



Power Quality Handbook

For Your Facilities

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Introduction



From generation, transmission to distribution, CLP Power provides reliable and safe electricity supply in Hong Kong at a world-class reliability of over 99.999% to over 2.6 million customers. CLP Power's high supply reliability is the result of our power expertise. We are working together with the community to achieve sustainable social and economic development in Hong Kong.

What is Power Quality?

Power quality (PQ) has become a concern of our customers in recent years with the increased application of sophisticated computing, automation and control technologies, especially in the financial, medical, telecommunications and industrial sectors.

Power quality is not a new topic and inherits with every power system. Rapid development in power electronics and computerised equipment over recent decades has ushered in many advantages including efficiency enhancements, cost reduction and quality improvements. These power electronics or computerised controls demand extra care in feeding them with electricity supply, i.e. having much higher power quality requirement, and are susceptible to supply voltage disturbances, voltage dips in particular. Power quality issues can be understood as the compatibility of modern equipment with the power system.

Although some fail-safe designs can work properly during power outages, unexpected or undesirable operations may be triggered as a result of voltage dips. A short voltage dip may eventually develop into a long supply interruption and the disruption of operations. Harmonics may also induce equipment damage or other potential hazards. The adoption of new technologies may also bring other power quality issues such as frequency deviation, voltage swell, notching, noise, etc.

This handbook describes the effects of these major power quality problems on some major commercial and residential facilities, aiming to provide customers like shopping centres, offices and hotels with mitigation references in reducing the impact brought by power quality issues.

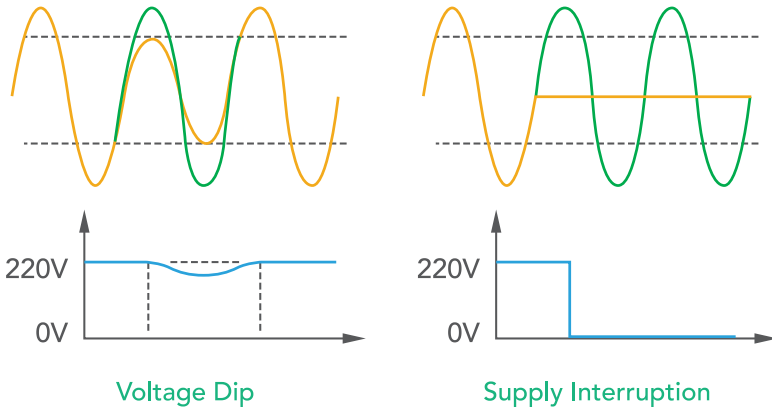


Common Power Quality Issues in Hong Kong

Of the power quality issues, voltage dips and harmonics are the two major contributors in Hong Kong.

Voltage Dips

A voltage dip refers to a temporary reduction of the r.m.s. voltage, typically resulted from a power system disturbance. The *European Standard EN50160* describes a voltage dip in two dimensions, residual voltage and duration (time). With reference to the *EN50160*, a voltage dip is defined as a sudden drop of the supply voltage that the residual voltage is from 5% to 90% of standard power supply voltage and the duration is from 10 milliseconds to 1 minute. In CLP Power's system, voltage dips generally last for around 0.1 second. The illustration below differentiates a voltage dip from a supply interruption.

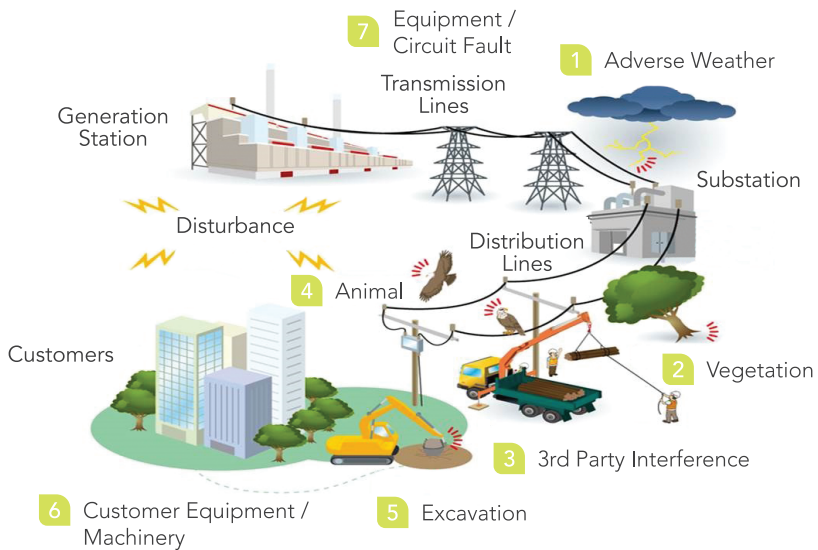


In the event of voltage dips, when CLP Power's electricity supply is not interrupted, individual user may still experience momentary dimming or flickering of lights. Some electrical installations which are sensitive to voltage fluctuation may stop operate as the protection mechanism is activated.

Causes of Voltage Dips

There are various factors that can lead to voltage dips. While overhead lines are exposed and susceptible to external interference such as adverse weather (typhoons, lightning strikes, etc.), vegetation and wildlife, both overhead lines and underground cables may also be affected by human activities around, resulting in third-party damages. Voltage dips may also be caused by power equipment failures or customer machinery starting.

For these reasons, voltage dips are unavoidable and power companies all over the world have not been able to eliminate the occurrence momentary voltage dips.



Causes of Voltage Dips

Mitigations

CLP Power's professional engineers have been carrying out ongoing study to improve the quality of our power supply. CLP Power actively engages customers and industry practitioners and shares engineering solutions for mitigating the impact of voltage dip such as ride-through devices with them.

Practically, customers may look for equipment with different levels of voltage dip compatibility as listed (or a combination of the three levels) according to their operational requirements: -

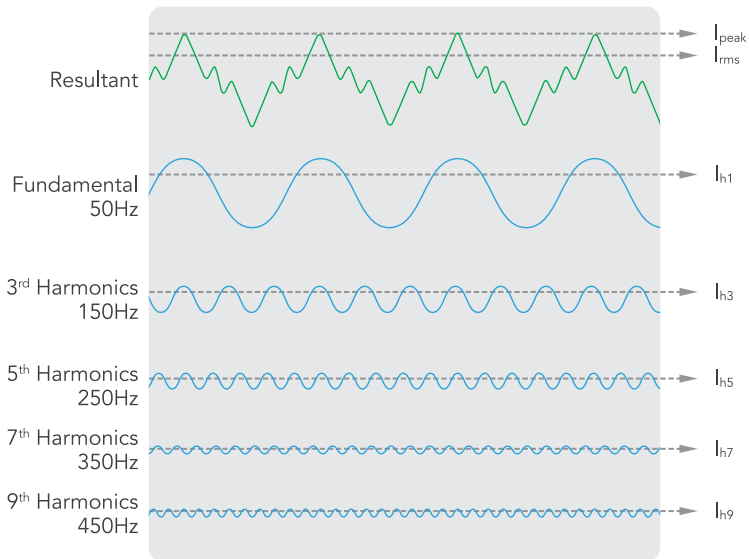
Level	Description	Examples
I	Equipment can function properly during voltage dips (EN50160: residual voltage from 5% to 90% for 10ms to 1 min)	<ul style="list-style-type: none"> • Central Control Management System (CCMS) computer supplied through true on-line uninterruptible power supply (UPS). • Changeover or automatic transfer scheme supplied by DC control supply.
II	Equipment can function properly during certain voltage dips, complying with ITIC, SEMI F47 or IEC61000-4-11/ IEC61000-4-34**	<ul style="list-style-type: none"> • Contactor complying with ITIC, SEMI F47 or IEC61000-4-11/ IEC61000-4-34. • Chilled water pump with battery-less UPS to secure its control contactors. • AC-DC power supply with DC buffer.
III	Equipment cannot function properly in voltage dips as in Level I/ II but equipped with automatic restart function or backup device	<ul style="list-style-type: none"> • Chiller automatically restarted by CCMS after voltage dip. • Standby chiller automatically switched in when the main chiller is tripped. • In case the lift is brought to an emergency stop due to voltage dips beyond the specified standards/ ride-through limit, the lift can be automatically restarted with post-voltage-dip operation (PVDO) to engage the lift car to the nearest landing floor and with door open to release the passengers trapped in a lift.

** The ride-through capabilities are illustrated in the Appendix of this Handbook.

Furthermore, the ride-through requirements for lifts and escalators can be referred to the latest editions of Electrical and Mechanical Services Department's (EMSD) the '*Lifts and Escalators Ordinance (Chapter 618)*' and the '*Code of Practice (COP) on the Design and Construction of Lifts and Escalators*'. Mitigation products/ solutions for lifts such as ride-through devices, emergency rescue devices and remote communication/ monitoring systems are commercially available. PVDO feature for lifts should inherent with ride-through capability, or by other means, to protect all sensitive electronic controls.

Harmonics

The power supply in Hong Kong is an alternating current in sinusoidal form with a fundamental frequency of 50 Hertz. Harmonic can be described as multiples of the fundamental frequency and may result in current or voltage distortions.



Harmonics in Multiples of the Fundamental Frequency

Harmonics may result in overheating of neutral cables, transformers and motors; mal-operation of circuit breakers and relays; excessive power consumption; damages to sensitive electronics devices and capacitor banks; and interference to telecommunication facilities.

