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Developing Laboratory Exercise in IEC 61850 Standard

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Abstract

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The main objective of this thesis is to integrate the knowhow related to the IEC61850 standard to the laboratory exercises of a data transmission course. This is done through a careful design of the experimental set up, selection of tools and devices and description of laboratory tasks and objectives.

The experimental setup provides step by step configuration of the devices to be used in different tasks. Selection of tools is according to the configuration required for a specific lab session, however, the detail of tools and devices are described in this document. The description of laboratory tasks involves the work to be done by the students during the laboratory hours. The entire laboratory exercise is divided into three parts: Digital Input Implementation of VAMP Feeder Manager, GOOSE message activated by an on/off event and GOOSE message activated by threshold event.

In addition to the written instructions of the telecommunication laboratory exercise for students and supervisor, the project provides detailed decoding information of GOOSE messages and a specific instruction for reading before the laboratory exercises.

This thesis principally describes the design, structure and implementation process of the laboratory exercises using VAMP Feeder Manager 257. Reliability of laboratory experiment is achieved through several tests.

Laboratory exercises documentation is not included in this document but delivered separately to the concerned teacher to be used in his lab course.

Keywords   IEC61850, GOOSE, VAMP Feeder Manager

Abbreviation

IED	Intelligent Electrical Device
MMS	Manufacturing Message Specification
IEC	International Electro technical Committee
ACSI	Abstract communication service interface
LN	Logic Node
ANS.1	Abstract Syntax Notation One
DAType	Data Attribute type
GCB	GOOSE control block
GOOSE	Generic object oriented substation event
GSE	Generic substation event
GSSE	Generic substation state event
LD	Logical device
LLN0	Logical node zero
PDU	Protocol data unit
RCB	Report Control Block
DI	Digital Input
U<	Under-Voltage
VO	Virtual Output

Table of Content

1. Introduction

With development of technical communication more and more reliable protocols were published in order to prove the quality of telecommunication. But it is difficult to integrate protocols into different IEDs manufactured by different companies. They always use specific communication protocol of their own manufacturer. Thus a protocol combines them and facilitates them the ability to work in a same network to share information and commands that are needed. IEC 61850 standard was introduced to avoid interoperability problems (Detail for IEC61850 is in Appendix). GOOSE is a kind of message applied for fast and reliable service in IEC 61850. It is also the main topic in the laboratory exercise you designed. This laboratory exercise is created for students of this institution. The aim is to let them get familiar with IEC 61850 standard and GOOSE messages i.e. how the protocol is used in real applications. The laboratory exercise contains five important functions:

1. Settings and functions of VAMP Feeder Manager

2. Getting familiar with all the software to be used

3. RCB application

4. Analyzing the structure of GOOSE messages i.e. decoding GOOSE messages

5. GOOSE messages application in power protection control

According to the functions above, the entire laboratory work is divided into four parts:

Exercise1: Digital Input Implementation

Exercise2: GOOSE message activated by an on/off event

Exercise3: GOOSE message activated by threshold event

Exercise4: GOOSE Decoding

In this thesis Exercise 1 to Exercise 3 are elaborated.

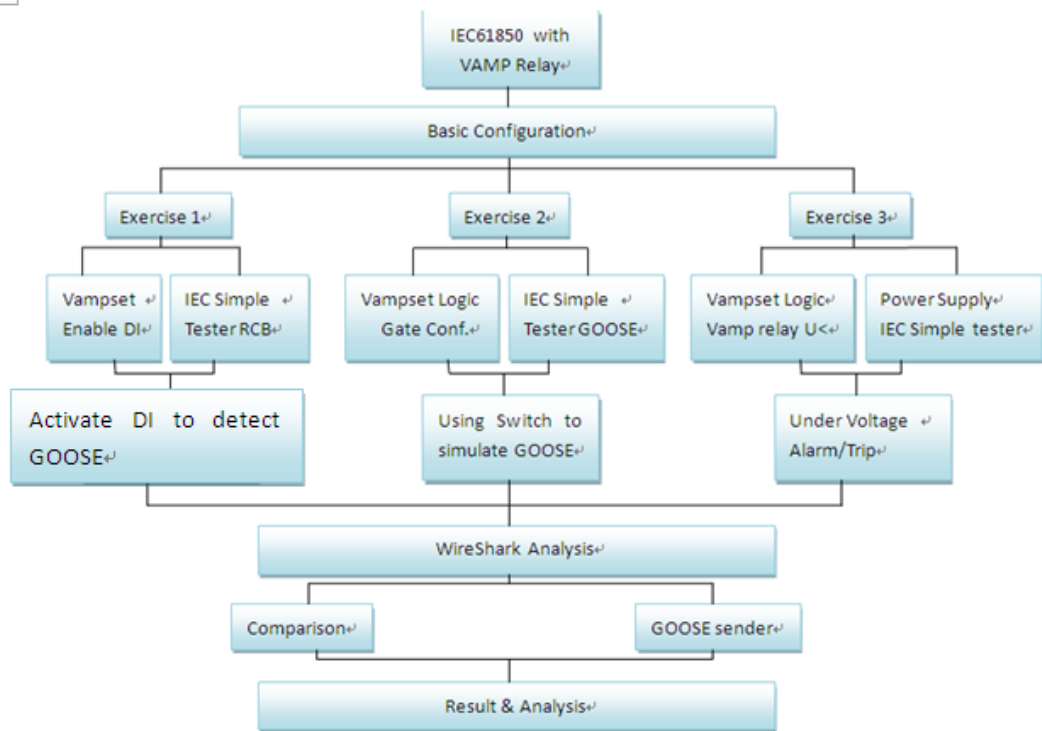The structure of entire laboratory exercises is shown below:

Figure 1.1: Architecture of laboratory

2. Equipments

The list for hardware and software using in this laboratory work:

Hardware:

Vamp Feeder Manager 257

Computer

Function Generator

Software:

VAMPSET

IEC Simple Tester

GOOSE Sender

Wireshark

2.1. Vamp Feeder Manager 257

The protection relay of VAMP is used for selective protection of cable, electric motor, capacitor, reactor and bus bars in substation, power plant and other industrial manufactures. It has normal protection functions and some special ones such as bay control, measurement and communication etc.

The main feature of Vamp Feeder Manager 257 can be found in *Ref 1.

