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Calculation of financial losses of Rice Industries against voltage sag

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Abstract: This paper presents the results of a survey on cluster of rice industries that investigates the effect of voltage sag on the industries feeding from same source. The survey also observed factory operation, products, equipment and processes used in production. In this paper we analyzed an electrical system sensitivity regarding voltage sags. Several proposals are there to analyzing the sensitivity of different electrical equipment for voltage sag problem. They often lead to tripping of sensitive equipment like power drives, process-control, etc. This paper also calculated the losses in the different departments due to voltage sag having different severity and sensitivity.

Keywords: Magnitude of voltage sag, sensitivity of equipments, ITIC curve, Sag severity, Economic Analysis.

Introduction

Voltage sag is "A decrease in rms voltage or current at the power frequency for duration of 0.5 cycles to 1 minute". The interest in voltage sag is mainly due to the problem they cause on several types of equipments like adjustable speed drives, process control equipments and computers are notorious for their sensitivity. Voltage sag disturbances are considered to be the most prominent power quality problem. This is largely due to the large number of occurrences throughout a typical transmission and distribution network, the increasing sensitivity of customer equipment to voltage sags, and the high costs of lost productivity and downtime. The number of voltage sags that can occur at service entrance to a facility depends on where the facility is located in the network. The sensitivity of individual equipment mainly determines how severely an industrial process will be affected by the sags. This implies that equipment has become less tolerant to voltage disturbances. Many sensitive loads cannot discriminate between a dip and a momentary interruption. The severity of the effects of voltage dips depends not only on the direct effects on the equipment concerned, but also on how important is the function carried out by that equipment. A failure of one single device, in response to a voltage dip, can stop the entire process. This can be one of the most serious and expensive consequence of voltage dips.

Causes of voltage sag

The physical nature of the distribution network makes voltage sags and momentary interruptions inevitable, notwithstanding the best efforts of individual utilities. Weather conditions, tree branch or animal contact, and insulation failures or human activity, can create single line to ground (SLG) or line to line (L-L) fault paths, and rarely a 3-phase to ground fault. The relatively few customers near the fault will see a deep voltage sag, even to zero, followed by a complete interruption when the utility circuit breaker or fuse operates.. These are usually 3-phase symmetrical sags of shallower depth and longer duration, which affect only the local area.

A. Magnitude of voltage sag

One common practice is to characterize the sag magnitude through the remaining voltage during the sag, called as 'retained voltage'. The magnitude of voltage sag can be determined in number of ways like one cycle or half cycle rms voltage, magnitude of fundamental component of voltage sag and peak voltage over each cycle or half cycle. Sag magnitude (retained voltage) is shown in Fig. 1.

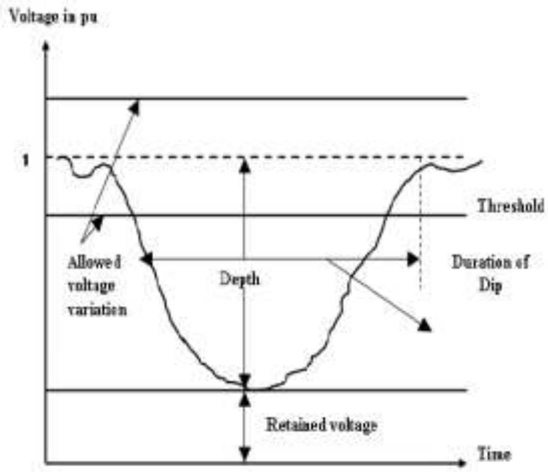

Fig. 1: Sag magnitude (retained voltage)

The residual voltage during the fault gives the magnitude of voltage sag depending on the type of fault.

B. Duration of voltage sag

The duration of sag is mainly determined by the fault clearing time as shown in Fig.2. Generally speaking, faults in transmission systems are cleared faster than faults in the distribution system, which affects the duration of faults depending on its location in the system.

