SVEUČILIŠTE U ZAGREBU
FAKULTET STROJARSTVA I PRODOGRADNJE

University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture

DIPLOMSKI RAD – DIPLOMA THESIS

u okviru/in the frame of ERASMUS+

Paolo Capparelli

Zagreb, 2016.

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Mentor:

Prof. dr.sc. Zoran Kunica

Student:

Paolo Capparelli

Zagreb, 2016.

Diploma theme

SVEUČILIŠTE U ZAGREBU
FAKULTET STROJARSTVA I BRODOGRADNJE
Središnje povjerenstvo za završne i diplomske ispite
Povjerenstvo za diplomske ispite studija strojarstva za smjerove: proizvodno inženjerstvo, računalno inženjerstvo, industrijsko inženjerstvo i menadžment, inženjerstvo materijala i mehatronika i robotika

UNIVERSITY OF ZAGREB
Faculty of Mechanical Engineering and Naval Architecture
Central Commission for final exams and graduation
Commission for diploma exams of study of Mechanical Engineering for fields: Production engineering, Computer engineering, Industrial engineering and management, Materials engineering and Mechatronics and robotics

Sveučilište u Zagrebu Fakultet strojarstva i brodogradnje	
Datum	Prilog
Klasa:	
Ur.broj:	

DIPLOMSKI ZADATAK/TASK FOR DIPLOMA THESIS

u okviru/in the frame of ERASMUS+

Student:	**PAOLO CAPPARELLI**	Mat. br.: 0035208248
Naslov rada na hrvatskom jeziku/Title in Croatian:	**Analiza izvedivosti primjene tehnologije RFID u tvornici kabela**	
Naslov rada na engleskom jeziku/Title in English:	**Feasibility analysis of application of RFID technology in the cable factory**	

Opis zadatka/Task description:

The thesis should encompass:
1. motivation and description of a product/business/phenomena – the cable business and products
2. the ELKA factory
   - 2.1. overview of production programme (portfolio) and markets
   - 2.2. technology (people, machinery and software (SAP, CableBuilder) in business, design and planning, production and other activities)
   - 2.3. microlocation, buildings, installations and plant (facility) layout
   - 2.4. processes and departments (management, engineering and production)
3. ideas on possible improvements (not limited to the content of the section 4.)
4. feasibility analysis of application of RFID technology in the cable factory
   - 4.1. considerations of RFID applicability in cable manufacturing (ELKA)
     - 4.1.1. packaging, packages and transport units in production processes (including choice of representative products – data on quantities (t, km), batch-sizes and packaging are required as well as technology data)
     - 4.1.2. analysis of present data flow and possibility to be upgraded by RFID
   - 4.2. description of RFID technology
   - 4.3. recommendations for RFID implementation in ELKA (procedure (participants, equipment, data flow), data integration (SAP), RFID technology specification (components of chosen manufacturers, costs, implementation schedule)).
5. conclusions, recommendations and suggestions for future work.

Zadatak zadan/Date of issuing:	Rok predaje rada/Date of thesis submission:	Predviđeni datum obrane/Predicted date of defense:
2015-12-01	February 2016.	February 2016.

Zadatak zadao/Issued by: Prof. dr.sc. Zoran Kunica

Predsjednik Povjerenstva/President of the Commission: Prof. dr. sc. Franjo Cajner

Statement

I declare that the work was developed independently using the knowledge gained at university and cited references.

I thank especially my parents Benedetto and Rosa, my brother Luca and my sister Giusy for their support during all the years, without whom I could not reach this important objective.

I thank to: my mentor in Croatia Professor Zoran KUNICA, my mentor in Italy Professor Alberto REGATTIERI, Mr. Damir LAZANIN and Mr. Martin VLAŠIĆ, both of ELKA d.o.o. for their help in preparing this final work and enabled production data.

I want also to say a special thanks to my friend Grazia always close to me in this period, and to all my friends and colleagues for their help during the study.

Summary

This work considers the application of RFID system in a cable manufacturing. The first part of the thesis depicts the electrical cables and their market by focusing on the Eastearn Europe. A description of ELKA d.o.o. – a Croatian cable manufacturer, is given, including details on production and technology (machines and software such as CableBuilder and SAP). Some of the most important – representative products are identified and used for RFID system dimensioning. The core contribution of the work is the feasibility analysis regarding the application of a RFID system with suggestions and estimations regarding the hardware to use, related costs and all the benefits that can derive from its applications as well as the possible integration of the production data generated by RFID system with in the factory already existing SAP software.

Sažetak

Rad razmatra primjenu sustava RFID u proizvodnji kabela. Prvi dio rada opisuje električne kabele i njihovo tržište s posebnim naglaskom na Istočnu Europu. Dan je opis tvornice ELKA d.o.o., uključujući detalje o njezinoj proizvodnji i tehnologiji (strojevi i softveri kao što su CableBuilder i SAP). Neki najvažniji – reprezentativni proizvodi su identificirani te su poslužili za dimenzioniranje sustava RFID. Glavni doprinos rada je analiza izvedivosti primjene sustava RFID s preporukama i procjenama u vezi potrebne opreme, troškova i prednosti koje mogu proisteći primjenom, kao i moguće integracije podataka generiranih sustavom RFID sa u tvornici već postojećim softverom SAP.

THE CONTENT

The list of bookmarks of physical variables and measurement units

Bookmark	Measurement unit	Name and description
V0	EUR	Initial investment needed
N	years	Lifetime of the system
Vr	EUR	Recovery value
I	%	Interest rate
S	EUR/year	Annual rate
NT	Tags/year	Number of tags per year
STC	EUR/tag	Single tag cost
NO	Orders/year	Number of orders
TCT	EUR/year	Total costs of tags per year
TCL	EUR/year	Total cost of labour

The list of figures

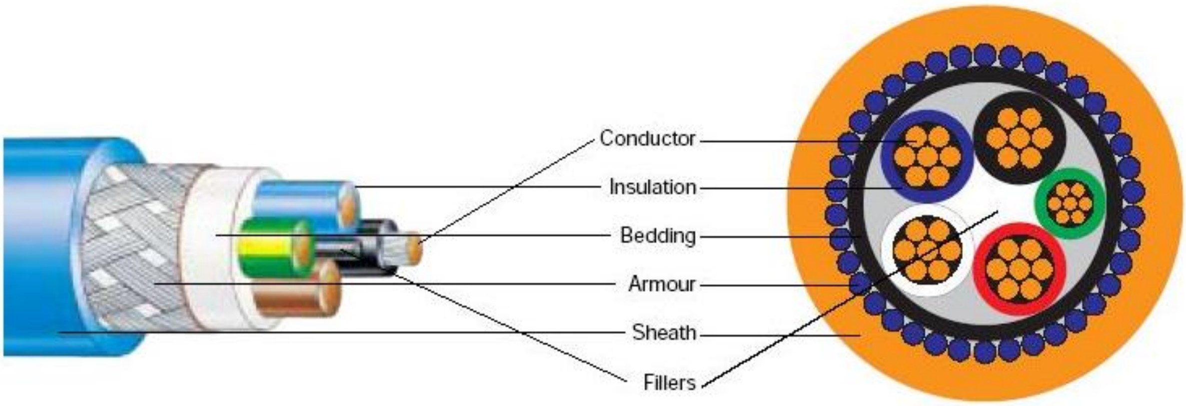
The list of tables

1. ELECTRICAL CABLES

An electrical cable is composed by two or more wires bonded, twisted or braided in order to have a single assembly that allows the transfer of electrical signal from one device to another. Electricity is the flow of electric current along a conductor. This electric current takes the form of free electrons that transfer from one atom to the next. Thus, the more free electrons a material has, the better it conducts.

Cables are used in different applications and for each of them the cables must be properly designed to satisfy specific needs. The cables are used in electronic devices for power and signal circuits. Power cables are used for bulk transmission of alternating and direct current power especially using high voltage cable. They are also used in building for lighting, power and control circuits installed. [1]

Electrical cable is composed by one or more conductors and each of them has its own isolation and optional screens, individual covering, assembly protection and protective covering. An example of cable is shown in Figure1-1.



Conductor Usually stranded copper (Cu) or aluminium (Al)

Conductor screen A semi-conducting tape to maintain a uniform electric field and minimize electrostatic stresses

Insulation Commonly thermoplastic (PVC) or thermosetting (EPR, XLPE) type materials

Bedding Typically a thermoplastic (eg. PVC) or thermosetting (eg. CSP) compound, the inner sheath is there to keep the bundle together and to provide a bedding for the cable armor.

Armor For mechanical protection of the conductor bundle.

Outer Sheath Applied over the armor for overall mechanical, weather, chemical and electrical protection. Typically a thermoplastic (PVC) or thermosetting (CSP) compound, and often the same material as the bedding.

Figure 1-1 Example of electrical cable

Electrical cables are more flexible by stranding the wires. With this kind of process it is possible to braid smaller individual wires together to produce large wires that are more flexible than a single wire of the same size. As said before, the main materials used for electric cable are copper and aluminum. Apart from their electrical conductivity, the other technologically important properties of copper and aluminum differ so significantly that their areas of application are and have always been clearly distinctive. Actually, there are really only four areas in electrical engineering in which aluminum and copper are competing in the same market segments as Figure 1-2 can shows. [2]

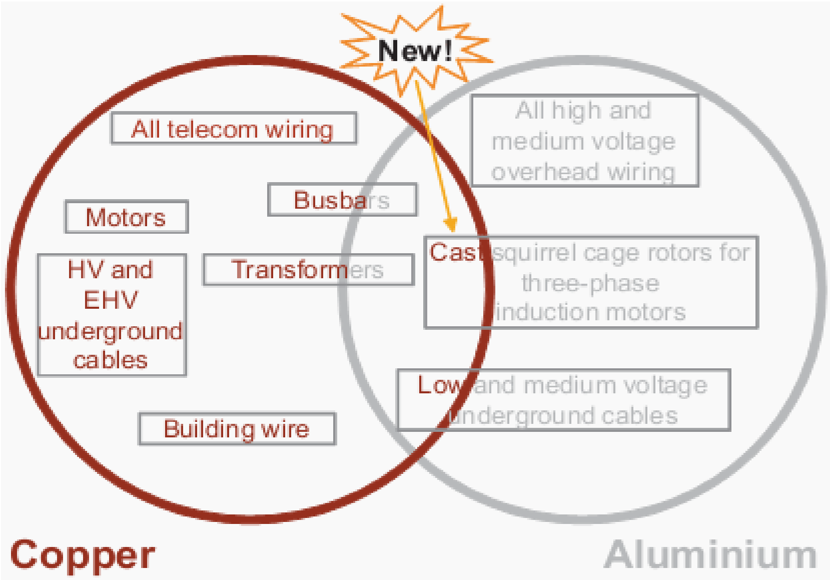


Figure 1-2 The application of aluminum and copper in cable

In general, aluminum cables would be cheaper than copper ones but copper cable are more ductile and less susceptible to electrical contact problems. So, copper cables have a greater margin of safety than a corresponding aluminum cables and thanks to their much smaller section they could be easier to install (It is possible to get very small stranded copper cables). In contrary, aluminum cables are only available at nominal cross-sectional areas of at least 10 mm^2 and the individual wires are still very thick compared to those in the equivalently sized copper cable. So, it may be cheaper to buy aluminum conductors but it is also possible to have some extra costs related to the installation of the less pliable aluminum cables. Hybrid configurations are now present in commerce and used in low voltage distribution. The three phase conductors are made of aluminum, while the same-diameter neutral conductor is of copper.

The dimension of the cable is obviously related to the voltage applied. Usually it depends on the application.

Regarding the voltage, the cables can be divide in four categories:

- Low Voltage (LW) that is less than 1000 V
- Medium Voltage (MV) from 1 to 40 kV
- High Voltage (HV) that ranges from 40 to 130 kV
- Extremely High Voltage (EHV) above 130 kV.

This is a general differentiation but the range between the different categories usually changes from country to country.

2. ELECTRICAL CABLE BUSINESS

2.1. THE GLOBAL CABLE MARKET

The European cable business saw impressive growth from 2004 to 2008. Then, due to the impact of the economic slowdown, the market has experienced a decline in the growth rate from 2009. However, most companies managed to bounce back from the financial crisis by virtue of capital spending and investments in industries worldwide. The economic recession showed its effect on the transmission and distribution sector and, due to the ongoing crisis in many countries, the pricing of cables has become a critical competitive parameter. Furthermore, the cancellation of expansion plans and order delays, significantly increased the competition among existing players. In order to survive in the market and face the competition, companies are adopting strategies such as: acquisitions, exploration of new markets, improvements in research and development, focus on customers. As a result, cable manufacturers need to be agile enough to respond quickly to changing levels of the demand.

The main reason why Europeans managed to fend off Asian rivals is that around the 70 % of cable production costs are raw materials (especially copper and aluminum) which have the same cost all the world. The biggest advantage of Asia is the lower labor costs, but this is such an irrelevant element, because of the labor accounts for a mere 10 % of overall costs.

The complexity of cable business derives from the features of copper and aluminum, whose costs are strongly fluctuating; this requires cable manufacturers to carefully manage the risk of volatile prices of these raw materials – figures 2–1 and 2–2. [3]

Figure 2-1 Historical copper price from 1989 to 2014 expressed in USD/t [3]

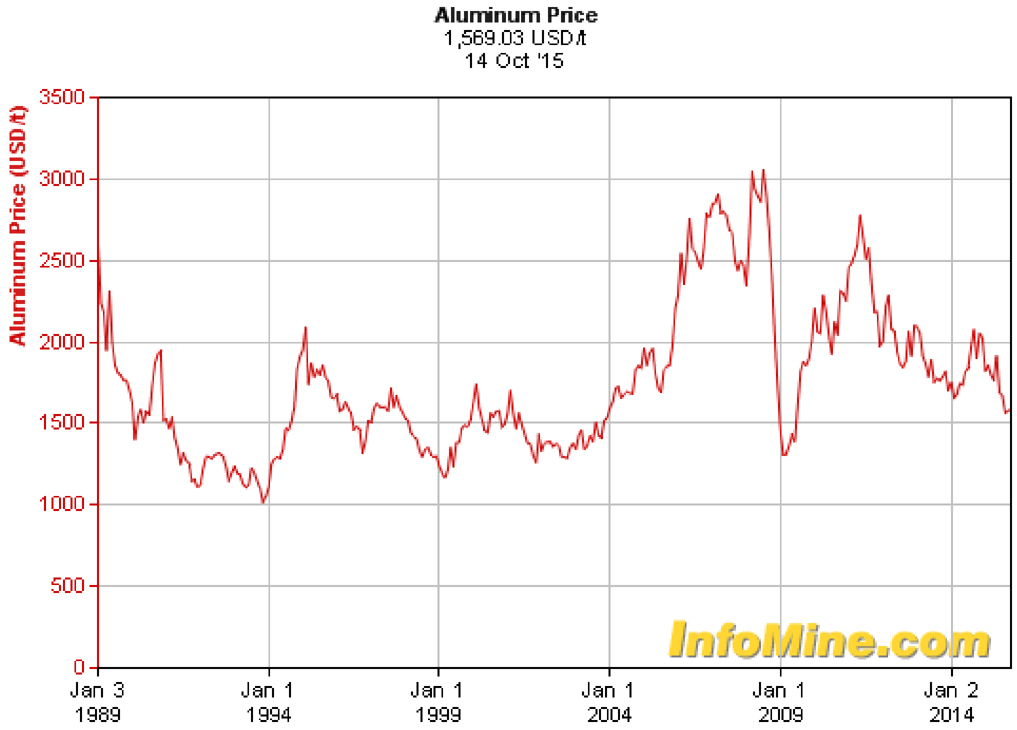


Figure 2-2 Historical copper price from 1989 to 2014 expressed in USD/t [3]

2.2.FOCUS ON THE EASTERN EUROPE

The Eastern European cable sector is becoming one of the most important growth markets in Europe. Yet, the only companies with operations in more than one country are Prysmian Group (Hungary, Slovakia and Romania), NKT (Poland and the Czech Republic), and Wilms Group (Czech Republic, Romania) – Figure 2—3. [4]