2.2. VAMPSET Setting and Configuration tool

VAMPSET is management software for configuring VAMP relays. All the parameters in VAMP relays can be represented by VAMPSET. Remote control of VAMP relays by using VAMPSET make configurations easier and safer for people. This software runs on Windows XP/98/95/2000/NT and Windows 7 environment. It supports TCP/IP and IEC 61850 communication. The following picture is the general interface of VAMPSET.
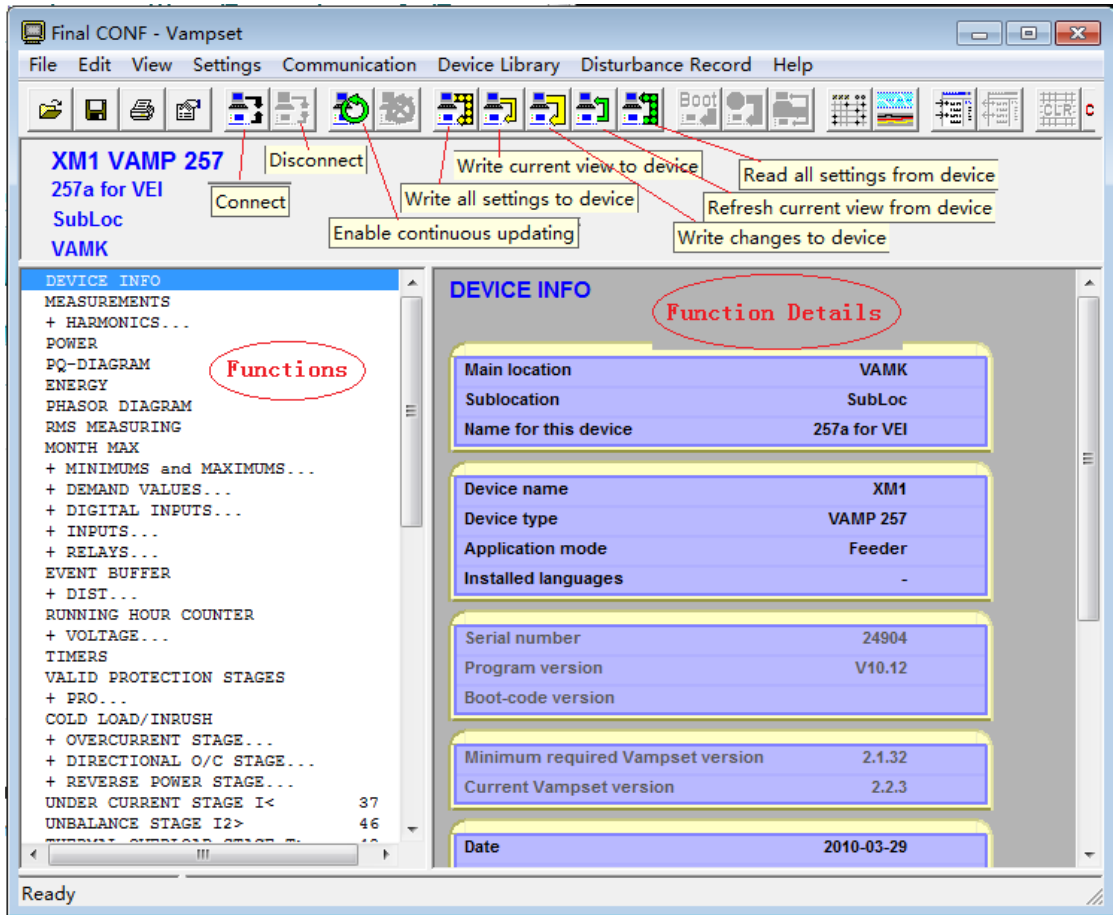
Figure 2.2.1: General Interface of VAMPSET

All functions and parameters of the relay can be found in the main menu which is on the left side of software interface. Configuration command is located on the above tool bar. For example there is a control panel in VAMPSET with which you can remotely control the relay manager, the push buttons on the panel are exactly the same as those on the machine.
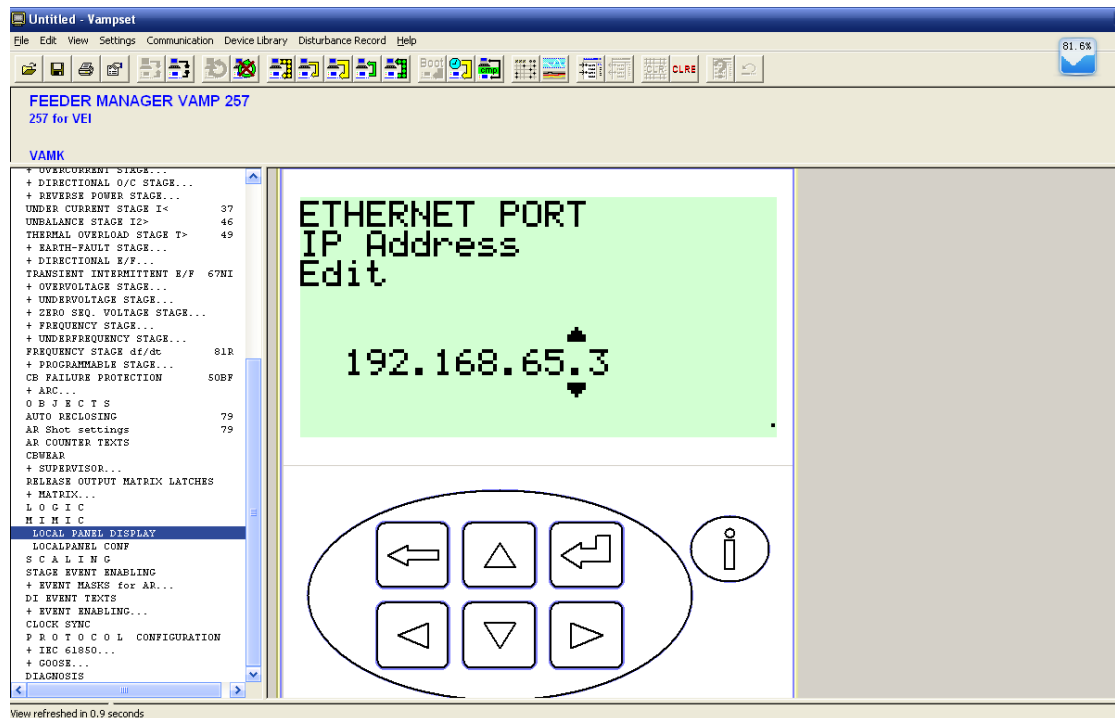
Figure 2.2.2: Control panel in VAMPSET

In addition, you can change the common configuration through the options in the main menu.

2.3. IEC Simple Tester

It is simple test software to monitor the LN, object and their attributes. It contains some main functions, such as read values from the device and control switch inside the relay. In addition to that, it has most important function that is RCB (Report Control Block) and GOOSE detector. In some circumstances, VAMP Feeder Manager will continuously send report to control system in order to make sure there is no problem, RCB is a model for monitoring this kind of report.
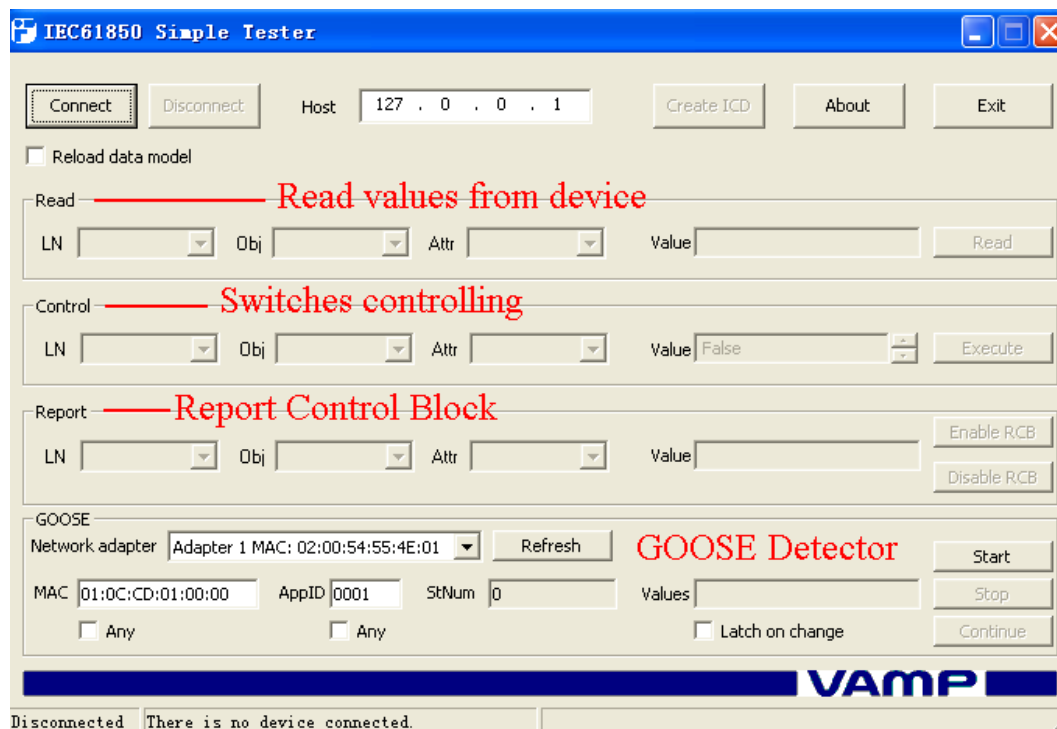
Figure 2.3.1: A connected IEC Simple Tester

2.4. GOOSE Sender

This software is used for simulating GOOSE messages. By using this software you can give a GOOSE command to VAMP Feeder Manager and if there is related configuration in the relay there will be some response from the relay according to the configurations made in GCB.

