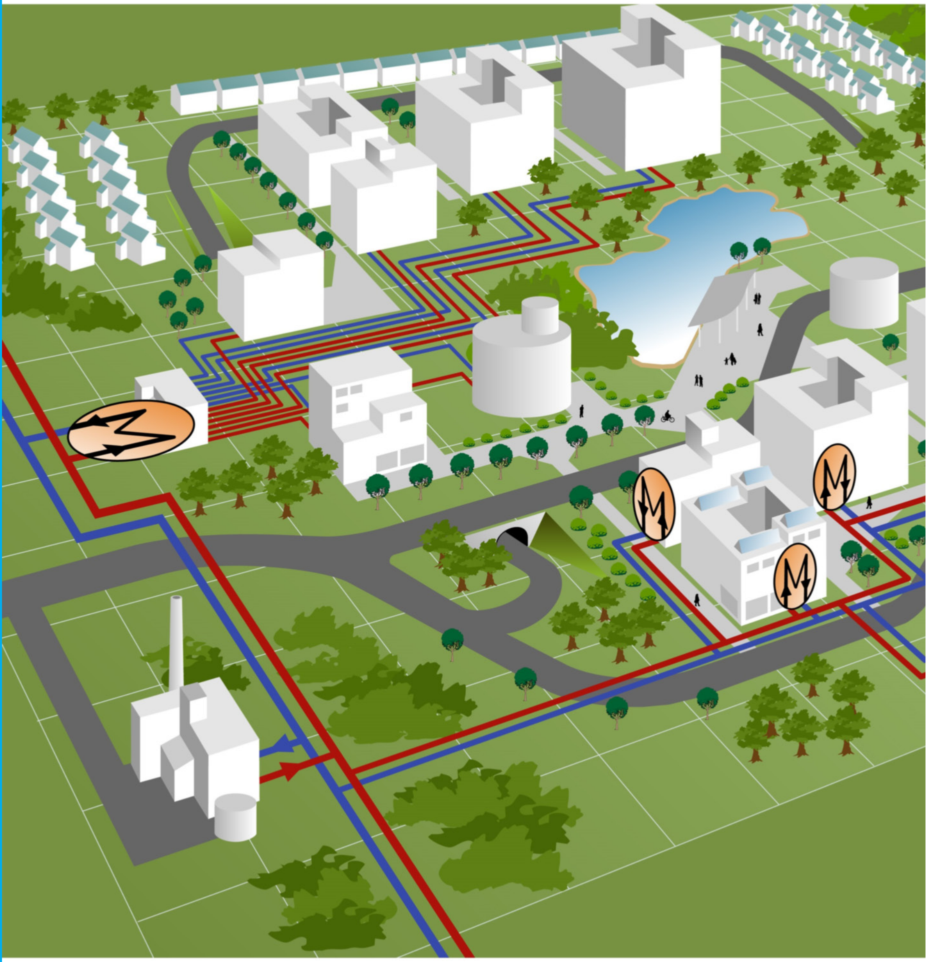

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# The building level substation – the innovation of district heating system

Version II

Kari Sipilä | Arto Nuorkivi | Jorma Pietiläinen

VTT

VTT TECHNOLOGY 250

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VTT Technical Research Centre of Finland Ltd

Arto Nuorkivi

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# Preface

The Manual is based on the request of the Ministry of Housing, Urban and Rural Development (MoHURD) on Dec. 2, 2014 to the Finnish VTT and Tekes delegation to support the national Heating Reform by providing guidance to building level substation (BLS) implementation from institutional, economic and operational point of view.

The authors of the Manual would like to extend their thanks to the comments provided by their excellences, Messrs. Liu Heming and Han Aixing from MoHURD, Ass. Prof. Xia from Tsinghua University, Dr. Zhou Zhigang and Dr. Wang Peng from Harbin Institute of Technology and by the task team leaders of district heating projects, Messrs. Yanqin Song and Gailius G. Draugelis as well as the technical expert Dianjun Zhang from the World Bank Group.

The Manual at hand is produced by VTT Technical Research Centre of Finland Ltd by Mr. Kari Sipilä in association with Dr. A. Nuorkivi under the sponsorship of the Finnish Energy Industries association, the Beautiful Beijing program of Finpro, City of Turku as well the individual companies such as Alfa Laval Nordic, Enoro, Högfors Valves, Kolmeks, Oilon and Vexve.