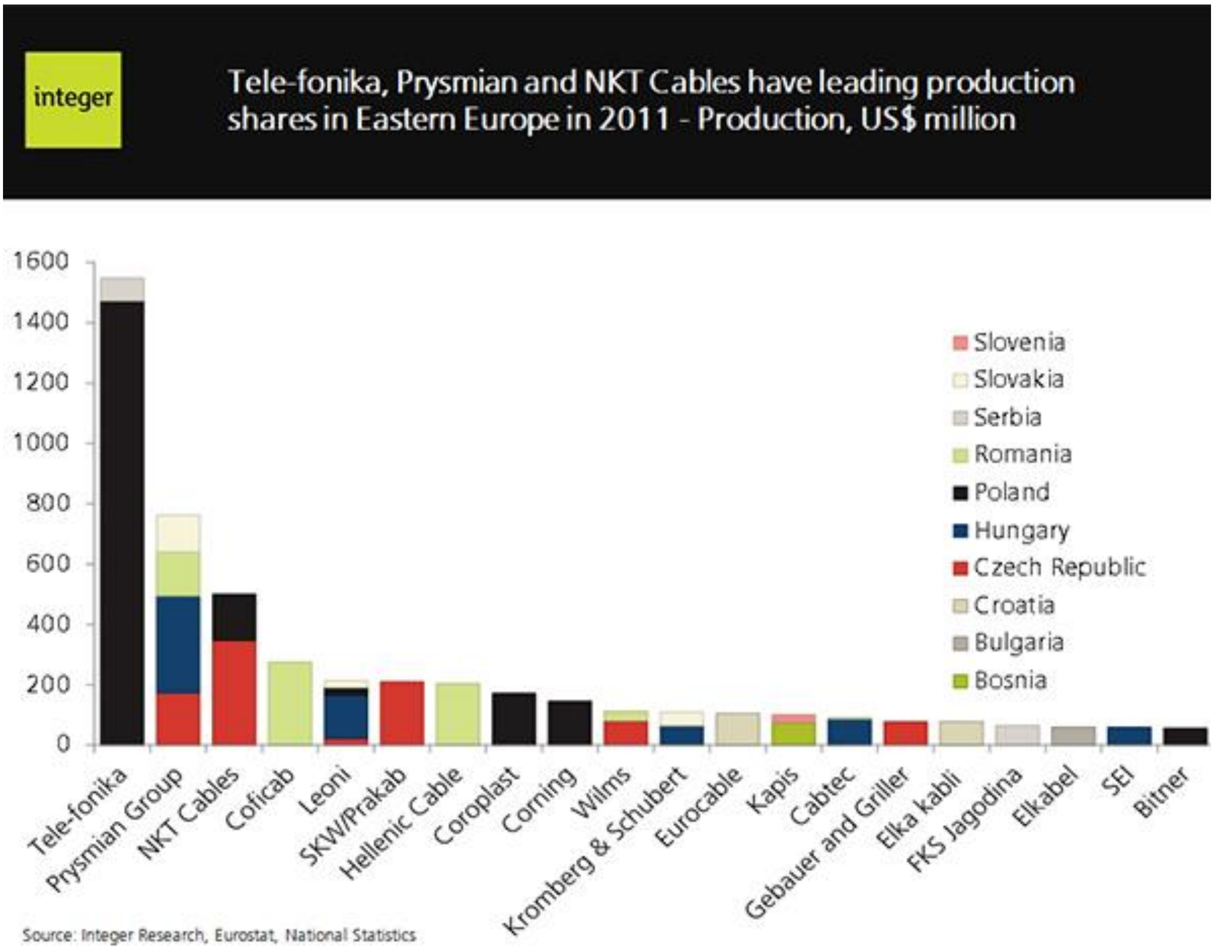


Figure 2-3 Important cable builder in the Eastern Europe

Major players

- NKT has consolidated its operations, following the acquisition of Kablo Electro;
- Hellenic Cables has a major stake in the Romanian cable sector, through ICME Ecab;
- Coficab, part of Elloumi Group, has operations in Romania;

- SKW/Prakab has cable manufacturing plants in Austria, the Czech Republic, Slovakia and now Ukraine;
- Kromberg & Schubert has a significant footprint, with plants in Romania, Hungary and Slovakia;
- Cabtec has plants in Hungary, Romania and Slovakia;

Specialist players

- Sumitomo Electric has a network of wiring harness operations in Eastern Europe, but a smaller footprint in the cable sector;
- Leoni has a number of specialist automotive wire producing plants in Slovakia, Hungary and Poland, and now Serbia;

New entrants

- A new entrant in the Balkans is Cablex, with operations in Poland, Serbia and Slovenia;

Absent from region

- Nexans is largely absent in terms of production, but exports into the region from its operations in Germany, Turkey, Sweden and Russia;
- General Cable has no footprint in Eastern Europe;

It can be seen in the Figure 1-5 that the most important cable builder in Balkans region are Kapis with operations in Bosnia and Slovenia, FKS Jagodina with operations in Serbia and Eurocable group and Elka kabeli with operations in Croatia. [4]

Kapis TKT production includes different kinds of products like: [12]

- Flexible products of various types for the automotive industry and household appliances
- Building cables with insulation and PVC jackets
- Copper and aluminium power cables with insulation and PVC and HDPE jackets, with XLP insulation and PVC jackets and with XLPE insulation and HFFR (Halogen-Free Flame Retardant) jackets

- Self-supporting cable bundles made of XLPE
- Ropes (Al/Fe, Fe, Cu, AlMgSi),
- Armoured cables
- The production of PVC granules.

In average Kapis production is about 10000 tons of products per year. Actually the number of employees is around 170.

FCS is the largest Serbian exporter of cable products and their products are: [11]

- Power Cable
- Telecommunication cable and enameled wire
- Microwares, connectors and electromechanical production
- Wire conductors
- Production of insulation materials
- Cable accessories

They produce 20000 different kinds of products.

Eurocable production includes different kinds of products like: [10]

- PVC insulated installation wires
- PVC insulated installation cables
- Rubber insulated wires and cables
- Power cables 1-30 kV
- Control cables
- Telecommunication cables
- Wires and cables halogen free
- Cables for electronics
- LAN cables
- Fiber optic cables.

The company employs 170 people with annual sales of 160 millions EUR.

3. ELKA FACTORY

ELKA, founded in Zagreb in 1927, is one of the leading factories in cable production in the markets of Croatia, Bosnia and Herzegovina and Slovenia. In those almost 90 years ELKA have produced a large number of quality products and expanded her markets. It has also consolidated professional skill and operational capability that let them be the major producer of electrical cables in this part of Europe. The Vision of ELKA is to remain a cable company, interested in vertical expansion by designing new products and horizontal expansion by increasing the personalization of the existing products, always with the goal of competitiveness increase. ELKA is focused on offering high quality products and services by giving importance to the customers satisfaction and pursuing engineering and flexibility with the orientation to objectives and result. The strategic goals are keeping a leader position in Croatian, Bosnian and Slovenian markets and trying to expand their business in the western Europe and to catch the opportunity of entering to new markets. The Figure 3‒1 shows ELKA's sales in the different countries in the year 2013 (that’s quite similar to the year 2014).

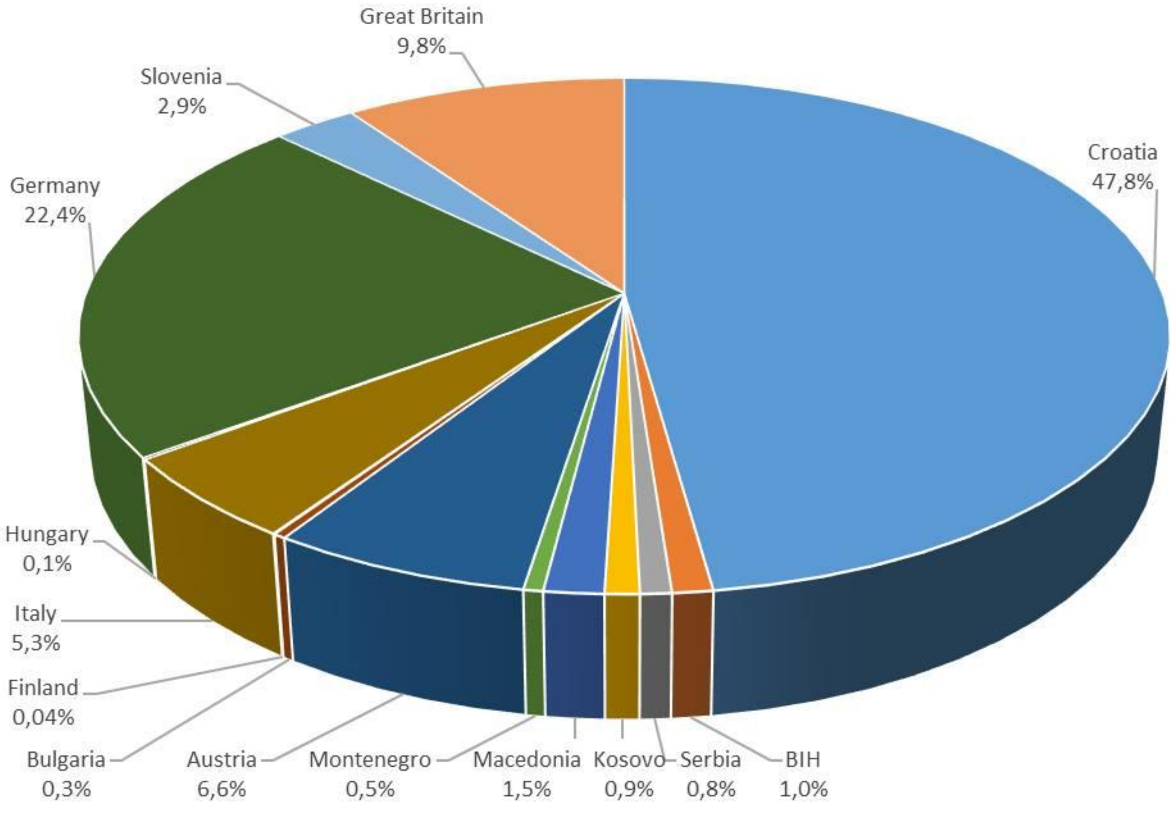


Figure 3-1 Percentage of ELKA’s Sales in 2013

ELKA is organized with a functional structure with different separated departments such as production, commercial, finance and development and technology, each of them managed by a functional responsible. In this moment ELKA has a total of 285 employees. The central factory in Zagreb and the plant in Zadar have an area of 188 000 m^2, whose 68 000 m^2 are of constructed ground. The annual capacities can support a production of 25 000 tons of products. [5]

ELKA factory is located in the industrial area of Zagreb in the south-east periphery. The Figure 3–2 shows the top view of the central factory in Zagreb.

Figure 3-2 Top view of ELKA factory in Zagreb

The most important buildings related to the production system are three, namely: the metal department, the rubber department, the and thermoplastics department. ELKA is organized with a functional structure with different separated departments such as production, commercial, finance and development and technology, each of them managed by a functional responsible. The offices are located in the main entrance in the taller building showed in Figure 6-1. There are a maintenance building and a system for the production of electrical power as well.

Thanks to the collaboration between ELKA and KONČAR distribution and special transformers, in December 2003, ELKAKON company was established. The production capacity of ELKAKON is 1150 tons per year and the company is also the only producer of round and profile industrial conductors in Croatia. Around 70 % of the ELKAKON production is sold in Croatia and the other 30 % is exported in countries close to Croatia.

4. PRODUCTION MIX IN ELKA

ELKA offers a large number of different products with specific characteristics at high quality level:

- **POWER CABLES**
  - 1 kV with PVC and XLPE (cross-linked polyethylene)
  - 6 kV to 36 kV with XPLE and EPDM (Ethylene-Propylene Diene Monomer) insulation
  - 1 kV to 36 kV self-supporting cables with XLPE insulation
  - 36 kV to 132 kV high voltage
- **FLEXIBLE THERMOPLASTIC INSULATED WIRING CABLES AND WIRES**
  - Power cable and wires
  - Automotive wires
- **FLEXIBLE RUBBER INSULATED WIRING CABLES AND WIRES**
- **SHIPBOARD CABLES**
  - With EPDM insulation and CR sheath
  - Flame-retardant halogen free cable
  - Fire-resistant halogen free cable
- **CABLE AND CONNECTORS FOR AIRPORT INSTALLATIONS**
- **TELECOMUNICATION CABLES**
  - Telephone cables with PE insulation
  - Telephone cables with PVC insulation
- **FIBRE OPTIC CABLE**
- **CONTROL, INSTRUMENT AND COMPUTER CABLES**
  - Control cables with PVC insulation for voltage up to 1 kV
  - Instrument cable with PE and XLPE insulation and PVC sheath
  - Cat.5 LAN cable with fibre optic and Cu conductor
- **MINING CABLES (MINIERE)**
- **WELDING CABLES**
- **SPECIAL CABLE AND WIRES**
  - for operating temperature from 70 °C up to 160 °C

- **ALUMINIUM, AI-STEEL AND AI-ALLOY ROPES**
- **OPTICALPOWER GROUND WIRE**
- **STEEL ROPES AND SLING FOR CRANES, SHIPS AND OTHER APPLICATION**
- **INSULATION MATERIAL**
  - Rubber compounds
  - XLPE (cross-linked polyethylene)
  - Halogen free flame-retardant polyolefin
  - PVC.

Figure 4–1 shows the percentage of sales of every product in 2013: it is possible to see that half of the total amount of sales is represented by the “Power cables > 1 kV”.

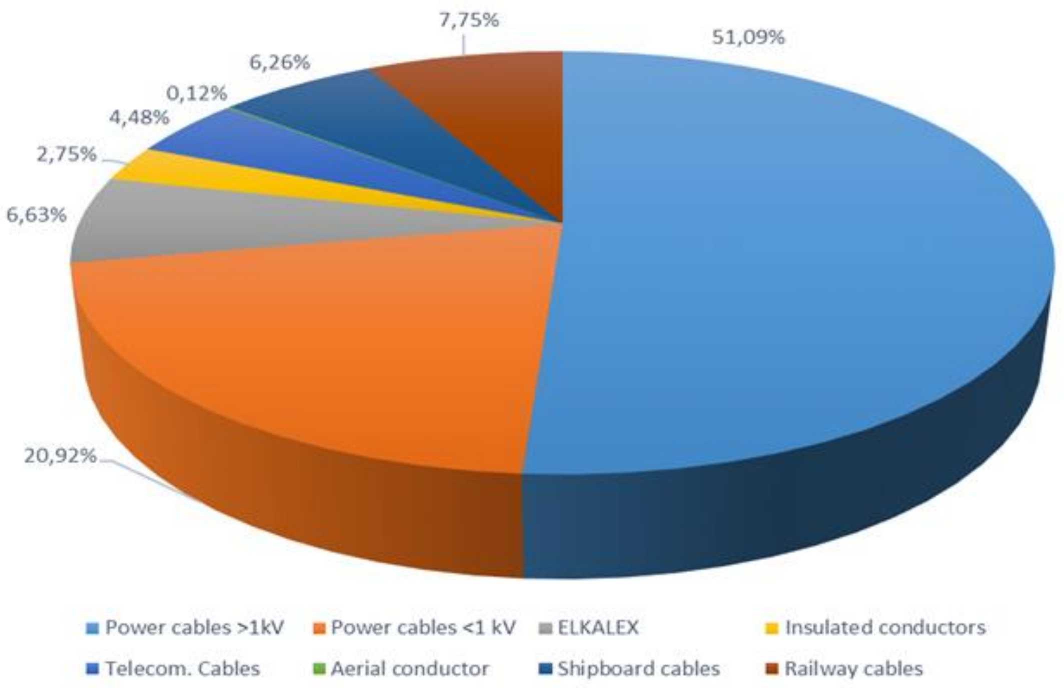


Figure 4-1 Percentage of sales of every product on 2013

Here is a list of the most important Elka’s products divided on the basis of different voltages and other characteristics:

- High-voltage power cables
- Medium-voltage power cables
- Power and control cables for voltage up to 1 kV

- New generation of pair cables.

Usually, the cable name, depending on the material it is composed of, can follow two different standards that are HRN HD or DIN VDE 0271/0276. [5]

4.1. HIGH-VOLTAGE POWER CABLES

Nowadays this kind of cables are more used all over in the world especially for electric power transmission at high voltage in densely populated areas. The main reasons for using them include efficiency (the maintenance is cheaper, smaller transmission losses, more reliability), safety for people, ecological reasons. An high voltage cable includes a conductor and the insulation, and it is suitable for being used underground or underwater. The XLPE (cross-linked polyethylene) represents the most used insulation and it is obtained by using the most recent technology of triple extrusion. It is better to use XLPE instead of PVC because the cross-linking inhibits the movement of molecules: this improves the thermal stability and consequently the current rating is higher than that of PVC.

High Voltage Cables are marked in the technical documentation and each letter in the name of the product has its meaning by following HRN HD standards:

- A- label for aluminum guide
- - - Symbol for copper conductors (no symbol)
- 2X- designation for XLPE insulation
- S designation for copper screen
- Y - stands for a layer of PVC
- 2Y- mark for the layer of PE
- (F) 2Y - mark for longitudinal waterproof with PE layers
- (FL) 2Y- mark for longitudinal and cross watertightness with A / PE layers.

2XS(F)2Y, A2XS(F)2Y

Power cables with XLPE insulation and PE sheath with longitudinal and transversal water-resistant version of electrical protection.

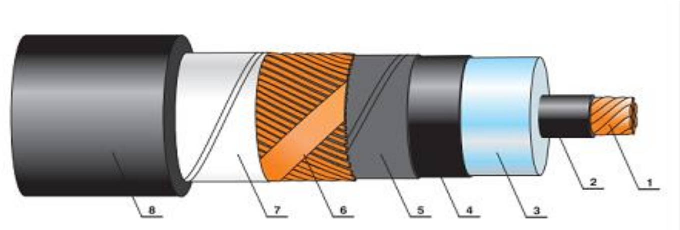


Figure 4-2 2XS(F)2Y, A2XS(F)2Y High voltage Cable

Cable structure:

1) **Conductor**: copper or aluminum compacted or segment rope of class 2
2) **Conductor screen**: extruded semi-conductive XLPE
3) **Insulation**: XLPE
4) **Insulation screen**: extruded semi-conductive XLPE
5) **Separator**: swelling tape, semi-conductive
6) **Metal screen**: copper wires and counter-helix of copper tape
7) **Separator**: swelling tape
8) **Sheath**: black HDPE

Technical aspects:

- **nominal voltage**: 64/110 kV
- **highest network voltage**: 123 kV
- **standards**: IEC 60840; HRN HD 632
- **old mark**: XHE 49, XHE 49-A

2XS(FL)2Y, A2XS(FL)2Y

Power cables with XLPE insulation and PE sheath with longitudinal water-resistant version of electrical protection.

