SRM UNIVERSITY
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Unit.3-Long and Short Interruptions

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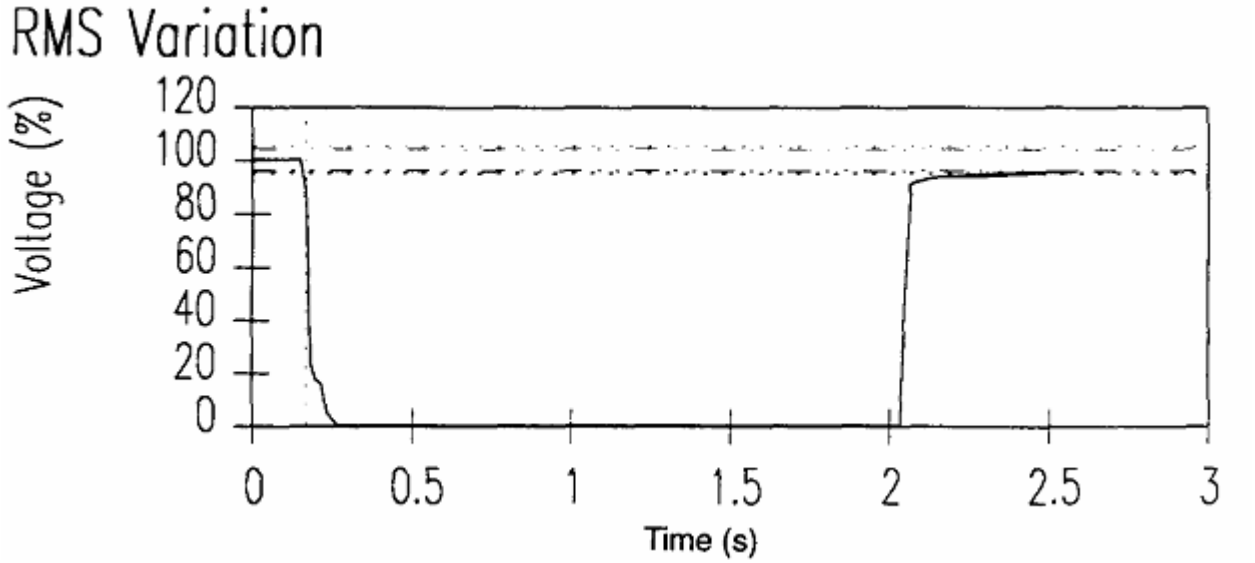
Unit-3.INTERRUPTIONS

- Origin of Long & Short interruption
- influence on various equipments
- Basic reliability indices related interruption

Definition

An *interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of* time not exceeding 1 min.



Classifications

Short duration variations

Momentary Interruption < 1 min , <0.1 pu

Temporary Interruption < 1 min , <0.1 pu

Long duration variations

Interruption, sustained > 1 min , 0.0 pu

According to voltages interruption time, following classification of the events (IEEE-1159-95) :

short time interruptions:

instantaneous (0.5 periods- 3 seconds) and temporal (3 seconds-1 minute)

long time interruptions

duration greater than 1 minute.