The attachment of the Manual offers a comparison of the practice in DH between China and Finland.

The Manual comprises the aspects as outlined in the Table of Contents to follow.

This BLS manual is updated from the 1st version done in Oct. 2015 (VTT Technology 231, available at: www.vtt.fi/inf/pdf/technology/2015/T231.pdf). Chapter 2 and 3 are added into the 2nd version. Also some parts of the text are reorganized in new order and some text is added and some taken off. The text called "Global trends" is added in Annex 2.

# Contents

## Abstract

# List of symbols

| **Abbreviation**<br>**缩写** | **In English**<br>**英文** | **In Chinese**<br>**中文** |
|---|---|---|
| BLS | Building level substation | 楼宇换热站 |
| CHP | Combined heat and power plant | 热电厂 |
| DH | District heating | 区域供热 |
| DHW | Domestic hot water | 生活热水 |
| EU | European Union | 欧盟 |
| GS | Group substation | 集中换热站 |
| HoB | Heat only boiler plant | 锅炉房 |
| SCADA | System for Computerized Automation and Data Acquisition | 计算机自动化及数据采集系统 |
| SH | Space heating | 室内供暖 |

# 1. General Introduction

## 1.1 Concept of BLS

The building level substation (BLS) is suggested here as an innovation to the DH sector development in China. But what is BLS and what would it change? Introduction of the BLS would provide obvious benefits in improved energy efficiency and living comfort, but it also faces institutional barriers to overcome. In the following, the CHP concept will be described, and the economic, institutional and technical issues associated to BLS will be addressed.

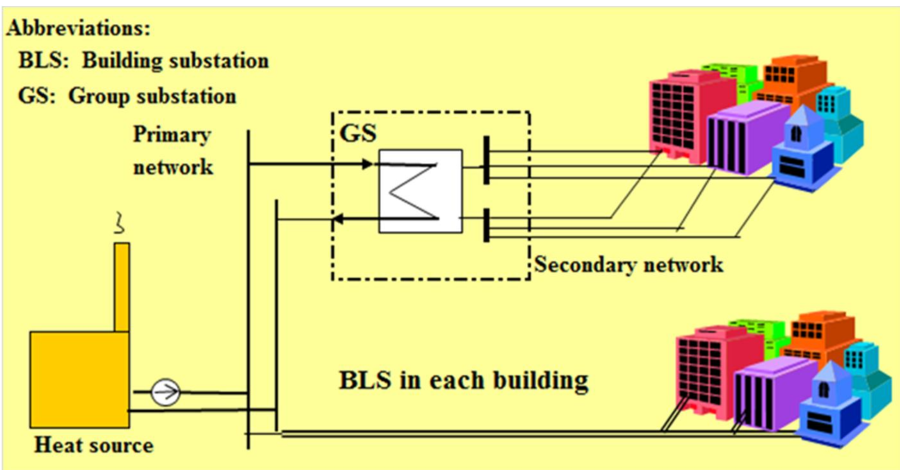


**Figure 1.** The network structures of the traditional group substation (GS) in China and the building level substation (BLS) in Finland.

Figure 1 illustrates the difference in the substation culture between China and Finland. In China, the substation serves 20–30 buildings through the secondary underground network, whereas in Finland, the primary network extends to the building basement where the BLS is connected to the indoor piping.

Typically, the BLS capacity is below 15 000 $m^2$ of heated area equal up to 1 MW. The BLS units are prefabricated compact products that are designed, manufactured and tested at the factory ready for transportation to the construction site, where the complete BLS unit will be mounted to the floor, connected to the existing indoor piping of heating and water, the remote communication facilities as well as to power supplies of the building.

The BLS as an integrated plate heat exchange unit shall be prefabricated and assembled and successfully tested both hydraulically and electrically in the factory already to meet the high functional and low noise requirements, and if he so wishes, at the presence of the Borrower's representative. Its base and brazed structures should have sufficient intensity and stability.

In Fig. 2 a number of BLS units wait for the delivery to China. The BLS units were installed in the city of Chengde, under co-financing of the grant from the Global Environmental Facility administrated by the World Bank.

