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MODBUS TO IEC 60870-5-104 GATEWAY FEATURES, PROGRAMMING AND PERFORMANCE

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Opinnäytetyön tarkoituksena oli tutkia MGate 5114 Series gateway-laitteen yleisiä ominaisuuksia sekä kerätä yleistä tietoa energian lukumittareista. Opinnäytetyön tavoitteena oli löytää vastaus siihen, voisiko Hitachi ABB Power Grids Grid Automation-yksikkö mahdollisesti käyttää gateway-laitetta tulevaisuudessa infrastruktuurille suunnatuissa SCADA-projekteissa.

Tämä opinnäytetyö antaa kokonaiskuvan siitä, miten MGate konfiguroidaan käyttämällä siihen tarkoitettua työkalua. Opinnäytetyö antaa lisäksi käytännön esimerkin siitä, miten järjestelmä sulautetaan osaksi MicroSCADAa, sisältäen tietokannan sekä kommunikoinnin. Keskeisin menetelmä oli testaukseen perustuva menetelmä. Gateway-laitteen ominaisuuksia, kuten sen ohjelmointia ja suorituskykyä tutkittiin testiympäristössä.

Testitulosten perusteella voidaan todeta, että MGate sisältää tarvittavat ominaisuudet sekä vaadittavan suorituskyvyn, jotta se soveltuu käytettäväksi infrastruktuurille suunnatuissa SCADA-projekteissa tulevaisuudessa.

Avainsanat	IEC 60870-5-104, MGate 5114 Series, MicroSCADA, Modbus RTU

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ABSTRACT

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The purpose of the thesis was to examine the main features of the MGate 5114 Series gateway device and to collect a wide set of information of the energy metering application. The aim of the thesis was to find the answer to the question whether Hitachi ABB Power Grids Grid Automation unit could possibly use the gateway device in the future in its infrastructure SCADA projects.

This thesis gives an overall picture of how to configure the MGate by using the dedicated tool and a practical example of how to establish the system with MicroSCADA, including database and communication. A test-based method was the main method used in this thesis. The device main features including programming and performance were targets to be evaluated and documented in a test environment.

Based on the testing results, the MGate have the reasonable features and demanding performance so that it can be used in future infrastructure SCADA projects.

Keywords: IEC 60870-5-104, MGate 5114 Series, MicroSCADA, Modbus RTU

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LIST OF TERMS AND ABBREVIATIONS

AFS675	ABB´s switch
ASCII	American Standard Code for Information Inter-change
ASDU	Application Service Data Unit
BOOTP	Bootstrap Protocol
Buffer memory	Contains temporarily stored data
CAT 6	Category 6 Ethernet cable
CET	Communication Engineering Tool
COT	Cause Of Transmission
CRC	Cyclic Redundancy Check
CT PRO XT	ABB´s current transformer
DC	Direct Current
DHCP	Dynamic Host Configuration Protocol
DIP	Dual In-line Package
DIN rail	Standard widely rail for mounting components
DNS	Domain Name System
DSU	Device Search Utility
FAT-area	Factory Acceptance Testing-area
FP2	Feature Pack 2

FIFO	First In First Out
GMT	Greenwich Mean Time
HF3	Hotfix 3
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
Hyper-V	Microsoft technology that allows users to create virtual machine environments
IfOperStatus	Interface Operational Status
IOA	Information Object Status
INS	Integer Status
IP	Internet Protocol
IEC	International Electrotechnical Commission
IEC 60870-5-101	International standard, one of the IEC 60870 set of standards
IEC 60870-5-104	International standard, one of the IEC 60870 set of standards
IEC 62443	International standard, specifies security capabilities for control system components
IED	Intelligent Electronic Device
LAN	Local Area Network

LD	Logical Device
LLN0	Logical Node 0
MGate	Moxa´s industrial Ethernet gateway
MIB	Management Information Base
Modbus RTU	Modbus protocol that is used in serial communication
Modbus TCP	Modbus protocol that is used for communication over TCP/IP networks
M4M 20	ABB´s Network analyzer
NTP	Network Time Protocol
OID	Object Identifier
OPCS1	OPC Server for SNMP
PC	Personal Computer
Quick Setup	Moxa´s configuration tool
RTU	Remote Terminal Unit
UART	Universal Asynchronous Receiver Transmitter
TCP	Transmission Control Protocol
MicroSCADA Pro	Hitachi ABB Power Grids product family for substation and network control system
RTS	Request To Send
RS-485	Interface, defined by the EIA/TIA standard

RTU	Remote Terminal Unit
Rx signal	Receive signal
SCADA	Supervisory Control and Data Acquisition
SCS	Substation Control System
SCIL	Supervisory Control Implementation Language
SPS	Single Point Status
STA object	Station object
SNMP	Simple Network Management Protocol
SnmpB	Open-source SNMP MIB browser
Sverker 750	Single-phase relay tester
Walk function	Can be used to walk through a directory tree and find the data
WAN	Wide Area Network
Web console	A web-based application that allows end-users to manage their data
Wireshark	Network protocol analyzer

1 INTRODUCTION

The purpose of this thesis was to examine the Moxa MGate 5114 Series gateway device and to find out more information about the energy metering application. This thesis was done for Hitachi ABB Power Grids Grid Automation unit. The aim of the thesis was to find out the answer to the question whether MGate have the reasonable features and the needed performance so that it can be used in infrastructure SCADA projects.

Usually there are several alternatives to collect data from energy meters to the MicroSCADA. In a MicroSCADA based system, simple and hierarchic data collection is the most suitable solution with high performance and reliability. A typical protocol in the energy meter device is Modbus RTU or Modbus TCP. One new alternative is to use Modbus to IEC 60870-5-104 gateway devices. The Moxa is one of the most well-known manufactures for such a gateway device as the MGate 5114 Series. According to the marketing material and base clarifications, it should have reasonable features. Also, ABB Power Grids Finland has a long experience in working with the manufacturer. The used gateway device during the test part of this thesis was provided by Suomen Addon Oy.

A test-based method was used in this thesis. The MGate main features including the programming and performance were targets to be evaluated and documented in a test environment. The practical target for the thesis was to establish the system with MicroSCADA, including the database and communication.

2 HITACHI ABB POWER GRIDS

In 2020, Hitachi and ABB´s Power Grids´ business came together in a joint venture. Together, as Hitachi ABB Power Grids, it is a new global leader with a combined heritage of almost 250 years. The company is headquartered in Switzerland and employs around 36,000 people in 90 countries. The business serves utility, industry and infrastructure customers across the value chain and emerging areas, such as cities, energy storage systems and data centers. /1-2/

2.1 Grid Automation

Hitachi ABB Power Grids in Finland is divided into the three main business units, which are Grid Automation, Grid Integration and Transformers. The Grid Automation unit provides systems for electric utilities and industry. Project management, engineering, commissioning, substations gateways, transmission and distribution network solutions, such as substations for energy and electricity companies are included in their line of business. The main market areas are Finland, Northern Europe and Middle East. /3-4/

3 THEORETICAL BACKGROUND

A typical MGate 5114 Series application consists of a SCADA as a client/master and a field device as a server/slave. These components use different kinds of protocols and thus there is a need to use a gateway device in between to exchange data. A field device during the test part of this thesis was a M4M 20 Network analyzer. /5-6/

3.1 MGate 5114 Series

As shown in Figure 1, the MGate 5114 Series is Moxa´s industrial Ethernet gateway device with 2 Ethernet ports, 1 console port and 1 serial port. The MGate provides the needed flexibility to fulfill the conditions that arise with field devices that use different communications protocols. The gateway device provides multiple conversion options between the different gateways, thereby fulfilling a wide variety of different requirements. The different variations when connecting to Ethernet-based networks can be seen in Figure 2. /5-6/

Figure 1. MGate 5114 Series. /5/

The main features of the gateway device are:

- Redundant dual DC power inputs and one relay output
- Designed to be attached to a DIN rail or mounted on a wall
- Equipped with a microSD card slot
- Possibility to apply the same configuration to the multiple units by using the configuration import and export function
- Easy configuration via a user-friendly web console
- Step-by-step configuration guide with Quick Setup
- Complete packet analysis and diagnostic information for maintenance and troubleshooting
- Embedded Modbus RTU/ASCII and IEC 60870-5-104 traffic monitoring
- Possible to restore the factory default setting by using the reset button
- Security features based on IEC 62443 standards. /5-6/

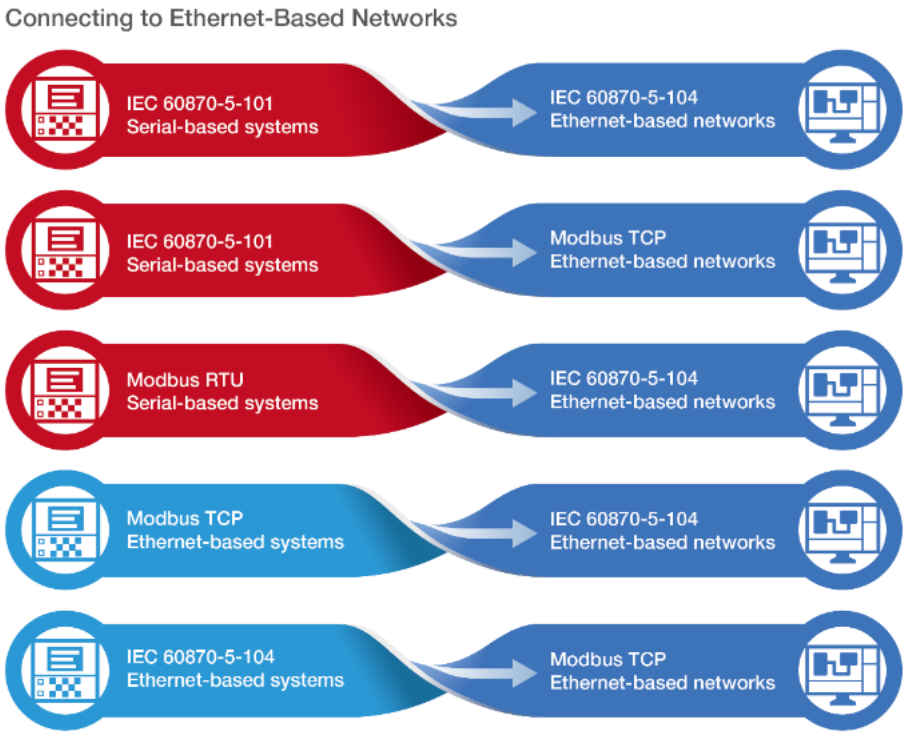


Figure 2. Different variations when connecting Ethernet-based networks. /7/

Before the test part of the thesis, the DIP switch number 3 in MGate was adjusted. The DIP switch needed to be adjusted to minimize the reflections from the end of the RS-485 serial cable. It is possible to adjust DIP switches after removing the MGate´s top cover, as seen in Figure 3.

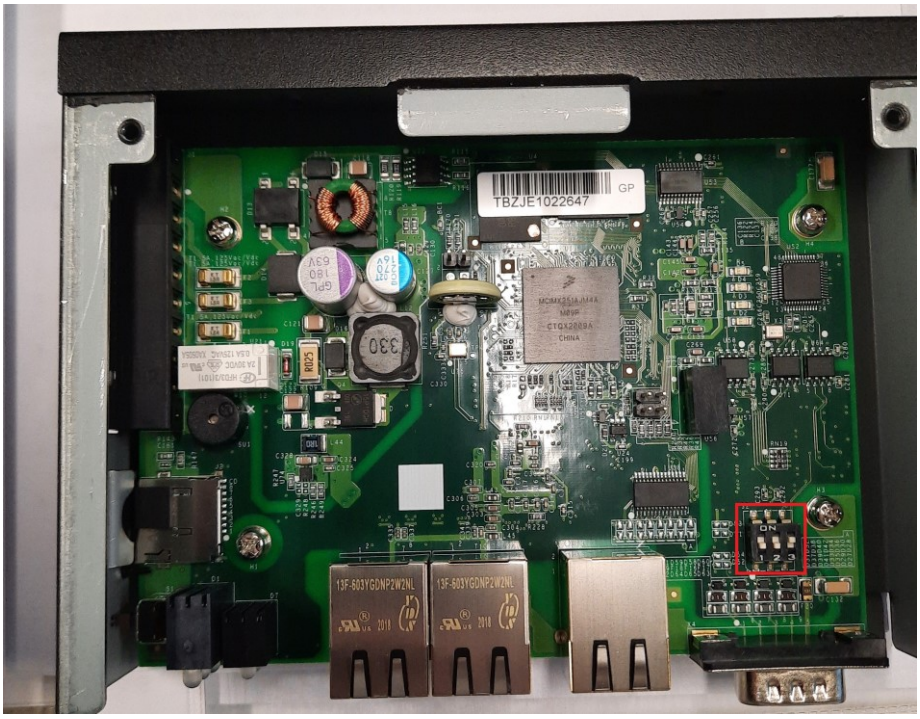


Figure 3. DIP switches in MGate.

During the tests the switch 3 was in position on and then the terminator value was 120 Ω. Each position specific explanation can be seen in Table 1.

Table 1. DIP switches possible positions. /6/

SW	1	2	3
	Pull-high resistor	Pull-low resistor	Terminator
ON	1 kΩ	1 kΩ	120 Ω
OFF	150 kΩ*	150 kΩ*	–*

*Default

3.2 M4M 20 Network Analyzer

M4M 20 is ABB´s Network analyzer that allow accurate real-time energy data monitoring. The picture of the M4M 20 can be seen in Figure 4. The used analyzers during the test part of this thesis were provided with Modbus RTU communication, which means that they were equipped with RS-485 port. The RS-485 terminal was a 3-pole plug contact. Figure 5 presents the principle of how to wire RS-485 serial cable on M4M 20. /8-9/

Figure 4. M4M 20 Network analyzer. /8/

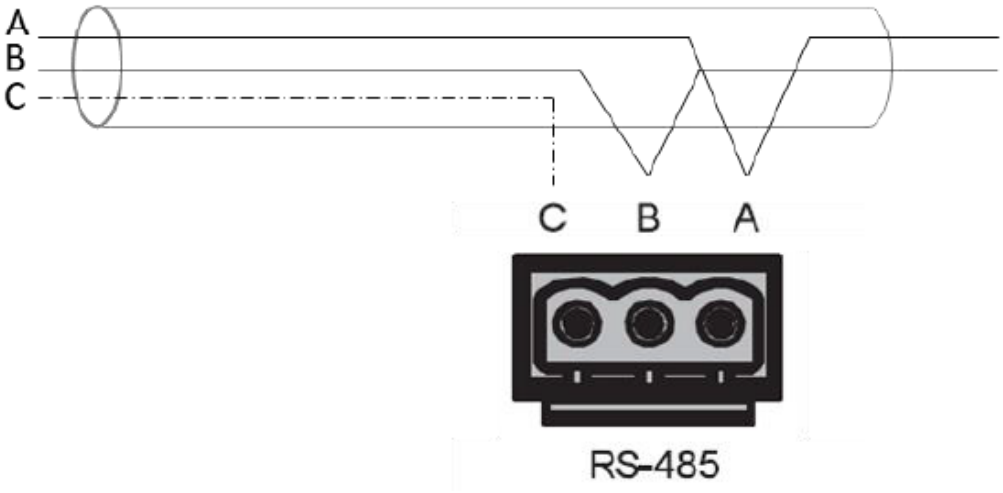


Figure 5. RS-485 wiring on M4M 20 Network analyzer. /9/

A and B are mandatory for the correct communication of the device. C can be connected to the data common ground if it is available and needed. RS-485 is a differential signal so common ground is not mandatory to use. A differential signal means that the signal is the difference between the A and B voltages. The third wire C, is also known as a common wire, is used to ensure that the common mode requirements from -7 V to +12 V of the transceivers are maintained. /9/

The M4M 20 can be used in different types of network. According to the type of the used network, the parameters visualized on the M4M 20 HMI change. The principle of the used wiring diagram during the tests was 1-phase 2 wire network with 1 current transformer, as shown in Figure 6. /10/

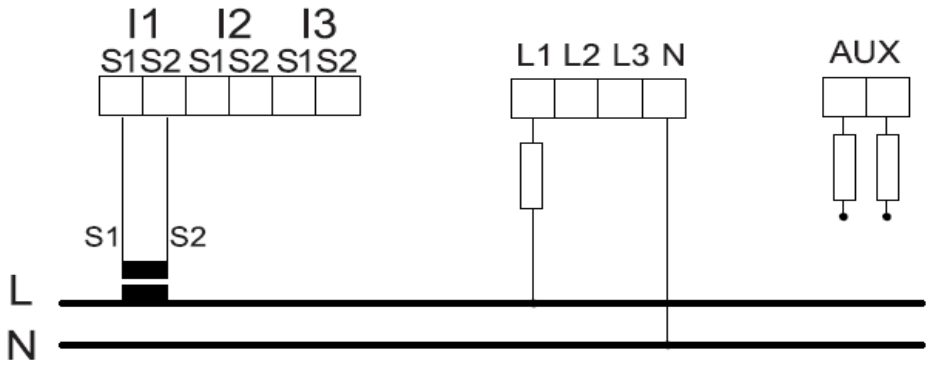


Figure 6. 1-phase 2 wire network with 1 current transformer. /10/

The Modbus RTU communication is based on the master-slave architecture. Usually the Modbus RTU message consists of the slave address, the function code, the actual data, which depends on the function code and the CRC of the checksum. The function code will tell the slave device what kind of action to perform. The function codes are used to read or write 16 bits (2 bytes) registers. Metering data, such as voltage, current or active energy are represented by one or more such registers. The following function codes were supported in M4M 20:

- Function code 3 (Read holding registers)
- Function code 6 (Write single register)
- Function code 16 (Write multiple register). /9/

The messages can be query-response or broadcast type. The used type of the message was the query-response-type command during the tests. It sends a query from the master to individual slave and is generally followed by a response, whereas the broadcast command sends a message to slave and is never followed by a response. Therefore, it is recommended that the user reads the value to confirm the result after the set value has set in the energy meter. This type of command is supported by function code 6 and 16. /9/

4 MGATE 5114 SERIES PROGRAMMING AND PERFORMANCE

A test-based method was used in this thesis. The main features of the Moxa MGate 5114 Series gateway device, including the programming and performance, were targets to be evaluated and documented in a test environment. The MGate programming was done by using the Moxa dedicated tool. The dedicated tool was a user-friendly web console and automated technologies including the Quick Setup configuration tool that allowed to configure the gateway device.

The test set-up consisted of the following devices: MGate 5114 Series gateway device, two M4M 20 Network analyzers, two CT PRO XT current transformers, AF675 switch, Sverker 750, different gateways and PC, which runs Microsoft Hyper-V virtual machine. A RS-485 serial cable was used to connect the MGate to the Modbus RTU slave devices. The CAT 6 Ethernet cable was connected between the MGate and IEC 60870-5-104 master device, via the AFS675. The picture of the test-set up can be seen in Appendix 1.

The MGate role 1 was IEC 60870-5-104 slave. MicroSCADA was used as an IEC 60870-5-104 master to monitor the Modbus RTU slave devices. It was possible to integrate the existing Modbus RTU slave devices into IEC 60870-5-104 network, when the MGate role 2 was a Modbus RTU master. The MGate collected the data from the Modbus RTU slave devices and exchanged it with IEC 60870-5-104 system. Figure 7 presents the principle of the system topology.

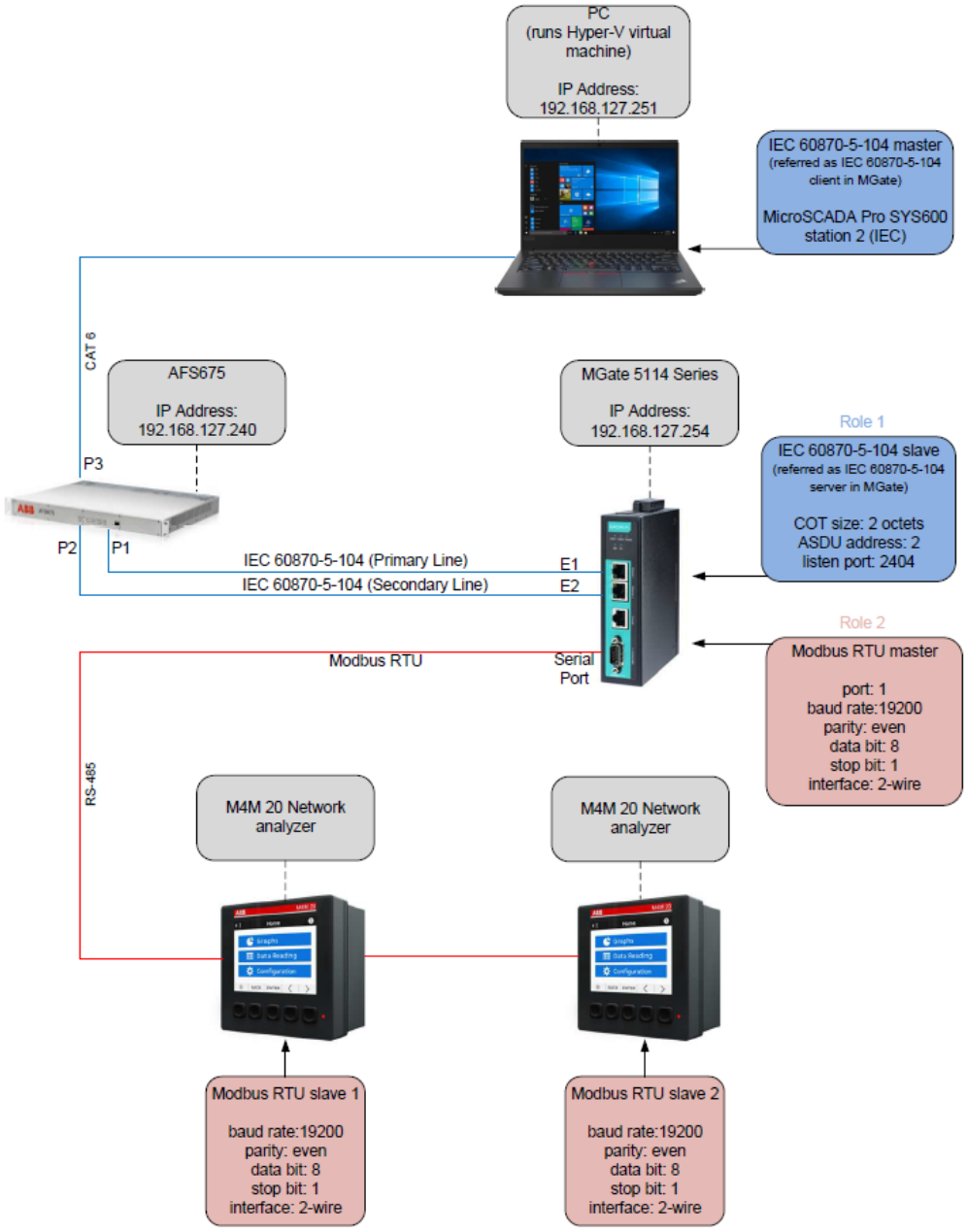


Figure 7. The principle of the system topology.