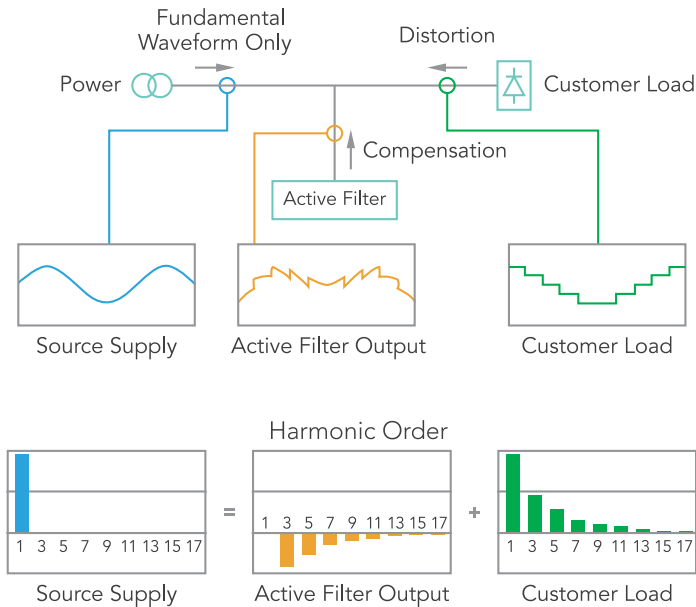
Causes of Harmonics

Harmonics mainly come from customers' non-linear loads like variable speed drives (VSD), power electronics devices and switch-mode power supply, etc.

Mitigations

Equipment like UPS, computers and motor drives generate high harmonic current. Equipment manufacturers are recommended to include harmonic suppressing or filtering devices in their products, whereby to conform with the maximum harmonic emission limit as set out by international standards.

For equipment users, they may consider adding active harmonic filters to reduce the harmonic content in their systems. Active harmonic filters counteract different harmonic orders with a feedback loop, which makes active filters a more flexible solution against dynamic harmonic distortions.



Working Principle of an Active Harmonic Filter

To add on, *Section 221 in CLP Power Supply Rules* serves as a useful reference on the limit of harmonic emissions. The requirement is extracted from the section and appended in this Handbook.

Enhancement of the Power System by CLP Power

PQ issues are considered as the compatibility issue of customers' equipment with the power system. This has to be tackled through collaborations with different parties: -

Supply Side	Customer Side	Equipment Side	Regulatory Bodies
Continuous power system improvement, e.g. <ul style="list-style-type: none"> • Lightning arresters installation • Vegetation management • Trenchwork/overhead line patrol 	CLP Power's PQ team assisting customers to identify cost-effective ways to protect their sensitive devices and reduce harmonic emissions	Incorporating PQ requirements at planning or design stage, product development or procurement	Setting out references for the industry by means of COP or Guidelines, etc.

Recognising our responsibility in providing reliable electricity to the customers, CLP Power has been taking proactive steps to monitor the status of the power system. CLP Power is constantly on the move to carry out maintenance and improvement works to ensure the integrity of the power supply system.

Over 30% of CLP Power's transmission network consists of overhead lines. There are more than 700 transmission towers forming the backbone of our 400kV power system. Considering overhead lines' susceptibility to external interference, devoted efforts are made to reduce voltage dips by: -



Installation of Lightning Arresters

To minimise voltage dips caused by lightning, CLP Power has installed line arresters on transmission towers and poles. Line arresters can drain tremendous lightning current to earth, whereby they stabilise the system voltage and achieve better supply reliability and power quality.

Vegetation Management

There are a large number of fast-growing tree species in Hong Kong. Fallen trees or branches that make contact with overhead lines under strong wind or heavy rain can cause voltage dips or even disrupt electricity supplies. CLP Power has adopted vegetation management techniques since 2001. The vegetation management team carries out pruning work on trees which might affect overhead lines. In addition, CLP Power has adopted airborne LiDAR scanning to accurately and efficiently measure the clearance between transmission overhead line conductors and nearby vegetation. By building 3D models and mapping the vegetation along the overhead lines, we can manage vegetation works more systematically and enhance the efficiency and effectiveness.



Trenchwork & Overhead Line Patrol

The *Electricity Supply Line Protection Regulation* has come into effect since April 2001, which carries penalties in terms of fines and imprisonment, aiming to reduce third-party damages to the power lines. Apart from the Government's regulation, CLP Power has carried out enhanced regular trenchwork patrol and established a COP illustrating the effective work steps to prevent damages to our power supply facilities.



For other outdoor power supply facilities, CLP Power introduces new technology, i.e. drones to remotely inspect transmission towers and overhead lines at high altitudes, making up for certain areas inaccessible for helicopters in the past.

Condition Monitoring

CLP Power introduces on-line condition monitoring systems at transmission power plant equipment for conducting round-the-clock health checks. Once irregularities are observed, the system will automatically issue alerts to relevant engineering staff, so that inspection or repair can be conducted at an early stage. The data collected can also serve to support the implementation of Condition Based Maintenance through the calculation of Asset Health Index to optimise the maintenance cost.



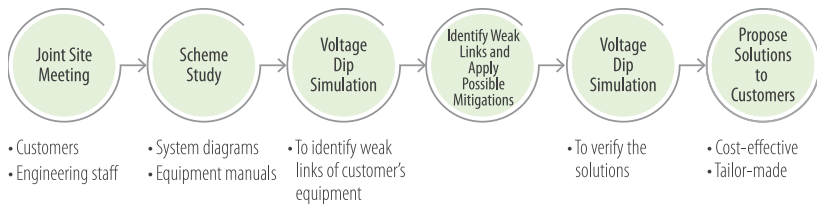


Power Quality Services Provided



Voltage Dip Simulation Test

By testing your equipment and identifying the sensitive components on site, we can recommend tailor-made and cost-effective solutions to improve the performance of your equipment when a voltage dip occurs.



Typical Workflow of Power Quality Investigation

Power Quality Measurement

We can also help identify possible types and sources of power quality problems by monitoring your electrical supply points.

Planning-Ahead

CLP Power invites developers or consultants to attend our planning-ahead meetings upon new supply applications. We believe that prevention is better than cure. With professional advices, planning-ahead can help customers identify critical systems in the development which may demand higher power quality standards. We encourage customers to incorporate suitable power quality specifications during project design stage and procurement process to save future efforts and downtime to improve the system.



Comparison between Different Mitigation Measures



The comparison tables in this section aim to give customers a glimpse on different mitigation measures and respective characteristics for their consideration. Adoption of mitigation measure subjects to site-specific conditions. Some mitigation measures may not be applicable for all equipment.

Typical Mitigation Measures for Harmonics

Description	Active Harmonic-Suppression Filter	Passive Harmonic-Suppression Filter	Built-in Harmonic-Suppression Filter
Harmonics Filtering Capability**	All orders of harmonics	Specific orders of harmonics	All/ specific orders of harmonics based on selection
Life Cycle Cost	\$\$	\$	\$

Typical Mitigation Measures for Voltage Dips

Description	Enable Automatic Restart Function	Post-Voltage-Dip Operation (PVDO) * for Lifts Only	Enable Kinetic Buffering and/ or Flying Start Features in VSD Settings to Enhance Ride-through Capability
Voltage Dip Ride-through Capability**	N/A	N/A	Less than 100%
Typical Compensation Time**	N/A	N/A	A few hundred milliseconds
Life Cycle Cost	Nil	For existing lifts without PVDO, lift modernization charge is required	Nil

** Please refer to the device's specifications for the actual capability from the market.

Mitigation Measures for High Rating Equipment – Three-Phase High Power Voltage Dip Ride-Through Devices

Description	Battery Static UPS	Flywheel Dynamic UPS	Transformer Voltage Dip Compensation Device	Capacitor Voltage Dip Compensation Device
Voltage Dip Ride-through Capability**	100%	100%	Less than 100%	100%
Typical Compensation Time**	Hours	Seconds	Seconds	Milliseconds to 1 second
Life Cycle Cost	\$\$\$ [#] [#] Requires regular battery maintenance	\$\$\$ [^] [^] Requires replacement of wearing parts	\$\$	\$\$\$

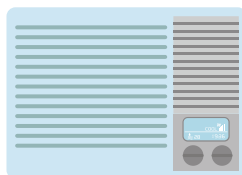
	Replacement of Sensitive Under-Voltage (UV) Relay	Add True Off-Delay Timer to Enhance Ride-through Capability	Battery-less UPS
	Less than 100%	Less than 100%	100%
	Milliseconds to 1 second	Milliseconds to 1 second	Milliseconds to 1 second
	\$	\$	\$\$\$



Mitigation Measures for Customers' Equipment



1 Air-Conditioner (Residential)



In Hong Kong, air-conditioners (A/C), especially window-type A/C, are widely used electrical appliances. Most high-density high-rise buildings and some primary and secondary schools are equipped with large numbers of window-type A/C. Although they enhance the comfort of the occupants, they also create problems during voltage dips. During a few hot summer nights in the past, some customers advised that their main air circuit breakers (ACBs) tripped during peak-load periods after voltage dips happened, resulting in a loss of power in some residential buildings. Nevertheless, the supply from the power utility side remained intact during the incident.

