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PLC communication and application

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Abstract

The thesis was assigned by Landis+Gyr, and its aim was to investigate PLC communication and implement a test environment. The objective was to bring up PLC communication and make a diverse and working test environment, which will be later on used to test devices, their reception, transmission and behavior of a device's signal in this test environment.

For executing this task the first demand was to study the devices and programs to be used in the project which was carried on with the help from other employees and by getting familiar with user manuals. The next step was to configure, parametrize and install the devices in their working spaces.

As a result, a working test environment and big picture of communication types that are and were in use at Landis+Gyr were acquired. With these results it is easier to picture the working principle on PLC communication and its importance.

It can be concluded that PLC communication is very important in places where extra wiring is impossible or just unnecessary for example in households. It was also concluded that if PLC communication were developed more it would be possible to replace all devices' control and reading with it.

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PLC, Landis+Gyr, Device testing

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Tiivistelmä

Opinnäytetyön tehtävänä oli tutkia PLC-kommunikaatiota ja tehdä testiympäristön käyttöönotto. Tavoitteena oli esitellä PLC-kommunikaatiota, joka on sähköverkkokommunikaatiota, jossa siirretään informaatiota kantoaallon avulla. Tavoitteena oli myös saada monipuolinen ja toimiva testausympäristö, jossa myöhemmin voidaan testata laitteita. Testeissä suoritetaan laitteiden signaalin vastaanottoa, lähetystä sekä laitteiden käyttäytymistä mainitussa ympäristössä, joka on pyritty mallintamaan tosielämän tilanteesta.

Työn toteuttaminen vaati ensin laitteisiin ja ohjelmiin tutustumista, joka suoritettiin muiden työntekijöiden avustuksella ja henkilökohtaisesti laitteisiin tutustumalla ohjekirjojen avulla. Seuraavana työvaiheena oli laitteiden konfigurointia, parametrisointia ja asentamista työympäristöön.

Tulokseksi saatiin toimiva testausympäristö ja kokonaiskuva Landis+Gyrillä käytetyistä ja käytettävistä PLC-kommunikaatioista, niiden avulla voidaan hahmottaa PLC-kommunikaation toimintaa ja sen tärkeyttä.

Johtopäätöksenä voidaan todeta, että PLC-kommunikaatio on hyvin tärkeä paikoissa, joissa ei ylimääräisen johdotuksen käyttö ole kannattavaa tai mahdollista, esimerkiksi kotitalouksissa. Kehityksen myötä PLC-kommunikaatiolla voisi mahdollisesti korvata kaikkien koneiden ohjaukset ja mittareiden luennat.

Avainsanat (asiasanat)

PLC, Landis+Gyr, Laite testaus

Muut tiedot

Contents

Figures

Tables

1 Possible competitor in control communication

The thesis is written about PLC communication (Power Line Carrier communication) because the University of Applied Sciences did not introduce this kind of communication. As the author of the thesis has been working with PLC communication in his practice it was noticed and realized that PLC communication is very important and needs to be introduced to automation students. Nowadays PLC communication can be used in every application and does not need extra wiring for control. The aim of this thesis is to bring PLC communication as potential control protocol for example to places where additional wiring is impossible. Later in the thesis application and further possibilities on power line communication are discussed more in detail.

2 What is PLC?

As mentioned above PLC stands for Power Line Carrier Communication and is usually used in energy distribution companies and households. Basic working principle of PLC communication is that after customer sends message from computer or other transmitting device onto power lines, the message converts into frequency package that goes to device and converts back to message that is readable by device and it does needed operation and sends confirmation message back the same way. In the PLC communication, transmitting device adds higher frequency to 50 Hz network and in the period of time, the higher frequencies equals 1 bit and the lower frequencies equals to the 0 bit. PLC in general has a lot of standards and the ones that author found while browsing are: Smart Grid into Home Devices Standards (IEEE 1547, 1675-1775, 1901, 2030), Home Networking Standards (IEEE 802-1905) and Smart Metering Standards (IEEE P1377, 1701-P1705).

Landis+Gyr is a part of IDIS (Interoperable Device Interface Specifications). Landis+Gyr and other three companies have also made common standards by which devices are made compatible with each other. Companies that are in IDIS are: ISKRAEMECO, Itron, Elster and Landis+Gyr. The table below lists PLC communications pros and cons in comparison with other control protocols that author used as student.