4.1 Basic Settings Configuration

Before the use of the Quick Setup configuration tool, the basic settings of the gateway device needed to be configured, including also network and serial settings configurations. The web console was used to configure the MGate through the Ethernet. A web browser such as Microsoft Internet Explorer or Google Chrome are suitable, when using the HTTP/HTTPS protocol. The MGate´s default IP address was 192.168.127.254. /6/

It was also possible to detect the MGate by using the DSU software. It can be used in case the user does not know the MGate´s IP address. The software can be downloaded from Moxa´s website. /6/

The first time, when logging up in the web console, the default settings were used. The default account name was admin and the default password was moxa. After a successful logging-in the warning message from the webpage popped out, as presented in Figure 8. /6/

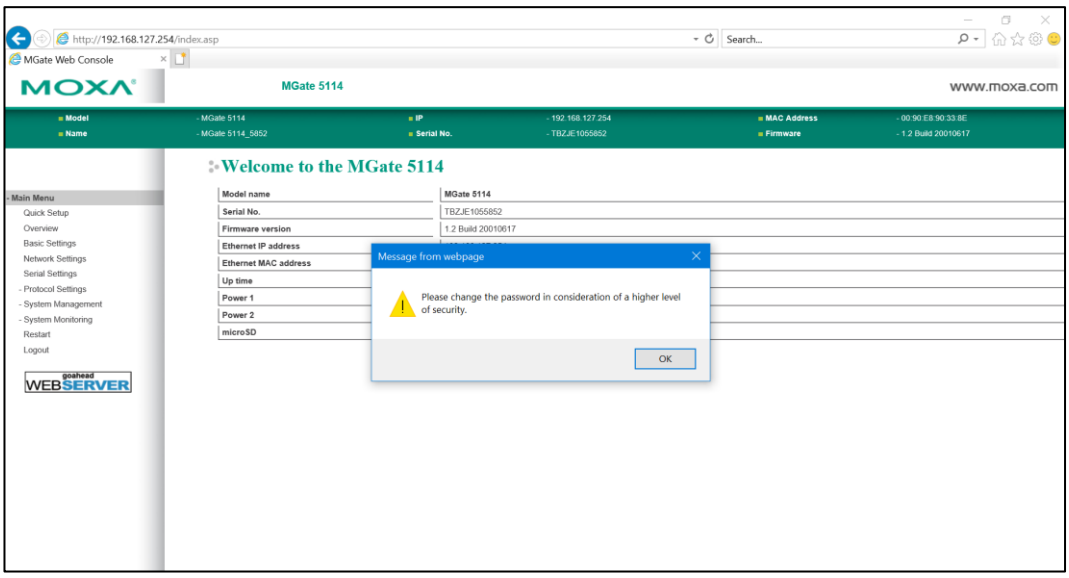


Figure 8. The warning message from webpage.

The new account and password were created by emphasizing a higher security level. The password can be changed by following the path: System Management > Miscellaneous Settings > Account Management.

As shown in Figure 9, the Basic, Network and Serial Settings were under the Main Menu header.

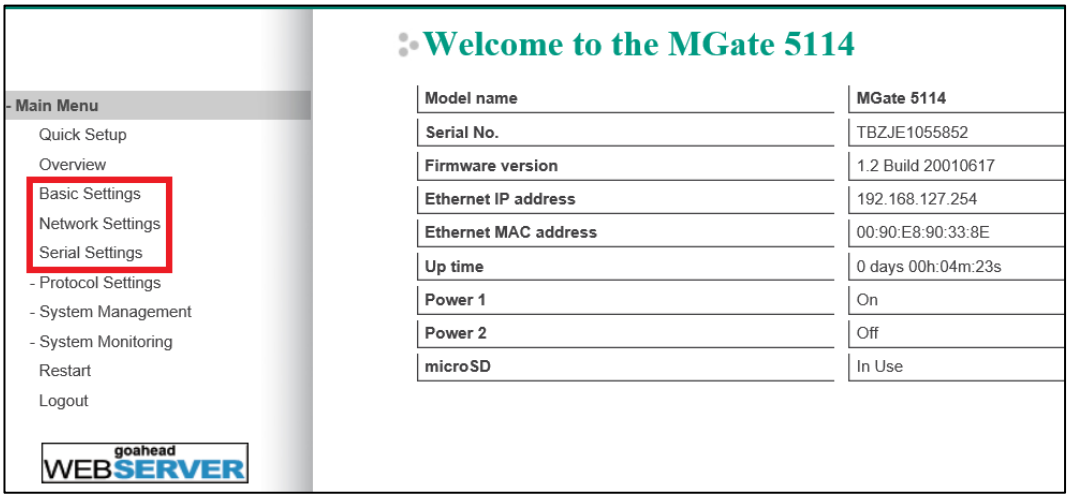


Figure 9. Main Menu.

Figure 10 presents how the server and time settings were configured. The server name can be given to help the user to identify the unit, such as its function if there are several similar units in use. The server name was MGate_5114_Test. Server location identifies the unit currently location, which was named as FAT-area_Vaasa. /6/

After the server settings were configured, the time settings needed to be configured, as well. The MGate has a built-in real-time clock for time calibrations functions. The functions such as log function can add a real-time information to the message. It is also worth to mention that the first-time users should select the time zone first, thus the console displays the “the real-time” according to the time zone relative to GMT. The user adjustable time can be changed by selecting the local time. The user can select the way how the time synchronization is done by selecting parameter time source. It can be NTP or Protocol. If the NTP is selected,

the time server can be an IP or Domain address. During the test part of the thesis time source was protocol and the time zone was (GMT+02:00) Helsinki, Riga, Sofia, Tallinn. /6/

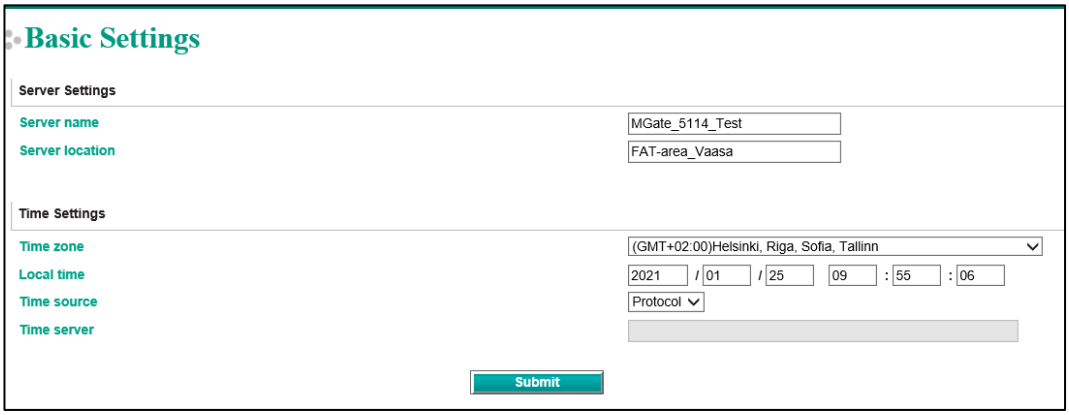


Figure 10. Basic Settings.

Figure 11 presents the Network Settings webpage where it was possible to modify the unit´s network parameters. Parameter IP configuration can have a value Static, DHCP or BOOTP. The Static IP address was in use during the tests and it means that the IP address does not change. The other options should be selected if the IP address is set dynamically. The IP address identifies the server on the TCP/IP network. The used IP address was the same as the earlier mentioned gateway device default IP address. The netmask identifies the server as belonging to a Class A, B or C network. Class C network was used this time. The gateway IP address was 192.168.127.1 and it is the IP address of the router that provides the network access outside the server LAN. Parameter DNS server 1 is the primary domain, whereas DNS server 2 is the secondary domain server. Neither of the DNS servers were in use and therefore these rows were left blank. /6/

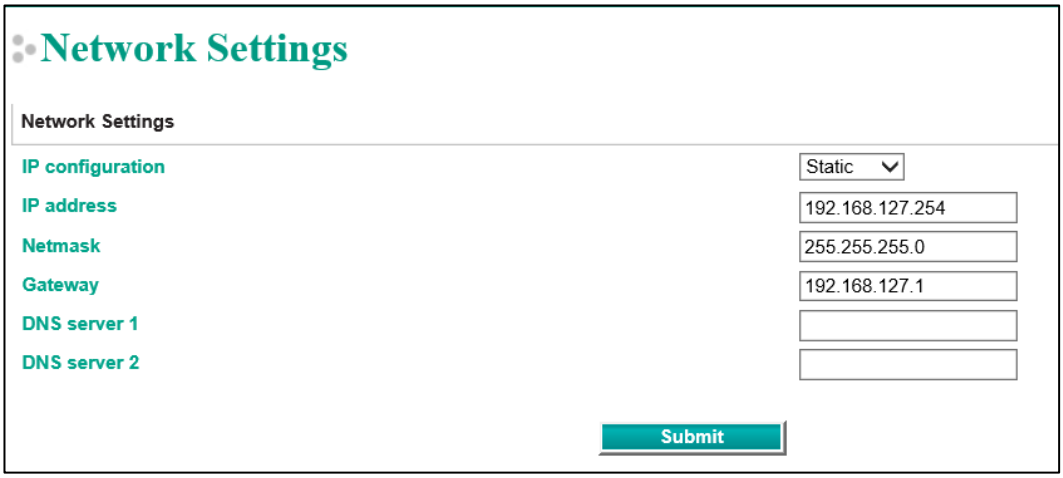


Figure 11. Network Settings.

The following serial settings, which can be seen in Figure 12, were configured to be the same in the MGate and Modbus RTU slave devices. MGate´s serial interface supports RS-232, RS-422 and RS-485 interfaces. Disabling the FIFO can reduce the latency time, when receiving the data from serial communications. FIFO means the internal buffer memory of UART. The RTS toggle function was available for RS-232 mode only. /6/

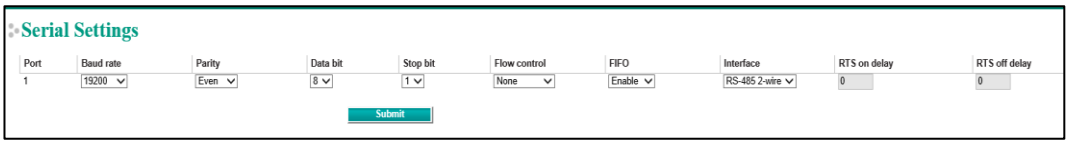


Figure 12. Serial Settings.

4.2 Quick Setup Programming

This section gives an example of how to program the MGate by using the Quick Setup configuration tool. Quick Setup is an illustrated guide which is designed to make the configuration process easy. It takes the user through the configuration process from the start to the end. The MGate´s performance when reading single Modbus registers was tested after the Quick Setup configurations were done. /6/

As seen in Figure 13, the server and network settings were first configured in System setting window. These settings were only checked that they were the same ones as earlier parameterized.

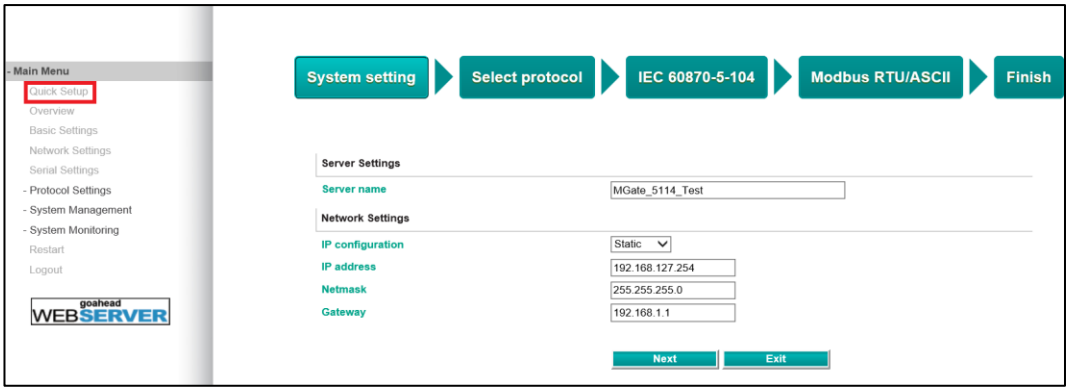


Figure 13. System setting (Quick Setup).

Figure 14 shows the Select protocol webpage, where the gateway device protocols on each side were selected. If the device 1, in this case the PC, is set as IEC 60870-5-104 client, then the MGate automatically configured the IEC 60870-5-104 server side by using the default settings. Table 2 shows the possible device 1 and 2 roles in MGate.

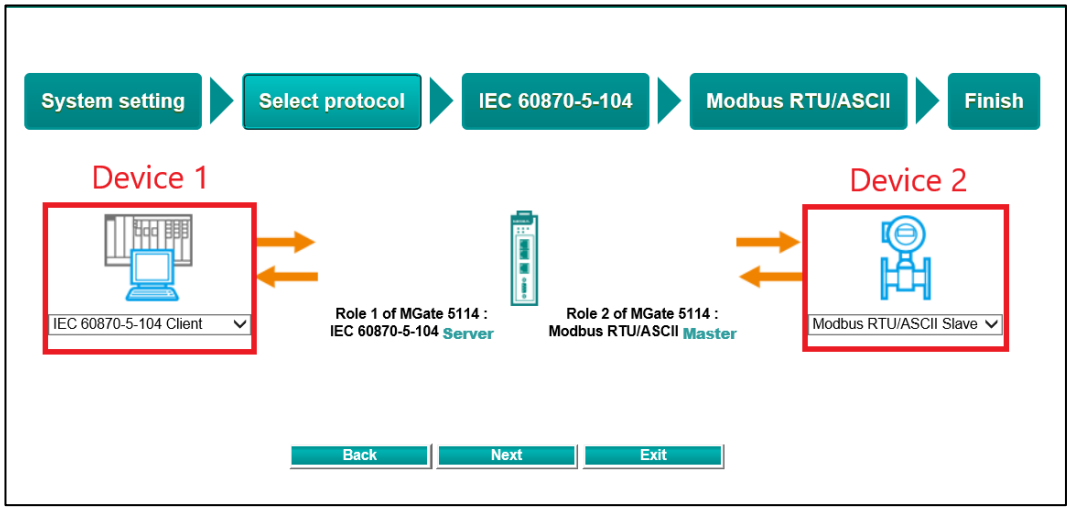


Figure 14. Select protocol (Quick Setup).

Table 2. Device 1 and 2 possible roles in MGate.

Device 1	Device 2
IEC 60870-5-104 Client	Modbus RTU/ASCII Slave
IEC 60870-5-104 Client	Modbus TCP Server
IEC 60870-5-104 Client	IEC 60870-5-101 Slave
IEC 60870-5-101 Master	Modbus TCP Server
IEC 60870-5-101 Master	IEC 60870-5-104 Server
Modbus TCP Client	IEC 60870-5-101 Slave
Modbus TCP Client	IEC 60870-5-104 Server
Modbus RTU/ASCII Master	IEC 60870-5-104 Server

On the IEC 60870-5-104 slave side, there were both the basic and advanced settings. As seen in Figure 15, only the basic settings were possible to configure during the Quick Setup process. The ASDU address was changed from default value 3 to the value 2. Otherwise the basic settings were the default ones.

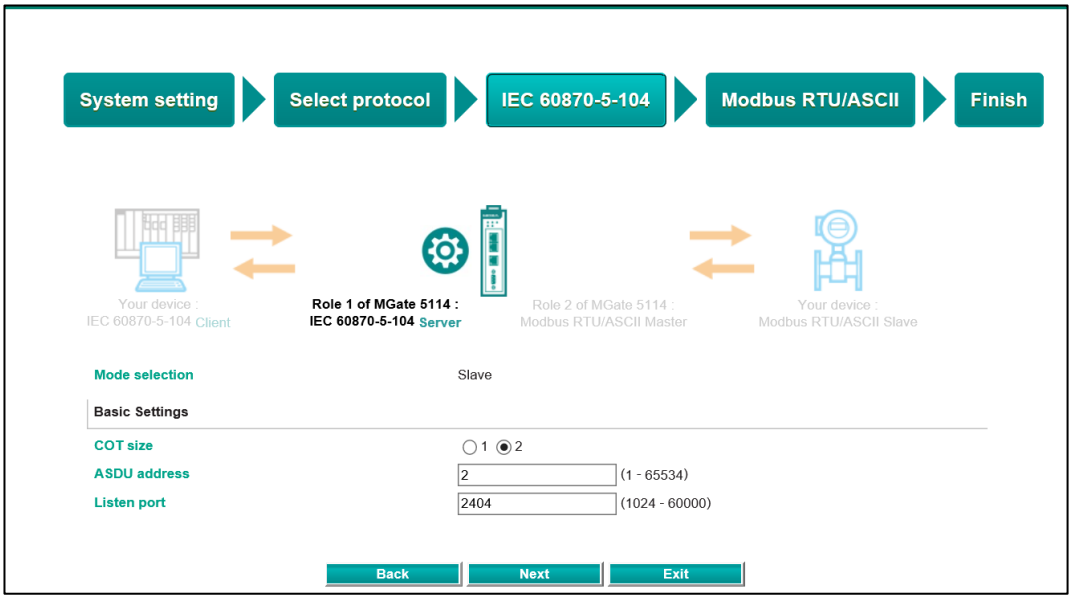


Figure 15. IEC 60870-5-104 (Quick Setup).

On the Modbus RTU/ASCII webpage the mode was selected as Modbus RTU and the serial settings were the same ones as configured in Chapter 4.1 Basic Settings Configuration. The function code 3 was used to read measurement value phase voltage L1 from the M4M 20 Network analyzer slave 1 and slave 2. The Modbus command was first created for slave number 1. As seen in Figure 16, the first created Modbus command was copied to the slave 2 by using the clone function.

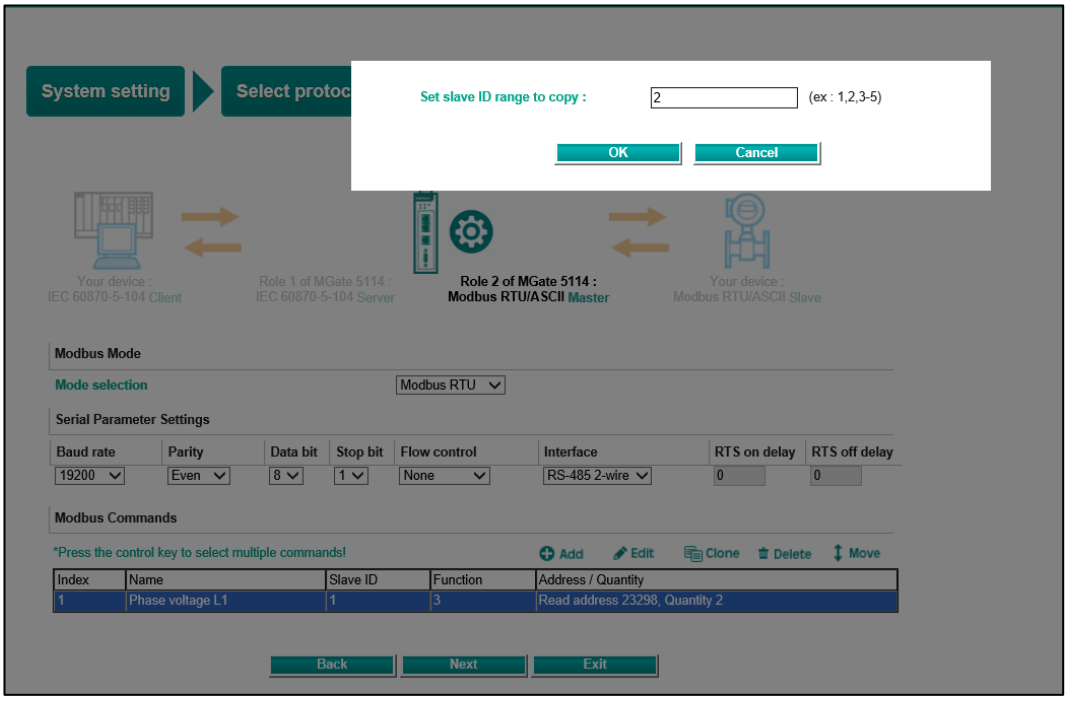


Figure 16. Modbus RTU/ASCII (Quick Setup).

