International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 11, November-2014

Simulation of Overvoltage and Undervoltage Protection in PSIM

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***Abstract*— This paper illustrates modeling and simulation of overvoltage and undervoltage protection scheme. The method is based upon the operation of relay under overvoltage and undervoltage faults. The term power quality is used to describe as the quality of power that is given as input to various electrical load and ability of load to function properly. Without proper power the devices may misoperate or fail. There are many ways in which electric power can be poor quality and many more causes for such poor quality. Among the various power quality problems, overvoltage and undervoltage are frequent and severe. This paper demonstrates power quality, various causes and effects of overvoltage and under voltage ,and their protection. The test model of 230V, 50 Hz, has been designed in PSIM Demo Version 9.2.1.100 .**

***Keywords*— Power Quality, Overvoltage, Undervoltage, PSIM .**

I. INTRODUCTION

One of the major problems that the industries face is to counter the sudden overvoltages in the system which results in the deterioration of power quality and damages to equipments. The consequences of power incidents show that industrial and digital firms are losing crores per year due to power interruptions. The cost to replace equipments damaged because of voltage spikes is very high. Industrial business has to deal with loss of production. In this project, the focus of the study is the effects of transient overvoltage and undervoltage on the substation equipment and the corresponding protection against it.

Protection against sudden overvoltages in substations is a vital part of the overall reliability of power systems. The degree of surge protection afforded to a station is governed by the reliability required and the economics to obtain such reliability. Since major stations generally include strategic and highly valuable power equipment, surge protection is essential to avoid or minimize major system disturbances as well as major equipment failures. Transient overvoltage occurring in our power system can cause operational breakdown and also cause failure in industrial and household equipments as well.

Transient overvoltages in power systems may be caused due to several reasons of which those occurring due to lightning strikes or switching operations of inductive or capacitive loads. The substations are protected in such a way that lightning never falls directly 2 over it, rather the travelling waves arising due to lightning at a distant point far from the substation, travels into the substation through the towers and incoming transmission lines.

Given the course of the thesis, a study of the transient overvoltages and undervoltage and its corresponding effects on the substation and household equipments is carried out and modeled in PSIM, including the protection of the device.

II. POWER QUALITY AND ITS PROBLEMS

According to Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "*The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment*".

In the past the term reliability and quality was same as because there were no power electronic equipments and all the equipments were linear in nature. All the equipments were heating, lighting and motors, which were not very sensitive to voltage variation.

In the last few decade power quality has become an important issue since many equipments are semiconductor based and controlling is done with power electronic equipments.

A. Causes of Power Quality Problem

Some common disturbances which may cause power quality problems are listed below:

- Lightning and natural phenomena,
- Formation of snow on transmission line, storm etc.

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- Energization of capacitor banks and transformers,
- Switching or start-up of large loads e.g. Induction motors,
- Operation of non-linear and unbalanced loads,
- Failure of equipment, e.g. transformers and cables,
- Wrong maneuvers in distribution substations and plants.

The main cause of power quality problem is the short circuit fault occurring in the distribution side. This short circuit can cause a huge increase in the system current and consequently a large voltage drop in the impedance of the supply system [1].

In systems where overhead lines are predominant, natural phenomena are responsible for the majority of faults in transmission and distribution systems, especially lightning [2, 3]. In principle, a lightning stroke is a transient increase in the voltage along the line. However, an arc is created between the phase hit by the stroke and ground and consequently the voltage is depressed to zero.

When unbalanced loading is done on a system it causes an unbalance voltage in the phases, which ultimately creates power quality problem. This unbalance voltage increases rotor heating due to negative sequence magnetic flux generated in the stator winding.

B. Effects of Power Quality Problem

Poor electric power quality has many harmful effects on power system devices and consumer goods. These effects are so dangerous that it is not visible until failure occurs in the equipments. Even if there is no occurrence of failure of the equipment, there will be losses and heating in the equipment which will ultimately reduce the life span of the equipment.

- When harmonics are added to the supply voltage equipment could receive high value of instantaneous voltage and may be susceptible to failure. This high voltage may also force electronic components of power system to operate in the saturation, producing additional harmonics and disturbances.
- The effects of poor power quality on capacitors, rotating machines, cables and transformers, fuses, and customers' equipment creates heating, noise, poor performance etc.
- Premature failure of distribution transformer due to heating can be caused by harmonics.
- Due to sudden rise in voltage and/or current, failure of power system components and customer loads can occur.

III. UNDERVOLTAGE

A voltage which is below the optimum operational or rated value of a component, circuit or device is called an undervoltage. Such a voltage may produce for instance a malfunction or failure of customer equipments. In computers and similar devices, undervoltages can lead to data losses.
Undervoltage is defined as a sudden drop in the root mean square (r.m.s.) voltage and is usually characterized by the remaining (retained) voltage. Undervoltage is thus, short duration reduction in r.m.s. voltage, caused mainly by short circuits, starting of large motors and equipment failures.