Table 1. PLC communication pros and cons

Pros	Cons
+ no wiring needed	-slow
+ long distance message sending	-messages are very vulnerable
+ do not depend on other companies (GPRS communication needs operators sim cards)	- communication signals are being restricted by standards, however devices that come from households and make interference are not
+ cheap	

3 Landis+gyr & PLC

This thesis was written with the help of Landis+Gyr. It is company that is “A leader on energy measurement solutions and advanced meter management for electricity, gas, heat and water utilities”. In total, Landis+Gyr has 5,527 employees (03/2014).The net sales in Landis+Gyr were USD 1539 million worldwide. Services and devices provided by Landis+Gyr are meters, communication options for data reading from meters and systems, software for smart meters, network management and tools for billings and customer services. (Landis+Gyr, Fact Sheet 2014)

Author worked at Landis+Gyr Jyskä office and this particular office has been under name of Landis+Gyr for about 8 years. Jyskä office was founded first in 1948 and was called Valmet meter department, and it was known with the name of Valmet until 1992 when name changed to well-known Enermet. Only in year 2007 did Enermet get the name of Landis+Gyr and in year 2011 Landis+Gyr became Toshiba’s subsidiary company. Below Figure 1 shows a more precise description of mentioned office’s history.

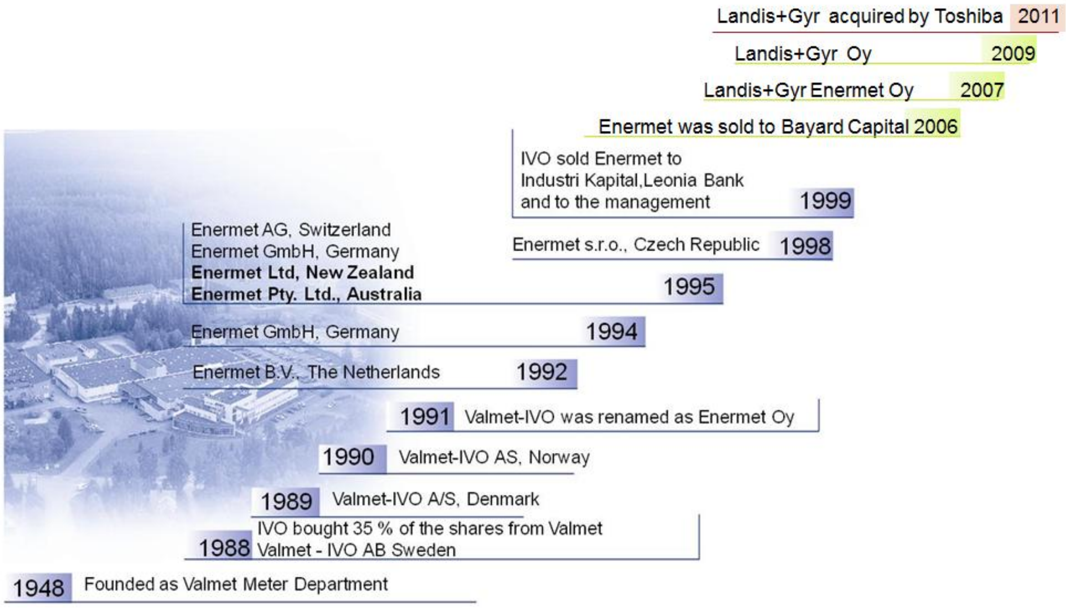

Figure 1. History of Landis+Gyr Jyskä office

The entire metering, data collecting and processing process can be seen in a figure below (Figure 2.). The thesis will concentrate more or less on PLC communication of process that takes place in “Interoperable meter park infrastructure” between DC450 concentrator and meters seen in Figure 2. In Figure 2 there is also Gridstream HES layer that processes all the information that comes from the meters and sends controls back to them, this layer will be introduced more later in the thesis. And the last layer where Gridstream MDUS (Meter Data Unifaction and Synchronization) and 3rd party MDM (Meter Data Management) are, is for the more customer-friendly meter control and the meter reading. During the author’s practical training at Landis+Gyr he was familiarized with four different PLC communications used in Valmet/ Enermet/ Landis+Gyr starting from MELKO communication and ending up with the present G3 in development.