2.5. Wireshark

Wireshark is a packet analyzer which is used for network analysis. It is easy for the user to see all traffic being transmitted over the network. Wireshark is convenient for common users without worrying about license keys or fees. Since the source code is freely available, new protocols are easily to be added to Wireshark. For Wireshark functions, it can capture the protocols you want in a large number of protocols or programs. The protocol decoders in Wireshark always are updated. This is good for the users saving time on decoding some

unusual protocols. In a word, Wireshark is free and convenient software for network analysis.

3. Laboratory Implementation

3.1. Configuration

Basically you use Ethernet to connect relay and PC. Use the Ethernet port for PC and the relay manager with a RJ-45 cable. After the connections are done, run Software VAMPSET on PC. To start with, set the IP address for the relay manager to make connections. Set the IP address of the Relay Manager to 192.168.65.2 and for the PC use IP address: 192.168.65.20
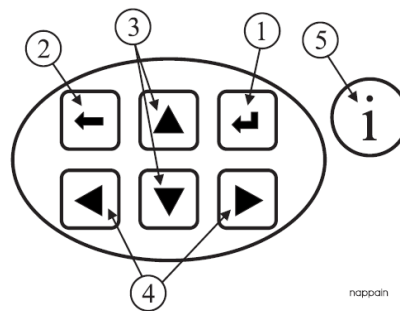
Use the following figure to use the keypad.

Figure 3.1.1: Keys on the keypad

1. Enter and confirmation key (ENTER)

2. Cancel key (CANCEL)

3. Up/Down [Increase/Decrease] arrow keys (UP/DOWN)

4. Keys for selecting submenus [selecting a digit in a numerical value] (LEFT/RIGHT)

5. Additional information key (INFO)

To set IP of relay manager, scroll the down key to find the menu "Comm. options". In case of those options, select 'Bus'. (In figure 3.1.2)
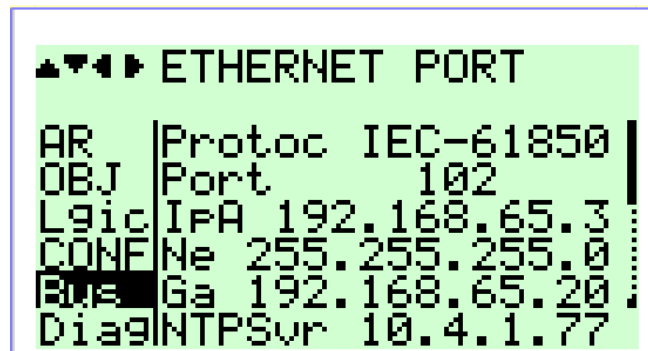
Figure 3.1.2

Now click the Right arrow key a few times to reach Ethernet Port. Hit enter key to enter in menu options. Here you need to enter password for configure the relay manager and the password is 0002. The original state for password was 0000.

Use the down key select IP A. Observe this IP address, should be according to the static range for IP address.

Figure 3.1.3: Setting static IP address for relay

3.2. Digital Input Implementation of VAMP Feeder Manager

3.2.1. About this work

The relay feeder managers are used to configure/command the relay devices connected to a specified network. In addition to that, students will get themselves familiar with different operating tools of VAMP relays using VAMPSET andIEC61850 Simple Tester.

3.2.2. Equipments

Vamp relay 257

RJ 45 Cable

Computer

3.2.3. Connections:

The PC and one of the Vamp Relays are connected by the RJ45 cable using the Ethernet interface. An external DC power supply of 40V is connected to pin 17 and pin 18(GND) of the X3 terminal of the relay. After the connections are completed, run Software VAMPSET on your PC.

3.2.4. Configuration and Result

After getting the previous configurations done, continue to check the status of enabled digital inputs. From the main menu, choose "Data Map2" and scroll down to check if the pin 1 "digital input 1" is set to "Yes" as shown in the following figure:
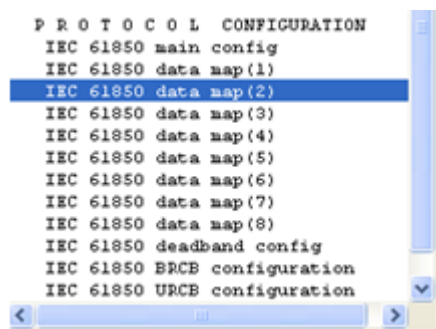

Figure 3.2.4.1: IEC 61850 data map (2) option in main menu

Figure 3.2.4.2: Enable DI1

Continue, repeating the same step to check the rest digital inputs from pin 2 to pin 7 on the Vamp Relay. These 6 pins are mapped in VAMPSET by selecting "Data Map 3". They correspond to the logical node from1 to 6.

After enabling these Digital Inputs, write all the changes to the device "Communication" and "Write changed setting to the device". Then start IEC Simple Tester.
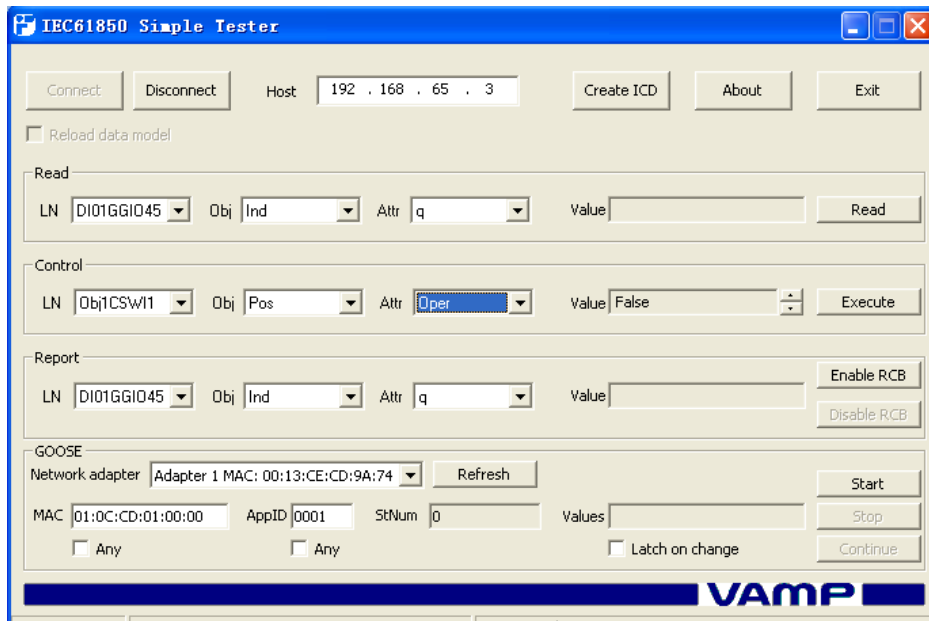

