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# Analysis of Interruptions and Protection against Interruptions in Electric Power systems

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**Abstract**: *Interruptions may occur when there is a fault on the circuit supplying the customer. But voltage sags occur even if the fault happens to be far away from the customer's site. Voltage sag may last only 4-5 cycles and it can cause a wide range of sensitive customer equipment to drop out but an interruption can be immediate and is the result of fault. To industrial customers, voltage sag and a momentary interruption are equivalent if both shut down the process. In this paper, the characteristics of interruptions and the remedial measures for the same are discussed. IEEE 9 bus system has been considered for study.*

**INDEX TERMS:** *Short duration interruptions, long duration interruptions, Causes of and Protection against Interruptions, IEEE 9 bus system*

## 1. INTRODUCTION

Interruptions may occur when there is a fault on the circuit supplying the customer. But voltage sags occur even if the fault happens to be far away from the customer's site. Voltage sag may last only 4-5 cycles and it can cause a wide range of sensitive customer equipment to drop out but an interruption can be immediate and is the result of fault. To industrial customers, voltage sag and a momentary interruption are equivalent if both shut down the process. There are short-duration and long-duration interruptions which lasts 0 to 1 minute and more than 1 minute respectively.

## 2. CATEGORIES OF INTERRUPTIONS

Interruptions are classified by IEEE 1159 into either a short-duration or long-duration variation. However, the term "interruption" is often used to refer to short-duration interruption, while the latter is preceded by the word "sustained" to indicate a long-duration. They are measured and described by their duration since the voltage magnitude is always less than 10% of nominal.

Interruption is the power quality problem with the most perceivable effect on facilities. It generally affects the industrial sector, particularly the continuous process industry. In addition, the communication and information processing business is also significantly disturbed.

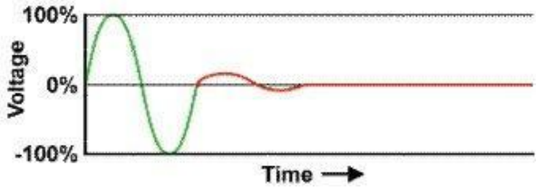


**Figure 1:** *Interruption*

*A. Short Duration Interruption*

Interruption is defined as the decrease in the voltage supply level to less than 10% of nominal for up to one (1) minute duration. They are further subdivided into: Instantaneous (1/2 to 30 cycles), Momentary (30 cycles to 3 seconds) and Temporary (3 seconds to 1 minute).

Interruptions mostly result from reclosing circuit breakers attempting to clear non-permanent faults, first opening and then reclosing after a short time delay. The devices are usually on the distribution system, but at some locations, momentary interruptions also occur for faults on the sub-transmission system. The extent of interruption will depend on the reclosing capability of the protective device. For example, instantaneous reclosing will limit the interruption caused by a temporary fault to less than 30 cycles. On the other hand, time delayed reclosing of the protective device may cause a momentary or temporary interruption. Aside from system faults, interruptions can also be due to control malfunctions and equipment failures.

*B. Long Duration Interruption*

Long duration/Sustained Interruption is defined by IEEE 1159 as the decrease in the voltage supply level to zero for more than one (1) minute. It is classified as a long duration voltage variation phenomena. Sustained interruptions are often permanent in nature and require manual intervention for restoration. In addition, they are specific power system phenomena and have no relation to the usage of the term outage. Outage does not refer to a specific phenomenon, but rather to the state of a system component that has failed to function. Furthermore, in the context of power quality monitoring, interruption has no relation to reliability or other continuity of service statistics.

## 3. INTERRUPTIONS AND VOLTAGE SAG

Some interruptions may be preceded by voltage sag, particularly when these PQ problems are due to faults on the source system. The voltage sag occurs between the time a fault initiates and the protective device operates. On the faulted feeder, loads will experience voltage sag followed immediately by an interruption. The figure below illustrates a momentary interruption during which voltage on one phase sags to about 20 percent for about 3 cycles, which subsequently drops to zero for about 1.8 s until the re-closer closes back in.

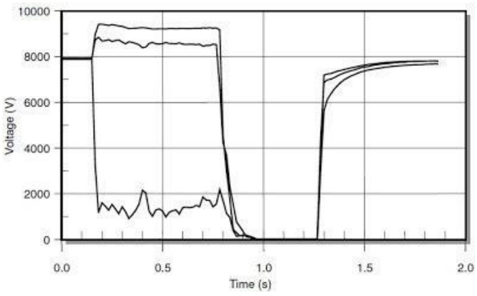


**Figure 2:** *Interruption after Voltage Sag*

## 4. CAUSES OF INTERRUPTIONS

*A. Causes of short Duration Interruptions*

They are the results of clearing of networks made by automatic or manual closure of contacts under fault conditions. The re-closure of circuit breaker may also result in momentary interruption but the ability of the customer facility over rides such reverse act as there will be no continuity in obvious if the foresaid condition prevails for very low time bounded interruption.