Symptoms

During a voltage dip, the compressors of some window-type A/Cs may stall due to the sudden drop in voltage. When the voltage recovers, the A/C compressor may fail to restart due to highly pressurised coolant remaining in the A/C refrigerating cycle. This can result in a locked rotor inside the A/C compressor. The current increases to around 3 to 7 times the normal value. As a large number of A/C are switched on at a hot summer night, the surge in current may in turn cause the main ACB to trip on over-current due to the simultaneous restarting of a large number of A/C compressors. Supply

interruption may then occur. The locked-rotor current may be detected by an A/C's internal thermo protection, but the operating time of the ACB's over-current protection is so short that the main supply will be interrupted before the thermo can operate.

Some compressors may not stall, but they still draw 3 to 7 times normal current value during restarting. Some window-type A/C models are equipped with a feature that will cut power to the compressor instantly on a voltage dip, and then resets automatically after a time delay. This type of window-type A/C will not cause the above-mentioned problem.



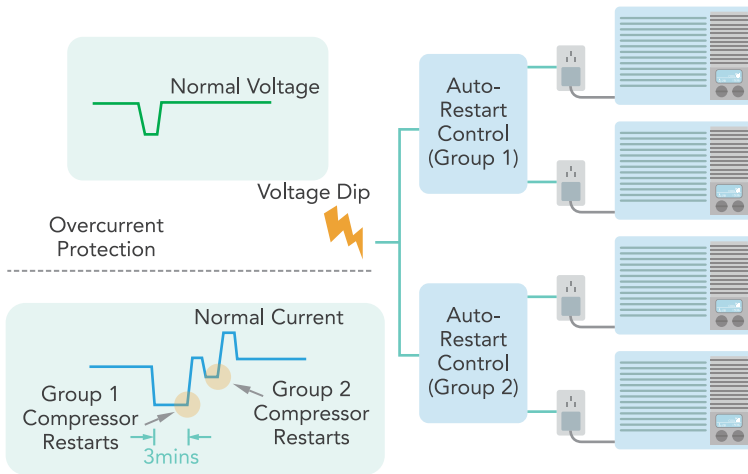
Mitigations

The tripping of the main ACB is attributable to uneven load distribution, high load demand under hot weather conditions, and sudden load fluctuations during a voltage dip incident.

For high-rise buildings:

- Internal supply upgrade or load diversion is proposed in order to reserve more capacity for sudden load demands and current fluctuations.
- Check if there is spare transformer bay and spare main incoming circuit breaker on customer LV board, please contact power company for considering addition of transformer or other supply upgrade if the reserved capacity is insufficient for load fluctuation.
- Replacement of conventional window-type or split-type A/C by inverter-type.
- Precise estimation of load growth and close monitoring of load demand would be necessary.

For schools:



3-Min Automatic Restart Control Box

- Installation of a 3-minute automatic restart control box is proposed to offer additional features for the contactor for grouped control of A/C. The control box will cause the contactors of all A/C groups to drop off on voltage dip and switch them in again, in sequence, after a 3-minute delay to limit the number of A/C to be started simultaneously.
- Supply upgrade or load diversion to allow more margins for the current surge.

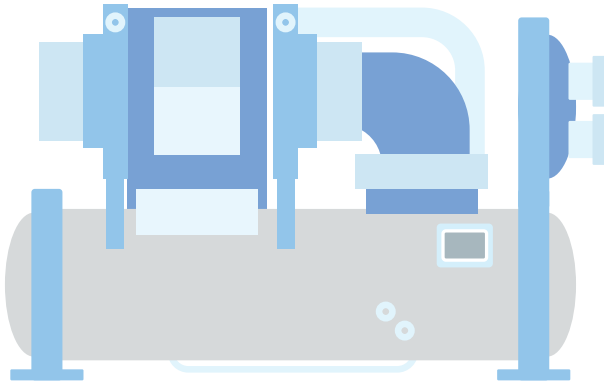


Tips for Planning-ahead

- Reserved capacity for load fluctuation.
- A/C or large machine-starting current under normal and voltage dip conditions.
- A/C with instant compressor cut-off on voltage dip and automatic time-delay reset.
- Window-type or split-type A/C with inverter for smaller starting current.

2 Chiller Plant (Commercial/ Industrial)

A/C equipment, in particular with chiller plants, is widely used in Hong Kong. Records show that chiller plants and their associated equipment (control panels, air handling unit (AHU), chilled water pump, etc.) are susceptible to voltage dips due to intrinsic overload protection, or lack of ride-through capability in the design of their control circuitry. Although the inconvenience incurred may be minimal for customers with operations staff who can quickly restart this equipment, the impact could sometimes be significant for customers managing large shopping malls, hotels, and public transportation systems. If their chiller cannot be not restarted automatically or quick enough by operations staff during a hot summer day, the room temperature may rise to 30°C in 5 to 30 minutes.



Symptoms

It was revealed that the controls of AHU and chilled water pump are sometimes electronic or computerised controls, and these are sensitive to voltage dips. These controls will trip, and their contactors may drop off when the control supply voltage drops below normal magnitude during voltage dip incidents.

When AHU and chilled water pump controls trip, the restart signal from the central chiller control will be blocked under the presence of trip alarms. Therefore, the compressor cannot be restarted automatically, manual attend and reset alarm will be required every time.

Mitigations

Possible solutions are summarised as follows:

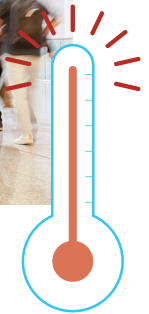
- Two common tactics for reducing the impact of voltage dips on the chiller plant are to allow the chiller to ride through the voltage dip and to introduce automatic restart control to the chiller. Effective solutions are to provide on-line UPS for the chiller controls and install new software with the automatic restart control option.
- Chiller plants are sometimes wired into the building automation system. Such a system sometimes provides a customised control sequence for automatically restarting the chiller plant equipment during a voltage dip incident. Modification to the building automation system software of the routine scheduling program can provide a new switching sequence to achieve this target.
- A centralised control panel is another typical feature of a chiller plant. By securing its control supply through a PQ-improvement device, e.g. UPS or a dip-proofing inverter, constant running of the chiller plant can be maintained.
- Some chillers may have stringent requirements that do not permit voltage dip ride-through. They therefore trip instantly during a voltage dip. However, improving the ride-through capability of the chilled water pump can maintain the flow of cold water throughout the building. This can help maintain the desired temperature of the building while the chiller is being restarted.
- Some chillers can cause voltage dip problem during motor starting, current limiting device should be used.

Most customers consider that the investment in and the effectiveness of the modification are fully justified in view of the benefit obtained in return. Solving the voltage dip issue is a good example of customer involvement and excellent cooperation between customer, chiller supplier and CLP Power.



Tips for Planning-ahead

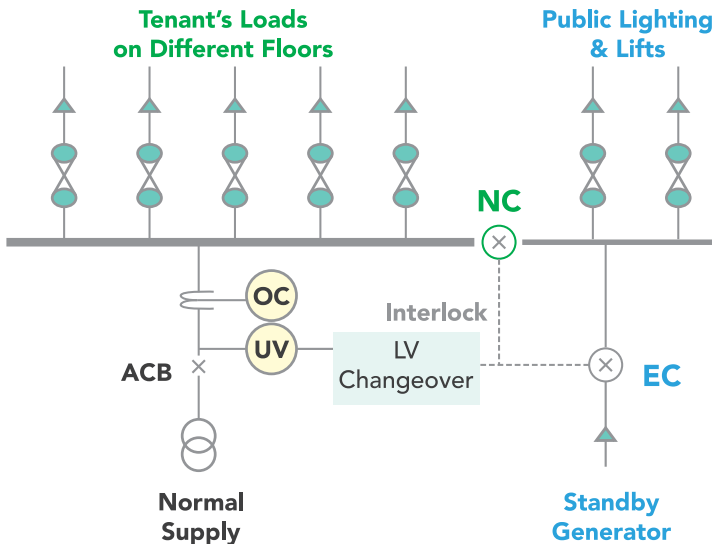
- Reserved capacity for load fluctuation.
- Program for automatic restart for chiller plant.
- Starting current control for large chiller motor.



3 LV Changeover System

Most estate buildings are equipped with a changeover scheme to provide alternative supply to the essential loads, e.g. public lighting, lifts, water pumps and security systems. However, certain changeover schemes may malfunction during voltage dip incidents and result in interruption to the essential supply.

Normally, essential loads are connected to the normal supply and share the supply bus with other major loads of the residents and tenants in the estate buildings. When the normal supply is lost, the supply to the essential loads can be resumed through the operation of the changeover scheme. The 'Normal' breaker (NC) is tripped off and the 'Essential' breaker (EC) is closed to connect the essential loads to the alternative supply. The aforesaid operations are fully automatic and are initiated by the changeover scheme logic. When the supply resumes, the breakers revert to their original status. However, proper operation failed during a voltage dip incident and caused supply interruption to essential loads.