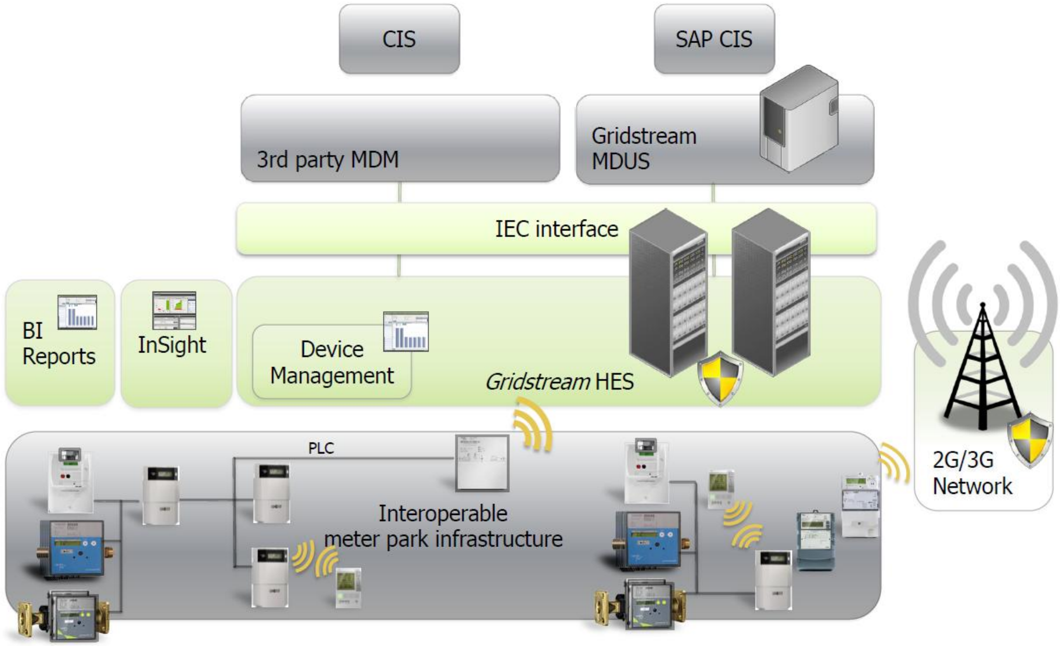

Figure 2. Tree structure of entire process

3.1 MELKO communication and devices

MELKO (Mittareiden Etä-Luenta ja Kauko-Ohjaus, Meter remote reading and remote control) was in use from 1980 to middle of 1990s when LONworks communication replaced it (Karkkulainen Toma, 2005, 66). By the end of the year 2013 all MELKO meters had to be replaced (Jyväskylän energia, 2013) and only few MELKO meters were left in places where long signal sending distances were essential, for example in Lapland or in Norway mountain ranges. MELKO communication's main difference is that it uses medium voltage network when other communications utilize low voltage network.

3.1.1 MS400

MS400 works on the medium voltage network and makes two way communication possible between the meters and HES. The MS400 device was incredibly stable against over-voltage and interference, and especially effective in rural areas. The device is same the first version of the later mentioned concentrators.

3.1.2 MH30

MH30E were made for remote device registering and reading electricity consumption and heat energy. It is possible to use device independently and read data straight from the device or as a part of MELKO system and communicate via electrical network. It is possible to connect eight meters to MH30E terminal unit; however only four of eight could be controllable, and four other meters could only send analog data to MH30E terminal unit (Terminal Unit MH30E, 1998, 1-2).

3.1.3 MH40

MH40 is a totally different device with a multi-tariff feature that was added for different prices for electricity, day and night electricity. It has only two pulse input channels, and it can store values in eight registers up to 333 days. With MH40 terminal unit it is possible have real-time control (Terminal Unit MH40, 1998, 1-2).

3.1.4 Pros and cons

In table below are listed pros and cons of devices that utilized MELKO communication

Table 2. MELKO communication pros and cons

Pros	Cons
+ long distance signal sending	- very slow
+ was the best at the time	- limited reading capacity because of slow communication
	- frequencies used in communication, can be heard by users

3.2 LONWorks communication and devices

LON is short for Local Operating Network, and LONworks was created by a company called Echelon Corporation. Echelon Corporation is an American company founded in 1988 in San Jose, California. Echelon develops open standard control networking platforms and all possible elements that are needed for design (Echelon corporation, Company; Wikipedia, Echelon Corporation).