Figure 3.2.4.3: A connected IEC Simple Tester

Set the IP host address: set the address of the relay and press "connect". After the connection has been established, start the device and the software; choose the enabled Digital Input from "Read" menu; i.e. choose LN (Logical Node). Set the attribute to "Stval" and Object as "Ind". "DI01GGIO45" is the name of LN you are

monitoring which is Digital Input 1. "Stval" stands for State Value which is the name of attribute. After this configuration, from the selection rear slot, choose Pin 1 and use a screw driver to insert the cable provided with the equipment and fix it. Do not fix the other end of the cable; just connect it to the corresponding Pin and press "read" button in IEC Simple Tester. You can see that the value became "True". Now take out the end which is not fixed with screw and click the button "Read" again you found that the value is "False". As shown in figure 3.2.4.4, you enable DI1 to DI6.
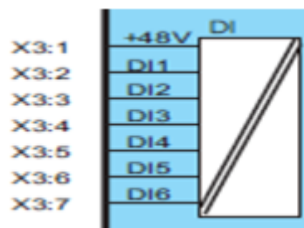

Figure 3.2.4.4: Digital Input pins in the back of relay

The first pin in Digital input is 48V, the second pin is DI1 (digital input 1) as soon as you connect these, the 2 pins relay will send a message which means when you connect DI1 to +48V you active DI1.

In the next step you will execute on and off operation of Circuit Breaker. In the control menu, you can only see the enabled LN Obj1CSWI1 which refers to the circuit breaker. Check the Obj=pos and attr=oper. Select False in Value and pree "Execute". After the operation you can clearly hear a sound from VAMP Feeder Manager that is the switch is turning off.

In the last step you generate a report signal by enabling the Report Control Block. Choose the enabled Logical Node under the report menu, "Obj" to "Ind", "Attr" to "Stval" and press "enable RCB". Then connect the unfixed end to enabled DI1. When DI1 is active by the cable value in RCB is "True" and when DI1 is not active value in RCB will change to "False" immediately. From this exercise you can

distinctly realize function of RCB. When some urgent situation is happening in the line RCB will report to control system in real time so that people can response to those troubles in time.

3.3. GOOSE message activated by an on/off event

3.3.1. About this work

Some of the information is transmitted by GOOSE message in protection relays. The main idea of this exercise is to capture GOOSE message through all the requests of the configuration. The important configurations are not only configured in Vamp Relay, but also in the software IEC61850 Simple Tester and VAMPSET. Connected, the physical connection firstly and do the software configurations in order to obtain GOOSE messages and monitor the transmission in Wireshark. Find out the information GOOSE messages tell about.

3.3.2. Equipments

Vamp relay 257
Three wires' switch
RJ45 Cables and a laptop (or a normal PC)

3.3.3. Connections:

The PC and one of the Vamp Relays are connected by the RJ45 cable using the Ethernet interface. The three wires of the switch are connected in pin 1 to pin 3 of the X3 terminal relay respectively which shows in Figure 3.3.3
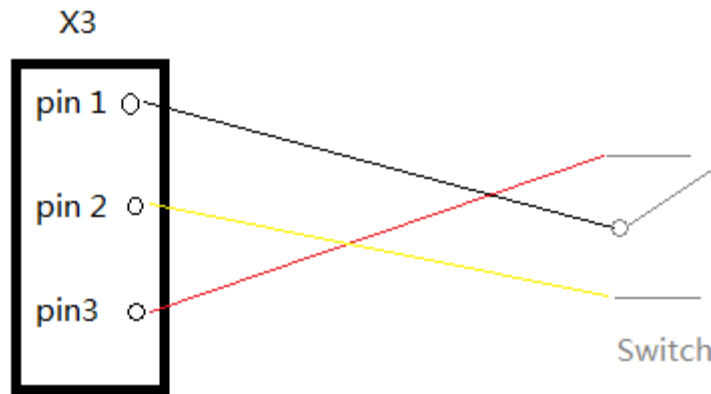
Figure 3.3.3: Switch connection

3.3.4. Configuration and Result

Do the same configurations in the Feeder Manager as exercise 1, for instance the IP setting both in Vamp Relay and the laptop. But in this exercise some improvements are made compare with exercise 1 that you change the cable to a simple switch to active DI1 and also DI2. There are three pins on the switch which are connecting to DI1, DI2 and +48V input. According to this design student can active DI1 and DI2 more convenient.   And other configurations must be the same, too. After the basic physical connection and the same settings in exercise 1's instruction, use the software VAMPSET to control and monitor the Relay Manager.

Configuration in VAMPSET

At first note if DIs are related to GCB1 or 2 (GOOSE control block) so that when you active DI1 you will receive a GOOSE message. To do so select option "GOOSE GCB1: DATA POINTS" first.
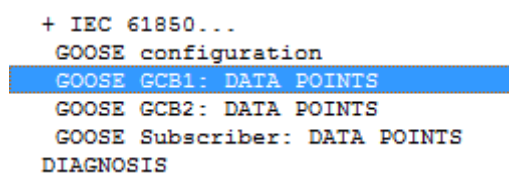

Figure 3.3.4.1: "GOOSE GCB1: DATA POINTS" in the left side menu

In this option different LNs can be added into GCB table so that the object of an LN will related to GOOSE messages. Then in the right side menu you can see the GCB attribute as shown below:

Index	IEC-61850 Variable	Signal	Status
0	DI01GGIO45.Ind.stVal(ST)	DI1	OK
1	VI1GGIO137.SPCSO.stVal(ST)	VI1	OK
2	VO6GGIO102.Ind.stVal(ST)	VO6	OK
3	None	None	OK
4	None	None	OK
5	None	None	OK
6	None	None	OK
7	None	None	OK

DSG1 data configuration

Figure 3.3.4.2: Attributes in GCB

DI1 should be added to the DSG1 data configuration list. When DI1 is added, information about its LN is displayed as you can see in the figure 3.3.4.2. As you can see from figure 3.3.4.2 that DI1 is already in it and its LN name is "DI01GGIO45" that is the same as appeared in IEC Simple Tester. Also ensure the status is OK. In the "GOOSE configuration", GCB1 must be used and check the MAC address and Application ID carefully. If GCB1 is not enabled, all attributes in GCB1 is useless. The range of MAC address for GOOSE multicasting is from 01-0C-CD-01-00-00 to 01-0C-CD-01-00-FF. In this VAMP Feeder Manager 01-0C-CD-01-00-00 is used. Application ID is for recognizing GOOSE messages, different models or IEDs have different Application ID to response for those GOOSE messages.
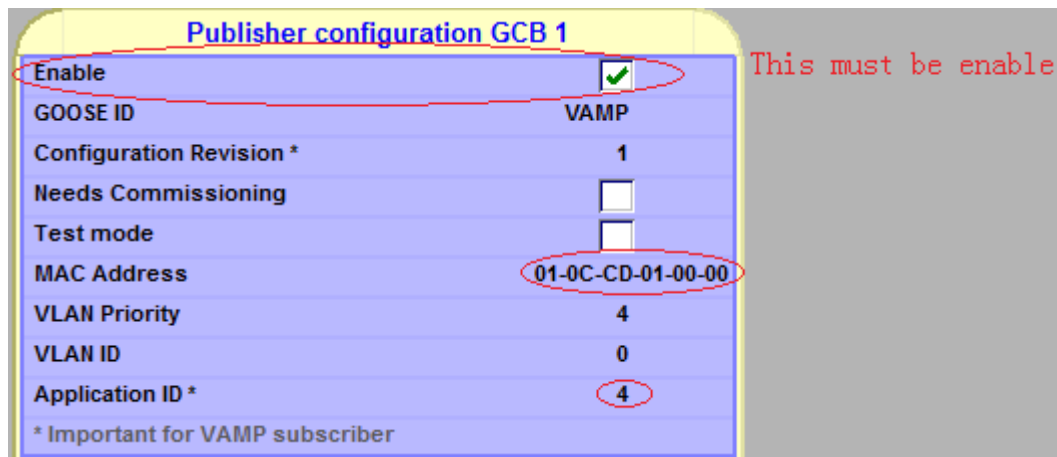
Figure 3.3.4.3: Configuration for GCB1

