The 16th Annual PQSynergy International Conference and Exhibition
30-31 May, 2016, Bangkok, Thailand

Advanced Power Quality Monitoring System in Hong Kong

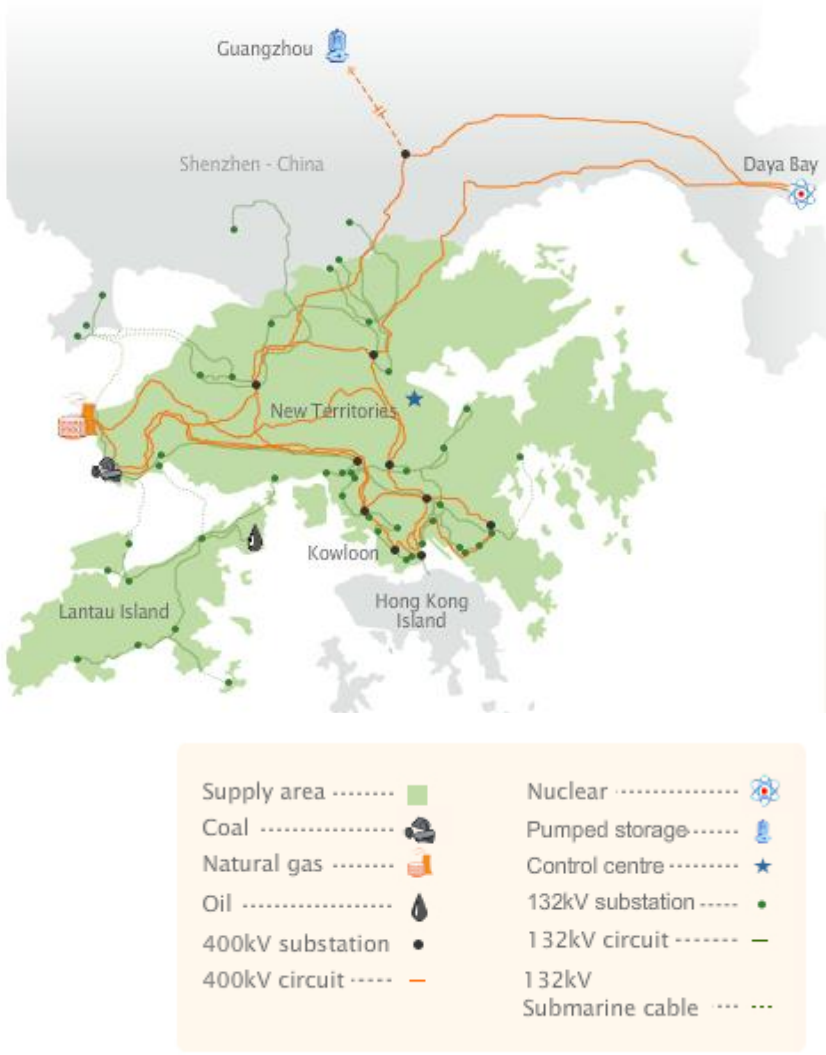
Ir. Y.Y. LEE (MHKIE, MIET) email: yanlee@clp.com.hk
Nick K.W. CHAN email: kw.chan@clp.com.hk

燃點生活力量
Energy for Life

CLP 中電

About CLP Power

- Established in 1901
- The largest vertically-integrated electricity generation, transmission and distribution company in Hong Kong
- No. of Customer Accounts: 2.48 M
- Population served: 6.0 M
- Total Generation Capacity: 8,888 MW
- Transmission and Distribution System
  - Over 14,900 km of transmission and high voltage distribution lines
  - 226 Primary Substations in operation
  - 14,019 Secondary Substations in operation
  - Average unplanned CML per year 1.51 mins
  - Electricity supply reliability > 99.999%



