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ELECTRIC POWER QUALITY MEASUREMENT

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Abstract— The term power quality means maintaining sinusoidal wave of voltage at rated frequency without distortion. The prime objective is to transmit uninterrupted wave of voltage. This distortion is caused by the changing behavior of electric loads which causes changes in their waveforms even, these loads are called as non-linear loads. It also causes nonlinearities in the form of voltage sags, flickers, fluctuation, voltage dips. So these distortions adversely affect the current nature in the circuit. Usually it is also used to level up the quality of power than power provided by electric boards. In this we will study briefly the cases and also give adequate solutions obtained after a brief study on power measurement.

Keywords— power quality, voltage sag, harmonic distortion, nonlinear load.

I. INTRODUCTION

The immediate concern for the organizations or individuals dealing with power supply at a large scale for industrial or domestic purpose is to maintain the quality of power. Basically it means providing pure supply of power (without any disturbances) to the consumer irrespective of the Load. Quality of power can be determined by the factor on which it mainly depends is Voltage, waveforms, frequency

Being an Instrumentation Engineer, we will be working in the industries further where we will come across the term “Power loss”. The project helped us to research further in this topic and learns the basics; the research is the representation what we have learnt through analyzing various statistics and references in this process.

The objectives of this research paper are:

- Influence of variations in current, voltage and resistance
- Example of process for presenting the result of power quality measurements.

Through the study of measurements, we can closely examine the changes in the power supply from distribution end to consumer end. This study can help us broaden the research by gathering the information about the solution through which the disturbances can be reduced and built co-relate and characterize between various impacts of various parameters on quality.

II. PARAMETERS AFFECTING POWER QUALITY

1) LOAD

The power drawn for any operations to function properly is due to load connected across it .as the power in industries deals with the electricity generation electric power transmission and finally the distribution. Load is electrical components of an electrical circuit that consumer active electric power. The electric power gives distributed power supply at constant voltage. where the electrical instruments connected to the power circuit works as load which deals the current from supply lines

when any electric instrument switch on its dramatically reduces the load impedance. There are two types of industrial loads:

- Linear Load
- Non-Linear Load

a) Linear Load: The one where voltage is applied across resistance which is constant which results in flowing current is called as linear load .That is they draw alternate current at the supply voltage frequency. They are arranged in combination of resistor, inductor and capacitor. It shows different behavior of current, voltage with respect to different parameters.
For example: Uncontrolled lightning and heating uncontrolled motors etc.
Effect of Linear loads on Pure resistance , Pure inductive and pure Capacitive is that they circulate reactive power back and forth from the supply and the current and power profiles of inductive and capacitive are opposite in nature.

b) Non-Linear Load: In this type of load impedance changes with applied voltage in simpler words the current drawn will not be sinusoidal in nature even if connected to sinusoidal voltage. In this it draws alternating current at supply voltage frequency as well as higher frequencies simultaneously

For example: All motors driven by VFDs, Modern HVAC systems, controlled power supplies, Laptops, TVs, etc.

The higher frequencies produced are termed "Harmonics". We will further discuss Harmonics in detail.

2) HARMONIC DISTORTION

The voltage and current results by using non-linear loads and devices for the operation in power system causes distortion of higher frequencies called as *HARMONICS.*
The nonlinear due to which harmonics are generated can be represented as current sources of harmonics.
The waveforms generated are the sum of different sine waves (with different magnitude and phase) which have frequencies multiple of power system.
It causes harmonic voltage drop in line and transformer impedances.

It has different effect on capacitor, on generators, on transformer, on motors, on cable which we will discuss in detail:

Effect on Capacitors:

- Increased heating and dielectric stress.
- Can create resonance.
- Reduces capacitor life

Effect on Generators:

- Drastic rise in Iron loss (both hysteresis and eddy current loss).
- Increased copper losses
- Excessive heating
- Needs to oversized and dreaded
- Torque pulsations reducing the life of bearing and other rotating parts
- Vibrations, mechanical resonance and noise

Effect on Transformer:

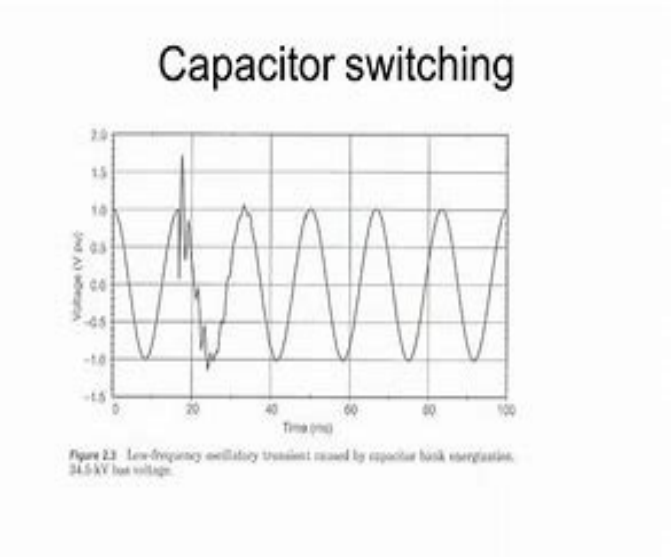
- Drastic rise in Iron loss (both hysteresis and eddy current loss).
- Increased copper losses
- Creates local hotspots and overheating
- Requires higher K factor rated transformers