Once all the configurations in Quick Setup were done, it was checked whether the parameters were the same as configured earlier. The Finish webpage shows a summary of the configurations, as seen in Figure 17. The Quick Setup process was finalized by clicking the ‘save’ button.

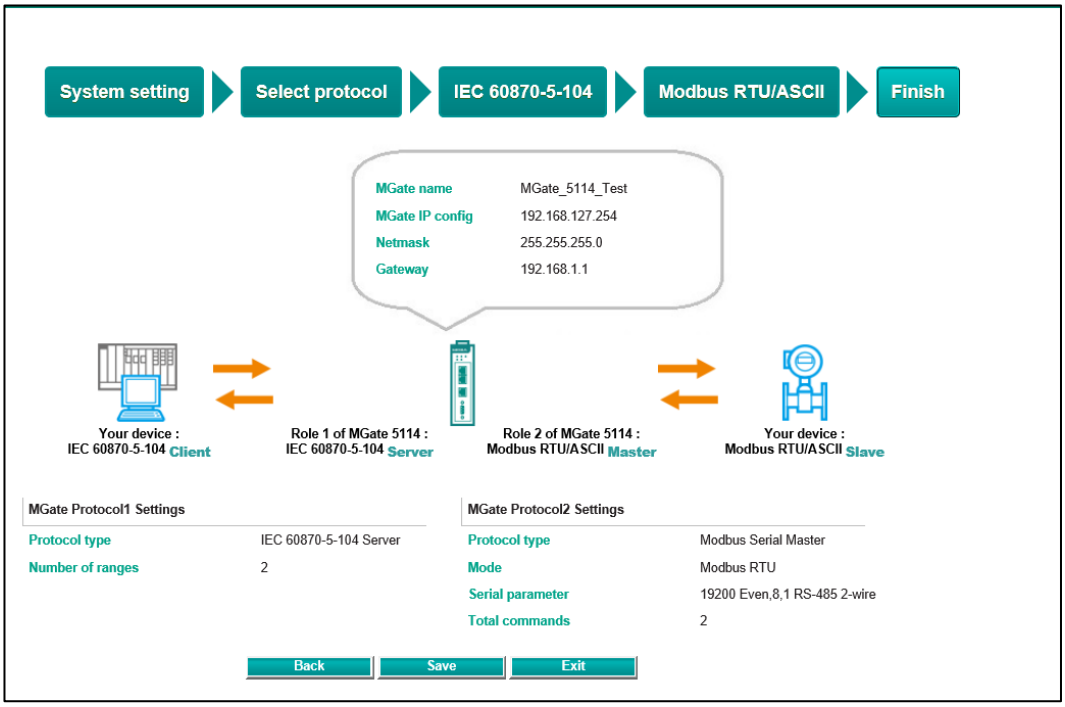


Figure 17. Finish (Quick Setup).

It was possible to view IEC 60870-5-104 and Modbus RTU mapping status by following the path: Protocol Settings > I/O Data Mapping. In this table it was meant to check that all object points were mapped correctly. There were two possible dataflow directions. The possible directions were read and written. In Figure 18 can be seen that, for instance the Modbus RTU master sends read ''Phase voltage L1'' command to Modbus RTU slave 2. The internal address area was then 4-7 on both sides of the MGate. The used object data type was the measured value normalized. The Quick Setup tool uses this type of object data type by default. After the mapping address arrangement was set from automatic to manual, it was possible to adjust internal addresses. In this case only the automatic mapping address arrangement was used.

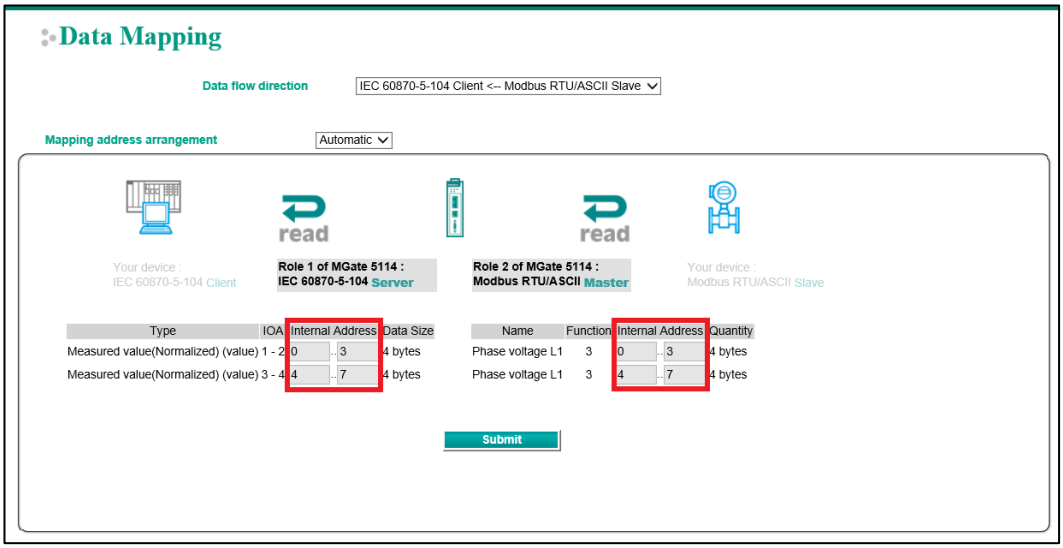


Figure 18. Data Mapping.

As seen in Figure 19, the Modbus RTU/ASCII Traffic webpage provided a traffic monitoring function, which captured the Modbus RTU communication logs. This webpage can be found by following the path: System Monitoring > Protocol Status > Modbus RTU/ASCII Traffic.

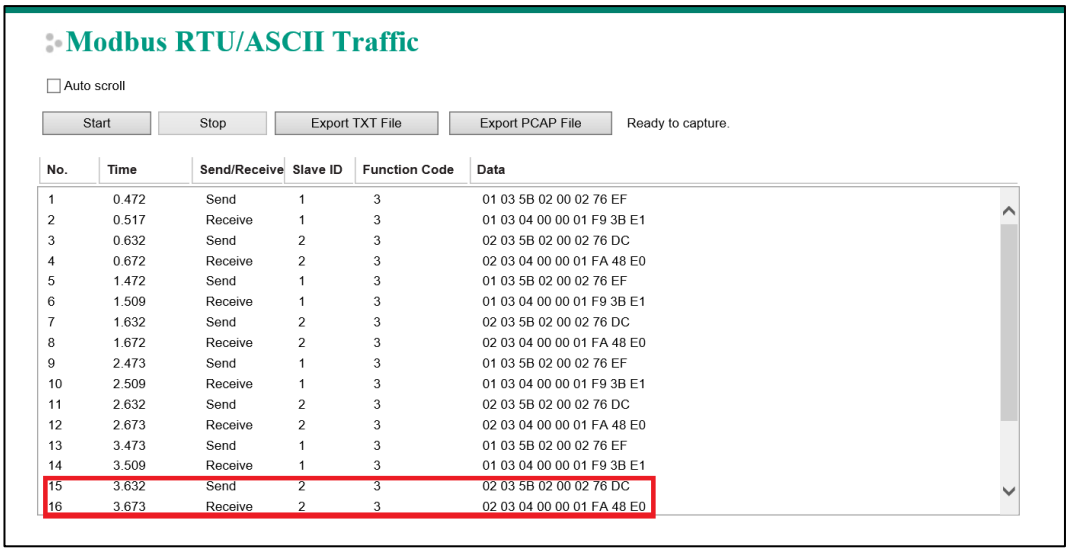


Figure 19. Modbus RTU/ASCII Traffic.

The actions number 15 and 16 are explained in Tables 3 and 4.

Table 3. Send frame.

Parameter	Hex
Slave address	0x02
Function code	0x03
Start address, high byte	0x5B
Start address, low byte	0x02
Number of registers, high byte	0x00
Number of registers, low byte	0x02
Error check (CRC), high byte	0x76
Error check (CRC), low byte	0xDC

Table 4. Receive frame.

Parameter	Hex
Slave address	0x02
Function code	0x03
Byte count	0x04
Value of register 0x5B02, high byte	0x00
Value of register 0x5B02, low byte	0x00
Value of register 0x5B03, high byte	0x01
Value of register 0x5B03, low byte	0xFA
Error check (CRC), high byte	0x48
Error check (CRC), low byte	0xE0

As Table 4 presents, the value of the register 0x5B03 was 01FA in hexadecimal, so it needed to be converted to decimals. In decimals the value was 506. The resolution was 0,1 according to ABB´s M4M Modbus mapping table, so the value needed to be multiplied by 0,1 /11/. The result after the multiplication was then 50,6 Volts. Then the phase voltage L1 measurement value was checked from M4M 20 Network analyzer slave 2. The value was 50,562 Volts. As a conclusion we can state that MGate´s performance is reliable when reading single Modbus registers.

4.3 Establishing the System with MicroSCADA

The practical aim of the thesis was to establish the system with MicroSCADA, including database and communication. The used version was MicroSCADA Pro SYS600 9.4 FP2 HF3 and it was installed in Microsoft Hyper-V virtual machine.

4.3.1 MGate 5114 Series Configuration

This section gives an example of the MGate´s configurations when reading multiple Modbus registers. The configuration of the MGate was done by using the earlier introduced Quick Setup configuration tool. This time some of the master and advanced settings also needed to be adjusted. These settings can be adjusted when the Quick Setup process is finished.

The Modbus mode and serial settings were the same ones as earlier configured in Chapter 4.2 Quick Setup Programming. Figure 20 presents the Modbus RTU/ASCII Master webpage, where the master settings were adjusted. For example, the MGate was forced to wait 200 milliseconds before sending the first request with the initial delay parameter. The maximum polling retry value was 1 and it is the adjusted number of times the master will retry the same request when the response times out. The response timeout was 5000 milliseconds and based on this response time, the master was configured to wait a certain amount of time for the slave´s response. This allows the Modbus system to continue operations even if a slave device is disconnected or faulty. /6/

The endian swap parameter can be configured either the Modbus RTU master side or the IEC 60870-5-104 server side. The value byte is suitable for most scenarios. The created Modbus commands are shown in Figure 21. /6/

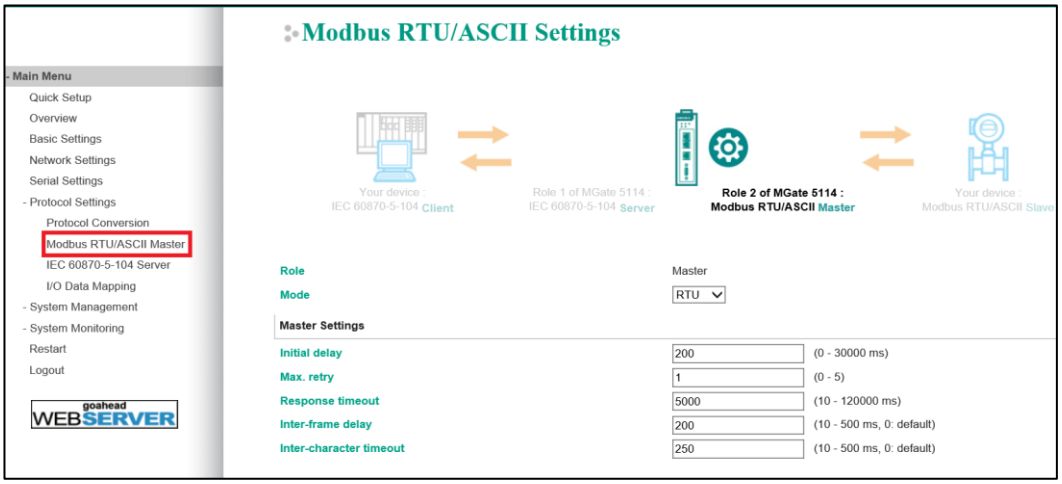
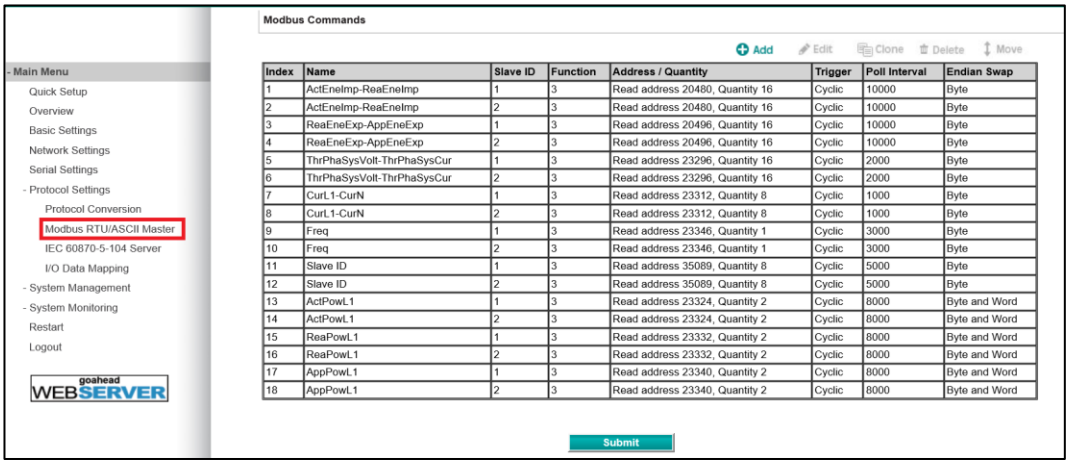


Figure 20. Modbus RTU/ASCII Master (Master Settings).



Index	Name	Slave ID	Function	Address / Quantity	Trigger	Poll Interval	Endian Swap
1	ActEneImp-ReaEneImp	1	3	Read address 20480, Quantity 16	Cyclic	10000	Byte
2	ActEneImp-ReaEneImp	2	3	Read address 20480, Quantity 16	Cyclic	10000	Byte
3	ReaEneExp-AppEneExp	1	3	Read address 20496, Quantity 16	Cyclic	10000	Byte
4	ReaEneExp-AppEneExp	2	3	Read address 20496, Quantity 16	Cyclic	10000	Byte
5	ThrPhaSysVolt-ThrPhaSysCur	1	3	Read address 23296, Quantity 16	Cyclic	2000	Byte
6	ThrPhaSysVolt-ThrPhaSysCur	2	3	Read address 23296, Quantity 16	Cyclic	2000	Byte
7	CurL1-CurN	1	3	Read address 23312, Quantity 8	Cyclic	1000	Byte
8	CurL1-CurN	2	3	Read address 23312, Quantity 8	Cyclic	1000	Byte
9	Freq	1	3	Read address 23346, Quantity 1	Cyclic	3000	Byte
10	Freq	2	3	Read address 23346, Quantity 1	Cyclic	3000	Byte
11	Slave ID	1	3	Read address 35089, Quantity 8	Cyclic	5000	Byte
12	Slave ID	2	3	Read address 35089, Quantity 8	Cyclic	5000	Byte
13	ActPowL1	1	3	Read address 23324, Quantity 2	Cyclic	8000	Byte and Word
14	ActPowL1	2	3	Read address 23324, Quantity 2	Cyclic	8000	Byte and Word
15	ReaPowL1	1	3	Read address 23332, Quantity 2	Cyclic	8000	Byte and Word
16	ReaPowL1	2	3	Read address 23332, Quantity 2	Cyclic	8000	Byte and Word
17	AppPowL1	1	3	Read address 23340, Quantity 2	Cyclic	8000	Byte and Word
18	AppPowL1	2	3	Read address 23340, Quantity 2	Cyclic	8000	Byte and Word

Figure 21. Modbus RTU/ASCII Master (Modbus Commands).

Table 5 shows the detailed explanation of index 1 addresses.

Table 5. Index 1 addresses explained.

Parameter	Data Type	Access	Start Register (Hex)	Start Register (Dec)	Read Quantity	Quantity in Bytes
Active energy - import	Unsigned	Read	5000	20480	1	2
	Unsigned	Read	5001	20481	1	2
	Unsigned	Read	5002	20482	1	2
	Unsigned	Read	5003	20483	1	2
Active energy - export	Unsigned	Read	5004	20484	1	2
	Unsigned	Read	5005	20485	1	2
	Unsigned	Read	5006	20486	1	2
	Unsigned	Read	5007	20487	1	2
Active energy - net	Signed	Read	5008	20488	1	2
	Signed	Read	5009	20489	1	2
	Signed	Read	500A	20490	1	2
	Signed	Read	500B	20491	1	2
Reactive energy - import	Unsigned	Read	500C	20492	1	2
	Unsigned	Read	500D	20493	1	2
	Unsigned	Read	500E	20494	1	2
	Unsigned	Read	500F	20495	1	2
Total	-	-	-	-	16	32

Figure 22 shows the IEC 60870-5-104 Server webpage where the advanced settings were possible to configure. The basic settings were the same ones as earlier configured in Chapter 4.2 Quick Setup Programming. For instance, the timestamp reference was set as local time, measured value spontaneous feature was enabled, cyclic interval value of the measured valued (scaled) was set as 60 seconds and point status value was 100 seconds. The parameter point status timeout is a critical in case of possible fault situations of the slave device. Its purpose is to check the MGate´s internal memory to see if the object status updates periodically. /6/

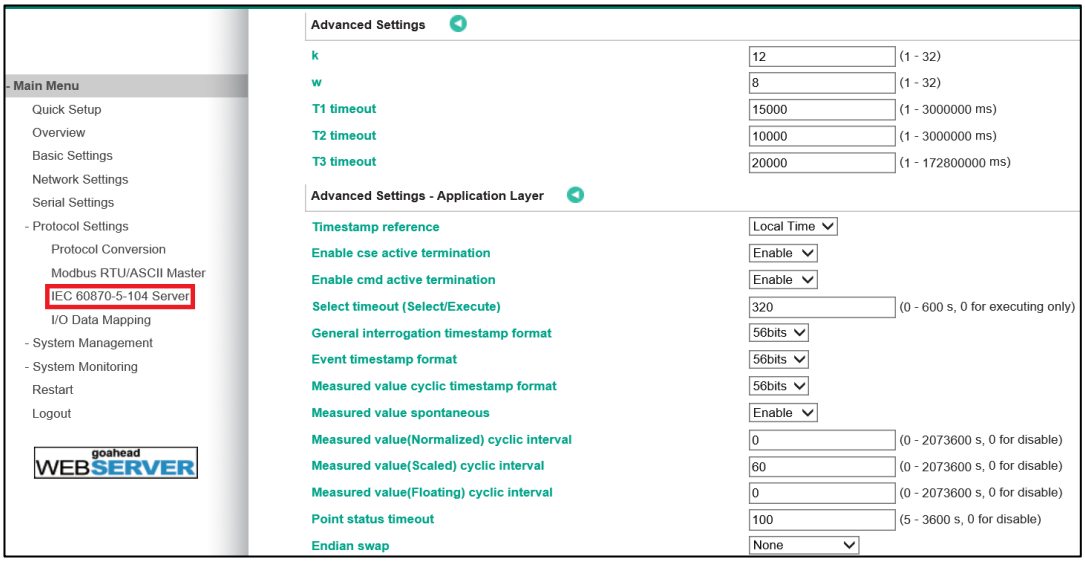


Figure 22. IEC 60870-5-104 Server (Advanced Settings).

The possible data object types and address areas in MGate are:

- Single point
- Double point
- Step position
- Bitstring of 32 bit
- Measured value Normalized (0-65535)
- Measured value Scaled (0-65535)
- Measured value Floating (0-100000000)
- Integrated totals. /6/

The data object type should be selected so that the address area of the data object is not exceeded. The used point settings can be seen in Figure 23.

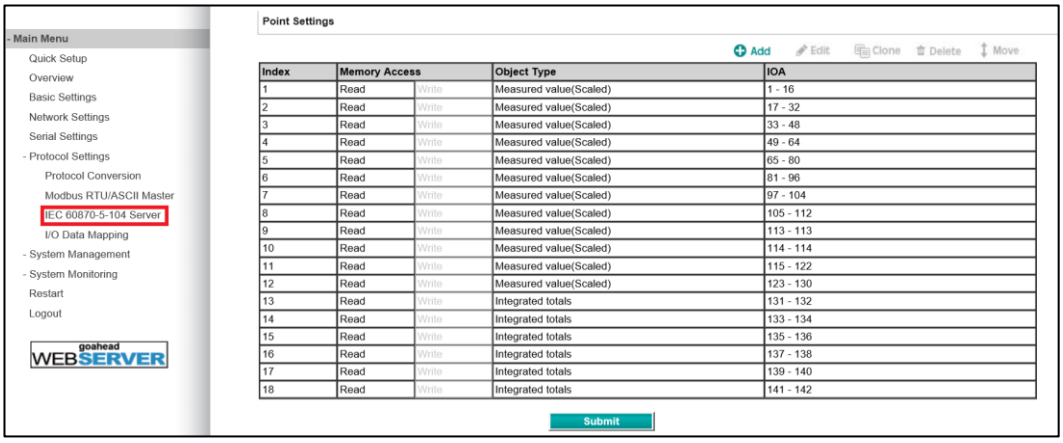


Figure 23. IEC 60870-5-104 Server (Point Settings).

Index numbers 13, 15 and 17 were requested by group 1 counter request, whereas the index numbers 14, 16 and 18 were requested by group 2 counter request. Figure 24 presents the index 13 configurations.