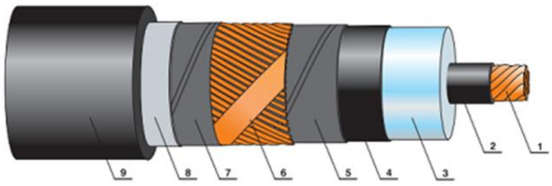


Figure 4-3 2XS(FL)2Y, A2XS(FL)2Y High Voltage Cable

Cable structure:

1) **Conductor**: Cu or Al compacted or segment rope, class 2
2) **Conductor screen**: extruded semi-conductive XLPE
3) **Insulation**: XLPE
4) **Insulation screen**: extruded semi-conductive XLPE
5) **Separator**: swelling tape, semi-conductive
6) **Metal screen**: Cu wires and counter helix of copper tape
7) **Separator**: swelling tape, semi-conductive
8) **Laminated sheath**: Al or Cu tape with copolymer
9) **External sheath**: black HDPE

Technical aspects:

- **nominal voltage**: 64/110 kV
- **highest network voltage**:123 kV
- **standards**: IEC 60840; HRN HD 632
- **old mark**: XH(A)E 49, XH(A)E 49-A

[5]

4.2. MEDIUM VOLTAGE POWER CABLES

New technologies are used in the manufacturing of medium voltage cables with XLPE insulation. By the utilization of complex procedures in ELKA high quality and tight connection between insulation and conductive layers are obtained avoiding their separation during the heating and cooling cycles of cables in operation. This operation increases the grade of dielectric strength of insulation a lot and prolongs the life of the cable. ELKA has got a proper development center and test laboratories for ensuring an high quality of final products, materials and cables. The Quality Management (Insurance) System is confirmed by ISO 9001 Certificate and Environmental Management by ISO 14001 Certificate.

Medium Voltage Cables are marked in the technical documentation and each letter in the name of the product has its meaning by following the HRN standards:

- A- aluminum
- Ay aldrey (alloy AlMgSi)
- X cross-linked polyethylene
- P polyvinyl chloride PVC
- E polyethylene
- O polyolefin
- H semiconductive layers of insulation around
- h semiconductive layer

The most important Medium Voltage Cable products are as follows.

XHE 46/29, XHE 49/24 (HRN standards)

Submarine power cables with XLPE insulation:

- single core with armour of aluminium alloy AlMgSi in watertight construction
- three core with armour of steel wires in watertight construction

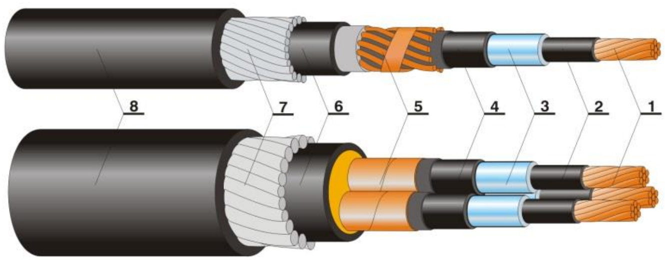


Figure 4-4 XHE 46/29, XHE 49/24 Medium Voltage Cable

Cable structure

1) **conductor**: Al or Cu rope, compacted
2) **conductor screen**: semi-conductive layer over conductor
3) **insulation**: XLPE
4) **insulation screen**: semi-conductive layer over insulation
5) **electric protection/screen**: made of Cu wires, watertight construction
6) **sheath**: semi-conductive PE
7) **additional electric protection**: of tinned copper wires (1 or 2 layers)

Technical and other data.

In dependence of buyer's request and application condition, with different specification.

XLPE-Ay Type-23, XLPE-Ay Type-27 (HRN standards)

Insulated medium voltage overhead power cables.

Suitable solution for construction of overhead networks in forest areas due to reduce cutting area and lower cost of construction and maintenance as related to the networks with bare conductors.

Figure 4-5 XLPE-Ay Type-23, XLPE-Ay Type-27 Medium Voltage Cable

Cable structure

1) **conductor**: rope of aluminium alloy, AlMgSi
2) **insulation**: XLPE, resistant to weathering factors

Technical data

- **nominal voltage**: 12/20 kV
- **max network voltage**: 24 kV
- **test voltage**: 24 kV
- **standards**: SFS 5791

XHE 48/0, XHE 48/0-Ay (HRN standards)

Self-supporting medium voltage universal power cables.

On overhead network pillars. Partially in earth, ducts or on cable trays when transferring from or to overhead network. As distributive cable in urban networks. As connective cable for industrial plants.

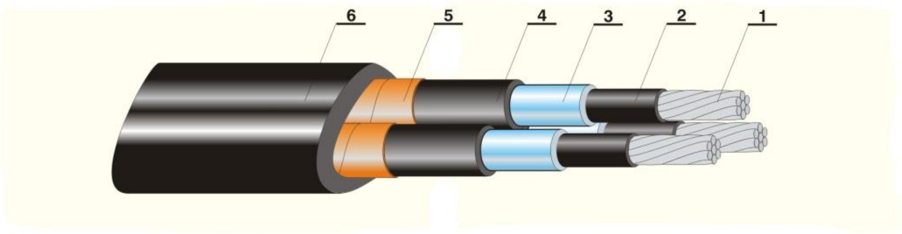


Figure 4-6 XHE 48/0, XHE 48/0-Ay Medium Voltage Cable

Cable structure

1) **conductor**: Al or Cu rope, compacted
2) **conductor screen**: semi-conductive layer over conductor
3) **insulation**: XLPE
4) **insulation screen**: semi-conductive layer over insulation
5) **electric protection/screen**: made of Cu tape
6) **external sheath**: PE-HD

Technical data

- **nominal voltage**: 12/20kV
- **max network voltage**: 24kV
- **test voltage**: 42kV
- **standard**: IEC 60 502-2

N2XSY, NA2XSY (DIN VDE 0271/0276 Standard)

Power cables with XLPE insulation and PVC sheath

In earth, ducts, on cable trays, where no mechanical damages or mechanical tensile strains are expected. As distributive cable in urban and rural networks. As connecting cable for industrial plants. [5]

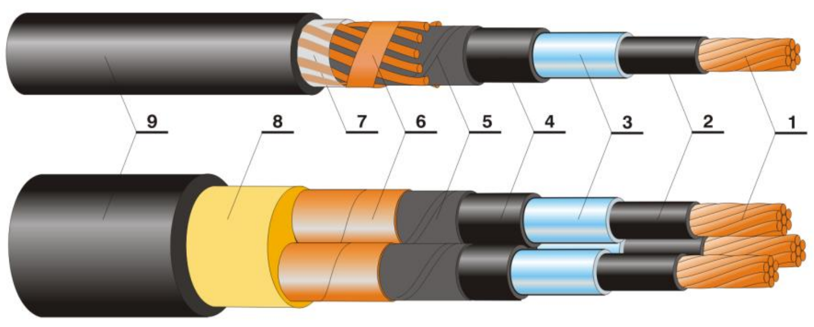


Figure 4-7 N2XSY, NA2XSY Medium Voltage Cable

Cable structure

1) **conductor**: Al or Cu rope, compacted
2) **conductor screen**: semi conductive layer over conductor
3) **insulation**: XLPE
4) **insulation screen**: semi conductive layer over insulation
5) **separator**: semi conductive tape
6) **electric protection/screen**: of Cu wire (single-core), of Cu tape (three-core)
7) **separator**: polyester tape
8) **filler**: PVC
9) **external sheath**: PVC

Technical data

- **former code**: XHP 48, XHP 48-A
- **nominal voltage**: 6/10/12 kV, 12/20/24 kV
- **max network voltage**: 12kV, 24kV
- **test voltage**: 21 kV, 35 kV
- **standard**: IEC 60 502-2; HRN HD 620 S2 Part 10C; DIN VDE 0276T 620

4.3. POWER AND CONTROL CABLES FOR VOLTAGE UP TO 1 kV

The catalogue “Power and control cables for voltages up to 1 kV” includes:

- cables with PVC insulation and sheath
- cables with flame-retardant PVC insulation and sheath
- cables with XLPE insulation and PVC sheath
- cables with XLPE insulation and PE sheath
- cables with flame-retardant XLPE insulation and flame retardant polyolefine halogen-free sheath
- self-supporting cable bundle with XLPE insulation and flame retardant polyolefine halogen-free sheath
- self-supporting cable bundle with flame-retardant XLPE insulation.

Some of the most important product are:

NYY, NAYY (DIN VDE 0271/0276 Standard)

Power and control cables with PVC insulation and sheath.

In earth, ducts, on support brackets, in dry and wet conditions etc, where one doesn’t expect mechanical damages and cables aren’t exposed to the mechanical tensile. In urban networks, industrial plants, electric power plants and other electricity consumers and for connection of control devices in industry, traffic etc. For the necessity of MTK control systems in distribution networks, at four-core cables of larger cross-section, an additional insulated conductor of 2,5 mm^2 is applied in the middle among the cable cores.

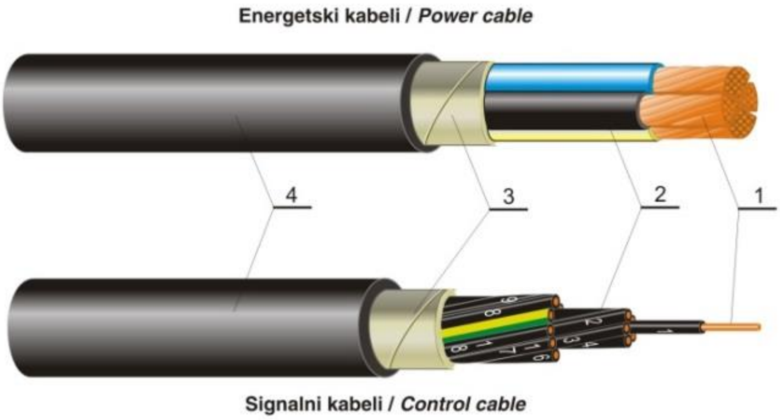


Figure 4-8 NYY, NAYY 1kV Cable

Cable Structure

1) **conductor**: Cu rope/wire (NYY), Al rope (NAYY)
2) **insulation**: PVC
3) **filling**: extruded elastomer or plastomer compound or wrapped thermoplastic tapes
4) **sheath**: PVC compound

Technical data

- **nominal voltage**:1 kV
- **test voltage**: 4 kV

NYCY (DIN VDE 0271/0276 Standard)

Power & control cables with PVC insulation and sheath, with concentric neutral conductor, i.e. protective conductor.

For underground laying of urban and interurban networks, on support brackets in dry and wet conditions etc. Concentric conductor applied as safety measure against touch voltage in case of severe damage by sharp metal object.

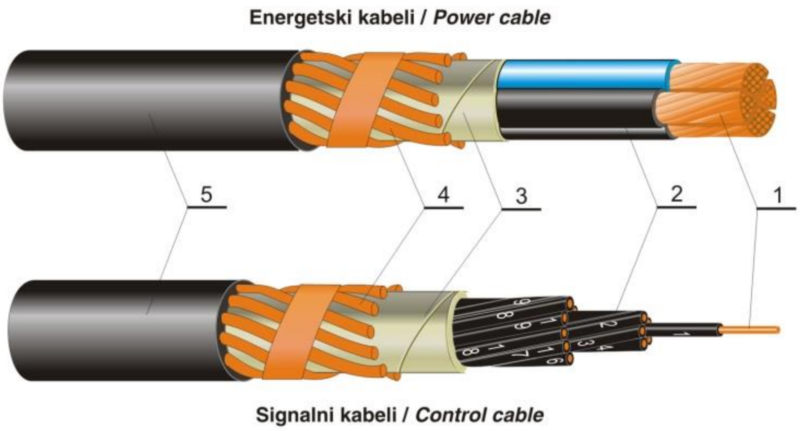


Figure 4-9 NYCY….

Cable structure

1) **conductor**: Cu rope/wire (NYY), Al rope (NAYY)
2) **insulation**: PVC
3) **filling**: extruded elastomer or plastomer compound or wrapped thermoplastic tapes
4) **concentric conductor**: Cu wires
5) **sheath**: PVC compound

Technical data

- **nominal voltage**:1 kV
- **test voltage**: 4 kV

FR-N1XD4-AR, FR-N1XD9-AR, FR-NFA2X (FR IEC 60331-21 fire resistance)

Self-supporting cable bundle with XLPE insulation. For distributive low-voltage air networks in urban, suburban and rural areas. For supply of remote facilities and villages of temporary and permanent character. For air household connections.

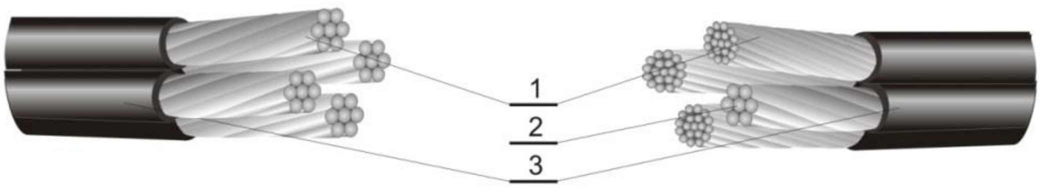


Figure 4-10 FR-N1XD4-AR, FR-N1XD9-AR, FR-NFA2X

Cable structure

1) **phase conductor**: compacted round shaped Al rope of 16, 25, 35, 50 and 70mm2
2) **neutral conductor**: compacted round shaped rope of aluminium alloy AlMgSi of 70mm2
3) **insulation**: XLPE black compound

Technical data

- **nominal voltage**: 1 kV
- **test voltage**: 4 kV

N2XH (DIN VDE 0271/0276 Standard)

Flame-retardant power cables with flame-retardant XLPE insulation and flame-retardant polyolefin sheath, halogen-free.

In ducts, on support brackets, in dry and wet conditions, where no increased mechanical strains are expected. For power and signal distribution in industrial plants, public purpose and other facilities where fire prevention safety measures are requested, for elevated electricity and thermic strains (operating temperature of the conductor up to 90°C).

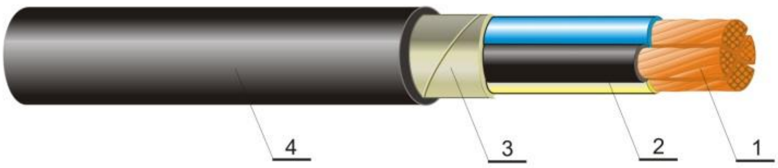


Figure 4-11 N2XH

Cable structure

1. **conductor**: Cu rope
2. **insulation**: halogen-free flame-retardant XLPE compound
3. **filling:** extruded flame-retardant elastomer or plastomer compound or wrapped flame-retardant thermoplastic tapes
4. **sheath**: flame-retardant halogen-free polyolefin

Technical data

- **nominal voltage**:1 kV
- **test voltage**: 4 kV
- **standards**: DIN VDE 0266, IEC 60 502-1
- **inflammability test acc. to**: IEC 332-3, kat. A
- **acidity of gasses test acc. to**: IEC 360754-2

XP 44, XP 44-A (IEC 60092 cable code designation)

Power cables with XLPE insulation and PVC sheath, armoured with round steel wires

In earth, ducts, on support brackets, in dry and wet conditions etc, where one can expect mechanical damages and cables are exposed to increased mechanical tensile strain by inclined or vertical laying. In urban networks, industrial plants, electric power plants and other electricity consumers for elevated electricity and thermic strains (operating temperature of the conductor up to 90°C. For the necessity of MTK control systems in distribution networks, at four-core cables of larger cross-section, an additional insulated conductor of 2.5mm2is applied in the middle among the cable cores.

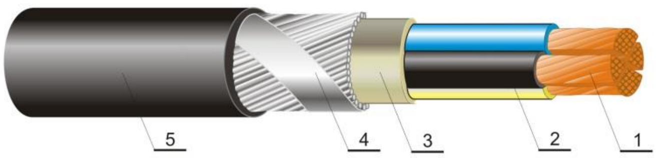


Figure 4-12 XP 44, XP 44-A

Cable Structure

1) **conductor**: Cu rope (XP 44), Al rope (XP 44-A)
2) **insulation**: XLPE compound
3) **filling**: extruded elastomer or plastomer compound or wrapped thermoplastic tapes
4) **armour**: galvanized steel round wires with galvanized steel tape wrapped around them in opposite direction
5) **sheath**: PVC compound

Technical Data

- **nominal voltage**:1 kV
- **test voltage**: 3,5 kV
- **standards**: IEC 60 502-1, BS 5467

[5]

4.4. NEW GENERATION OF PAIR CABLES

New generation of pair cables (Figure 4-13) allows big rates of data transmission through xDSL technologies. ELKA designed, tested and produced a new generation of cables for ADSL technologies. ELKA produces different kinds of xDSL cables:

- TK59-50 x DSL 100x2x0,4 GM
- TK59-50 x DSL 100x2x0,4 GM
- TK59-50 x DSL 200x2x0,4 GM
- TK59-50 x DSL 400x2x0,4 GM
- TK59-50 x DSL 600x2x0,4 GM
- TK59-50 x DSL 800x2x0,4 GM
- TK59-50 x DSL 1000x2x0,4 GM.