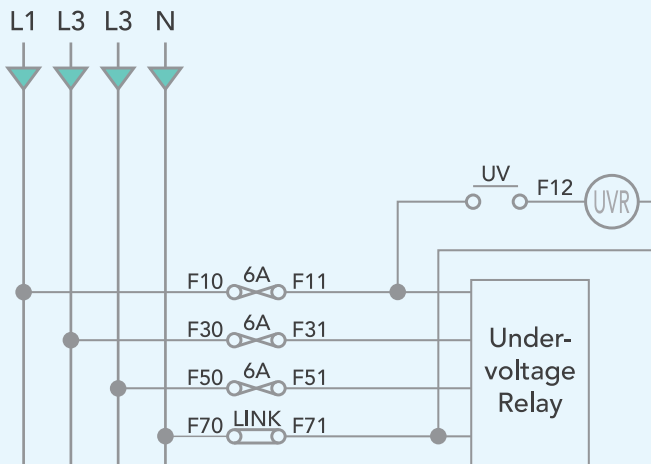
Schematic of a LV Changeover System

Another property management company reported that their standby generator started up for several seconds during a voltage dip incident. Fire and security equipment alarms also came on.

Symptoms

There was the possibility that the changeover scheme might malfunction and result in supply interruption under voltage dip conditions for the following reasons:

- The changeover scheme employed common AC supply as control supply.
- Voltage dip with critical magnitude and duration caused the AC under-voltage repeat relays (UVR) of the scheme to chatter.
- The chattering was fast enough to trip off the NC but the time was too short to close the EC.
- The scheme was equipped with time-delay operated under-voltage relay (UR) but the trip command was not effectively guarded.
- The scheme could not reset itself and thus was locked off after both breakers were opened.



Under-Voltage Repeat Relay (UVR) in Wiring Diagram

There was no true off-time delay to reduce the unwanted start-up of the standby generator during voltage dip condition.

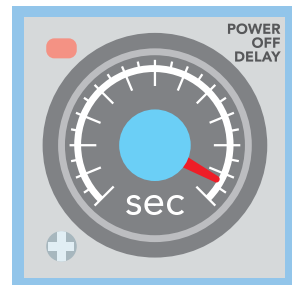
Site inspection also revealed that the control setting of some changeover schemes was too sensitive. The over- and under-voltage setting could not tolerate minor voltage fluctuations caused by load change and switching of power-factor improvement capacitor bank. Moreover, time delay setting was found set to zero second.

An over-sensitive changeover scheme may divert the essential supply to the non-started standby generator end during minor voltage fluctuations. This results in supply interruption although the supply from the power utility is healthy.

Mitigations

Possible solutions are summarised as follows:

- To employ DC supply for the changeover and other control schemes because AC-driven relays malfunctioned during voltage dip incidents. This is similar to most fire and security systems that employ DC with battery back-up as control supply to enhance scheme reliability. To be more reliable, use battery-less UPS as control supply during voltage dips.
- To employ coil hold-in device to reduce the chance of relay-chattering under voltage dip conditions.
- To employ true off-delay relay to coordinate with the under-voltage relay in order to allow a short delay before issuing trip signal to the respective breaker under voltage dip conditions, or start command to standby generator.



True Off-Delay Timer

- It would be desirable to adjust the voltage setting of the scheme in order to allow sufficient margin to ignore transient disturbances which may be produced by the starting of heavy machinery or sudden load changes at the load side. The operating time setting should be long enough to ride-through most voltage dips in order to achieve higher reliability.

The best solution depends on the actual site situation. CLP Power is ready to provide consultancy services to assist customers in solving this kind of problem.



Tips for Planning-ahead

- Reliability of the scheme under voltage dips.
- Use of DC scheme and equipping with battery and charger.
- True off-delay timer.
- Over-/ under-voltage and time-delay setting of changeover scheme.



4 Lift



As with public transport, lifts and escalators are subject to passenger-safety concerns. The requirements on both lifts and escalators are stated in the '*Lifts and Escalators Ordinance (Chapter 618)*' and the '*Code of Practice (COP) on the Design and Construction of Lifts and Escalators*' in Hong Kong.

There are around 70,000 lifts in Hong Kong. During voltage dips, some lifts may be tripped with passengers trapped inside ('shut-in-lift').

Symptoms

Most lifts are designed to restart automatically after a voltage dip, and perform the 'Homing' function, which is an essential feature of the fireman's lift. However, there are still incidents which may result in 'shut-in-lift' due to problems with different components.

As regards mechanical parts, the possible causes are:

- Activation of mechanical safety devices, e.g. landing-door safety switches and over-speed governor.
- Upper/ lower limit switch operated as a result of lift marginally overshooting when travelling towards terminal floors (G/F or roof floor).

As regards electrical parts, the possible causes are:

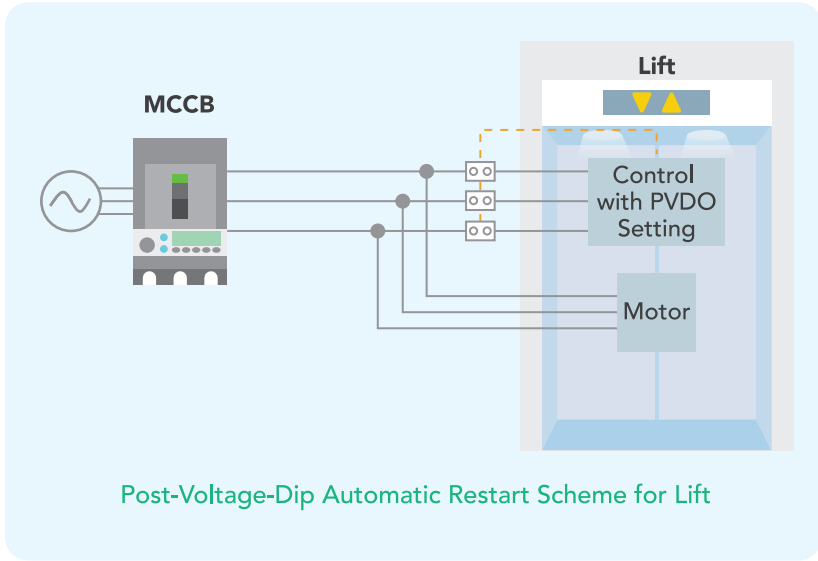
- Loss of memory due to temporary shutdown of computerised controls.
- Too long homing time during automatic restart.
- Stalled-motor timer expired while automatic restarting in the tunnel zone (at no designated landing floor).
- Fault counter overflow.
- Fuse and control PCB blown.

Although some lifts do restart after a voltage dip, the restarting time may be too long with consequent misinterpretation by passengers as shut-in-lift.

Mitigations

Possible solutions are summarised as follows:

- If no hidden mechanical defects, the lift should be able to automatic restart and perform the 'Homing' function, which is an essential feature of the fireman's lift. Inclusion of checking of automatic restart or power loss homing function in maintenance procedures should be considered.
- If the homing time was too long during restarting, an emergency floor opening in the tunnel zone could be modified as a landing floor for passenger evacuation. Alternatively, high-speed floor locating should be considered. Low-speed floor locating during restart is always misinterpreted by passengers as shut-in-lift.
- If the lift tripped on stalled-motor timer when the lift was repositioning itself at low speed, a sensor should be added in order to feedback running status to reset the timer. Alternatively, high-speed floor locating software should be considered.
- Mechanical defects and damaged voltage arrestors should be cleared and replaced during compulsory routine maintenance.
- Effective intercom to duty guard post is desirable (instead of relaying to unmanned machine room).
- Lift-status display lantern should be considered for comforting passengers when the lift has tripped or is restarting at low speed.
- Dynamic reactive compensator should be added to reduce voltage dip caused by starting current surge.
- Voltage dip immunity components should be considered to enhance the ride-through capability of the control circuits and/ or motor drive.
- Adopt lift modernization to include post-voltage-dip operation (PVDO) feature (please refer to the latest edition of '*COP on the Design and Construction of Lifts and Escalators*') and Automatic Rescue Device (ARD) should be considered.
- Advanced type motor drive equipped with kinetic buffering and/ or regenerative feature should be considered.



Tips for Planning-ahead

- Voltage dip ride-through capability of the lift.
- Effectiveness of automatic restart or homing feature of lift under different conditions after a voltage dip.

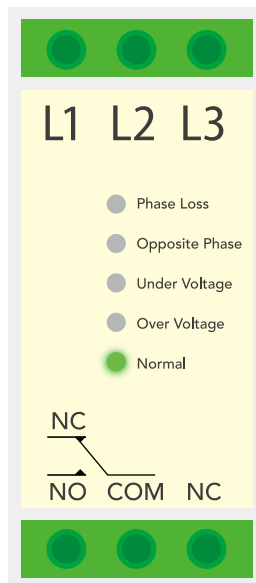
5 Escalator

Property management team advised that escalators were found tripped during voltage dip incidents. In addition to requiring manual reset of all affected escalators, passengers may experience a loss of balance and suffer injury during the sudden arrest of the escalator.

Symptoms

During voltage dips, the control circuit operated and stopped the escalator. The control contactors and PLC dropped off. Moreover, the phase-monitoring (PM) relay was not equipped with a time-delay setting, such that the escalator was tripped by the PM relay even though the contactors and PLC did not drop off.

For escalators with variable speed drive (VSD), the VSD was found tripped due to incorrect settings.