Second step, choose the Logic tag to create a new logic map. As the in original there's only a sample map like figure3.3.4.4 shows.
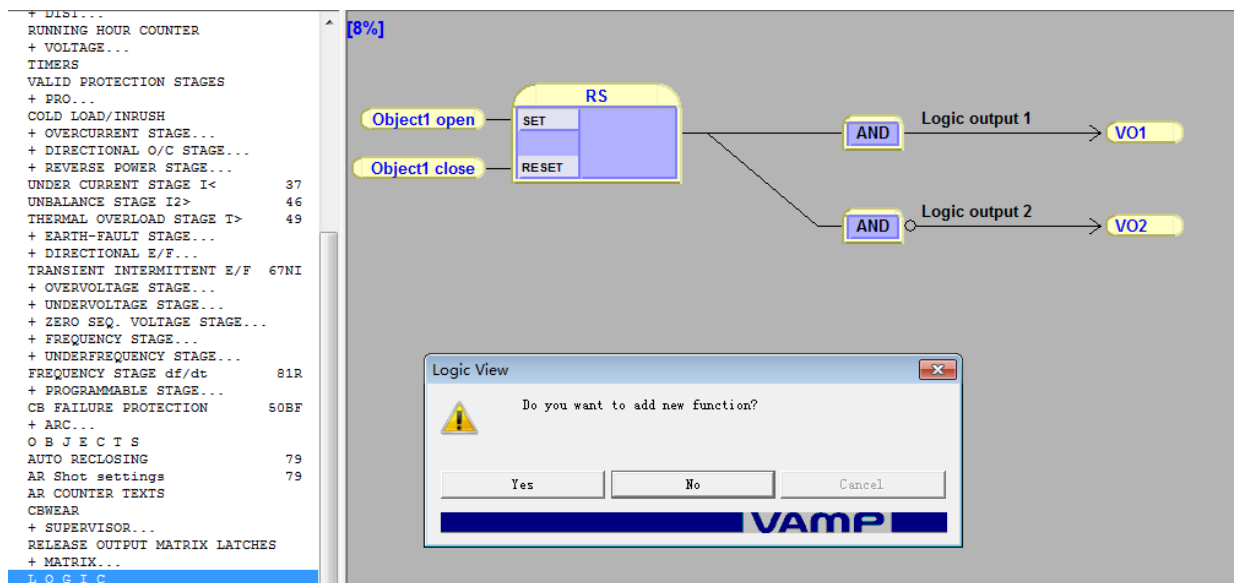

Figure 3.3.4.4: Logic Map

Add the new logic map which shows the digital input is in use. In order to see clearly the changes after GOOSE messages are sent in this map, digital input should be connected to the LED light which on the Vamp Relay in logic. As soon as you finish this step, when you active DI1 the light "A" on VAMP relay will be switched ON which shows that a GOOSE message is detected.
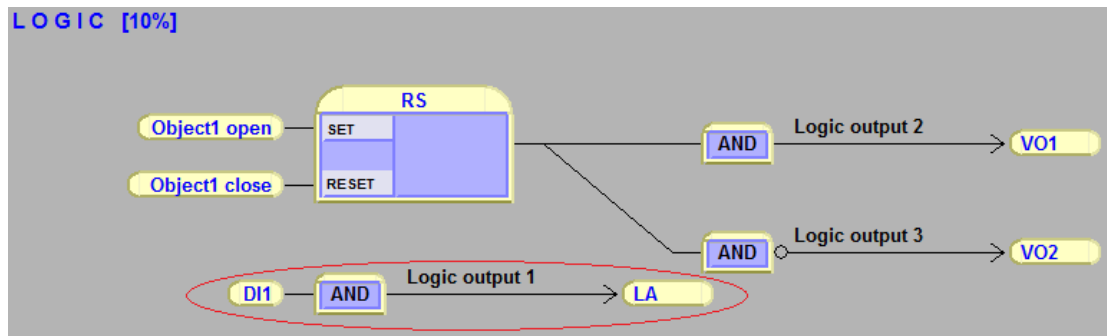
Figure 3.3.4.5: Connect DI1 with LED A in Logical Map

In tag "IEC 61850 main-config" there are all other LN, you can enable any LN you are going to use there. Also they can be edited the way to use them in Logical Map.

Index	LN	Description	Dataset 1	Dataset 2	Dataset 3	In use
0	AR1ftGGIO16	AR1 final trip	No	No	No	No
1	AR2ftGGIO17	AR2 final trip	No	No	No	No
2	AR3ftGGIO18	AR3 final trip	No	No	No	No
3	AR4ftGGIO19	AR4 final trip	No	No	No	No
4	AR5RREC1	Auto-reclose (AR)	No	No	No	No
5	ARcftGGIO15	AR critical final trip	No	No	No	No
6	ARcreGGIO13	AR critical request	No	No	No	No
7	ARftGGIO14	AR final trip	No	No	No	No
8	ARlocGGIO2	AR locked	No	No	No	No
9	ARre1GGIO3	AR request 1	No	No	No	No
10	ARre2GGIO4	AR request 2	No	No	No	No
11	ARre3GGIO5	AR request 3	Yes	Yes	No	No
12	ARre4GGIO6	AR request 4	No	No	No	No
13	ARre5GGIO7	AR request 5	No	No	No	No
14	ARrunGGIO1	AR running	No	No	No	No
15	ARsh1GGIO8	AR shot 1	No	No	No	No
16	ARsh2GGIO9	AR shot 2	No	No	No	No
17	ARsh3GGIO10	AR shot 3	No	No	No	No
18	ARsh4GGIO11	AR shot 4	No	No	No	No
19	ARsh5GGIO12	AR shot 5	No	No	No	No
20	CBFPPIOC4	CB failure protection	No	No	No	No
21	CBWA1GGIO20	CB wear alarm 1	No	No	No	No
22	CBWA2GGIO21	CB wear alarm 2	No	No	No	No
23	CN01GGIO103	Counter 1	No	No	No	No
24	CN02GGIO104	Counter 2	No	No	No	No
25	CN03GGIO105	Counter 3	No	No	No	No
26	CN04GGIO106	Counter 4	No	No	No	No
27	CN05GGIO107	Counter 5	No	No	No	No
28	CN06GGIO108	Counter 6	No	No	No	No
29	CN07GGIO109	Counter 7	No	No	No	No

