DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

REMOTE METERING THE ENERGY DELIVERED OR ABSORBED BY WIND TURBINE

by

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January, 2006

İZMİR

REMOTE METERING THE ENERGY DELIVERED OR ABSORBED BY WIND TURBINE

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by

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İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"REMOTE METERING THE ENERGY DELIVERED OR ABSORBED BY WIND TIRBUNE"** completed by **AHMET KÜRŞAD ÇANAKÇI** under supervision of **PROF.DR. EYÜP AKPINAR** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Ahmet Kürşad ÇANAKÇI

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ABSTRACT

In recent years, information technology has entered in many areas of industry, trade and business although it was only a business segment under the electronic industry before. New technologies and techniques in electronics enhanced this fast grow up in information technology.

Some of the applications of information technology and electronics resulted in metering reading and related utility services. Even though in most of the countries are still using the conventional methods to read and invoice the subscriber meters now, the automated meter reading systems have very large application area especially in the North America and Western Europe. There are also some new projects in Far East like Japan, Chinese and etc. It is expected that meter automation technologies will have a much higher importance in the following decades.

Keywords: Automated Meter Reading (AMR), Meter Automation, Remote Metering, Electronic Electric Network Analyzer, RS485.

RÜZGAR TİRBÜNÜ TARAFINDAN ÜRETİLEN VEYA TÜKETİLEN ENERJİNİN UZAKTAN OKUNMASI

ÖZ

Bilişim teknolojileri, önceki senelerde sadece elektornik endüstrisinin bir alt dalı olmasına rağmen, son yıllarda endüstri, ticaret ve iş hayatının birçok alanına girmiş durumdadır. Elektronik alanındaki yeni teknolojiler ve teknikler bilişim teknolojilerinin bu hızlı çıkışını artırmıştır.

Bilişim teknolojileri ve elektronikteki bazı uygulamalar sayaç okuma ve diğer servis sağlayıcı çözümlerinde de uygulama alanı bulmuştur. Her ne kadar birçok ülke abone sayaçlarını okuma ve faturalama işlemlerini geleneksel yöntemlerle yapıyor olsa da, otomatik sayaç okuma teknolojileri özellikle Kuzey Amerika ve Batı Avrupa'da birçok uygulama alanına sahiptir. Ayrıca, Uzak Doğu'da da (Japonya, Çin ve diğer) yeni birtakım projeler vardır. Sayaç otomasyon teknolojilerinin önümüzdeki yıllarda çok daha önemli hale geleceği beklenmektedir.

Anahtar sözcükler : Otomatik Sayaç Okuma, Sayaç Otomasyonu, Uzaktan Okuma, Elektronik Elektrik Şebeke analizörü, RS485.

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CHAPTER ONE
INTRODUCTION

Fast growing national & global economic level, the industrial advance and people's increasing living standards compel electric distributor companies to take their full effort to enhance the network infrastructure to provide more reliable and much higher quality electricity to the people. In fact, distribution system is the most downstream level of the electric power system, and is directly related to the customer's electricity consumption. However, due to its wide spread in area and easily affected by natural phenomena such as weather, electric network fault is unavoidable. When fault occurs, it is their aim to locate and isolate the fault in the shortest possible time, such that power could be restored quickly.

Fast growing economy that causes the highly concentrated population in the metropolitan area, traffic jams would occur very often. Whenever outages occur, it is nearly impossible to reach the fault location quickly to carry out emergency repair. The duration of power outage would be extended and induces many complaints from the customers. Therefore, to reduce the outage time and the affected area are the essential points for improvement on distribution power system.

Meter Automation system uses the latest technology, which fully integrates the distribution system, communication system and computer control system into a comprehensive control and monitoring system. Not only does it includes functions such as distribution feeder automation, distribution system analysis, customer-end management, but also can automatically perform the fault detection, isolation, and restoration of power to the healthy levels.

Here below, the Automated Meter Reading (AMR) report prepared by Chartwell can be found. Figure 1.1 shows the Automated Meter Reading (AMR) usage according to utilities and years.

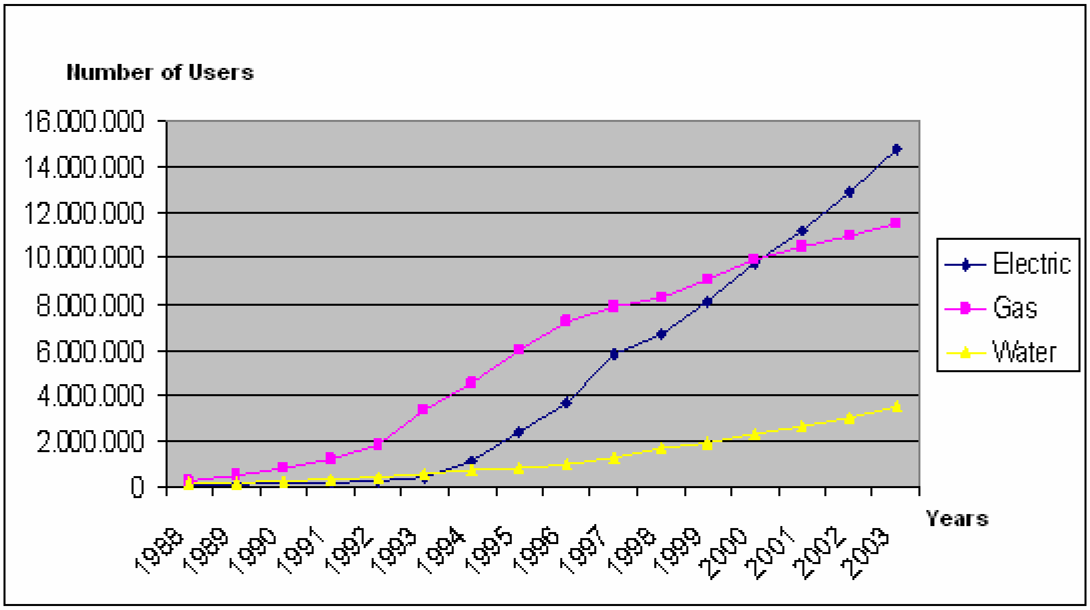

Figure 1.1 AMR Applications according to Chartwell AMR Report 2001

The main purpose of an Automated Meter Reading system is most generally; to reduce outage duration and affected area and increase reliability of power supply, to provide more enhanced customer-end management and upgrade electric power supply efficiency, to computerize the supervision of distribution system and establish comprehensive information for operation. Besides promoting the technical level of distribution system operation can be another reason for Automated Meter Reading system.

4.1 The History and Evolution of Metering Technology

Meters in general have the most inertia to change. Many of the trusted mechanical and electromechanical meters which continue to form the majority of meters installed are still in the early stages of their 15- to 30-year life cycle. This embedded base is often a major barrier for utilities considering AMR.

Any type of automation process requires the physical flow measurement of gallons, kilowatt hours or cubic feet to be converted into information that is sent to a central location. Suppliers have developed several devices that enable traditional meters to become automated through the conversion of rotation movements into electronic information.

The retrofitting devices, which need energy to convert information, are powered by batteries, remote lines, a gateway device or even the metered product. At this stage of technological development, the electric AMR meter has an advantage because it can receive power either before the meter (which the distribution company pays for) or after the meter (which the customer pays for).

Though meters often use flow to load and initiate spring-loaded moving magnets through a static field to create a pulse-per-unit measure, there is little useful energy that could power an electronic storage unit to retain this information for subsequent reading. In the not too distant future, however, meter developers may create gas-powered, water-pressure or flow-powered devices.

Emerging market demands have created a growing need for more intelligent meters. Trend-setting companies are developing electronic devices that incorporate digital readouts and software-driven functions such as time-of-day accumulations.

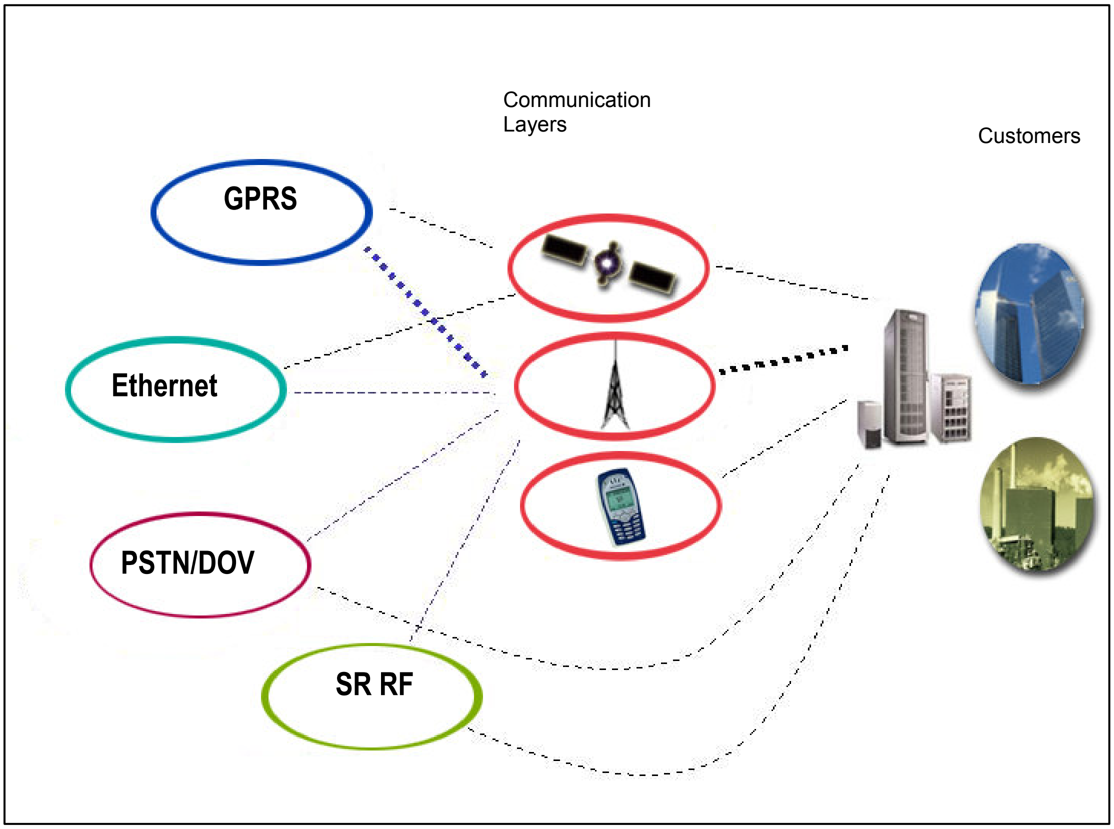

Figure 1.2 - A classical Meter Automation system scheme

Dramatic changes are also taking place with gateway devices. Basically, the gateway provides a bridge between the meter and the communications network. The advent of full-scale microprocessors with robust operating systems now permits gateways to support a variety of protocols, devices, interfaces and functions. But, like meters, gateways need some form of power to operate.

The many types of gateways available today range from simple units that link the meter and the communications system to complex devices those provide local-user display and input from peripherals, such as intelligent panels and thermostats.

The communications link between the distribution company and the end-user usually dictates the gateway's level of technology and function.

Companies wanting to improve customer service in the competitive market are encouraging the development of more intelligent and flexible gateway devices that are configured by software rather than hardware. Just as computers now perform various applications, these devices may include ports for a variety of household appliances, including telephones, televisions and personal computers.

Communications links fall into two main categories wired and wireless. Wired services include standard telephone lines, power lines, dedicated and switched data lines, and broadband services, such as coaxial and fiber-optic cable. Wireless services range from one-way drive-by systems that use low-power transmitters to send data over unlicensed radio frequencies to fixed two-way networks using advanced communications technologies such as cellular and satellite.

Some systems use an intermediate communications node between the gateway and the utility to combine and distribute information to a limited number of devices within a particular area.

These concentrating units allow data to be processed locally and the results to be forwarded to the head-end. Neighborhood nodes also permit re-use of address and frequencies. Communication between the neighborhood node and the head-end often uses a higher bandwidth link, such as fiber-optic networks or conditioned high-speed dedicated data links. An emerging trend in communications-link technology is the use of public wireless networks such as cellular and personal communications systems, as well as broadband wired networks. In these cases, meter reading is an added benefit of implementation, not the compelling reason for the deployment of the infrastructure.

Once usage data travels from the meter through the gateway and across the communications network, the computer system at the master station is responsible for accumulating and processing the information before sending it to billing and other departments. Early communications systems were proprietary computers dedicated to operating the network. Now these systems have migrated to platforms including Windows NT and Windows 95, as well as workstations such as UNIX.

A compelling need for meter data in several utility departments which analyze the data for load balancing, forecasting and marketing, to name only a few uses has driven technological advancement. Creating interfaces that link these systems with existing legacy systems remains a key challenge to integrating meter data into utility operations. (Chebra, R. (1997) The History and Evolution of Metering Technology. Metering International, Magazine Archive, 1997 Issue 2)

4.2 The Aim of the Thesis

The main aim of this thesis is to present the recent innovations in metering technology and depict the components and applications of different meter automation systems.

A brief explanation of the meter automation system with its near history is presented in the introduction section, Chapter One. In Chapter Two, the major components of a standard meter automation system are described deeply with some examples, especially various network configurations for remote metering. In the third Chapter, an electronic network analyzer with remote metering feature and the results of the application with this analyzer are presented. A prototype metering system (electronic network analyzer) is used in the laboratory in order to record the power demanded by the load powered via motor control center. The results are also given in this thesis.

CHAPTER TWO
METER AUTOMATION

The components of a meter automation system can be grouped into three main units:

- Electronic Meters equipped with Remote Terminal Units
- Local and/or Wide Area Networks
- Data Acquisition and Central Processing System

As far as these are not compulsory components, different systems may vary according to the computer and software infrastructure.

Most generally, meter automation systems contain three layers; first one is the physical hardware layer consisting of electronic meters (electric, water, gas and etc.) Second layer is the real data communication layer either wired or wireless. Even this second communication layer can be segmented into different sub-layers like wide area network, local area network and etc. It depends on the communication configuration, geographical conditions and of course customer demands. The last layer is the high level software layer with mostly contains a gateway infrastructure which collects and acquisitions the data coming from the meters via communication layer. Software layer also contains data processing and some graphical user interface functions to fulfill the customer needs and demands. All of these are the most common components of meter automation systems so different types of meter automation systems can be established based on this general structure with various components.

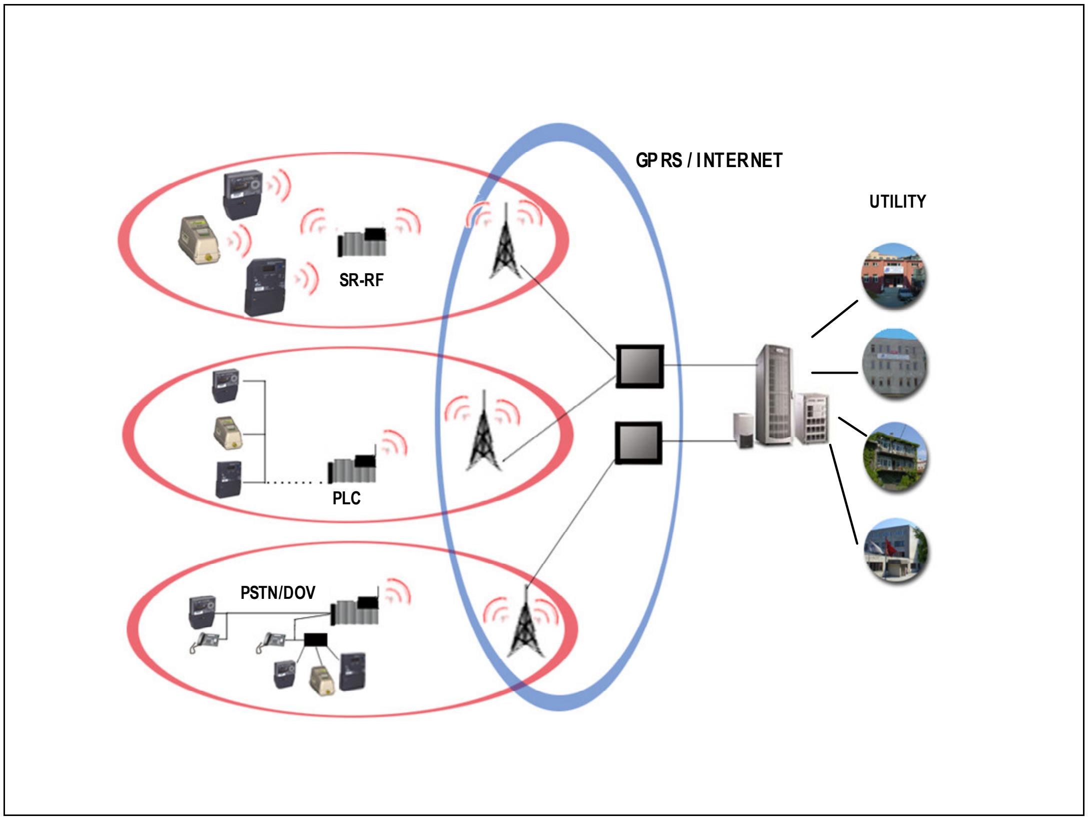

Figure 2.1 System scheme of a typical Meter Automation system

In Figure 2.1 the system scheme of a typical Meter Automation system is drawn. It may have very different components as well as very different communication layers and central processing units. Depending on the application, different communication techniques can be used either together or separately to accomplish the most efficient data transmission during operation. For example, as a wireless method Global Packet Radio Switching (GPRS) can be used with a wired method like Power Line Carriage (PLC) to be sure that the data is transferred without any loss. Besides this, two wireless techniques can be used at the same time for different purposes like, a Global Radio Packet Switching technique to fulfill wide area network operation and a Short Range Radio Frequency technique to fulfill local area network operation.

2.1 Electronic Meters Equipped with Remote Terminal Units

As can be seen in Figure 2.1, a Meter Automation system shall consist first of all electronic meters equipped with Remote Terminal Units. These electronic meters may be electric, water, gas or any other meter which have the capability of providing the necessary data to the Remote Terminal Units. The remote terminal Unit is a special purpose electronic unit that works in accordance with the electronic meter; communicates bi-directionally with the meter, gets the required data from the meter, sends the upcoming data from the Central Processing Unit and vice versa. According to the communication infrastructure, the Remote Terminal Unit uses one or some of these techniques like Global Packet Radio Switching, Public Switched Telecommunication Network, Short Range Radio Frequency, Ethernet or something else. Some examples of meters are given below.