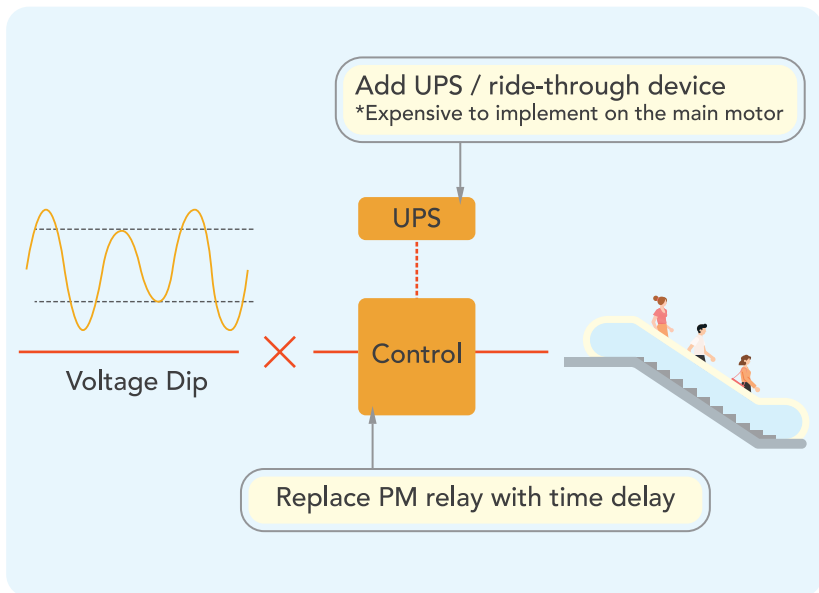


PM Relay with
No Time-Delay Setting

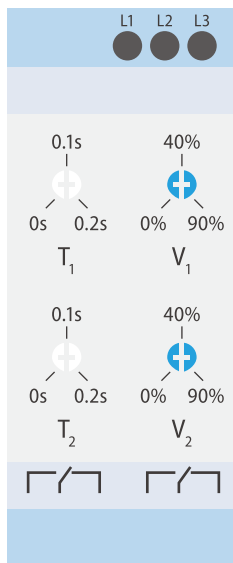
Mitigations

Possible solutions are summarised as follows:

- It was recommended to add an UPS to secure the power to the control contactors and PLC.
- In addition, the PM relay was replaced with a new relay equipped with a short time delay allowing the escalator to ride through the voltage dip for 0.2 second.



- To modify the settings of VSD in order to enhance ride-through capability.
- Some VSD provide a voltage dip ride-through feature should be considered, e.g. kinetic buffering, which requires enabling by users.
- DC buffering unit can be added to supply energy to VSD during voltage dip.
- For adding ride-through feature, a two-stage under-voltage (UV) relay should be used to comply with requirements in “Code of Practice (COP) on the Design and Construction of Lifts and Escalators”.
- For public safety, an escalator with “soft-stop” function allowing it to slow down gradually during failures should also be considered.

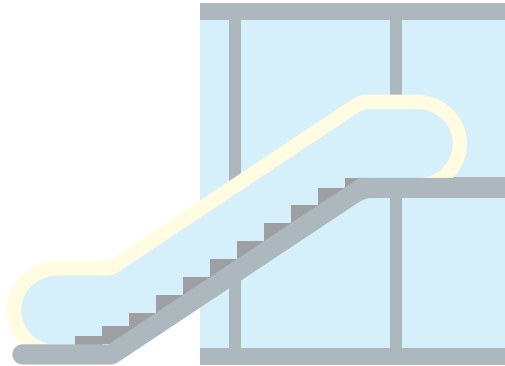


Two-Stage UV Relay



Tips for Planning-ahead

- Voltage dip ride-through capability of the escalator.
- VSD voltage dip ride-through setting.



6 Variable Speed Drive

A chemical manufacturer experienced tripping on one or more machines on its production line. As a stoppage anywhere along the line brings the whole production process to a halt, tripping of even one single machine was causing significant losses to the company. Tripping occurred during voltage dips and overall restoration time to get the production line back to normal was as long as one or two hours.

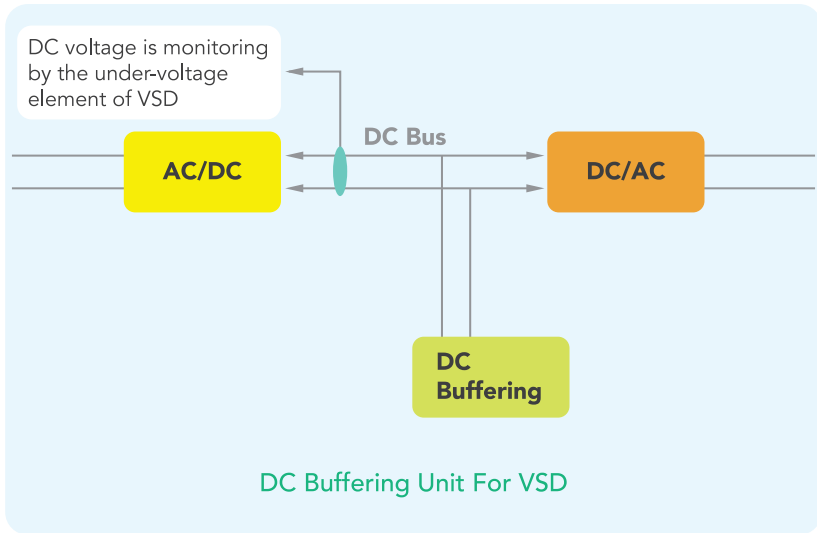
Symptoms

It was soon established that most of the machines used on the production line were motor-driven and controlled by variable speed drive (VSD). It was discovered that the machine had an ON/OFF control contactor and a variable frequency controller (VFC). Through testing and examination, it was found that the control contactor dropped off during a voltage dip. The VSD was also found to be equipped with an automatic restart option designed to restart the machine after a short power failure. However, default setting of the automatic restart was set at 'Inactive'.

Mitigations

Possible solutions are summarised as follows:

- It is recommended to by-pass the control contactor and also modify the VSD to take up the ON/OFF control function.
- The VSD voltage dip/ power loss automatic restart function should be activated in this case. To be more reliable, ride-through device should be used.
- DC buffering unit can be added to supply energy to VSD during voltage dip.
- These requirements have been incorporated in the purchasing specifications for new machines.



Tips for Planning-ahead

- Control contactor drop-off.
- VSD voltage dip ride-through setting, voltage dip/ power loss automatic restart setting.
- Specifications for new machines.

7 Uninterruptible Power Supply & Automatic Transfer Switch

Customer advised that their residual current device (RCD) tripped when uninterruptible power supply (UPS) ran at battery mode (discharging) and UPS out-of-sync alarm came up occasionally.

Another customer advised that their UPS discharged and automatic transfer switch (ATS) operated too frequently. Occasionally, some sensitive equipment was found tripped even though UPS was provided.



ATS

Symptoms

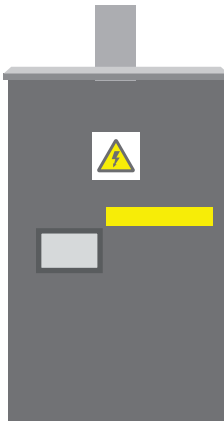
Measurements revealed that the harmonics of some major circuits were very high. High harmonics caused tripping of RCD. Sometimes, UPS might also trip on out-of-sync.

Investigation also revealed that the rated input voltage of the UPS was 240V which was higher than the actual rated voltage value. Switched-type UPS was also used. The voltage sensitivity of the UPS was set too high.

Mitigations

Possible solutions are summarised as follows:

- It is recommended to add a harmonic-suppression filter or equivalent device. Harmonic-immune RCD should be considered alternatively.
- UPS/ ATS voltage sensitivity set too high and caused UPS to switch to battery mode or ATS to operate on minor voltage variations and shorten equipment life.
- Switched-type UPS was used and it responded too slowly under marginal voltage fluctuation condition. It is recommended to use true on-line UPS.



Active
Harmonic-Suppression
Filter



True On-Line UPS

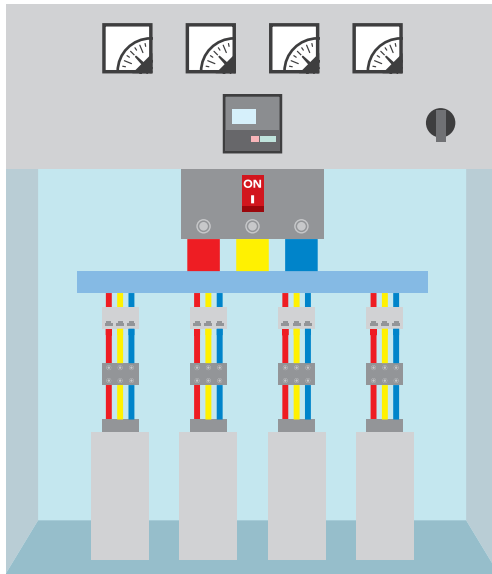


Tips for Planning-ahead

- UPS voltage rating, sensitivity level and mode of operation, i.e. switched-type or true on-line type.

8 Capacitor Bank

Capacitor banks/ units are commonly employed for power-factor correction. Customer advised that some capacitor banks frequently blew out. The temperature of the main neutral conductor was found to be too high. Computerised and telecommunications equipment was found to have failed occasionally.