Figure 4-13 Example of TK59-50 xDSL cable

The pilot project started in Trnje, an area close to Zagreb, where xDSL ELKA cable works very well with the requirement of T-Com (Hrvatski Telekom). In ELKA a new type of terminal cable has been developed, TC3 PO HFFR, for installation cable for household which are linked to xDSL cables and compatible with the entire broadband system. The cables are flame-retardant, halogen-free, with low smoke release in case of fire. [5]

5. TECHNOLOGY

Technology is the collection of techniques, skills, methods and processes used in the production of goods or services or in the achievements of objectives. Technology can be also intended as the knowledge of techniques, processes or it can be embedded in machines, computers, devices and factories, all of which can be actually used without an in-depth knowledge of how they work. So technology is present in the machinery (a detail list of machine present in ELKA with some of the main characteristics is shown in the next chapter) and software that can be used for making the flow, conservation and transmission of information inside and outside the company easier. CableBuilder and SAP are example of softwares used in ELKA whose integration could be used for obtaining better improvements in terms of information and knowledge achieved inside an enterprise.

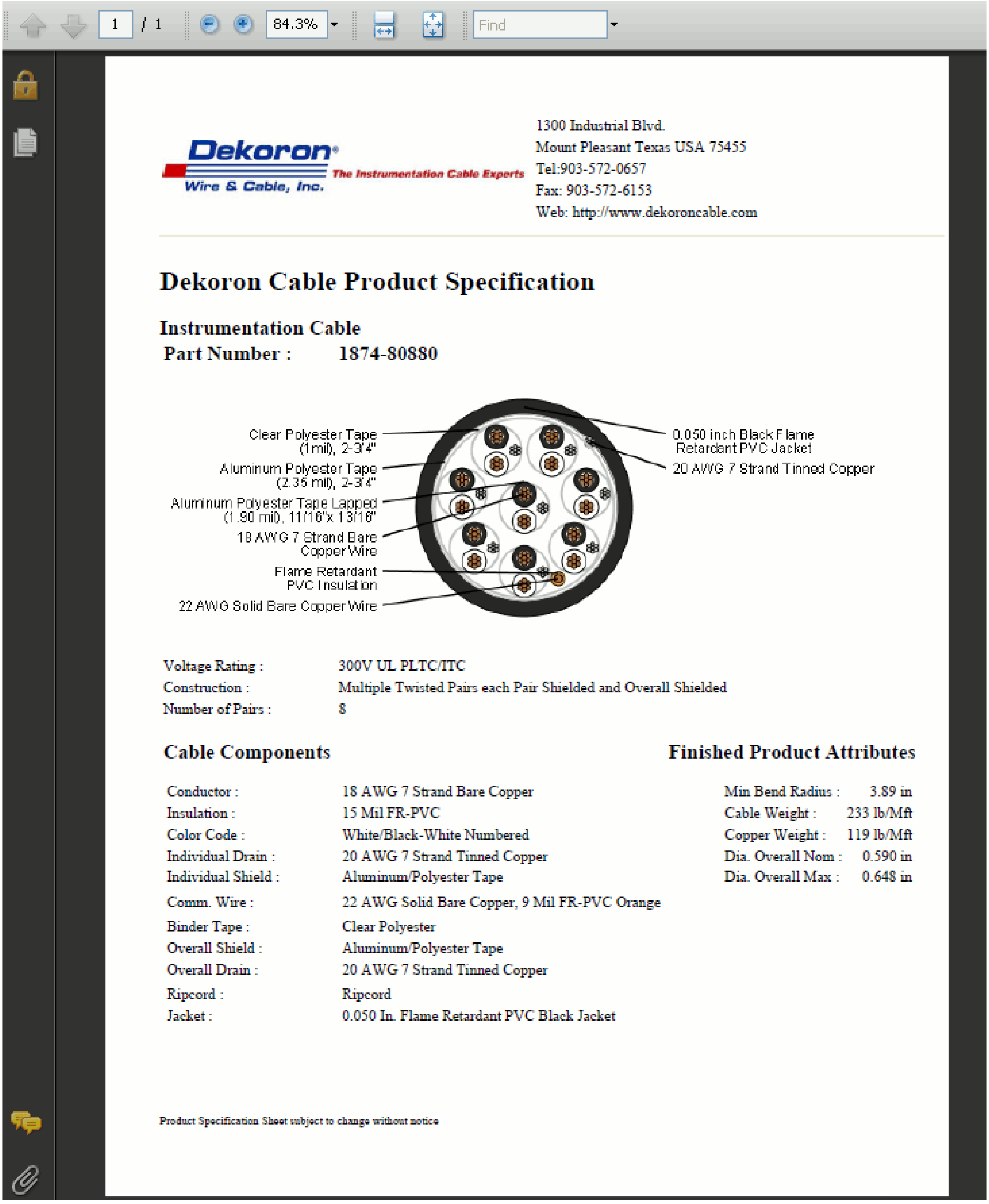
5.1. CABLE DESIGN AND CABLEBUILDER

There are different types of softwares in the market created for cable design; in ELKA for example CableBuilder is used for design activities. Property of CIMTEQ, CableBuilder is a cable design software used for all cable types . It is an application that reduces design and maintenance time, produces professional datasheets and catalogues, improves manufacturing and reduces reworks and scraps. The advantages of using a software like this are related to: the improvement of existing design and an easy creation of new design, by using the What-if scenario to evaluate the impact of some changes in the design; the fact that it helps keeping existing design up-to-date by ensuring the quality of information entered; the fast distribution of products and processes inside and outside the company in the different format available; the fact that it reduces the total costs of ownership for cable design tools. [6]

The business benefits related to the use of this type of softwares are: the fact that it increases sales and improves efficiency by reducing the gap between sales and design departments; that, customers can use the self-service web environment to design the product by themselves so that then cable builder may help the designer to find an existing design which is similar to a customer demand; that it centralizes and shares information inside and outside the company in the format desired; and finally that it reduce costs by experimenting different construction of the cable. [6]

In the market there are a lot of cable producers competing for a not large number of orders. The standardization increases the competition and in this way it is important to design products that have an high quality level and try to increase sales by using the same or less resources.

CableBuilder is integrated with datasheets and reporting that are always updated. Different reporting types are available like PDF, RTF and Microsoft Excel. An example of reporting system is shown in the Figure 5-1.



Dekoron® Wire & Cable, Inc. The Instrumentation Cable Experts

1300 Industrial Blvd.
Mount Pleasant Texas USA 75455
Tel:903-572-0657
Fax: 903-572-6153
Web: http://www.dekoroncable.com

Dekoron Cable Product Specification

Instrumentation Cable
Part Number : 1874-80880

Voltage Rating :	300V UL PLTC/ITC
Construction :	Multiple Twisted Pairs each Pair Shielded and Overall Shielded
Number of Pairs :	8

Cable Components

Conductor :	18 AWG 7 Strand Bare Copper
Insulation :	15 Mil FR-PVC
Color Code :	White/Black-White Numbered
Individual Drain :	20 AWG 7 Strand Tinned Copper
Individual Shield :	Aluminum/Polyester Tape
Comm. Wire :	22 AWG Solid Bare Copper, 9 Mil FR-PVC Orange
Binder Tape :	Clear Polyester
Overall Shield :	Aluminum/Polyester Tape
Overall Drain :	20 AWG 7 Strand Tinned Copper
Ripcord :	Ripcord
Jacket :	0.050 In. Flame Retardant PVC Black Jacket

Finished Product Attributes

Min Bend Radius :	3.89 in
Cable Weight :	233 lb/Mft
Copper Weight :	119 lb/Mft
Dia. Overall Nom :	0.590 in
Dia. Overall Max :	0.648 in

Product Specification Sheet subject to change without notice

Figure 5-1 Example of reporting system in CableBuilder

With Cablebuilder it is possible to design different types of cables like Power Cable, Telephone cable, Optical fibre cable and more. The outputs of CableBuilder can be in 2D or 3D, colour or black and white and saved for example in JPEG format. Examples of CableBuilder's output are given by figures 5–2 and 5–3.

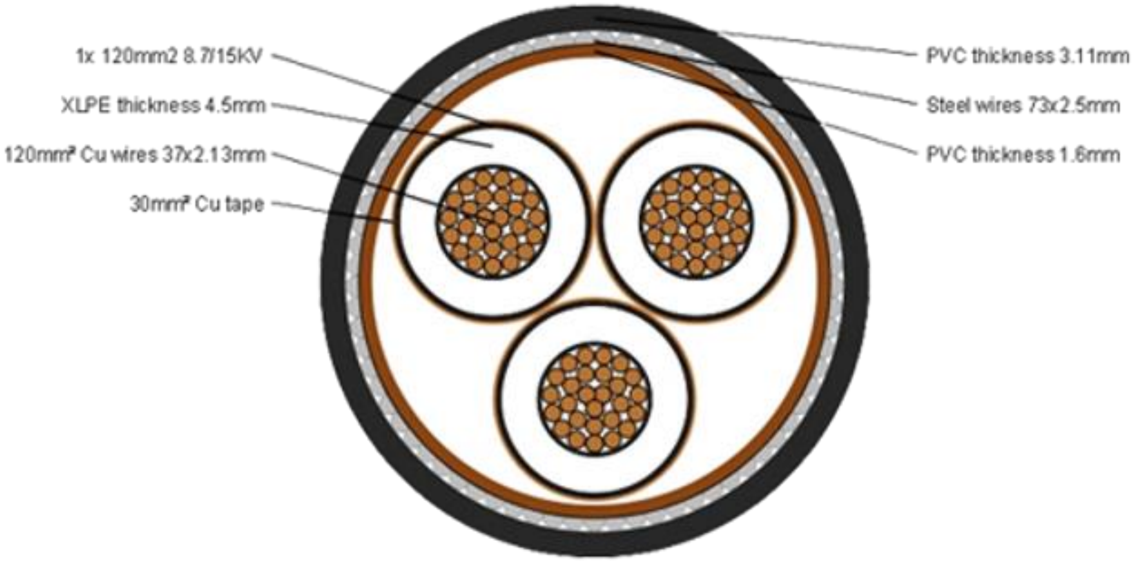


Figure 5-2 2D output in CableBuilder

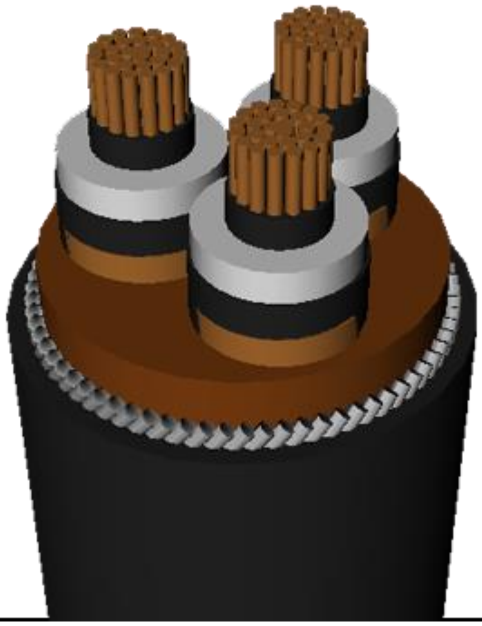


Figure 5-3 3D output in CableBuilder

5.1.1. Cable design

The design module is the most important one in CableBuilder. It has a lot of features that allows to create accurate designs quickly. The most important features are: support for every cable type; datasheet available in multiple format; generation of product catalogue for the website; automatic and interactive cable and calculation of minimum diameter; design comparison between a number of designs or version of the same design; generation of manufacturing instruction; powerful search engine to help designer to find design quickly, avoiding the redesign of existing product; secure data access. [6]

5.1.2. Process design

The process design is very important to ensure the quality of the outputs. So it’s important to choose the right machine, the correct setup and processing time. All of them are important for the calculation of the product cost. These information are important to schedule manufacturing and raw material ordering to give the right lead time to the customer.

5.1.3. Mass Updates

CableBuilder helps with changes with: mass update on selective groups of design, change through the export and import of group of design to and from Microsoft Excel, swapping of raw materials, machines and work centres, mass transfer to ERP System.

5.2. ERP SYSTEM: SAP

ERP (Enterprise Resource Planning) is a management system that integrates all the important business processes inside an enterprise like sales, purchasing, stock management, accounting, management control, distribution, Material Requirement planning (MRP) and others. The first ERP systems were used for integrating accounting and logistics management and then it was extended to other activities like sales, purchase production. One of the most important is the MRP system that allows automated orders that considerate time delivery and production time. This system allows the optimum rotation of material inside the warehouse in order to minimize stock costs. The ERP systems are usually composed of three main parts: a common database for all applications in order to avoid problems of updating data; a modular structure, which allows a great interoperability between the functional groups and, allows the company to decide which strategy to use, the 'one stop shop' that is to buy all the product from a single seller or strategy 'best of breed' that is to choose the product from the best manufacturer. The most important producers of ERP systems are: SAP, Oracle, Microsoft. [7]

SAP (System, Application and Products in data processing) is a German software corporation that makes enterprise software for managing business operation and customer relations. SAP is one of the most popular and powerful of ERP systems. Among the most important users of SAP we can find big enterprises like BOSCH, MAGNETI MARELLI, DELOITTE, FIAT, ENI and many more. [8]

SAP is composed by different modules and each of them is used for managing different topics inside the enterprise.

SAP's modules are:

- BC Basic Components
- FI Financial Accounting
- W FI-CA
- AM Asset Management
- CO Controlling
- CS Customer Service
- MM Material Management
- WM Warehouse Management
- SD Sales and Distribution
- LE Logistic Execution
- PP Production Planning
- PS Project System
- PM Plant Maintenance
- QM Quality Management
- HR Human Resources.

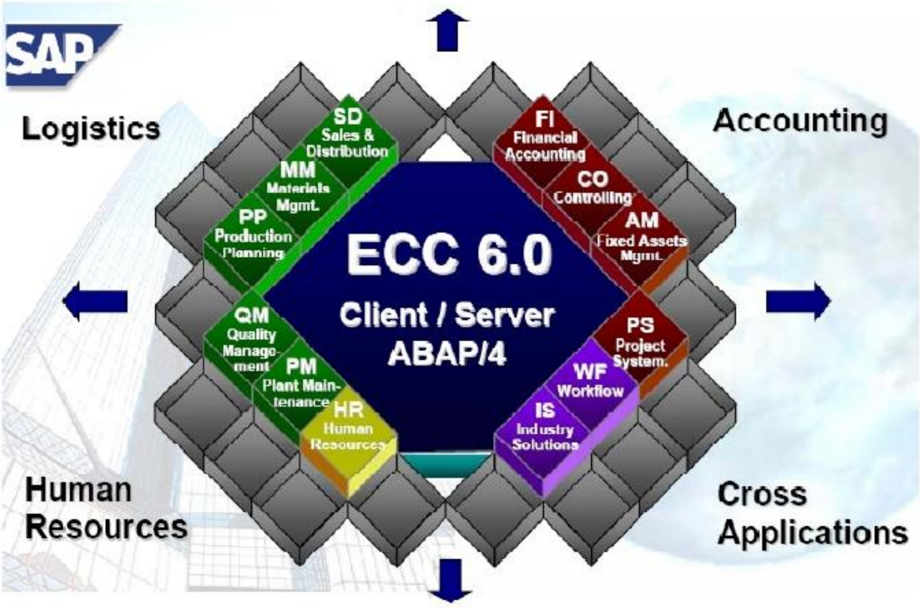


Figure 5-4 SAP's modules and applications

Usually, not all the modules are implemented inside the particular enterprise. For engineers and people who works in logistics the most important modules are MM and SD.

5.3 CABLEBUILDER AND SAP IN ELKA

The implementation project of SAP in ELKA started [redacted]

5.4 DEPARTMENTS AND MACHINERY IN ELKA FACTORY

For each department, the most important and the mainly used machineries are listed and for some of them, the main features like the name of material worked, productive capacity, working speed and the diameter of the output product.

5.4.1. Metal department ("Hala Metali")

It is the department where the cables production starts. As said the most important materials used in conductor cable are copper and aluminum. The first manufacturing process in a cable production is wire-drowning that consists of producing the diameter of the conductor. The copper in input is 8 mm of diameter. The first stage of the wire-drawing is simply called drawing in which the diameter of the material is reduced in 2 mm and then further reduced in the dimension needed for the particular type of the cable in production.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

5.4.2. Rubber department ("Hala Guma")

The next process in cable manufacturing is the insulation by placing an insulation cover over the conductor to prevent current leakage. In this process the insulation is added by a process of extrusion at high temperature. Several insulated material can be used like PVC, EPR and XLPE. Different insulated material are used depending on the characteristics of the cable. The quality of an insulation material depends on two basic characteristics: insulation capacity and heat resistance.

Other processes related to cable manufacturing can be considered putting some additional coverings to the cable in order to improve its protection or operation. One of these process is the screening with witch the signal that circulates in the cable is isolated. Mechanical coverings protect the cable from external damage and it is usually made of steel or aluminum.

Figure 5-7 Insulation, screening and covering of cable

For protection cables have an outside polymer covering that is called sheath. Different kinds of material can be used for the sheath according to the particular applications the cable is going to be used like final flexibility of the cable or environmental features. All the cables are marked with the most important information like manufacturer, cable name, number of conductors, cross section and construction regulation standards.

The most important machines in this department are: [9]

[redacted]

[redacted]

[redacted]

[redacted]

5.4.3. Thermoplastics department ("Hala Termoplastika")

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

5.5. ORGANIZATION OF PRODUCTION PROCESS

In this section it will be described the entire production system from the raw material product to the finished product. The procedure is composed by different steps: [9]

5.5.1. Technological preparation of production

Technological and product documentation (TPD) is created for new products by SRI (sector of development and information) and/or ORPM (Department for the development and application of materials) and the documents are completed after receiving an order. If there are some changes in the customer demand for the production of standard products (the label, packaging or changes in other technical parameters) the Commercial sector has to write all the changes in the proper documents, to consider a specialist solution of SRI and /or ORPM and to introduce agreed changes in the request for the production (ZP).

