

IEC 61850 MMS SCADA Network Optimization for IEDs

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Abstract—Supervisory control and data acquisition (SCADA) data flow optimization within networks of intelligent electronic devices (IEDs) communicating via the IEC 61850 Manufacturing Message Specification (MMS) protocol is critical to guarantee fast data updates. Optimization of report messages (produced by IEDs using IEC 61850 MMS methods for use on the network) involves configuring dead bands for analog quantities, selecting appropriate trigger options, and eliminating unnecessary optional fields. The trigger options and optional fields are defined in the report definition, known as a report control block, for each required report.

This paper discusses a field-proven methodology to optimize the behavior of MMS messages within a SCADA network that contains IEC 61850-compliant devices. Using actual system commissioning experience, the paper describes an optimal method to minimize SCADA network traffic by taking advantage of the flexible reporting capabilities of IEC 61850. These methods ensure fast data updates to the communications gateway client while considering the unique requirements of the software application acting as an MMS client, known as a software protocol driver, in use on the communications gateway.

I. INTRODUCTION

The optimization of supervisory control and data acquisition (SCADA) networks containing IEC 61850-compliant devices is dependent on the behavior of the Manufacturing Message Specification (MMS) reports, determined by the report control block configurations for each report and the frequency that the analog intelligent electronic device (IED) data cause new report publications, determined by reporting dead bands.

The strategy discussed in this paper was used to minimize network traffic in a system installed to monitor and control the power system at a refinery. The result was significant improvement in data update performance at the client application level for a large refinery with five substations. In particular, the latency between data updates to the human-machine interface (HMI) in the larger substations was reduced from a 4- to 5-second average to a 2- to 3-second average. Additionally, updates to the remote terminal unit (RTU) client improved from a 3-second average to a 1-second average. This reduction enabled reduced latency of data processing and conversion to DNP3 messaging for communication 600 miles between two of the substations and the main distributed control system (DCS) control center.

II. COMMUNICATIONS DESIGN REQUIREMENTS

The communications design for this refinery required all relays to communicate IEC 61850 MMS protocol to the HMI and RTU clients. However, one type of relay was not

IEC 61850 compliant, so special mapping was needed to make that device “look” like an IEC 61850-compliant device. Fig. 1 shows the basic steps used to map the device that was not IEC 61850 compliant.

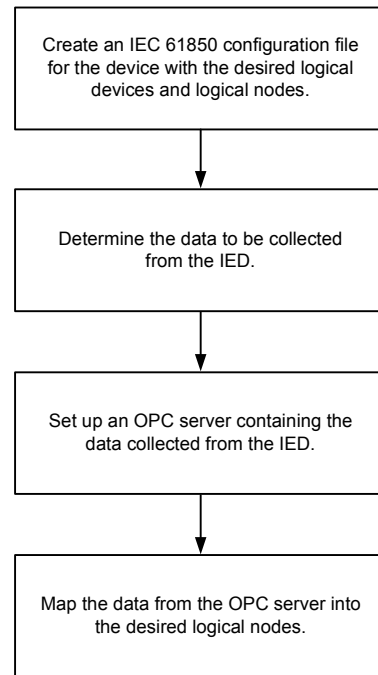


Fig. 1. Steps to map a device that is not IEC 61850 compliant

III. GENERAL NETWORK LAYOUT

In the refinery, two substations contained 67 IEC 61850-compliant devices and two devices that were not IEC 61850 compliant. The other three substations contained 34 IEC 61850-compliant devices and no noncompliant devices. In the two larger substations, there were at most three client applications active at a time. These applications included an HMI, which collected data via an IEC 61850 MMS driver, and two MMS-to-OPC clients. Both OPC clients were components of protocol conversion software, which, in turn, converted data from OPC to DNP3. DNP3 was then used to communicate data to the RTU from each IEC 61850-to-OPC server. The HMI resided on a server running Microsoft® Windows Server® 2007. The two OPC clients resided on industrial computing platforms, both running Microsoft Windows® XP. The communications network design included Ethernet switches to accommodate all IEDs, computing platforms, and two additional ports for engineering access. Fig. 2 shows the basic communications architecture.