LV Capacitor Bank

Symptoms

Switching mode power supplies, variable speed drives and other power electronics could generate different level of harmonics in the network. Harmonics are disturbances which can cause capacitor bank and neutral cable overload. They can also affect or even damage sensitive equipment.

Mitigations

Measurements revealed that the harmonics of the building were too high. It is recommended to install harmonic-suppression filters. For new installations, baseline measurements should be taken. Periodic review of the harmonic content should be carried out in order to mitigate the problem caused by excessive harmonics.



Tips for Planning-ahead

- Estimate harmonic level of all related circuits.
- Harmonics of future equipment added/ installed by tenants.
- Application of active harmonic filter.

9 Building Automation

BMS (Building Management Systems) are in widespread use in Hong Kong for building automation. BMS are equipped with centralised computers and distributed units (sometimes called direct digital controllers). These devices are sensitive to voltage dips. In some cases where an UPS has been installed, the system still crashes occasionally during voltage dip incidents.



Symptoms

In one case, investigations revealed that the UPS was of the switched-type. A switched-type UPS, which had a slow response under marginal conditions, could cause the distributed unit/ controller to hang due to voltage fluctuations.

Moreover, too many status changes and alarms occurred during system disturbance. These also caused the BMS and associated system to hang.

Mitigations

Possible solutions are summarised as follows:

- It is recommended to use true on-line type UPS to secure the power supply to computer equipment.
- It is recommended to ensure/ improve system performance on signal flooding.
- Scheduling program should include automatic restart of chiller and chilled water pump after voltage dip.



Tips for Planning-ahead

- Ensure reliability of central PC and distributed unit under voltage dip or other disturbances.
- Perform simulation of alarm flooding under system disturbance.
- Program automatic restart for chiller plant.

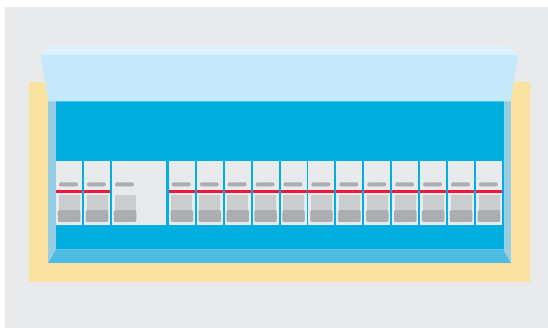
10 Residual Current Device

Based on the sensitivity to various types of residual currents, the RCDs are typically subdivided to types AC, A and B.

- Type AC are only for alternating residual currents.
- Type A are for alternating and pulsating direct currents.
- Type B for all types of residual current, i.e. alternating, pulsating direct and smooth direct residual currents.

Pulsating direct residual currents may occur in some of electronic installations where frequency inverters, photovoltaic power plants and other equipment with power semiconductor elements are applied. Hence, a correct type of RCD shall be selected for the specific applications.

Some residual current devices (RCD) of certain circuits in commercial offices could trip occasionally. CLP Power carried out an investigation and found that harmonics and current transients produced by a large number of computers was the major cause of RCD tripping.



RCD

Symptoms

Harmonics are disturbances which may be generated by power electronics and non-linear loads (electronic devices, computers and printers). They can also affect the performance of precision machinery or even cause damage to some sensitive electronics. For installations with high harmonics, there is a technical limitation to the application of RCD on computers and peripherals. In general, one RCD can provide stable protection for a few computers only (say 3 to 6 sets, depending on loading). Grouping too many computers (or electronics devices) on one RCD alone reduces the stability of the device. The chance of malfunction then increases.

Mitigations

Possible solutions are summarised as follows:

- High harmonic content could be a major cause of RCD tripping. The addition of a harmonic-suppression filter is suggested.
- The cumulative trace capacitance of electronic device/ computer loads could introduce transient leakage current under voltage dip conditions and thus trigger the operation of the RCD.
- It is recommended to consult an electrical contractor on adding a new and selecting a correct type of RCD and checking the insulation and current leakage on individual devices.
- Harmonic-immune RCDs are available on the market which can provide leakage protection for circuits with high harmonics.



Tips for Planning-ahead

- Estimated harmonic level of all related circuits.
- Harmonics of future equipment added/ installed by tenants.
- Application of active harmonic filter.

11

Production Line

A beverage production company experienced tripping on its drink production line during voltage dips. Not only some drink filling and packaging machines were down, some special machines like homogeniser and steriliser were also affected. It caused the production line to stop for hours as re-sterilising of different machines is required after a relatively long downtime due to manual restart of machines.



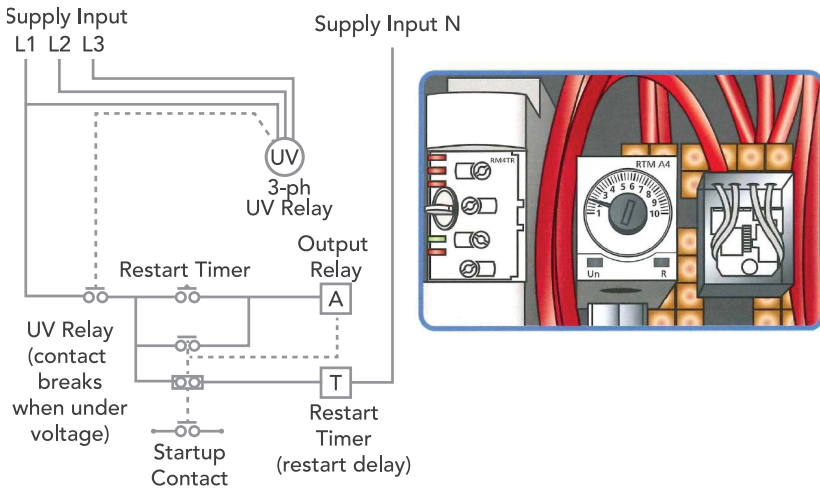
Symptoms

After investigation, it was found that the concerned machines equipped with a compressor or a pump driven by variable speed drive (VSD) and a controller connected to a 24V DC power supply. As these components are sensitive to voltage dips, the VSD were tripped and the controllers hang. The VSD was also found to be equipped with an automatic restart option designed to restart the machine after a short power failure. However, default setting of the automatic restart was set at 'Inactive'.

Mitigations

Possible solutions are summarised as follows:

- The VSD voltage dip/ power loss automatic restart function should be activated in this case. To be more reliable, ride-through device should be used.
- For VSD without an automatic restart option, an external automatic restart scheme should be considered.
- DC buffering units can be added at the output of the existing 24V DC power supply to supply energy to the controller during voltage dip.



Simplified Connection Diagram of External Automatic Restart Scheme



Tips for Planning-ahead

- VSD voltage dip ride-through setting, voltage dip/ power loss automatic restart setting.
- Use of DC buffering for AC/DC power Supply.
- Specifications for new machines.



Problem-Solving & Planning-Ahead Table



The table below summarizes the symptoms, possible causes and recommended solutions:

Mitigation Measures for Customers' Equipment

Appliance	Symptom	Recommendation
Air-Conditioners (Residential)	<ul style="list-style-type: none"> • Original design did not cater for load growth and use of high-demand appliances, like air-conditioner. • Customer's main building ACB tripped after voltage dip as a result of over-current protection activated due to excessive restart current surge. 	<p>The tripping of the main ACB is attributable to uneven load distribution, high load demand under hot weather conditions, and sudden load fluctuations during a voltage dip incident.</p> <p>For high-rise buildings:</p> <ul style="list-style-type: none"> • Internal supply upgrade or load diversion is proposed in order to reserve more capacity for sudden load demands and current fluctuations. • Check if there is spare transformer bay and spare main incoming circuit breaker on customer LV board, please contact power company for considering addition of transformer or other supply upgrade if the reserved capacity is insufficient for load fluctuation. • Replacement of conventional window-type or split-type A/C by inverter-type. • Precise estimation of load growth and close monitoring of load demand would be necessary.

Appliance	Symptom	Recommendation
Air-Conditioners (Residential)		<p>For schools:</p> <ul style="list-style-type: none"> • Installation of a 3-minute automatic restart control box is proposed to offer additional features for the contactor for grouped control of A/C. The control box will cause the contactors of all A/C groups to drop off on voltage dip and switch them in again, in sequence, after a 3-minute delay to limit the number of A/C to be started simultaneously. • Supply upgrade or load diversion to allow more margins for the current surge.

Planning Ahead Tips

- Reserved capacity for load fluctuation.
- A/C or large machine-starting current under normal and voltage dip conditions.
- A/C with instant compressor cut-off on voltage dip and automatic time-delay reset.
- Window-type or split-type A/C with inverter for smaller starting current.

Appliance	Symptom	Recommendation
<p>Chiller Plant (Commercial/ Industrial)</p>	<ul style="list-style-type: none"> Chiller plant tripped after voltage dip. 	<ul style="list-style-type: none"> Two common tactics for reducing the impact of voltage dips on the chiller plant are to allow the chiller to ride through the voltage dip and to introduce automatic restart control to the chiller. Effective solutions are to provide on-line UPS for the chiller controls and install new software with the automatic restart control option. Chiller plants are sometimes wired into the building automation system. Such a system sometimes provides a customised control sequence for automatically restarting the chiller plant equipment during a voltage dip incident. Modification to the building automation system software of the routine scheduling program can provide a new switching sequence to achieve this target. A centralised control panel is another typical feature of a chiller plant. By securing its control supply through a PQ-improvement device, e.g. UPS or a dip-proofing inverter, constant running of the chiller plant can be maintained. Some chillers may have stringent requirements that do not permit voltage dip ride-through. They therefore trip instantly during a voltage dip. However, improving the ride-through capability of the chilled water pump can maintain the flow of cold water throughout the building. This can help maintain the desired temperature of the building while the chiller is being restarted. Some chillers can cause voltage dip problem during motor starting, current limiting device should be used.