5.5.2. Operational preparation of the production

The department of production planning (PP) plans and schedules the production on the basis of ZP and TPD and release a work order (RN). The production planner determines the work order (RN) to a production engineer or technologist that signs the work order (RN) and approves further process of implementation of production at the delivery facility of materials to the manufacturing machine. [9]

5.5.3. Transport of production material to the machine

Only materials conforming the agreed terms of quality are delivered to the machine. The foreman takes over material in the facility and unused material in the warehouse with the type label and label status.

5.5.4. Production

The scheduling for all shifts at the facility has to respect the planned timetable performed by the plant manager and to indicate the order of production orders by machines. The production starts after the machine operator is instructed by the foreman about the work orders, appropriate internal work instructions and the technological list. If the work order needs some changes in technological-production there should be an hand-write on the existing WO with all the adjustments and corrections parameters. If the production has been started according to the sale application, there is no change in the sales request. For a sales application whereby the production has not begun, the commercial sector can change the label according to the ordinary procedure.

The worker realizes the work operation: work order and technological document. Semifinished manufactured products are delivered to the next operation by reference to the work order. Each unit of packaging and/or series fulfills the accompanying card, markup card or label and after the last operation of production the warehouseman delivers the product with an accompanying card to final testing. After all the tests have been carried out, the plant brings the finished products with confirmed quality and properly labeled to the warehouse, with a products documentation and the accompanying card. Defective products and semi-finished products are immediately repaired or prominently indicated, as appropriate, and must not be used in the following operations. [9]

6. WAREHOUSE MANAGEMENT

In ELKA, some procedures related to acquisition, storage and management of production material are present in order to preserve the level of quality for the materials that enter and therefore to ensure the quality of the final product. The main production material that enters ELKA consist of granules, raw materials for rubber and rubber mixture, Aluminum copper and optical fibers, tapes of paper, plastic or metals, paint diluent and varnishes, wire for reinforcement and metal wire (steel and aluminum) and packaging. The material can be stored indoor, outdoor and there is also present a warehouse for flammable materials. [9]

Figure 6-1 An example of outdoor cable factory stock

The most important warehouse present in ELKA are: warehouse for production material, metal canopy storage, canopy for waste materials, warehouse for finished products, big service area outdoor where the finished materials ready to be delivered to the customers are stored and a storage for flammable materials. The layout of the storages ensures the optimal positioning of the product, safety, orderliness and preserves the materials from damages.

6.1. RECEPTION OF PRODUCTION MATERIAL

Purchase managers refer to warehouse about the orders of material and the expected delivery day. After receiving the information about the incoming production material, the storekeeper defines the location of the storage and goes to the place of unloading where he carries out a previous directed control and data about the amount of packaging that arrives, supporting documentation and certificates. In case of damages in packaging, waste materials or other irregularities, they have to be reported and the document has to signed by the warehouseman and the truck driver. If the state of materials is in compliance the warehouseman defines its code and prints the document related to the input material. All the next procedures about coding are defined by following the IUR-100.0007 standards. The amount of material stored in the stock is related to the production needs.

After this step the material is in a status of MATERIAL TESTING and for each packaging [redacted]

6.2. STORAGE OF PRODUCTION MATERIAL

The materials inside the warehouse have to be organized and have to be available immediately for the different needs with a visible label that gives information about the status of material as said before. Palletized materials can be stored and stacked in different levels according to the label on the packaging. If there is no label that indicates the height level of storing material it’s possible to stock materials by following these rules:

[redacted]

Figure 6-2 Example of storage of production material in a cable factory

6.3. RELEASE OF PRODUCTION MATERIALS FROM A WAREHOUSE

When the production starts, it’s important to release two documents: the material order document and the warehouse material delivery note. Both documents are created in SAP and stored in the factory archive.

When the production starts, the material is taken out from the warehouse in this order:

- Material that was already in production but was returned as unpacked and correct
- The order works by following a FIFO (first in first out) approach.

[redacted]

6.4. THE RETURN OF PRODUCTION MATERIALS IN THE WAREHOUSE

[redacted]

7. IDEAS ON POSSIBLE IMPROVEMENTS

Inside an enterprise there is always something that can be done better or in a different way with cost saving or by introducing new methods and technologies. Everything is changing and technology gives a fundamental support in terms of time, money that can be saved and wastes that can be avoided. Some ideas that can be useful for ELKA in the next future are given as follows.

The first one is related to the **software integration**. A [redacted] more. With this integrations, there would be possibly a big amount of money and time saved.

Another idea is related to the **market expansion**. ELKA already produces a large amount of [redacted] because they already have the right channels consolidated in their long experience.

Another example is that some of the **machines** present inside the [redacted]

[redacted]

Utilization of **AGV (automated guided vehicle)** that are used in factories for the movement of raw materials, semi-finished products and products inside the factory. Different [redacted]

In every business sector **information is power.** Being able to truck assets, reducing the time of the product hold into a stock and monitoring the flow of working progress can help the enterprise to save money and improve itself by reducing the product lead time. For these activities two kinds of systems can be useful: **bar code** and **RFID** system. By using these technology it is possible "to interrogate" product in order to understand what and where things are. For example it is possible to truck components in the assembly line, individual [redacted]

It can be also possible to study by using software like Cape Pack the best way for palletizing spools, drums in the pallet by respecting the weight, height and positioning standards. Once decided the best way to put products in pallet can be study the best way to insert the pallet with finished product inside the truck for delivering orders.

8. CONSIDERATION OF RFID TECHNOLOGY APPLICABILITY IN ELKA CABLE FACTORY

The importance of information in every business is crucial for a better understanding of the entire production process, as, for example, holding the right data at the right moment or tracking products during the production process or along the entire supply chain. The application of RFID technology in this case can help to better understand the process, to know what the products are and where they are or in which process a client′s order is in specific moment and forecast when the product can be ready to be shipped. The utilization of RFID technologies brings a lot of improvements in terms of efficiency and this is why the number of factories that use RFID technology is increasing. The companies can see its competitive advantages and so they are starting to integrate it into their production processes (i.e. supply chain, logistic and asset tracking operation). As a result, these companies are gaining improvement in supply chain visibility, forecast accuracy, reduced out of stock situations and countefering reduction.

[redacted]

9. PACKAGING, PACKAGES AND TRANSPORT UNITS IN PRODUCTION PROCESS

Inside a cable factory there is a big flow of materials moving through the different departments, from the warehouse of raw materials and from the warehouse of finished products. Different kinds of products arrive in the factory and in ELKA case there are spools with copper, aluminum and optical fiber, pallet with packages that contain granules, raw materials for rubber and rubber mixture for insulation and shape making, tapes of paper, paint diluent, varnishes, wire for reinforcement and metal wire. Usually they are moved by using some forklifts from one department to another or by using (kind of transpallet).

During the production processes spools are the main transport unit used, aluminum and copper in entrance and the finished products are also in spools. Providing wire or cable on reels or spools is the most common method of packaging used today.

The package is easy to ship or transport; it protects the cable; it is easy to store, and allows the product to be partially unspooled, as it is consumed or cut to the lengths needed.

[redacted]

[redacted]

[redacted]

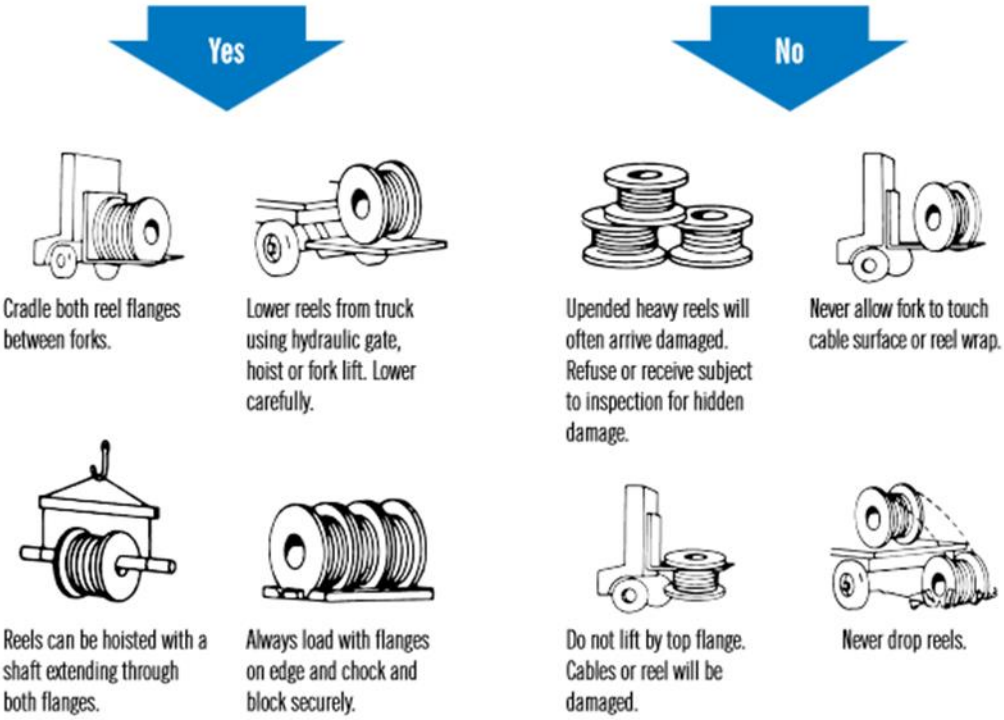


Figure 9-1 Rules related to movement and storage of spools

[redacted]

[redacted]

[redacted]

Figure 9-2 Example of spools of different sizes

For each production process there are spools with the material in input and spools that "receive" the process output. For example, in the wire drawning machine there are several spools that feel the machine in input, with copper and aluminum of standard diameter, and just one spool that receives the product in output with a bigger diameter. In the insulation process there is one spool in input and one in output. Generally the spool is always the same, for the same type of product and same type of process. The spools are present in different dimensions and each dimension is strictly related to the diameter of the product winded. The bigger is the diameter of the product and the much bigger has to be the spool radius; everything is related to the bending radius. Below it is shown a classification of standard spools, followed by a discussion on the number of meters for each of them which is possible to wind in relationship to the diameter of the cable. The next figure shows how the different measures D1, D2, D3 and A for dimensioning the spools are considered. [18]

Table 1 shows the different types of spools with different kinds of diameters weight and dimensions.

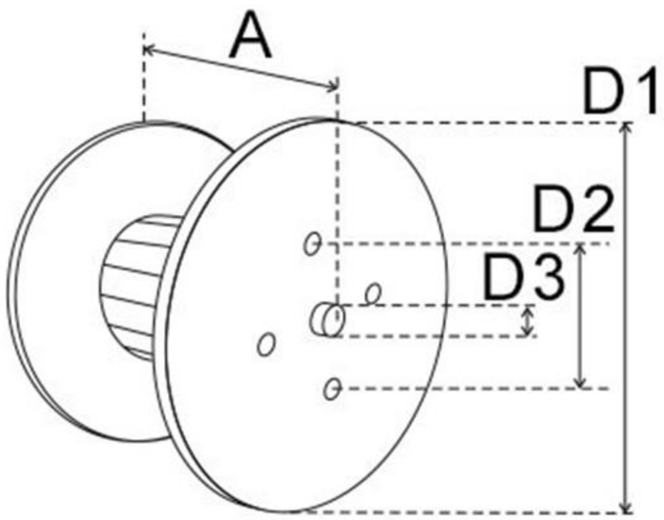


Figure 9-3 Benchmarks for the tables below

Table 1 Dimension of the different type of spools

Type of Spool	D1, mm	D2, mm	D3, mm	Weight, kg	Encumbrance	A, Mm
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
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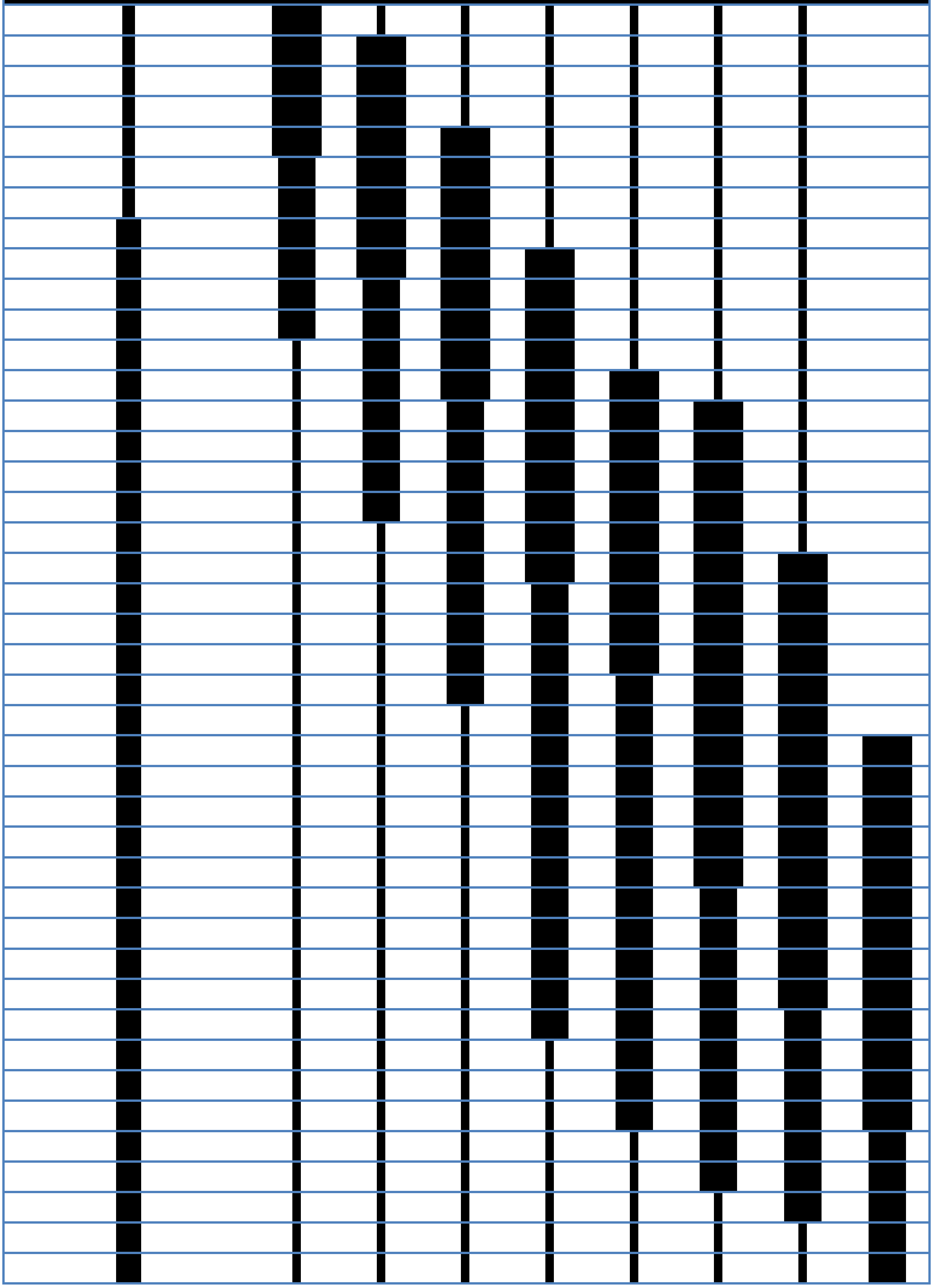
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]

Table 2 shows the relationship between the cable diameter in mm and the different kinds of spools and how many meters can be winded in each spool. In each spool different kinds of cables can be winded: the bigger is the diameter and the fewer meters can be winded. [20]

Table 2 Meters of cable in each spool in relation to cable diameter

Cable diameter, mm	06	08	10	12	14	16	18	20



9.1. CHOICE OF REPRESENTATIVE PRODUCTS

For the analysis and the application of RFID system it is possible to consider four different representative products: two medium voltage cables and two 1 kV cables that are the one with the higher production rate. So it can be possible to start from them and consider all the spools used during the production process and track all the movements and information by using the RFID system.

