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CHUBU Electric Power Grid

Study Committee B5

Protection and Automation

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Verification of a New Protection Relay System based on High Reliable Process Bus with Oversampling

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1.Introduction

New oversampling process bus system which excludes any active communication devices and time synchronisation functions in order to improve the system reliability is being developed. This process bus system has two important technical points.

A) The use of over-sampling technology.

B) To replace the intelligent multiport network bridges, e.g. L2 switch, with an optical splitter device.

2. POINTS OF ISSUE

A) Realise a new oversampling process bus based on asynchronous AC sampling scheme that would be free from the time management system reliability degradations.

B) Applied technics, functions or principles are simple. This requirements would improve the reliability and cost of the communication devices, IEDs and MUs,

C) Conventional IEC 61850 series harmonised engineering, maintenance and interoperability should be assured.

D) Transmission line current differential relays do not require time synchronisation between substations as conventional.

3. SOLUTIONS

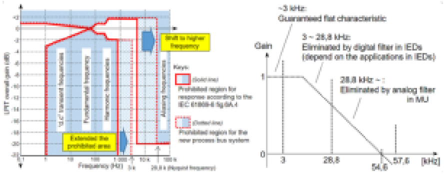
3-1. Oversampling Technology

3-1-1. Oversampling rate

- As an actual and reasonable sampling frequency, 57,6 kHz was selected.
- The 57,6 kHz is integral multiple of the prevailing rates, 4,8 kHz and 5,76 kHz.
- The 17,4 μs (= 1 / 57,6 kHz) is corresponded to 0,3125 ~ 0,375 degree electrical angle at the 50/60 Hz system. These electrical angle error values would be acceptable in most PAC systems.

3-1-2. Analog input characteristics as a LPIT

- Input signal over the Nyquist frequency component shall be sufficiently attenuated.
- Input signal less than 3 kHz (50th harmonic) frequency area would be required to keep flat and non-attenuation. Characteristic between 3 kHz and Nyquist frequency would be determined for applications and processed by digital filter based on 57,6 kHz SV data in each IED.



a) Comparison of the overall characteristics
Note: Characteristic (Solid line) over 10 kHz is not shown in IEC 61869-6 Figure 6A.4.

b) Specification of analog filter for the 57,6 kHz system (See Bibl.[3])

Figure 2. Frequency characteristics in analog input port

3-1-3. Compatibility with existing systems and technics

- IEDs which subscribed 57,6 kHz SV data would execute conventional protection and control application algorithms based on sampling data in every 3,75 or 4,5 degree electrical angle periods with SV data extraction (Figure 3).

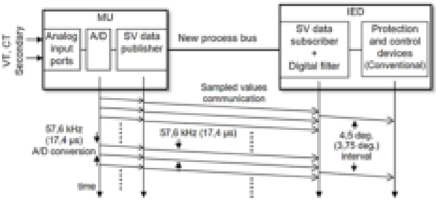


Figure 3. Sampled data flow on new process bus base on oversampling technology

Study Committee B5

Protection and Automation

10614_2022

Verification of a New Protection Relay System based on High Reliable Process Bus with Oversampling

continued

3-2. Passive communication device network

3-2-1. A problem of to use active communication devices

- Communication delay time fluctuation so called "Jitter" might decrease the merits of oversampling, and this fluctuation should be mitigated.
- Active communication devices, e.g. L2-switch, are not so reliable, because they most likely contain DC power supply and digital signal processing circuit.

3-2-2. Optical splitter as a passive communication distributer

As a solution of the jitter problem, authors applied an optical-splitter, a kind of optical fibre divider using optical grass material. The features of this device are as below;

A) SV data communication channels between MUs and IEDs are built with optical fibres and optical splitters only.

B) Because of a splitter does not contain DC power supply or electronic circuit, the splitter has good reliability, environment resistance and lifetime.

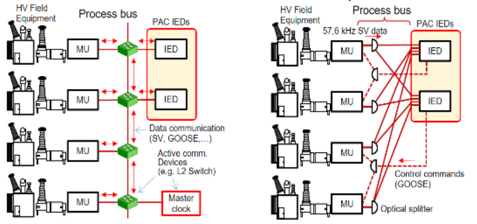
C) Connection strategy between each MU and IED is recognized as a peer to peer connection in physically and logically.

The below factors would be considered or cleared;

A) The one-to-n ports type splitter will reduce input optical signal power to 1/n times for outputs.

B) These features, peer to peer configuration and four ports split, the communication cable assignment might be more complicated than the active devices based (Figure 5).

C) Each IED that connects to some MUs shall have the same number of communication ports.



(a) Example of cable connection based on conventional process bus system

(b) Example of cable connection based on the optical splitter application

Figure 5. Comparison of the process bus physical connection

4. VERIFICATION TEST

To verify the performance of the oversampling process bus based protection system, authors demonstrated by two MUs plus three IEDs configuration with splitters shown in Figure 6.