Enermet started using LONworks communication about in mid 1990s and used it until PLAN communication came in about 2006 and replaced it. The LONworks communication devices are still highly in use, however their mass reproducing has stopped.

3.2.1 E120 LiME


Figure 3. E120LiME Device

In this device E120 stands for "Integrated kWh meter with profile meterings" meaning that this device can measure electricity consumption and can have different profiles that can be done for different consumers. "Li" in "LiME" stands for LonWorks communication and "ME" indicates that it also supports multi-energy (gas/liquid flow, heat energy metering etc.)(E120LiME User Manual, 8.1.2015, 5-9). These meters are pretty common in residential areas and there is high possibility if commoner will go and look at their electricity meter at home they will see this model (Figure 3.).

3.2.2 EMPC100i

EMPC100i is a device that collects metering data from the meters in LONworks communication network, stores data and transfers information then to the central unit by using TCP/IP and PPP protocol. EMPC100i can also receive messages from the central unit and use them to control the meters and other devices.

3.2.3 Pros and cons

In table below there are listed pros and cons of devices that use LONworks communication in Landis+Gyr.

Table 3. LONWorks communication pros and cons

Pros	Cons
+ reliable connection	- expensive
+ easily accessible	- cannot be easily modified
+ being used in many applications	

3.3 PLAN communication, DLMS/COSEM and devices

PLAN is a Power Line Automation Network and is uses DLMS/COSEM communication protocol. DLMS is short for Device Language Message Specification and COSEM for COmpanion Specification for Energy Metering. DLMS/COSEM uses IEC 62056, IEC61361, IEC 61334 and EN13757 standards as a base (WHAT IS DLMS/COSEM).

PLAN communication has been in use for a long time now and is still in use. All new devices that are assembled nowadays by Landis+Gyr are using PLAN communication, and next communication in line is G3.

3.3.1 DC450

DC450 is a data concentrator, and as the name says, it concentrates data from all meters under it in one place and then sends “data to Message Max platform and on to upper level systems”. It is also possible to send controls from DC450 to meters and in general, if line has DC450 in it every information goes through it (DC450 User Manual, 2014, 10). Figure 4 illustrates the design of DC450 device that was used later in application example.

Figure 4. DC450 Device

3.3.2 E450 IDIS PLAN+

E450 Is one of the most common of smart meters that uses PLAN communication and supports multi energy reading and control, which means it all kinds of energy can be measured, for example energy used in flowing gas/ liquid, heat energy and electricity. It is also possible to control and even shut down electricity from customer that is not paying his/her electricity bills. In Figure 5 below is shown E450 device that is the most common device and were used in test environment application that will be reviewed later on.

Figure 5. E450 Device

3.3.3 Pros and cons

In table below are listed things that are good and bad features in PLAN communication.

Table 4. PLAN communication pros and cons

Pros	Cons
+ cheaper than LONworks	- vulnerable to disruptions
+ possibility of using device with other companies devices (IDIS)	- uses only two frequencies

3.4 G3 communication

G3 is the newest form of communication, and it is being in development now. First G3 devices were released for tests in 2013. G3 communication is being implemented to DC450 and E450 devices and these devices are being released on markets in nearest future. Down below is a table that lists all pros and cons of G3 communication.

Table 5. G3 communication pros and cons

Pros	Cons
+ bigger faster message sending and re-ceiving	- new technology which is still under development
+ better signal receiving sensitivity	

4 TOOLS USED IN PROJECT

4.1 Device Management and HES

“Device Management is a web-based application for managing the configuration of the reading system of Gridstream products.”(Device Management User Manual, 2015, 6). Gridstream products are all LON, PLAN and G3 meters, and Device management uses Gridstream HES (Head End System) as a “communication and data collection layer between itself and metering network (PLC)”. The purpose of Gridstream HES is to collect metering data from the meters and provide the collected data to the other systems, for example the Device management, or monitoring tools. The Gridstream also provides status reading, alarm data, event logs, power cut data and other power quality information from the devices. Scalability of the Gridstream HES is outstanding, and it is possible to connect single metering point, or up to three million metering points to Gridstream HES. (Gridstream HES Product Description, 2014, 8-11).