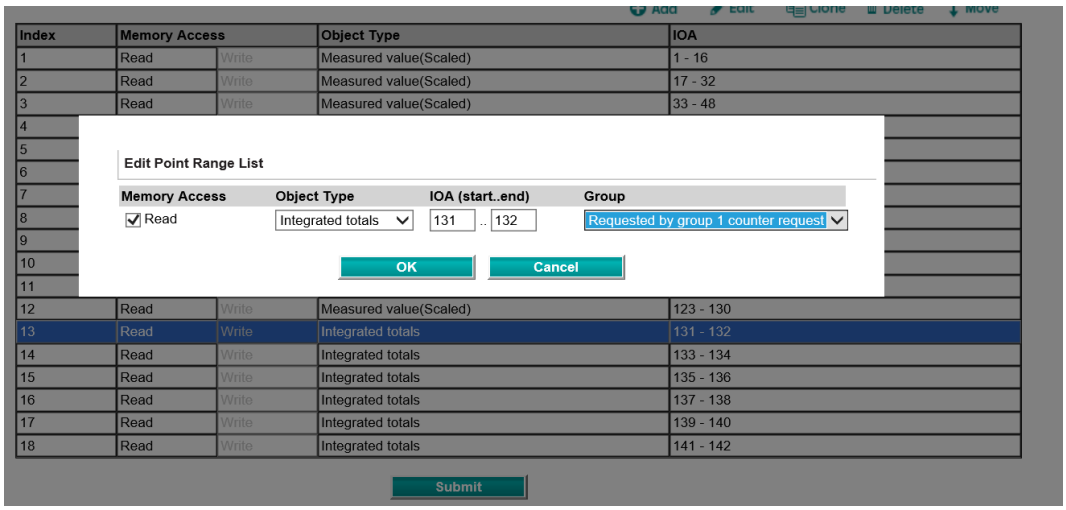
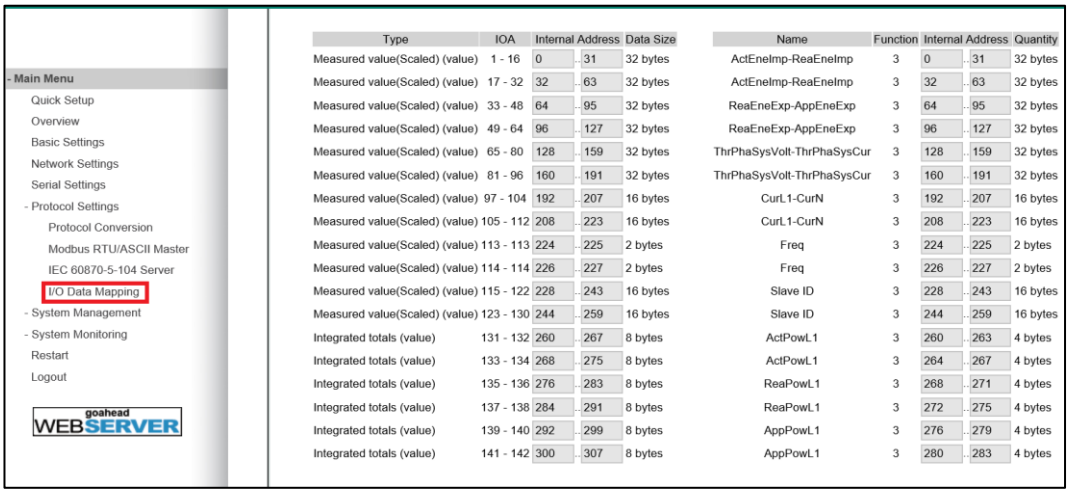


Figure 24. IEC 60870-5-104 Server (Index 13).

It is worth to mention that the integrated totals data object type acts as a counter. The IOA addresses of these kinds of data object types can be double-checked by using the later introduced IEC 60870-5-104 Server Diagnostics tool in cases it seems that the IOA addresses are different than what the data mapping table gives. In this case the IOA addresses of the integrated totals were mapped by using the automatic arrangement tool. The addresses of the integrated totals data object types were different than the table gives and thus the diagnostics tool was

used to find the right addresses. The used data mapping table can be seen in Figure 25. /6/



Type	IOA	Internal Address		Data Size
Measured value(Scaled) (value)	1 - 16	0	31	32 bytes
Measured value(Scaled) (value)	17 - 32	32	63	32 bytes
Measured value(Scaled) (value)	33 - 48	64	95	32 bytes
Measured value(Scaled) (value)	49 - 64	96	127	32 bytes
Measured value(Scaled) (value)	65 - 80	128	159	32 bytes
Measured value(Scaled) (value)	81 - 96	160	191	32 bytes
Measured value(Scaled) (value)	97 - 104	192	207	16 bytes
Measured value(Scaled) (value)	105 - 112	208	223	16 bytes
Measured value(Scaled) (value)	113 - 113	224	225	2 bytes
Measured value(Scaled) (value)	114 - 114	226	227	2 bytes
Measured value(Scaled) (value)	115 - 122	228	243	16 bytes
Measured value(Scaled) (value)	123 - 130	244	259	16 bytes
Integrated totals (value)	131 - 132	260	267	8 bytes
Integrated totals (value)	133 - 134	268	275	8 bytes
Integrated totals (value)	135 - 136	276	283	8 bytes
Integrated totals (value)	137 - 138	284	291	8 bytes
Integrated totals (value)	139 - 140	292	299	8 bytes
Integrated totals (value)	141 - 142	300	307	8 bytes

Name	Function	Internal Address		Quantity
ActEneImp-ReaEneImp	3	0	31	32 bytes
ActEneImp-ReaEneImp	3	32	63	32 bytes
ReaEneExp-AppEneExp	3	64	95	32 bytes
ReaEneExp-AppEneExp	3	96	127	32 bytes
ThrPhaSysVolt-ThrPhaSysCur	3	128	159	32 bytes
ThrPhaSysVolt-ThrPhaSysCur	3	160	191	32 bytes
CurL1-CurN	3	192	207	16 bytes
CurL1-CurN	3	208	223	16 bytes
Freq	3	224	225	2 bytes
Freq	3	226	227	2 bytes
Slave ID	3	228	243	16 bytes
Slave ID	3	244	259	16 bytes
ActPowL1	3	260	263	4 bytes
ActPowL1	3	264	267	4 bytes
ReaPowL1	3	268	271	4 bytes
ReaPowL1	3	272	275	4 bytes
AppPowL1	3	276	279	4 bytes
AppPowL1	3	280	283	4 bytes

Figure 25. I/O Data Mapping.

4.3.2 SYS600 Base and Communication System Configuration

The IEC 60870-5-104 master protocol is used in LAN and WAN networks to connect central stations and substations to each other. In MicroSCADA the IEC 60870-5-104 master protocol uses the Ethernet connection, whereas the IEC 60870-5-104 slave communicates with a master using the TCP/IP. Figure 26 shows an example of how the IEC master sees the SCS as an IEC slave. /12/

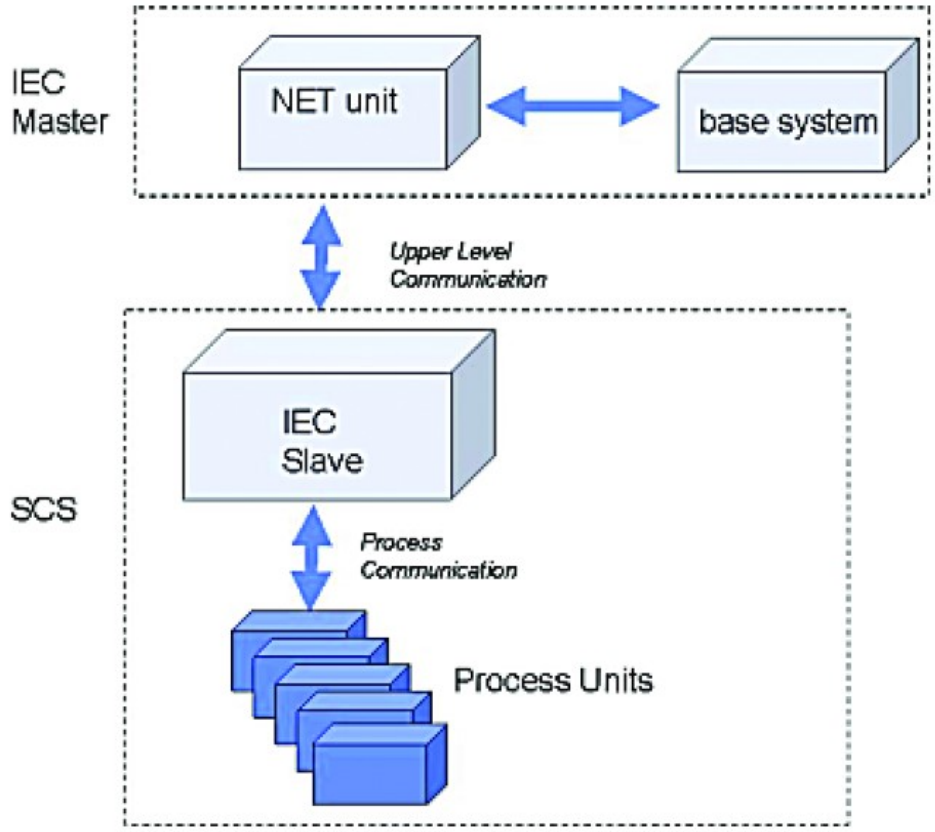


Figure 26. The communication between SYS600 and SCS. /12/

In SCADA, the base system and the communication system was configured to establish communication to the IEC 60870-5-104 slave device. The configuration was made by using the System Configuration Tool. The configuration in SYS600 can be divided into two parts:

- Base system configuration
- Communication system configuration. /12/

In SYS600 the IEC 60870-5-104 master protocol is implemented in the PC-NET software. This means that the PC-NET unit communicates over an INTEGRATED link via the Ethernet, as shown in Figure 27. /12/

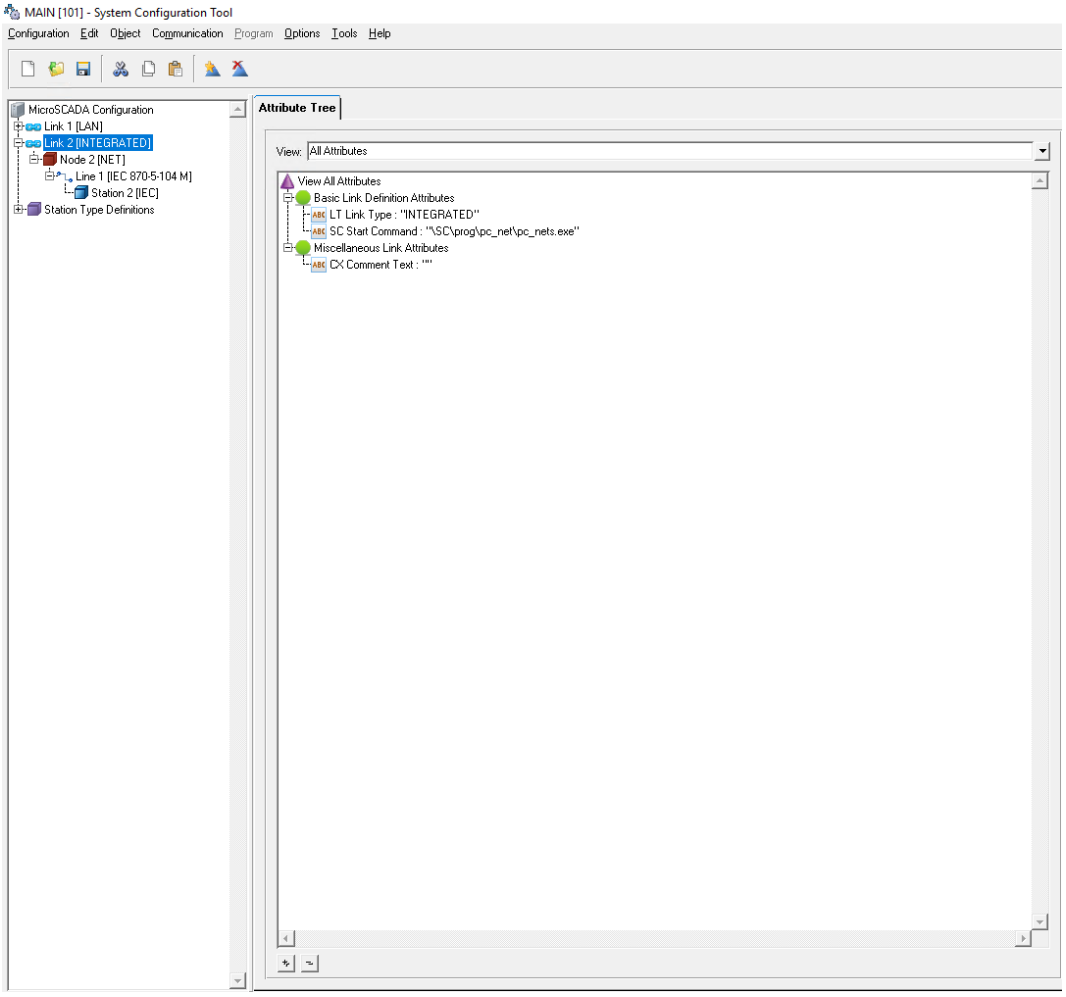


Figure 27. Link 2 (INTEGRATED).

NET instance contains a set of system which specify the existence and the usage of the communication line and the station object. In IEC 60870-5-104, there are two kinds of addresses:

- Station address, which is a common address of an ASDU. There can be several common addresses of an ASDU with the same link address.
- Signal address, which is an information object address. This address is unique for each signal with the same common address of an ASDU. /12/

Figure 28 shows that the station object was named as Station 2 and it was connected to Line 1.

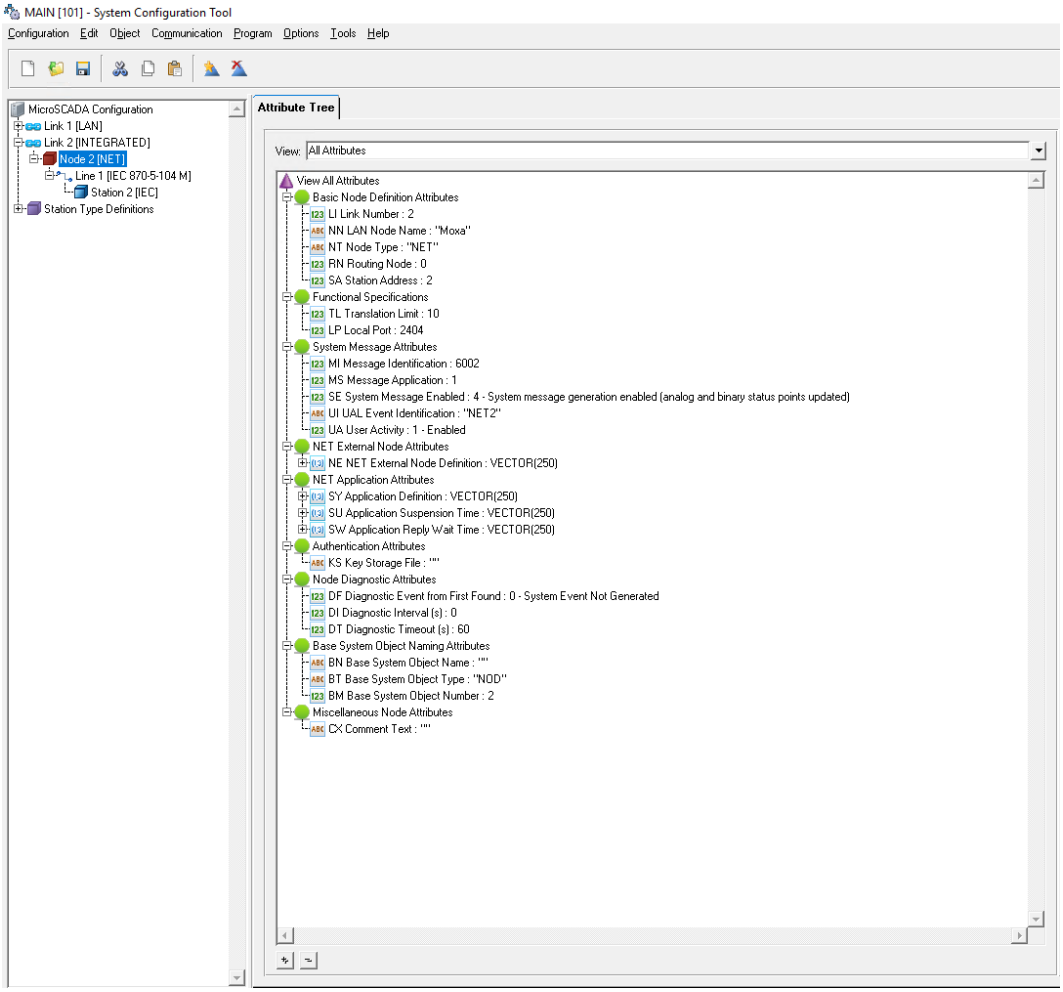


Figure 28. Node 2 (NET).

In SYS600 the communication system can be divided into two layers. These layers have a specific functionality and a set of attributes. The possible layers are:

- Line layer
- Station layer. /12/

The line process of a NET unit performs the functions of the line layer. The purpose of the IEC 60870-5-104 Line layer is to send and receive messages to/from devices using the IEC 60870-5-104 protocol. Figure 29 shows the attributes that were used to configure the IEC 60870-5-104 Master Line 1 in SYS600. /12/

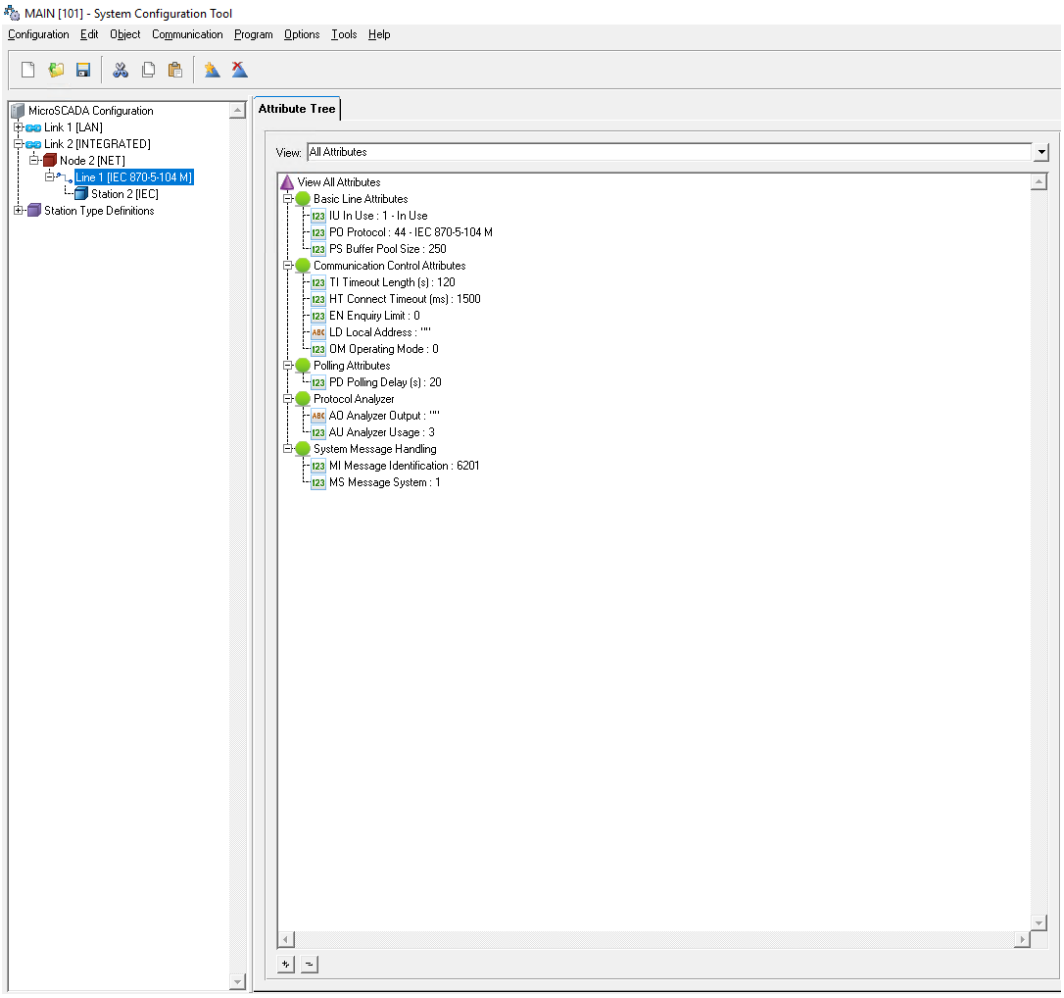


Figure 29. Line 1 (IEC 60870-5-104 Master).