Planning Ahead Tips

- Reserved capacity for load fluctuation.*
- Program for automatic restart for chiller plant.*
- Starting current control for large chiller motor.*

Appliance	Symptom	Recommendation
LV Changeover Scheme	<ul style="list-style-type: none"> • LV changeover scheme malfunctioned after voltage dip and resulted in interruption to the essential supply. 	<ul style="list-style-type: none"> • To employ DC supply for the changeover and other control schemes because AC-driven relays malfunctioned during voltage dip incidents. This is similar to most fire and security systems that employ DC with battery back-up as control supply to enhance scheme reliability. To be more reliable, use battery-less UPS as control supply during voltage dips. • To employ coil hold-in device to reduce the chance of relay-chattering under voltage dip conditions. • To employ true off-delay relay to coordinate with the under-voltage relay in order to allow a short delay before issuing trip signal to the respective breaker under voltage dip conditions, or start command to standby generator. • It would be desirable to adjust the voltage setting of the scheme in order to allow sufficient margin to ignore transient disturbances which may be produced by the starting of heavy machinery or sudden load changes at the load side. The operating time setting should be long enough to ride-through most voltage dips in order to achieve higher reliability.

Planning Ahead Tips

- *Reliability of the scheme under voltage dips.*
- *Use of DC scheme and equipping with battery and charger.*
- *True off-delay timer.*
- *Over-/ under-voltage and time-delay setting of changeover scheme.*

Appliance	Symptom	Recommendation
Lifts	<ul style="list-style-type: none"> Lift tripped and with passenger 'shut-in-lift' during voltage-dip. 	<ul style="list-style-type: none"> If no hidden mechanical defects, the lift should be able to automatic restart and perform the 'Homing' function, which is an essential feature of the fireman's lift. Inclusion of checking of automatic restart or power loss homing function in maintenance procedures should be considered. If the homing time was too long during restarting, an emergency floor opening in the tunnel zone could be modified as a landing floor for passenger evacuation. Alternatively, high-speed floor locating should be considered. Low-speed floor locating during restart is always misinterpreted by passengers as shut-in-lift. If the lift tripped on stalled-motor timer when the lift was repositioning itself at low speed, a sensor should be added in order to feedback running status to reset the timer. Alternatively, high-speed floor locating software should be considered. Mechanical defects and damaged voltage arrestors should be cleared and replaced during compulsory routine maintenance. Effective intercom to duty guard post is desirable (instead of relaying to unmanned machine room). Lift-status display lantern should be considered for comforting passengers when the lift has tripped or is restarting at low speed. Dynamic reactive compensator should be added to reduce voltage dip caused by starting current surge. Voltage dip immunity components should be considered to enhance the ride-through capability of the control circuits and/ or motor drive. Adopt lift modernization to include post-voltage-dip operation (PVDO) feature (please refer to the latest edition of 'COP on the Design and Construction of Lifts and Escalators') and Automatic Rescue Device (ARD) should be considered. Advanced type motor drive equipped with kinetic buffering and/ or regenerative feature should be considered.

Planning Ahead Tips

- Voltage dip ride-through capability of the lift.*
- Effectiveness of automatic restart or homing feature of lift under different conditions after a voltage dip.*

Appliance	Symptom	Recommendation
Escalator	<ul style="list-style-type: none"> Escalator tripped during voltage-dip. 	<ul style="list-style-type: none"> It was recommended to add an UPS to secure the power to the control contactors and PLC. In addition, the PM relay was replaced with a new relay equipped with a short time delay allowing the escalator to ride through the voltage dip for 0.2 second. To modify the settings of VSD in order to enhance ride-through capability. Some VSD provide a voltage dip ride-through feature should be considered, e.g. kinetic buffering, which requires enabling by users. DC buffering unit can be added to supply energy to VSD during voltage dip. For adding ride-through feature, a two-stage under-voltage (UV) relay should be used to comply with requirements in "Code of Practice (COP) on the Design and Construction of Lifts and Escalators". For public safety, an escalator with "soft-stop" function allowing it to slow down gradually during failures should also be considered.

Planning Ahead Tips

- Voltage dip ride-through capability of the escalator.
- VSD voltage dip ride-through setting.

Variable Speed Drive	<ul style="list-style-type: none"> Control contactor dropped off. Variable speed drive tripped under voltage dip. 	<ul style="list-style-type: none"> It is recommended to by-pass the control contactor and also modify the VSD to take up the ON/OFF control function. The VSD voltage dip/ power loss automatic restart function should be activated in this case. To be more reliable, ride-through device should be used. DC buffering unit can be added to supply energy to VSD during voltage dip. These requirements have been incorporated in the purchasing specifications for new machines.
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Planning Ahead Tips

- Control contactor drop-off.
- VSD voltage dip ride-through setting, voltage dip/ power loss automatic restart setting.
- Specifications for new machines.

Appliance	Symptom	Recommendation
Uninterruptible Power Supply (UPS) and Automatic Transfer Switch (ATS)	<ul style="list-style-type: none"> • RCD tripped when UPS ran at battery mode (discharging) and UPS out-of-sync alarm came up. • UPS discharged or ATS (automatic transfer switch) operated too frequently. • Sensitive equipment tripped even when UPS was provided. 	<ul style="list-style-type: none"> • It is recommended to add a harmonic-suppression filter or equivalent device. Harmonic-immune RCD should be considered alternatively. • UPS/ ATS voltage sensitivity set too high and caused UPS to switch to battery mode or ATS to operate on minor voltage variations and shorten equipment life. • Switched-type UPS was used and it responded too slowly under marginal voltage fluctuation condition. It is recommended to use true on-line UPS.

Planning Ahead Tips

- *UPS voltage rating, sensitivity level and mode of operation, i.e. switched- type or true on-line type.*

Capacitor Bank	<ul style="list-style-type: none"> • Capacitor bank blown out frequently. • Neutral conductor high temperature. • Computerised and Telecommunications equipment failure. 	<ul style="list-style-type: none"> • Harmonics of the building too high. • Add harmonic-suppression filter. • Baseline measurement and periodic review of harmonic level would be desirable.
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Planning Ahead Tips

- *Estimate harmonic level of all related circuits.*
- *Harmonics of future equipment added/ installed by tenants.*
- *Application of active harmonic filter.*

Building Automation	<ul style="list-style-type: none"> • Centralised PC or distributed units hung. 	<ul style="list-style-type: none"> • It is recommended to use true on-line type UPS to secure the power supply to computer equipment. • It is recommended to ensure/ improve system performance on signal flooding. • Scheduling program should include automatic restart of chiller and chilled water pump after voltage dip.
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Planning Ahead Tips

- *Ensure reliability of central PC and distributed unit under voltage dip or other disturbances.*
- *Perform simulation of alarm flooding under system disturbance.*
- *Program automatic restart for chiller plant.*

Appliance	Symptom	Recommendation
Residual Current Device (RCD)	<ul style="list-style-type: none"> • RCD tripped occasionally after voltage dip. 	<ul style="list-style-type: none"> • High harmonic content could be a major cause of RCD tripping. The addition of a harmonic-suppression filter is suggested. • The cumulative trace capacitance of electronic device/ computer loads could introduce transient leakage current under voltage dip conditions and thus trigger the operation of the RCD. • It is recommended to consult an electrical contractor on adding a new and selecting a correct type of RCD and checking the insulation and current leakage on individual devices. • Harmonic-immune RCDs are available on the market which can provide leakage protection for circuits with high harmonics.

