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## **TO SURVEY POWER QUALITY OF HIGH VOLTAGE KEY-CUSTOMER BY USING VOLTAGE EVENT RECORD**

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### **Abstract:**

*According to IEEE-1159 definition and classification of power quality of applying at supply-side and demand-side of power system to evaluate the power quality of high voltage key-customer and using the voltage events record (VER) in low voltage level supply. Which voltage parameter set of VER with specific software Event View software by Fluke and can collect event data, plot graphic of event data sets that can using the data mining skill to analysis the voltage swell, voltage sag, power outage, frequency events and three phase load unbalance of high voltage key-customer. By abnormal voltage event statistics with discriminated by quantization of high voltage key-customer which can evaluate the own power quality and an also provide reference for quality requirements for related semiconductor factories with higher demand that can avoid the significant effect the economic losses.*

**Keywords:** Power Quality; Voltage Events; Frequency Changing; Power Interruptions; Three Phase Load Unbalance.

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### **1. Introduction**

The reliability [1~3] of power supply is different from the power quality [4~6]. The former emphasizes the number of power outages and duration of power outages and the latter problem which involves a lot of problems, some caused by improper operation of the supply-side and demand-side of electrical equipment, poor equipment and electricity pollution.

There are the following reasons for the deterioration of power quality; such as voltage and current surge, voltage swell [7,8] and voltage sag [9,10], harmonics, three-phase unbalance, frequency variation [11], electromagnetic interference, voltage flicker, and power interruption, etc... That all may affected the normal operation of electrical and electronics devices so that a well power quality of power provider and demand are very important issue.

According to the International Institute of Electrical and Electronics Engineers (IEEE) for the definition of power quality [12] is the disturbance of power system and which can be summarized

into three parts, one for voltage phenomenon, and another for frequency phenomenon and the other for the state of continuous power supply.

In recent years develop in Taiwan, the high-tech manufacturers in the science park such as the semiconductor IC design factory and the packaging factory that possess the high-precision equipment to produce their product, but they required power quality requirements are very high of power provider. These manufacturers are improved and ensure well power supply and power quality is its basic requirement because the poor power quality of supply-side and will also affect the quality of the factory's objects and overall that may be even cause huge economic losses.

In recent years, the literature for improving power quality is as follows, they are many artificial intelligent method apply to improve the power quality to Diagnosis and classification such as using symmetrical cascaded multilevel converter for power quality improvement of micro-grid [13], with fractional Fourier transform for classification of events of power quality [14], apply Derrended Fluctuation method to Diagnosis of Power Quality Events [15], and using Dual-tree complex wavelet transform-based algorithm to enhance the power quality [16] and dual P-Q theory based energy optimized dynamic voltage restorer for power quality improvement [17] but above literature must be based on the measurement historical and their classify catalog to reach the purpose of the many literatures.

It is selected a high-voltage key-customer user to simulate the high-tech manufacturers in the science park. First find the location of low voltage side of none protective gear system in the factory to install voltage event recorder and measure the voltage events during three months. Second sort and classify the voltage swell, voltage sag, power interruption and frequency variation of the measuring events. And installing three voltage accident recorders to monitor the voltage of the three-phase data mining analysis and judgment of the state of three-phase imbalance. Perform and execute the steps of this research are as follows:

- Step1: It is selected a key-customer as high voltage 11.4kV of overhead feeder that the load vary characteristic with the time.
- Step2: Install the power quality event recorder in low voltage side of high voltage key-customer and which location must be not affect by the protective relaying system of user itself.
- Step3: Set the critical value of the power quality and start recording the power quality during three month a season.
- Step4: Retrieve the power quality events form the cloud to notebook or laptop computer using the internet or wireless communication channel.
- Step5: According to the IEEE-1159 definition power quality event to statistics the different power quality event times and duration.
- Step6: Analyze the power quality affect margin.

## 2. Power Quality Specification

According to IEEE-1159 definition and classification of power quality of applying at supply-side and demand-side of power system such as table 1.