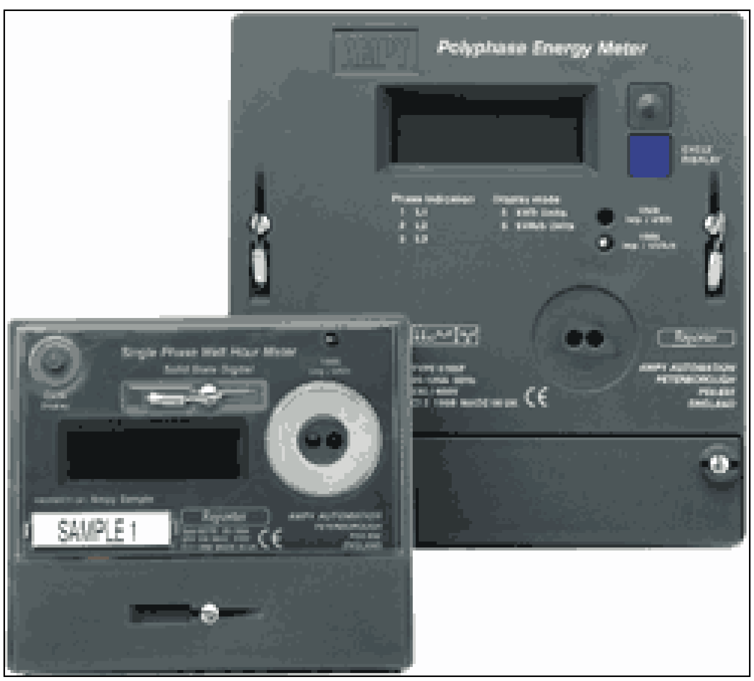

Figure 2.2 Typical single & three phase active power electronic electric meters

In Figure 2.2, there are two active power measuring electronic electric meters one is single phase and the other is three phase. Single phase electronic electric meters are generally used in residential subscribers to measure the consumed electric power. Three phase electronic electric meters are most commonly used for commercial non-industrial subscribers which can not measure the reactive power. There are some several types of electronic electric meters which vary according to the usage areas, e.g. three phase direct connected active reactive meters, three phase indirect connected active reactive capacitive meters and etc.

Figure 2.3 Typical gas and water meter examples

In Figure 2.3 there are one typical residential usage gas meter and one pre-paid electronic water meter. For gas and water metering purposes, there are generally pulse outputted meters those are enable to give electronic pulse as when some value of consumption is exceeded. The remote terminal unit counts these pulses, calculates the energy consumption and sends this data to the central processing unit. For this kind of remote metering, the communication is generally one directional.

2.2 Local and Wide Area Networks

Every Meter Automation system uses either or both a local and a wide area network. This depends on the automation usage area, geographical conditions and automation purposes. The examples of networks are given below.

2.2.1 PSTN and GSM Networks

Public Switched Telephone Network (PSTN) is one of the most widely used meter automation networks. By the means of this network, the meters can be read instantaneously by making a data call from the Central Unit to the Remote Terminal Unit. Although PSTN is a conventional way of meter automation, the new technology "GSM" started taking the place of it recently.

When remote metering solutions for meters were first implemented, the cost of installing a telephone line was acceptable. Today GSM is truly a global form of wireless communication, with almost total coverage in most developed countries. Competition has brought down the cost of both hardware and communications, and GSM has gradually become a challenge to earlier solutions.

GSM had the merit of not needing a phone line, and overall costs are now generally lower than PSTN. The primary aim of the GSM networks originally was to service voice calls, but most people now own a GSM phone and the revenue from the voice business is stagnating. Operators and hardware developers have therefore turned to new GSM network services, including machine-to-machine communications (M2M), text messaging (SMS) and GPRS. M2M services today represent a major opportunity for growth for the GSM business world and GSM has become a viable and competitive form of data communication.

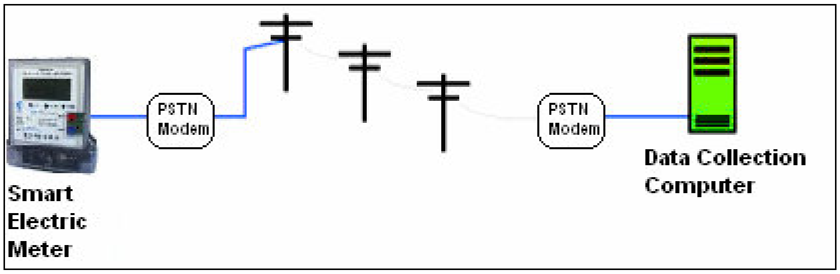

Figure 2.4 - Traditional outbound electric meter remote reading system

Figure 2.4 illustrates a traditional electric meter remote reading system scheme. The system is easy to understand that the electric meter is read by the remote terminal unit which consist a public switched telephone network modem. When the meter data is taken by the remote terminal unit, it makes a phone call to the central processing unit or vice versa. By the way, the data transmission is accomplished and the central processing unit stores this data.

Early attempts to introduce GSM technology to remote metering employed a GSM modem as a substitute for the existing telephone line, by 'emulating' a telephone modem; it was therefore compatible with existing data collection systems. The latest developments in GSM call for a review of the available technology, to help select the most suitable communications mode. The choices are as follows:

2.2.1.1 Data Calls

Using a GSM modem connected to the meter's serial port, the data collection computer calls the meter and a virtual circuit is made between the computer and the meter. The computer can then proceed to exchange data with the meter, as it would in the case of a telephone modem. Because the system is outbound the GSM modem must be powered all the time to be available to answer the call. The disadvantages of data call are:

- The polling computer modem needs to dial up every site one at a time, establish a connection, communicate and then disconnect. This procedure is time consuming and can take two minutes per meter. In a utility with tens of thousands of meters the collecting computer may require hundreds of modems and telephone connections to call every site every day.

- When the data call is established, interference on the GSM network or poor coverage can cause interruptions in the virtual circuit, leading to the need for re-tries.

2.2.1.2 SMS (Text Messaging)

This involves a block of up to 160 characters (an SMS) being sent or received using the GSM phone. The SMS handling is done by a network of computers managed by the network operators, called SMSC, which receive and deliver the SMS to and from mobile phones. In Meter Automation applications, the GSM device can communicate with the meter locally and package the data into an SMS, which it then sends to the data collection computer.

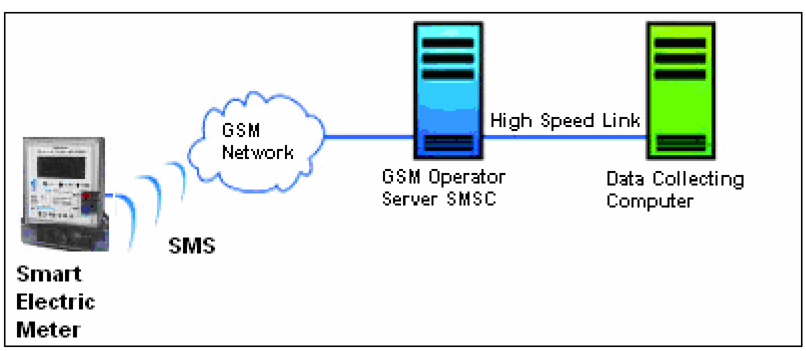

Figure 2.5 – GSM SMS electric meter reading system

In this system, the GSM/SMS device can be switched off during periods of inactivity, which greatly reduces its power consumption. The SMS method of data communication is well suited to interval and other commercial meter reading, as the small amount of data is contained in one text message. The reading is sent to the GSM network, an acknowledgment from the network is received, and the device can be switched off until the next day. The SMS is securely held in the SMSC of the operator and is recovered by the data collection computer, provided it is linked in a suitable way to the SMSC through a high speed permanent connection (see Figure 2.5).

The GSM network is designed to handle millions of SMS messages and all GSM devices can send their SMS messages almost simultaneously. The system is completely scalable and the hardware required at the data collection computer is simply one link to the GSM operators' SMSC.

One advantage of using SMS in metering system is that the GSM/SMS device is not required to wait for a call, and so does not need to remain powered. The device wakes up once a day, determines the data to be transmitted by communicating with the meter, transmits an SMS, and then turns itself off. Battery powered solutions using this technique already exist for water and gas meters that cannot provide power to the GSM device; this is a distinct advantage to multi-utilities wishing to have compatible solutions for all their meters.

Another advantage of using SMS is the technique's relative immunity to poor network coverage. Users of mobile phones know that they can send a text message even in areas where coverage makes it impossible to maintain a voice or data call.

Table 2.1 Comparison of communication techniques

		GSM			PSTN
		SMS	Data Call	GPRS	
COST	Connection	***	***	***	-
	Modem	**	**	**	***
	Operation	***	**	**	*
TECHNICAL	Ease of installation	***	***	***	*
	Low power operation	***	**	-	***
	Scalability	***	*	***	*
	Compability with existing data collection systems	*	***	**	***

2.2.1.3 General Packet Radio Service (GPRS)

The GPRS service was introduced to provide improved communication speed between two computers using the GSM network. The targeted use of this service is for access to web-based services from a laptop or PDA.

In this application, the GSM device has first to establish a connection to the collecting computer server. Once that is done the meter and data collection computer can communicate, usually over an Internet protocol. The GSM device may respond to commands issued by the computer, or deposit data using a file transfer protocol (ftp).

GSM operators have made major investments in upgrading their base stations to support GPRS and they have strongly promoted this service. This has resulted in misunderstandings in the metering industry regarding its suitability for meter automation. GPRS is particularly suitable for applications that require the connection between the two remote computers to be always on, such as e-mail messaging, web browsing from a PDA and exchanging relatively large amounts of data. For these reasons GPRS tariffs tend to be based on the amount of data traffic rather than the length of communication.

There are no known advantages to using GPRS in an interval metering application, since the data to be transmitted is relatively small (a few hundred bytes) and is only carried out once a day. GPRS, however, could be considered in special applications such as real-time monitoring of demand, where constant communication is sustained with every meter site.

GSM has become a convenient and low-cost form of data communication for the remote monitoring of electronic meters, and should support both data calls and SMS transmission methods. In existing PSTN-based meter networks, where GSM data calls will be used for compatibility, this solution will benefit from specific improvements to the unit's design, such as deriving power from the meter where available, and an integrated GSM antenna and automatic detach/re-attach from the network for maximum reliability.

As far as mentioned before, GPRS is not a very advantageous method for remote metering applications but for may be very cost efficient for some applications. For example, if the metering point is a very critical station or distribution and/or power transformer, it may be needed to monitor this information centre instantaneously. For this kind of an application, GPRS may be very cost efficient solution for remote metering.

2.2.2 Power Line Carrier (PLC)

The new generation of Power Line Communications utilizes the latest in modem and chipset technology to deliver high speed data transmission and broadband communications across an electric utility's medium and low voltage distribution systems. The services that PLC will support fall into two categories.

2.2.2.1 *Utility Related Services*

To understand the utility related services more accurately, the electrical transmission and distribution networks from the source to the consumer shall be described obviously. It's illustrated very simply in the figure below.

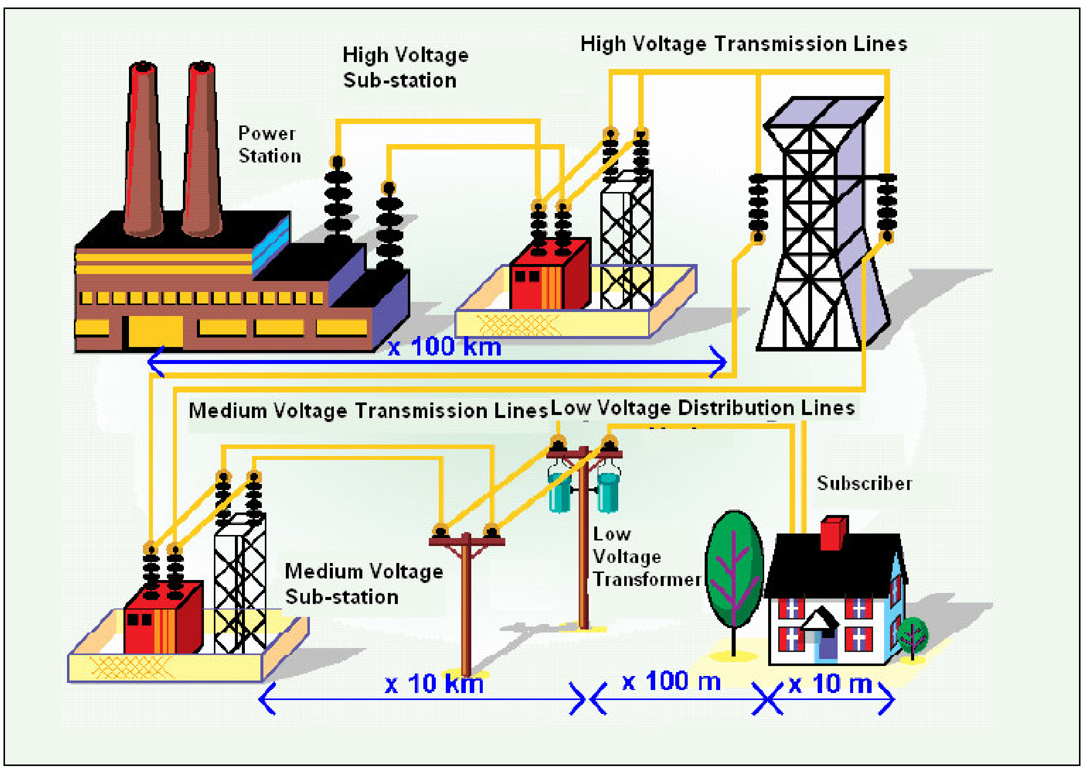

Figure 2.6 – A simple illustration of an electric network, PLCA, (n.d.).

Electric networks generally can be divided into three types according to the voltage levels:

- High Voltage Lines
- Medium Voltage Lines
- Low Voltage Lines

High voltage lines generally constitute the transmission lines and medium and low voltage lines constitute the distribution lines. The electric energy mostly produced in medium voltage level and transformed to high voltage level to reduce the power loss during transmission. After transmission, the electric energy arrives to the distribution areas and it’s first of all reduced to medium level by the means of HV/MV substations and then with the local reduction substations (MV/LV) it’s reduced to low voltage level. Low voltage electric reaches to the consumer premises to be used in TV, lighting, heating or something else.

The utility and service provider companies sometimes want to take the advantage of their electrical network and uses it as a communication media. They wanted use their own cable network for metering and monitoring purposes. Utilities accomplish this operation by injecting high frequency data (ranges according to the application from 10 kHz to 500 kHz) from one side of the 50 Hz or 60 Hz network.

The high voltage energy transmission lines have been being used as high frequency data transmitter for some decades. Supervisory Control and Data Acquisition (SCADA) system is a very common industrial application of this technology. Let’s see the frequency spectrum of a transmission line with high frequency components.

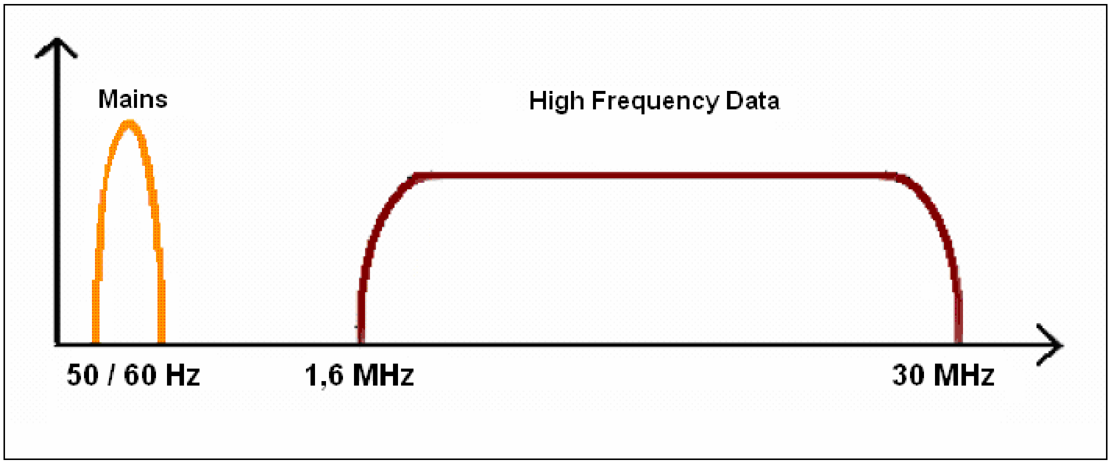

Figure 2.7 – The frequency spectrum in a transmission line with high frequency data

As can be seen in the figure above, the mains frequency is either 50 Hz or 60 Hz and the high frequency data is in the ranges of MHz. The high frequency data injected from one side of the electrical network is filtered at the other side of the network by special band-pass filters.

One of the most important advantages of Power Line Communication method to the utilities is that they can be informed about the power outages very instantly and more duly. In the common networks, the utilities can learn the power outages by inspecting the network or telephone calls from the subscribers. Although they are informed from the customer side, this information can be often not true because most of the subscribers intend to think that every power outages cause from the utility network. In fact, the utilities are responsible from the electric network up to the metering point of the electricity, in other words up to the electric meter of the customer. A reasonable power failure in the electric network does not mean that it's a problem stimulated by the negligence of the utility. By the means of Power Line Carrier system, the utilities and service providers can take the advantage of this even though the investment cost of it is not so much.

Another advantage of Power Line Communication system is that the utilities and service providers have to make some demand forecasts according to the load profile of the customers. In the classical systems, these forecasts can only be done according to the statistical data evaluated from the past consumption values of the subscribers. This technique is surely a good way of successful results but it takes much time and effort to enhance the data from library or database. By using the Power Line Communication system, these forecasts can be done instantaneously and more accurately because the consumption values can be read very quickly in the digital media.

Although the PLC network is based on the power distribution network, it will be able to provide and will enable services to utility the power network operators to improve the safety and efficiency of the power network. These services include: Network Switching, Network Monitoring Fault Diagnosis, Demand Management of Power Distribution Network, Remote Load Control and Meter Automation.

