining transformer centers exceed the standard value. When voltage harmonics were examined, it was determined that they did not exceed their standard values. At the same time, voltage imbalance was observed twice

in a substation. In order to eliminate the voltage imbalance, necessary maintenance work should be carried out at the substation.

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