The base system sees each IEC device as a station object that has been created to a line of a NET unit. Each station works then as a protocol converter that converts data between the internal protocol of SYS600 and the IEC 60870-5-104 protocol. The station object takes care of the application level communication with the slave device. Figure 30 shows the most important attributes that used for configuring the IEC 60870-5-104 Station 2 in SYS600. /12/

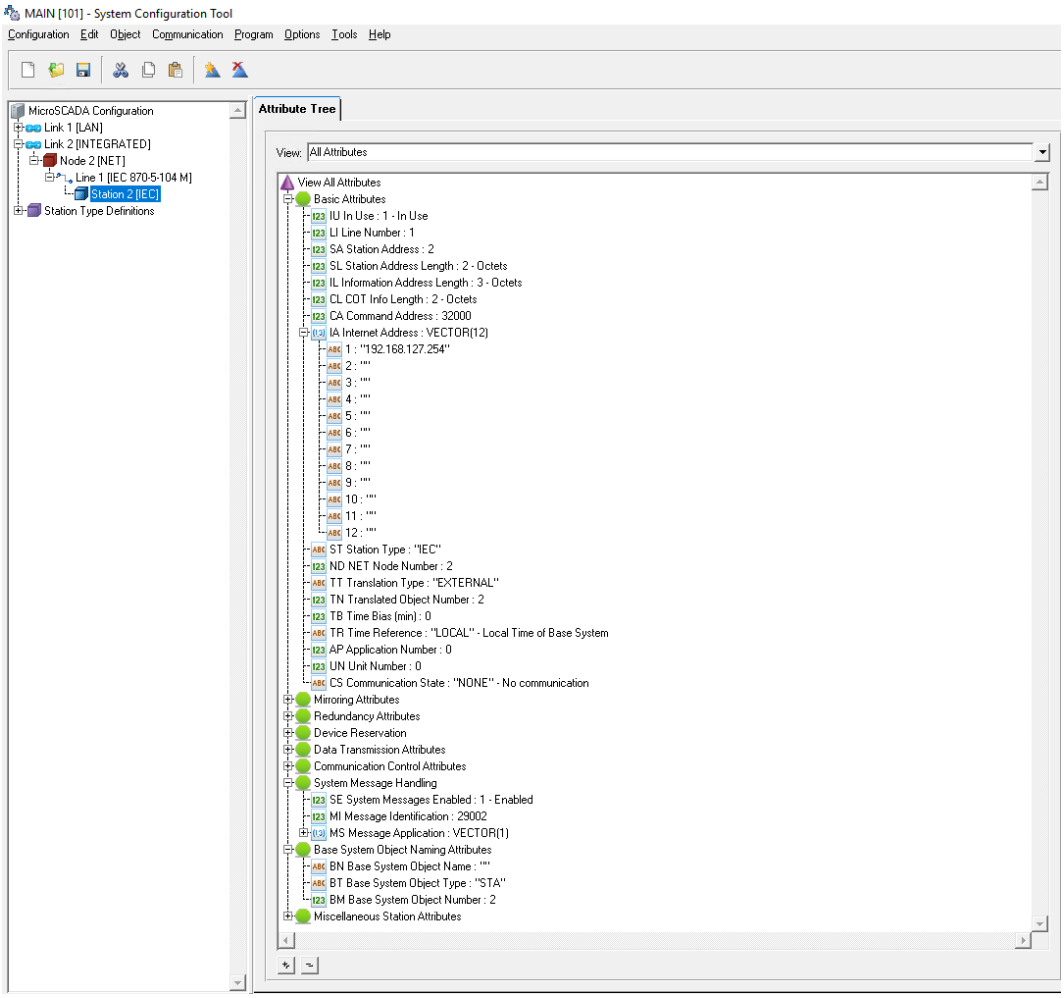


Figure 30. Station 2 (IEC).

4.3.3 SNMP Engineering

SNMP is a protocol for managing and monitoring devices on the IP network. The devices that supported SNMP were the MGate gateway and AFS675 switch. This section gives an example of the configurations which establish the SNMP communication in MGate. The MGate supports the SNMP agent versions V1, V2c and V3 /6/. It was possible to adjust SNMP agent settings in MGate by following the path: System Management > SNMP Agent. The used SNMP agent settings in MGate can be seen in Figure 31.

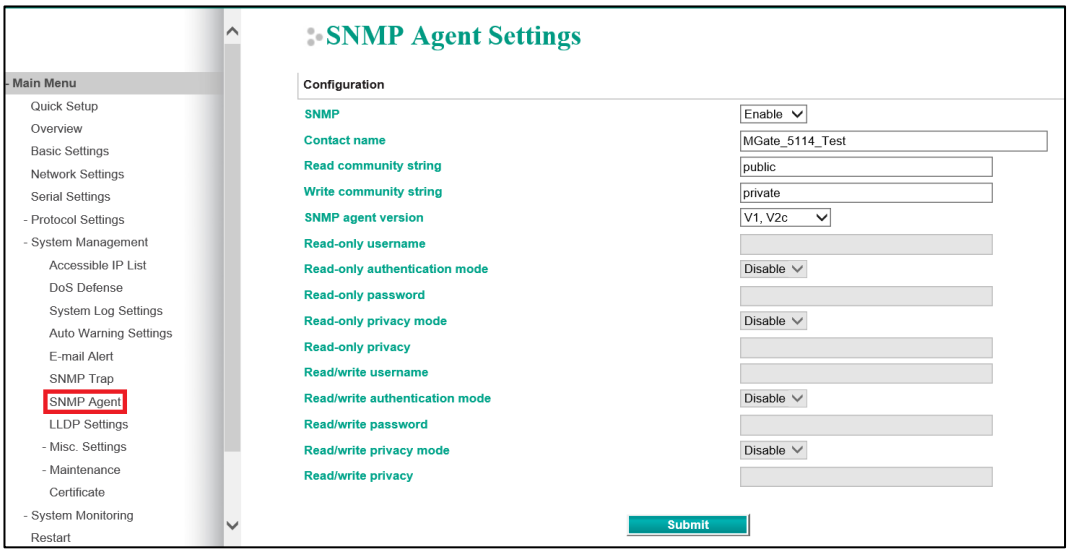


Figure 31. SNMP Agent.

The objects are defined an a MIB, which provides a standard presentation of the information /13/. The MGate has a built-in SNMP agent software that supports RFC1213 MIB-1, as seen in Figure 32. /6/

RFC1213 MIB-II Supported SNMP Variables

System MIB	Interfaces MIB	IP MIB	ICMP MIB
sysDescr	ifNumber	ipForwarding	icmpInMsgs
sysObjectID	ifIndex	ipDefaultTTL	icmpInErrors
sysUpTime	ifDescr	ipInReceives	icmpInDestUnreachs
sysContact	ifType	ipInHdrErrors	icmpInTimeExcds
sysName	ifMtu	ipInAddrErrors	icmpInParmProbs
sysLocation	ifSpeed	ipForwDatagrams	icmpInSrcQuenchs
sysServices	ifPhysAddress	ipInUnknownProtos	icmpInRedirects
	ifAdminStatus	ipInDiscards	icmpInEchos
	ifOperStatus	ipInDelivers	icmpInEchoReps
	ifLastChange	ipOutRequests	icmpInTimestamps
	ifInOctets	ipOutDiscards	icmpTimestampReps
	ifInUcastPkts	ipOutNoRoutes	icmpInAddrMasks
	ifInNUcastPkts	ipReasmTimeout	icmpInAddrMaskReps

Figure 32. RFC1213 MIB-II Supported SNMP Variables in MGate. /6/

The MicroSCADA SNMP OPC Server uses the OID identification to request the information from the SNMP agent. The software named as SnmpB was used to discover the OID number. The OID is a number structure that is used to identify the signal. In SnmpB, the network was scanned on a given IP-range. After the SNMP agent MGate_5114_Test was discovered, it was added to the Remote SNMP Agent list. The OID of the MGate´s Ethernet port link status was found in IfOperStatus, as shown in Figure 33. After the Walk function was done, the Query Results subwindows gave the stats of Ethernet ports 1 and 2. /13/

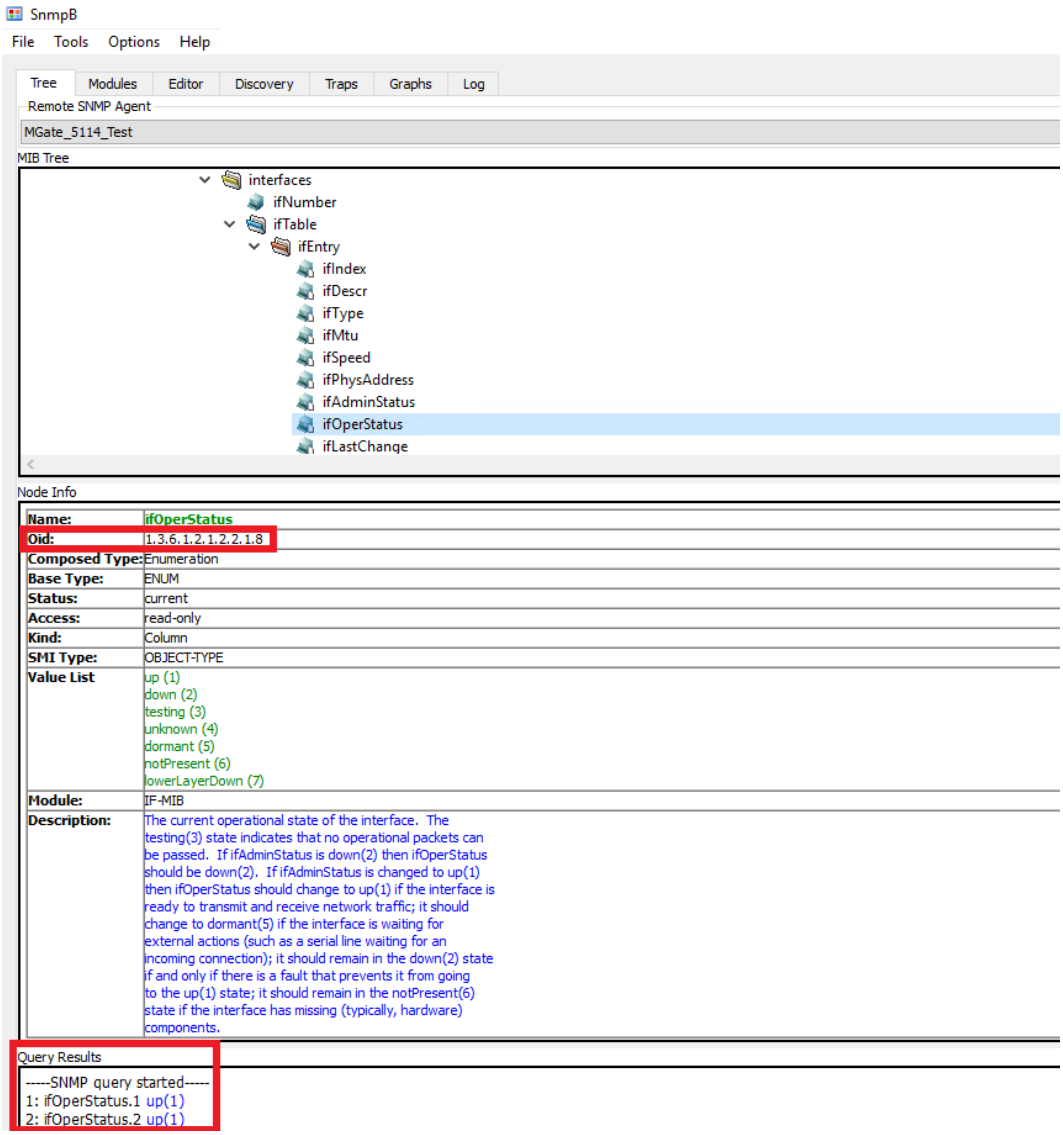


Figure 33. MIB Tree in SnmpB.

A new project was created in the Communication Engineering Tool. OPC Server for SNMP (OPCS1), Subnetwork (Subnet1) and SNMP IED objects (MGate and AFS675) were added under the Computer Node. After the LD was added to tree, the INS data objects were created under the LLN0. These were named as Port01 and Port02. In the Object Properties windows, the last digit was added in Object Identifier to point to a specific port, as seen in Figure 34. /13/

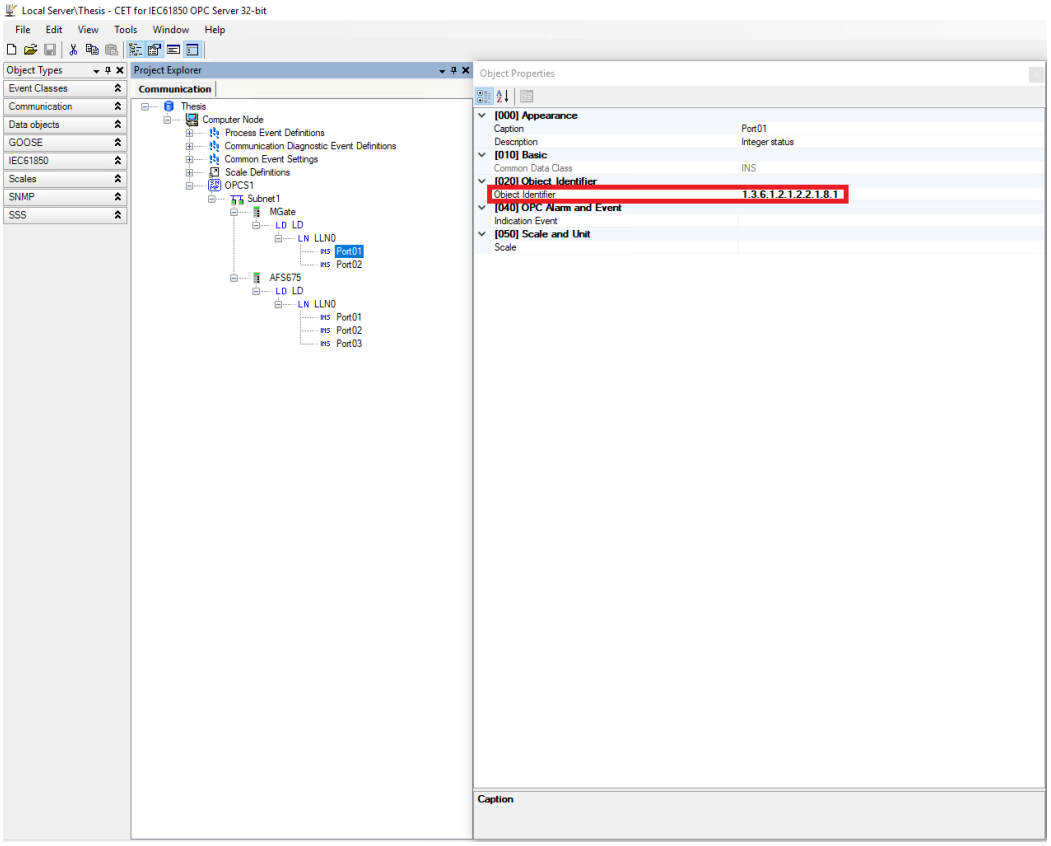


Figure 34. CET for IEC61850 OPC Server (Object Properties of the Port01).

In the SNMP OPC DA Client Configuration Tool, the stations 203 and 204 were created under the CPI Node. The connected OPC items were added under the Group_1 and Ground_2, as Figure 35 presents. After the configuration, the configuration file was named as SNMP.ini and saved to a specific path.

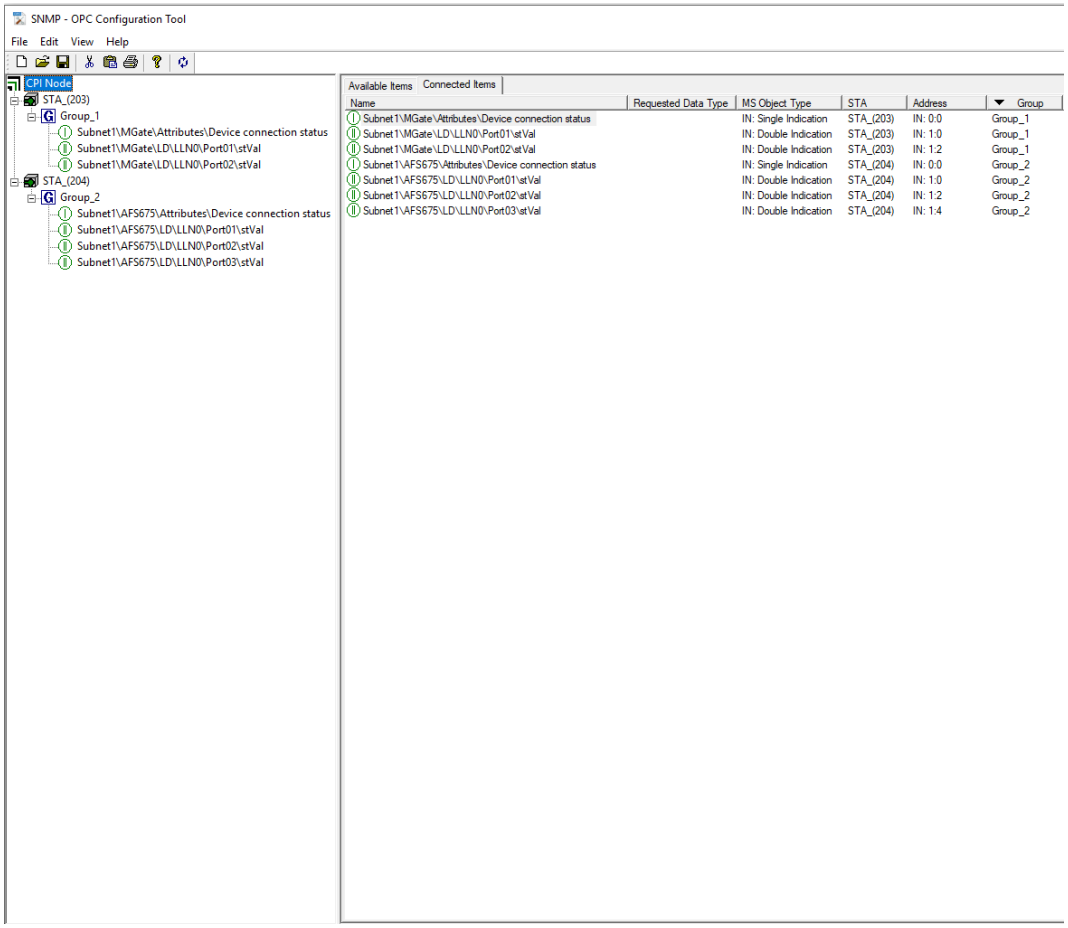


Figure 35. SNMP OPC DA Client Configuration Tool (Connected OPC items).

In the SYS600 System Configuration Tool the Node 3 (IEC61850) was created under the Link 1 (LAN). As seen in Figure 36, the added stations were the same ones as the earlier created stations 203 and 204 in SNMP OPC DA Client Configuration Tool.

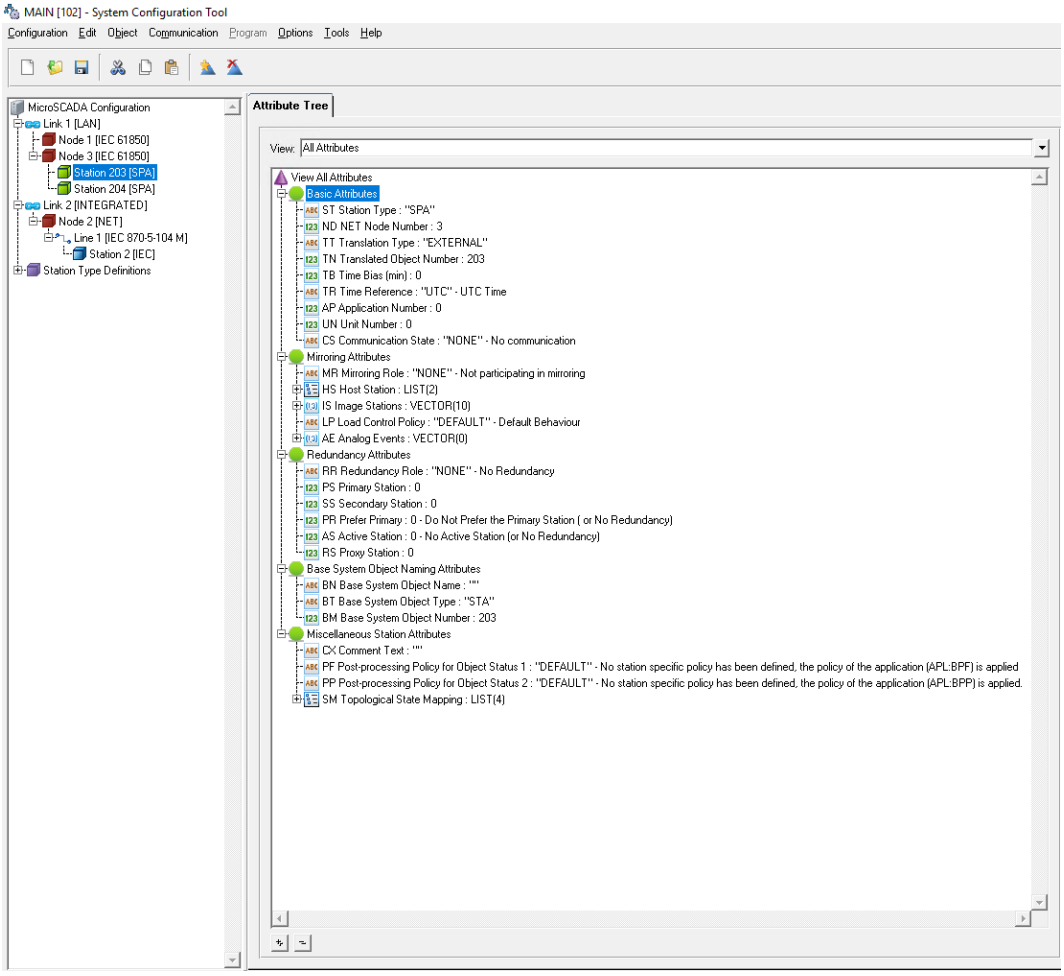


Figure 36. System Configuration Tool (Stations 203 and 204).

The command procedures in SYS600 were created to start and stop DA Client communication. As shown in Figure 37, the configuration file SNMP.ini started automatically after the SYS600 has started.