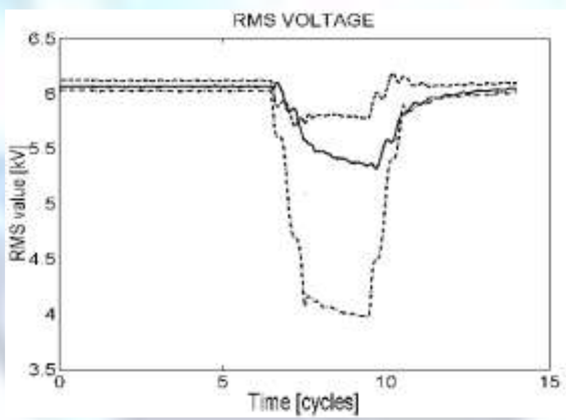

Fig. 2: Sag Duration (fault clearing time)

Sensitivity of electrical system

The effects produced by voltage sag over industrial customers depending upon the magnitude and duration of sag and type of load fed by the depressed voltage are:

- Electromechanical relays and motor contactors in low voltage systems are reported to drop out, when voltage sag is in the range 20% - 30% lasting some cycles. [3]
- 120 V AC PLC I/O disrupts by sags of less than 15 % magnitude and more than 16 ms duration. [5]
- Many AC drives will trip if the voltage magnitude on any of the supply phases falls below 10%. [5]

AC contactors installed in this industrial plant drop out after 90 milliseconds when voltage drops below 40% of its nominal value. In addition, it is assumed that static load does not disconnect during or after a voltage sag of any magnitude has occurred.

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Table 1.1: Threshold values for Sensitive Equipments

Equipment Name	V_{min}	V_{max}	T_{min}	T_{max}
PC	46%	63%	40ms	205ms
PLC	30%	90%	20ms	400ms
ASD	59%	71%	15ms	175ms

Voltage magnitude-threshold and duration-threshold of three type of equipments namely PLCs, ASDs and PCs shown in table 1.1 may vary between V_{min} and V_{max} and between T_{min} and T_{max}.

A. Sensitivity Analysis

The sensitivity study is made to analyze how affected loads could be when voltage sags are produced at Utility bus bar. The sensitivity of a plant is depend upon the types of equipments are installed in the plant. Fig. 1.3 shows the probabilistic behavior of the voltage sag.

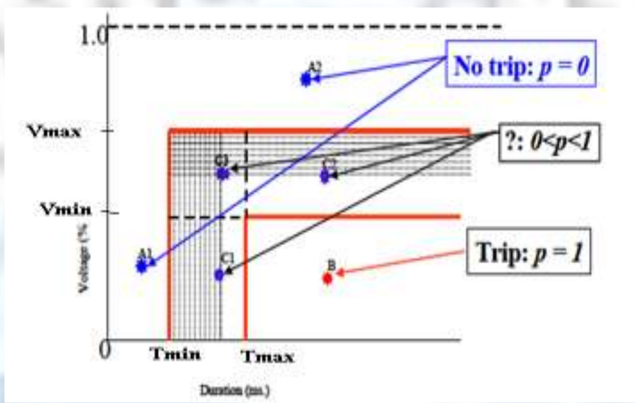

Fig. 3: Probabilistic behavior of the voltage sag

Analyzing the uncertain behavior of the voltage sag literature, sensitivity is classified in four zones.

A.1 Low sensitivity

Exponential distributions assumed to be reverse exponential distributions will represent equipment with low sensitivity means having very good ride through capabilities against voltage sags.

$$f(t) = \begin{cases} 0 & \text{oherwise} \\ 1 - e^{-\lambda t} & 0 \leq t < \infty \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Where λ = arrival rate of sag, which can be calculate from no. of sag events in a particular period (from survey)

A.2 Uniform Sensitivity

If there is an equal probability that the equipment voltage tolerance curve may assume any location within the region of uncertainty.

$$f(t) = \frac{1}{t_1 - t_2} \qquad t_1 < t < t_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

$$f(v) = \frac{1}{v_1 - v_2} \qquad v_1 < v <, v_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(iii)}$$

Where f(t) and f(v) are the functions of independent variable t i.e time and v i.e magnitude respectively.

A.3 Moderate Sensitivity

This type of sensitivity can be expressed by normal probability density functions. There is higher probability that the knee of the equipment's sensitivity curve will occur in the center of the region of uncertainty.

$f(t) = \frac{1}{\sigma 2\pi} e^{-\frac{1}{2}\left[\frac{t-\mu}{\sigma}\right]^2}$ …………….(iv)

Where $\sigma > 0$, $-\infty < \mu < \infty$, σ, μ are the mean and standard deviation of distribution respectively

A.4 High Sensitivity

If probabilities are assumed in exponentially decreasing order from high-voltage threshold to low-voltage threshold and from low duration threshold to high duration threshold, it will represent highly sensitive equipment having very poor ride through capabilities against voltage sags.