4.2 L740 Load Switch

L740 is a device that can consist from one to five controllable and monitorable relays. The device can be operated by using RPT01 and optic head cable, HES or SoapUI. It is possible to make automated functions with using timelines as indicator to when to run the program if some kind of program needs to be used each hour, day or week. L740 has two kind of controls in it PLC PLAN/PLAN+ and ripple control. The ripple control differs from PLAN communication in a way that the ripple control is only for controlling a device; however, with PLAN it is also possible to read different data from L740 Load switch (L740 User Manual, 2013, 10). In this project L740 load switches with five relays were used to control filters that put weakening in lines and also controlled phases in lines. Below Figure 6 shows the design of L740 switch with 4 relays.

Figure 6. L740 Device

4.3 RPT01

RPT01 is a parametrization tool for ripple control receivers and load switch devices. For using tool you need to use USB optic head and device that can be parametrized. Things that can be done with this tool are address, program, timeline editing, time synchronizing and printing labels and printing lists of different events in devices. In my project I used RPT01 tool to reset all programs in L740 so that they won’t change state without command from HES of SoapUI (RPT01 User Manual, 2013, 7).

4.4 SoapUI

SoapUI is a Java based free open source cross-platform functional testing solution. SoapUI supports Groovy and JavaScript languages (SoapUI. The Swiss-Army Knife of Testing.). In Landis+Gyr it has been in use for about 10 years and it has been used on the layer between HES and customer's interface. In this project SoapUI was used to control L740 relays because in Device Management it was only possible to change single relay's state at the time. Even though command for relays was to change all relays at the same time, restrains in L740 made it only possible to change many relays; however, only one at the time when the previous relays were in right state, and it took usually for five relays to change state about in 15 seconds.

4.5 MAPtools

MAP and .MAP tools are made by a Landis+Gyr for parametrizing and configuring devices that are registered in IDIS organization. There is .MAP (dot MAP) and MAP tools and their difference is that, MAP tools are for older devices without IDIS compatibility and .MAP tools are for newer meters. Then there is MAPtools105, 110 and 120. 105 is made for developers, 110 is for data reading and 120 is for configuring devices.

4.6 DC450 Concentrator web application

DC450 concentrator has its own web application/ webpage that is being used mostly by developers and service personnel. In this application it is possible to see what devices are under concentrator and it is also possible to send different updates and configurations to devices by using this application. It is also possible to wirelessly send updates and configurations to DC450 itself. In this project author pinged devices from this web application to see if devices were in reach and could response to messages with quality good enough to be in use.

Figure 7. Landis+Gyr PLAN Analyzer

4.7 Landis+Gyr Signal analyzer

PLAN analyzer is a device manufactured by Landis+Gyr for measuring concentrators signal and its quality in power network. This device works without batteries or other external power source as it takes needed power straight from the network. In case if metering devices do not work or response, by using PLAN Analyzer you can find spot where signal can reach and where it disappears, or in situation where there is more than one transmitting device PLAN Analyzer can detect crosstalk between devic-es(PLAN Analyzer User Manual, 5).

4.8 MFA400 Multi Frequency Analyser

MFA400 is a frequency analysis device made by Swedish company SWEMET. By connecting one end to computer and another end to electrical network, it is possible to see in real time what happens on different frequencies via user interface that comes for computer with MFA400 de-vice.

Figure 8. MFA400 Device by SWEMET

5 Test environment application

The objective was to make environment similar to a street that is being controlled and monitored. This test environment had four different chains of streets. The first chain has five blocks and between every block there is at least 13dB weakening that is made by special filters. The other three chains have only two filters and only two blocks. Filter weakening is made to reflect weakening generated by long cables in real life situations.

The author got involved with this project when the idea emerged, and the first weakening filters had to be tested. Therefore, the first action was to get used to product L740. After acquiring the first L740 relay box, it had to be registered under

DC450 concentrator in personal testing environment. Then the author proceeded to relay control via Device Management. After confirming that the L740 relay box works under Device Management and that it is controllable, the device operation ability had to be tested via SoapUI program that used IEC communication. First SoapUI had to be configured on computer, then the author learned the program with help of other workers. At that moment L740 relay control needed investigating, because there was not control for the relays in SoapUI, and it was found under E450 disconnector control. After getting used to SoapUI a short program was made that tested every relay by switching them on and off once, however the confirmation had to be done physically by looking at the relay box. Then the same tests were made for another four relay boxes to confirm that they worked right, after which the devices were handed to another worker to connect them to filters so that they could be used in the project. Filter + L740 switch combination that was made is shown in Figure 9.