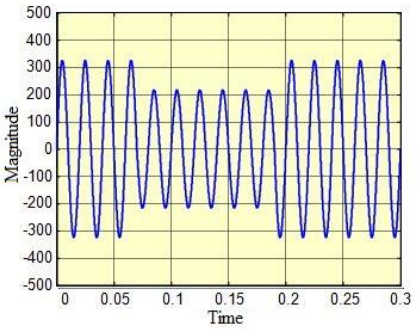

Fig. 1. Undervoltage

Furthermore, Undervoltage may be classified by their duration as shown in Table-1.

TABLE I. Classification of Undervoltage according to IEEE

Type of Undervoltage	Duration	Magnitude
Instantaneous	0.5 – 30 cycles	0.1 – 0.9 p.u.
Momentary	30 cycles – 3 secs	0.1 – 0.9 p.u.
Temporary	3 secs – 1 min	0.1 – 0.9 p.u.

Undervoltages are the most common power disturbance whose effect is quite severe especially in industrial and large commercial customers such as the damage of the sensitivity equipments and loss of daily productions and finances. The examples of the sensitive equipments are Programmable Logic Controller (PLC), Adjustable Speed Drive (ASD) and Chiller control. Undervoltage at the equipment terminal can be due to a short circuit fault hundreds of kilometers away in the transmission system.

A. Causes of Undervoltage

There are various causes for which undervoltage is created in system voltage:

1. Closing and Opening of Circuit Breakers: When the circuit breaker of a phase is opened suddenly, then the line which it is feeding will be temporarily disconnected. The other feeder lines from the same substation system will act as a undervoltage.

2. Due to Fault: Undervoltage due to fault can be critical to the operation of a power plant. The magnitude of undervoltage can be equal in each phase or unequal respectively and it depends on the nature of the fault whether it is symmetrical or unsymmetrical.

3. Due to Motor Starting: Undervoltage due to motor starting are symmetrical since the induction motors are balanced three phase loads, this will draw approximately the same high starting current in all the phases.

4. Due to Transformer Energizing: There are mainly two causes of undervoltage due to transformer energizing. One is normal system operations which include manual energizing of a transformer and another is the reclosing actions. These undervoltages are unsymmetrical in nature.

5. Equipment Failure: Failure of electrical equipment occurs due to insulation breakdown or heating or short circuit etc.

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6. Bad Weather: Lightning strikes in the power line cause a significant number of undervoltages. A line to ground fault occurs when lightning strikes the line and continues to ground.

7. Pollution: Flash over takes place when there is storm in the coastal regions, where the power line is covered with salt. This salt formation acts as a good conductor of electricity and faults occur.

8. Construction Activity: Generally all power lines are undergrounded in urban areas, digging for doing foundation work of buildings can cause damage to underground cables and create undervoltages.

B. How undervoltage can be prevented

An underground voltage relay which removes a motor from service when low-voltage condition develops, so that the motor will not draw excessive current, or which prevents a large induction or synchronous motor from starting under low-voltage condition.

IV. OVERVOLTAGE

A Overvoltage is defined as an increase in the r.m.s. value of the voltage up to a level between 1.1 pu to 1.8 pu at power frequency for periods ranging from a half cycle to a minute as shown in fig. 2.

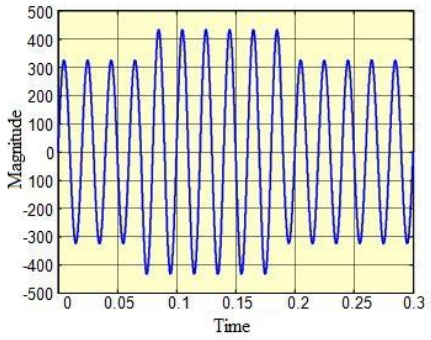

Fig. 2: Overvoltage

Overvoltage are less common than undervoltage but they also arise due to system faults. Overvoltage can occur due to single line to ground fault, which in turn will raise the voltage of the other phases. It can also cause due to disconnection of heavy industrial loads or switching on the capacitor banks [2]. This is generally due to ungrounded or floating ground delta systems, where a change in ground reference would give voltage rise to the ungrounded system.

Type of Overvoltage	**Duration**	**Magnitude**
Instantaneous	0.5 – 30 cycles	1.1 – 1.8 p.u.
Momentary	30 cycles – 3 secs	1.1 – 1.4 p.u.
Temporary	3 secs – 1 min	1.1 – 1.2 p.u.

Table II: Classification of overvoltage according to IEEE 1159

Causes of overvoltage are mainly due to energization of capacitor bank. It can also be generated by sudden load deduction. Due to the disconnection of load there is a sudden reduction of current, which will give rise the voltage, $v = L\frac{di}{dt}$, where L is the inductance of the line.

The effects of overvoltage are more severe and destructive. It may cause the electrical equipment to fail, due to overheating caused by high voltage. Also electronic and other sensitive equipment are prone to malfunction.