$f(t) = \begin{cases} 1-e^{-\lambda t} & 0 \le t < \infty \\ 0 & \text{oherwise} \end{cases}$ …………….(v)

Where λ = arrival rate of sag

Effect of voltage sag on Rice industries

Effects of power quality can be shown up in many aspects on industrial operations. The aspects include loss of production, manufacturing interruptions, loss of revenue, decreased competitiveness, lost opportunities, product damage, and wasted energy and decreased equipment life. Following are brief explanations that define those aspects;

- Loss of production
- Manufacturing interruption
- Loss of revenue
- Productivity costs
- Decreased competitiveness
- Lost opportunity
- Product damage
- Wasted energy
- Decreased equipment life time

Survey: Cluster Rice industry

The task is to observe the effects of voltage disturbances to the industries. This paper is focused on the selected industrial zone, which are Rice House. The electric power supply to this zone is taken from HVPNL, Gharaunda main Substation. This survey is carried out based on voltage sag for a period of one year. Data are analyzed, and an interview with factory facility workers and Engineer are conducted. All information and data are gathered to observe the effect of voltage disturbance to the industry. This paper summarizes the effect of power quality disturbances to the rice industries. In Rice mill there are four different departments i.e. Sortax, Boiler, Production and DG Room.

Table 1.2: summary of events on Gharaunda substation

Sag Severity	10-20 %	20-30%	30-40%	Less than 40%
No. of events	37	25	18	1

Table 1.2 shows the occurrence of voltage sag events in Gharaunda substation during one year. This data is collected from substation.

Table 1.3: Average sag events in rice industries

Sag Severity	10-20%	20-30%	30-40%	Less than 40%
Avarge Numbers of events	27	13	4	1
Safety measures	Step up the voltage for some extant	Eqipments have on security alaram	Stop working	Malfuncioning
Effects	Some data losses	Motors speed reduced	Risk of Eqipment Damage	Equipment Damaged

Table 1.3 shows the averge numbers of events in rice industries.From survey we had collected these data after continuous monitoring of cluster of rice industry which were feeding from same source.Then this data is analyze to calculate the average losses which occur in rice industry as shown in Table 1.4.

Table 1.4: Summary of average losses in rice industries due to sag

Sag Severity	(10-20)%	(20-30)%	(30-40)%	Less than 40%
No. of Events (N)	27	13	4	1
Production Loss	Nil	2362	2835	75000
Material Loss	1kg	15 Kg	15 Kg	1575
Equipment Loss	Nil	Computer and PLC damage	Computer get shut down	Equipment get damage
Other Loss	Danger for PLC Devices	1. Speed of motor slow down 2 .Rag m/c not get start 3 .AC device life may decay	1. Spark in induction motor 2.PLC devices Damage 3.Electronic Equipment's Damage	1.Complete Shut down 2.Danger for Electronic device
Total Loss (Rs.)	15,205	2,00,200	52,00,000	11,00,000

In Table 1.4 numbers of events that has been occurred is encounter as well as the production cost, material cost and equipment reliability has been also discussed. From the questionnaire method we analyze that if the severity of sag is less than 40% it will damage most of the equipment and completely shut down the whole plant.

Economic Analysis

The accurate evaluation will need the following inputs:

- Information about density of events i.e. Voltage sags profile at bus bar
- Information about the reaction of the customer load to the different events i.e. load susceptibility

Each machine will cause a different interruption cost, but for any given machine the interruption cost will depends on the individual process interruption.

$$\text{cost} = C_{pld} + C_{plr} + C_{mw} + C_{em} + C_{dp} - S_{rm} \quad \ldots\ldots\ldots\ldots\text{(vi)}$$

where,

C_{pld} = cost of production loss due to disturbance of power
C_{plr} =Cost of production loss during the restart time
C_{mw} =Cost of material wastage during the disturbance
C_{dp} = Cost of equipment damaged due to disturbance
C_{em} = Extra Maintenance cost
S_{rm} = saving of raw material

A. Loss calculation

Total financial losses can be calculate as follows

$$\text{Financial}_{\text{losses}} = \text{Cost}_{\text{process\_distrub}} * N \ldots\ldots\ldots\text{(vii)}$$

Where N= Number of sag per year

Results

In Fig. 4 to Fig. 7 show losses due to reduction in voltage from 10-20%, 20-30%, 30-40%, less than 40% respectively. As voltage decreases amount losses increases. From fig 7 it is analyzed that maximum losses occur when voltage is drop less than 40%.