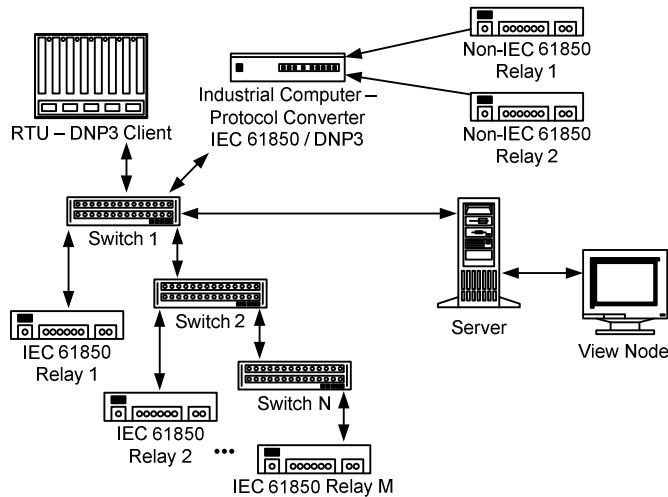


Fig. 2. Basic communications architecture

IV. IEC 61850 SCADA NETWORK OPTIMIZATION

Accelerating the data updates to the SCADA system MMS clients required properly configured communication. The communications parameters included dead bands for analog data object values, report trigger options within the report control block, and careful consideration of optional data object fields that could be chosen to accompany the values before they were included in the report. The following discussion addresses the IEC 61850 configuration file, configuration of the IEC 61850 MMS driver for the HMI, and the other IEC 61850 MMS driver for the OPC clients. All configuration modifications were made with the goal of network traffic minimization, while maintaining quick data flow to clients.

In the refinery, there were a total of nine different IEC 61850 MMS configuration template files, one for each of the nine different relay types. All data collected by the client applications used the IEC 61850 reporting model and took advantage of the unsolicited data update mechanism to trigger publication rather than traditional client-solicited polling mechanisms.

A. To Buffer or Not to Buffer?

IEC 61850 provides two different reporting models, buffered and unbuffered. Each system design requires a choice between these two models. This choice is highly dependent on the data type that will be included in the report. For example, when using analog quantities, dead bands are critical in minimizing network traffic, while, at the same time, determining the updates to the client for these points. If the dead band is too large, updates rarely occur, if at all. If the dead band is too small, updates occur more often than needed and increase the network traffic. Table I and Table II show the recommended dead bands for five different relay types in this refinery. Relay A provides current differential and voltage protection; Relay B provides protection, automation, and control; Relay C provides bus differential and breaker failure protection; Relay D provides motor protection; and Relay E provides feeder protection.

The choice between buffered and unbuffered reporting mechanisms is typically associated with the type of data to be

updated to the clients and the availability of those data following a possible loss of communication. The two primary classifications of data for this purpose are analog and digital. The analog data include measurement and metering data, while the digital data are single-point and double-point status information. Analog measurements are typically updated either by using appropriate dead bands to achieve data change updates and/or regular polling or integrity updates. Multiple change indication and detection between reports for analog data are generally not required, so unbuffered reporting is the mechanism chosen for analog data updates to the client applications.

The position indications of circuit breakers, disconnect switches, grounding switches, and other information about the connected state of the electric power system are represented as digital data. Because each change of these data is critical for understanding power system events, it is necessary to capture the change of state and multiple changes in a sequence, retrieve Sequential Events Recorder (SER) records, and buffer these data changes, along with associated time stamps. To satisfy this need, IEC 61850 buffered reporting is used.