Figures as at March 2016

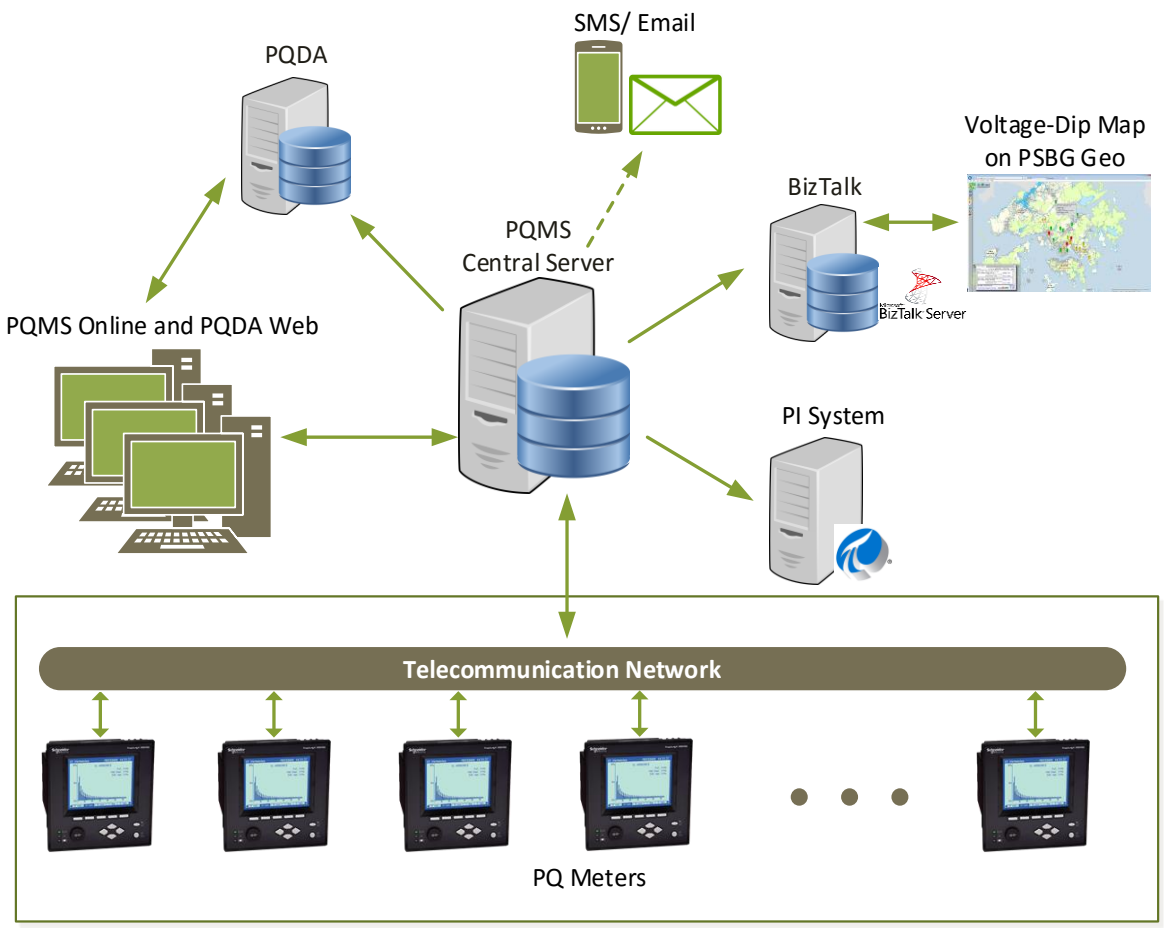
燃點生活力量
Energy for Life

CLP 中電

PQMS System Objectives

- **To develop a System-Wide PQ monitoring system on 400kV, 132kV and 11kV of power network**
  - Track real-time conditions, analyze power quality, and respond quickly to critical alarms
  - Facilitate effective PQ Benchmarking
  - Provide notification for power quality events
- **To capture the current and voltage transients under system disturbance by PQ meters installed at Substations**
  - Determine the nature of a system disturbance
  - Make correct decision in fault diagnosis

PQMS System Architecture



- PQMS started as pilot project in 2001
- Major system upgrade in 2015:
  - PQMS central server migrated to Virtual Machine
  - No. PQ meters extended to 462
- External Systems (e.g. PQDA, BizTalk etc) connected to PQMS for data analysis, data archive and information dissemination
- Network-based communication infrastructure
- Proprietary protocol for communication