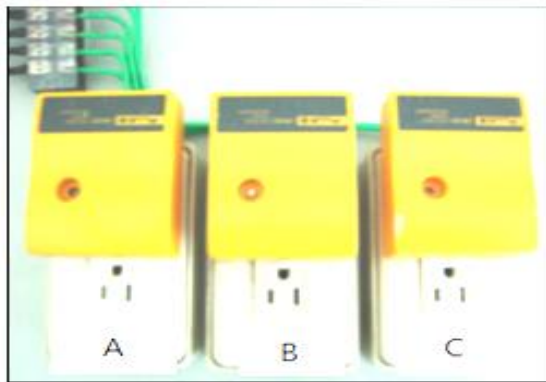
### 3. Equipment Installation and Power Quality Event Record

#### 3.1. Equipment Installation

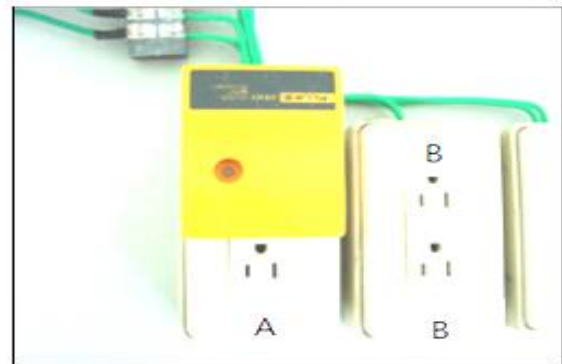
Figure 1 shows the application and appearance of the voltage event recorder FLUCK VR101, for figure 1(A) is applied in three phase be combination and connection by three piece of the voltage event recorder, and for figure 1(B) is applied in single phase just need one voltage event recorder. Both have a common opinion that is must be set in low voltage side such as voltage level with A.C. 220V or 110 V

Table 1: Definition and classification of power system interference phenomena

NO	Classification			Typical duration	Typical voltage magnitude
1	Short time voltage variation	Instantaneous	Voltage swell	0.5~30 cycles	0.1~0.9 p.u.
			Voltage sag	0.5~30 cycles	1.1~1.8 p.u.
		Moment	Power interruption	0.5 cycles~3s	< 0.1 p.u.
			Voltage sag	30 cycles ~3s	0.1~0.9 p.u.
			Voltage swell	30cycles 3s	1.1~1.4 p.u.
		Temporarily	Power interruption	3s ~1min	< 0.1 p.u.
			Voltage sag	3s ~1min	0.1~0.9 p.u.
Voltage swell	3s ~1min		1.1~1.2 p.u.		
2	Long time voltage variation	Continuous voltage interruption	-	>1 min.	0.0 p.u.
		Under voltage	-	>1 min.	0.8~0.9 p.u.
		Overvoltage	-	>1 min.	1.1~1.2 p.u.
3	Power frequency changing	-	-	< 10 s	-
4	Voltage imbalance	-	-	-	0.3~2%



(A) For three-phase connection



(B) For single-phase connection

Figure 1: The application and appearance of voltage event recorder

### 3.2. Power Quality Event Record and Communication Connection

In figure 2 show the events data flow of the power quality event. It is explain the event data flow that can divided into two parts, one for bottom data delivery and the other for up data receive. The first part is from the bottom to retrieve event date by power quality event record and store in database. Furthermore, using the data collector through the internet or wireless communication channel to the cloud and complete finish the data delivery that said the bottom data delivery. The other part is form the cloud to back up the power quality event data by using the internet or wireless communication channel to the database of notebook or laptop computer that said the up data receive.

The VR101 recorder can store up to as many as 4000 events and a flashing LED tells you when events have been captured. To get data out of the recorder, hook it back up to your computer or through the communication channel. EventView software can download a complete history of the events that occurred while the recorder was plugged into the receptacle. The software lets you build a detailed report of sags, swells, transients, outages and frequency variations with time-stamps and durations.