TABLE I
FIELD-CHOSEN DEAD BANDS FOR TWO DIFFERENT RELAYS

Relay A Current Differential and Voltage Protection			Relay B Protection, Automation, and Control		
TotW	0.05	MWatts	TotW	0.05	MWatts
TotVAr	0.05	MVAr	TotVAr	0.05	MVAr
TotVA	0.05	MVA	TotVA	0.05	MVA
Hz	0.1	Hz	TotPF	0.05	none
PPV.phsAB	50	kV	TotEN	0.05	MWh
PPV.phsBC	50	kV	MaxVA	0.05	MVA
PPV.phsCA	50	kV	DemVA	0.05	MVA
PhV.phsA	50	kV	Hz	0.1	Hz
PhV.phsB	50	kV	PPV.phsAB	0.05	kV
PhV.phsC	50	kV	PPV.phsBC	0.05	kV
A1.phsA	1	A	PPV.phsCA	0.05	kV
A1.phsB	1	A	PhV.phsA	0.05	kV
A1.phsC	1	A	PhV.phsB	0.05	kV
A2.phsA	1	A	PhV.phsC	0.05	kV
A2.phsB	1	A	A1.phsA	1	A
A2.phsC	1	A	A1.phsB	1	A
A12.phsA	1	A	A1.phsC	1	A
A12.phsB	1	A	A2.phsA	1	A
A12.phsC	1	A	A2.phsB	1	A
A3.phsA	1	A	A2.phsC	1	A
A3.phsB	1	A	A3.phsA	1	A
A3.phsC	1	A	A3.phsB	1	A
			A3.phsC	1	A

TABLE II
FIELD-CHOSEN DEAD BANDS FOR THREE DIFFERENT RELAYS

Relay C Bus Differential and Breaker Failure Protection			Relay D Motor Protection			Relay E Feeder Protection		
Amp01	1	A	TotW	0.05	kWatts	TotW	0.05	kWatts
Amp02	1	A	TotVAr	0.05	kVAr	TotVAr	0.05	kVAr
Amp03	1	A	TotVA	0.05	kVA	TotVA	0.05	kVA
Amp04	1	A	TotPF	0.05	none	TotPF	0.05	none
Amp05	1	A	Hz	0.1	Hz	Hz	0.1	Hz
Amp06	1	A	MaxWW	0.05	kWatts	TotEN	0.05	MWh
Amp07	1	A	MinWW	0.05	kWatts	MaxW	0.05	kWatts
Amp08	1	A	TotEN	0.05	MWh	MinW	0.05	kWatts
Amp09	1	A	TimeRST	1	none	PPV.phsAB	50	V
Amp10	100	A	StartsAv	1	none	PPV.phsBC	50	V
Amp11	100	A	Slip	1	none	PPV.phsCA	50	V
Amp12	100	A	MotorLd	1	none	PhV.phsA	50	V
Amp13	100	A	HrsOp	1	none	PhV.phsB	50	V
Amp14	100	A	PPV.phsAB	50	V	PhV.phsC	50	V
Amp15	100	A	PPV.phsBC	50	V	PhV.res	50	V
Amp16	100	A	PPV.phsCA	50	V	A.phsA	1	A
Amp17	100	A	PhV.phsA	50	V	A.phsB	1	A
Amp18	100	A	PhV.phsB	50	V	A.phsC	1	A
Vol01	0.05	V	PhV.phsC	50	V	A.neut	1	A
Vol02	0.05	V	PhV.res	50	V	A.res	1	A
Vol03	0.05	V	A.phsA	1	A			
			A.phsB	1	A			
			A.phsC	1	A			
			A.neut	1	A			
			A.res	1	A			

B. Data Set Configuration

With the distinction between buffered and unbuffered reports made, the next step is to configure the data sets, which are the collections of data attributes to be published within the reports. When configuring the data sets, it is important to understand that certain data attribute types are defined by IEC 61850 to have a data change trigger, quality change trigger, or data update trigger [1]. For example, the quality attribute associated with any data object has the quality change trigger associated with it. Similarly, the status value

attribute types have the data change trigger associated with them. Understanding which trigger is associated with which attribute type helps define the data sets.

Keep in mind that analog and digital points within the IEDs are defined by IEC 61850 to possess not only values but also quality and time attributes. Thus, when configuring the data sets, special attention needs to be paid to whether or not the client application requires both the data values and corresponding quality and time attributes.