燃點生活力量
Energy for Life

CLP 中電

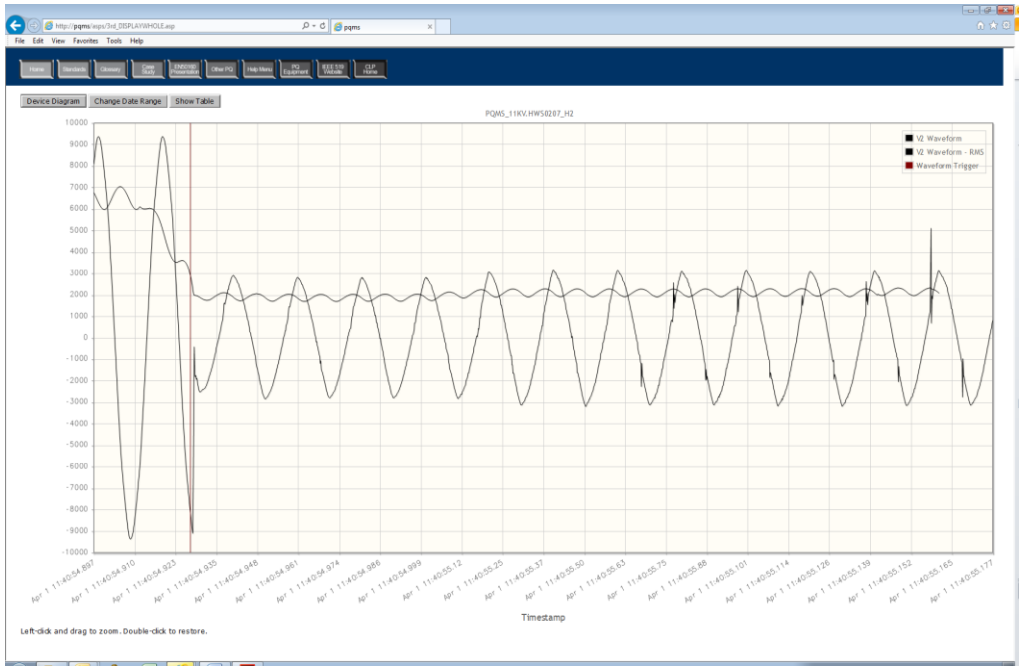
PQ Measurement Details

- **Parameter Measured**
  - Basic power data
    - V, I, frequency
    - kW, kVAr, power factor
  - Power quality data
    - Voltage dip, Swell, Transient
    - Harmonics (voltage and current)
    - Voltage Imbalance, Voltage Flicker
  - Time interval for data monitoring: 10 mins (except frequency in 10 secs interval)

- **Monitoring Standards**
  - EN50160 – Voltage Characteristics of Electricity Supplied by Public Electricity Networks
  - IEEE 519 – IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
  - IEC 61000-4-30 – Testing and measurement techniques - Power quality measurement methods

Waveform Captures

- Voltage and current waveforms for transients, dips and swells are recorded by PQ meters
- Sampling rate: 128-sample per cycle, 14 cycles for capture (2 cycles pre-trigger and 12 cycles post-trigger)
- Users are able to view and zoom in/out the waveforms through PQMS Online (Web)



System Components

➢ Central Server

- Collect data from each PQ meter every 10 minutes (polling)
- Receive data from PQ meters when system disturbances occur (unsolicited)
- Generate reports of voltage dip incident from the data reported by PQ meters
- Enhance the PQMS reliability and availability to migrate to virtual machine server in data centre

➢ PQ Meters

- 4 x voltage inputs, 5 x current inputs
- THD measurement up to 40th order
- Logs ~340 x parameters of PQ data in each meter
- Power quality measuring points:

400kV EHV S/S	132kV Bulk Infeed S/S	132/11kV Primary S/S	11k/380V Distribution S/S
OHL transmission feeder	Transmission feeder, 132kV EH Tx	Distribution line supply	LV Supply