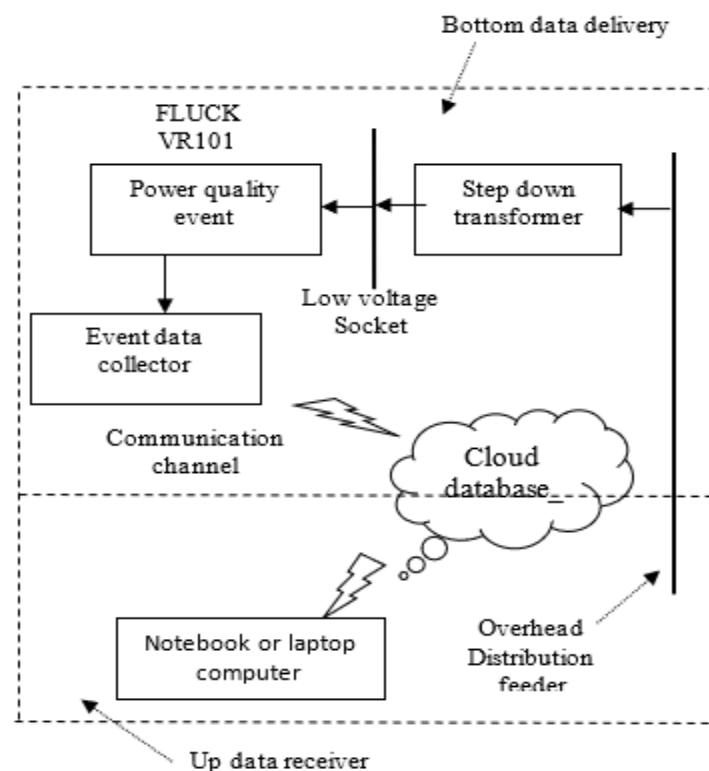


Figure 2: The events data flow of the power quality event

### 3.3. Parameter Setting of Events

The data value obtained by the power quality event recorder can use the specific program of the power quality events recorder to measure and record the type of event, the root mean square (RMS)

value and duration of each event. Figure 3 shows the setting critical value of the power quality events of high voltage key-customer.

Status	Events
<b>Hot to Neutral Thresholds</b> Swell Voltage (Vrms): <input type="text" value="121"/> Sag Voltage (Vrms): <input type="text" value="100"/> Transient Deviation (V): <input type="text" value="200"/>	<b>Frequency Thresholds</b> Minimum (Hz): <input type="text" value="58.8"/> Maximum (Hz): <input type="text" value="61.2"/> <input type="radio"/> 50 Hz <input checked="" type="radio"/> 60 Hz
<b>Neutral to Ground Thresholds</b> Swell Voltage (Vrms): <input type="text" value="15"/> Transient Deviation (V): <input type="text" value="100"/>	<b>Options</b> <input type="radio"/> Stop Recording When Full <input checked="" type="radio"/> Overwrite Oldest Events When Full <input checked="" type="checkbox"/> Flash when Events Captured
<b>RealTime</b> Line Frequency (Hz): <input type="text" value="0"/> Line Voltage (Vrms): <input type="text" value="0"/> Ground Voltage (Vrms): <input type="text" value="8"/>	<b>Recorder Info</b> 467 Events Recorded: from 2006/1/17 02:25:52 下午 to 2006/4/12 03:42:32 下午. VR101 Firmware Version 9
<b>User Names</b> Site Description: <input type="text" value="Fluke Voltage Event Recorder"/> File Name: <input type="text" value="C:\EV101\SNF18911.VER"/>	
<input type="button" value="Default Setup"/> <input type="button" value="Save as Default Setup"/> <input type="button" value="Send Setup/Clear Recorder"/>	

Figure 3: The setting critical value of the power quality event of high voltage key-customer

#### 4. Partial Event Data by Measurement

From the power quality event record FLUCK VR101 by specific software Event View can download the power quality event of the high voltage key-customer that can summary the events by same event. In rough speaking, it is divided into single phase and three-phase event data.

##### 4.1. Single-Phase Event Data

Table 2 is the partial of single phase event data of high voltage key-customer that including the events such as voltage swell, voltage sag, frequency variation and power interruption.

##### 4.2. Three-Phase Event Data

Table 3 is the partial of three-phase event data of high voltage key-customer which only recoding the voltage imbalance of three-phase that mean the three-phase loadings imbalance.