Interruption

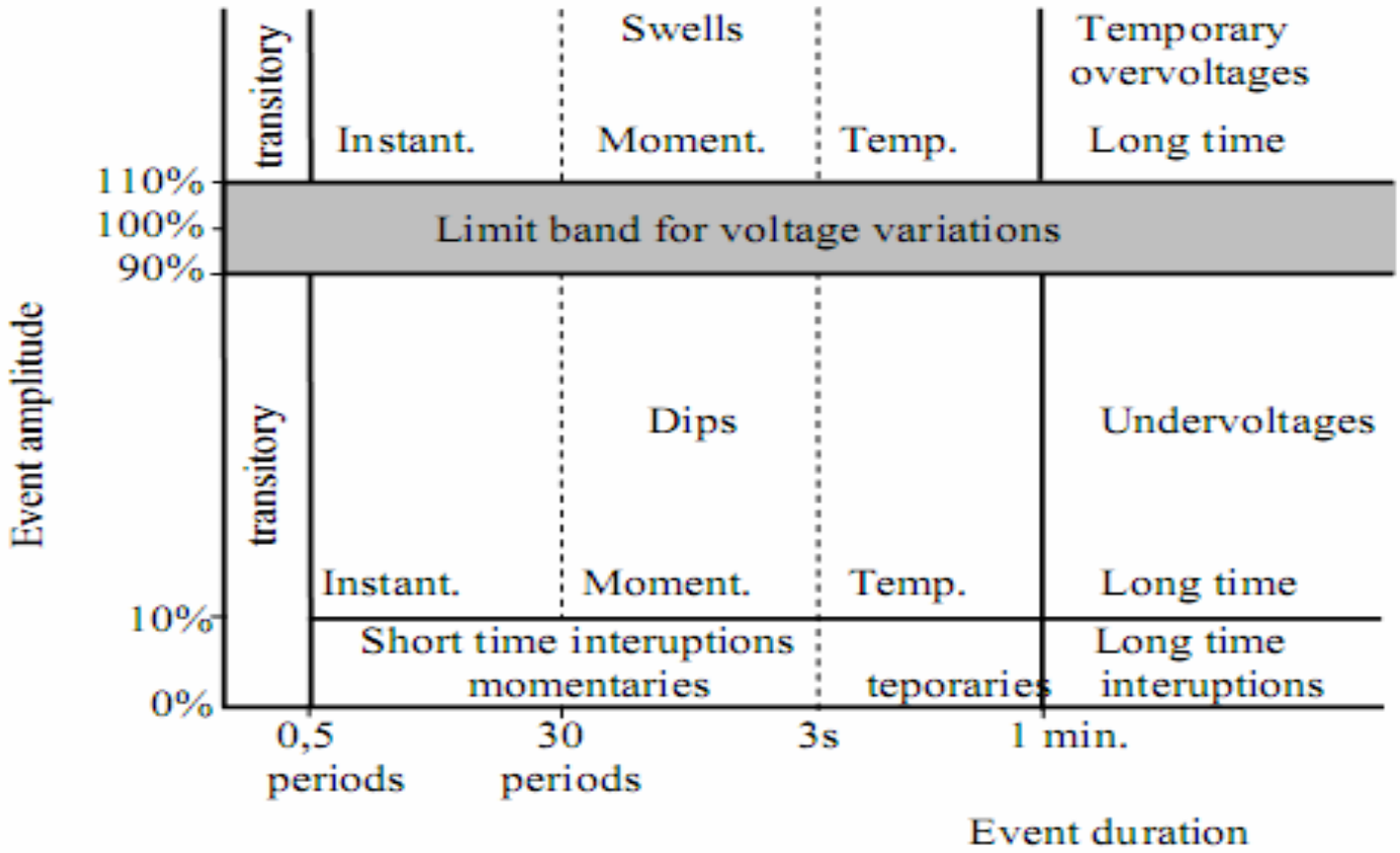


Fig. 1 – Events classifying according to IEEE 1159-1995 Standard.

Origin of Short and Long Interruptions

Interruptions can be the result of

-scheduled, the customers are announced before doing any programmed actions into the distribution network

-accidentals, caused by the permanents or temporary faults, generally produced by external events, equipments faults etc.

- power system faults
- equipment failures
- control system malfunctions
- Delayed reclosing of the protective device may cause a momentary or temporary interruption.

Causes for Short time interruptions

- The short time interruptions are,
  - the results of the clearing of the network faults by the reclosers or ARC (automatic closing of the reserve),
  - the customers being submits of a dips and/or short time interruptions succession, caused by the existence of an intermittent arc, followed by automatically reclosing in order to clear all semi permanent and transitory faults

Causes for Long Time interruptions

- The long time interruptions are the results of the definitive insulation of a permanent fault outcome of the relay protections working, being necessaries reparations or replacing of some components before energizing.
- An inadequate configurations of network power supply, by the low performances of the equipments, as well by the inexistence of some specific maintenance procedure of the installations.

Voltage sag followed by Interruptions

- Some interruptions may be preceded by a voltage sag when these 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 a voltage sag followed immediately by an interruption.

- Instantaneous reclosing generally will limit the interruption caused by a non-permanent fault (30 cycles).

Finding duration of Interruption

- Only duration is measured since the voltage magnitude is always less than 10% of nominal.

- The duration is determined by utility protective devices and the particular event that is causing the fault. Thus, The duration of the interruption will depend on the reclosing capability of the protective device.

- The duration of an interruption can be irregular due to equipment malfunctions or loose connections

Parameters of Interruptions

The continuity of power supply is illustrated by the following parameters

- Interruption time:

$$\Delta t_i = t_f - t_i \ , \quad [\mathrm{s}] \qquad (1)$$

where t_f is the moment of power supply return; t_i - power supply interruption moment;

- interruption frequency:

$$f_a = \frac{N_i}{T_r} \ , \qquad (2)$$

where

N_i is the number of interruption;

T_r -reference time.

- the percentage or relative amplitude:

$$\varepsilon_g[\%] = \frac{\Delta U_g}{U_c} \cdot 100[\%] = \frac{U_c - U}{U_c} \cdot 100[\%] \qquad (3)$$

where U is the phase voltage residual value, and U_c – contracted phase voltage.

Interruptions

The interruption indicators (performance indicators regarding the service reliability), are defined relative to the frequency, to the interruption time or simultaneously.

Impact of Interruption

- 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.

Impact on customers' equipment

- 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.

Influence on various equipments

- Stoppage of sensitive equipment (i.e. computers, PLC, ASD)
- Unnecessary tripping of protective devices
- Loss of data
- Malfunction of data processing equipment.

Interruption Indicators

The interruption indicators (performance indicators regarding the service)

According to the interpretation way of the power supply interruption it can be define:
-indicators for power supply system; -utility supply side.
-indicators for the customer supplying. –customer supply side.

