Centralized Protection & Control
Enhancing reliability, availability, flexibility & improving operation efficiency
Presenter: Joe Xavier, Global Product Manager ANSI, Digital Substation Products & Systems
Centralized Protection & Control for Distribution Substations

Content

• Introduction
• Traditional microprocessor relay architecture
• Centralized Protection & Control (CPC) architecture
• Comparison of CPC with traditional P&C approach
• Application examples
• Lessons learned from field installation
• Conclusion
• Questions & Responses
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Evolution of protective relay technology

The first relays began to appear in the early 1900s… and have evolved to advanced IEDs of today.
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Evolution of P&C communication architecture

Modbus / DNP architecture

Proprietary architecture: peer-to-peer communication
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P&C architecture using native IEC 61850 GOOSE communication

**Fast bus protection scheme**

Utilizes advanced intelligent microprocessor relays with native IEC 61850
GOOSE publishing and subscribing set up within the relays
P&C logics built with in the relay itself
Direct fiber port on the device
Relays networked using a managed Ethernet switch
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IEC 61850 architecture – Station bus (8-1) and Process bus (9-2)

**MMS, GOOSE & Sampled Values**

- MMS for vertical communication
- GOOSE for horizontal (peer-to-peer) communication
- Sampled Values (SV) for process bus communication
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CPC System components

**System concept & components**

Based on IEC 61850 global standard for power system applications

Move protection and control from multiple feeder level devices to **single central processing unit**

**Merging units (MU)** acts as interface between CT/VT and CPC device

Option of using **Intelligent merging unit (IMU)** – protective relay capable of performing MU functionality

Substation **time synchronization** according to IEEE 1588 PTP and IEC 61850-9-3 - 1 μs accuracy

**Redundant communication** as per IEC 62439-3 - PRP, HSR
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System design considerations

Cybersecurity

Follow international standards and guidelines for cybersecurity
- IEEE 1686, IEC 62351, NERC-CIP
- Role based access control
- Secured communication protocols
- Audit trails
- Signed software packages
- Remote asset management capability
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How does it compare with traditional P&C system approach?

**Traditional approach vs. CPC approach**

- Relay selection
- System engineering
- Redundancy & reliability
- Testing
- Operation
- Maintenance
- Safety
## Centralized Protection & Control for Distribution Substations
How does it compare with traditional P&C system approach?

### Traditional approach

**Relay selection**
- One or more relay per feeder based on application
- Example – Transformer, feeder, bus, etc.
- Wrong order code selection has significant cost and time impact on project cost and execution time
- Spares maintained for each relay type

**System engineering**
- Each protection relay is configured individually for protection elements, settings, GOOSE messaging and interlocking schemes
- Alarms, events and DRs are distributed
- Reconfiguration of protection and control requires extensive re-engineering effort

### CPC approach

**Relay selection**
- Eliminates the need of one relay per feeder per application
- All feeders have same type of merging units
- Protection functions no longer dependent on the hardware
- Only two types of hardware for the entire substation – CPC unit & the MU

**System engineering**
- All protection elements, settings and control for the whole substation at a single point - about 30% reduction in engineering time
- Centralized alarms, events and disturbance recording facility
- Reconfiguration of protection and control easily performed to adapt to changing substation / grid requirements
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Redundancy and reliability

Redundant system #1
Redundant CPC units – eliminates loss of protection
One MU per feeder
Recommended for users with single multifunctional relay per feeder

Redundant system #2
Single CPC unit, Single **Intelligent Merging Unit (IMU)** per feeder
IMU provides local protection in the event of communication downtime - Ideal solution where: protection redundancy is desired
Communication redundancy (not shown for simplicity's sake)
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Redundancy and reliability

**Redundant system #3**
Redundant CPC units, MU
Avoids single point of failure at CPC and MU levels

*Doubling the MU reduces CPC protection capacity to half*

**Redundant system #4**
Redundant CPC units, MU, back-up IMU
No circuit will go unprotected
Highest level of reliability, highest cost

*Doubling the MU reduces CPC protection capacity to half*

**Redundant system #5**
Single CPC unit, one MU, one IMU
Avoids single point of failure at CPC, MU, IMU

*Doubling the MU reduces CPC protection capability to half*
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Testing (1/2)