#### 5. Data Statistics and Graphical Corroboration

##### 5.1. Single-Phase Event

The statistical the times of power quality event during the measurement period is such as voltage swell, voltage sag, frequency electric and power interruption. Fig. 4 is the statistical graph of the power quality event number of high voltage key-customer. It has been calculated that there are 444 times voltage swell, 0 times voltage sags, 2 times frequency variation and 7 times power

interruptions. Figure 5 is a graph showing the percentage of single-phase events. Which the voltage swells account for 98.01%, frequency variation account 0.44% and power interruptions account for 1.55 %. Observe the duration and magnitude of events with between live to neutral (H-N) line, neutral to ground (N-G) line and reach the relative relationship. In figure 6, by the voltage magnitude can infer the underpower quality events which section A is the voltage swell phenomenon of high voltage key-customer; Section B is the voltage sag phenomenon and section C is the power interruption phenomenon.

Statistics of power outage events such as shown in table4 and figure 7. It is a of 7 times power outages occurred during the measurement period and total duration is 640 minutes. The average power outage lasted 91 minutes or 1 hour and 30 minutes which for demand side that is not endure.

Table 2: Partial of single-phase event data of high voltage key-customer

Order	Event	Extreme	End time/during/degree
1	Low Frequency	58.8 Hz	0.5 cycles
2	Outage	0 Vrms	10:38:48
3	N-G Swell	140 Vrms	80.9 seconds
4	1 N-G	+300 Vp	320°
5	1 H-N	+350 Vp	320°

Table 3: the partial of three-phase event data of high voltage key-customer

Phase	Event #	Event	Extreme	End time/Duration/Degree
A	0	H-N Sag	105Vrms	Open Event
C	1	H-N Swell	114Vrms	31.8 seconds
A	6	H-N Swell	114Vrms	03:26:16
C	7	H-N Swell	114Vrms	00:05:12
A	8	H-N Swell	114Vrms	00:14:56
C	8	H-N Swell	114Vrms	00:50:08
B	1	H-N Swell	114Vrms	00:29:12

From the view of voltage swell event which can discussed with two parts, one for the H-N voltage swell event and the other for N-G voltage swell event. The former has 440 times, all events duration summation time is 19453.91 minutes and the average per event is 44.21minutes. The latter has 4 times, all events duration summation time is 5.68 minutes and the average per event is 1.42minutes. It is the H-N voltage swell event is calculate in table 5 and the consistency graphic as figure8. As the same describe, the N-G voltage swell event is calculate in table5 and the consistency graphic as figure 9.

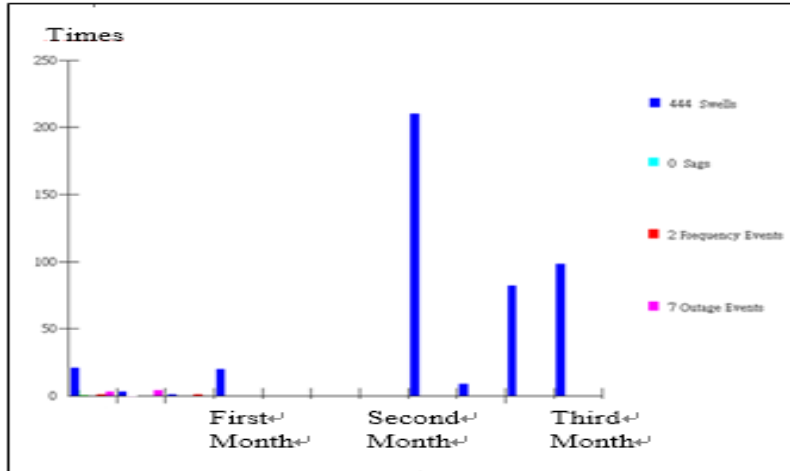


Figure 4: Statistical bar chart of the number of high-voltage key-customer single-phase power quality events.