Fig. 3 is an example of configuration software demonstrating two methods of data selection for IEC 61850 reporting data set creation. In this example, the data available in the IED, shown in the left-hand pane, are filtered by a functional constraint, in this case, MX (measurands). This simplifies the configuration process by displaying only a small fraction of the complete IED data available attributes of the logical device and logical node (measurands) for mapping to data sets. Selecting other functional constraints displays other subsets of the complete IED data list. In the right-hand pane, two measurands are selected, both from the *MET* logical device and *MMXU1* logical node. The first item shows the magnitude attribute *mag* selected as a separate data set item. The second item shows the complete Hz data object, which includes not only the magnitude value *mag* but also the time *t* and quality *q*. In this way, any change to either the magnitude or quality will create a report containing all three attributes. When attributes and individual items are entered into the data set individually rather than as the object collection, only the item that changes will be reported. As mentioned earlier, for analog quantities, most applications are only concerned with the analog measurement magnitude value. If the complete structure of an analog quantity is not chosen, the data updates at the client level will include only the magnitude value and not include this extra information, resulting in less network traffic.

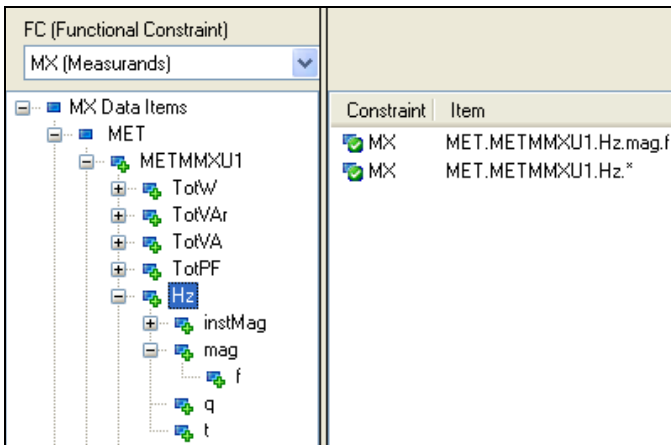


Fig. 3. Selecting correct measurand for analog points

Fig. 4 shows a similar example using digital status data. This example shows the IED light-emitting diode (LED) status point *stVal* in the *ANN* logical device and *TLEDGGIO7* logical node under the functional constraint *ST* (status information). Similar to the previous example, Fig. 4 shows two methods for point selection to create the report data set. In particular, this status point reflects the state of an LED that appears on the front panel of one of the relays in the refinery. If SER time stamps are needed to track multiple changes for

this status, choose the second item (the data object *Ind01*) because it contains the status value and its associated quality and time-stamp attributes. If SER time stamps are not required, use the first item (that only maps the status value *stVal*).

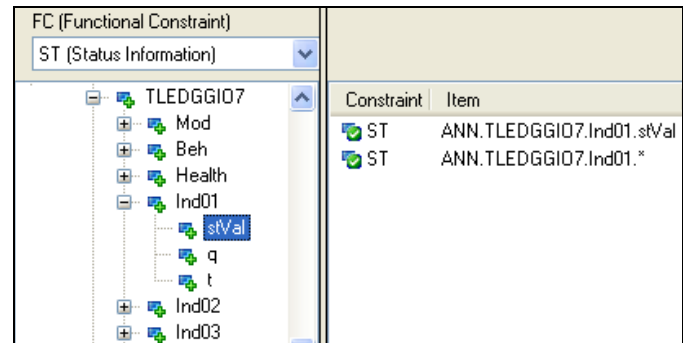


Fig. 4. Selecting correct status value for digital points

In the refinery, separate data sets were defined for messages to report analog values or digital and control values. For each IED, data sets containing analog values were associated with an unbuffered report. These data sets included currents, voltages, and energy quantities only. These data sets contained the dead-band magnitude attribute *mag*. Similarly, for each IED, data sets containing digital and control values included front-panel LED statuses, alarm statuses, trip statuses, and all other desired internal statuses. These digital data items were mapped in the data set at the data object level because of the need to retain the association between the *stVal* change and its associated time for SER purposes.