Planning Ahead Tips

- *Estimated harmonic level of all related circuits.*
- *Harmonics of future equipment added/ installed by tenants.*
- *Application of active harmonic filter.*

Production Lines	<ul style="list-style-type: none"> • Machines tripped during voltage dips. 	<ul style="list-style-type: none"> • The VSD voltage dip/ power loss automatic restart function should be activated in this case. To be more reliable, ride-through device should be used. • For VSD without an automatic restart option, an external automatic restart scheme should be considered. • DC buffering units can be added at the output of the existing 24V DC power supply to supply energy to the controller during voltage dip.
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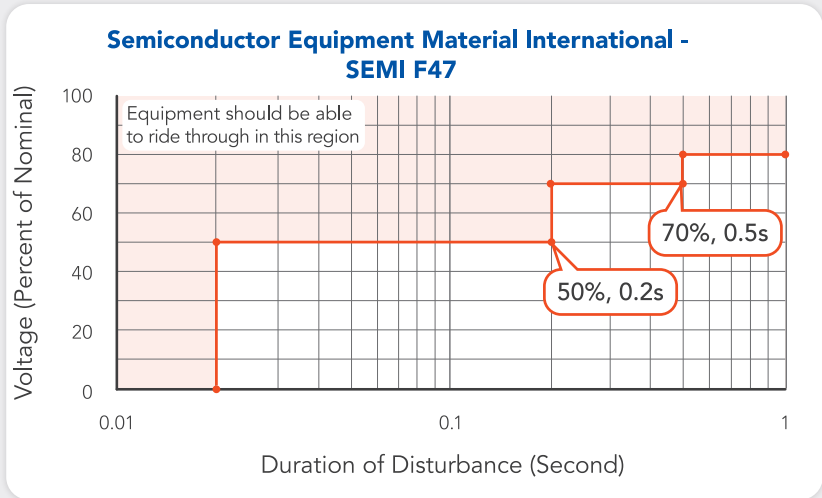
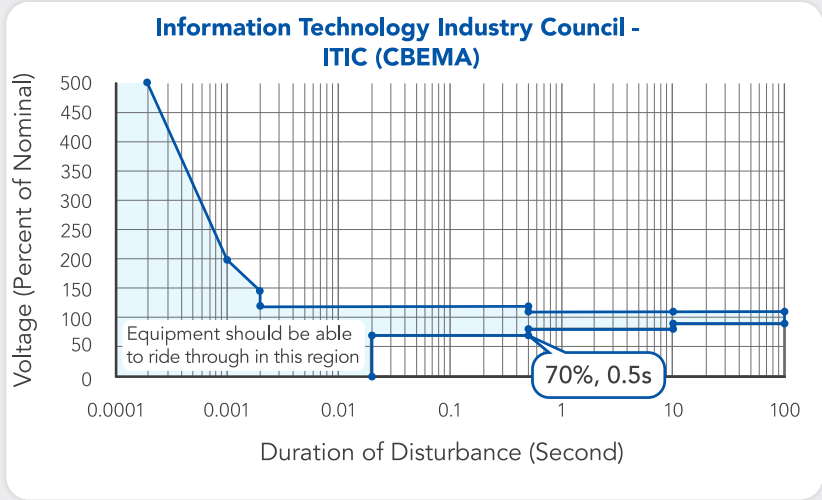
Planning Ahead Tips

- *VSD voltage dip ride-through setting, voltage dip/ power loss automatic restart setting.*
- *Use of DC buffering for AC/DC power Supply.*
- *Specifications for new machines.*

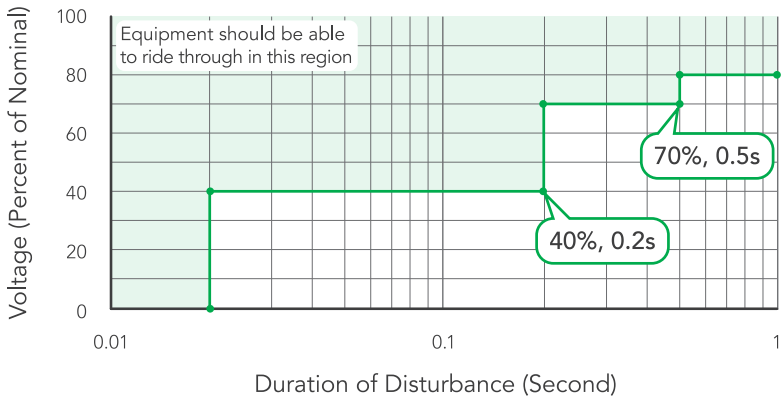
Appendix

International Standards

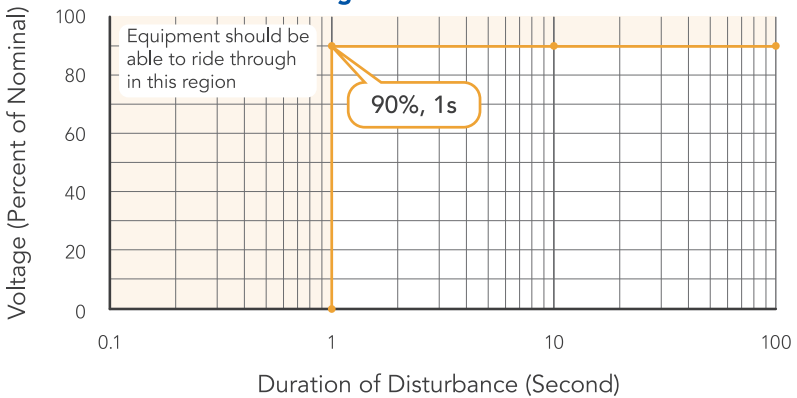
Voltage Dip Ride-through Capability



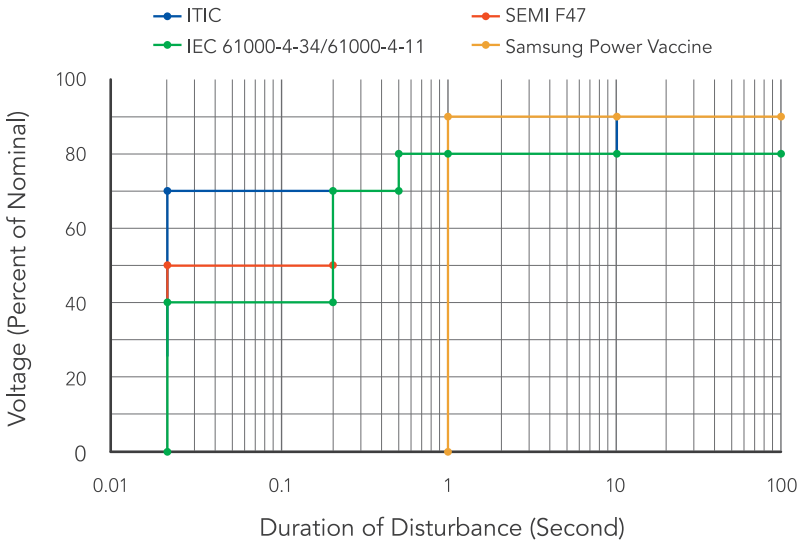
International Electrotechnical Commission - IEC 61000-4-34 / 61000-4-11



Samsung Power Vaccine



Voltage Dip Immunity Summary



Equipment is expected to operate properly for any voltage dip with a depth-duration pair that lies above the curves.

Standards for Harmonics

CLP Power's Supply Rules – Section 221

Types of Distortion	Operational Limits			
Harmonic Voltage Distortion	Supply Voltage	Total Harmonic Distortion (THD) #	Individual Harmonics	
	132kV	3%	2%	
	33kV	5%	3%	
	11kV	5%	3%	
	380V or 220V	5%	3%	
# Weekly 95 th -percentile of the 10-minute values				
Harmonic Current Distortion	Supply Voltage	Total Demand Distortion (TDD) #		
	11kV or above	IEEE519 sets out the detailed limits of the permissible current distortion.		
	380V or 220V	Max Demand Current at PCC ^	TDD _{odd} #	
		I < 40A	20%	
		40A ≤ I < 400A	15%	
		400A ≤ I < 800A	12%	
		800A ≤ I < 2000A	8%	
	I ≥ 2000A	5%		
# Weekly 95 th -percentile of the 10-minute values Even harmonics are limited to 25% of the odd harmonics				
^ By historical data or actual measurement of the daily maximum for a period of at least 7 days				

Table 1 – Voltage Distortion Limits

Bus Voltage V at PCC	Individual Harmonic (%)	Total Harmonic Distortion THD (%)
$V \leq 1.0 \text{ kV}$	5.0	8.0
$1 \text{ kV} < V \leq 69 \text{ kV}$	3.0	5.0
$69 \text{ kV} < V \leq 161 \text{ kV}$	1.5	2.5
$161 \text{ kV} < V$	1.0	1.5 ^a

^a High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Table 2 – Current Distortion Limits for Systems Rated 120 V through 69 kV

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics) ^{a, b}						
I_{sc}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
$< 20^c$	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

^a Even harmonics are limited to 25% of the odd harmonic limits above.

^b Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.

^c All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L .

where

I_{sc} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Standard for Other Operational Limits of Customer Equipment

CLP Power's Supply Rules – Section 221

Types of Distortion	Operational Limits		
Voltage Fluctuation	Electric arc furnaces	For 132kV and below	2%
	Motors	<ul style="list-style-type: none"> • Infrequent starting (intervals exceeding 2 hours) • Frequent starting (intervals not exceeding 2 hours) 	3% 1%
	Rolling mills and traction loads (motor starting intervals not exceeding several minutes)	<ul style="list-style-type: none"> • Step-type change: up to 33kV 132kV • Ramp-type change: up to 33kV 132kV • Limit of the total change: up to 33kV 132kV 	1% 0.75% 1% /sec 0.75% /sec 3% 2.25%
Voltage Unbalance	Single-phase electric traction loads	<ul style="list-style-type: none"> • Voltage: Negative sequence 2% of positive sequence • Current into generators: Negative sequence 5% of positive sequence 	
Current Unbalance	Any 3-phase 4-wire circuits rated at 400A or above with single-phase loads	Maximum current deviation among 3 phases at the point of common coupling (PCC)	10%

Contact Us

CLP Power is committed to maintaining and delivering reliable electricity supply. We are pleased to provide further assistance on power quality.

If you have any enquiry on power quality, please contact us via the following channels: -

Customer Service Hotline: 2678 2678

E-mail: csd@clp.com.hk

Submit your enquiry or feedback on the CLP Power Website:

<https://www.clp.com.hk/en/help-support/submit-enquiry-feedback>



2022 Edition

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