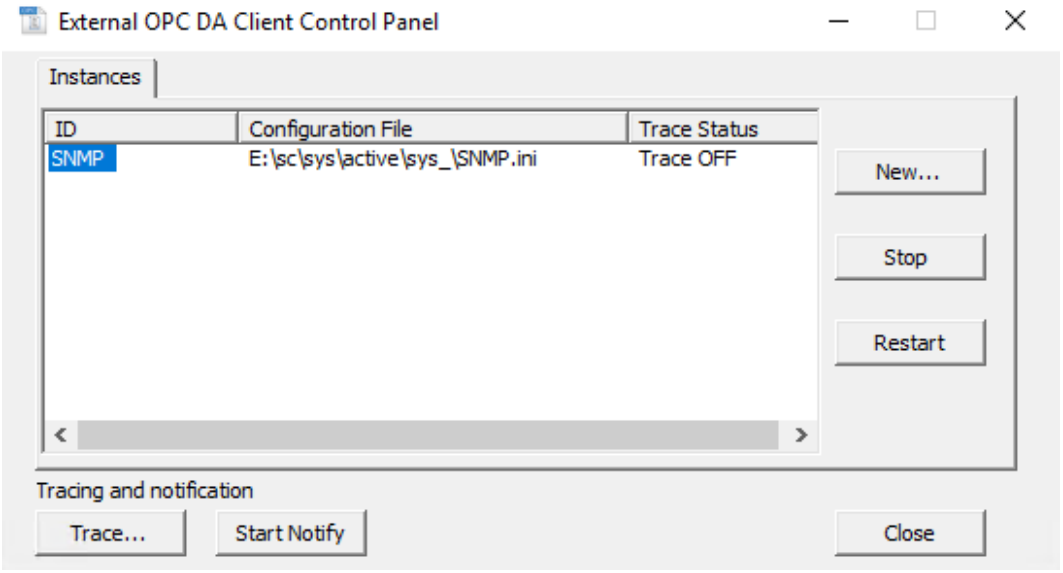


Figure 37. External OPC DA Client Control Panel.

4.3.4 SYS600 Process Object Database

The process object database in SYS600 should contain a process object whose value changes after the process data is received from the process device. The data types and the addresses of the data points used by each process device needed to be identified to create a process object database. The process objects were created for stations 2, 203 and 204. Figure 38 presents the process object database of the station 2. /12/

LN	IX	[UN]	[OA]/IN	[OB]/EH	OI	OX	ST
STA2BAY1CT1	10	2	98	STA2 BAY1 M4MS1	Current L1	A	
STA2BAY1CT1	11	2	100	STA2 BAY1 M4MS1	Current L2	A	
STA2BAY1CT1	12	2	102	STA2 BAY1 M4MS1	Current L3	A	
STA2BAY1CT1	13	2	104	STA2 BAY1 M4MS1	Neutral current I0	A	
STA2BAY1ET1	33	2	4	STA2 BAY1 M4MS1	Active energy - import		
STA2BAY1ET1	34	2	16	STA2 BAY1 M4MS1	Reactive energy - import		
STA2BAY1ET1	35	2	44	STA2 BAY1 M4MS1	Apparent energy - import		
STA2BAY1PT1	73	2	131	STA2 BAY1 M4MS1	Active power L1	kW	
STA2BAY1PT1	76	2	135	STA2 BAY1 M4MS1	Apparent power L1	kVA	
STA2BAY1PT1	79	2	133	STA2 BAY1 M4MS1	Reactive power L1	var	
STA2BAY1SLD	27	2	115	STA2 BAY1 M4MS1	Slave ID 1		
STA2BAY1VT1	24	2	113	STA2 BAY1 M4MS1	Frequency f	Hz	
STA2BAY1VT1	50	2	68	STA2 BAY1 M4MS1	Voltage U1	V	
STA2BAY1VT1	51	2	70	STA2 BAY1 M4MS1	Voltage U2	V	
STA2BAY1VT1	52	2	72	STA2 BAY1 M4MS1	Voltage U3	V	
STA2BAY1VT2	16	2	74	STA2 BAY1 M4MS1	Voltage U12	V	
STA2BAY1VT2	17	2	76	STA2 BAY1 M4MS1	Voltage U23	V	
STA2BAY1VT2	18	2	78	STA2 BAY1 M4MS1	Voltage U31	V	
STA2BAY2CT1	10	2	106	STA2 BAY2 M4MS2	Current L1	A	
STA2BAY2CT1	11	2	108	STA2 BAY2 M4MS2	Current L2	A	
STA2BAY2CT1	12	2	110	STA2 BAY2 M4MS2	Current L3	A	
STA2BAY2CT1	13	2	112	STA2 BAY2 M4MS2	Neutral current I0	A	
STA2BAY2ET1	33	2	20	STA2 BAY2 M4MS2	Active energy - import		
STA2BAY2ET1	34	2	32	STA2 BAY2 M4MS2	Reactive energy - import		
STA2BAY2ET1	35	2	60	STA2 BAY2 M4MS2	Apparent energy - import		
STA2BAY2PT1	73	2	132	STA2 BAY2 M4MS2	Active power L1	kW	
STA2BAY2PT1	76	2	136	STA2 BAY2 M4MS2	Apparent power L1	kVA	
STA2BAY2PT1	79	2	134	STA2 BAY2 M4MS2	Reactive power L1	var	
STA2BAY2SLD	27	2	123	STA2 BAY2 M4MS2	Slave ID 2		
STA2BAY2VT1	24	2	114	STA2 BAY2 M4MS2	Frequency f	Hz	
STA2BAY2VT1	50	2	84	STA2 BAY2 M4MS2	Voltage U1	V	
STA2BAY2VT1	51	2	86	STA2 BAY2 M4MS2	Voltage U2	V	
STA2BAY2VT1	52	2	88	STA2 BAY2 M4MS2	Voltage U3	V	
STA2BAY2VT2	16	2	90	STA2 BAY2 M4MS2	Voltage U12	V	
STA2BAY2VT2	17	2	92	STA2 BAY2 M4MS2	Voltage U23	V	
STA2BAY2VT2	18	2	94	STA2 BAY2 M4MS2	Voltage U31	V	

Figure 38. The process object database of the station 2.

Figure 39 shows an example of the used process signal type of the station 2. The other used process signal type was IEC analog input. The used process signal type of the stations 203 and 204 was the IEC 61850 double indication.

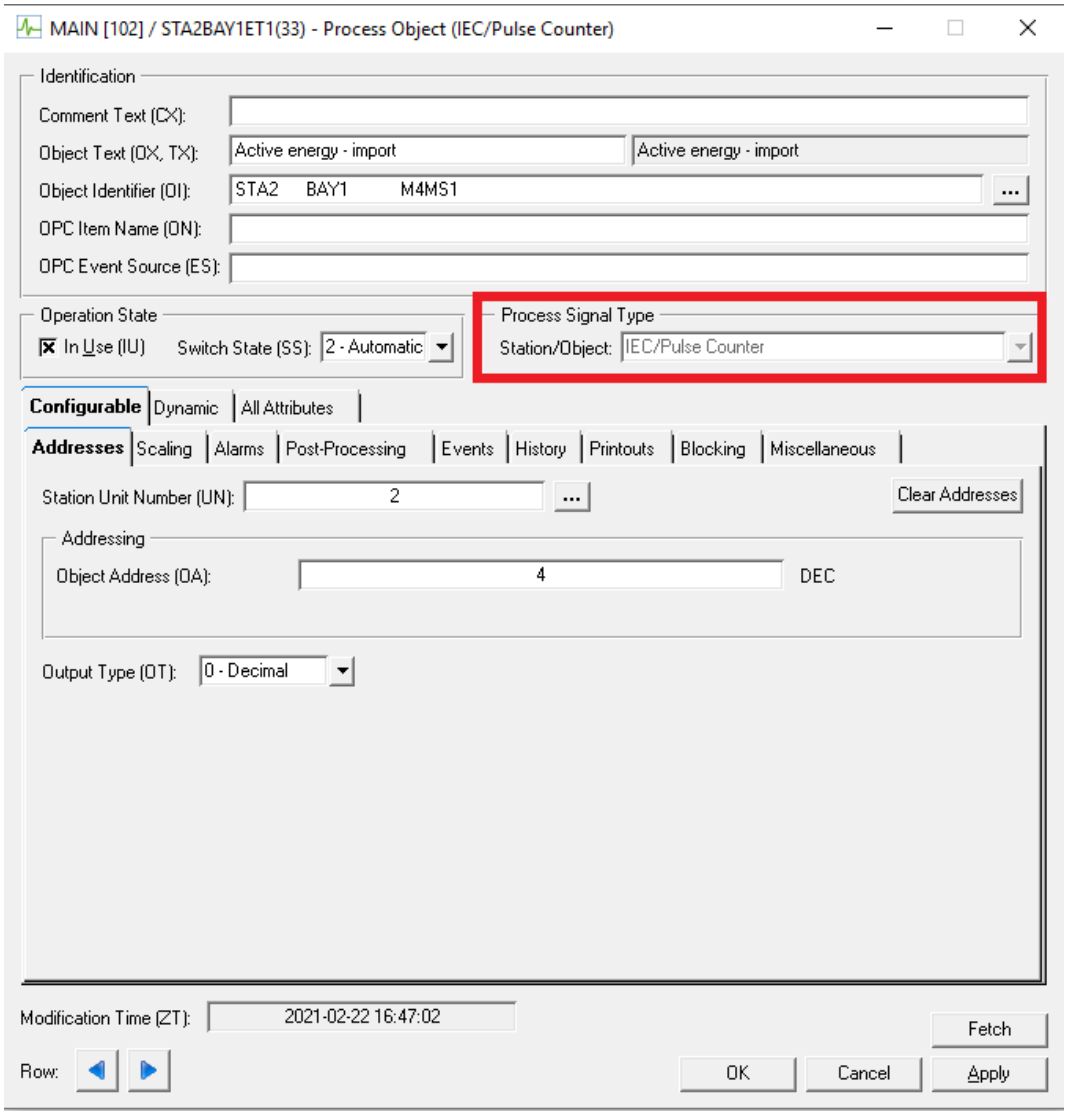


Figure 39. Example of the used process signal type of the station 2.

4.3.5 Testing the Connection and Configuration

As seen in Figures 40 and 41, the Modbus RTU/ASCII Diagnostics and the IEC 60870-5-104 Server Diagnostics webpages in MGate provided the needed status information. In these webpages it was possible to verify that the data or packet counters were running and thus to make sure that the communications were running smoothly. These webpages can be founded, when following the path: System Monitoring > Protocol Status >Modbus RTU/ASCII Diagnostics or IEC 60870-5-104 Server Diagnostics.

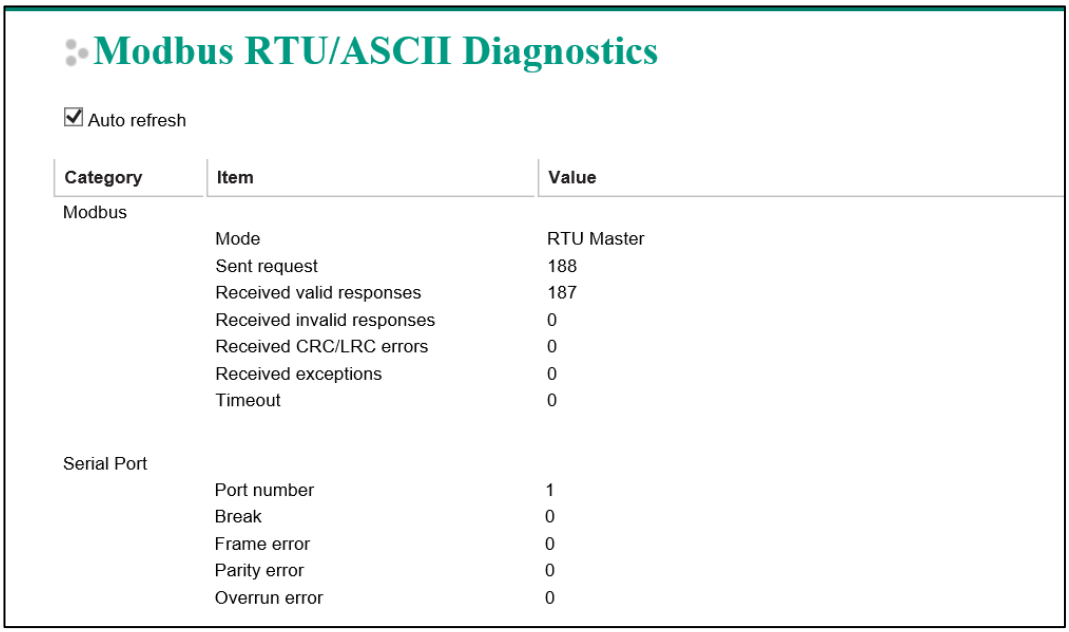


Figure 40. Modbus RTU Diagnostics.

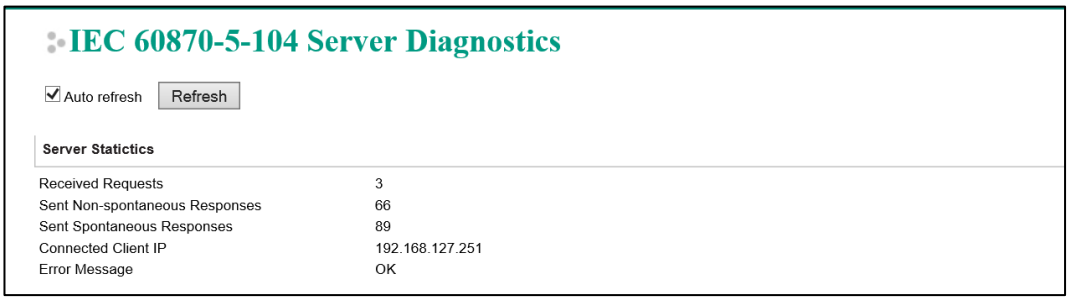


Figure 41. IEC 60870-5-104 Server Diagnostics.

In the SYS600 System Configuration Tool, the diagnostic counter was indicating the number of received and sent messages, when the communication between the master and slave was running. Figure 42 presents the station 2 in online mode.

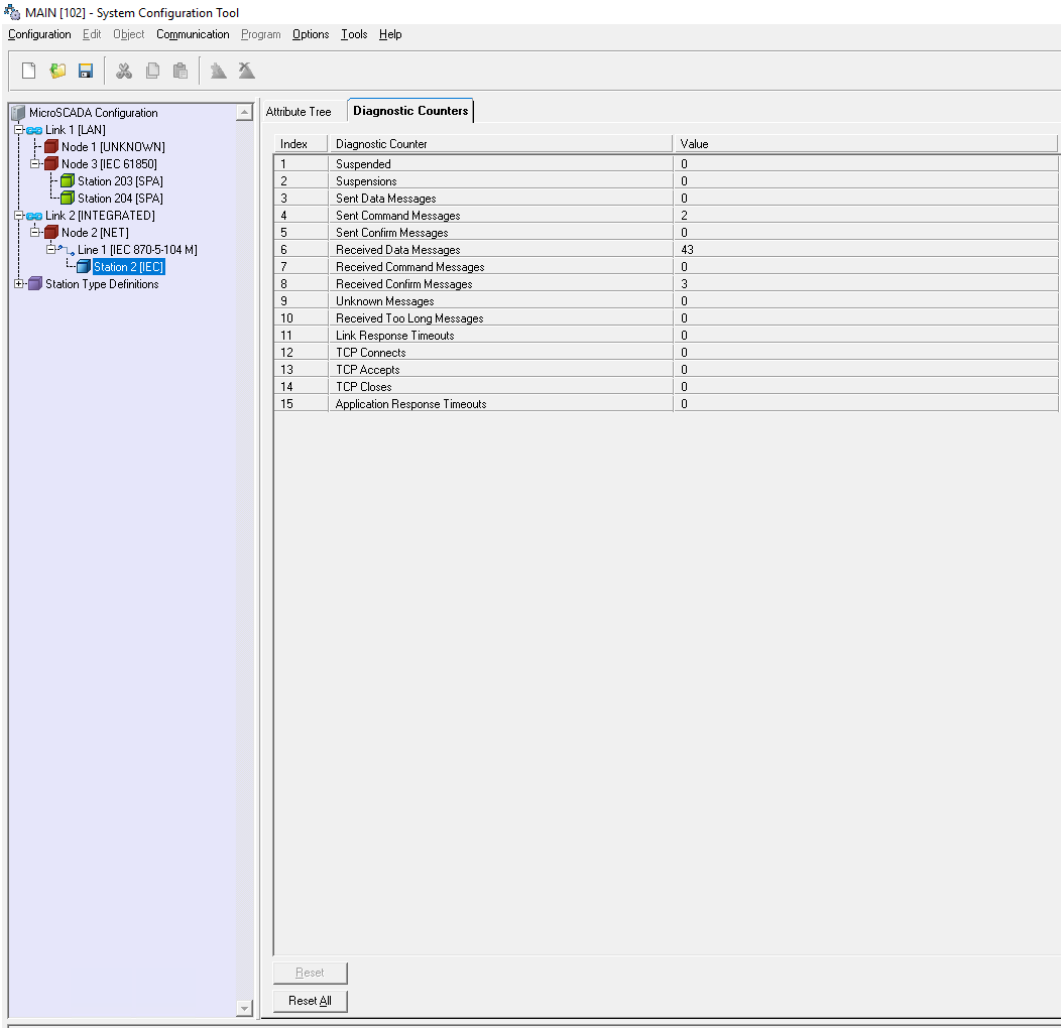


Figure 42. Station 2 in online mode.

In SYS600, the System Self Supervision display was created by using Display Builder. Its purpose in the MicroSCADA system is to supervise and monitor the system itself. The installation of System Self Supervision functionality was enabled from the Tools menu of the System Configuration Tool. The supervised SNMP devices were the MGate 5114 Series and AFS675 port statuses. As shown in Figure 43, the System Self Supervision display also contained the information of the station 2 communication and process display devices measurement panels. Green

colour in measurement panels, communication ports and station 2 indication mean status ok. The communication of the station 2 was in running state. /14/

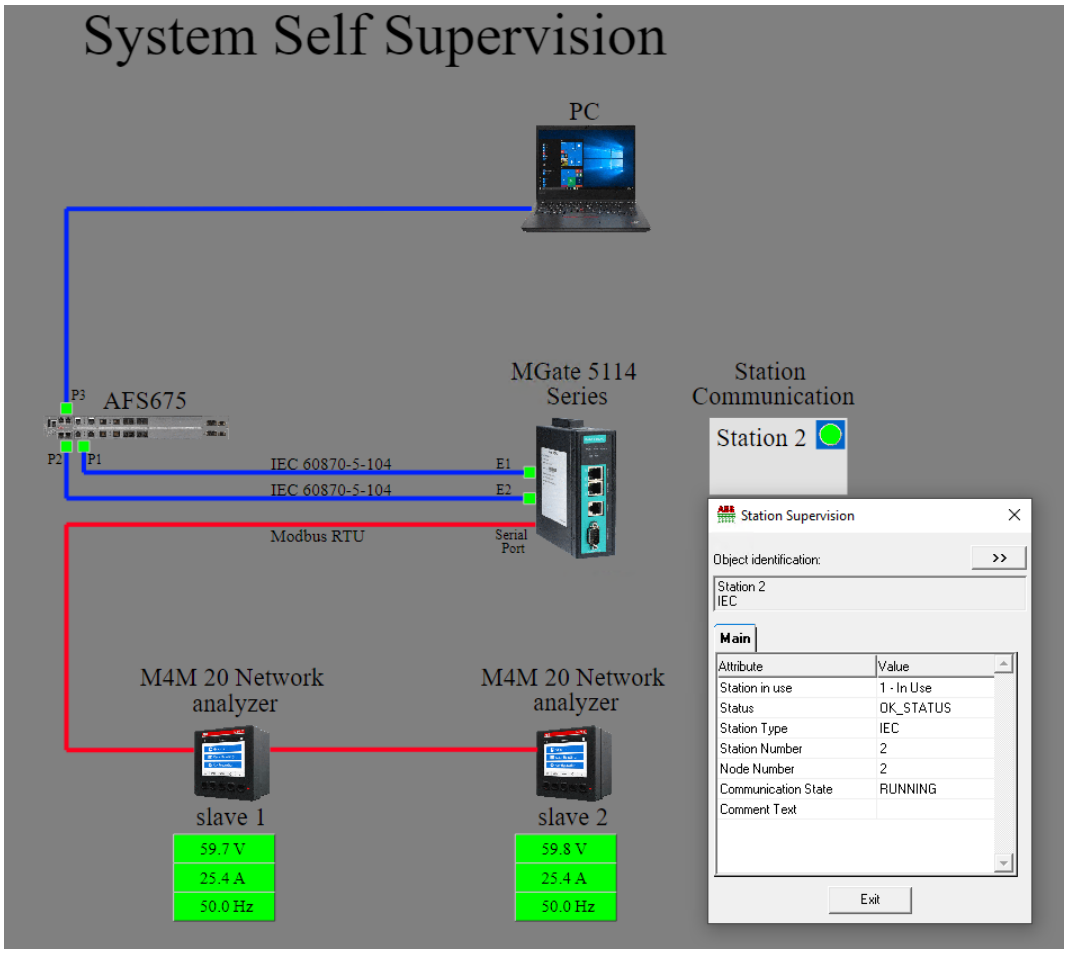


Figure 43. System Self Supervision (No malfunction situations).

Figure 44 shows that process object Active power L1 value was 1.52 kilowatts.