V. MODELLING AND ITS CONTROL STRATEGY

This circuit protects refrigerators and other electronics appliances from over and under voltages. By the name itself we can say that if the input voltage is more or less than the required voltage then the electrical appliance gets turned off and it gets disconnected from its respective power supply. This voltage protection circuit is designed to develop a low voltage and high voltage tripping mechanism to protect a load from any damage. In many of the homes and industries fluctuation in AC mains supply take place frequently. The electronic devices get easily damaged due to the fluctuations. To overcome this problem, we can implement a tripping mechanism of under/over voltage protection circuit to protect the loads from undue damage. The PSIM model is shown in the figure below.

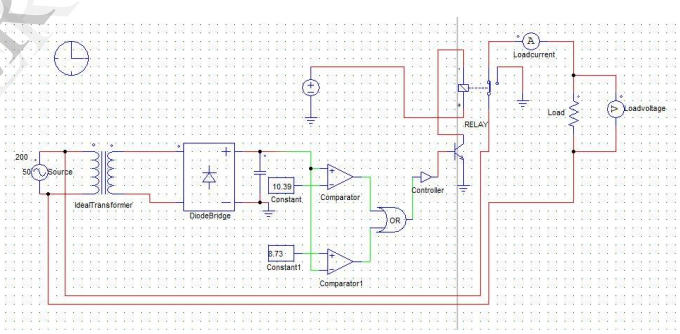

Fig. 3. PSIM model of the Test System

The specification of the test system is shown in Table III.

TABLE III. Specification of Test system

Source	230 V, 50 Hz,
Single phase transformer	Ideal, K=23:1
Single phase diode bridge	Ideal
Capacitor	0.019 mF
Resistive load	120 Ω
D.C. voltage source (Relay operation)	12 V
Relay with 1 NO and 1 NC changeover switches.	Coil voltage= 12 V, Operating voltage= 10 V

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A. *Simulated Results:*

Normal voltage (230 V)

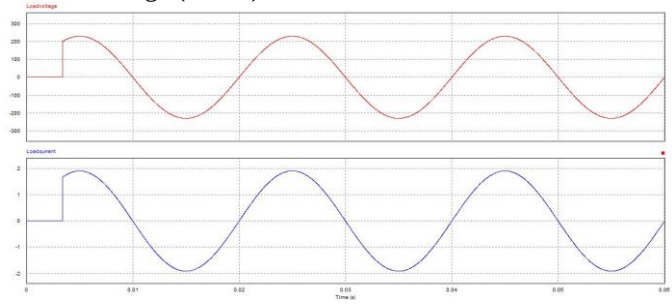

Fig. 4. Voltage and current output during normal working condition

The waveform shown above is for the load voltage and load current during normal working condition. When the supply voltage is 230 V, the control circuit sees that there is no undervoltage and overvoltage problem. So the relay allows the supply voltage to be fed to the load.

Undervoltage Condition (200 V)

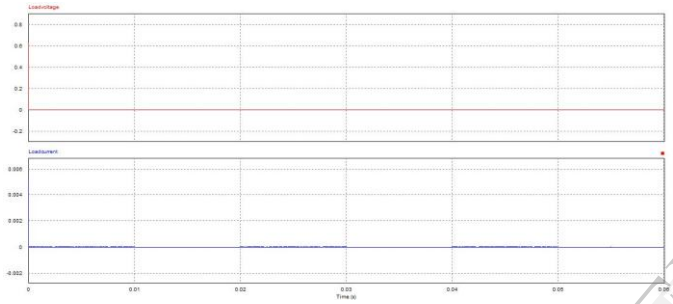

Fig. 5. Voltage and current output during undervoltage condition

As it can be easily depicted from the waveform that as soon as the supply voltage is less than the lower limit of the circuit which is 200 V, is falls in undervoltage region. So it disconnects the the supply to the load.

Overvoltage Condition (240 V)

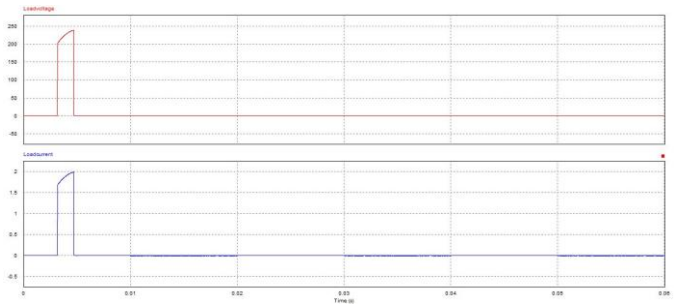

Fig. 6. Voltage and current output during overvoltage condition

In this waveform the supply voltage is 240 V, which crosses the upper voltage limit. So it falls in overvoltage criteria. The relay will see this overvoltage problem and disconnect the supply from the load. Thus saving the equipment.

VI. CONCLUSION

It has been discussed that undervoltage and overvoltage problem are very common and can create problem for consumer good and industrial application. So a system has been modeled using relay and comparator and it is found to be good in disconnecting the supply when if sees any of the above problems.

VII. ACKNOWLEDGMENT

I would like to thank my parents and my supervisor who has helped me in all possible ways towards successful completion of this work.

VIII. REFERENCES

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