According to general coding used in ELKA each number and letter has its own meaning by following the subsequent scheme:

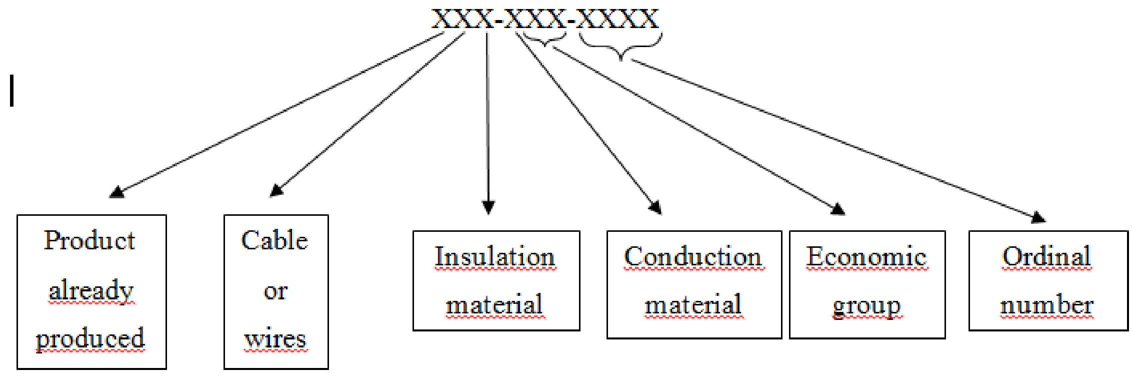


Figure 9-4 Meaning of each number and letter in cable name

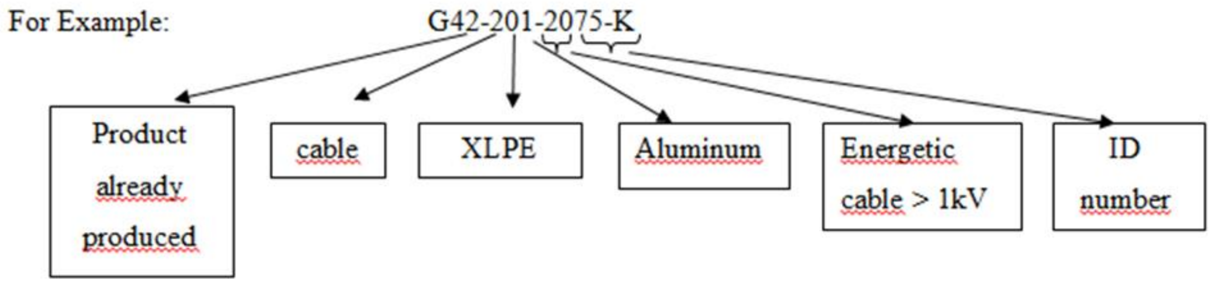


Figure 9-5 Example of product code meaning

The products taken into account for the Medium Voltage Cables are given by Table 3.

Table 3 Representative Medium Voltage Cables

[redacted]

The products taken into account for 1 kV cables are given in Table 4.

Table 4 Representative 1 kV cables

[redacted]

[redacted]

[redacted]

[redacted]

Table 5 Meters of cable winded in each spool

[redacted]	[redacted]				
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Table 6 Meters of cable winded in each spool

[redacted]	[redacted]				
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

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Table 7 Meters of cable winded in each spool

[redacted]	[redacted]				
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Table 8 Meters of cable winded in each spool

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

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[redacted]

[redacted] kg/km.

9.2. MANUFACTURING PROCESS FOR THE REPRESENTATIVE PRODUCTS

In general it is possible to see that the production process needed for the Medium Voltage Cable production is the same; it is only the cable sizes that change. The same consideration can be made for the 1 kV representative cable.

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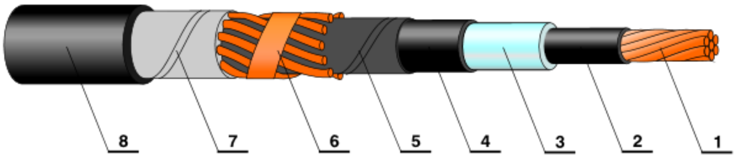

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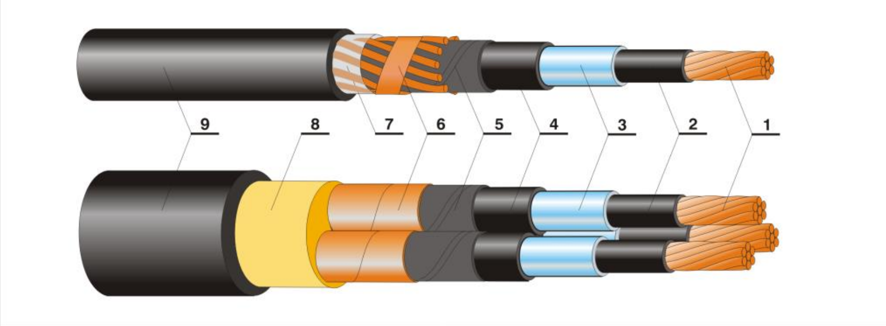

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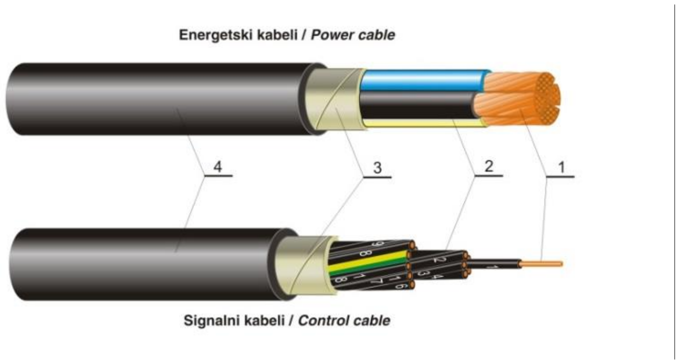

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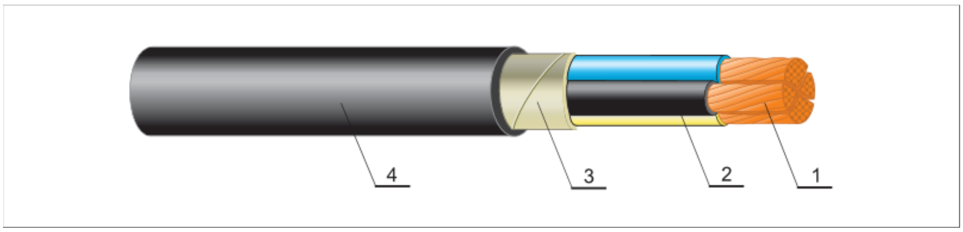

[redacted]

For each of these production processes different kinds of spools are used, and the materials in input and output are always hold in spools.

During the production process in ELKA the data flow is managed by labeling the spools and by inserting information in the labels and then manually in the informative system.

9.3. ANALYSIS OF PRESENT DATA FLOW AND POSSIBILITY TO BE UPGRADED BY RFID

In ELKA, the materials used during the production process are different: copper, aluminum, optical fiber, rubber mixture, tapes of paper, plastic or metals, varnishes, wire for reinforcements and metal wires. It is possible to study how data flow is managed in ELKA currently and how the introduction of RFID system can improve all the operations on the plant. Since in ELKA there is the necessity to check the material flow, the employees of the company are thinking of introducing the barcode to perform this task. RFID and barcode perform the same job, but, as it is possible to see in the section 10.4, each of them has different advantages and disadvantages in their application. Probably for ELKA introducing a RFID system can be better for the characteristic of the production process and for the potentiality that this technology has.

The production flow in ELKA, shown in the section 5.5, is managed by using a documentation and a proper labeling system. When an order arrives, the Technological preparation of production (TPD) is completed. The department of production planning plans and schedules the work in relation to the TPD document and releases a work order. After signing the work order the material is delivered to the machines and the production is ready to start. Only the material with the agreed terms of quality are delivered to the machine.

The production can start when the machine operator is instructed by the foreman about the work orders and the technology list. Semi-finished manufactured products are delivered to the next operation by following the work order, each unit of packaging and/or series fulfills the accompanying card to final testing. If the product gets over the quality control it is opportunely labeled and sent to the warehouse of finished products with the documentation and the accompanying card, ready to be sold. If there are some faults in the products or in the semi-finished ones during the production process, it has to be quickly indicated and not used in the subsequent operation.

Basically, in ELKA there are three different types of internal transportation, spools used during the entire manufacturing process, tapes and boxes for bringing rubber and other materials for the insulation or screening, for example, that arrive directly in the department where they need to be used.

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[redacted]

9.3.1. Synchronization of processes with data tracks

Each production process has to be inserted in the back-end system after it is finished. This process can ensure the track of all production processes. Before a production process can start, it is important that the material is transported to the next machine and that it is ensured when the previous production step is finished. Using RFID can improve process efficiency by ensuring that booking and transporting occur in a synchronized way. For doing that the internal transport unit has to be equipped with RFID TAG.

9.3.2. Maintenance of Process data

The time that sometimes workers waste in maintaining data for the TPD and accompanying card can be very high. One third of this time is lost in maintaining tickets for internal transportation. Part of data maintenance could be automated if tickets can be replaced with RFID tag. This can increase worker productivity and reduce errors in manual data entries. The option is to write the data in rewritable tag with a sufficient amount of memory.

9.3.3. Utilization of uniform labeling system

The labels can change from costumer to customer. Labels can change in the paper being used and the information printed on them. In this way the different format can be handled much more easily if costumers agree to replace paper labels with RFID tag. Different kind of information can be written on the same type of standard tags. In this case an RFID tag with user memory can be used.

9.3.4. Process safety

Workers has to be careful not to mix material for a process step and avoid confusing labels. If RFID were used in the respective process steps, accuracy could be automatically ensured. RFID readers could be used to identify the materials that are about to be processed at every step. these data and information about planned production tasks could be used for consistency checks to ensure a correct machine configuration. [25]

10. DESCRIPTION OF RFID TECHNOLOGY

The market of RFID technology is a market still in growth. This application gives the opportunity to add value to each business where this technology is applied. RFID technology can be important for tracing, checking, during the manufacturing process, the types and the location of the products, in a material warehouse for checking the availability of a raw material and in a finished products warehouse to know, for example, the number of the products inside and how many of them are and ready to be sold. RFID technologies are not only used in manufacturing but they have different applications like: □16□

- animal tracking tags, inserted beneath the skin
- tags can be used to identify trees or wooden items
- chip RFID in keys machine safety
- credit-card shaped for use in access applications
- the anti-theft hard plastic tags attached to merchandise in stores are also RFID tags
- rectangular transponders are used to track shipping containers, or heavy machinery, trucks, and railroad cars.

RFID (Radio Frequency Identification) is basically a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, an animal, or a person. Low-frequency RFID systems (30 kHz to 500 kHz) have short transmission that are generally less than six feet. High-frequency RFID systems (850 MHz to 950 MHz and 2,4 GHz to 2,5 GHz) offer longer transmission ranges that can be more than 90 feet. In general it is possible to say that, the higher the frequency is, the more expensive the systems are.

10.1. THE ELEMENTS OF A BASIC RFID SYSTEM

For better understanding how data moves in waves and then in a network it's important to know all the components of a RFID system better. The most important components of a RFID system are: [15]

- Transponder or TAG which is programmed to contain the information that distinguishes it from the other.
- Transceiver or READER to handle radio communication through the antennas and pass tag information to the outside world
- Antenna attached to the reader to communicate with tag
- A reader interface layer, or middleware, which compresses thousands of tag signals into a single identification and acts as a bridge between the RFID hardware elements to the application software systems.

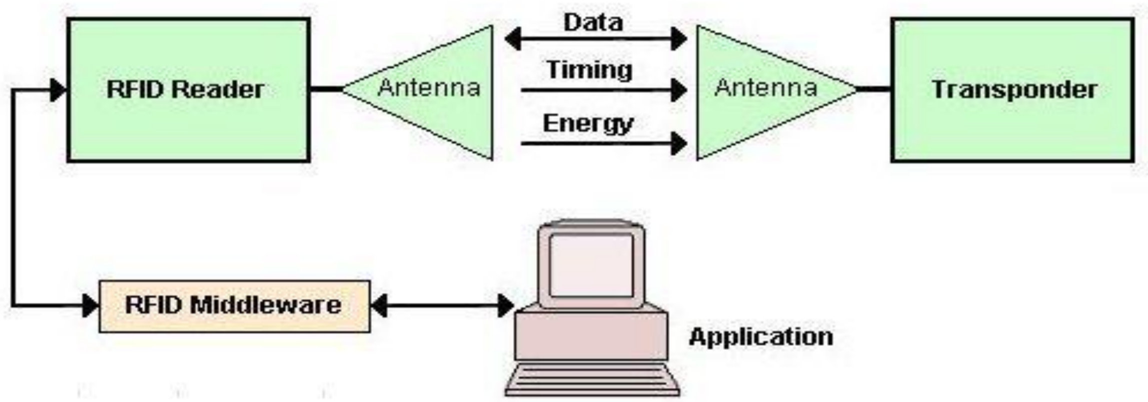


Figure 10-1 Schematization of a general RFID system

10.1.1. Transponder (tag)

There are three different kinds of TAGS: the active, the passive and semi-active (or semi-passive) one.

The active system uses a self-power RFID tag that continuously send its own signal. Usually they have a battery that powers the microchip inside the tag and allows it to send signal. This kind of tag is generally used for tracking the real-time location of assets or in high speed environment. Active tags can ensure a longer read range than passive ones but they are more expensive.

Semi-active tag has a battery for powering the chip in the TAG but it has to take power from the magnetic field created by the reader

The passive RFID system uses tags that are powered by the electromagnetic energy transmitted from a RFID reader. Passive tags wait for an interrogating signal from an RFID reader. Once the tag is within the range of the interrogation zone, the RFID tag's antenna draws energy from the electromagnetic waves. Once the tag's microchip, or integrated circuit, becomes powered, it transmits a signal. The lower price of the passive RFID system makes it more competitive. As already said, the RFID is composed by a microchip and an antenna that is constructed like a little spool of wire. The assembly is covered by a protective layer that can be laminated paper.

The most expensive active RFID TAG can have a **Microchip** with a memory capacity of 1 MB; it means that is possible to write in it one million of alphanumeric symbols. But in general the most common RFID tags are passive ones that are less expansive and can store only 32 to 128 bit of information, so the only datum that a microchip can contain is an identification number. After the number is ridden detailed information stored in a computer database can be accessed. More or less it is the same principle of barcode.

The Antenna allows the chip to receive and send information such as the identification number of a single product. Some antennas are constructed of metal and are etched or stamped from metal, such as copper.

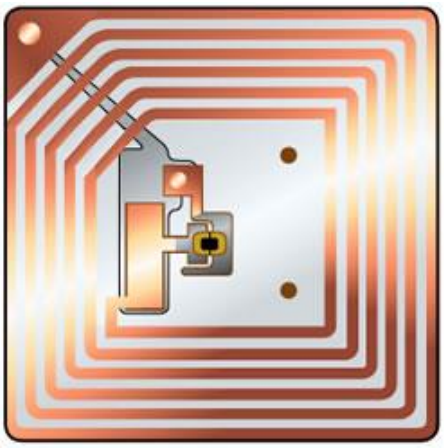


Figure 10-2 Example of RFID tag

The RFID tags can have different dimensions and shape in relation to the field in which they are applied:

Some of them can have a dimension of less than half-inch and can be inserted inside the skin of animals and livestock; others are like screw and can be used for the identification of trees; rectangular RFID tags are positioned like anti-theft device in shops; big and heavy tag long and large a lot of inches in are used to track shipping containers, or heavy machinery, trucks, and railroad cars.

10.1.2. RFID reader

Both tag and reader have their own antenna because both are radio devices, the tag antenna is only a few centimeters and usually the reader antenna is longer than the tag one. Reader antenna sends radio signals into the air to activate a tag, listens to an echo (or backscatter) from the tag, reads the data transmitted by a tag, and, in some cases, writes data onto a tag. Antennas can work continuously or on demand. The first one is used when items that are present in regular basis or when multiple tags are passing through the antenna's field. As regards the second one, there is the activation of the antenna only when it is needed by a sensor that, for example, can be an optical or a pressure one. As said before, antenna can be available in different shapes and sizes and so it can be placed in different locations like a warehouse door (this is a possible solution in ELKA) or in a highway tollbooth. The antenna and the reader are connected, the RF field, can cover an area small as 1 inch or a large one of 100 feet or more, depending on the power output and the frequency. When the Tag, is in the Antenna Radio field, becomes active and sends the information back stored in its memory. Then reader receives the tag signal through its array of antennas, decodes it and then sends the information to the host computer system.

Figure 10-3 RFID reader system

RFID systems works with different frequencies and that depends on the application. The frequencies ranges are:

- LF : 125 kHz - 134,2 kHz : Low Frequencies
- HF : 13.56 MHz : High Frequencies
- UHF : 860 MHz - 960 MHz : Ultra High Frequencies
- SHF : 2.45 GHz : super high frequencies.