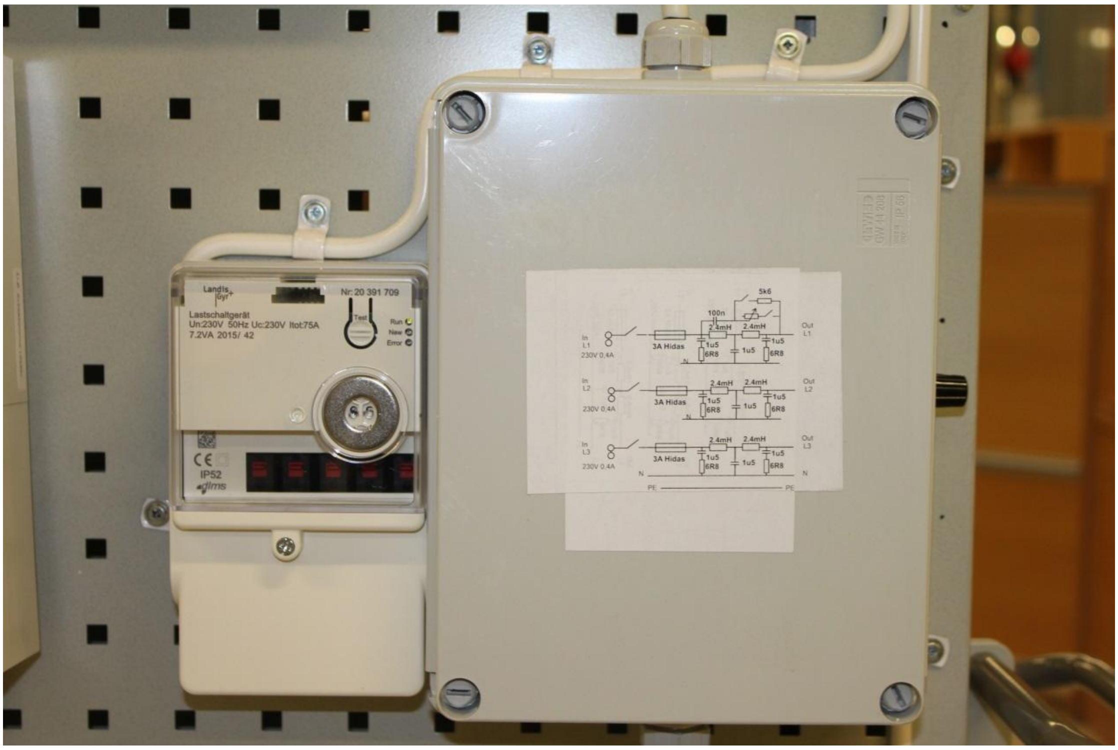

Figure 9. L740 device + Filter and its electrical circuit diagram

The next assignment was to test how the new filter + L740 relay box combination works and how weakening affects the signal that runs between connector and meters. Filter + L740 relay box combination was made so that the weakening could be changed from 13dB to 81 dB, and for example, the first four steps were 13dB, 37dB, 48dB, 53dB. As the author tested this combination he noticed that weakening had effect around at 37dB-48dB so much that all the signals did not reach the device or could not reach back to the connector.

After noticing that one combination of filter + L740 relay box does not give much variety to testing, a new testing environment was made with four filters with L740 relay boxes. With this new testing environment the signal could be weakened that much that it went from source to second line; however, could not reach the third. Thus, what happened then is that the meter on the second line worked as repeater and sent a signal to the meter on the third line, and so on until all meters got their messages back and forth. While doing the signal check for this new environment it appeared to be working in the same manner as with one filter + L740 combination, the signal goes through 13 and 37 dB weakening and starts to get disturbance at 48dB, and at higher weakening messages do not pass.

Matters were different with G3 meters. They withstood more weakening, however, when the devices reached their limit, all meters just stopped getting any messages at all, as with PLAN meters they only lost some of messages.