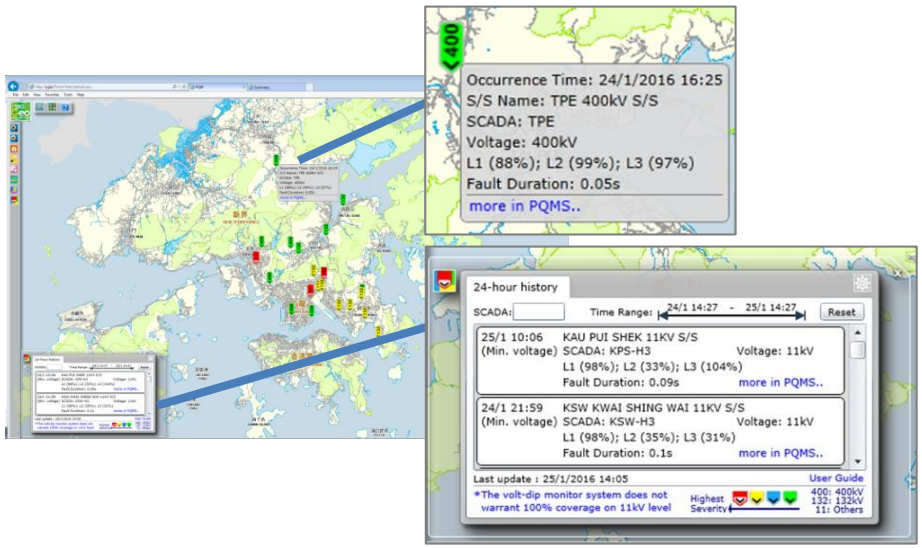
燃點生活力量
Energy for Life

CLP 中電

System Components (Cont'd)

- **Networking equipment**
  - Company-owned telecommunication infrastructure (e.g. Fibres, Microwave, MUX, pilot wires etc)
  - Almost all PQ meters using Ethernet for communication

- **PQ Cloud**
  - Detect voltage dip events from PQ meters and then generate XML file to BizTalk Server
  - Allow other systems (e.g. GIS portal) to subscribe the XML file from BizTalk
  - Able to visualize voltage dip incident locations, voltage level and remaining voltage % and duration on map



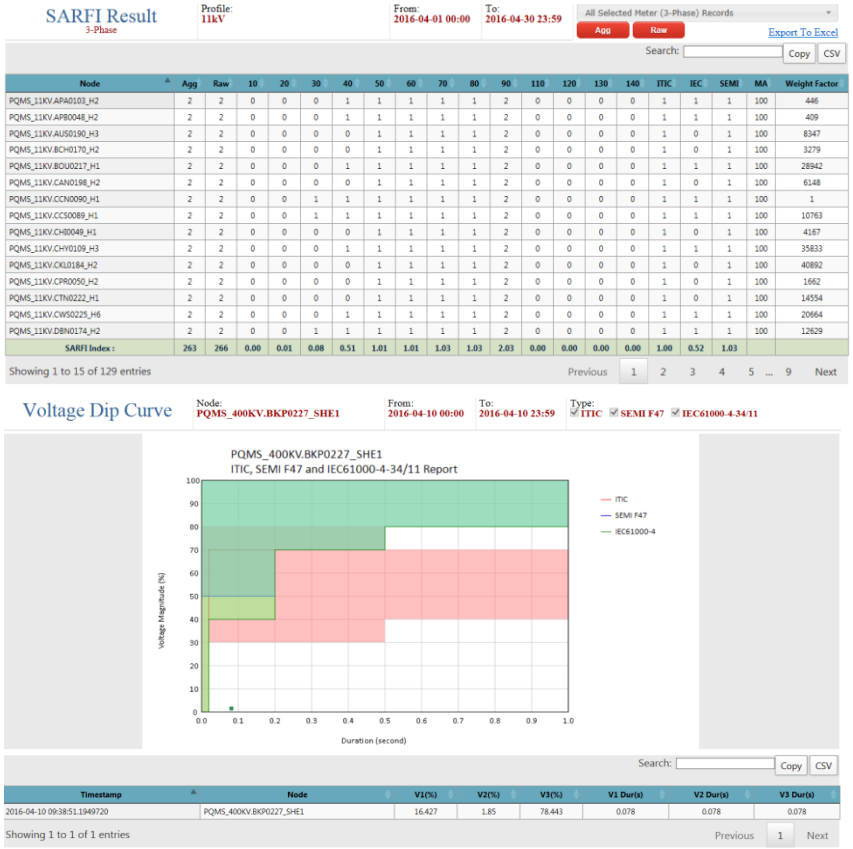
燃點生活力量
Energy for Life

System Components (Cont'd)

➢ Power Quality Data Analyzer (PQDA) Web

- Developed for comprehensive PQ analysis and benchmarking
- Data archive for 5 years

Module	PQDA Functions
Waveform	Display the waveform of an voltage dip event
SARFI	Calculate the SARFI index in according to list of PQ meters and the period specified by users
Zoning	Display the zoning map for voltage dip events, which the zone can be classified by districts and the customer types
Voltage Dip Curve	Display the voltage dip event against the curves of international standard (e.g. ITIC, SEMI F47 and IEC61000-4-34/11) for compliance check
Harmonics	Display the voltage and current harmonics of PQ meters in a graph and tabular format