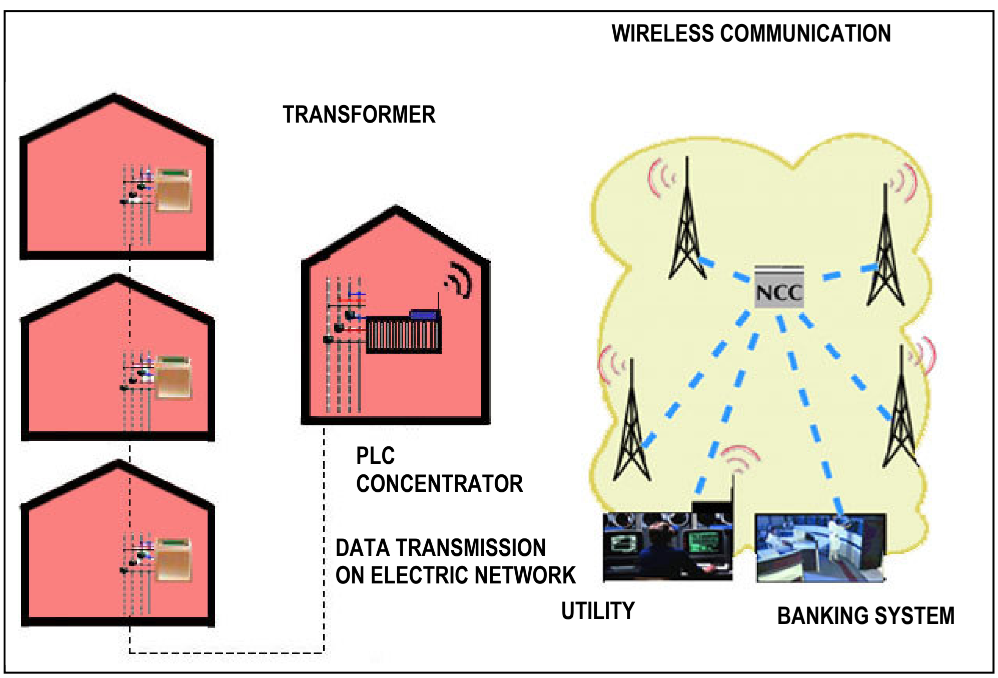

Figure 2.8 – A typical application of Power Line Carrier system

Power Line Communications or PLC is simply data transfer via a combination of the power network within the home or office, the metropolitan power distribution grid. Of key important here, is that no new wires need to be installed in the "last mile", and PLC takes advantage of the largest network on earth by far, the global power grid. Using the existing power grid as a data transfer medium makes it possible to send and receive communications signals through standard power sockets.

In the local network station or aggregation points, communications signals and electricity are carried together on the grid and transported to the home. Once in the home, all existing power sockets can now symmetrically send and receive communications signals.

2.2.2.2 Internet Access/Home & Business Networking

Broadband Power Line Communications or PLC is simply data transfer via a combination of the power network within the home or office, the metropolitan power distribution grid. Of key importance here is that no new wires need to be installed in the "last mile," and PLC takes advantage of the largest network on earth by far, the global power grid.

2.2.3 Short Range Radio Frequency (SR-RF)

Short-range RF networks use low-cost transceivers to send and retrieve data to/from water, gas or electricity meters. When used with numerous accounts, individual unit costs become negligible. Installation time and expenses are minimal because the RF hardware requires very little space and can be made to fit within the existing enclosure, whereas other communication systems often involve the high cost of replacing the entire meter.

RF-based meter reading systems are ideally suited to industrial applications, relatively dense urban and suburban areas, and even some rural areas. A typical short-range wireless metering system includes:

2.2.3.1 Client or peer transceiver module

Client or peer transceiver module attached to each utility meter to create a short-range LAN. Each meter collects usage data and stores it in preparation for interrogation.

The transceivers can communicate to one another as well as to a server module. They use customized over-the-air protocol and proprietary technology for cost savings and reliability.

2.2.3.2 Server transceiver module

Sever transceiver module attached to a central data-collection system such as a computer or handheld reader. Server transceivers send and retrieve data from client or peer transceivers with an instant RF link, and the client transceiver responds with a signal containing usage details.

2.2.3.3 Head-end data processing system

Head-end data processing system maintained at utility headquarters. The head-end system sends and retrieves data from the server unit(s) via land-line or cellular technology. The details quickly gathered from each site transceiver can contain info about usage patterns and allow for conveniences such as Internet-accessible data, quality monitoring and automated outage notices.

Fixed RF networks maintain a continuous link between meters and the utility. This link lets the utility company access meter information at any time it chooses and use the information to offer enhanced customer service (e.g. client-specific rates or incentives). Because wireless gives utilities flexible access to information, it can be used to help prepare and position the utility for changes in regulation and the business climate.

Portable RF systems give highly reliable access to data by personnel in the field. Mobility solutions are designed to offer safe, reliable transmission of data to and from the field and can secure corporate data from intrusions or eavesdropping.

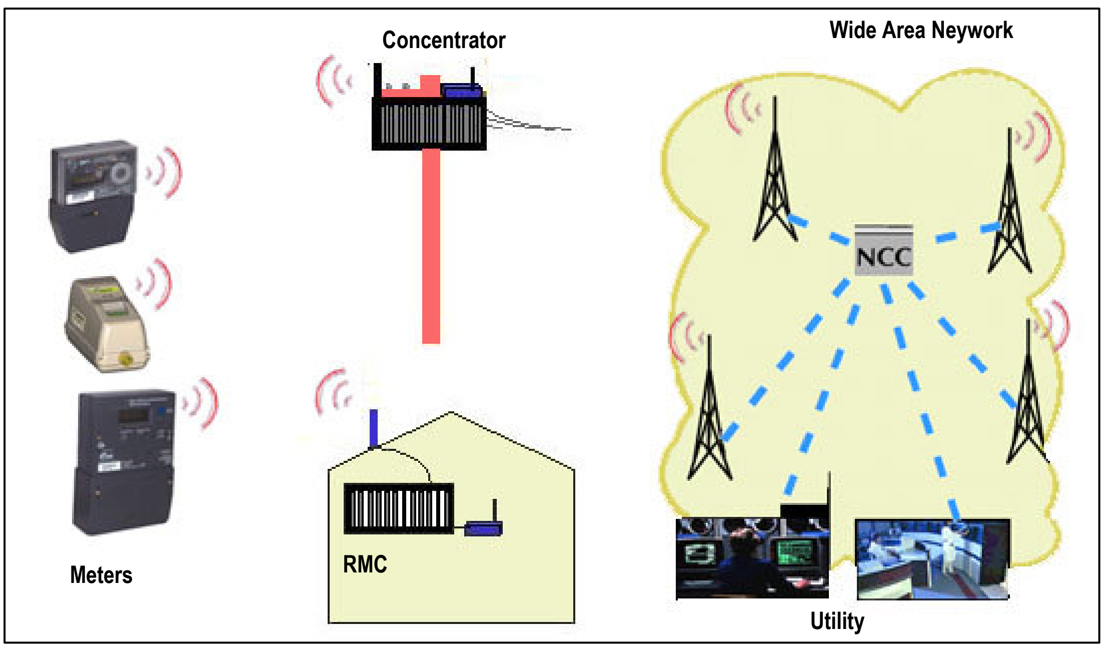

Figure 2.8 – The system scheme of a short range RF system

In Figure 2.8, the meter reader is able to drive through the meter route at posted vehicle speeds to collect meter readings, which are stored in the laptop. A simple graphical user interface provides easy-to-navigate status reports and graphs.

Plus, advanced addressing protocol allows the system to automatically interrogate each meter, keeping operator intervention to a minimum. Once the data is retrieved, it is stored locally until is can be uploaded to interface with route management or billing.

By integrating short-range RF transceivers into the local LAN and then widening the network via cellular-based WAN, utilities can wirelessly cover 100% of their metering population. Accurate daily and peak forecasts give companies the opportunity to offer time-differentiated prices and customized billing options. Some advantages of short range radio frequency networking are given below:

- Less invasive than cable installation.
- Easy to install, supports expanding networks.
- Operates in harsh environments & extreme temperatures (-40° to +80°C).
- Fits into space-constrained enclosures, stationary and handheld.
- Resists interference & eavesdropping.
- Provides real-time access to data.
- Simplifies purchasing and distribution planning.
- Saves service costs by eliminating estimates & automating notifications.
- Allows for instant reprogramming to alter the data collection process.
- Supports regular, increased and unscheduled readings.
- Always-on communications for fast notifications of meter-tampering.
- Enables safe data collection in high crime areas & dog-guarded yards.
- Well-established networks can replace personnel in the field.
- Supports value-added services to the network for any establishment.
- Scalable networks allow for addition/subtraction of metering points.

2.2.4 RS422 and RS485 Serial Communication

RS 232 is well-known due to popularity of today's PC's, unlike the RS422 and RS 485. These are used in industry for control systems and data transfers (small volumes, No hundreds of Mb/s).

The main difference between RS 232 and RS 422 & 485 can be explained as follows. The RS 232 signals are represented by voltage levels with respect to ground. There is a wire for each signal, together with the ground signal (reference for voltage levels). This interface is useful for point-to-point communication at slow speeds. For example, port COM1 in a PC can be used for a mouse, port COM2 for a modem, etc. This is an example of point-to-point communication: one port, one device. Due to the way the signals are connected, a common ground is required.

This implies limited cable length - about 30 to 60 meters maximum. (Main problems are interference and resistance of the cable.) Shortly, RS 232 was designed for communication of local devices, and supports one transmitter and one receiver.

RS 422 & 485 use a different principle: Each signal uses one twisted-pair (TP) line - two wires twisted around each other. It’s named as 'Balanced data transmission', or 'Differential voltage transmission'. Simply, let's label one of the TP wires 'A' and the other one 'B'. Then, the signal is inactive when the voltage at A is negative and the voltage at B is positive. Otherwise, the signal is active, A is positive and B is negative. Of course, the difference between the wires A and B matters. For RS 422 & 485 the cable can be up to 1200 meters (4000 feet) long, and commonly available circuits work at 2.5 MB/s transfer rate.

What is the difference between RS 422 and RS 485? Electrical principle is the same: both use differential transmitters with alternating voltages 0 and 5V.

However, RS 422 is intended for point-to-point communications, like RS 232. RS 422 uses two separate TP wire, data can be transferred in both directions simultaneously. RS 422 is often used to extend a RS 232 line, or in industrial environments.

RS 485 is used for multipoint communications: more devices may be connected to a single signal cable - similar to e.g. ETHERNET networks, which use coaxial cable. Most RS 485 systems use Master/Slave architecture, where each slave unit has its unique address and responds only to packets addressed to this unit. These packets are generated by Master (e.g. PC), which periodically polls all connected slave units.

Due to the communication technique applied in our project, we will mainly cover the Master/Slave architecture because it is sufficient for 95% of applications too. In special cases (security systems, etc.), an improved version of multiprocessor communication is used.

This system uses only a single line for bidirectional communication; however, there is no Master. All units announce a packet transmission of a specified length, and at the same time listen whether the data has been successfully transmitted. If it's not the case, they stop communicating and listen for what has happened. At this time, urgent packets can be transmitted over the line. This system is ideal for devices, which need to immediately transfer some very important and up-to-date data, without waiting for Master to give them a chance to do so. On the other side, useful data transfer is less effective (about 30% less effective than the first system). In Master/Slave architecture, slave never starts the communication. It is critical for Master to send correct addresses.

RS485 exits in two versions: One twisted-pair and two twisted-pairs:

- In single twisted-pair RS 485, all devices are connected to a single twisted-pair. Thus, all of them must have drivers with tri-state outputs (including the Master). Communication goes over the single line in both directions. It is important to prevent more devices from transmitting at once.

- In double twisted-pair RS 485, Master does not have to have tri-state output, since Slave devices transmit over the second twisted-pair, which is intended for sending data from Slave to Master. This solution often allows implement multipoint communication in systems, which were originally designed for RS232. Of course, Master software needs to be modified, so that Master periodically sends query packets to all Slave devices. Increased data throughput is evident in large volumes. Sometimes it can be seen that an RS485 system in a point-to-point system. It is virtually identical to RS 422; the high impedance state of the RS 485 output driver is not used. The only difference in hardware of the RS 485 and RS 422 circuits is the ability to set the output to high impedance state.

2.2.4.1 Balanced differential signals

At this stage, the advantages and disadvantages of RS 422/485 shall be mentioned. For a basic RS 422/485 system, an I/O driver with differential outputs and an I/O receiver with differential inputs are needed. Noise and interference is introduced into the line; however, since the signal is transferred via a twisted pair of wires, the voltage difference (between A and B) of this interference is almost zero. Due to the differential function of the RS 422/485 input amplifier of the receiver, this interference is eliminated.

The same is true for crosstalk from neighboring lines, as well as for any other source of interference, as long as the absolute maximum voltage ratings of the receiver circuits are not exceeded. Differential inputs ignore different earth potentials of the transmitter and the receiver. This is very important for communications of diverse systems, where great problems would otherwise arise (e.g. different power sources, etc.) Twisted-pair cables, together with correct terminations (to eliminate reflections), allow data transfer rate of over 10Mbit/s with cables up to 1 km long.

However, all of these advantages come at a cost. RS 422/485 circuits are more complex, and thus more expensive. Higher data transfer speeds require correctly connected and matched terminations, which can be a problem in systems where the number of connected devices changes. And, of course, Twisted-pair cables are required.

In a RS 232 unbalanced data transmission system, each signal is represented by a voltage level with respect to ground. For example, the TxD signal of a PC's communication port (COMx) is negative when idle, and switches between positive and negative level when transmitting data. Amplitude ranges between -15 to -5V in negative state, and between +5 to +15 V in positive state.

In a balanced differential system, the transmitter generates a voltage between 2 to 7V (approx.) between the A and B outputs. Although the transmitter and the receiver are connected with a ground wire (GND) as well, it is never used to determine logic levels at the AB wires. RS422 transmitters usually don't provide such input. Voltage level of most commonly sold transmitters is 0 and 5V. When idle, there is +5V on B and 0V on A.

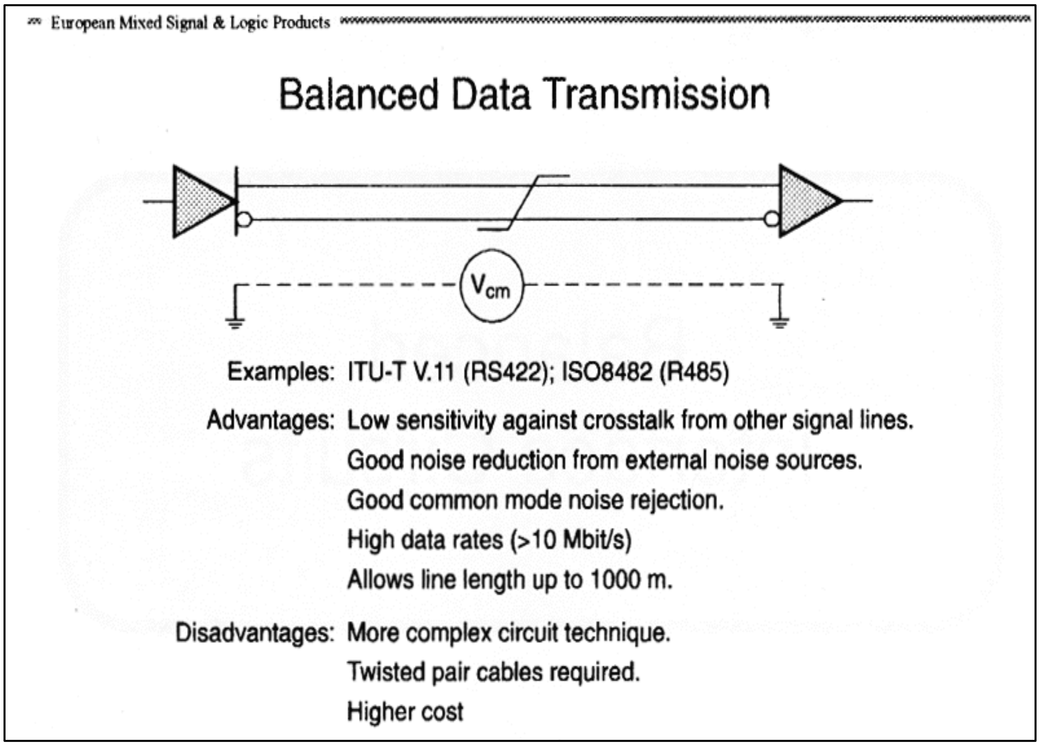

Figure 2.9 – Balanced Data Transmission, RS485 (n.d.).

RS422/485 receivers react to voltage difference between the A and B inputs. If V_{ab} is greater than 200mV, a logic level is defined on the receiver output. For V_{ab} less than 200mV, the logic level is opposite.

Ground potential difference between different devices is +- 7V max, according to EIA-RS 422. EIA-RS 485 defines maximum voltage range at the receiver input (ground potential difference + alternating signal voltage) from -7V to +12V. RS 422/482 circuits have a short-circuit protection. Point-to-point (EIA-RS 422) defines short circuit as a current greater than 150mA, between A and B or against the ground. Multipoint (EIA-RS 485) defines short circuit as current greater than 150mA against the ground, or more than 250 mA between A and B.

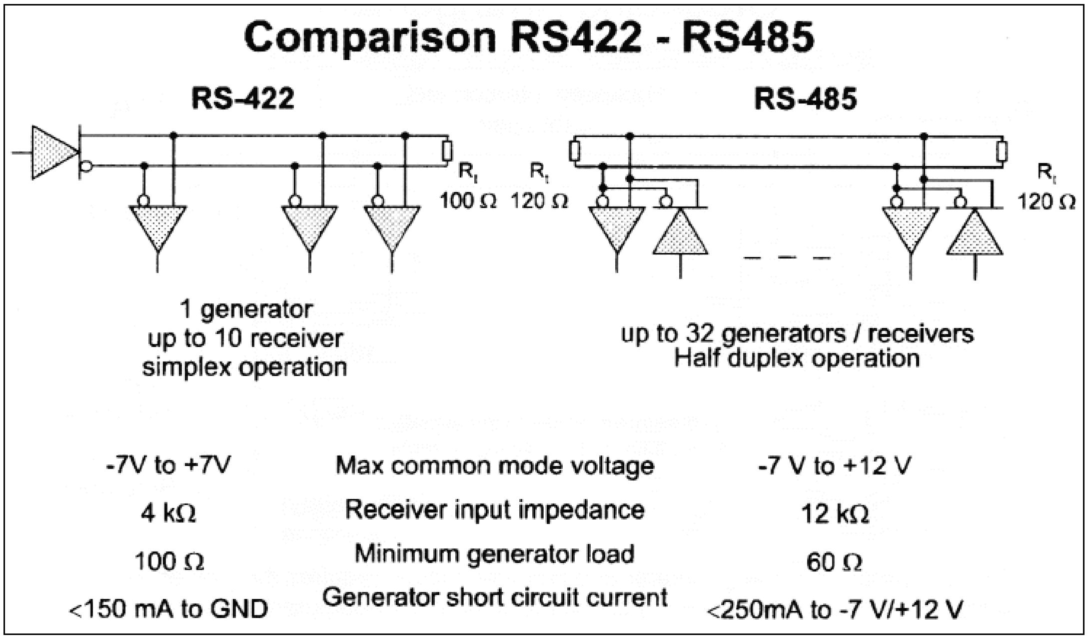

Figure 2.10 – Comparison of RS422 and RS485, RS485 (n.d.).

For correct operation of the transmitter and the receiver, a return signal path between the grounding of individual devices is required. It may be realised either by a third wire, or by grounding each device (third pole in the mains socket). If a third (ground) wire is used, resistors (approx. 1kOhm) should be connected in series to eliminate unwanted currents resulting from ground potential differences.

2.2.4.2 Terminations, capacities, cable lengths and data transfer speed

RS 422/485 line termination is essential, especially for faster data transfer rates and long cables. Main reasons for correct termination are reflections at the ends of the line, and the minimum transmitter load requirement. For RS 422, the termination is fairly simple. A terminating resistor of 100Ohm is connected to the end of the line. If there are more RS 422 receivers connected to the line, the resistor can be a little bigger. The value can be calculated since the input impedance of the receivers is known.