*B. Causes of Long Duration Interruptions*

Sustained interruptions are usually caused by permanent faults due to storms, trees striking lines or poles, utility or customer equipment failure in the power system or faulty coordination of protective devices. Consequently, such disturbances would result to a complete shutdown of the customer facility.

The short and long duration interruptions may be preceded by voltage sag in the power system and the term voltage sag is defined as the reduction in nominal voltage by more than 10% of the nominal voltage.

The voltage sag occurs between the time a fault initiates and the protective device operates. On the faulted feeder, loads will experience voltage sag followed immediately by an interruption.

## 5. IMPACT OF INTERRUPTIONS

The problems and the damages caused to the consumers because of the inadequate voltage conditions, dips and short and long time interruptions determine substantial additional costs. The costs of those perturbations are retrieved in the raw materials and a production loses the restarting of production means, inaccurate products from the quality point of view and the delivery time delays. At all this, it can be added the additional preventive maintenance costs, necessaries to approach a high performance standards.

In an industrial environment, interruptions can cause disruption in production by increasing the number of rejects or material wastage. In some areas, interruptions can increase the risk of equipment damage or even injury. Information technology is affected in two ways. First, current data can be lost and the system can be corrupted. Second, after interruption is over, the re-boot process, especially on a large and complex system, can last for several hours. Because of these reasons, critical computer systems and telecommunication equipment are supplied with UPS power.

## 6. INTERRUPTION INDICATOR

The interruption can be indicated by any one of the following with respect to supply side.

A. SAIFI (System average interruption frequency index) – it indicate the interruption mean number into the electrical network per year.

B. SAIDI (System average interruption duration index) – it indicates the mean time of an interruption for the customer serviced by the Distribution Operator

C. ASAI (Average service availability index) - it is defined as the ratio between the total number of customer hours (how the distribution service was available) and the total number of customer hours (how the distribution service was required).

D. ASUI (Average service unavailability index) ASUI = 1-ASAI

E. ASIFI (Average system interruption frequency index) – it is the ratio between sum of power in kVA at interrupted locations and total functional power in kVA.

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## 7. PREVENTION AND PROTECTION AGAINST INTERRUPTIONS

To prevent interruptions, the utility may do the following:

A. Reduce occurrence of faults in system - Includes arrester installation, feeder inspections, tree trimming and animal guards

B. Limit the number of affected customers interrupted - Improve selectivity through single-phase re-closers and/or extra downstream re-closers

C. Fast reclosing -To protect equipment from interruptions, end-users may use Uninterruptible Power Supply (UPS) and other energy storage systems.

D. Back-up generator or Self-generation is necessary for sustained interruptions. Other solutions include the use of static transfer switch and dynamic voltage restorer with energy storage.

Protection: The utility can be protected against interruptions by using / installing Uninterruptible Power Supply (UPS), Self-generation and /or Energy storage.

The installation of UPS should be carried out by properly selecting the type of electronic converter used as the converter can cause harmonics in the system/utility and hence the nearby circuits. Self generation and energy storage can be considered only if the coordination/interconnection with existing supply system is proper.

## 8. CASE STUDY

A power system with three main generators and different loads was tested with an interruption. The test was carried out using ETAP 12.6.5 and the standard IEEE 9 bus system was used. It was observed that the interruption had caused severe current flow just before the discontinuation of service. The method proposed to counter-act this interruption was self-generation.

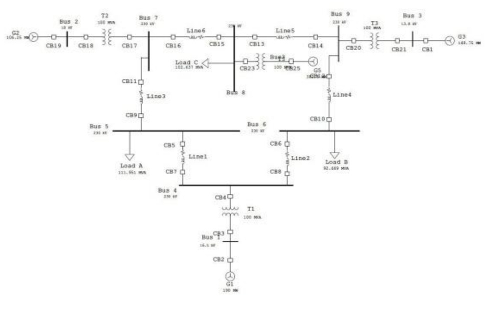

**Figure 3:** *Proposed system*

The generator, transmission line and load data are tabulated as given below.