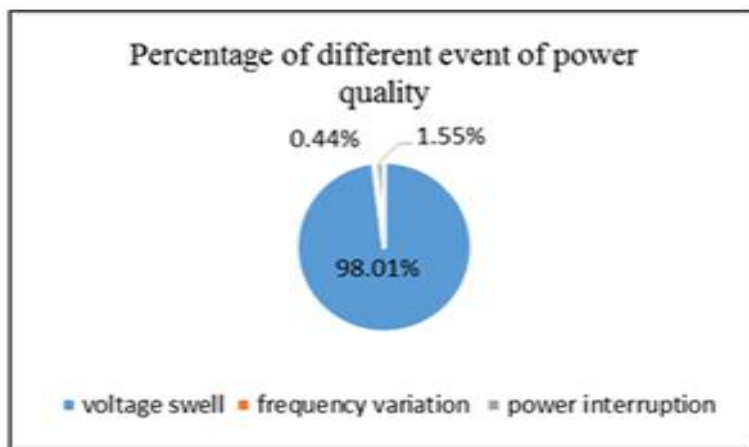


Figure 5: The percentage of single-phase events.

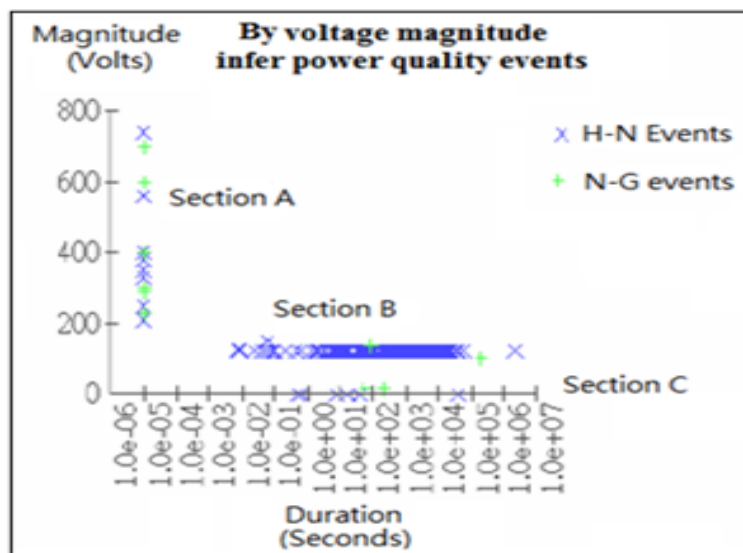


Figure 6: By the voltage magnitude infer the power quality events

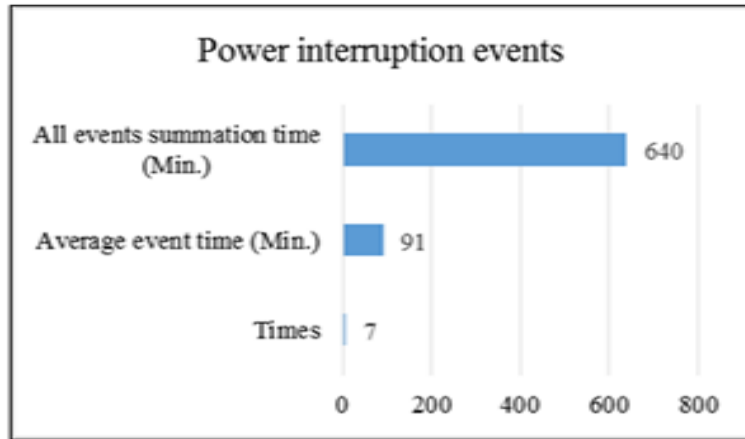


Figure 7: Power interruption event of high-voltage key-customer

Table 4: Statistics power interruption event of high-voltage key-customer

Events: Power interruption	
Times	7
Average time (Min.)	91
All events summation time (Min.)	640

Table 5: Statistics on the data of voltage swell of H-N and N-G voltages events

Events	Voltage swell	
	H-N	N-G
Times	440	4
Average time (Min.)	44.21	1.42
All events summation time (Min.)	19453.91	5.68