C. Report Control Block Overview

For an IEC 61850 report, the report control block is used to configure and enable when and what to send in the report message. A client application will receive the contents of a report based on the configuration of this control block as well as the configuration of the client. Subscribed data at the client level can be updated without solicitation, as long as the data reside within a data set associated with a report and the report is enabled by the client.

1) Trigger Options

The following trigger options were taken into consideration for all IEDs within the refinery: data change, quality change, data update, and period. Only data change, quality change, and period were used for the IEDs in the refinery because these IEDs did not contain any data associated with the data update trigger option.

Certain data attributes are defined by IEC 61850 to have the data change trigger, quality change trigger, or data update trigger. The report data sets are selected based on these criteria.

As an example, Fig. 5 shows the data set member *MET.METMMXU1.Hz.** from Fig. 3 and what is reported after the dead-band magnitude of the data set member changes. Note that three attributes are reported.

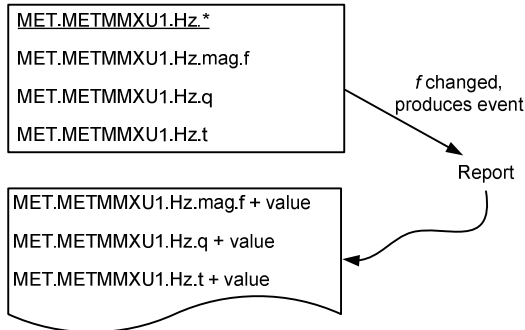


Fig. 5. Data change trigger example

Similarly, Fig. 6 shows the data set member *ANN.TLEDGGIO7.Ind01.** from Fig. 4 and what is reported after the quality of the member changes. Note that three attributes are reported.

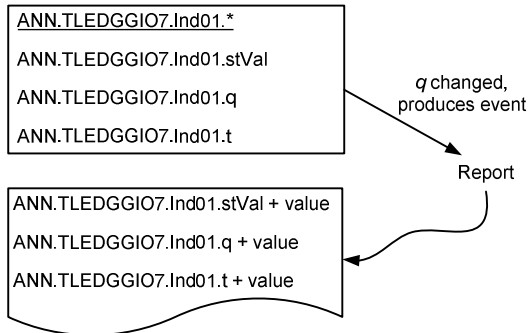


Fig. 6. Quality change trigger example

Fig. 5 and Fig. 6 are examples that show the importance of understanding how the IEC 61850 data structures are defined. In turn, data sets can easily be configured, taking into consideration which attributes are part of the data set and which corresponding triggers exist.

2) Optional Fields

The report control block also controls the inclusion of additional information in the report sent to the client application. This information is controlled via the *OptFlds* attribute. The optional items include: sequence number, report time stamp, reason for inclusion, data set name, data reference, buffer overflow, entry ID, and configuration revision. For the refinery reports, only two of these optional fields were required by the client application—data set name and sequence number. These items were included based on the client applications, not the specifications in IEC 61850. Limiting the extra information to only what is needed by the client applications reduces the amount of data transmitted for each report, thus reducing the communications traffic on the substation network.

Table III summarizes the trigger options and optional fields used for both IEC 61850 MMS drivers in the refinery.