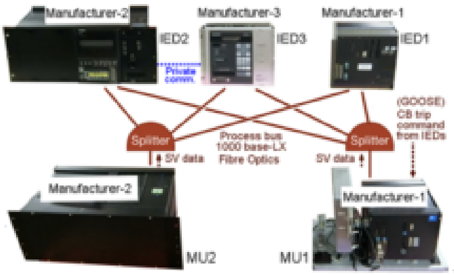


Figure 6. Multi vendor's MUs and IEDs configuration under verification test

4-1. Target protection systems and test items

- Test configuration is shown in Figure 7 and 8.

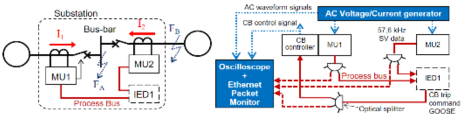


Figure 7. Test configuration for bus-bar protection system in substation

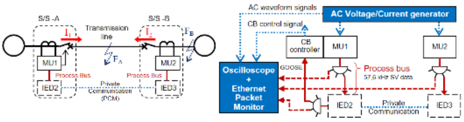


Figure 8. Test configuration for transmission line protection on inter-substation

Main test items are as below;

A) Effects of asynchronous error between MUs.

B) Performance test for the current differential protection relay.

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Study Committee B5

Protection and Automation

10614_2022

Verification of a New Protection Relay System based on High Reliable Process Bus with Oversampling

continued

4-2. Test results

Test results are shown in Figure 9, Table Ⅱ and Table Ⅲ.

4-2-1. Differential current characteristics depending on asynchronous error

Figure 9 introduces a measured data of the instantaneous SV data (IED received) and differential current value in case of 5 A r.m.s. penetration current input.

- Each SV instantaneous current (“MU1-I” and “MU2-I”) shows same waveform, and maximum differential current (sine wave form component) was up to +/-0,2% per input.
- The differential current “diff-I (Waveform)” also contained 0,1% offset value error

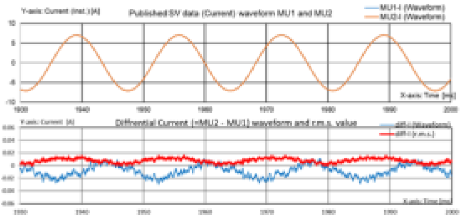


Figure 9. Example of SV data waveform and instantaneous differential current

4-2-2. Characteristics of differential protection relay

- Table Ⅱ and Ⅲ are the performance test results for current differential protection relay using oversampling process bus system.
- Two vendor’s MUs and three vendor’s IEDs were used in this test shown in Figure 6.
- Test configurations are in Figure 7 and 8. Each criterion in Table Ⅱ and Ⅲ are for conventional system.
- Test results provide us the equality of performances between differential protection relay on oversampling process bus system and conventional relay system.

Table Ⅱ. Results of the bus-bar protection performance test (current differential relay)

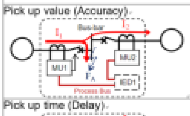
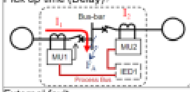
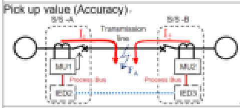
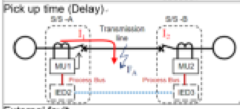
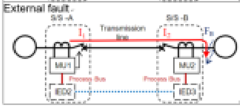
Item	Test condition	Criterion	Result (P/F)
Pick up value (Accuracy) 	Fault point: F_A Settings: Tap:20%, Ratio: 45% I1: 40% (fixed) Operating value(theoretical): I2: 20% (100% = 5 A @CT 2[nd] base)	I2: Less than +/- 5% of theoretical	Pass
Pick up time (Delay) 	Fault point: F_A Settings: Tap: 20%, Ratio 45% I1: 60% (Tap setting x 300%) + Transient DC current I2: 0%	Time: Less than 16,5 ms @ Fault phase angle = 90 deg.	Pass
External fault 	Fault point: F_B Settings: Tap: 20%, Ratio: 45% I1: 60% (Tap setting x 300%) I2: 60%	Operation: No operation	Pass

Table Ⅲ. Results of the line protection performance test (current differential relay)

Item	Test condition	Criterion	Result (P/F)
Pick up value (Accuracy) 	Fault point: F_A Settings: Tap: 10% I1: 20% (fixed) Operating value(theoretical): I2: 6,66% (100% = 5 A @CT 2[nd] base)	I2: Less than +/- 5% of theoretical	Pass
Pick up time (Delay) 	Fault point: F_A Settings: Tap: 10% I1: 30% (Tap setting x 300%) + Transient DC current I2: 0%	Time: Less than 16,5 ms @ Fault phase angle = 90 deg.	Pass
External fault 	Fault point: F_B Settings: Tap: 1,0A I1: 60% (Tap setting x 300%) I2: 60%	Operation: No operation	Pass

Conclusion

- The protection system using oversampling process bus system has a good availability as a fault detection and protection system, and its performance is equal to the conventional system.
- This oversampling process bus system does not need any sampling timing synchronisation, which allows protection functions of the substation or inter-substation to be sustained despite of the time synchronisation or master clock fault, and the system has a potential as a highly robustness and resiliency system.