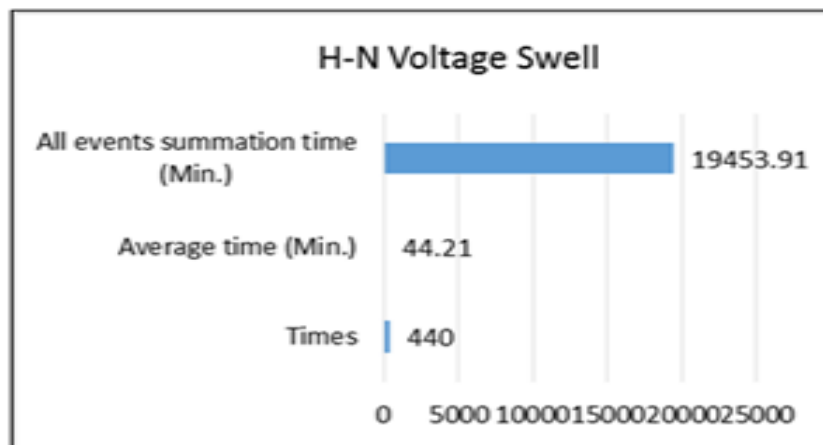


Figure 8: H-N voltage swell events times and average time statistics



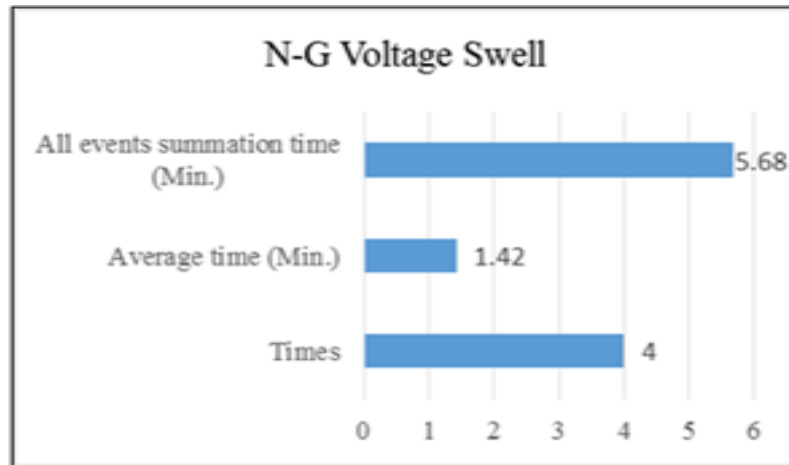


Figure 9: N-G voltage swell events times and average time statistics

## 5.2. Three-Phase Event Data

The high-voltage user three-phase unbalanced voltage swell and sag are compiled out which data is shown in table 6 for the voltage swell of H-N and the voltage sag of H-G events.

### 5.2.1. H-N Voltage Swell

The phenomenon of voltage swell of H-N voltage of each phase in the three phases during the actual measurement is discussed and the phases A, B and C are described separately. The first is the A-phase H-N voltage swell event which is happen 54 times, the accumulation time is 3835.85 minutes and the average A-phase H-N voltage swell event is 71.03 minutes. Another is the B-phase H-N voltage swell event which is happen 24 times, the summation time is 1813.18 minutes and the average B-phase H-N voltage swell event is 75.55 minutes. The other is the C-phase H-N voltage swell event which is happen 55 times, the total time is 3835.85minutes and the average C-phase H-N voltage swell event is 41.56 minutes. Discuss the phenomenon for the H-N voltage of each phase voltage swell in the three phases which based on A,B,C each phase with times and average during of voltage event swell that such as the figure10. In terms of three-phase average which can be seen that the average ABC three-phase H-N voltage swell event to 44.33 times, the cumulative time is 2554.44 minutes and the average three-phase H-N voltage swell event is 62.71 minutes. And from the view of the three-phase average number of events just only the phase A the bigger than average times. Base on the average duration per times of the event they have B and C phases that exceed the average. Compared with the proportion of the total number of occurrences, phase A accounts for 41%, phase B accounts for 41%, and phase C accounts for 18%. The percentage of three-phase occurrences times is shown in Fig. 11. With the similar way for average during time, phase A accounts for 34%, phase B accounts for 36%, and phase C accounts for 30%. The percentage of three-phase average duration is shown in Fig. 12.