For RS 485, the termination is somewhat more complex. Since each device communicates bi-directionally (single twisted-pair version), we are unable to determine where is the transmitter and where is the receiver - this changes constantly, according to which device transmits at the moment. So, both ends of the line have to be terminated with a 100Ohm terminator. However, it is not that easy. Since all device have tri-state outputs, situations occur (very often - every time the transmitting device or data direction changes), when all transmitters are in high impedance state, and the line, due to termination resistors, is in undefined state (V_{ab}; 200mV). It is, however, define idle state in this situation (V_{ab}<-200mV).

In Figure 2.10 the dependence of transfer speed on several basic conditions is shown.

Maximum data transfer rate over short distances, where the line influence can be neglected, is determined by the output parameters of the transmitter. The duration of the rising and falling edges matters. Standard assumes speed of 10Mbit/s; today's fastest chips, e.g. SN76ALS176, can achieve up to 25 MBit/s.

When the line length exceeds 10m, we have to take into consideration losses caused by capacities and the so-called skin effect, when the current begins to flow only on the surface of the conductors. The rule for standard twisted-pair cables says, that data transfer speed (Mbit/s) multiplied by cable length (m) is less than 10^8. So, for example, if a cable is 100m long, we get maximum data transfer speed of 1Mbit/s. Last limitation applies to very long cables. Speed is limited by the ohmic resistance of the line, and following the signal loss. Maximum cable length is determined by its resistance, which should be less than the line impedance - 100Ohm.

Standard twisted-pair cable, diameter 2x0,6mm has a resistance of around 100W/km. Capacity of the cable needs to be considered as well.

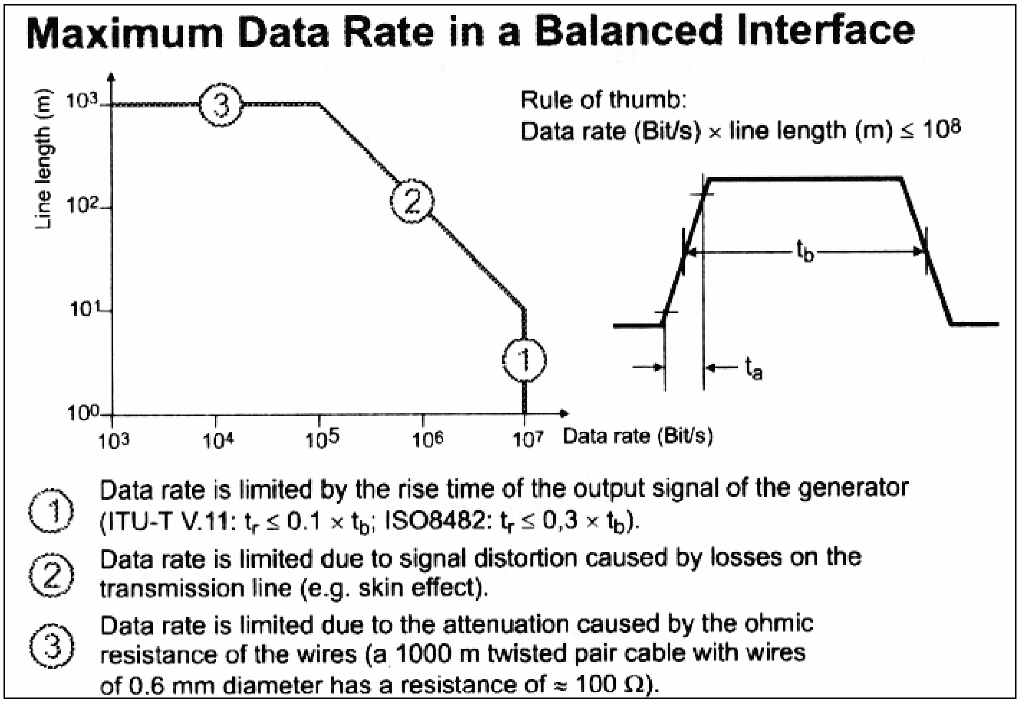

Figure 2.11 – Maximum Data Rate in a Balanced Interface, RS485, (n.d.).

As some examples; for a data transfer speed of 1200 baud, maximum cable capacity of 250nF; for a data transfer speed of 9600 baud, maximum cable capacity of 30nF can be mentioned.

2.2.4.3 Protocols and software

This part is to be short because software is custom-designed for each individual application, including the transfer protocols. RS 422, as a point-to-point connection, operates similarly to the RS 232 serial port. However, there are certain things software needs to take into account.

First, the communication media (twisted-pair line) needs to be assigned to individual stations, so that there are no collisions and those responses are fast enough.

The fact should be taken into account, that only a single channel is available for communication. It has to transfer both data and the bit and byte synchronization. For transferring of individual bits, one of the data network modulations can be used, e.g. coding NRZ, NRZI, phase modulation NRZ, or differential phase modulation. These modulations are not covered because they are a topic of network and protocol theory.

For byte synchronization, several options are available. Maybe the simplest is to reserve one byte to be a sync character. Software then needs to convert data bytes equal to the sync byte to a sequence of different bytes. Or, protocols SLDC/HLDC, suitable for high-speed transfers, may be used. When an application requires only slower data transfer rates (115200bd, or up to 2Mb/s with special UART circuits), we can take advantage of the RS 232 format for both bit and byte synchronization. This solution saves a lot of effort, especially when a PC is used as Master, and Slave is equipped with a microcontroller containing its own UART, e.g. 8051 compatibles.

From a network point of view, the RS 485 incorporates a bus topology. Since Slave stations have no means of starting the communication without a risk of collision, they need to be assigned a 'right to transmit' by the Master station. Assignment is done centrally via pooling, where the central (Master) station periodically asks all Slaves whether they have data to transmit. If so, the questioned station sends the data immediately; otherwise, it replies with a confirmation packet only, or does not reply at all.

Of course, individual system requirements need to be considered. Mentioned 100 stations is for an "on-line" system, where stations have to interactively react to user requests, thus the reply delay needs to be less than 0,5 sec (considered for 115200bd data transfer rate, which is seldom available in industrial environments).

Of course, in systems where the Master has no priority function, or due to other factors (e.g. large number of stations with low frequency of data transfers) different access methods may be used. For example, in the random access method any station sends its data regardless of the transfer channel status. If a collision occurs, the station does not receive a confirmation, and repeats transmission. However, this method utilizes on average only about 18% of available bandwidth, and with larger volumes of data the throughput decreases rapidly due to larger number of collisions. With RS485, where transmitters can at the same time "listen" for the channel status, the random access method can be improved by "a carrier" (data activity) detection. In this case, stations begin transmission only if the channel is idle. Both methods essentially require a transfer protocol with error detection.

In any data transfer, including the RS 485, there is no way to 100% guarantee that a transmitted packet has been successfully received. Especially with the random access methods, collisions may occur; interference, cable length, etc. causes errors too. It is useful for the communication software to take such situations into consideration. In the central assignment method it is useful for slave stations to send a reply packet with information of last packet received. Some several options are available and choice depends on individual use. In case an application requires more than 32 devices, there are basically two options. The simpler is to use transmitters with 4 times the input impedance (48k), allowing connect up to 128 devices at the same time; these are commonly available.

In this case, it should be adapted to the whole termination system. The other option is to use a RS 485 repeater. Such a device has two twisted-pair ports. When data appear on one of them, the repeater sends them to the other port, and vice versa. In this way, it can be connected to other 31 (or 127) stations. Data activity detection can be very simple, using the RS 485 definition - V_{ab}>200mV; or, such a repeater may incorporate its own processor and work as a router as well - like in computer networks. (RS485, (n.d.).

2.3 Data Acquisition and Central Processing System

The data acquisition and central procession system may vary according to the automation system and reading mechanism but the main components of that system is generally the same. The main components are subscriber entries and database, job orders those related with utility and meter stocks and subsystems and application software which are specialized for tracking the meter stocks (input and output processes).

Meter automation data acquisition and central data processing system most generally work on a single database, this may be SQL (different versions), Oracle and other systems according to the meter quantity to be automated and meter information to be read.

The main program of the system runs on a single computer (this can be a workstation according to the application) with also carries the database, all of the information acquisitioned on this computer (or server) and the other client computer access to the server to read and write processes. No other computer than the server can make execution because all of the processes run on the server, the clients only screens the results.

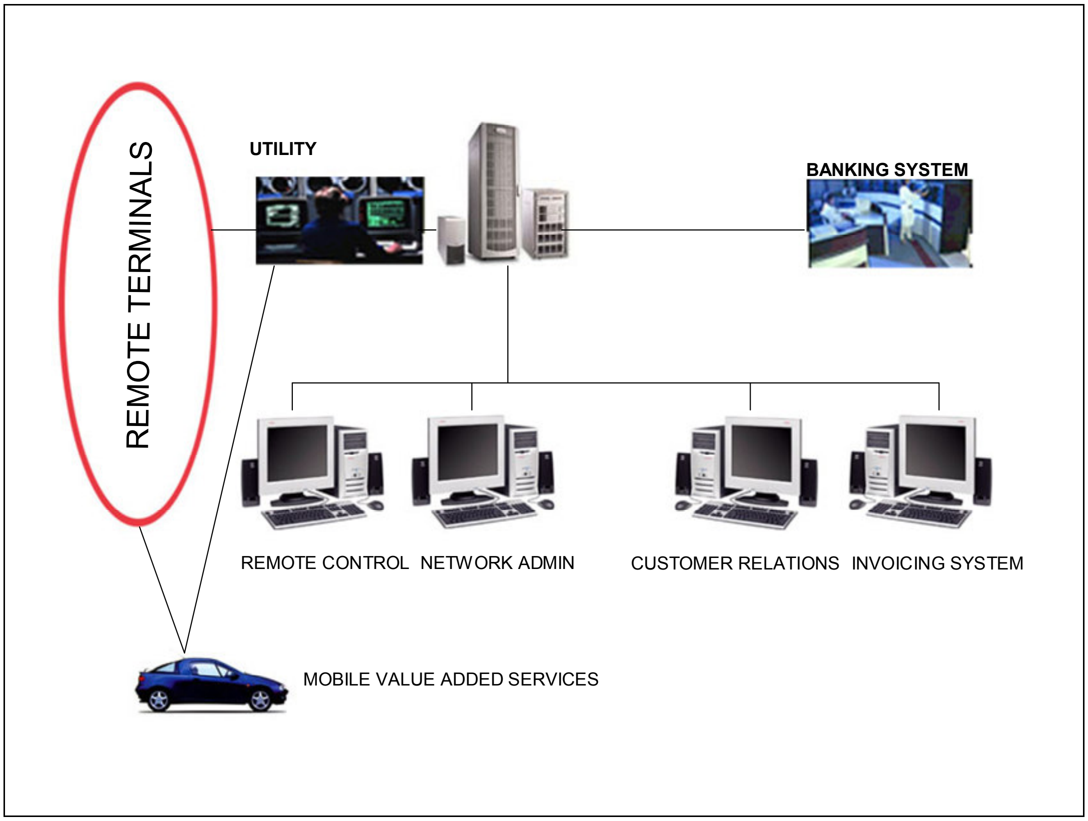

Figure 2.12 – The computer system of a typical Remote Metering application

In the figure above, it can be seen that on the utility side of the meter automation system, the server does the data acquisition and central processing mechanism. Although there are some other computers accessing the meter automation system cycles, the master is the main server and all of the processes run on the main server.

The remote control computer can monitor the remote terminals for data assessment and subscriber meter control purposes. The remote control computer accesses the main server and requests the data submitted by the remote terminals. These data can be the data readouts, power on and off cycles, power consumptions and some other subscriber information produced by the remote terminals. However in some cases, the other computers are blocked and the remote control computer obeys the system.

The network administrator computer manages the data network continuity and data communication. For example, in case of power failures and customer frauds, the network administrator computer scans the systems via the main server and searches for reasons the unwanted cases.

The customer relations computer works for only the administrative purposes related with the customer data. The data verification and customization between the readout data and customer invoices are handled with the customer relations computer. The sales and marketing activities, tariff and seasonal pricing policies are accomplished by the customer relations computer.

The invoicing systems, as well as can be understood from the name, does only the invoicing of the customer consumptions in coordination with the accounting department. The periodical and/or instantaneous/on-demand data reads are invoiced by the invoicing system. For the delivery of invoices, the utility may use some conventional methods like mailing, etc, or use technological new methods like SMS messaging, e-mailing or something else.

In the figure below, the system components of the data acquisition and central processing system are sketched from the hysterical side of the system. The figure shows the data transmission from the meters to the main server and utility chronologically. The data from the remote terminal are transferred to the concentrator, control orders executed, power on and off processes established, emergency and fraud cases determined and the other ordinary operations are accomplished by the system. In case of any failure in the system is determined by the network administrator and/or remote control computers and directly reported to the main server as emergency case and the required routines are triggered by the server itself.

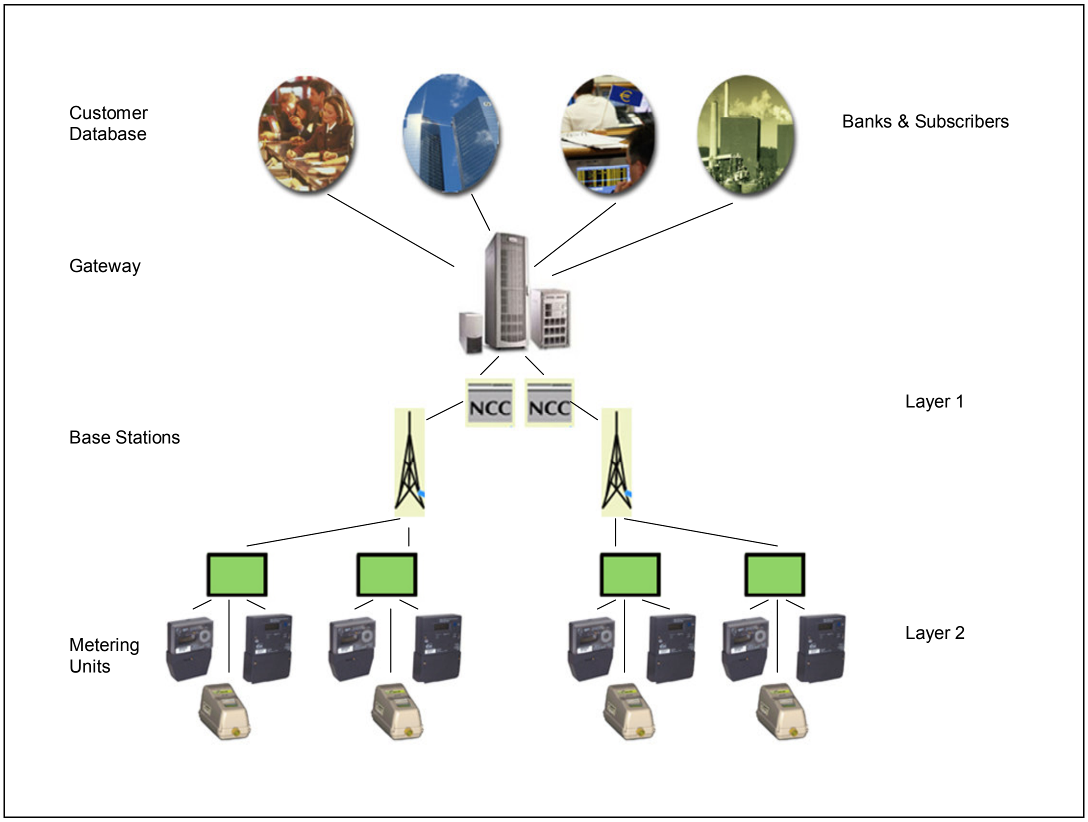

Figure 2.13 – The system architecture of computer system of a typical Remote Metering application

CHAPTER THREE
REMOTE METERING APPLICATION

As far as it has been introduced and explained the general issues of meter automation and remote metering technology, an application of remote metering consisting of one electronic network manager monitored and controlled via RS485 data communication is presented.

After some applications of meter automation systems like residential and commercial metering, some specific applications were needed and industrial remote metering solutions are demonstrated in industrial areas. The presented remote metering system is one of the examples of industrial remote metering applications.

3.1 MPR-53S Electronic Network Analyzer

MPR-53S is a universal electronic microprocessor based electric network analyzer that is capable of metering many electric parameters of a three phase electric network. The metered parameters are shown in five different displays. This gives network administrator to see more than fifty parameters simultaneously. The voltage and current transformers' ratios can be to set to required values. Phase-to-phase voltages, phase currents and total currents and their minimum and maximum values can be measured by MPR-53S electric network analyzer. Besides, total active and reactive powers in both directions as well as appearent power can also be measured and shown in the associated displays. MPR-53S has also a RS485 serial communication interface to enhance remote metering applications.

Figure 3.1 – The physical view of MPR-53S electrical network analyzer, ENTES A.Ş, (n.d.).

As seen in the figure above, MPR-53S has five different displays to show various parameters at the same time.

3.1.1 Usage Fundamentals of MPR-53S

A detailed technical specification table of MPR-53S is given in the following sections but some of them shall be mentioned now to explain the usage criteria duly. MPR-53S has dimensions of 96mm width and 96mm height meaning that it is very easy to montage it to standard electric panels. The nominal and maximum voltages depend on the version but we used a standard version that can be connected directly to 220V electrical networks. Nominal phase currents are limited with 5,5A that is why current transformers shall be necessarily used.

