

GENERIC SUBSTATION EVENT MONITORING BASED ON IEC 61850 AND IEEE 1588 STANDARDS

by

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KEYWORDS

Substation events, electromechanical protection device, IED, IEC 61850, IEEE 1588, Ethernet, GOOSE, sampled values, synchrophasor, PTP, electric utility, substation automation, decentralised state estimation, topology processing Hall Effect, electronics, embedded systems, Linux, kernel, device driver

ABSTRACT

Electricity has become not only an essential element to people's everyday life but also the most important power source to most industries and businesses. The continuously increasing demand of electricity consumption has resulted in a consistent expansion of power grid as it was seen in the past few decades. This in turn has dramatically increased the cost of electricity during the same period in Australia. In contrast, the recently recorded low economic activities and significant growth of rooftop photovoltaic has led to a reduction in the forecasted electricity demand in Australia. This has resulted a reduced number of network augmentation projects for most electric utilities across the country. Instead, the substation refurbishment work has become the focus for most electric utilities in the foreseeable future. Such sharp turning point of trend has placed an enormous challenge in front of electric utilities on how to make the power system operation more cost effective and preserve a high level of reliability and security. In response to the challenge, the integration of advanced technologies with the existing power system has been recognised as a viable solution. The international standard IEC 61850 for substation communication system has gained momentum globally to be implemented in power utility automation systems. The flexibility and vendor independent feature of the standard inspired a range of innovative approaches for power grid projects including substation refurbishment work.

This research aims to develop and verify a vendor independent device, which is named as substation event monitor, with the capability of interfacing the legacy and existing substation automation system equipment to the modern intelligent electronic devices (IEDs) over Ethernet network in a non-intrusive and cost effective manner. The substation event monitor is also equipped with the ability of providing synchronised time information at the accuracy level of ± 1 microsecond over the same communication infrastructure via IEEE 1588 standard, also called the Precision Time Protocol (PTP). The created device is suitable for substation refurbishment work and has the potential in many other utility applications, such as network state estimation and substation commissioning. This thesis takes a bottom-up approach to the form of information on the construction and verification of substation event monitor. It begins with the provision of the critical review on the detailed knowledge of both international standards of IEC 61850 and IEEE 1588. This work was needed because there is lack of concise, publicly available and informative material on these complex standards for power utility engineers. The thesis is then expanded with the in-depth design information on the developed prototype of substation event monitor. Finally, the verification results of the prototype device were produced at both component level and system level in this thesis. The provision of the comprehensive knowledge of the prototype device will

deliver confidence to utility engineers in considering the adoption of substation event monitor as a low cost, non-intrusive, IEC 61850 compatible and synchronised IED that meets the needs of substation refurbishment work and other potential power utility applications.

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LIST OF ABBREVIATIONS

1PPS	One Pulse Per Second
9-2LE	UCA User Group Implementation Guidelines for IEC 61850-9-2 Standard
AC	Alternating Current
ACSI	Abstract Communication Service Interface
AEMO	Australian Energy Market Operator
ASN.1	Abstract Syntax Notation One
BER	Binary Encoding Rules
BMC	Best Master Clock algorithm
CID	Configured IED Description
CDC	Common Data Class
CFI	Canonical Format Identifier
CT	Current Transformer
DA	Data Attribute
DC	Direct Current
DO	Data Object
DPC	Controllable Double Point
DS	Data Set
E2E	End-to-End
EPRI	Electric Power Research Institute
FAT	Factory Acceptance Testing
FC	Functional Constraint
FCD	Functional Constraint Data
FCDA	Functional Constraint Data Attribute
GGIO	Generic Process I/O
GMR	Giant Magneto-Resistive
GOOSE	Generic Object Oriented Substation Event
GPIO	General Purpose I/O
GPS	Global Positioning System

GSE	Generic Substation Event
HMI	Human Machine Interface
HSR	High availability Seamless Ring (IEC 62439-3 Standard)
HVDC	High Voltage Direct Current
ICD	IED Capability Description
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronic Engineers
IID	Instantiated IED Description
IP	Internet Protocol
IRIG-B	Inter Range Instrumentation Group Code B
ISO	International Standard Organisation
LD	Logical Device
LED	Light Emitting Diode
LLN0	Logical Node Zero
LN	Logical Node
LNPD	Logical Node Physical Device
MI	Magneto Impedance
MMS	Manufacturing Message Specification
MTTF	Mean Time To Failure
NCIT	Non-Conventional Instrument Transformer
NEM	National Electricity Market (Australia)
NIST	National Institute for Standards and Technology
NTP	Network Time Protocol (RFC 5905)
OSI	Open System Interconnection
P2P	Peer-to-Peer
PDU	Protocol Data Unit
PRP	Parallel Redundancy Protocol (IEC 62439-3 Standard)
PSRC	Power System Relaying Committee (IEEE Power and Energy Society)

PTP	Precision Time Protocol (IEEE 1588 Standard)
QoS	Quality of Service
SAS	Substation Automation System
SAT	Site Acceptance Testing
SCD	Substation Configuration Description
SCL	Substation Configuration Language
SCSM	Specific Communication Service Mapping
SED	System Exchange Description
SEM	Substation Event Monitor
SLD	Single Line Diagram
SSD	Substation Specification Description
SV	Sampled Values
TLV	Tag, Length, Value
TPID	Tag Protocol Identifier
UCA2.0	Utility Communication Architecture version 2.0
UDP	User Datagram Protocol
UTC	Coordinated Universal Time
VLAN	Virtual Local Area Network (IEEE 802.1Q Standard)
VT	Voltage Transformer
XCBR	Circuit Breaker Logical Node
XML	eXtensible Markup Language
WLS	Weighted Least Square
WG	Working Group

LIST OF PUBLICATIONS

Liu, Y., Zivanovic, R. and Al-Sarawi, S., 2014. Industrial Case Study of an IEC 61850 Standard Compatible and Synchronised Tripping Circuit Monitor for Electric Substations. *Symposium of Specialists in Electric Operational and Expansion Planning*, 18-21 May.

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