Traditional P&C test set up

CPC test set up
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Testing (2/2)

CPC test set up

CPC unit receive Sampled Values from MU / IMU
CB - 52a, 52b contacts, CB - trip and close signals from CPC to MU as GOOSE signals
All P&C interlocks are created within the CPC unit
CPC is put in the test and simulation mode
Secondary injection test set with GOOSE and SV simulation capability is connected to the network switch
Test set injects the operating quantities in the simulation mode for each feeder, one at a time.
In the simulation mode CPC ignores the real MU values
All the feeder can be tested without changing the test set up – tremendous time savings!
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Operation and maintenance

CPC benefits (1/2)

– All settings, configurations and applications at CPC unit
– Sequence of events, fault records, disturbance fault records available at CPC unit with accurate time synchronization
  • Drastically reduces time in fault identification and fault analysis
– Firmware upgrade, if necessary, is performed at the CPC unit
  • Tremendous savings in time and effort with firmware upgrades and associated testing of multiple devices in traditional approach
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Operation and maintenance

CPC benefits (2/2)

- Dynamically allocate applications to meet evolving substation protection & control needs like:
  - Addition of a feeder
  - Addition of protection functions
  - Conversion of a feeder bay to transformer bay
- CPC can unit double up as substation HMI
- Minimize spare requirement – CPC and MU are the main components
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Safety

Possibilities to enhance safety

- Testing the CPC involves digital signals only (need not deal with CTs and PTs directly)
- Remote control of breakers from CPC
- Possible to use current and voltage sensors in place of traditional CT/PT
- Possibility to integrate Arc Flash Detection in the CPC
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Application examples

**CPC - Common applications**

Any protection application which require input from multiple feeders:

- Substation wide protection
- Bus bar differential protection
- High impedance ground fault detection
- Load shedding, Islanding and Loss of mains protection
- P&C interlocking applications
- Self healing control applications
- Substation wide disturbance recording
- Adaptive protection for DER applications

Advanced condition monitoring and asset management requirements
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Application examples

**CPC applications**

**Greenfield projects**
- MU installed in the yard, CPC & Network switch in the control house

**Brown field (retrofit / upgrade) projects**
- Existing CT/PT wiring from the yard to the control house
- MU, CPC, Network switch installed in the control house

**MV switchgear application**
- CPC, MU, Network switch installed in the LV cabinet of switchgear or standalone rack beside the switchgear
- If existing relays have MU capability, only CPC unit and Network switch needs to be added

**Building digital substations**
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Lessons learned from field installation

**Utility – 110/20kV substation in Finland (1/2)**

Noormarkku - 13 feeder substation
Relays with conventional OC + EF (distribution feeders, cables/lines) upgraded with MU functionality (IMU)
Needed special ground protection due to weatherproofing and UG cabling – added in CPC unit
All bay level protection functionality for all feeders added in the CPC
Time synch. as per IEEE 1588 PTP (in addition to SNTP)
Based on IEC 61850 Ed2, tripping as per GOOSE type 1A, Class P1 (<=3 ms)
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Lessons learned from field installation

Utility substation in Finland (2/2)

Initially CPC unit in non-trip mode (parallel detection of faults & tripping event generation)

Subsequently taken fully into service (CPC as main protection, IMU units as backup protection); in operation since May 2017

Testing and commissioning done on live substation without interruptions

System is in successful operation for over 3 years

CPC detected 99 overcurrent faults and 69 ground faults during this period
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Conclusion

**CPC system offers unmatched flexibility …**

- Takes full advantage of *proven IEC 61850 standard*
- Redundant protection, redundant communication architecture *enhances reliability and availability of protection*
- Provides *flexibility to build optimal protection schemes and freedom to adapt to changing network* requirements
- Improves *P&C engineering efficiency*
- Drastically improves *operation and maintenance efficiency*:
  - substation wide measurements, events, DFRs available at CPC
  - minimizes spare requirement
  - firmware upgrades, if required, performed at CPC unit and not on multiple relays

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* … in substation protection & control*

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*CPC enhances reliability, availability, flexibility and improves operating cost efficiency of Substations*
Thanks for your attention!

QUESTIONS?