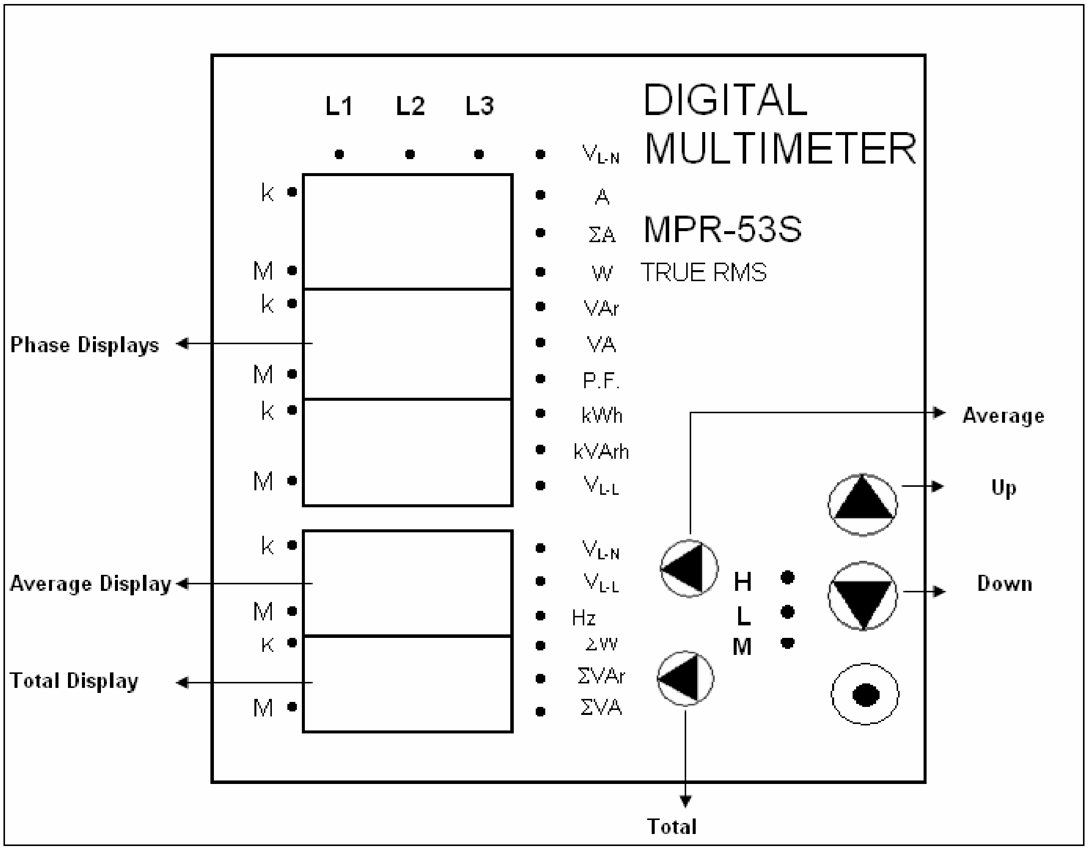

Figure 3.2 – The representative figure showing button usages

In the figure above, the individual roles of the buttons are sketched representatively. With the “UP” and “DOWN” buttons; in the L1, L2 and L3 displays, the parameters instantaneous line-to-neutral voltages (V_{LN}), instantaneous line currents (A), instantaneous total currents (ΣA), real power values (W), instantaneous reactive power values (VAr), instantaneous appearant power values (VA), total active energy consumption and delivery (kWh), total reactive energy consumption and delivery (kVArh) and instantaneous line-to-line voltages (V_{LL}); can be seen on the display. By pressing the “AVERAGE” button, average values of line-to-neutral voltages (V_{LN}), line-to-line voltages (V_{LL}) and frequency; by pressing the “TOTAL” button, total active power consumption or delivery (ΣW), total reactive power consumption or delivery and total appearant power (ΣVA) can be seen on the associated displays.

MPR-53S has also demand (maximum consumed power during a specific time interval) feature enabling the user to control is some power value set is exceeded or not.

Here below in the Table 3.1 all of the measured parameters can be found:

Table 3.1 List of measured parameters on MPR-53S

V_{LN}	Phase-to-neutral voltage
VLL	Phase-to-phase voltage
A	Phase current
EA	Total current
W	Active power (imported or exported)
VAr	Reactive power (imported or exported)
VA	Appearant power (imported or exported)
P.F.	Power Factor
I (kWh)	Imported Active Energy
E (kWh)	Exported Active Energy
C (kVArh)	Capacitive Reactive Energy
L (kVArh)	Inductive Reactive Energy
ΣV_{LN}	Average phase-to-neutral voltage
ΣV_{LL}	Average phase-to-phase voltage
Hz	Frequency
ΣW	Total active power
ΣVAr	Total reactive power
ΣVA	Total appearant power

The current and voltage transformer ratios can be set manually by using the related buttons and displayed accordingly. The current transformer ratio can be set between values of 5-10.000. For example for a current transformer ratio of 150/5, “Ctr” value is set to 150. The illustration of setting the current transformer ratio (Ctr) is given in the figure below:

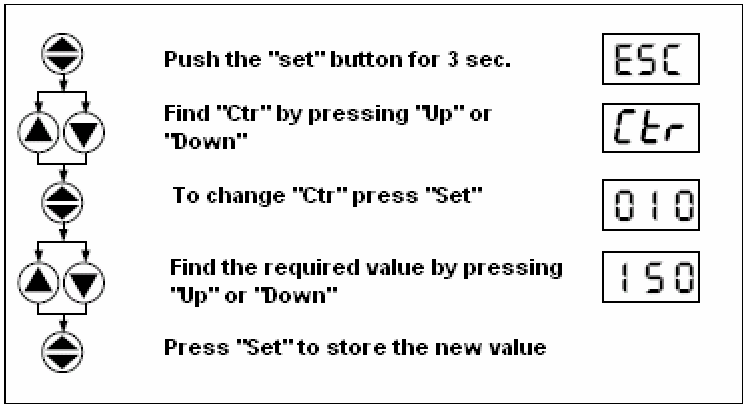

Figure 3.3 – Steps showing how to set the current transformer ration “Ctr” on MPR-53S

The voltage transformer ratio “Utr” can be set between values of 1-2000. The entrance of transformer ratio is given below:

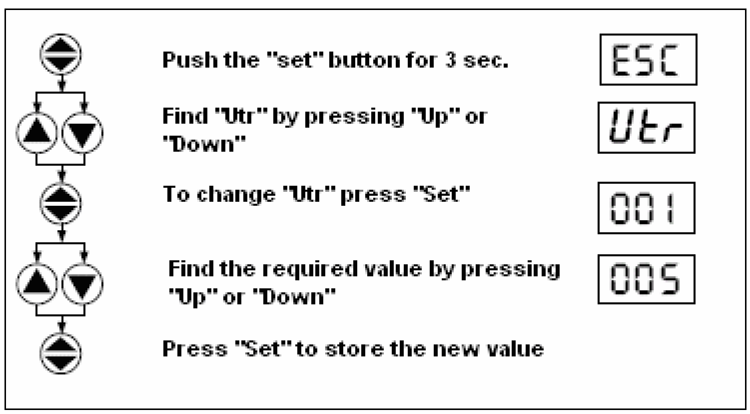

Figure 3.4 – Steps showing how to set the voltage transformer ration “Utr” on MPR-53S

MPR-53S has pulse outputs “Pul1” and “Pul2” to enhance energy measurement from outside of the relay. “Pul1” is for the reactive energy pulse output and this output produces one pulse for every 1kVArh of reactive energy consumption. “Pul2” is for the active energy pulse output and this output produces one pulse for every 1kWh of active energy consumption. This pulse can be used for both consumed and delivered active energy.

The “Min” and “Max” values of instantaneous line-to-neutral voltages (V_{LN}), instantaneous line currents (A), instantaneous total currents (ΣA) are calculated. The demand values are calculated for instantaneous total currents (ΣA), total active energy consumption and delivery (kWh), total reactive energy consumption and delivery (kVArh).

If the measured instantaneous value is lower than the one before, it’s stored as the new “min” value; if the measured instantaneous value is greater than the one before, it’s stored as the new “max” value. The “demand” value is the highest one measured during the specified intervals. If a measured demand value is greater than the one before, it’s stored as the new “demand” value. The stored demand and energy values can be changed as follows:

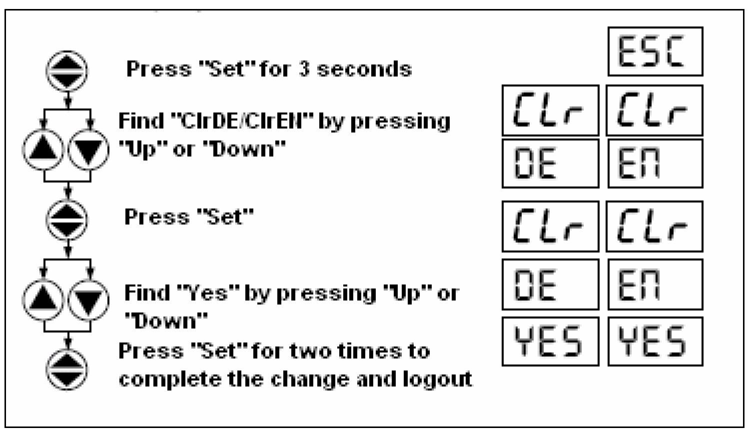

Figure 3.5 – Steps showing how to reset the demand/energy values on MPR-53S

3.1.2 The Technical Specifications of MPR-53S

The technical specifications of MPR-53S are given in Table 3.2. It can be seen that especially the voltage and current values are very flexible that you cannot connect it to any low voltage network directly.

Table 3.2. The technical specifications of MPR-53S

Rated Voltage	220V/380V AC
Frequency	50/60Hz
Feeding Input Power Consumption	< 4VA
Measurement Inputs Power Consumption	< 1VA
V_{in}	10-300V AC 20/90Hz (L-N) 10-500V AC (L-L)
I_{in}	0,05-5,5 A (AC)
Measurement Range	0...200kV
Class	1+/- 1 digits [(%10-%100)x full scale)]
Voltage Transformer Ratio	1...2000
Current Transformer Ratio	5...10000/5A
Demand Interval	1-60 minutes
Communication	RS485 (Modbus RTU) Optically isolated, programmable Baud Rate: 12000-38400 bps Address:1-247 No, Odd and Even Parity
Pulse Outputs	NPN Transistor
Switching Period	Min. 1,6 second (400msec. pulse width)
Rated Current	Max. 50mA
Rated Voltage	5...24V DC, max. 30V DC
Input	12...48V DC
Ambient Temperature	-5C/+50C
Display	Red LED Display
Dimensions	PR-19
Device Protection Class	Double isolated - Class II
Case Protection Class	IP40
Terminal Protection Class	IP00
Case Material	Non-flammable
Connection Type	Front access panel
Cable size for terminal connections	2,5mm^2
Weight	0,45kg
Installation Class	Class III

3.1.3 Serial Communication with MPR-53S

MPR-53S has optically isolated RS485 serial communication feature and this allows transfer the measured values in a remote metering application. All of the measured values can be read from a distant computer, as well as the transformer ratios can be changed and the demand and energy values can be reset.

Table 3.3. The standard MODBUS RTU Message Format

T	ADDRESS 8 BIT	FUNCTION 8 BIT	DATA N X 8 BIT	CRCH	CRCL	T

The standard Modbus RTU message format is given in Table 3.3. The start and finish durations are (3,5 character time) the minimum steady state duration of the line for the devices to be able to understood by the others. The address byte (1-247) determines the serial address of the connected devices. In this application, only one device is connected to the computer, for this reason it's chosen as "1". The data register contains the data transferring from master to slave or vice versa.

There are some applicable Modbus functions with MPR-53S network analyzer. These are "Read Hold Registers – 03H", "Preset Single Register – 06H" and "Preset Multiple Registers – 10H". The registers between 0-68 can also be read. If some register other than these is tried to be read, the device sends an error signal.

Table 3.4. The applicable communication functions

Hexadecimal Code	Applicable Function
03H	Read Hold Registers
06H	Preset Single Register
10H	Preset Multiple Registers

For example, to read the phase-1 line to neutral voltage the message below shall be sent to MPR-53S:

01 03 00 00 00 01 84 0A

01 The device address (assumed to be 1)
03 Function
00 Most Significant Byte of Address
00 Least Significant Byte of Address
00 Most Significant Byte of Register Number
01 Least Significant Byte of Register Number
84 Most Significant Byte of CRC
0A Least Significant Byte of CRC

The function “Preset Single Register” is used to set the transformer ratios and reset the minimum, maximum or demand values. As it was stated before, the current transformer ratio can be set between 5 and 10000 the voltage transformer ratio can be set between 1 and 2000. The demand registers can only be reset, no other value than “0” can be set to them. As an example, the code below shall be sent to the device to set the current transformer ratio to “100”.

01 06 00 41 00 64 D8 35

01 The device address (assumed to be 1)
06 Function
00 Most Significant Byte of Address
41 Least Significant Byte of Address
00 Most Significant Byte of Data
64 Least Significant Byte of Data
D8 Most Significant Byte of CRC
35 Least Significant Byte of CRC

The function “Preset Multiple Registers” is used to change the values of more than one registers. The example is below to set the current transformer ratio to “100” and voltage transformer ratio to “20”.

01 10 00 41 00 02 04 00 64 00 C8 84 8F

01	The device address (assumed to be 1)
10	Function
00	Most Significant Byte of Address
41	Least Significant Byte of Address
00	Most Significant Byte of Register Number
02	Least Significant Byte of Register Number
04	Byte Number
00	Most Significant Byte of Data
64	Least Significant Byte of Data
00	Most Significant Byte of Data
C8	Least Significant Byte of Data
84	Most Significant Byte of CRC
8F	Least Significant Byte of CRC

Each parameter is sent as a 16bit hexadecimal data block. For example, 230V voltage level is transferred as 00E6H. The current and power factor values shall be divided by “100”. For example, 0,76A is transferred as 004CH and a power factor value of 0,98 as 0062H. When the sign of the power factor is negative (-) the most significant byte is sent as 1. For example, -0,98 is sent as 1062H. The frequency value shall be divided by “10”. A frequency value of 49,8Hz is sent as 1F2H. The energy values are sent in 8 byte blocks. As an example, 1234567891234,567 kWh is represented as 0C 22 38 4E 5B 17 2D 43 hexadecimal. In Table 3.5, the Modbus register table is given.

Table 3.5. The applicable communication functions

REGISTER				REGISTER			
No	Address	Parameter	Length	No	Address	Parameter	Length
0	00H	VLN1	2 Byte	34	22H	I High1	2 Byte
1	01H	VLN2	2 Byte	35	23H	I High2	2 Byte
2	02H	VLN3	2 Byte	36	24H	I High3	2 Byte
3	03H	ILN1	2 Byte	37	25H	I Low1	2 Byte
4	04H	ILN2	2 Byte	38	26H	I Low2	2 Byte
5	05H	ILN3	2 Byte	39	27H	I Low3	2 Byte
6	06H	TA	2 Byte	40	28H	I Demand1	2 Byte
7	07H	W1	2 Byte	41	29H	I Demand2	2 Byte
8	08H	W2	2 Byte	42	2AH	I Demand3	2 Byte
9	09H	W3	2 Byte	43	2BH	TA High	2 Byte
10	0AH	VAr1	2 Byte	44	2CH	TA Low	2 Byte
11	0BH	VAr2	2 Byte	45	2DH	TA Demand	2 Byte
12	0CH	VAr3	2 Byte	46	2EH	TW Demand	2 Byte
13	0DH	VA1	2 Byte	47	2FH	TVAr Demand	2 Byte
14	0EH	VA2	2 Byte	48	30H	TVA Demand	2 Byte
15	0FH	VA3	2 Byte	49	31H	kWh(import) 1	2 Byte
16	10H	PF1	2 Byte	50	32H	kWh(import) 2	2 Byte
17	11H	PF2	2 Byte	51	33H	kWh(import) 3	2 Byte
18	12H	PF3	2 Byte	52	34H	kWh(import) 4	2 Byte
19	13H	VLL1	2 Byte	53	35H	kWh(export) 1	2 Byte
20	14H	VLL2	2 Byte	54	36H	kWh(export) 2	2 Byte
21	15H	VLL3	2 Byte	55	37H	kWh(export) 3	2 Byte
22	16H	TVLL	2 Byte	56	38H	kWh(export) 4	2 Byte
23	17H	TVLN	2 Byte	57	39H	KVArhL-1	2 Byte
24	18H	Hz	2 Byte	58	3AH	KVArhL-2	2 Byte
25	19H	TW	2 Byte	59	3BH	KVArhL-3	2 Byte
26	1AH	TVAr	2 Byte	60	3CH	KVArhL-4	2 Byte
27	1BH	TVA	2 Byte	61	3DH	KVArhC-1	2 Byte
28	1CH	VLN High1	2 Byte	62	3EH	KVArhC-2	2 Byte
29	1DH	VLN High2	2 Byte	63	3FH	KVArhC-3	2 Byte
30	1EH	VLN High3	2 Byte	64	40H	KVArhC-4	2 Byte
31	1FH	VLN Low1	2 Byte	65	41H	CT Ratio	2 Byte
32	20H	VLN Low2	2 Byte	66	42H	VT Ratio	2 Byte
33	21H	VLN Low3	2 Byte	67	43H	Demand Dur.	2 Byte
				68	44H	DIN input	2 Byte

As far as it's mentioned before, if an appropriate message is sent to MPR-53S, it'll prompt with an error message.

The error codes are as follows:

01 Invalid Function: If any other functions than three functions mentioned above is used, this code is sent by the device.

02 Invalid Register: In MPR-53S the only register between 0 and 68 can be accessible. If any other registers are tried to be access, this error code produced.

03 Invalid Data: If any value different from the transformer ratios or any value different from zero for the demand values is sent to the device, it produces this error code.

3.1.4 Connection Diagram Alternatives of MPR-53S

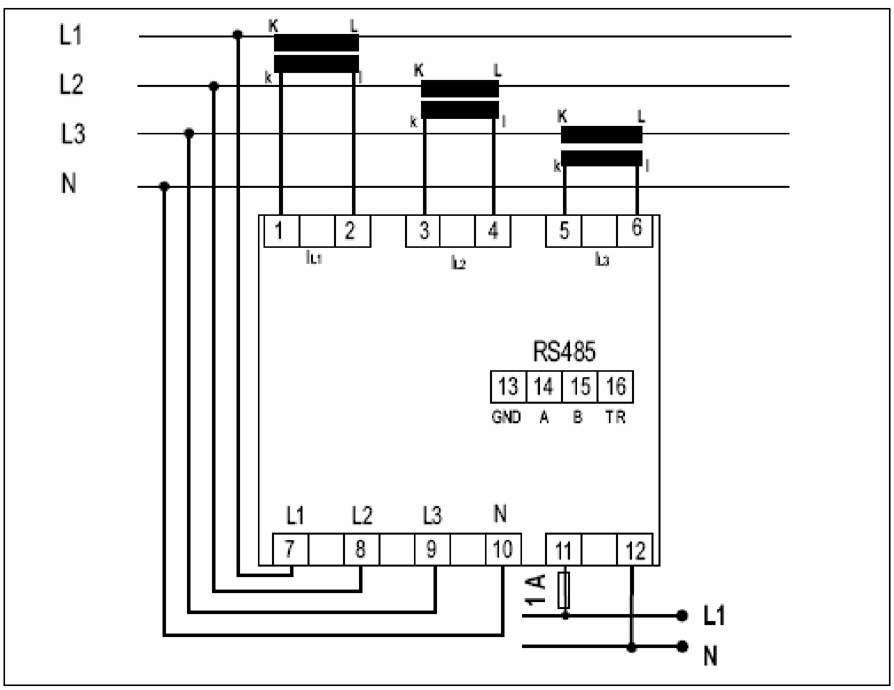

Figure 3.6 – Three phase one neutral connection diagram

This is the conventional connection mostly used in industry. In our application this connection is going to be used.