Figure 3.3.4.6: All other LN is in IEC 61850 Data Map

You are going to use GOOSE detector in IEC Simple Tester to monitor GOOSE message status at the end of this exercise. The configuration for IEC Simple Tester is shown as follows.
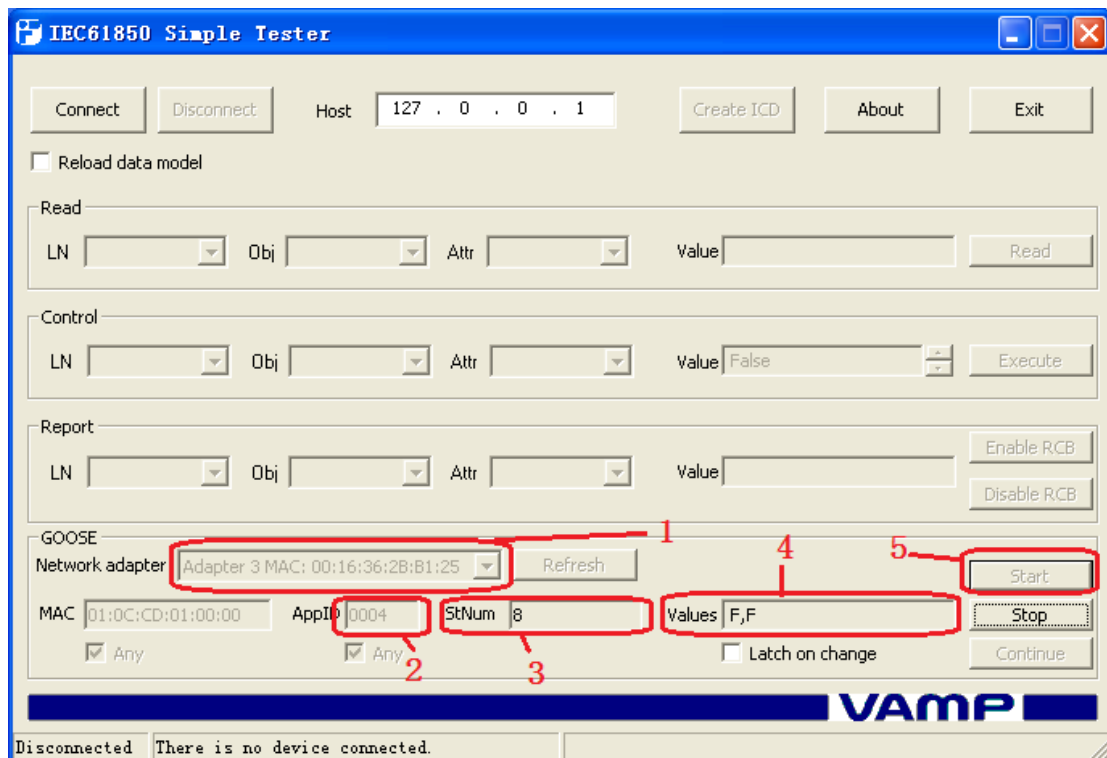
Figure 3.3.4.7: GOOSE detector in IEC 61850

1. Network adapter: Here is for the MAC address of computer which connected to VAMP Feeder Manager. In this case the MAC address of laptop in use is 00:16:36:2B:B1:25. This address is recognized automatically by IEC Simple Tester.

2. AppID: Application ID is for filtering the right GOOSE messages belong to it. In the transmission there are many GOOSE messages so IEC Simple Tester will choose the one it needs. If you active the option "any" it will accept and monitor all the GOOSE messages during data transmission.

3. STNum: Status Number tells us how many times status changes. Every time when it deals with a different GOOSE message the number will automatically count by 1.

4. Values: Here shows the Boolean values contained in the GOOSE messages, "F" is False and "T" is True. As it shows now there are 2 "F" in the block now which means there are two LNs are active in GCB1 and one is DI1 you

created in above steps. Any of them changes status will cause a sending of GOOSE message and the value in the GOOSE message is shown in this block in the way of "F" or "T".

5. Start: As soon as clicking this button you begin to monitor GOOSE message status. Whenever there is a GOOSE message containing a different Boolean value sent the values in this block will update them in real time.

In this exercise when you open/close the switch it will deny/active DI1 afterwards, a GOOSE message includes False/True value is sent to control system which here is the laptop you are using. Therefore the value in GOOSE detector is "F" when switch is open or "T" when switch is closed.

Figure 3.3.4.8: Value of DI1 is active

Figure 3.3.4.8 shows when DI1 is activated by switch the value in GOOSE detector changes from false to true immediately. In the same time through Wireshark you get several frames of GOOSE messages in a short time.

3.4.GOOSE message activated by threshold event

3.4.1. About this work

The main function of Vamp257 is protection. When there is a leakage or overload of current, voltage or power, it should alarm itself and transmit the message to the network administrator. Such messages are time critical and hence transmitted immediately whenever detected. Students must get familiar to the theory information how this function operates. The abstract information of the Relays' structure should also be known.

3.4.2. Equipments

Vamp relay 257

Functioin Generator

Cables and a laptop (or a normal PC)

3.4.3. Connections:

The PC and one of the Vamp Relays are connected by the RJ45 cable using the Ethernet interface. The Function Generator is connected to the pin 11 and pin 12 of the X1 terminal of the relay.

3.4.4. Configuration and Result

Do the same configurations in the Feeder Manager as in exercise 1 and 2, for instance the IP setting both in Vamp Relay and the laptop. And other configurations must be the same, too.

Based on physical connection and the same settings in exercise 1's instruction, you can use the software VAMPSET to control and monitor the Relay Manager.

Configuration in VAMPSET

In this exercise you are going to test under-voltage function in order to get GOOSE message. One most significant function of VAMP Feeder Manager is that it will send an alarm signal to control system when line voltage is too high or too low. Line Voltage can be monitored in the main menu of relay:
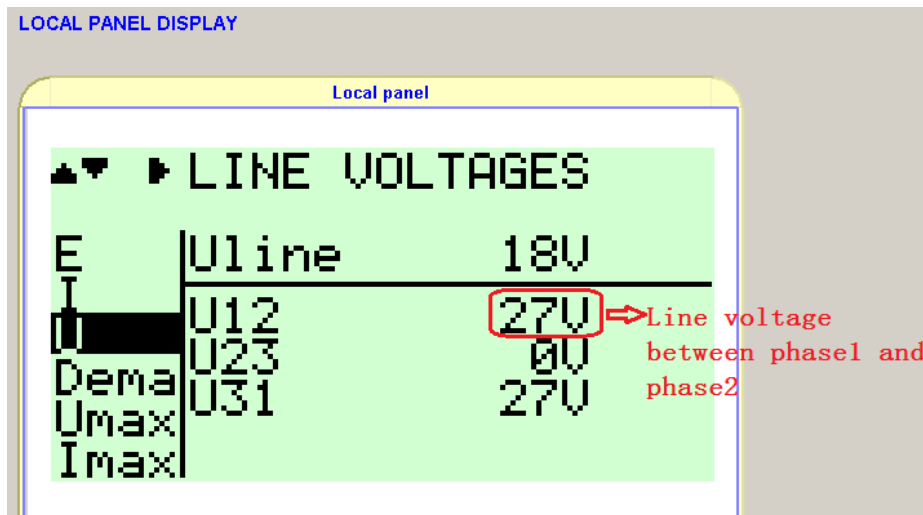

Figure 3.4.4.1: Monitoring line voltage

In this kind of emergency VAMP relay will send GOOSE messages by multicasting continuously in a short time interval until control centre solve the problem. Under-voltage is represented as U< in VAMPSET and you should enable this function first.

Figure 3.4.4.2: Enable under-voltage protection

To enable the U<, U<< and U<<<< stages to send data to the Ethernet the following must be done: Set the "Dataset 1" and "In use" selection of the LNs UV1PTUV1, UV2PTUV2 and UV3PTUV3 to "Yes".