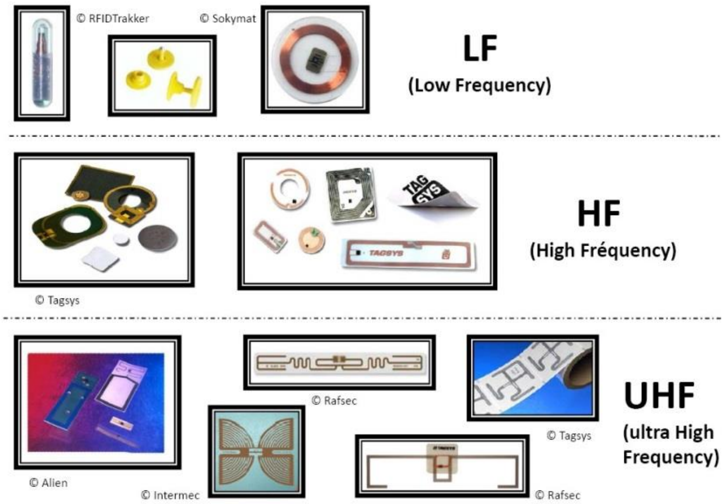


Figure 10-4 Different types of TAGS for different frequencies

- RFID LF tags are well adapted for logistics and traceability applications. Glass tags are small and light. They can be used with all kinds of material - textiles, metals, plastics and are sufficient in many contest even though their range is limited to 1-2m. Transponder are not protected against collision and bulk reading of many transponder is not possible
- RFID HF tags are used in traceability and logistics applications. Loop antenna can be printed or etched on flexible substrates. The tag are not resistant to adverse mechanical and thermal conditions. It is possible to read several TAG in the same time
- RFID UHF tags have dipole like antenna etched or printed on all kind of substrate. The read range of such a tag can be around 3 to 6 or even 8 meters. Specific antenna design is required for metallic or wet environments. Multiple transponders can also be read simultaneously

10.1.3. RFID middleware

The basic elements of an RFID system are rarely useful in isolation. They gain value as part of a production or logistics system. Middleware connects the data coming into a reader to the software systems. The middleware provides a coherent and stable interface between the RFID hardware operations and the flow of data elements, such as EPC (electronic product code) numbers, into inventory, sales, purchasing, marketing, and similar database systems distributed throughout an enterprise. The elements of an RFID middleware include:

- Reader and device management: RFID middleware allows users to configure, monitor, deploy, and issue commands directly to readers through a common interface.
- Data management: RFID captures EPC data or other data from readers and that data can be filtered and sent to appropriate destination
- Application integration: RFID middleware solutions provide messaging and connectivity features that allows the integration of RFID data with other software like ERP systems, SCM (supply chain management), WMS (warehouse management system) or CRM (customer relationship management systems)
- Partners integration: Middleware can provide collaborative solution like business-to-business (B2B) integration with partners

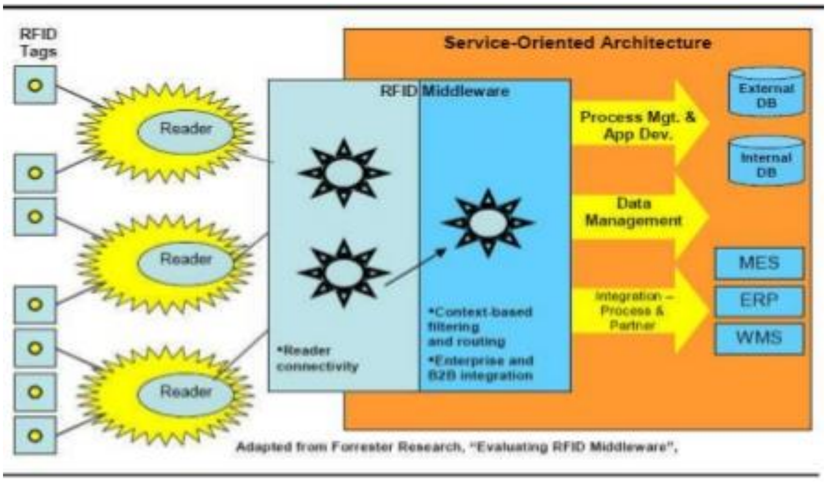


Figure 10-5 RFID Middleware

The RFID data, in this way, so can be used from a by a big variety of software systems. In a manufacturing environment, the application is typically part of MES (Manufacturing execution system) or ERP system.

10.2. RFID POTENTIAL

RFID technologies can give solid return on investment. There are different fields in which the use of this technologies can bring improvements and these are:

More **reliable scanning**, in fact RFID tags can be read even though there isn't a line of sight. This situation probably can make the scanning process easier especially in a manufacturing system. RFID tags allow for bulk reading and probably, thanks to the fact that they can be covered they are more suitable than barcode for example in hostile environments conditions.

Better tracking is important for ensuring accurate and real time reporting about production status. If high level data of the production process are available, labor costs can be reduced and it can be possible to accelerate the entire process. If RFID tags are applied directly to the material or the transportation units used during the production process can be possible for readers to know when materials are moving from one process to another. Tracking can also ensure a better process analysis which can help to reduce production error and product quality.

Better tracing is another improvement possible to get with RFID application especially in case of failure of the manufactured product. Improving traceability and thereby narrowing recalls can be crucial in saving resources. Exact information regarding which object was manufactured and which components or materials were used is important for identifying all products that can have potentially flawed parts.

If it is possible to store data in RFID tag, but higher is the memory capability and higher should be the price. With this condition can be possible to get information directly from the tag avoiding in this way to consult the **back-end** system. In this way data retrieval could be faster.

Accompanying documents are frequently used to maintain data in the production line. Usually the documents are moved together with the materials and are used for recording data related to the production process. In the moment data are written in the paper this is separated from the product is following and so can be possible that documents are mixed and as a consequence have incorrect data maintenance. RFID tags with writable memory can be used for storing **metadata** about relevant events and processes of the corresponding object. In this way information can't be lost or mixed with some others. Users should be aware that information could also be stored in automatically in the back-end system.

Problems sometimes can occur in **label management**, when manufacturers face challenges in handling labels at the outbound shipment because different customers demand and different barcode solution for labeling, transportation units and packages are used. The differences can be related to the label format, coding scheme or information in the label. The problem can be solved by using RFID tags with writable memory that can hold data in arbitrary coding schemes. In this way one kind of RFID tag can be used for all customers. RFID readers can be used for writing customer specific information on tags in the outbound, avoiding in this case to buy expensive specialized printers for labels.

The introduction of RFID technologies in manufacturing can improve the **cooperation of enterprises** along the supply chain. For obtaining a successful collaboration, sharing information is really important. The information can be transferred on RFID tags that traverse the supply chain or it can be held in one or several back–end repositories. [25]

10.3. RFID SYSTEM VS BARCODE

The main forms of automated data collections used inside the enterprises are RFID systems and Barcode. They both are fine as data collection and it isn't possible to know which one is better than the other because it depends from the field they are applied to. In chapter 10.1 there is a deep description of RFID system, but what about barcode? [21]

A barcode is a visual representation of data that is scanned and interpreted for information. Barcode is the small image of lines (bars) and spaces that is affixed to retail store items. The code uses a sequence of vertical bars and spaces for representing numbers and other symbols.

0 123456 789012

Figure 10-6 Example of barcode

A barcode reading is used for reading the code. This kind of reader uses a laser beam that is sensitive to the reflection from the line thickness and variation. The reader translate the reflection into digital data that is immediately transferred to a computer for immediate action or storage. Barcode and reader are often seen in supermarkets and retails store but they have a large amount of uses, such as for taking the inventory in retail stores, used in library to check out books, for tracking manufacturing and shipping movements, for identifying hospital patient and others. Readers are usually connected with a computer and so they can store the data ridden. There is no one standard bar code but there are several different barcode standards called simbologies that have different uses, industries or geographic needs. Some of the most important standards are: Uniform Product Code (UPC), developed in1973 that has provided a standard barcode used by most of the retail stores; the European Article Numberign system (EAN) which is becoming widely used too; and the POSTNET, that is the standard barcode used in the United States for coding in BULK mailing.

As already said, it is no easy to establish in which feature a system is better than another but it can be possible to list a series of advantages and disadvantages in the utilization of the systems: [21]

Table 9 Advantages and disadvantages of RFID system

RFID system	
Advantages	**Disadvantages**
Can read RFID tags from a greater distance than barcodes	RFID involves assembling and inserting a computerized chip; which works out to be more expensive.
RFID tags don’t need to be positioned in a line of sight with the scanner	RFID readers struggle picking up information when passing through metal or liquid
RFID tags can be read at a faster rate than barcodes; as approximately 40 RFID tags can be read at the same time	Reader collision can occur where two signals from different readers overlap and the tag is unable to respond to both.
RFID tags can work within much greater distances; information can be read from a tag at up to 300 ft	Tag collision can occur when numerous tags in the same area respond at the same time
RFID tags are read/write devices	RFID still has two separate chips (read only and readable/writable), which cannot be read by the same machine.
RFID contain high levels of security; data can be encrypted	
RFID tags carry large data capabilities such as product maintenance, shipping histories and expiry dates	
Once these are set up; it can be run with minimal human participation	
RFID tags are more reusable and rugged as they are protected by a plastic cover.	

Table 10 Advantages and disadvantages of barcode

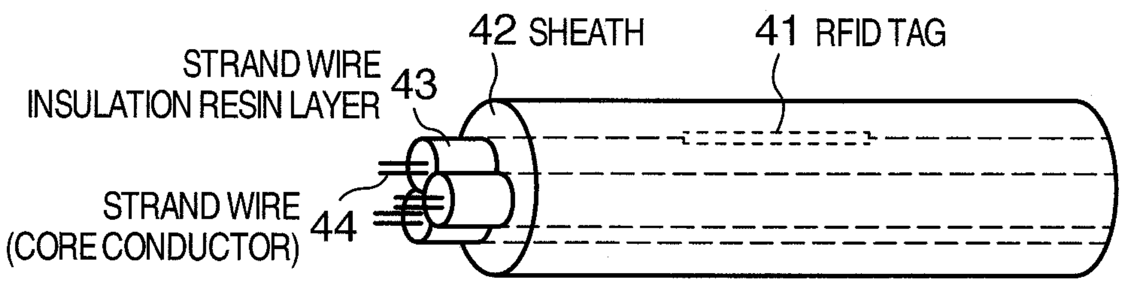
Barcode	
Advantages	**Disadvantages**
Much smaller and lighter than RFID tags and therefore easier to use	Barcode scanners need a direct line of sight to the barcode to be able to read
Less expensive than RFID tags; as barcodes are directly printed onto plastic or paper materials and therefore the only cost involved is the ink; a tiny overall cost.	In order to read the barcode, the barcode scanner needs to be quite close; around no more than 15ft
Barcodes work with the same accuracy on various materials in which they are placed.	Barcodes have no read/write capabilities; they do not contain any added information such as expiry date etc. They only contain the manufacturer and product
Barcodes are a universal technology in that they are the norm for retail products; stores that own a barcode reader can process barcodes from anywhere in the world	They are very labour intensive; as they must be scanned individually
In many cases; barcode accuracy has been said to be the same or even better than RFID tags	Barcodes have less security than RFID; as they can be more easily reproduced or forged
Today barcodes are found on almost every item and there are no privacy issues involved with its use	Barcodes are more easily damaged; as the line of sight is needed to scan, the printed bar code has to be exposed on the outside of the product
	If a barcode is ripped or damaged there is no way to scan the product

For the nature of the production process in ELKA probably the RFID system can better fit with the enterprise needs. As we can see from the tables above the use of RFID system can give advantages in terms of fast reading, user memory available with number of information contained, and also the fact that they can be protected with plastics probably can better fit with the nature of the production process. Barcode for sure are less expensive than RFID tag. Barcode probably can be used in the case ELKA decide to categorized all the spool and assign each of them to a total amount of product and for some type of processes.

11. RECOMMENDATIONS FOR RFID IMPLEMENTATION IN ELKA INCLUDING DATA INTEGRATION (SAP) AND RFID TECHNOLOGY SPECIFICATION

There are different ways for the practical introduction of a RFID system in a cable factory. In fact there are different possible ways to use the RFID tag into the product. In the following part four different method are mentioned, two with the tag stuck directly in the product and the other two with the tags stuck in the spools used during the production process.

[redacted]



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[redacted] in input and one in output, implying that, a different management system can be applied.

11.1. WHAT IS BETTER FOR ELKA: CONSIDERATIONS REGADING THE 4 METHODS PROPOSED

It is not obvious which of these systems is better suitable for ELKA needs. Each of them has its advantages and disadvantages.

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This is the solution choose for implementing the RFID application. In fact in this way we are following the order and so the information inside the tag must related to the order identification.

11.2. HOW TO APPLY RFID AND WHICH COMPONENTS TO USE

With the tag in the spool it is possible to put all the information that actually are inserted manually in the accompanying ticket that follow the product during the production process, inside the tag. Thanks to the reader it is possible to understand when products have finished one process and are ready to go to the next step, and, thanks to software integrations, workers don't have to manually insert the data in the system after the end of each production step. The idea for the application is to instruct workers in the production line in the use of an handheld RFID reader with incorporated display, as the next pictures show:

Figure 11-3 Handheld RFID reader with display

Figure 11-4 UHF RFID mobile phone

Prices range from the [redacted]

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Figure 11-5 Example of hard passive RFID with mechanical coupling

Figure 11-6 Example of passive tag with polyester material with pressure-sensitive adhesive

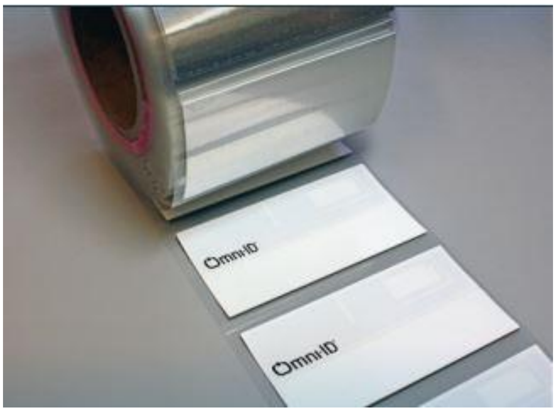

Figure 11-7 Example of synthetic passive label tag with self-adhesive for flat surfaces

In any case, kit with different kind of RFID tag are available on the market. It is possible to buy it and try all the different configuration possible and see which better fits with ELKA needs.

Figure 11-8 Generic sample pack with different kinds of RFID tag

[redacted]

The only thing is to provide all the spools used with the right solution for hooking the tag in it. It can be done with two holes in which to fix the tag with a system of screws or providing an hanger for fixing the tag with screws as well.

11.3. SCHEDULE AND DURATION OF IMPLEMENTATION

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11.4. COST AND BENEFITS FOR THE APPLICATION OF RFID SYSTEM

It is possible to make a comparison between costs and the estimation of benefits of an RFID implementation. Those kind of equation can be used as a rough guidelines for a general calculation. In any case it is difficult to calculate the right amount of them because some costs and benefits are very difficult to calculate and some of them can't be measured in monetary terms. Hidden costs can incur and this can be related to adaption and changes in the actual business process. The calculation that follows is related to the general aspects that can be measured in monetary terms and can be applied to any manufacturer.

11.4.1. Costs

Some considerations about fixed costs and variable costs related to the application can be made. Fixed costs can be calculated by using the subsequent equation:

$$\mathbf{C_{F} = S + T + H_{RR} + H_{NT} + H_{RT} + H_{TC} + M + I}$$

where (all variables in EUR):

$\mathbf{C_F}$ Fixed costs

S Cost for software

T Costs for training staff

$\mathbf{H_{RR}}$ Costs for RFID reader

$\mathbf{H_{NT}}$ Costs for network technology

$\mathbf{H_{RT}}$ Cost for reusable RFID tag

$\mathbf{H_{TC}}$ Costs for terminal computer

M Average costs per hour for maintenance

I Integration costs.

S is a fixed cost related to additional software needed, for example controller for readers and middleware for data integration with the back-end system.

T refers to training costs for the department of configuring and maintaining the software and worker on the plant that needs to know how to use the new technology.

H are related to all the hardware needed to be purchased to run the RFID application.

M maintenance cost for the RFID application.

I integration costs in the introduction phase of RFID that comprises necessary tests and consultancy in the planning phase of the application. Details of the desired use case must be planned and suitable technological setup has to be designed.

If an alternative solution from RFID, like barcode, is present the difference in cost for this solution must be calculated. But this isn't ELKA case because no other system is used. Anyway the value of this is:

$$\mathbf{C_{FA} = C_F - (S_A + T_A + H_A + I_A + M_A)}$$

C_{FA} Additional fixed costs for RFID application

S_A Software costs for alternative solution without RFID

T_A Training costs for alternative solution without RFID

H_A Hardware costs for alternative solution without RFID

I_A Costing for the integration of RFID alternative

M_A Maintenance cost of alternative.

Variable costs can be calculated by two different equation depending on the fact that the tags are reused or not (namely if they stay in the product sent to the client). In case of ELKA decides to use tags in a closed-loop application, the equation for variable costs calculation would be the one below:

$$\mathbf{VC_C = T \times L \times (A + R + TR)}$$

VC_C Variable costs in closed-loop application

T Service life of the application

L Number of RFID labels applied per hour

A Costs for applying a label

R Costs for removing a label

TR Costs for transporting a Label.

T is the expected service life of the application expressed in TAG

L how many items per hour are labeled with the RFID tags in the application.

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R refers to the costs per tagged item that occur where RFID tag are removed from the corresponding object at the end of the production process.

[redacted]

In case the RFID tag is used only once the calculation of variable costs is expressed as it follows:

$$\mathbf{VC_N = T \times L \times (A + HT - CO)}$$

VC_N Variable cost in cases in which RFID tags are not reused

T Service life of the application

L Number of RFID labels applied per hour

A Costs for applying a label

H_T Hardware costs for one RFID tag

CO Compensation payments.

[25]

11.4.2. Cost estimation

It is also possible to make a cost estimation of the application of the system. But it is actually impossible to apply the formulas reported in the paragraph 11.4.1 directly. Thus some hypotheses on other formulas to apply to the system are required. What has to be considered first is the calculation of the fixed costs for an established period.

Hypotheses:

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Fixed costs are as follows:

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Variable costs

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Accelerating scan process

The application of RFID system is for accelerating and completely automating the scanning of identifiers. The benefits are:

$$\mathbf{S_S = F_S \times T \times (S_A - S_R) \times P}$$

S_S Savings due to the acceleration of scan process

F_S Frequency of scan transaction

T Service life of the application

S_A Time for scanning without RFID

S_R Scanning time with RFID

P Hourly cost of an employee.

Extending scan processes for improving quality and efficiency

RFID can help to increase the visibility of the production process and to help to give a better knowledge of all the production plant. If it is possible to better analyze the running processes it can be also possible to find inefficiencies and try to obtain improvement in productivity. The value of this factor highly depends on the particular manufacturer.