After all this testing of working principle and signal/message behavior it was time to put the mentioned environment on a bigger scale, and the test environment was implemented as follows: it had four “blocks” and three of the “blocks” had two lines and one ”block” had six lines. All these lines could be connected together as a big tree or could be separated into smaller pieces. The minimum length can be one line and the biggest length can be achieved by connecting eight lines together in a row. All these “blocks” and lines can be seen in Figure 10 below.

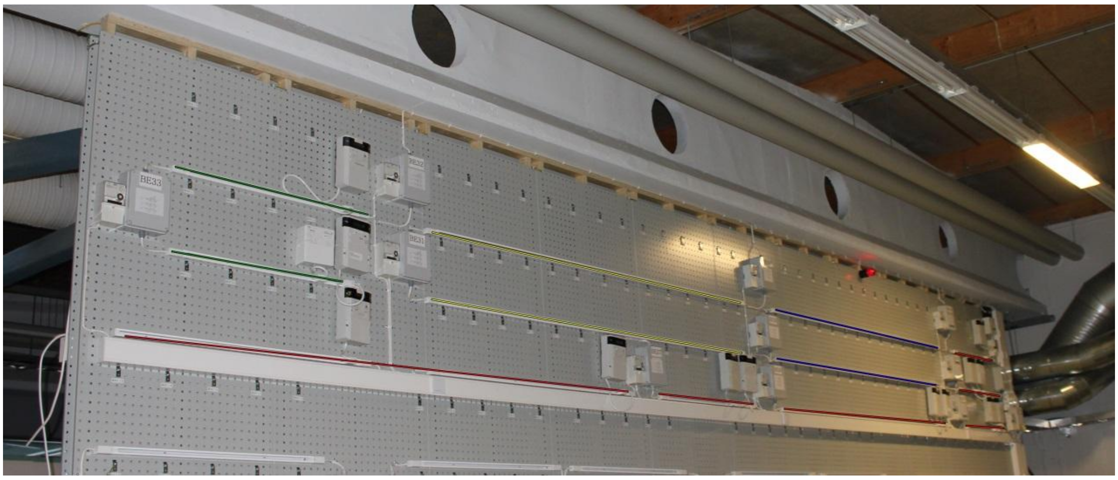

Figure 10. Test environment with marked lines

The first thing was to register controlling L740 relay switches under specific DC450 concentrator and it did not go right from the start. Four of eleven devices did not register under concentrator and HES just sent error message of devices being already registered. The problem was found when HES servers' database was checked, for some reason when the devices were previously removed from HES it did not remove them from the database, however, removed them still from Device management application. When the devices were removed from HES database and then registered back everything worked well.

The next step was to make a working program for changing relays states of L740 relay boxes on testing wall. As a base for this program the previously made testing program was used. This time the program was made to switch all relays off or all relays on; if only one relay needs to be switched on/off it can be done inside the program by choosing only one operation. When the program was made, for one relay box it could have been very troublesome to copy the same code and change the serial number of the device in at least ten different spots for eleven devices. Therefore, after consulting with co-workers the author learned how to do variables that could be changed in one place, which would replace all the serial numbers in code. So all fixed serial numbers were replaced with variables, and variables' value was put in test suite properties. Then the test suite was copied eleven times and variables value was just changed to match the controllable devices. At this point the test walls' control was ready, and it only needed metering devices that could be tested and are usually used in this kind of environment.

The first test that was done needed sixteen (16) E450 devices and one DC450 concentrator that collected data from the devices. The devices were placed on a wall and after waiting for one day the following discoveries were made: At night L1 and L3 phases disconnected. As the matter was closely investigated, the problem occurred because of the first L740 in line had a timeline program in it that switched relays in state where L1 and L3 phases were off and only L2 phase were left on. Thus, a clean program had to be uploaded into the mentioned L740 switch by using RPT01 program.

At this point the test environment was ready to use and some tests were made, where the position of DC450 was changed in the test environment to test how it affects the signal quality and message travel time.

6 Reflection on progress of tasks

In my opinion this project went on as planned and I learned much in process. The test environment was finished for the tests in about six months, and the most of delays were because the particles for completing the test environment were in making. In process of completing this test environment I first learned how to handle devices that are being used, I also learned how to parametrize and configure devices, how to detect faults in devices. Because this test environment needed more than one person to complete it I learned how to communicate with others that worked on same project and how to report every step to people that were involved in test environments completion.