Effect on Cables:

- Increased copper loss due to increased current.
- Skin effect and Proximity cause increased effective cable resistance and hence further increase in copper losses
- Increased voltage stress on cables leads to dielectric (insulation) failure over the time.
- Need table to be oversized than the designated sizes.

3) TRANSIENTS

When there is a sudden change of state, burst of energy takes place that is transition from one steady state condition to another, this lasts for shorter period of time.
They are majorly classified into categories of disturbances which include sudden high increase in current and voltage also both in some cases. One of the main causes of transients is capacitor switching, which we use capacitor bank in distribution lines for power factor correction and maintain acceptable voltage, but this has negative impact on power quality causing transients and eventually the electrical and electronic equipment to damage. .



Transient have various effect on different parameters:

1) Electronic Equipment

- Equipment will malfunction and produces corrupted results
- Improper specification and installation of TVSS can aggravate the failures
- Efficiency of electronic devices will be reduced

2) Motors:

- Due to transients motors run at higher temperatures
- There is increase in heat generation and noise in the motor
- The insulation is affected leading to motor damage
- The temperature and motor losses are increased.

3) Electrical Equipment

- The contacting surfaces are affected because of transients
- Breakers trips because of non-existent current demand
- Reduce transformer efficiency because of increased hysteresis losses impacted.

These transients can be eliminated by using surge protection which are properly sized devices such as electro flow in which it will eliminate as well as save energy and device. Another way to eliminate is also by use of magnetic relays which are applied at the distribution part in which the transients are blocked. By controlling the transient and changing the characteristics of system parameter, problem of transients can be solved.
There are two basic divisions of transient:

- Impulsive Transients
- Oscillatory Transients

4) VOLTAGE VARIATIONS

Voltage variations are basically of the variations in magnitude which are caused because of fluctuations in transmission lines.
The variation is observed by reference to nominal voltage , this deviation observed can be for short interval of time or for long interval. Based on this voltage variation characteristics can be classified as:

- Short duration variations
- Long duration variations

In the Short duration variations, variation last for less than 1 minute. Some of the phenomenon in voltage variation which are for short duration are:

- Dips or Sag
- Spike or Spurge
- Swells

In Long duration variations lasts for more than 1 minute. The phenomenon related to long duration voltage fluctuations are :

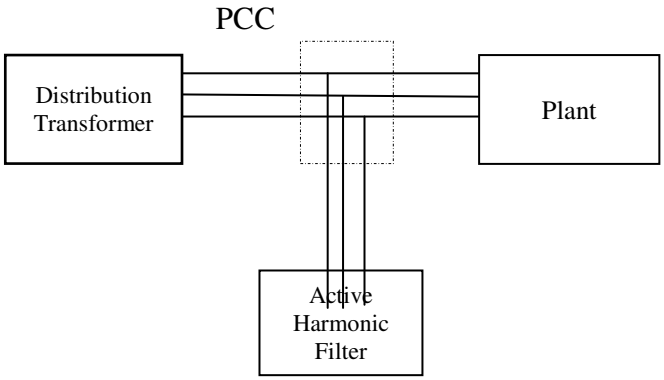
- Voltage flickers
- Under voltage
- Interruption

Voltage Variations	Description	Effect
1)Dip	A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage within 1 min or cycle	a)It leads to stoppage of process which consists of microprocessors b)It causes tripping of relay and contactors
2)Spike	The variation in voltage in this is almost thousands of volts, the variations range is very fast	It causes destruction of materials used for insulation and electronics
3)Swell	It has momentary increase in the voltage for less than few seconds	It causes data loss, adversely effects sensitive elements

III. GENERAL BLOCK DIAGRAM

Thus, the Power Supply is mainly categorized in three different levels as;

- Generation
- Transportation
- Distribution



- Distribution Transformer- Electricity Board can assure quality from their side only when the consumers do meet the certain power quality standards (IEEE-519-1992-2014).

EB Provides us power with - Rated magnitude
- Rated Frequency
- Sinusoidal Waveform

- Plant- The Plant is 80% consumed of Non-linear loads. This draws different amount of currents from the supply. Due to variations in Non-linear loads the signal quality gets affected (e.g. Harmonics, Reactive power).