TABLE III
REFINERY TRIGGER OPTIONS AND OPTIONAL
FIELDS FOR IEC 61850 MMS DRIVERS

Trigger Options	Driver A	Driver B
Data change	Yes	Yes
Quality change	Yes	Yes
Data update	No	No
Integrity interval	3 seconds	3 seconds
Buffer time	0 seconds	0.1 seconds
Optional Fields	Driver A	Driver B
Sequence number	Yes	No
Report time stamp	No	No
Reason for inclusion	No	No
Data set name	No	Yes
Data reference	No	No
Buffer overflow	No	No
Entry ID	No	No
Configuration revision	No	No

V. ON-SITE MODIFICATIONS

As with any large automation system, time was spent on-site optimizing communication. In this IEC 61850 system, modifications were made to the trigger options, optional fields, and analog dead bands. With these modifications, data updates in the larger substations between the IEDs and HMI were reduced from the initial 4-second average latency to a 2-second average. Additionally, data updates between the IEDs and RTU dropped from a 3-second average to a 1-second average. This reduction was the result of reducing the amount of extra information included in the report by disabling all optional fields except data set name and sequence number, as shown in Table III. Thus, it is recommended that all optional fields be disabled unless required by the IEC 61850 driver in use. Additional time was spent observing the behavior of the analog values in order to adjust the dead bands to match the installation. The final dead bands are given in Table I and Table II.

In summary, the following steps should be taken when optimizing a SCADA network for IEDs using the IEC 61850 MMS protocol reporting services:

1. Create data sets based on required structures while keeping in mind which trigger options relate to which attributes of each structure.
2. Disable as many report control block optional fields as the IEC 61850 driver allows.
3. Use appropriate trigger options based on the data objects and attributes included in the data set.
4. Modify dead bands on-site to meet actual measured values and achieve required update rates to the client application.
5. Repeat Steps 1 through 4 until network optimization and any other requirements are reached.

VI. CONCLUSION

Following the directions in this paper, the HMI update speed improved from an average latency of 4.5 seconds down to 2.5 seconds. The rate of updates to the RTU SCADA system improved from 3 seconds to 1 second. IEDs using the IEC 61850 MMS protocol have been successfully applied in substations for local HMI integration. Achieving needed and required update rates for these systems using IEC 61850 methods requires an understanding of the reporting services, data structures, and trigger options defined by the standard. Additional understanding of the IEC 61850 client applications and their configuration is also necessary. The final optimization requires configuring dead bands for analog quantities and selecting appropriate trigger options, while, at the same time, understanding how each trigger option affects the related attribute and eliminating unnecessary optional fields within each report control block.

VII. REFERENCE

- [1] *Communication Networks and Systems in Substations – Part 7-1: Basic Communication Structure for Substation and Feeder Equipment – Principles and Models*, IEC 61850-7-1, July 2003.

VIII. BIOGRAPHIES

Ryan L. O’Fallon is an automation engineer for the engineering services division of Schweitzer Engineering Laboratories, Inc. Ryan received his M.S. Mathematics, B.S. Electrical Engineering, cum laude, B.S. Computer Engineering, cum laude, and B.S. Mathematics, cum laude, from Washington State University. He has experience in integration and automation services, commissioning, and protocol settings configuration.

Dean A. Klas received his B.S. Electrical Engineering from the University of Wyoming in 1984. After graduation, he worked as a development engineer in the defense industry for Texas Instruments, Martin Marietta, and EG&G, Inc. He joined Schweitzer Engineering Laboratories, Inc. in 1992 and was a member of the development team for several relays and PC software packages. In 2002, he joined the engineering services group, where he currently is an engineering supervisor.

Timothy Tibbals received his B.S. Electrical Engineering from Gonzaga University in 1989 and is a senior automation systems engineer with Schweitzer Engineering Laboratories, Inc. He has worked as an application engineer, development engineer, automation services supervisor, and product engineer. He has experience in electric power protection, integration, automation, communication, control, and SCADA. Tim is a patented inventor and has authored numerous technical papers and application guides. He is a member of several IEC TC57 working groups, the IEEE PES Substations Committee and PSRC, and CIGRE, all addressing global standards for communication and security for electric power substations.

Saurabh Shah is a branch manager in the engineering services division of Schweitzer Engineering Laboratories, Inc. (SEL). He received his B.S. in 1995 and A.S. Computer Systems in 1991 from Lewis-Clark State College. He has a broad range of experience in the fields of power system operations, protection, automation, and integrated systems. He has served nearly 19 years at SEL, where he has worked in relay testing, sales, business development, and engineering project management.