### 5.2.2. H-N Voltage Sag

Discuss the phenomenon of H-N voltage dip in each phase of the three phases and describe the phases A, B, and C separately. IN measurement period, first for phase A, the H-N voltage sag events is happen to 14 times, the accumulation time is 312.98 minutes and the average duration

of H-N voltage sag event is 22.34 minutes. Second for phase B, the H-N voltage sag events happen to 29 times, the summation time is 522.70 minutes and the average duration of H-N voltage sag event is 14.59 minutes. Finally, the C-phase H-N voltage sag event occurred to 7 times, the total during time is 117.95 minutes and the average duration of C-phase H-N voltage sag event was 16.85 minutes. The number of H-N voltage sags events and the average duration bar chart for each phase are shown in Figure 13. The average ABC three-phase H-N voltage sag event occurred to 16.67 times, the cumulative time is 284.54 minutes, and the average three-phase H-N voltage dip event is 17.93 minutes. And from the view of the three-phase average number of events just only the phase B the bigger than average times. Base on the average duration per times of the event it just only phase A exceed the average. Compared with the proportion of the total number of occurrences, phase A accounts for 28%, phase B accounts for 58%, and phase C accounts for 14%. The percentage of three-phase occurrences times of voltage sag events shown in Fig. 14. With the similar way for average during time, phase A accounts for 39%, phase B accounts for 30%, and phase C accounts for 31%. The percentage of three-phase average duration is shown in Fig. 15

## 6. Conclusion

Set up power quality event recorders for high voltage key-customer and record power quality events for three months such as voltage swell, voltage sag, frequency variation, power outage and H-N voltage swell and voltage sag and so on.

General conclusion is distinguished into four parts such as power interruption, power quality, three-phase H-N voltage swell and sag and solution.

### 6.1. Power Interruption

It is a total of 7 power outages occurred during the measurement period and total duration is 640 minutes. The average power outage lasted 91 minutes or 1 hour and 30 minutes which for demand side that is not endure. Since all electrical systems of high-voltage key-customer that including power provider channel and protective relaying system etc. are designed by the user to be licensed by the power supplier but the operation is user-driven and power supplier has no right to interrogate. The number and duration of this power interruption are too much and too long by measurement and statistics. The average power outage is about twice a month and the average time is about 90 minutes. The user must have a high endure for this power outage challenge.

### 6.2. Power Quality

It has been calculated that there are 444 times voltage swell, 0 times voltage sags and 2 times frequency variation. It can be seen that this power quality is monopolized by the voltage swell event which can infer the two times frequency variation have been related to the voltage swell events. Voltage swell can be said to be a sudden release in load and the relative frequency will also change and if the frequency above the up-limit and below the down-limit will form a frequency variation event.

### 6.3. Three-Phase H-N Voltage Swell and Sag

#### 6.3.1. H-N Voltage Swell

Compared with the proportion of the total number of occurrences, A-phase accounts for 41%, B-phase accounts for 41%, and C-phase accounts for 18%. With the similar way for average during time, A-phase accounts for 34%, B-phase accounts for 36%, and C-phase accounts for 30%.

Table 6: The voltage swell of H-N and the voltage sag of H-G events of high voltage key-customer

Phase of imbalance	Events	Swell	Sag
		H-N	H-N
A	Times	54	14
	Average time (Min.)	71.03	22.34
	All events summation time (Min.)	3835.85	312.98
B	Times	24	29
	Average time (Min.)	75.55	14.586
	All events summation time (Min.)	1813.18	422.70
C	Times	55	7
	Average time (Min.)	41.56	16.85
	All events summation time (Min.)	2287.18	117.95
Average for three phase	Times	44.33	16.67
	Average time (Min.)	62.71	17.93
	All events summation time (Min.)	2645.40	284.54

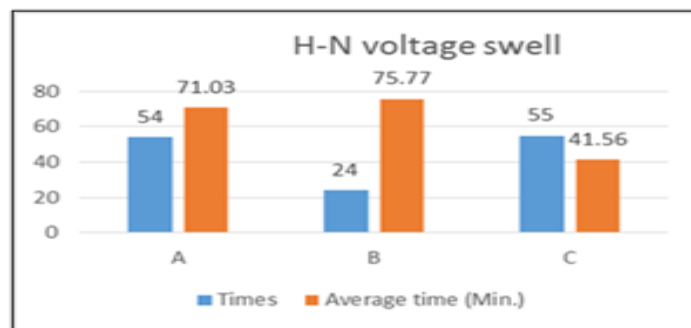


Figure 10: H-N voltage swell times and average time statistics for each phase in three phases.