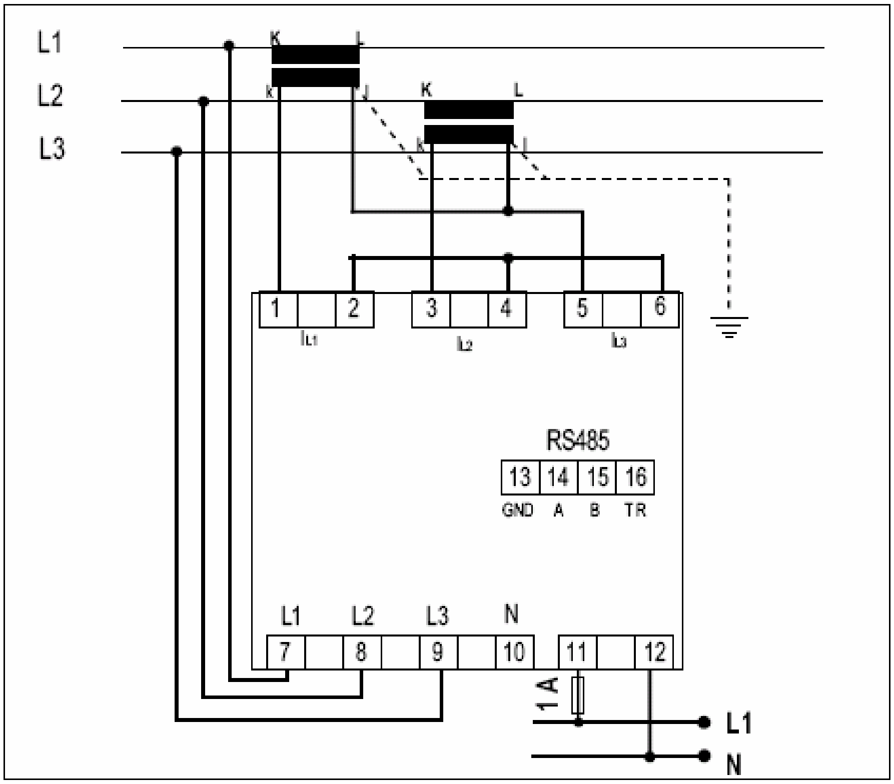

Figure 3.7 – Three phase without neutral (Aron) connection diagram

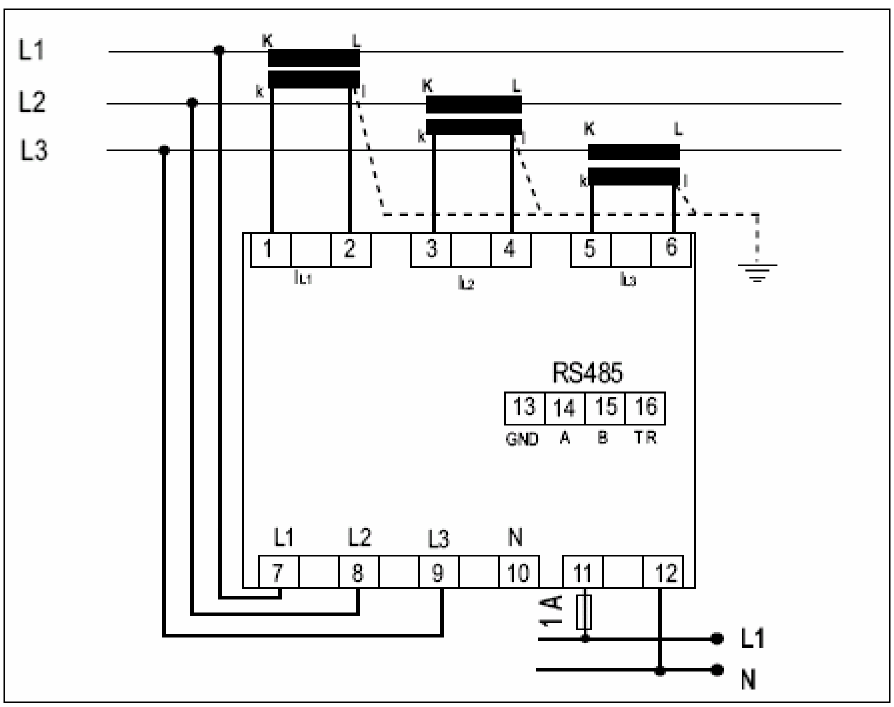

Figure 3.8 – Three phase without neutral connection diagram

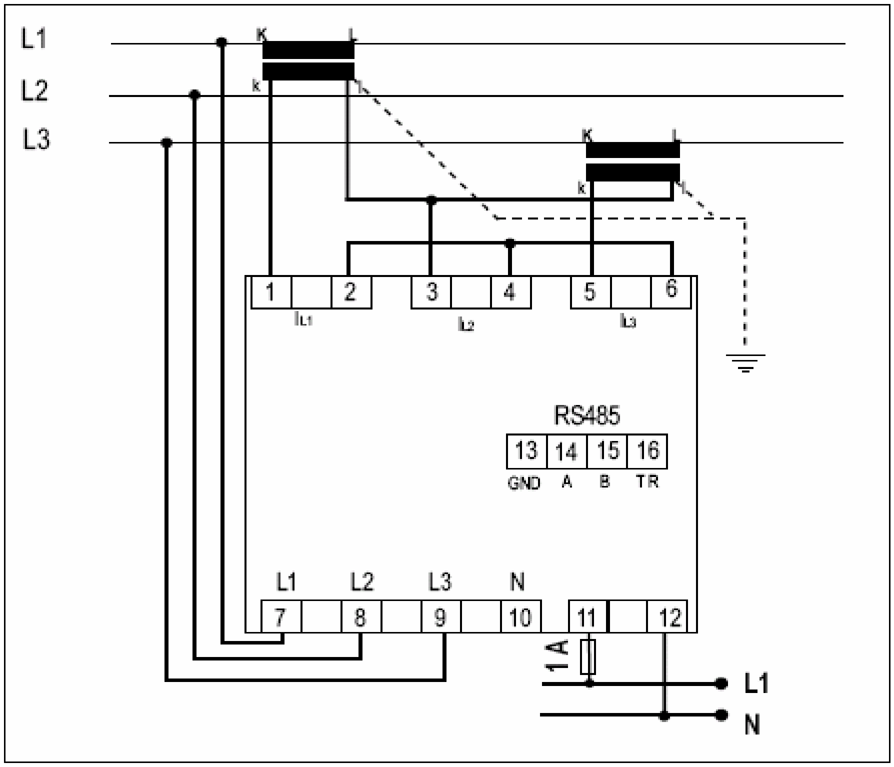

Figure 3.9 – Three phase without neutral (Aron) connection diagram

3.2 Remote Metering with MPR-53S Electronic Network Analyzer

In the application performed, a three phase induction motor was remotely metered with the aid of MPR-53S electronic network analyzer. The application results were matched with the values of another network analyzer whose metering accuracy was known to be in acceptable range and seen that the measured values ware to be true. MPR-53S was connected to the electrical network in an appropriate place by applying the connection diagram described in the last section. The data line connected between the personal computer and MPR-53S via an RS232/485 converter which accomplishes the signal level conversion between RS232 and RS485. Because the main technical similarities and differences between RS232 and RS485 were given in the last chapter, the conversion will not be examined in this work.

3.2.1 Remote Metering Software MPR-SW2

MPR-SW2 is a special purpose software prepared for only remote metering of MPR-53S using RS485 protocol. The usage details of this program are as follows.

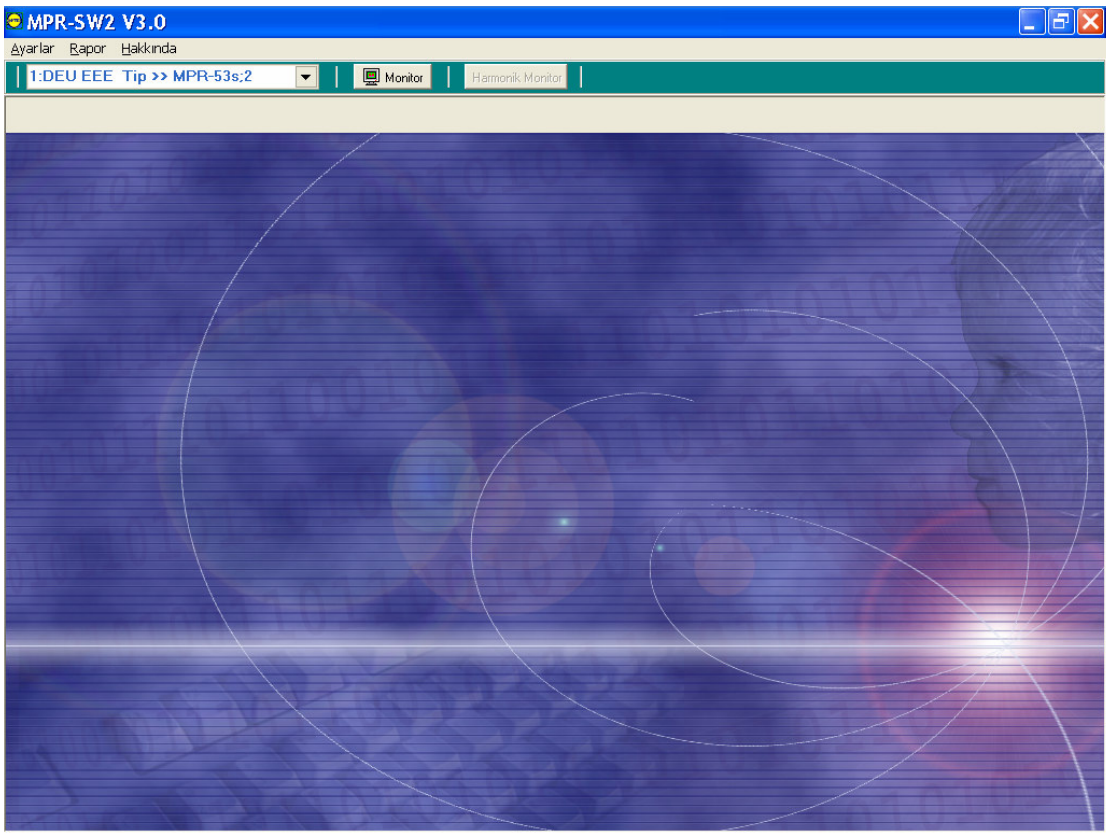

Figure 3.10 – The main screen of MPR-SW2 Metering Software

In Figure 3.10 the main screen of the program is shown. When the program icon is double clicked, this main screen is opened on the display. The main menu of the program contains “settings” and “reports”. When the “settings” menu is selected, the general settings, device sensing and database setting items can be found. In the reports menu, various types of reports can be reached which will be explained in more details in the following paragraphs.

In Figure 3.11 the general settings screen is shown. In the general settings screen, the communication port, baud-rate (communication speed) and parity are set. The communication port shall be the one where MPR-53S is connected, COM1, COM2, or other else. The baud-rate shall be set to 38400 to ensure most reliable communication speed. The parity shall be set to none.

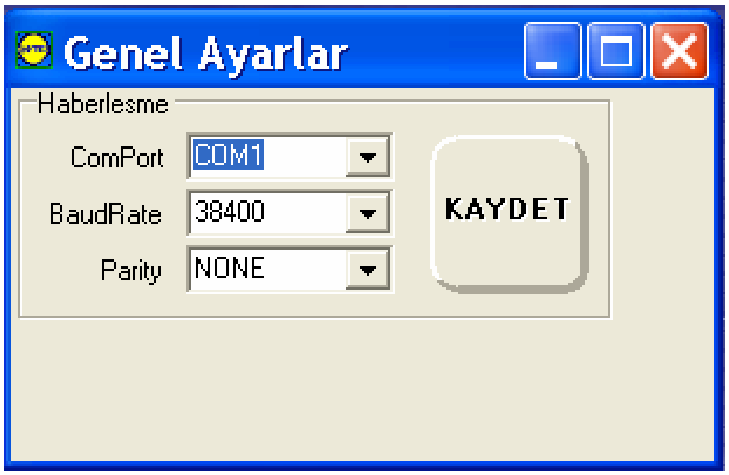

Figure 3.11 – The general settings menu screen

The device setting screen is shown Figure 3.12. On this screen, MPR-53S network analyzer is sensed to establish the first communication with computer. The quantities of connected network analyzers, the first and last addresses are entered. As far as in this application only one MPR-53S network analyzer is used, the quantity is entered as “1”. The first address and the last address is entered as “1”.

In device setting screen, the name of the device is defined and the type of the device is selected. For this application, the device name is defined as “DEU EEE” and he device type is selected as “MPR-53S”. As the “OK” button is clicked, the computer starts to search for the defined device and in a few seconds the device is found as seen in Figure 3.12.

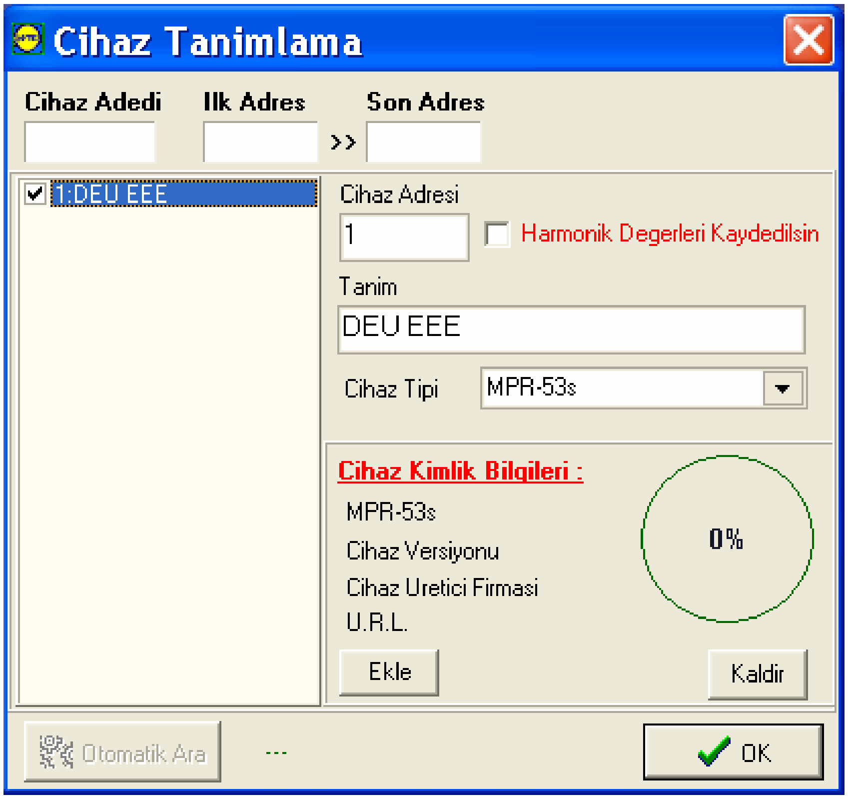

Figure 3.12 – The device sensing menu screen

In Figure 3.13, the database setting is shown. In this screen, the database settings re entered for write frequency and first write date.

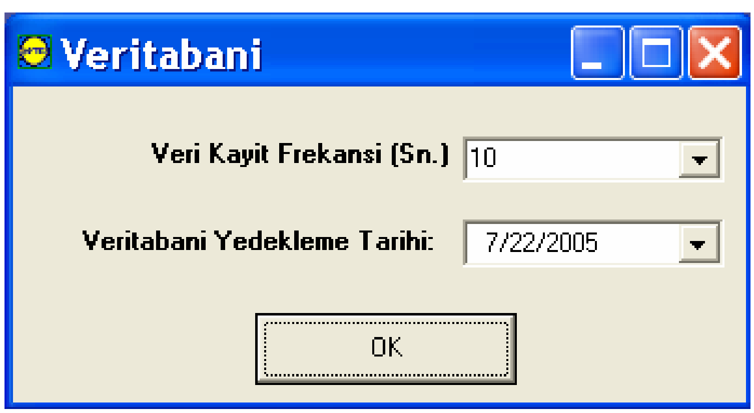

Figure 3.13 – The database setting menu screen

In Figure 3.14 the screen view of MPR-SW2 is shown while MP-53S is running. The measured values are shown and updated periodically and at that time of moment the values are acquisitioned in the database. On the right hand side of the screen, in the tabular format, the measured and displayed parameters on this main screen are; V_{LL} (Line to Line Voltages), V_{LN} (Line to Neutral Voltages), I (Current), W (Active Power), VAr (Reactive Power), VA (Appearant Power), I_{Hi} (Highest Current values), I_{Lo} (Lowest Current values), W_{Dem} (Active Power Demand), VAr_{Dem} (Reactive Power Demand) and VA_{Dem} (Appearant Power Demand. For all of these parameters, three phase values are shown separately. For I_{Dem} (Current Demand) and Hz (Frequency), the values are for average of three phases. On the left hand side, the instantaneous consumed energy type, active or reactive are shown with a circular graph and also the cumulative active and reactive energy values are displayed in this screen.

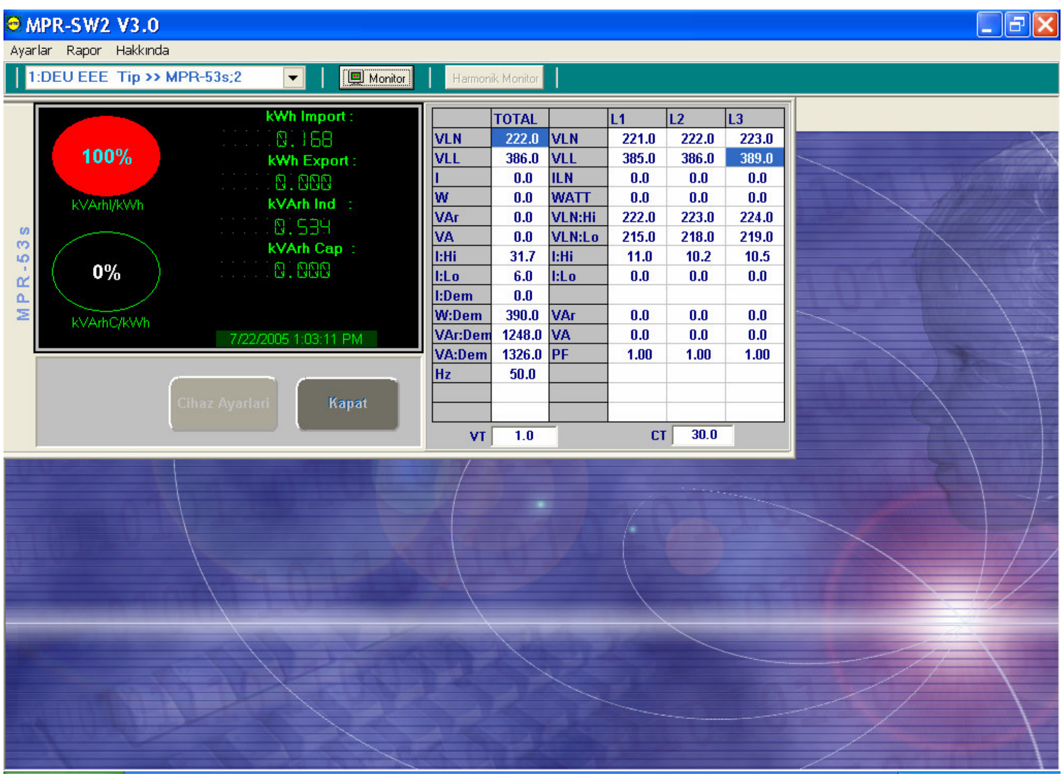

Figure 3.14 – The screen view when the network analyzer is running

CHAPTER FOUR
RESULTS AND CONCLUSIONS

4.1. Results

A three phase, 380V voltage source is connected to a three phase induction motor through a motor control center (MCC). A network analyzer (MPR-53S) is located between the MCC and motor.