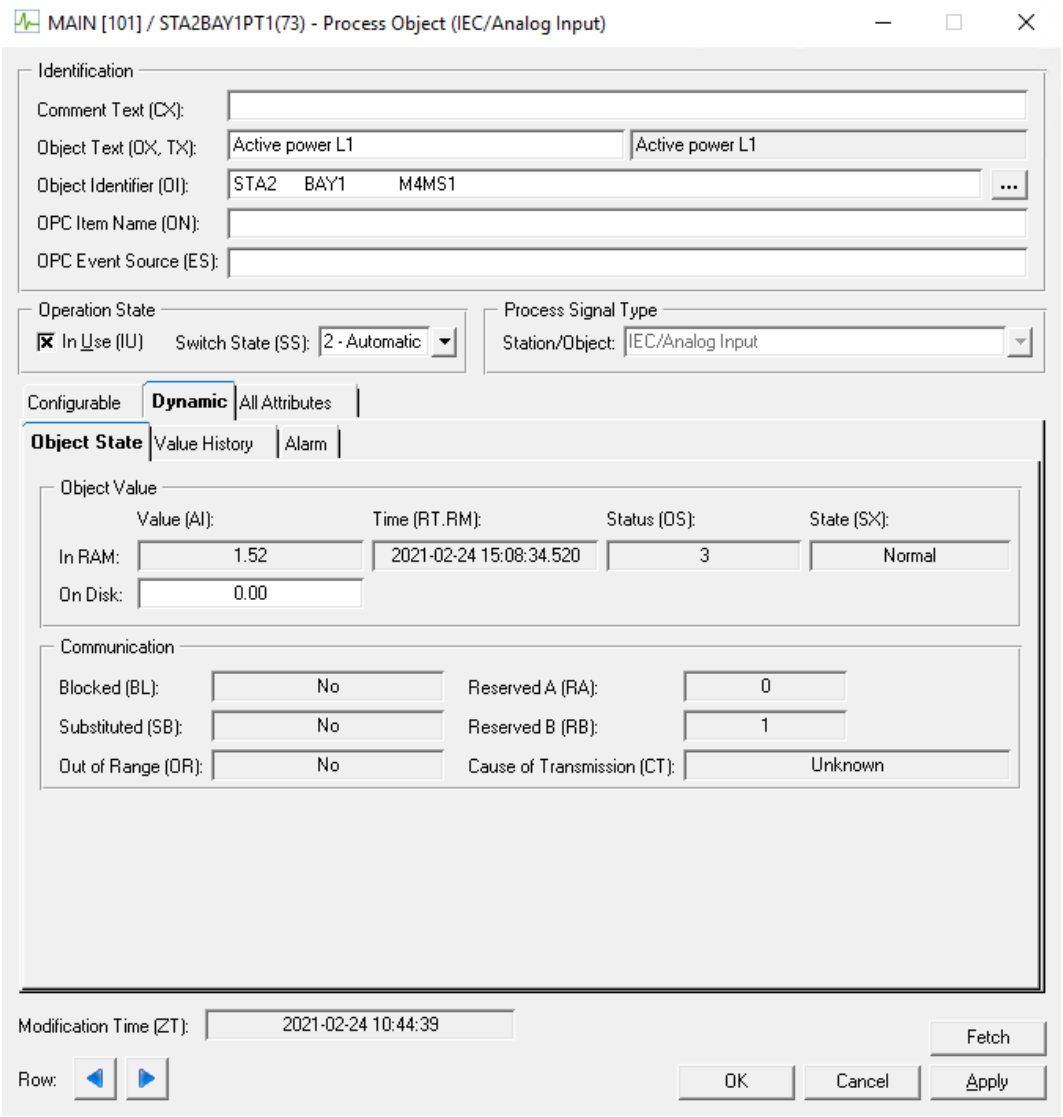


Figure 44. The value of the process object Active power L1.

Figure 45 shows the same measured value in M4M 20 Network analyzer slave 1.

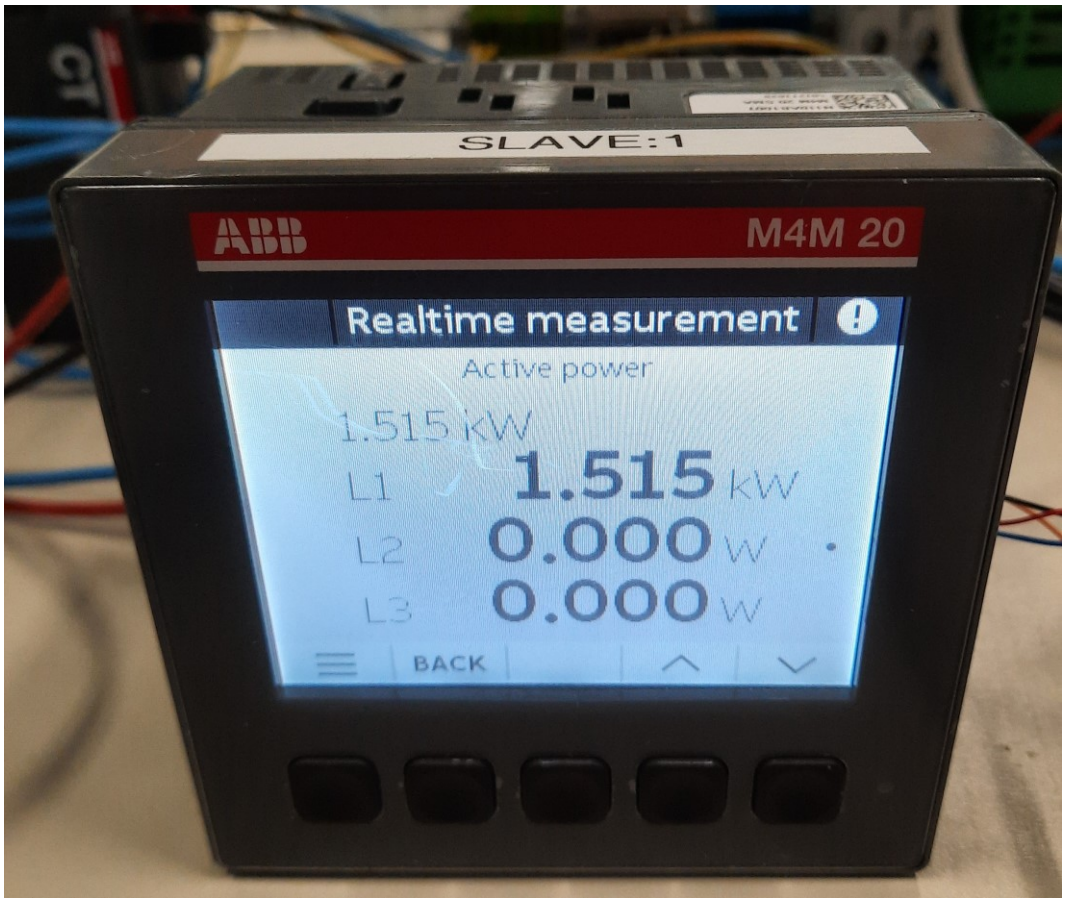


Figure 45. Active power L1 in M4M 20 Network analyzer slave 1.

As a conclusion we can state that MGate is also capable to read multiple Modbus registers without any performance problems.

4.4 MGate 5114 Series Performance in a Malfunction Situations

Typically, the infrastructure SCADA system includes a large numbers of various energy meters. Different types of the malfunction situations must be noticed and informed to the SCADA system. When an error occurs in the SCADA system, finding the root cause can be a difficult and complex task. The MGate provides different types of useful troubleshooting tools, which are helpful in case of possible malfunction situations. The following simulated malfunction situations are the typical fault situations in infrastructure SCADA projects.

4.4.1 Malfunction Situation in M4M 20 Network Analyzer Slave 1

The first simulated test was the malfunction situation of the M4M 20 Network analyzer slave 1. The aim of this section was to ensure that the performance of the data collection of the remaining analyzer is not be disturbed even if the other analyzer communication fails due to power error. Figure 46 presents the System Self Supervision display when the M4M 20 slave 1 is not responding and thus its measurement statuses are in unknown state. Otherwise the statuses of the system are in ok status.

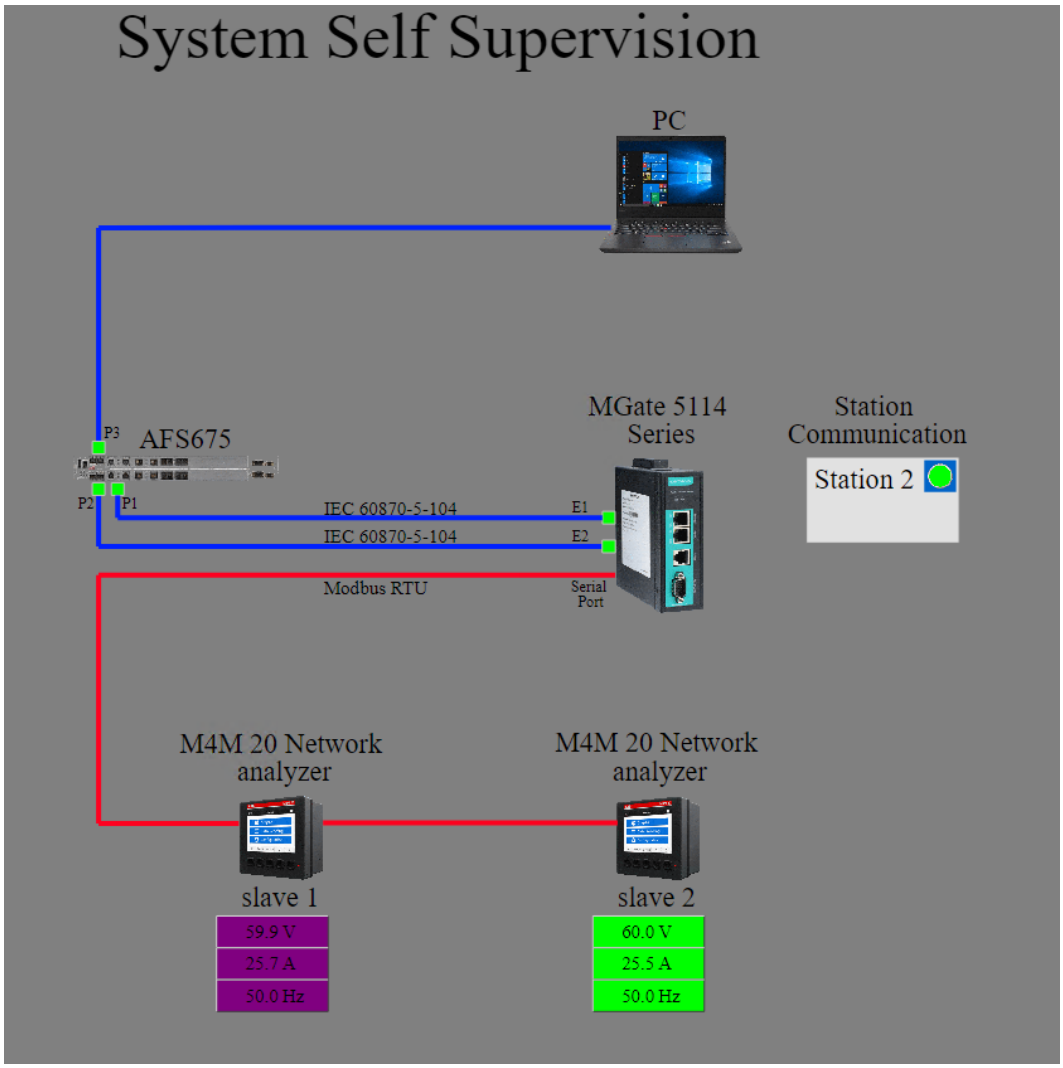
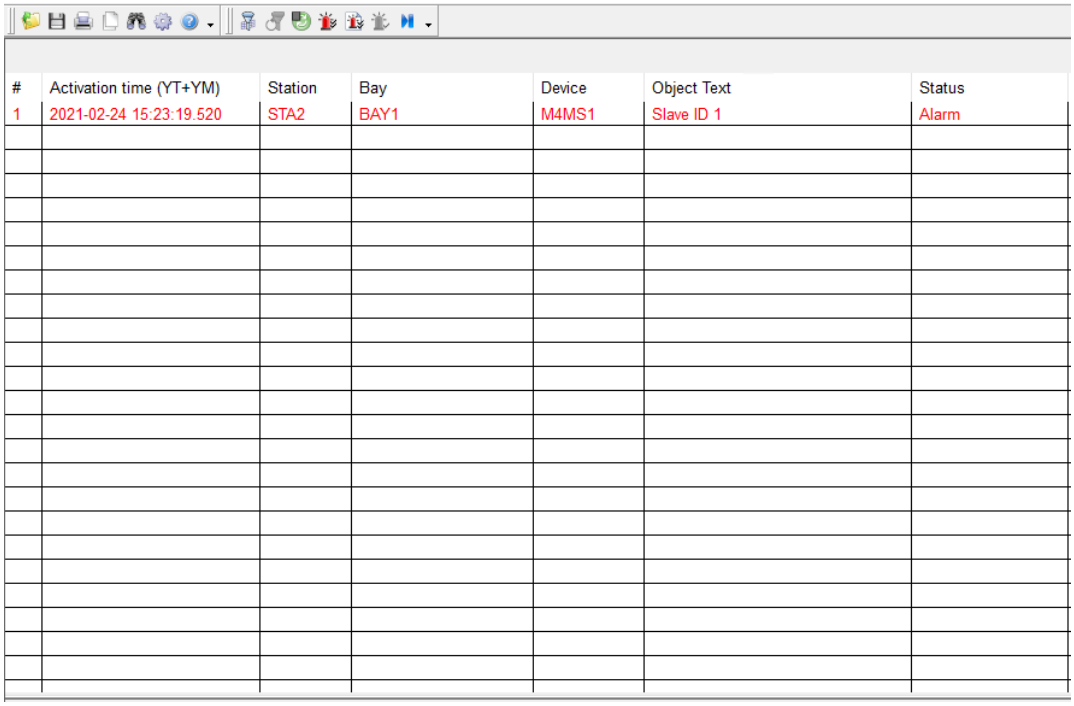


Figure 46. System Self Supervision (M4M 20 slave 1 is not responding).

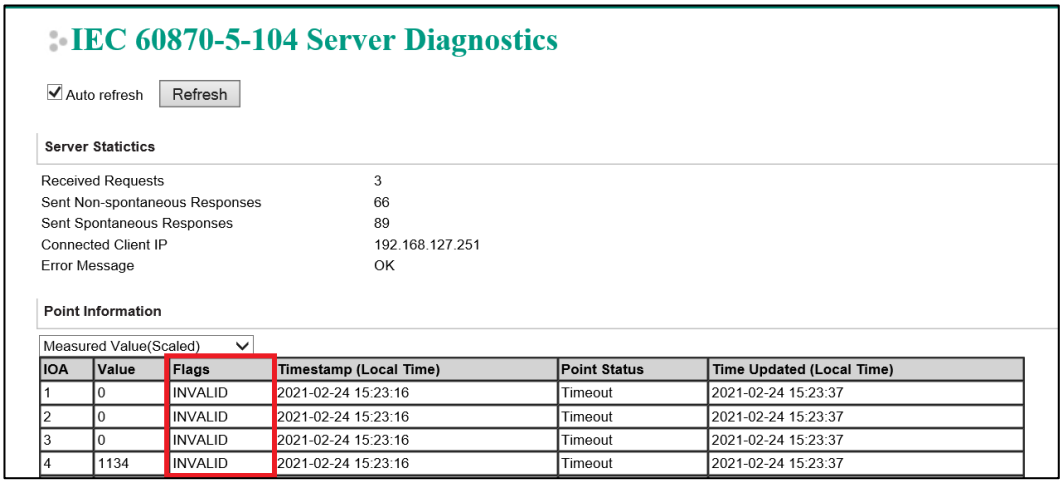
The Alarm Display in SYS600 shows a summary of the present alarm situation of the supervised system. As shown in Figure 47, the device M4MS1 indicated alarm status. Usually, each alarm is presented as an alarm text row, which describes the cause of the alarm in the process. In this case the alarm text row has a time stamp, an object identification, an object text and text indicating the alarm status.



#	Activation time (YT+YM)	Station	Bay	Device	Object Text	Status
1	2021-02-24 15:23:19.520	STA2	BAY1	M4MS1	Slave ID 1	Alarm

Figure 47. Alarm Display (M4M 20 slave 1 is not responding).

As shown in Figure 48, the diagnostics webpage in MGate provides status information for IEC 60870-5-104 troubleshooting. MGate uses the flag capability to indicate the state of the object point status. The Modbus commands in M4M 20 slave 1 failed due to communication error, which was caused by the loss of power. The IOA objects flags of the M4M 20 slave 1 turned from “VALID” to “INVALID”. This webpage can be found by following the path: System Monitoring > Protocol Status > IEC 60870-5-104 Server Diagnostics.



IEC 60870-5-104 Server Diagnostics

Auto refresh | Refresh

Server Statictics

Received Requests	3
Sent Non-spontaneous Responses	66
Sent Spontaneous Responses	89
Connected Client IP	192.168.127.251
Error Message	OK

Point Information

Measured Value(Scaled)

IOA	Value	Flags	Timestamp (Local Time)	Point Status	Time Updated (Local Time)
1	0	INVALID	2021-02-24 15:23:16	Timeout	2021-02-24 15:23:37
2	0	INVALID	2021-02-24 15:23:16	Timeout	2021-02-24 15:23:37
3	0	INVALID	2021-02-24 15:23:16	Timeout	2021-02-24 15:23:37
4	1134	INVALID	2021-02-24 15:23:16	Timeout	2021-02-24 15:23:37

Figure 48. IEC 60870-5-104 Server Diagnostics (Flags are turned INVALID).

As a conclusion of the first simulated fault situation we can state that the performance of the data collection of the remaining analyzer continues even if the other analyzer was not responding. The unnormal operation of the M4M 20 slave 1 was seen in System Self Supervision display and informed to the Alarm Display in SYS600. The malfunction of the other analyzer was also seen in MGate´s diagnostics tool.

4.4.2 Malfunction Situation in Both M4M 20 Network Analyzers

The second simulated test was the malfunction situation, when the both M4M 20 Network analyzer slaves were powered off. The aim of this section was to ensure that the MGate continues to respond to SCADA and its normal operation is not disturbed even if the communication of the analyzers fails due to power error. Figure 49 presents the System Self Supervision display when the M4M 20 slaves are not responding and thus the measurement statuses of the analyzers are in unknown state. Otherwise the system is in ok status.

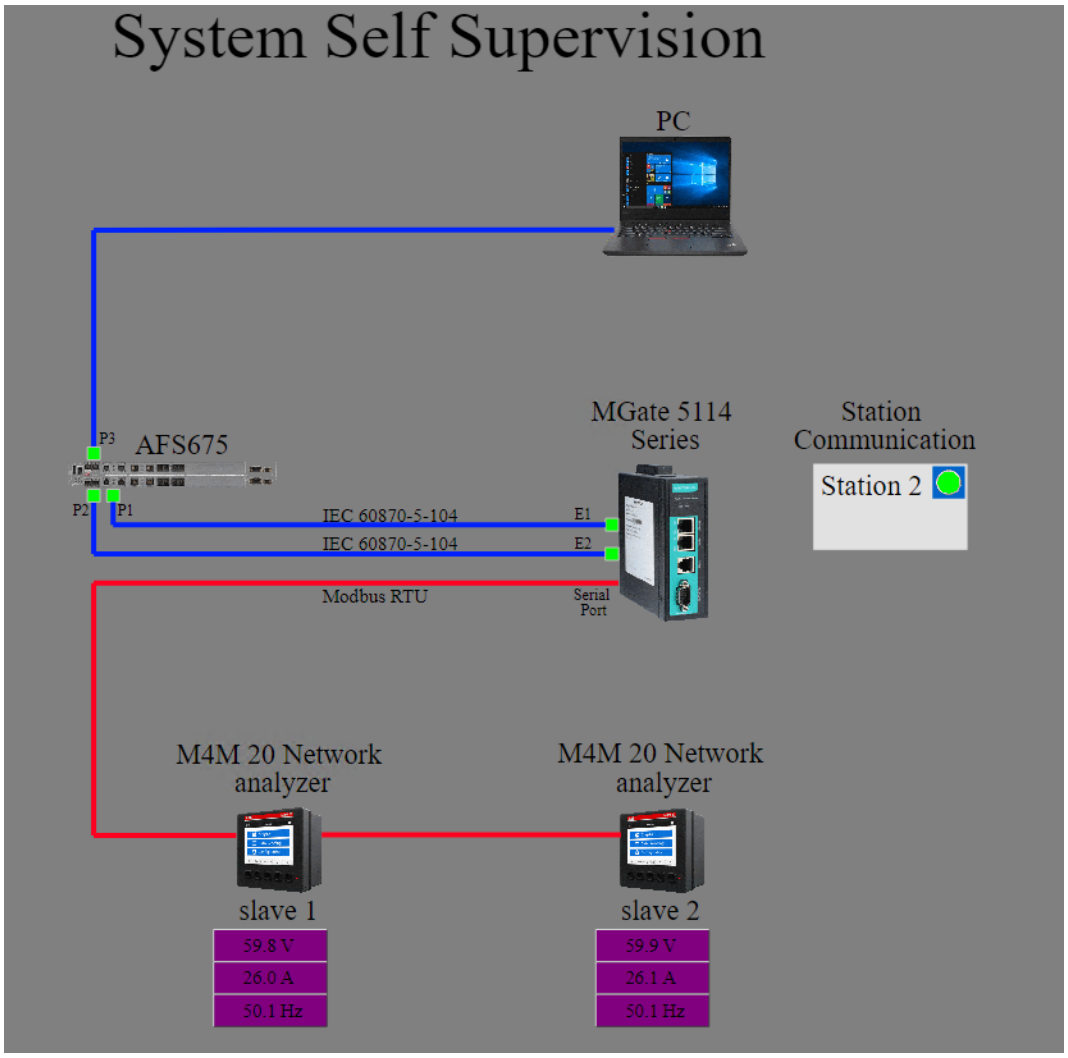
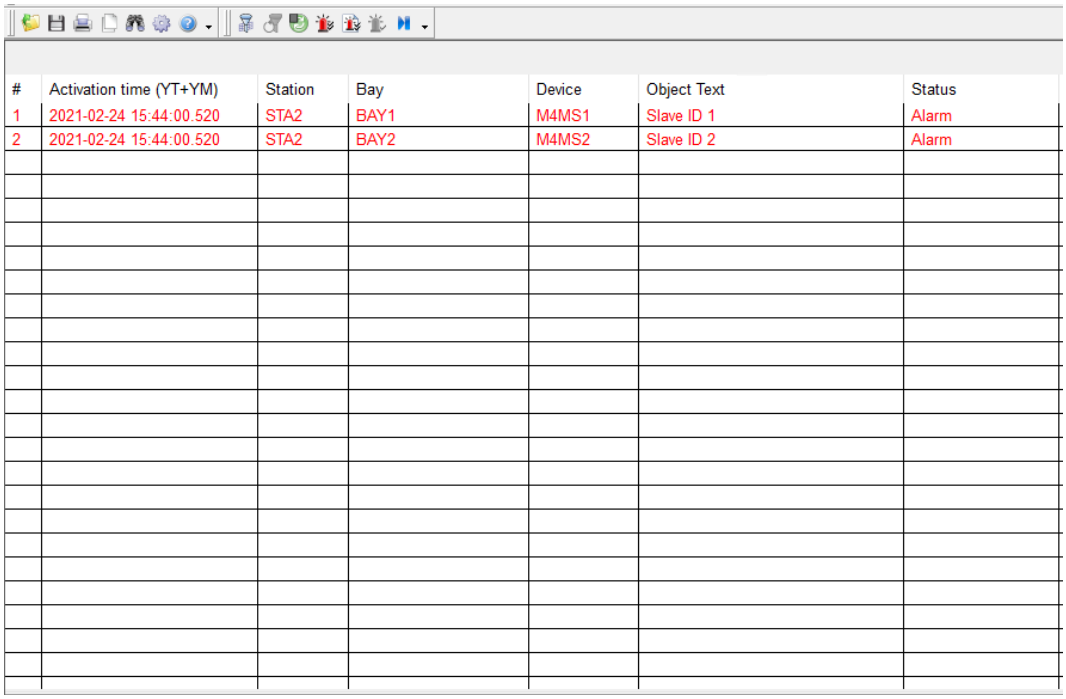


Figure 49. System Self Supervision (M4M 20 slaves are not responding).