Objectives

The goal of the thesis was to bring power line communication in light and show how is it possible to use it. For the company the biggest goal was the work that was done, the initializing of the test environment. After initializing that it is also important that many tests were done successfully and as much as possible test data was retrieved from the project.

Results

The results were satisfying, the test environment was finished in time and it worked as planned. We also learned how L740 behaves and how to use it as an extra result. Also, we got some new improvement ideas as result.

Challenges

We had many obstacles in work and it did not always go as planned; however, through many hardships and investigations on problems a great deal of about devices' behavior was learned and was beneficial in many ways.

From the start our problem was that we did not have any specialists on L740 device and before even using the device it had to be investigated thoroughly. Because the only purpose for this device in the new test environment was to just change relay state it worked well, however, it had its own downsides. For example, at the beginning the idea was to control L740 switches via Device Management, however, as we later found out that it is possible to send control for only one relay at the time. We fixed the problem by using SoapUI and programming a program that would change all relays state on one device. It helped user in a way that now only one command is needed to change many relays' state; however, it did not still change the fact that the device still receives one command per one function, and it still takes plenty of time when changing relays' states, also when the device tries to receive five commands at the same time it is very vulnerable to errors, and control program does not inform about these errors, thus it is a problem that is not fixed yet.

Because L740 device was not very used device in SoapUI we did not have the needed operations and support in SoapUI and everything had to be done from nothing, for example it is impossible to read real state of relays in the device, the program remembers the last operation done to the device and gives relay's state information based on that; however, if someone changes the state by hand or a relay is being held by physical limitation in another state it will show wrong information for user.

Weakening filters were made according to the plan; however, as I investigated them I found a flaw that could be done in a slightly different manner. The scale for filters was from 13dB to 82dB, and it had 11 steps in total. The problem is that it takes about 37dB-48dB to fully weaken PLAN device and 53dB to weaken G3 device, which means that weakening 61dB-82dB is totally useless, and they take six out of eleven steps in weakening filter that could be used to make smaller steps in 13dB-53dB range.

One thing that we forgot to do for this test environment is weakening of 0dB that could be useful, for example it could be useful to test devices communication and signal quality before applying weakening; in the current situation if we take the longest route from concentrator to the device without repeaters, the weakening will be 13dB*7dB =91dB and the signal will be already fully weakened at fourth or fifth filter.

6.1 Problems and reliability of sources

For a reader of this thesis I would recommend to read everything with consideration and with an idea in mind that this thesis is a written by a student and most of the information comes from his own experience of six-month work with communication that is not necessarily the most broad-minded point of view. On top of that even though PLC communication has been in use for a long time it does not have that much of information outside of the internet and does not have a general description on it because every company that uses PLC communication has its own interpretation and modification of PLC communication.

6.2 Benefits from thesis

The results from this thesis can be used in many ways. The first way of use is that it serves as a report of done job on a test environment or at least upper side of whole test environment for Landis+Gyr. From my analysis it is also possible to think of new things that could be improved in the future on test environment. In addition, when new test environments are done the same mistakes as I did will not be made if the person reads this thesis. My point of view on this project is from a person that is working for just half a year there, so a person whose been working here many yeas could also see some things from a different perspective and probably gets some ideas to strengthen their own knowledge on an issue.

For people that read this from outside of Landis+gyr, they will learn what PLC communication is and how it works, and for readers who know PLC communication from before, they will get to see how PLC is used by different companies and in different use probably. And from my point of view as a student I could probably learn about new communication type that did not get introduced to me when I was studying and get one kind of communication possibility in my repertoire.

6.3 Next steps

As I mentioned before there are several things that could be fixed but are not necessary. For example, things that I would start to improve is weakening filters steps on weakening and for L740 relay box control precision and speed could be improved a lot and would improve stability of device and environment where it is being in use. If L740 switches speed and stability could be improved it would add a lot of new test possibilities for other devices and for L740 itself.

6.4 General meaning

In my opinion when PLC will be improved to its maximum potential it could replace all other communications because making new wirings when there is already one kind of wires been laid is too much extra work and usually that kind of work requires workers with specific education that concentrates no this kind of wiring and connections.

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