The remote metering of network analyzer via RS485 protocol was performed and recorded for one hundred minutes to use the sample results. During the time period between 14:20 and 16:00, the parameters V_{LN} (Line to neutral voltage), V_{LL} (Line to line voltage), I (Line current), W (Active power), VAr (Reactive power), VA (Appearant Power), Total Power and PF (power factor) are recorded on each phase. The test results will be given with graphical diagrams on the next pages.

The graphical report has two parts to identify the measured parameter; one part is the graphical section in the upper side and the other is numeric section in the bottom of the page. Time is settled on the horizontal axis and the measured parameter is displayed on the vertical axis during the test.

In Figure 3.15 the line to neutral voltages recorded during the test period are shown. As can be seen in the figure, all of the line to neutral voltages are close to each other meaning that the source seems to have balanced output voltage during the test. All of the line to neutral voltages on each phase were between 208V and 212V.

But after some time, in the time interval between 15:20 and 15:25 an anomaly has happened and the voltages started to rise up to level between 220V and 225V. This has happened in nearly one minute and most probably due to shut down of a large electric load like building site near the test laboratory on the same transformer line. After that event, the line to neutral voltages moved in the band of 220V and 225V till to the end of test. This was maybe a coincidence that an unexpected voltage level change has happened during the test but it was useful to show the benefits of a remote metering system on a network analyzer. Because, by assessing the results of this test, some developments and optimizations can be done on the electric network.

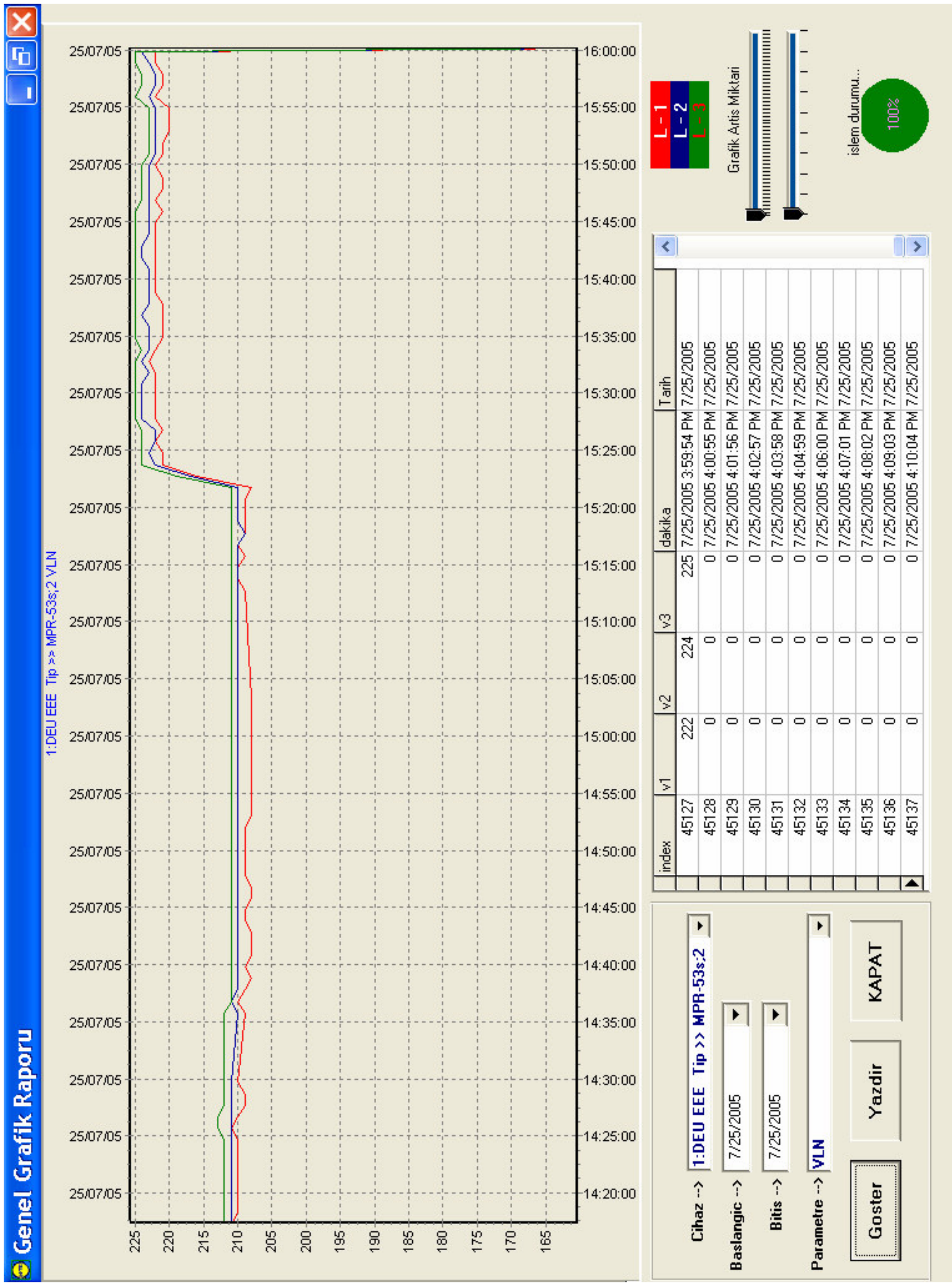

Figure 3.15 – The line to neutral voltages during test

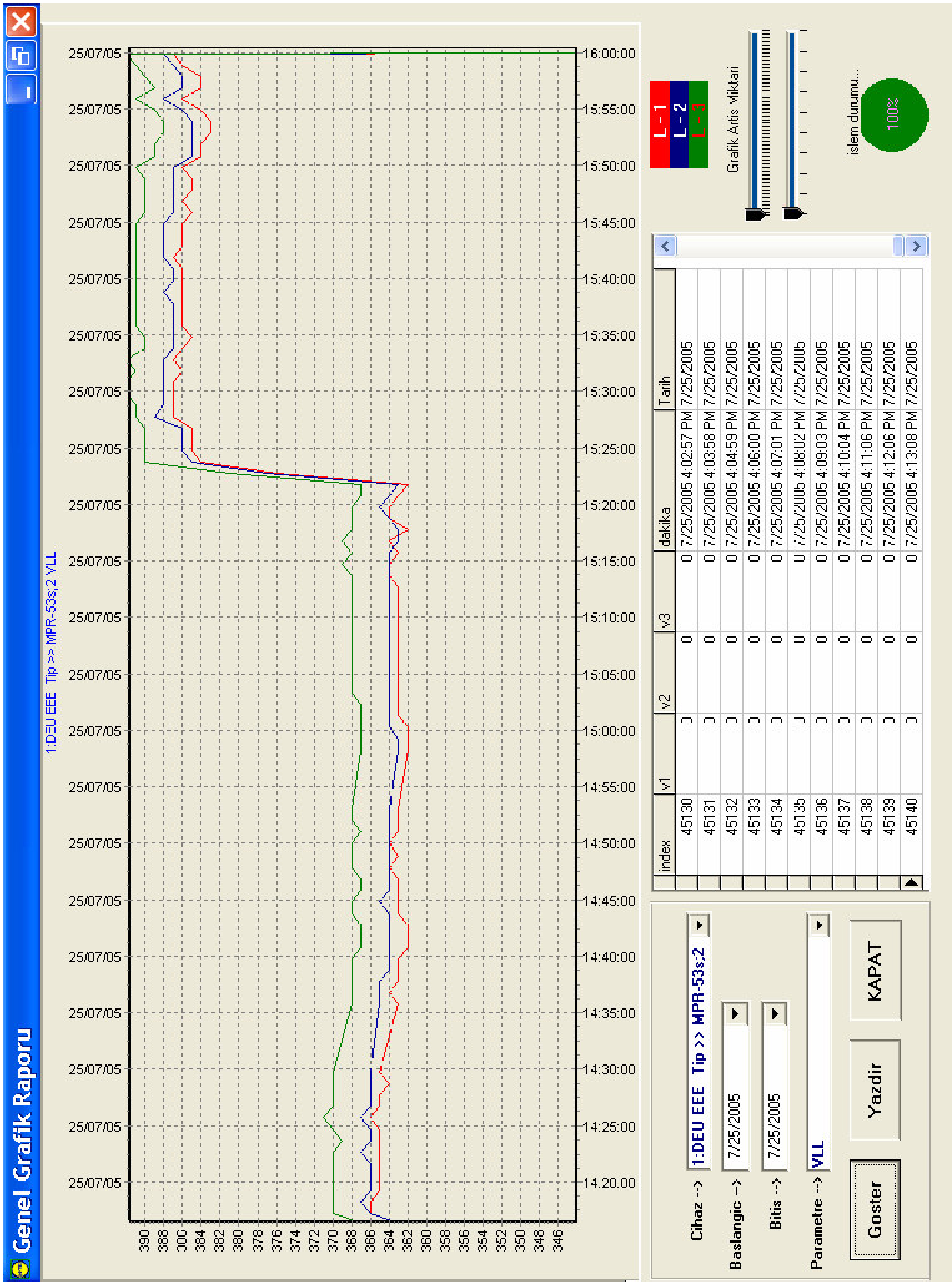

Figure 3.16 – The line to line voltages during test

In Figure 3.16 the line to line voltages on each phase are shown which were recorded during the same time interval. As can be seen on the graphical diagram, the line to line voltages have also a narrow bandwidth of voltage level while one of them was slightly higher than the others. This was the line to line voltage between the lowest and highest line to neutral voltages. The line to line voltages were moving between the range of 362V and 372V.

The same anomaly has happened in the line to line voltages as in the line to neutral voltages. In one minute they rise up to level between 383V and 393V. The possible reason of that anomaly was explained before that of shut down of a large consumer.

In Figure 3.17 the line currents on each phase are shown. The line currents were not stable as the line to neutral or line to line voltages. While one current moving in a range of 4A and 5A, the other two currents were in the range of 5A and 6A. This was most probably due to the unbalanced and unloaded motor that was used in the test.

The results of the anomaly happened between 15:20 and 15:25 were not so stable like in the voltages. Slight differences have happened in upper direction but as mentioned before the currents were not stable for that reason only the average of the currents were observed to be rise up.

In Figure 3.18 the power consumptions on each phase are shown in the graphical diagram. Due to unstable situation of the line currents, the consumed active powers were not stable eventually. Two of the active powers were around 360W and 380W, while the other one around 240W and 260W. The anomaly has also changed the movement of the consumed active powers but not all of these changes were in the upper direction. During this anomaly, the active power consumptions fluctuated within very large ranges but after some minutes they got more stable situation.