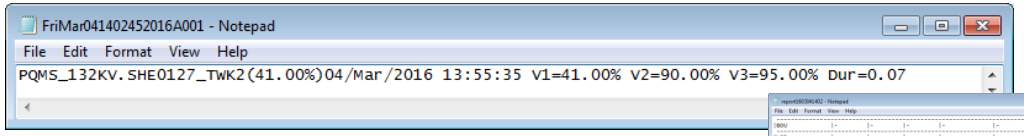


燃點生活力量
Energy for Life

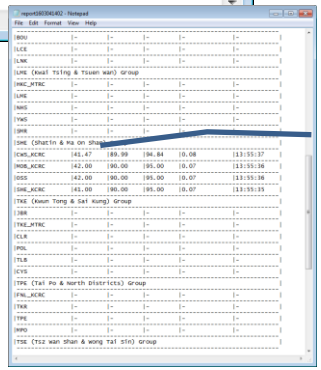
CLP 中電

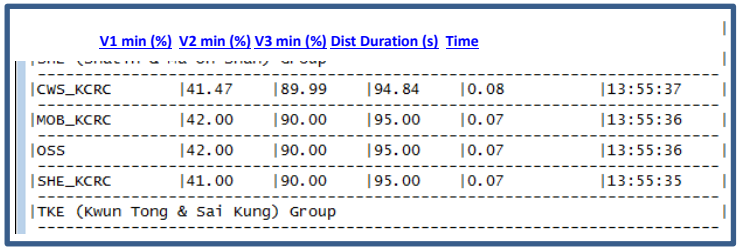
System Functions

- **Data aggregation for voltage dip incident**
  - Aggregate all voltage dip events (PQ events) recorded at all voltage levels occur within 1 min as one voltage dip/ swell event
  - For PQ events in 132 and 400kV, PQMS waits for 5 mins to receive data from PQ meters before data aggregation
- **Real-time voltage dip notification**
  - Customized program in PQMS to generate:
    1. Voltage-dip notification message in email and SMS
    2. Voltage-dip table for 132 or 400kV voltage dip incident after data consolidation



Voltage-dip Notification Message





	V1 min (%)	V2 min (%)	V3 min (%)	Dist Duration (s)	Time
CWS_KCRC	41.47	89.99	94.84	0.08	13:55:37
MOB_KCRC	42.00	90.00	95.00	0.07	13:55:36
OSS	42.00	90.00	95.00	0.07	13:55:36
SHE_KCRC	41.00	90.00	95.00	0.07	13:55:35
TKE (Kwun Tong & Sai Kung) Group					

Voltage-dip Table

燃點生活力量
Energy for Life

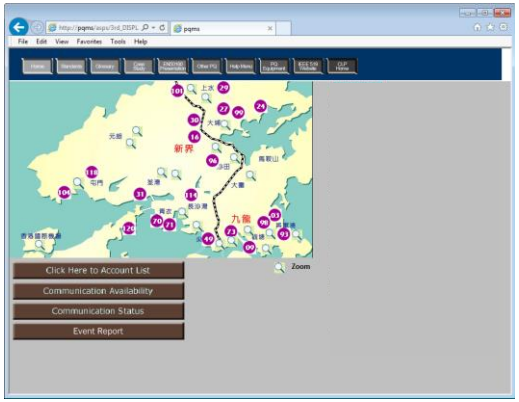
CLP 中電

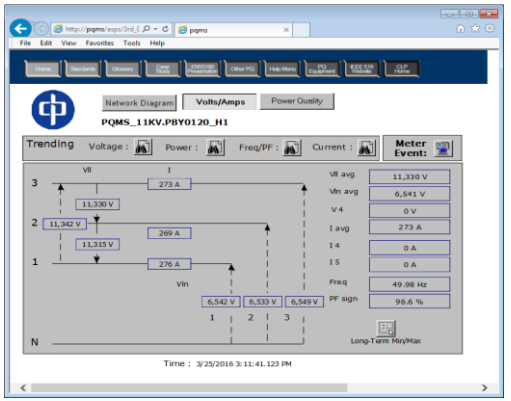
System Functions (Cont'd)

➢ PQMS Online – Web Interface

- Allow users to retrieve PQ data and waveforms from all PQ meters easily
- No software download required for utilizing the features of PQMS online
- Facilitate the communication diagnostics
- Role-based access control