**Table 1:** *Generator Data*

| Generator No. / Data | 1 (Swing) | 2 (Voltage controlled) | 3 (Voltage Controlled) | Self (Swing) |
|---|---|---|---|---|
| Power rating (MW) | 190 | 106.25 | 148.75 | 382.5 |
| Voltage (kV) | 16.5 | 18 | 13.8 | 230 |
| Power factor (%) | 85 | 85 | 85 | 85 |
| Efficiency (%) | 90 | 80 | 95 | 95 |
| Xd (%) | 25 | 19 | 19 | 19 |
| Ra (Ohm) | 0.0544 | 0.0648 | 0.0190 | 3.5266 |

**Table 2:** *Transmission Line data*

| Transmission Line No. / Data | Sequence Impedance (Ohm per km) | |
|---|---|---|
| | Positive | Negative |
| 1 | 44+j333 | 44+j333 |
| 2 | 49+j299 | 49+j299 |
| 3 | 81+j579 | 81+j579 |
| 4 | 90+j677 | 90+j677 |
| 5 | 53+j395 | 53+j395 |
| 6 | 38+j282 | 38+j282 |

**Table3:** *Load Data*

| Load | Voltage (kV) | Power (MW) | Power factor (%) |
|---|---|---|---|
| LOAD A | 230 | 100 | 89 |
| LOAD B | 230 | 88 | 95 |
| LOAD C | 230 | 97 | 94 |

### Results:

The system results were obtained for two different cases. First, the normal system was analyzed and power flow was estimated and is shown in table 4.

**Table 4**

| Generation Details | | | | | | |
|---|---|---|---|---|---|---|
| ID | Rating (MW) | Rated kV | MW | Mvar | Amp | % Generation |
| G1 | 190 | 16.5 | 160.05 | 34.62 | 5509 | 84.2 |
| G2 | 106.25 | 18 | 50 | -4.124 | 1570 | 47.1 |
| G3 | 148.75 | 13.8 | 85 | -10.64 | 3497 | 57.1 |
| Loading details | | | | | | |
| ID | Rating (MW) | Rated kV | MW | Mvar | Amp | % Loading |
| Load A | 99.99 | 230 | 98.3 | 49.487 | 271.6 | 96.6 |
| Load B | 87.71 | 230 | 86.064 | 28.688 | 224.1 | 96.5 |
| Load C | 96.88 | 230 | 95.673 | 33.472 | 249.5 | 96.9 |

Second, an interruption was observed at bus no. 8. As part of typical protection, the faulty and healthy zones were isolated. In other words, the sources namely generator 1 through generator3 were separated from the generator 1 through generator3 were separated

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from the faulty location. Now, the loads were to be supplied after clearing fault which was supplied by self-generator. The data observed after the occurrence of interruption are shown in table 5.

**Table 5:**

| Generation Details | | | | | | |
|---|---|---|---|---|---|---|
| ID | Rating (MW) | Rated kV | MW | Mvar | Amp | % Generation |
| G1 | 379.02 | 230 | 261.139 | 35.478 | 645.4 | 68.3 |
| Loading details | | | | | | |
| ID | Rating (MW) | Rated kV | MW | Mvar | Amp | % Loading |
| Load A | 111.95 | 230 | 80.166 | 40.358 | 245.2 | 87.3 |
| Load B | 92.44 | 230 | 77.646 | 25.882 | 212.8 | 91.7 |
| Load C | 102.63 | 230 | 96.694 | 33.829 | 250.9 | 97.4 |

## 9. CONCLUSIONS

The problems of interruptions have to be understood and analyzed as they could even cause blackout. Thus obtained data can be stored and used for obtaining improved system reliability. Power conditioning may be advised but it is expensive but is economical in the long term perspective to improve the overall performance.

## REFERENCES

[1] J.Lamoxee, et -at"The impact of voltage sags on industrial plant loads"' presented at the First international conference on Power Quality, Paris France Oct 14-16,1991.

[2] L Conn ad etal" Predicting and preventing problems associated with remote fault clearing voltage dips" IEEE Trans . I.A Vol.27 P 167-172 Jan 1991

[3] Case studies published by M/s Dranetz-BMI Corporation, a prominent PQ Monitoring Equipment manufacturer in USA at their web site *http://www.dranetz.com*

[4] AlexMcEachern "Introduction to Power Quality and Energy Consumption". Power standards Lab (www.powerstandards.com), San Francisco, California, USA, sep 2009.

[5] AlexMcEachern " An overview on Issues in Power Quality" September 12-13, 2006 - Montreal, Quebec, Canada.

[6] Jared Newton, "Introduction to Power Quality Issues",March 9 2009, Tower, Minnesota,USA.

[7] Optimal Load Flow with SteadyStateSecurity by0.Alsacand Scott

[8] H. W. Dommel & W. F. Tinney, "Optimal power flow solu-tions", IEEE Trans. (Power App. & Syst.), Vol. PAS-87, pp. 1866-1876,October, 1968.

[9] E-Tap 12.6.5 Demo Guide by Operation Inc. U.S.A.