The difference between that all the reports are made relative to the number of the customer (interrupted, deserved or affected) in comparison with the system indicators which are made relative to the number of the incidents.

Interruption index-Indicators for the power supply system

Short and long time interruptions characterization from the distribution operator are used :

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

$$SAIFI = \frac{\sum_{i=1}^{n} N_i}{N_c} [\text{interruption/customer}],$$

Where N_i is the number of all the customer interrupted for more than 1 minute in i interruption;
N_c – the total customer number; n – total interruptions number.

$$\text{SAIFI} = \frac{(\text{no. customers interrupted})\,(\text{no. of interruptions})}{\text{total no. customers}}$$

Interruption index-Indicators for the power supply system-contd..,

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

$$SAIDI = \frac{\sum_{i=1}^{n}(N_i \cdot D_i)}{N_c} [\text{ system minute /customer}]$$

Where D_i are the inerruption times (minutes), in the i interruption.

$$\text{SAIDI} = \frac{\Sigma\,(\text{no. customers affected})\,(\text{duration of outage})}{\text{total no. customers}}$$

Interruption index-Indicators for the power supply system-contd..,

- *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).

$$\text{ASAI} = \frac{\text{customer hours service availability}}{\text{customer hours service demand}}$$

$$ASAI = \frac{AD - ENS}{AD} = \frac{8760 - \frac{SAIDI}{60}}{8760},$$

Where *ENS is undelivery energy because of the power supply interruptions [MWh/yaer]; AD - the actual yearly consumption of electrical energy for the* energetical system- without the own technological consumption [MWh/year].

Interruption index-Indicators for the power supply system-contd..,

ASUI (*Average service unavailability index*)

$$ASUI = \frac{ENS}{AD} = \frac{\frac{SAIDI}{60}}{8760} = 1 - ASAI$$

ASIFI (*Average system interruption frequency index*)

$$ASIFI = \frac{\sum_{i=1}^{n} S_i}{S_t}$$

Where S_i is the interrupted power at the i interruption [kVA]; S_t – the total power in function (instaled, conected) [kVA].

ASIDI (*Average system interruption duration index*)

$$ASIDI = \frac{\sum_{i=1}^{n} S_i \cdot D_i}{S_t} [\text{min}]$$

Interruption index-Indicator at the customer level

CAIFI (*Customer average interruption frequency index*) – it show the average number of interruptions/interupted customs during one year. It can determined from the relation:

$$CAIFI = \frac{\sum_{i=1}^{n} N_i}{N_{ca}} [\text{interruptions/afected customers}] \qquad (13)$$

Where the N_{ca} represent the total number of the afected customers during the analyzed periode.

$$\text{CAIFI} = \frac{\text{total no. customer interruptions}}{\text{no. customers affected}}$$

CAIDI (*Customer average interruption duration index*) – it alow the evaluation of the power supply inerruption average duration during one year.

$$CAIDI = \frac{\sum_{i=1}^{n} (N_i \cdot D_i)}{\sum_{i=1}^{n} N_i} = \frac{SAIDI}{SAIFI} [\text{minutes/interrupted customers}] \qquad (14)$$

$$\text{CAIDI} = \frac{\Sigma \text{ customer interruption durations}}{\text{total no. customer interruptions}}$$

Interruption index-Indicator at the customer level –contd..,

MAIFI (*Momentary average interruption frequency index*):

$$MAIFI = \frac{\sum_{m=1}^{M} N_m}{N_t}, \quad (15)$$

Where M is the total number of the short time incidents(momentary);N_m – the number of the customers interrupted for short time (under 1 minute), at each interruption m; N_t – the total number of the customers supplyed from the analyzed electrical network.

AIT (*Average Interruption Time*) is a performence parameter, defind from the voltage disparitiy to the re-establishment, wich it calculated with the relation:

$$AIT = 8760 \cdot 60 \cdot \frac{ENS}{AD} [\text{minutes/year}], \quad (16)$$

Where *ENS* is the undelivered energy because of power supply interruptions [MWh/yea]; AD – actually yearly consumption for the energetical system-without the own technological consumptions [MWh/year].

Interruption - Prevention and Protection

To prevent interruptions, the utility may do the following:

1. Reduce incidents of system faults

   -Includes arrester installation, feeder inspections, tree trimming and animal guards

2. Limit the number of affected customers interrupted

   -Improve selectivity through single-phase reclosers and/or extra downstream reclosers

3. Fast reclosing

   -To protect equipment from interruptions, end-users may use Uninterruptible Power Supply (UPS) and other energy storage systems. 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: Uninterruptible Power Supply (UPS) , Self-generation, Energy storage

PQ Standards…

- IEEE 159-1992
- IEEE 1159-1995
- IEC 61000-2-8

References

- **Understanding Power Quality Problems: Voltage Sags and Interruptions by** Math H. Bollen
- **Power Quality Enhancement Using Custom Power Devices by** Arindam Ghosh, Gerard Ledwich