- Active Harmonic Filter- Point of Common Coupling (PCC), where the AHF is connected. This works for removing the Harmonics present as well as improving the Power Factor.
  - Working: Supply gets distorted by connecting Non-linear load across it. This generates the unwanted Harmonics.

Thus, Any filter is used for filtering out the impurities. AHF creates a signal which is equal in magnitude of the harmonic signal to be removed but exactly opposite in Phase. This signal is then cancel outs the harmonic signal and other discontinuities

IV. POWER FACTOR IN POWER QUALITY

Power can be defined as capacity to work. In electrical domain, electrical power is the amount of electrical energy that can be transferred to some other form (heat, light) per unit time. Mathematically it is the product of voltage drop across the element and current flowing through it.
The entire circuit acts as resistive circuit and the heat is dissipated. The voltage is in phase with the current. Hence, it can be calculated as :
Electric power= Voltage across circuit*Current in circuit

Penalty on monthly electricity bills: Maharashtra

Sr. No	Range of Power Factor	Power Factor Level	Penalty
1.	0.895 to 0.900	0.90	0%
2.	0.885 to 0.894	0.89	2%
3.	0.875 to 0.884	0.88	3%
4.	0.865 to 0.874	0.87	4%
5.	0.855 to 0.864	0.86	5%
...	...	...	...
10.	0.805 to 0.814	0.81	10%
...	...	...	...

Incentives on monthly electricity bills: Maharashtra

Sr. No	Range of Power Factor	Power Factor Level	Incentive
1.	0.951 to 0.954	0.95	0%
2.	0.955 to 0.964	0.96	1%
3.	0.965 to 0.974	0.97	2%
4.	0.975 to 0.984	0.98	3%
5.	0.985 to 0.994	0.99	5%
6.	0.995 to 1.000	1.00	7%

For efficient operation, expected power factor is unity. Maintaining it at unity is an important task. If power factor is less than 0.95 i.e. when loads (motor, circuits) connected draw excessive current from distribution line, penalty is applied by the distribution board. On the contrary if this power factor ranges between 0.95 to 1 i.e. when load drives less current and eventually power is saved at the distribution line, incentives on electric bills are provided by the distribution board.

For example, when power factor is maintained at the desired value, the electricity saved by switching of a single motor remains on the distribution lines so when the fresh quota of 440V is supplied by the board; this saved power is also added to it. So the along with the ample amount of power at the user end one is also provided with the incentives on the electricity bill.

V. POWER QUALITY STANDARD

As the power system is the conducting vehicle in between consumers. An important role of power system is the ability to transmit and deliver electrical energy to the consumers within the limits specified by the EMC standards.

The widely used standards for electric power consumption:
MAHARASHTRA REGION

– General (IEC 61000-1-x):it represents standards
– Environment (IEC 61000-2-x): a description of the characteristics of the environment and the compatibility levels for various disturbances.
– Limits (IEC 61000-3-x): this defines the interference limit for various parameter like fluctuations in voltage and flickers

– Testing and Measurements Techniques (IEC 61000-4-x): it is used for testing methods of interference
– Installation and Mitigation Guidelines (IEC 61000-5-x): it describes the methods which can be used as remedy
– Generic Standards (IEC 61000-6-x): the interference immunity requirements and emitted interference limits

The IEEE-519 standard contains several additional terms related to the IEC terminology:

“Electricity supply code and other conditions of supply-2005”: Maharashtra State Electricity Distribution Company Ltd. – Regarding Power Factor and Harmonics.

– It shall be obligatory for all the consumers to maintain the average power factor in accordance with the relevant orders of the Commission.
– It shall be obligatory for the HT consumers and LT consumer (Industrial and Commercial only) to control the harmonics of his load at levels prescribed by the IEEE STD 519-1992
– Provided that the MSEDCL, may charge Penalty or provide Incentive for high or low Power Factors and for Harmonics, in accordance with the relevant Orders of the Commission.

Maharashtra State Electricity Distribution Company Ltd., petition submitted to **Maharashtra Electricity Regulatory Commission.**

"Pass relevant order, for the effective implementation of Clause No. 12.2 of MERC (Electricity Supply Code And Other Conditions of Supply) Regulations 2005, regarding charging of Penalty to the Consumers for Harmonic Exceeding limits of IEEE STD 519, 1992."

VI. SUMMARY

The main objective of the project is to study all the parameters which affect Power Quality.
Modern Power Electronics involves more use of Non-linear loads. This generates unwanted signals in the power system. To examine this, We have measured two cases of Industries which are having Non-linear loads. The readings were taken under observation of the Trainee Instructor. By studying these two cases we come to know that the unwanted signal (Harmonics, Transients etc.) degrades the quality of the Power Signal. This can be improved by using suitable circuitry like AHF.

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