After enabling U< function the configuration of U< should be done. Before going to U< configuration menu one parameter has to be set, that is Un. Press "down" key to determine right option "CONF" for setting Un. For this exercise Un can be set as 200V. The reason of changing Un here is that this value has a kind of relationship with other values you are going to use later such as Line Voltage. Un is a sort of basic voltage standard that many other variables are represented by this Un. So this is the first thing to change when configuring U< or U>.

Figure 3.4.4.3: Un configuration

If you want to do some changes to the device you must login as an administrator. The big exclamatory mark on the right side is for login.
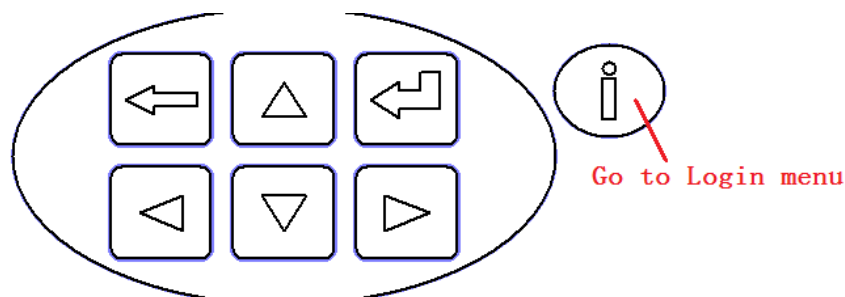

Figure 3.4.4.4: Login Menu

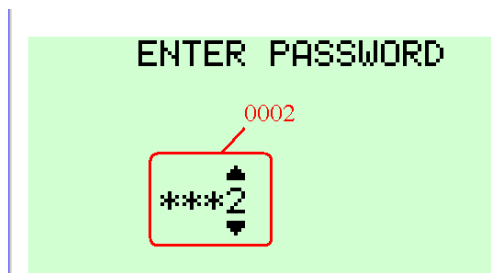Relay system asks key to let user login as administrator so press "Enter" to give the key "0002" for administrator.

Figure 3.4.4.5: Key for administrator

As Un is determined you can go on to configure U<. Find U< settings in relay menu and give the changes like shown in figure 3.4.4.6.
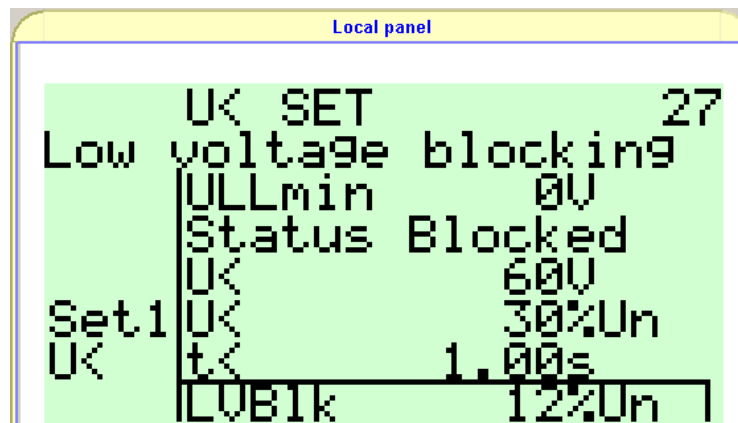

Figure 3.4.4.6: U< configuration

Notice the option "LVBlk" (Low voltage blocking) which means if line voltage is lower than the trigger value relay will block the line to avoid error. And as you can see the trigger value is represented by the percentage of Un. Un is set as 200V so 12%Un is 24V. Now if line voltage is smaller than 24V according to function of U< the status will become "Blocked". In the other hand if you adjust line voltage up to 24V the status will change to "Trip". For testing the configuration, function generator should be connected to VAMP Feeder Manager. The input signal has to be AC (Alternating Current) voltage otherwise there will be no line voltage detected on relay.

After connection is established, adjust the amplitude of input signal and read from

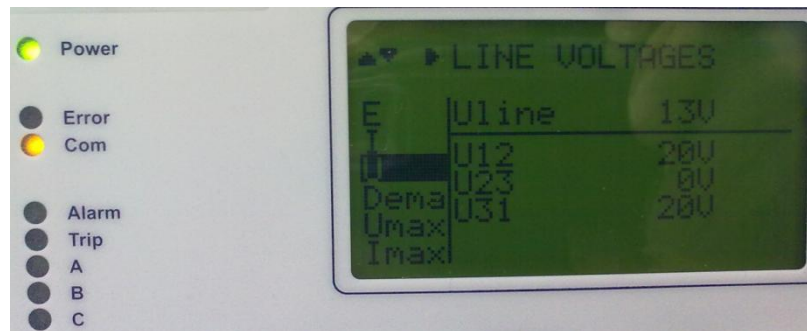relay. The line voltage is increasing or decreasing. At the beginning line voltage is less than 24V:

Figure 3.4.4.7: Line voltage is less than 24V

Photo above shows the highest line voltage is 20V and it is less than trigger value. So now the status for U< is "blocked" as shown below:
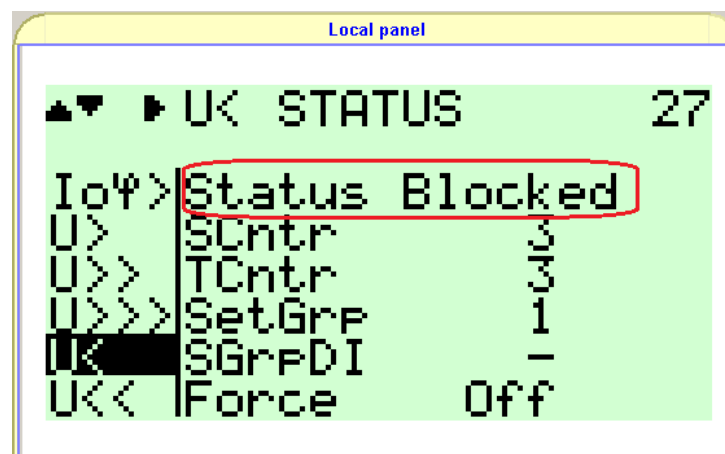

Figure 3.4.4.8: In U< status is "Blocked"

In this situation because of the block function relay is protecting lines. Next you try to increase input voltage until it is more than trigger value so that relay will send an alarm message to control system and change the status to "Trip".

Figure 3.4.4.9: Trip

Line voltage now is 27V which is more than 24V and it clearly shows the light of Alarm and Trip is on. All above prove us that under-voltage protection of this relay is working fine but the data during transmission is not GOOSE yet. Last step is to make VAMP relay accomplish the function with sending GOOSE message so that you can capture GOOSE message to study.

To link U< function with GOOSE the same step as in exercise 2 has to be done which is to enable the LN of U< in GCB1. But unfortunately there is no option in GCB1 for LN of under-voltage. Another way to achieve the aim is to use Logical Map. In Logical Map you use logical gate to connect U< function and GOOSE output. But still you cannot directly link U< and GOOSE messages together so here a "bridge" is needed to achieve our purpose which is VO6 (Virtual Output 6). VO6 must connect with U< function by an AND gate.
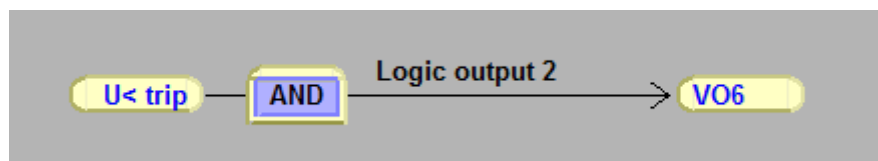

Figure 3.4.4.10: U< connected with VO6

Meanwhile VO6 should be enabled through IEC 61850 data map.