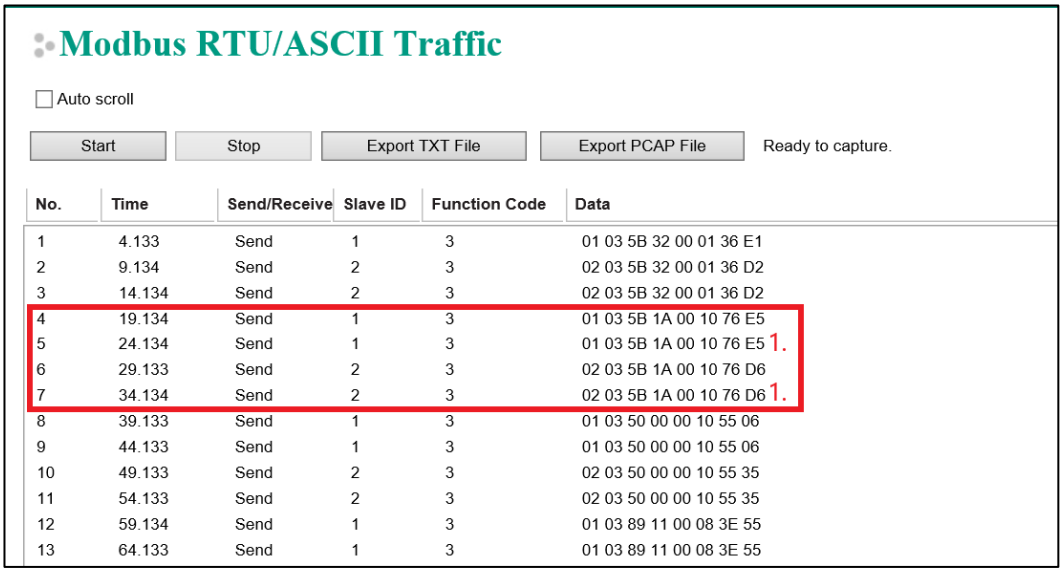
The devices M4MS1 and M4MS2 indicated the alarm status, as presented in Figure 50.



#	Activation time (YT+YM)	Station	Bay	Device	Object Text	Status
1	2021-02-24 15:44:00.520	STA2	BAY1	M4MS1	Slave ID 1	Alarm
2	2021-02-24 15:44:00.520	STA2	BAY2	M4MS2	Slave ID 2	Alarm

Figure 50. Alarm Display (M4M 20 slaves are not responding).

MGate has built-in traffic monitoring that provides comprehensive information of all the raw data. That helps the user to identify the problem quickly and easily. The traffic log can be viewed in the popular troubleshooting tool Wireshark. In the traffic monitoring tool the user can export the PCAP file so that it is possible to import data into a Wireshark tool, based on Ethernet and serial troubleshooting demands. It is also possible to export the traffic log as a TXT file and then viewed in Notepad or similar type of text editor program. Figure 51 presents the Modbus RTU/ASCII Traffic webpage, when the maximum retry value was 1 and response timeout was 5000 milliseconds. /11/



Modbus RTU/ASCII Traffic

Auto scroll

Start | Stop | Export TXT File | Export PCAP File | Ready to capture.

No.	Time	Send/Receive	Slave ID	Function Code	Data
1	4.133	Send	1	3	01 03 5B 32 00 01 36 E1
2	9.134	Send	2	3	02 03 5B 32 00 01 36 D2
3	14.134	Send	2	3	02 03 5B 32 00 01 36 D2
4	19.134	Send	1	3	01 03 5B 1A 00 10 76 E5
5	24.134	Send	1	3	01 03 5B 1A 00 10 76 E5 1.
6	29.133	Send	2	3	02 03 5B 1A 00 10 76 D6
7	34.134	Send	2	3	02 03 5B 1A 00 10 76 D6 1.
8	39.133	Send	1	3	01 03 50 00 00 10 55 06
9	44.133	Send	1	3	01 03 50 00 00 10 55 06
10	49.133	Send	2	3	02 03 50 00 00 10 55 35
11	54.133	Send	2	3	02 03 50 00 00 10 55 35
12	59.134	Send	1	3	01 03 89 11 00 08 3E 55
13	64.133	Send	1	3	01 03 89 11 00 08 3E 55

Figure 51. Traffic (Maximum retry=1, response timeout=5000 milliseconds).

As a conclusion of the second simulated fault situation we can state that the MGate continues to respond to the SCADA and its normal operation is not disturbed even if the M4M 20 slaves are not responding. The unnormal operation of the analyzers was informed to the SCADA and it was also seen in MGate`s traffic monitoring tool.

4.4.3 Malfunction Situation in MGate 5114 Series

The third simulated situation was the malfunction of the MGate 5114 Series. The aim of this section was to ensure that the unnormal situation of the MGate is informed to the SCADA and it also activates the suitable alarms. When MGate was powered off, this caused different types of alarms. As seen in Figure 52, the ports P1 and P2 are in alarm state, whereas the ports E1 and E2 are in unknown state. The communication state of the station 2 is in suspended state. The measurement panels of the field devices are in unknown state.

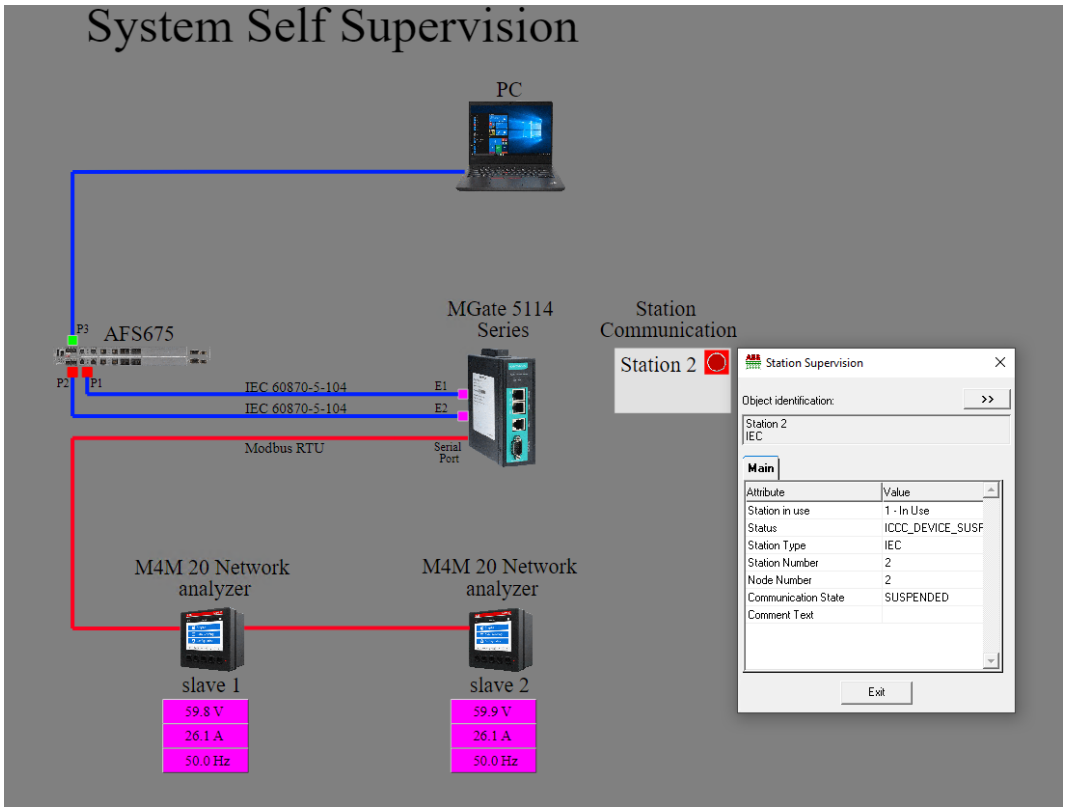
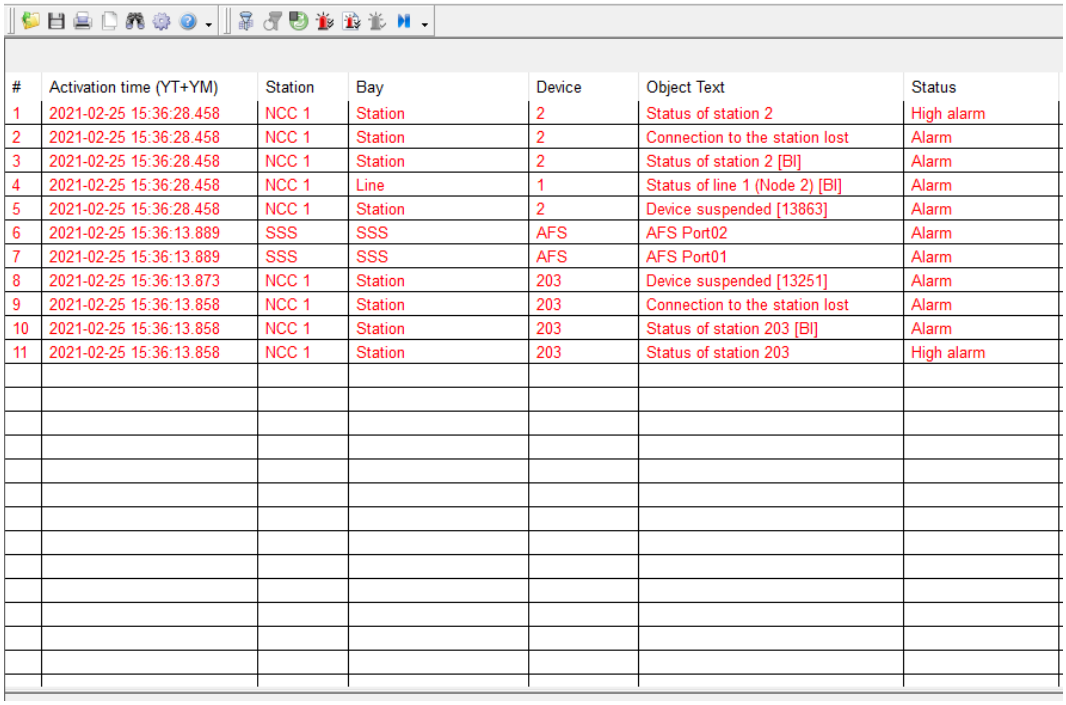


Figure 52. System Self Supervision (MGate 5114 Series is not responding).

Figure 53 presents the alarms, which were activated when the MGate was powered off.



#	Activation time (YT+YM)	Station	Bay	Device	Object Text	Status
1	2021-02-25 15:36:28.458	NCC 1	Station	2	Status of station 2	High alarm
2	2021-02-25 15:36:28.458	NCC 1	Station	2	Connection to the station lost	Alarm
3	2021-02-25 15:36:28.458	NCC 1	Station	2	Status of station 2 [BI]	Alarm
4	2021-02-25 15:36:28.458	NCC 1	Line	1	Status of line 1 (Node 2) [BI]	Alarm
5	2021-02-25 15:36:28.458	NCC 1	Station	2	Device suspended [13863]	Alarm
6	2021-02-25 15:36:13.889	SSS	SSS	AFS	AFS Port02	Alarm
7	2021-02-25 15:36:13.889	SSS	SSS	AFS	AFS Port01	Alarm
8	2021-02-25 15:36:13.873	NCC 1	Station	203	Device suspended [13251]	Alarm
9	2021-02-25 15:36:13.858	NCC 1	Station	203	Connection to the station lost	Alarm
10	2021-02-25 15:36:13.858	NCC 1	Station	203	Status of station 203 [BI]	Alarm
11	2021-02-25 15:36:13.858	NCC 1	Station	203	Status of station 203	High alarm

Figure 53. Alarm Display (MGate 5114 Series is not responding).

As a conclusion of the third simulated fault situation, we that can state that the malfunction situation of the MGate was informed to the SCADA system and the needed alarms were activated. The use of the MGate´s troubleshooting tools was not possible due to fact that the connection to the web console was lost.

4.4.4 Malfunction Situation of the IEC 60870-5-104 Primary Line

The fourth and the last simulated situation was the malfunction of the IEC 60870-5-104 primary line. The aim of this section was to verify that the connection is transferred to the IEC-60870-5-104 secondary line after the primary line was disconnected. This should be possible with minimal connection timeout. Figure 54 shows that the alarms of the ports P1 and E1 were activated, when the communication of the IEC 104 primary line failed.

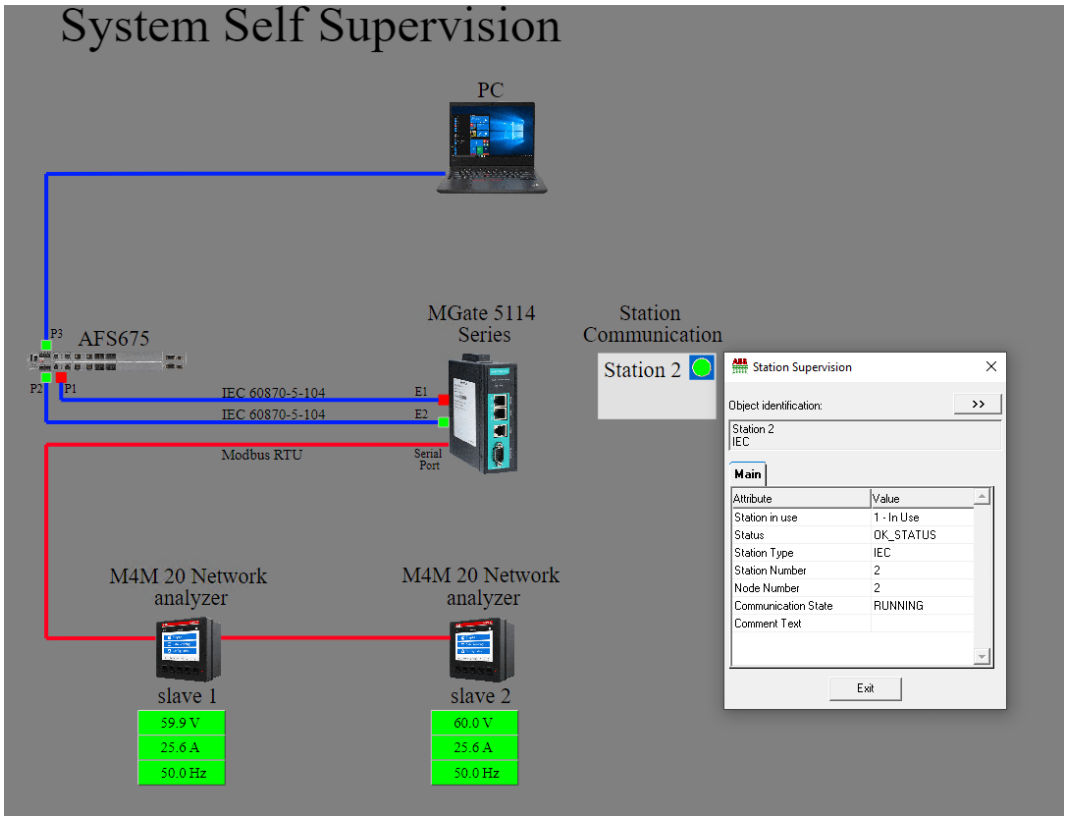
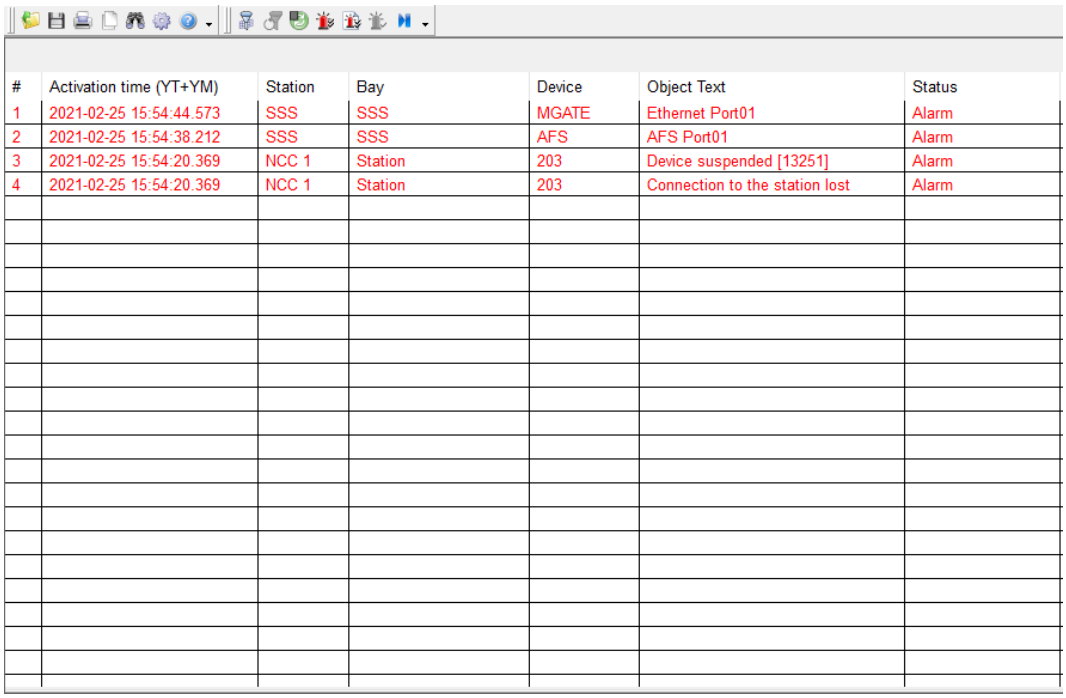


Figure 54. System Self Supervision (IEC 60870-5-104 Primary Line Failed).

In addition, the minimal timeout caused a few station 203 alarms as seen in Figure 55.



#	Activation time (YT+YM)	Station	Bay	Device	Object Text	Status
1	2021-02-25 15:54:44.573	SSS	SSS	MGATE	Ethernet Port01	Alarm
2	2021-02-25 15:54:38.212	SSS	SSS	AFS	AFS Port01	Alarm
3	2021-02-25 15:54:20.369	NCC 1	Station	203	Device suspended [13251]	Alarm
4	2021-02-25 15:54:20.369	NCC 1	Station	203	Connection to the station lost	Alarm

Figure 55. Alarm Display (IEC 60870-5-104 Primary Line Failed).

As a conclusion of the fourth simulated fault situation, we state that the MGate can operate almost normally when the connection of the IEC 104 primary line failed. The communication was transferred to the remaining IEC 104 secondary line with minimal connection timeout.

5 CONCLUSIONS

This thesis gives an overall picture of how to configure the MGate 5114 Series gateway device by using the Moxa dedicated tool and a practical example of how to establish the system with MicroSCADA, including database and communication.

The other aim of this thesis was to find out more information about the energy metering applications and this purpose was met in this thesis. The used M4M 20 Network analyzers is one of the examples of used energy metering devices in infrastructure SCADA projects. The test results show that this kinds of analyzers are capable to interface with MicroSCADA.

One of the best features in MGate is that it provides a useful configuration tool. The gateway device provides various troubleshooting tools, which are helpful in case of a possible malfunction situation of the system. The automatic mapping arrangement makes engineers' work easier. The addresses should be double-checked that they are mapped right in cases where the automatic mapping arrangement is used. The performance of the MGate is reliable when reading single or multiple type of Modbus registers. Based on the testing results of this thesis, the MGate has the needed performance and reasonable features so that it is possible to use the gateway device in the future infrastructure SCADA projects.

It would have been interesting to test performance of MGate in a larger system, but due to the given scope of this thesis and test environment limits, it was not possible. The performance of the gateway device in part of a system, where there are multiple and different types of energy meters would be ideal to test in future. This could be a possible topic for a thesis in the future.

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APPENDIX 1. Test Set-up