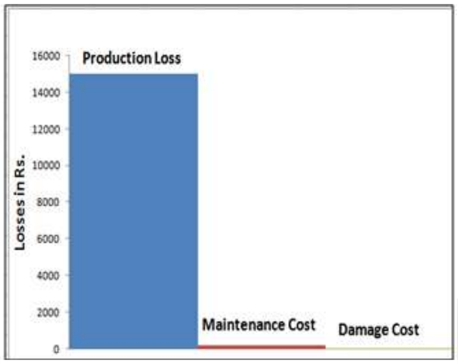

Fig. 4: Losses due to sag 10-20%

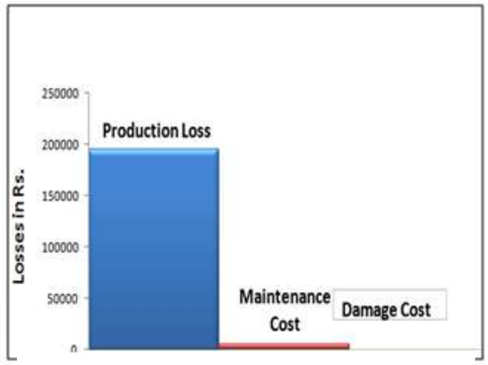

Fig. 5: Losses due to sag 20-30%

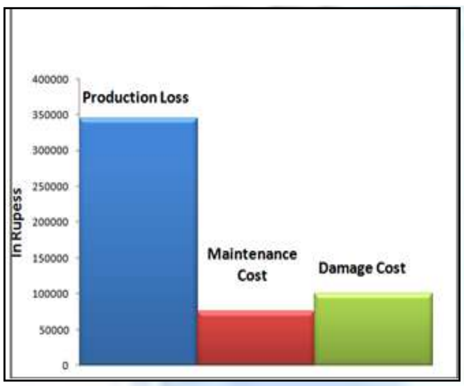

Fig. 6: Losses due to sag 30-40%

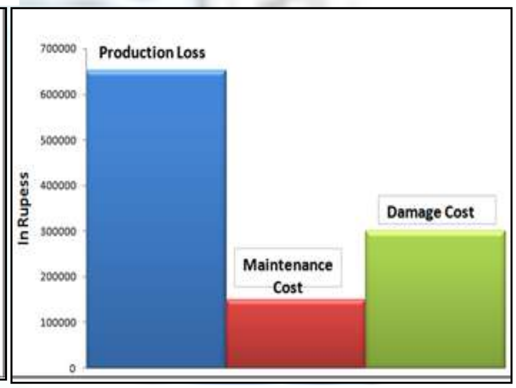

Fig. 7: Losses due to sag less than 40 %

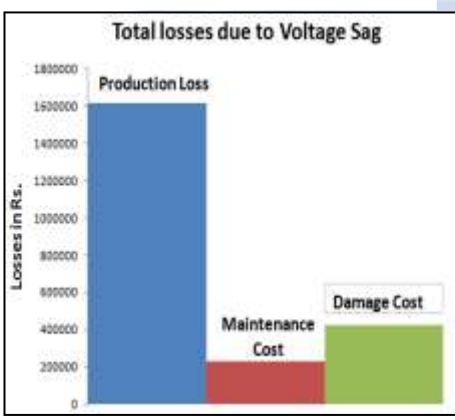

Fig. 7: Total loss due to sag

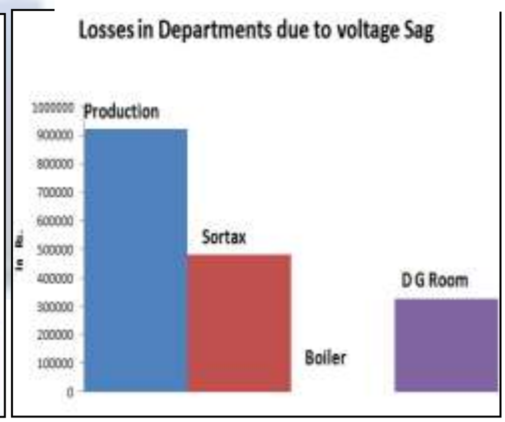

Fig. 8: Department-wise loss

Solution assessment for voltage sag problem

There are several solutions currently available that will provide ride through capability to critical loads.