Figure 3.4.4.11: Enable VO6

Now new logic map is added which shows the Virtual Output in use. At this time, though the principle is the same as exercise 2, you must add new logic element you need to use like the voltage. This step is one of the most important one because it affects the GOOSE message in wireshark.

After this setting, go to tag "GOOSE GCB1" in VAMPSET, set one more option to signal as "VO6".

Figure 3.4.4.12: Append VO6 to signal option

So far U< function is successfully connected to GOOSE messages. Also in the "GOOSE configuration", GCB1 must be used and check the MAC address and Application ID carefully. Now as soon as relays trip/block the line you will get a trail of GOOSE messages in Wireshark. The same as exercise 2, at the end of this exercise IEC Simple Tester is needed to detect GOOSE messages. Before adjusting line voltage over 24V which means line voltage is blocked you can find that value in GOOSE detector is "F".
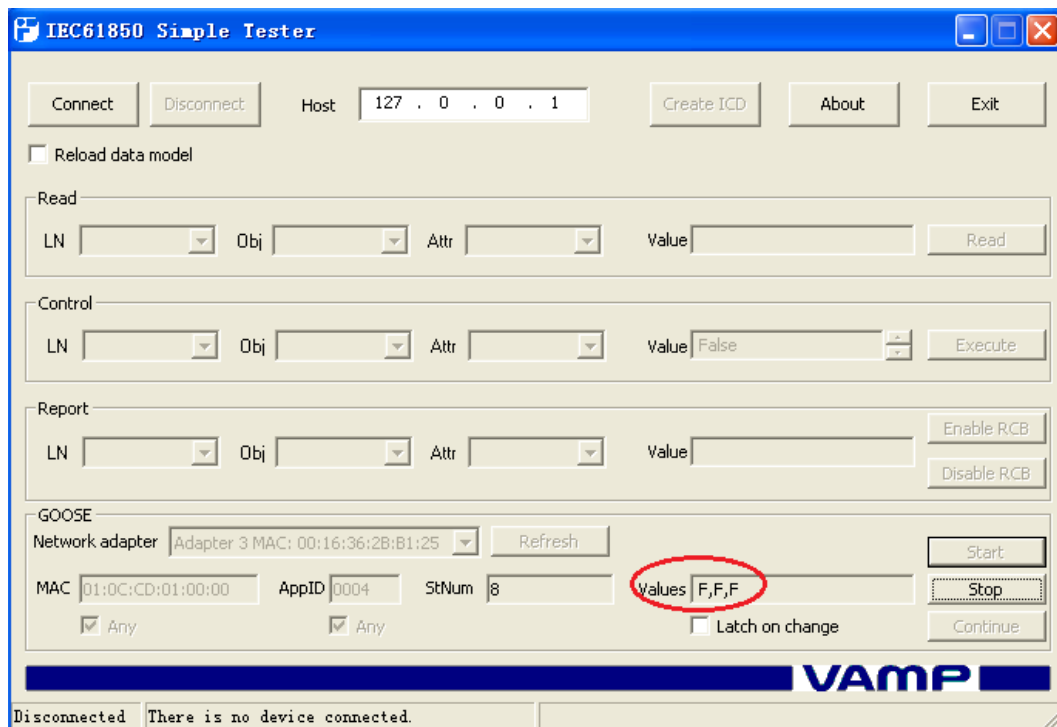
Figure 3.4.4.13: Line Voltage is blocked

In the result there are three "F" appeared that is because in the basis of exercise 2 one more LN for VO6 is appended to GCB1. Checking signals in GCB1 you discover there are three LNs enabled in signal option. Now the last "F" is for U< function which you just build up. Now increase amplitude of function generator until alarm message is sent by relay and status of line voltage is trip.
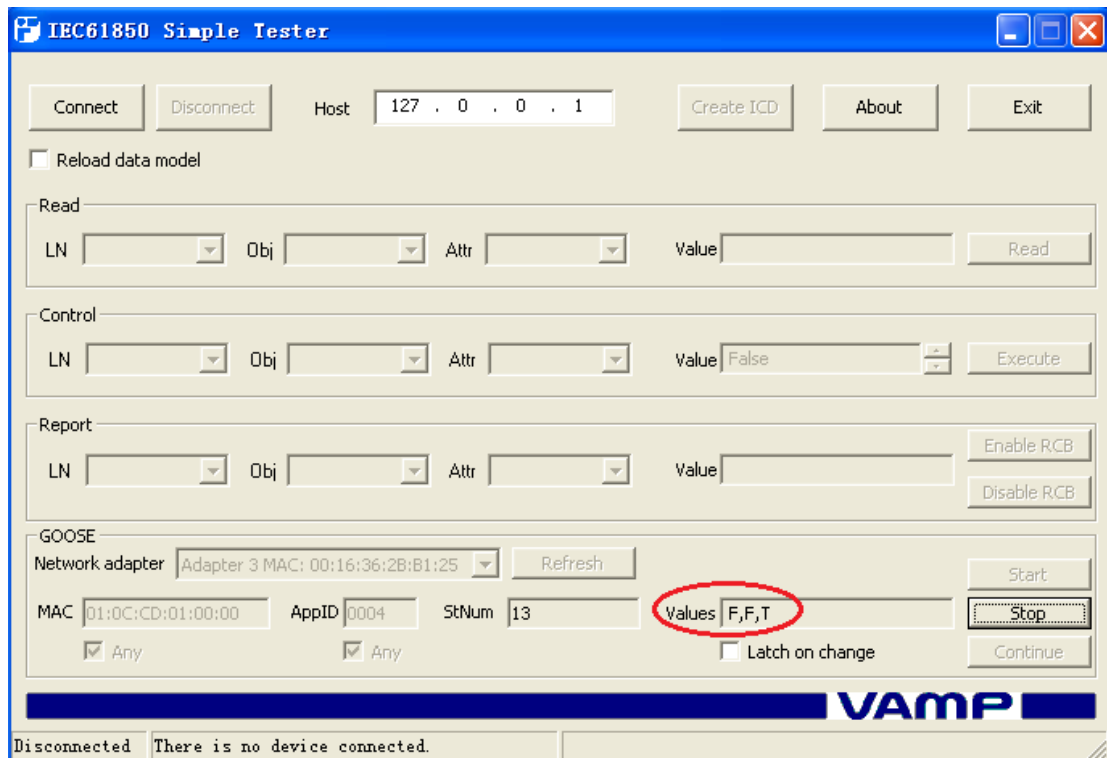
Figure 3.4.4.14: Line Voltage is trip

In the same time GOOSE message of alarm is sent GOOSE monitor changes value from "F" to "T".

4. Conclusion

The whole project was completed in a success. I and my team created three laboratories in which we designed different configurations and different problems to be solved In addition to that we created the instructions for the students which will be used as preliminary instructions by the students. After completing the whole project we tested the created work with a fresh student to solve the exercises using the material we provided and he successfully without any problem solved all three of them with no problem at all. This test is the guarantee for the work I did.

This thesis generalizes the information of GOOSE messages and VAMP Feeder Manager 257 in form of laboratory experiment. The procedure during laboratory exercises shows how IEC61850 works and how to use the relay. This is a group-work project also; the entire team developed their own team spirit to confront difficulties with team members together. The application of communicating between relay and computer is a precious experiment for researchers in their future, and it is also a preferable development for engineering and technology of the future. This project will equip the upcoming student with the latest technology being used for substation automation and will provide adequate information to those who want to proceed with these devices in their future.

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