PQMS Online Pages	Description
Account List	• Link the sensitive customer accounts to the corresponding PQ meters installed in the power circuit. • Users can access the user diagrams of the PQ meters to view real-time and logged data (e.g. V, I, THD, f, PF etc) and voltage dip/ transient waveform via the page
Communication Availability	• Real-time monitor communication status between PQMS and PQ meters • Consist of "Data Availability", "Communication Availability" and "Data Log"
Communication Status	• Display the communication information of PQ meters (e.g. PQ meter site ID, meter name, timestamp of last communication with PQMS, IP address and the device enable/ disable status)
Event Report	• Display the sag/swell event report details (e.g. PQ meter ID, timestamp of event, duration, min. and max. voltage magnitude (3-phase), nominal voltage and circuit information) for a selected voltage level or PQ meter in a selected time-frame.





燃點生活力量
Energy for Life

CLP 中電

System Diagnostics

- Ensure system running normal and allow timely follow-up when the system has defects
- Continuously and automatically monitor system healthiness
- System check messages generated to notify system admin every day

No.	Types of Check Message	Description
1	132/400KV Health Check (every 30 minutes)	• If the program detects more than 5 Inactive meters in 132 or 400kV level, it will send out Email/SMS alert • A notification email/ SMS is also sent out everyday when all PQ meters' communication are active
2	Communication Status (daily)	• The program will check the latest recorded time of all PQ meters. If the scheduled time checking and the latest recorded time has a 15 minute difference, the PQ meter is considered as Inactive • A notification email/SMS is also sent out everyday when all PQ meters' communication are active
3	Power up Down Alert (daily)	• Check all PQ meters with power up-down counts of 20 or more in a day from 00:00 to 23:59
4	VoltDip Alert (daily)	• Check all PQ meters with sag/swell count of 20 or more in a day from 00:00 to 23:59
5	Zero Voltage Alert (10:00 am)	• Check all PQ meters with zero voltage log for one or more than a week
6	Program Alert (every 30 minutes)	• Check the PQMS programs (e.g. PQCloud + VoltDip, File Distribution System and SMS Email Program) are running or not

Benefits of PQMS

- **High availability**
  - Efficient system recovery when VM hardware fails
  - Flexible to expand the system for increasing PQ meters and PQ data
- **Wider system coverage for power quality monitoring**
  - Additional 200 x PQ meters installed in 2014-2015, covering almost all 132/11kV Primary S/S
  - Provide accurate information for power quality incident investigation
- **System benchmarking and compliance validation**
  - Monitor power network characteristics and disturbances throughout the network
  - Facilitate SARFI benchmarking
  - Enhance compliance validation by using the comprehensive PQ data
- **Predictive power system diagnostics**
  - Enable development of performance baseline to evaluate the healthiness of electrical equipment over time
  - Assist to formulate preventive maintenance programs

Future Challenges of PQMS

- **Open platform for PQMS**
  - Single vendor Vs Multi-vendor Approach
  - Proprietary Vs Open Protocol
  - PQMS to integrate PQ data for multi-vendor devices
- **Growing penetration of alternative sources of energy**
  - Increasing penetration rate of EV charging stations and distributed renewable energy cause different PQ issues
  - Continuous PQ monitoring may be required close to PCC to identify the cause of power system disturbances
- **Integrate power quality data from the smart meters/ IEDs**
  - Lots of smart meters/ IEDs embedded with PQ functions
  - "Big data" issue when integrates the data from smart meters/ IEDs in PQMS

Conclusion

- Reliable system hardware of PQMS is critical for power system operations
- Paradigm shift in the use of PQMS from a traditional post-fault analysis to a fully automated intelligent monitoring for fault prevention
- Growing needs of PQ monitoring for new energy resources and PQ functions integration in IEDs create opportunities and challenges of PQMS

Reference

[1] Tommy CW Li, Paul Doig, Simon Ki, CONSIDERATIONS AND REQUIREMENTS FOR AN INTEGRATED POWER QUALITY MONITORING SYSTEM

[2] The Benefits and Challenges of Virtual Machine Hosting

Thank You

Q&A

Acknowledgement

The authors wish to thank the Management of CLP Power for the support and permission to publish this paper.

燃點生活力量
Energy for Life

CLP 中 中電