- Motor-Generator Sets
- Uninterruptible Power Supplies(UPS)
- Ferro resonant Constant Voltage Transformers(CVTs)
- Magnetic Synthesizers

As indicated before, many solutions are available for mitigating voltage sags, but also there are special problems or consideration inherent to each solution. For example, taking actions in the transmission or distribution system is responsibility of the Utility Company and some of these solutions are not so easy to apply whether the complex of the system or the great investment of money and time to make these changes.
To mitigate the effect of voltage sags on rice industry, one of the attractive solutions is the use of UPS, but the range of power that this device can handle is about 1 MVA. The installation of this equipment is feasible due to the amount of power consumed by the each equipment exceeding than this load. [7]

Conclusion

Voltage sags are power quality problems that cause severe damage to several industry processes. Actual electrical power systems or equipment are not immune against voltage sag. Several methods for voltage sag mitigation are already developed and have different areas of action; there are actions that could be taken in the transmission and/or distribution grid, preventive actions and improvement of voltage sag immunity in equipment. It is possible to minimize sensitivity of electrical system regarding voltage sags using the solution. The voltage sag integration program if implemented by utilities can yield the benefits to utility. It has been concluded that the losses due to sag depends upon the number of parameters such as types of industry, production of industry, load of industry, types of equipments, and connection of the equipments. From the business point of view, the most important parameter in voltage sag management is the value of the service provided.

$$\text{value}_{\text{service}} = \text{Inital}_{\text{f\_loss}} - \text{Cost}_{\text{mitigation}} \quad \ldots\ldots\ldots\ldots\ldots\text{(viii)}$$

where, $\text{value}_{\text{service}}$ =Value of service,
$\text{Inital}_{\text{f\_loss}}$ =Initial financial losses, $\text{Cost}_{\text{mitigation}}$ =Cost of mitigation
A positive value indicates a gain in return of investment and potential profit for both the customer and service provider.

Reference

[1]. Bollen M. H. J, "Understanding Power Quality Problems", Voltage Sags and interruptions ser., IEEE Press Series on Power Engineering, Piscataway, NJ, 2000.
[2]. Juarez E. E., Hernandez A, "An analytical approach for stochastic assessment of voltage sags in large system", In IEEE Transaction on Power Delivery, Vol.21, No.3, July 2006.
[3]. G. Electric Company,"C-2000™ contactors & starters technical Information" General Electric catalog DET-034B, 1996.
[4]. IEEE Gold Book, IEEE Recommended Practice for Design Commercial Power Systems., NJ: IEEE Press, 1998, p. 504.
[5]. A. Sannino, G. Michelle and M. Bollen, "Overview of voltage sag mitigation" IEEE Power Engineering Society 2000 Winter Meeting, vol. 4, 23-27 January 2000.
[6]. Jeff Lamoree, Dave Mueller, "Voltage Sag Analysis Case Studies", IEEE Transaction on Power Delivery, p 55-61
[7]. W. Brumsickle, R. Schneider, G. Luckjiff, D. Divan and M. McGranagham, "Dynamic sag corrector: cost effective ndustrial power line conditioning" [On Line Web Page] Available: www.softswitch.com
[8]. R. Grümbaum, S. Raghuveer and J. Charpentier, "Improving the efficiency and quality of AC transmission systems (Draft 3)" Joint World Bank / ABB Power Systems .
[9]. Angel Felce, Guillermo Matas, Ysmael Da Silva "Voltage Sag Analysis and Solution for an Industrial Plant with Embedded Induction Motors" IEEE Transaction on Power Delivery, pp 2573-2578,year 2004.
[10]. E.R. Collins, Jr., A. Mansoor, "Effects of voltage sags on AC motor drives,"IEEE Annual Textile, Fiber, and Film Industry Technical Conference, 1997, pp. 7.
[11]. Ching-Yin Lee, Bin-Kwie Chen, Wei-Jen Lee, Yen-Feng Hsu, "Effects of various unbalanced voltages on the operation performance of an induction motor under the same voltage unbalance factor condition," Industrial and Commercial Power Systems Technical Conference, IEEE 1997, 11-16 May 1997, pp. 51 – 59.