Extending Scan Processes for narrowing Recalls

Each recalled item may be responsible of expenses for penalties and for conducting the recalls. Reducing the number of items in recall is an issue of highest priority for many manufacturing companies. RFID data collected can help to track items that are potentially affected by production errors. The next equation shows the benefit related to the scan process:

$$S_R = F_R \times T \times (B_A - B_R) \times C_R$$

S_R Savings due to narrowed recalls

F_R Frequency of recalls

T Service life of the application

B_A Tracked batch size if RFID is not used

B_R Tracked batch size if RFID is used

C_R Costs related to the recall of one item.

Reducing paper-based data management

With the improvement in data Maintenance by using RFID system, it may be possible to reduce costs that result from errors in collected production data. RFID can help to automate data maintenance in some application and reduce human mistakes and RFID automate tasks for data maintenance and to save labor costs.

$$S_D = T \times (F_M \times C_M \times F_F \times C_F + F_W \times C_W + F_E \times (T_A - T_R) \times P)$$

SD Saving due to easier data maintenance

T Service life of the application

F_M Frequency of data-mix that can be avoided by using RFID

C_M Resulting costs of a data mix-up

F_F Frequancy that data entries are forgotten

C_F Resulting costs of a forgotten data entry

F_W Frequency that data entries are wrong

C_W Costs resulting from a wrong data entry

F_E Frequency of manual label scan

T_A Needed time for making a data entry without RFID support

T_R Needed time for making a data entry with RFID

P Hourly payment of an employee.

Automating Asset Tracking

During the production process having the right assets available at the right time is crucial for the good pursuit of the production in a plant. Missing some assets can bring to financial losses and for this reason RFID can help implement automated tracking applications. The monetary benefits of this application can be counted with this equation:

$$S_A = T \times (F_A - F_R) \times (O_C + P_E)$$

S_A Saving due to automatic asset tracking

T Service life of the application

F_A Frequency that asset are missing without RFID-based tracking

F_R Frequency that asset are missing with RFID- based tracking

O_C Opportunity costs resulting from downtimes of the production

PE Penalties for delays resulting from downtimes of the production.

Reducing Back-End Interaction

RFID Allows storage of data with the corresponding object rather than in back-end database. This can help to ensure a faster access to production data without tuning the back-end system database and network infrastructure. Deciding where to store data if in RFID or on in the back-end system depends on the specific application and on the available IT infrastructure. Applications that work on data from RFID are less vulnerable to system failures than centralized solution.

$$\mathbf{S_B = T \text{ x } (F_B \text{ x } A_B \text{ x } T_B - F_R \text{ x } A_R \text{ x } T_R) \text{ x } (OC + PE)}$$

$\mathbf{S_B}$ Saving due to reduced back-end interactions

T Service life of the application

$\mathbf{F_B}$ Frequency of breakdowns in the back-end system

$\mathbf{A_B}$ number of product affected by a back-end failure

$\mathbf{T_B}$ Duration of a breakdown in the back-end system

$\mathbf{F_R}$ Frequency of failures in an RFID-based system

$\mathbf{A_R}$ Number of products affected by a nonworking RFID tag

$\mathbf{T_R}$ time until a nonworking RFID tag is replaced

OC opportunity costs resulting from downtimes of the production

PE penalties for delays resulting from downtimes of the production.

Unifying Labels

Sometimes customer can demand different labels for their shipments and, label handling, in turn can be challenging for manufacturers. If barcode labels are replaced by RFID tags, RFID readers could be used for writing in multiple data formats. For example another cost factor related to label handling concerns the penalties for label that cannot be ridden. The monetary effect is resumed in the following equation:

$$\mathbf{S_L = T \text{ x } (((F_B - F_R) \text{ x } PE_L) \text{ x } C_T \text{ x } L)}$$

$\mathbf{S_L}$ Saving due to unifying label handling with RFID

T Service life of the application

F_B Frequency that a barcode label is unreadable

PE_L Penalties for unreadable label

C_T Costs for transporting a label from printer to packing station

L Number of RFID labels applied per hour.

[25]

11.5. INTEGRATION OF RFID DATA WITH SAP

Manufacturers are increasing the utilization of RFID system in their plant since they discovered the different ways in which its benefits can be used to enhance the accuracy of data collection and identification of products in a significant way. At the beginning RFID systems were used extensively in the retail industry as a tool for identifying and tracking inventory, and now these benefits are also being recognized in manufacturing. A lot of manufacturing companies are using an Enterprise Resource Planning (ERP) solution like SAP. Moreover for getting the maximum benefits from RFID, they have to ensure that the appropriate RFID solution for their processes can integrate with their ERP solution. [23]

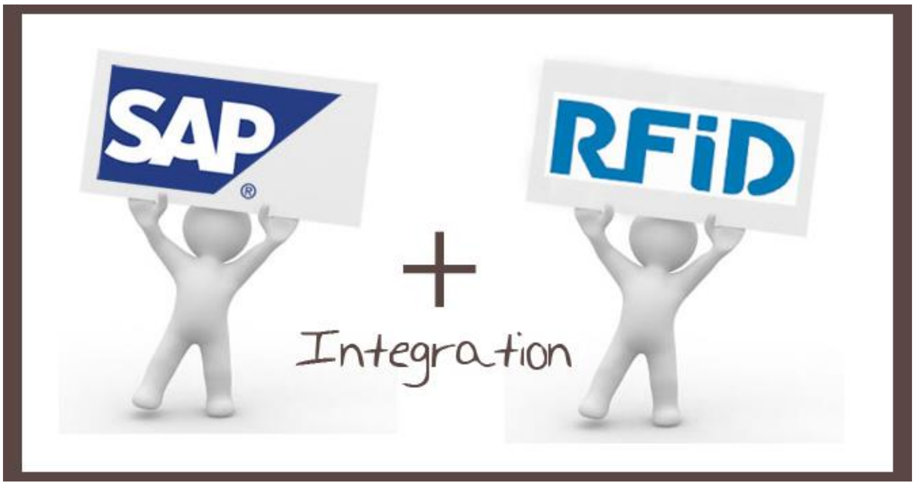

Figure 11-10 Importance in the solutions integration

Manufacturing companies using SAP can use RFID to track their products along the supply chain and during the manufacturing processes. This means that items can be identified during the inbound delivery process, when the items are in inventory or in the manufacturing process and then during the outbound delivery process. Customers can have the possibility to have access and to track their items during the shipping process by the RFID tags on the items.

The SAP solution for using RFID with an enterprise solution, SAP ERP, is called **SAP Auto-ID**. It is a middleware system that receives data from an RFID data capture source, which is usually a RFID reader, and then integrates the data from the RFID tag directly into the enterprise application. The system is composed by two main parts:

- Core Services that includes the flexible definitions and rule set environment.
- Integration Services – Auto-ID interacts with three types of environments; the backend systems via SAP XI, the RFID devices, and the web user interface for control and user maintenance.

When an RFID reader activates a tag the information is captured and sent to the device controller. From there the information is sent to the SAP Auto-ID system via Extensible Markup Language (XML) or Product Markup Language (PML). Then the SAP Auto-ID core services verifies the captured data against the defined rule definitions and passes the information to the SAP XI system via XML. SAP XI then converts the XML data into an IDOC which is received in SAP ERP. [23]

SAP XI has to translate the two formats so that the messages can be passed without errors between SAP ERP and the execution system. If the data from a tag is captured for a goods receipt, then the information contained in the IDOC will be processed so that a goods receipt is generated automatically, based on the rules defined in SAP Auto-ID.

SAP Auto-ID offers two user interfaces; a mobile user interface, which is used on handhelds and PDA's, and a desktop user interface which allows users to enter the SAP Aii settings. The standard SAP Aii system contains a set of predefined rules and the associated activities. Users can modify the rules or add new rules via the user interface. However there is a number of processes that are pre-defined in SAP Aii:

- Goods Issue – defines the dispatch of serialized products
- Goods Receipt – defines the receipt of serialized products
- Returnable Transport Items – defines the tracking of reusable items
- Kanban – defines the serialization of containers in the production processes and the automatic initiation of Kanban replenishment strategies
- Product Tracking – defines the recording of ID's and serial numbers.

The next figures show 2 different ways of managing data after scanning it with handheld reader.

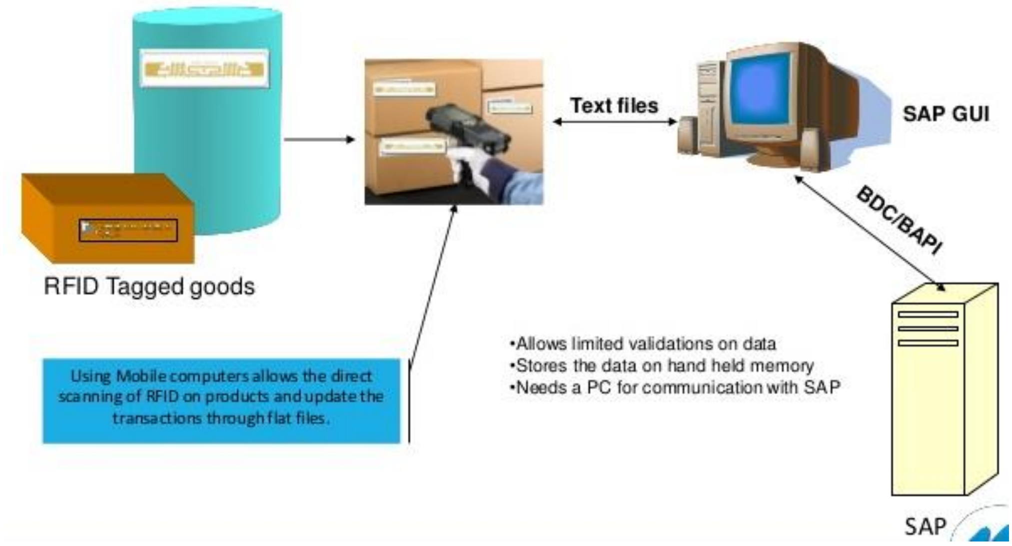

Figure 11-11 Text files SAP GUI RFID

Text files SAP GUI RFID tagged goods Using Mobile computers allows the direct scanning of RFID on products and update the transactions through flat files.

- Allows limited validations on data
- Stores the data on hand held memory
- Needs a PC for communication with SAP.

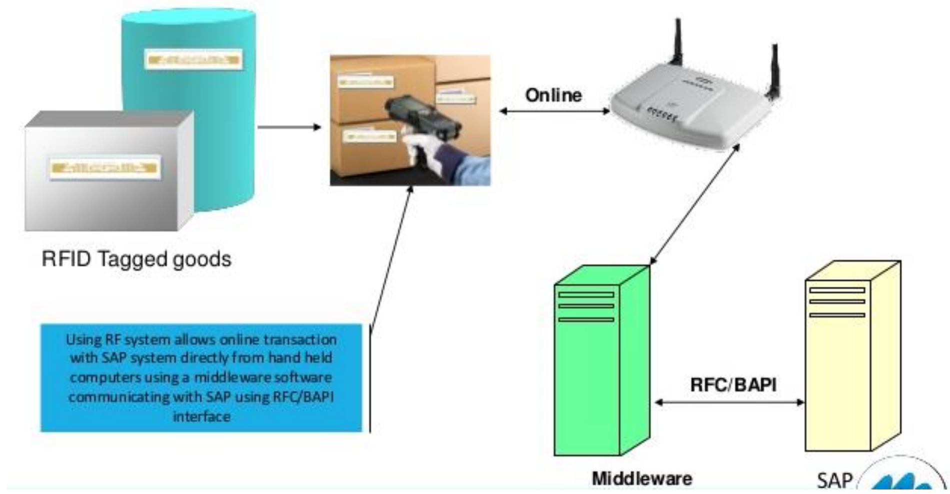

Figure 11-12 Online transaction

Online RFID Tagged goods Using RF system allows online transaction with SAP system directly from hand held computers using a middleware software communicating with SAP using RFC/BAPI interface.

The architecture of SAP Auto-ID infrastructure can be divided into four system layers (Figure 11–12).

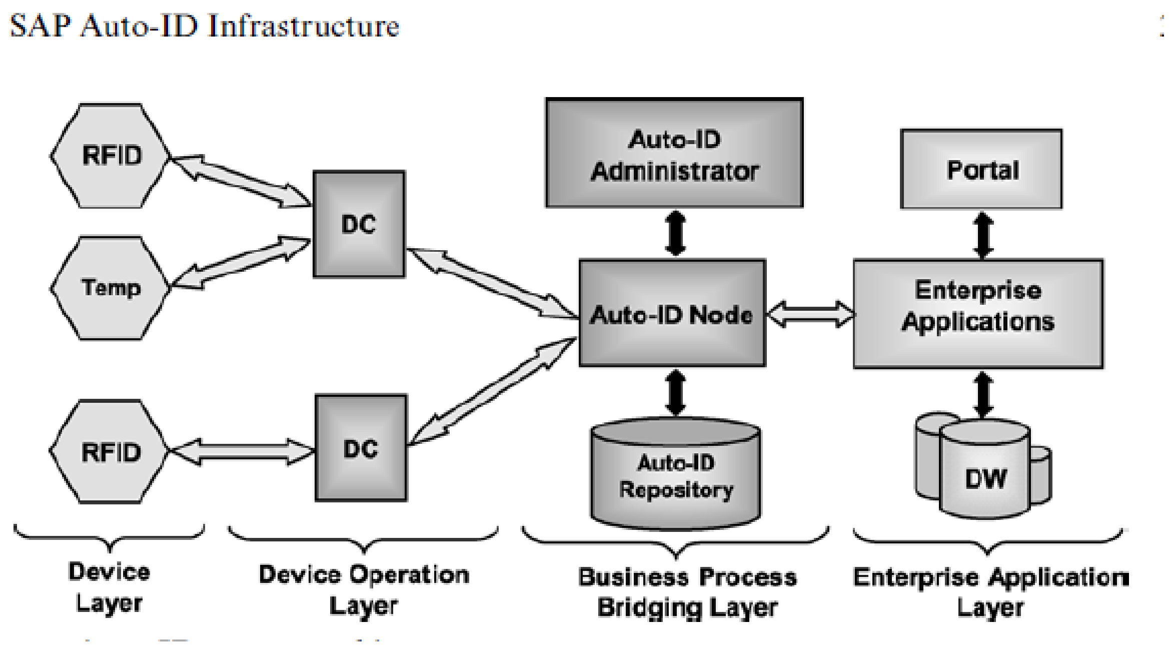

Figure 11-13 SAP Auto-ID infrastructure

The **device layer:** different types of sensor devices can be supported via an hardware-independent abstraction layer. It consists of the basic operation for reading and writing data and a publish/subscribe interface to report observation events RFID readers can include environmental sensors or PLC devices.

The **device operation layer** coordinates multiple device. It has the task of filtering, condensing and aggregating all the data before passing it to the next layer. This layer is formed by one or more device controllers

The **business process bridging layer** associates incoming observation messages with existing business processes. In this layer, status and history information of tracked objects are maintained.

Finally there is the **enterprise application layer,** that supports the business process and the enterprise application (such as those for the supply chain management or asset management) running on SAP. [25]

SAP AUTO-ID infrastructure provides an infrastructure for realizing a complete AUTO-ID solution. Because this one can be present in different organization and countries , standards for the interface between components are essential.

Essentially the integration between SAP and RFID reader system is important for meeting the needs of flexibility and service-oriented architectures, in fact they link sensor and information from the real world to SAP’s business process platform and enterprise application. SAP AUTO-ID infrastructure is the SAP solution for integrating RFID data.

12. CONCLUSIONS

Now it is possible to make a general evaluation of the discussion of the previous chapters. The cable manufacturing is composed of a lot of steps from moving to raw material to final products. Electrical cable is composed by one or more conductors and each of them has its own isolation and optional screens, individual covering, assembly protection and protective covering. Following them in each production step could bring a lot of improvements in terms of efficiency and traceability of the product.

The utilization of an RFID system can bring to a lot of benefits inside an enterprise like: accelerating scan process, extending scan processes for improving quality and efficiency, extending scan process for narrowing recalls, reducing paper-based data management, automating asset tracking, reducing back-end interaction, unifying labels. All these benefits need costs that are fixed and variable and that derive from hardware costs for all the components required, from costs for the software, training of the worker and all the variable costs related to the application and removal of labels and transportation.

In the assembly line, in general, components are marked with a tag; their flow during the assembly process can be checked by using fixed RFID reader that can be activated by using a sensor or the reader that can be an handheld one. As a matter of fact, the cable manufacturing can be considered an assembly process but with some particular considerations. Raw materials, semi-finished products and finished products are generally hold in spools that change every time during the different production steps. There are several problems in terms of how to apply tags in material, in fact is difficult to stick them in the material for the nature of some processes (for example in the wiring process there is no possibilities to put tag in the single wires). The only solution for tagging directly the cable seems the built in cable one, but this would imply the introduction of a new production process.

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At the end the integration with SAP and ERP, systems already used in ELKA, could give some good improvements in terms of connecting and sharing data with all the actors involved in the supply chain and also to have information regarding the status of the order.

Finally it is possible to say that the application of the RFID system can start as a pilot project for the representative products, then if the benefits got from ELKA are higher than the costs they had to sustain, it can be possible to use the system for all the orders that arrive from the customer. The initial investment should not be so high and since in ELKA SAP is already used, the only important thing to do is to understand the best way to integrate the two systems, that can be done with SAP AUTO-ID infrastructure.

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