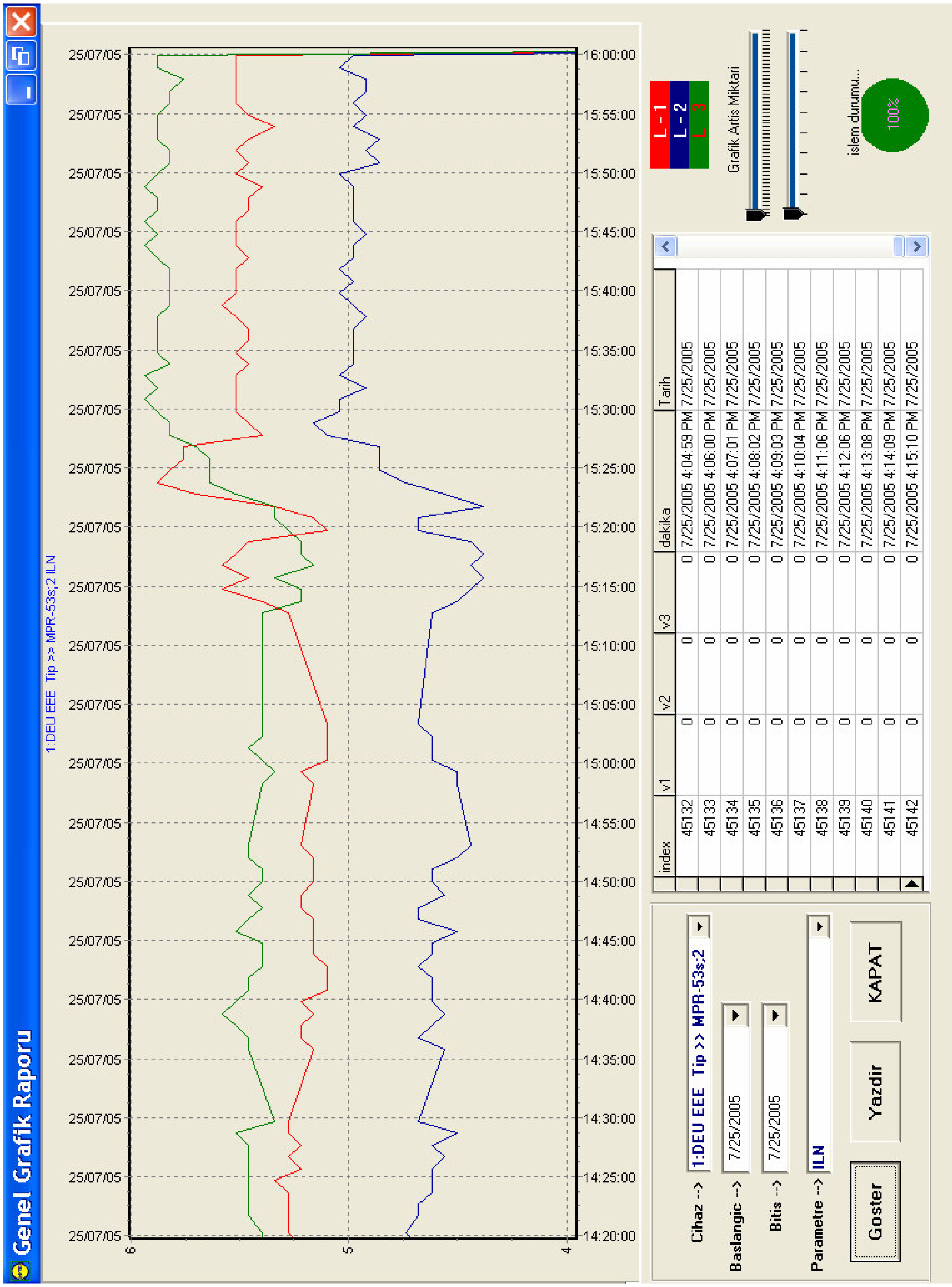

Figure 3.17 – The line currents during test

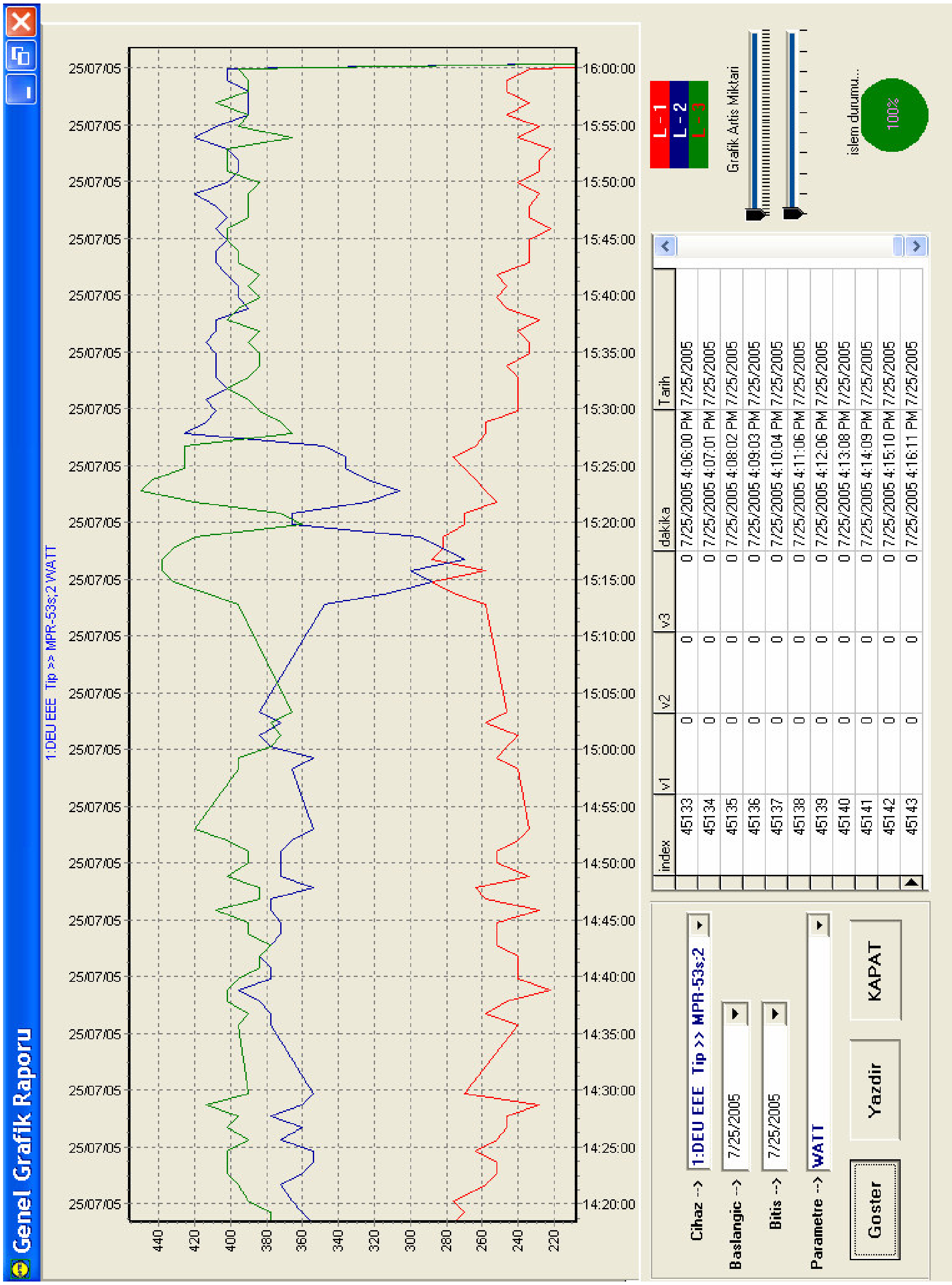

Figure 3.18 – The power consumption in each phase during test

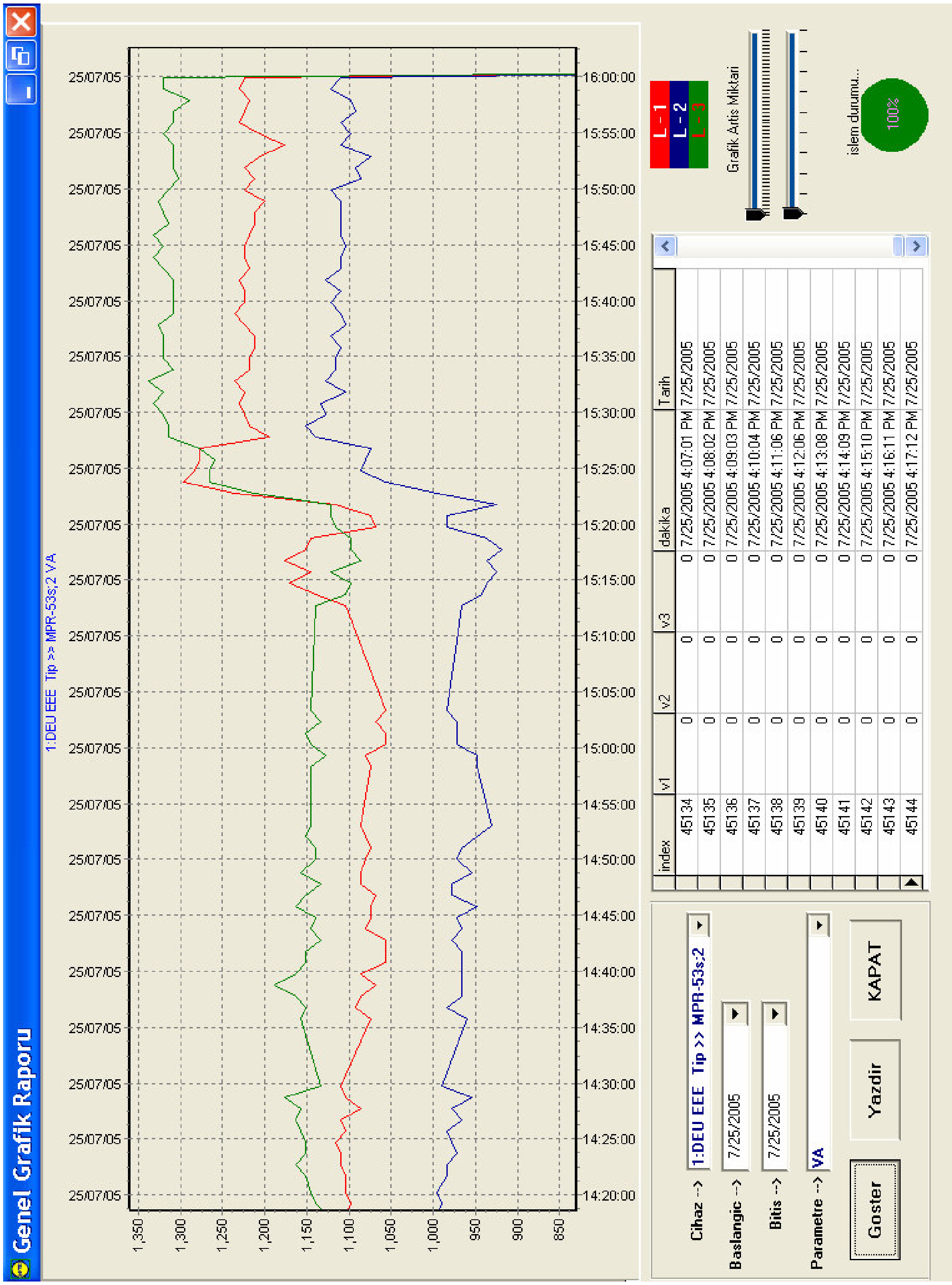

Figure 3.19 – The appearant power consumption in each phase during test

In Figure 3.19 the appearant powers on each phase are shown during the test. The appearant powers had also similar characteristics like the line currents. Before the voltage rise up all of them were in the range of 900VA and 120VA. But during the voltage rise, all of the appearant powers rose up to higher values and after they tended to move in a range of 1100VA and 1350VA.

In Figure 3.20 the reactive powers on each phase are shown during the test. Two of the reactive power values were very different than the other one like the currents and active powers. This was explained before that the unbalanced and unloaded motor may cause this kind of results but one of the reactive powers was very seriously lower that the others. The anomaly has also affected the reactive power consumtions on each phase.

In Figure 3.21 the summation of total active power, total reactive power and appearant power on each phase are shown. The unbalanced nature of the load can be seen clearly on this graphical diagram. Two of the phases seem to be very higher than the other one. On the other side, as far as the voltage rise up resulted in rise up in every parameter, one of the phases has shown no effect due to this situation.

In Figure 3.22 the power factors on each phase are shown which were recorded during the test. Due to the unloaded characteristics of induction motors, the power factors had very poor values around 0,20 and 0,36. The voltage rise up during the test had affected the power factors least. They fluctuated for some minutes but after that time, they tend to move in a narrower range.

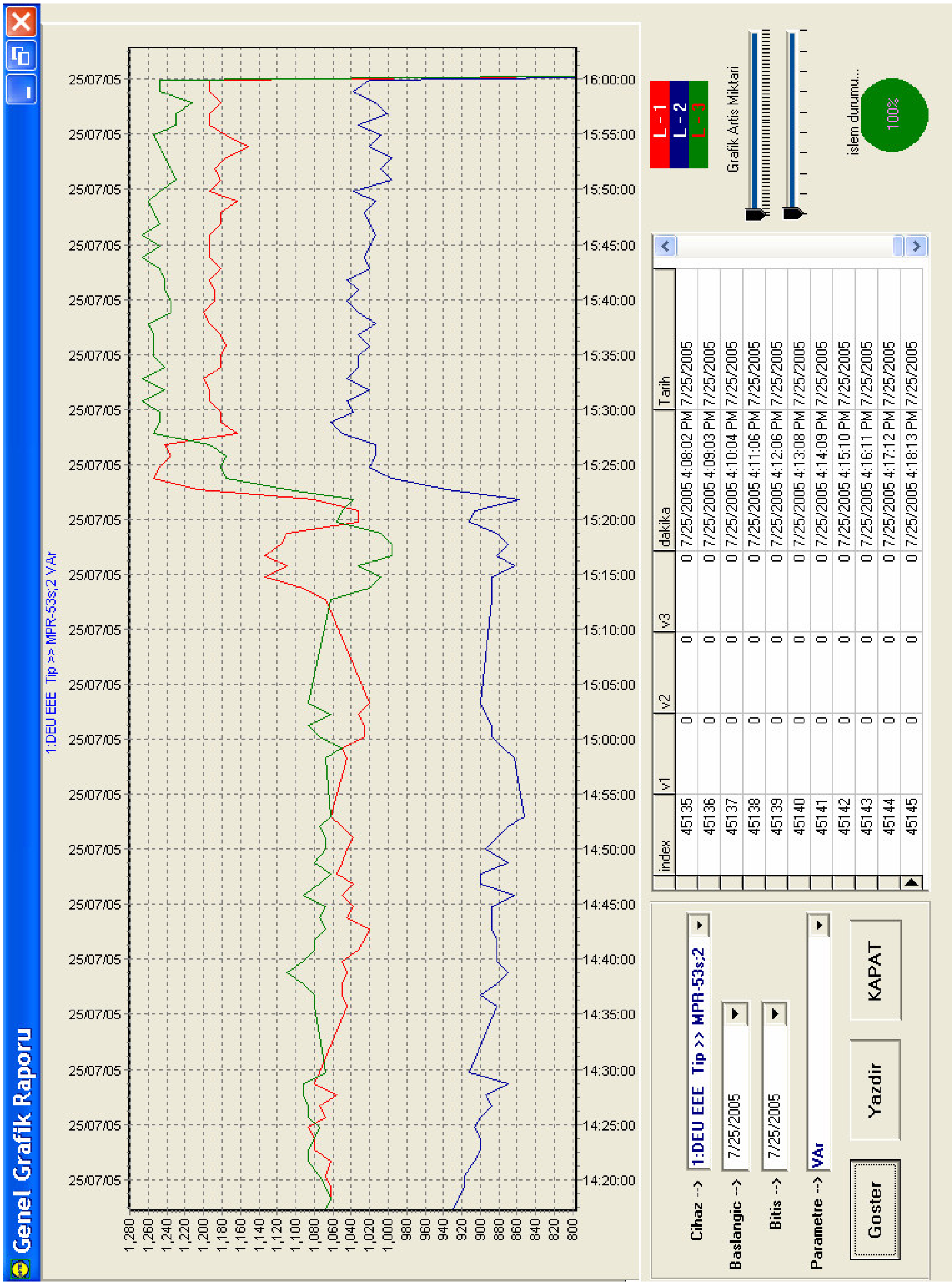

Figure 3.20 – The reactive power consumption in each phase during test

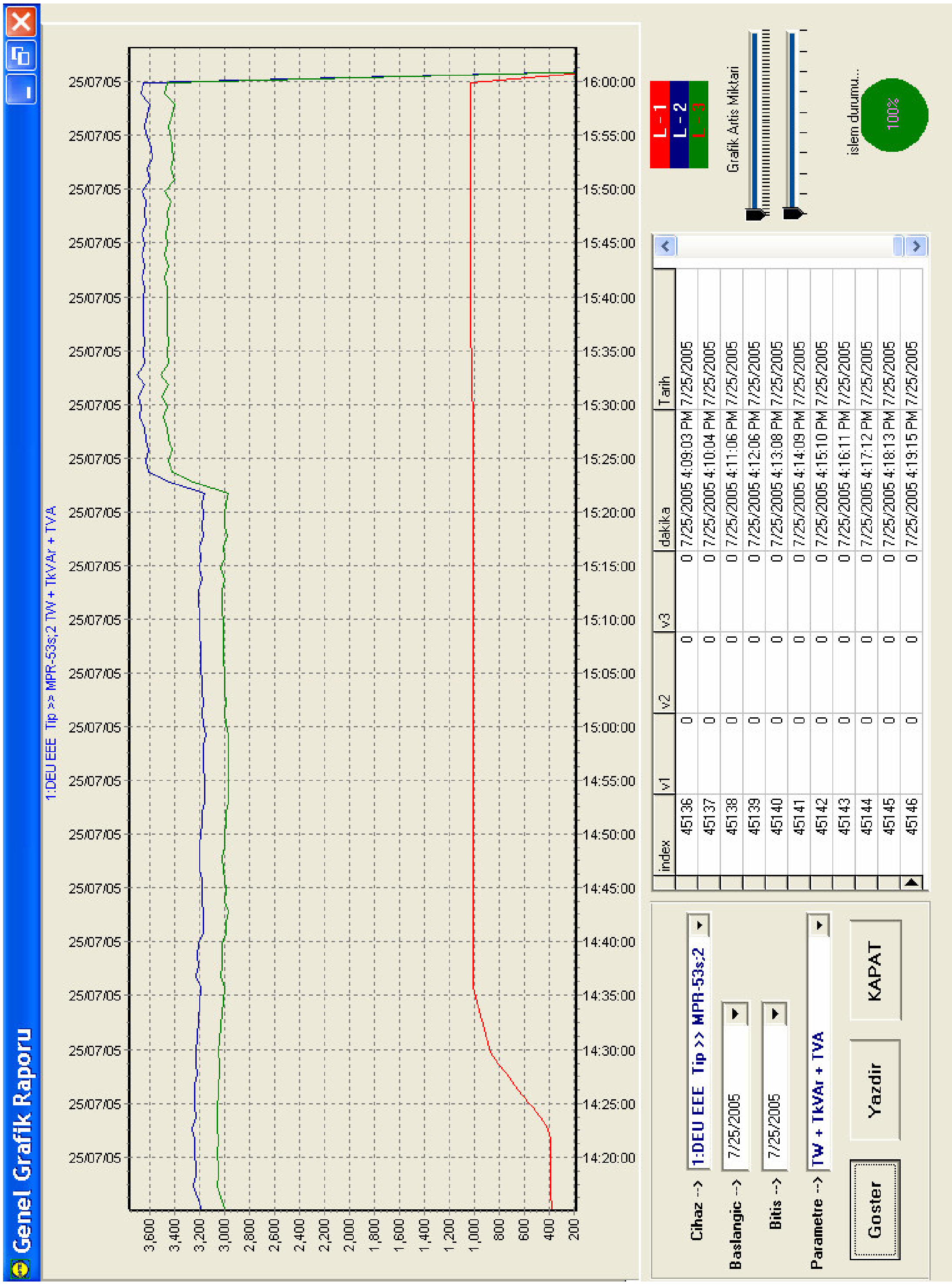

Figure 3.21 – The total active, reactive and appearant power consumptions during test

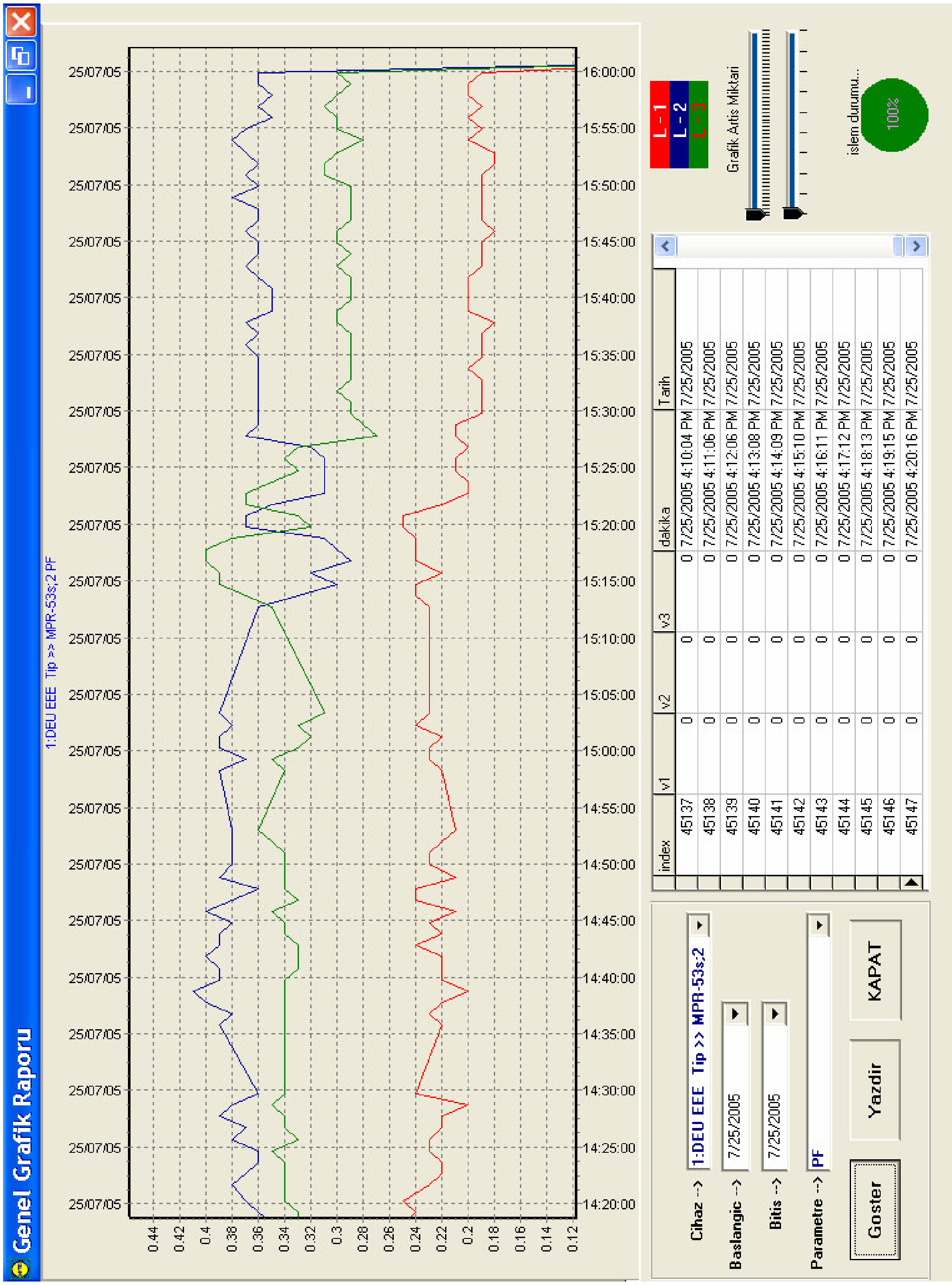

Figure 3.22 – The power factors in each phase during test

4.2 Conclusions

Automated Meter Reading solutions are the reasonable results of new technologies in both electronic industry and utility service providence. Whereas the privatized electric, water and gas service providers need more convenient and efficient systems to control their utility system and improve their value added services to their customers. This will yield to the consumer side as cheaper prices and better services.

As far as these automation systems get more common, the telecommunication systems like RS485 protocol will have a more important place. Among all of the telecommunication systems either wired or wireless, RS485 is an industrial solution at the moment. As far as it has a very large range of transfer capacity while the other conventional serial communication protocols are very limited, the most important advantage of RS485 with respect to its competitors is that the cable can be up to 1.200 meters long. Another advantage of RS485 is that up to 255 different devices can be connected to the same RS485 line. On the other hand, the technology is going toward wireless solutions like Wireless LAN, Bluetooth, Infrared and etc. This is a disadvantage for RS485 because wireless solutions present more flexibility and comfort. If RS485 is used in an application, the communicating devices shall be stationary due to the wiring. There is another disadvantage for RS485 as a wired solution which is the transmission length. When it's compared with RS232, Modbus and etc, 1.200 meters of transmission capability seems to be very sufficient. But if Public Switched Telephone is taken into account, RS485 loses its priority.

An application is performed in thesis to remotely meter the consumed electric energy and store the readings. This application can provide successfully metering of both residential consumptions and wind turbine production. The experimental study shows that these data reached can be correct and reliable. In the future, remote metering of production and consumption of electric energy will be unavoidable.

REFERENCES

Chebra, R. (1997) The History and Evolution of Metering Technology. *Metering International, Magazine Archive,* 1997 Issue 2. http://www.metering.com/archive/972/11_1.htm

Entes A.Ş. (n.d.). Retrieved June 15, 2005, from http://www.entes.com.tr/

Frati, R. (1998). The Progress Towards Deregulation in Europe. *Metering International, Magazine Archive*, 1998 Issue 1. http://www.metering.com/archive/981/12_1.htm

RS485 Summary, (n.d.). Retrieved June 15, 2005, from http://www.rs485.com/rs485spec.html

Stallings, W (1999) Computer Networking with Internet Protocols and Technology

Wilkinson, R. (2004) GSM for Remote Reading Electricity Meters. *Metering International, Magazine Archive*, 2004 Issue 3. http://www.metering.com/archive/mi_3_2004/42_1.php