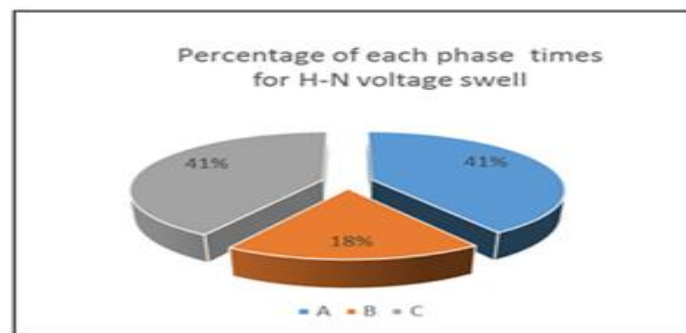


Figure 11: Percentage of each phase times for H-N voltage swell.

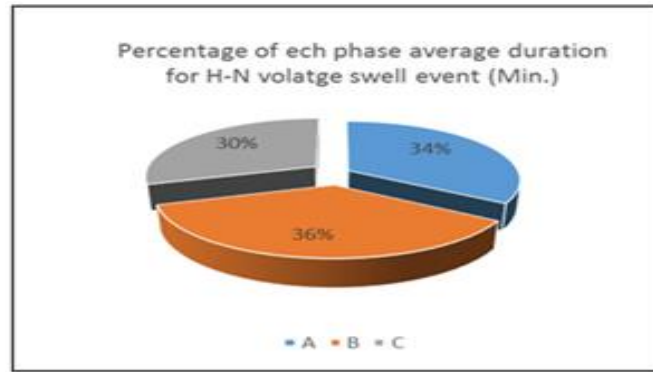


Figure 12: Percentage of each phase average duration for H-N voltage swell event

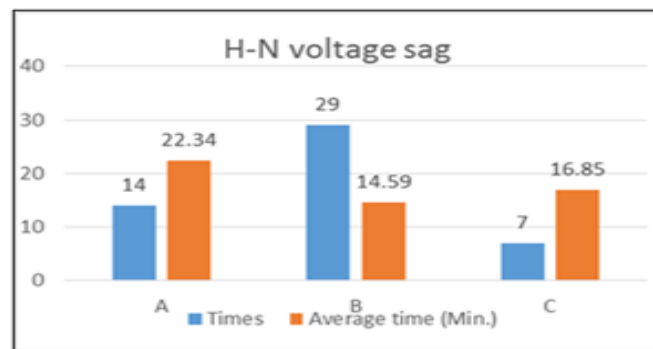


Figure 13: N-G voltage swell times and average time statistics for each phase in three phases

### 6.3.2. H-N Voltage Sag

Compared with the proportion of the total number of occurrences, phase A accounts for 28%, phase B accounts for 58%, and phase C accounts for 14%. From the point of the number of occurrences which number of occurrences per phase is very different.

For the time of occurrence duration which H-N voltage swell and H-N voltage the similar way for average number, phase A accounts for 39%, phase B accounts for 30% and phase c accounts for 31%. It is said that nearly one-third of each phase is close.

That is to say which the load distribution of the three phases is uneven and that is mean three-phase unbalance by loadings. The H-N voltage swell event and the H-N voltage sag event of each phase are caused by the load switching in and disconnection of each phase.

## 6.4. Solve Problem

### 6.4.1. Solve Upper Items Problem

- 1) Power interruption: Deeply discuss the blackout caused by the protective relaying system or human mistake operation and compare it with the power supply feeder's power outage to judge the main reason of the power outage. If most of the events come from the circuit

under its control circuit or protective relaying system that must be modifying the protective relaying system and resetting the parameters.

- 2) Power quality: All power quality events are monopolized by the voltage swell event so that it can be judged whether the ratio of step-down transformer is improperly set. By the ratio resetting can improve the lack of power quality in this area.
- 3) Three-phase H-N voltage swell and sag: This event occurs in a single phase and can be improved of the voltage swell or sag by installation the voltage regulator.

#### 6.4.2. Overall Solution

All the above accidents are related so that we must coordinate with each other event to find the optimal solution.

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