**Figure 2.** Building level substation (BLS) with capacity of about 10 000 $m^2$ in the factory ready for shipment to Chengde, Hebei Province, China.

## 1.2 Comparison between the Traditional GS and BLS

### 1.2.1 General Benefits

There are several reasons to believe that the BLS is competitive, and even superior to the traditional GS in future, in China.

The required number of small BLS units themselves alone are more costly than the GS alone indeed, but including replacement of the multi-pipe secondary network with primary 2-piping and with more optimal pipeline layout often makes the total investments of the BLS option lower than the traditional one with GS and multi-pipe secondary networks.

The arguments supporting BLS introduction in China are as follows:

- Eliminating the underground secondary network which is bothered by poor water quality and strong corrosion.
- Optimal layout of network as the GS is not needed in the middle of the residential area anymore.
- Easier installation of primary network in the middle of buildings as it requires much less land area than the traditional secondary piping consisting of 2–6 pipes installed in parallel depending on whether up to 12, 24 or 36 floor buildings are concerned.
- Electricity savings in pumping in BLS as the water flow of the primary network is 70–80% smaller than that of the secondary flow of GS.
- Make-up water savings as the water losses are better controlled on the building than on a region basis.
- Heat energy savings as the temperature control will be closer to the customer than in traditional group substations.
- Improved heat comfort at the customer apartment as the heating conditions are more stable, because the temperature control is closer to the customer than in the traditional GS case.
- Reduced return water temperature on the primary side thanks to optimized circulation inside the buildings, which improves the power-to-heat rate of the CHP, reduces the need of pumping as the water flow is smaller and reduces heat losses of the network.
- Flexibility in extension of the building stock in case the area will be gradually built in accordance of people moving in, and not the entire district at once and having a number of apartments empty.

### 1.2.2 Reduced Pumping

There are two issues related to DH circulation pumping to be discussed here.

First, in China it is common, according to the studies of Tsinghua University, that the DH pumps are oversized. Too powerful pumps cause many problems such as noise and cavitation (pump inlet pressure too low), for instance, the latter cavitation being a reason to frequent damage of pump bearings. As the real BLS is optimized and completed in the factory already, there are no such risks.

Second, in the drawing below, the pumping efficiency improvement due to the BLS introduction is illustrated. While secondary network is converted to primary network, the total water flow falls as much as 60% to 80%, which consequently reduce the need of pumping, and thus the associated electricity consumption. The water flow fall is often more drastic than in the drawing, as in practice the secondary water temperature differences are 15 °C and 10 °C for radiator and floor heating systems at highest, respectively. Having both types of heating in a building, the design follows the floor heating temperatures, this giving the maximum temperature difference of only 10 °C.

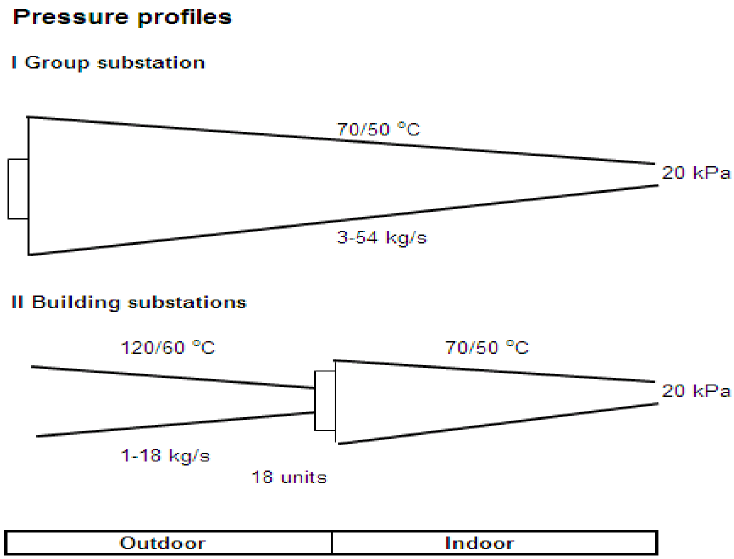


**Figure 3.** Comparison of water flows in GS and BLS cases. In the GS case the water flow is three times the water flow of the BLS case, which is the reason to excess pumping and high costs of electricity associated with GS.

All in all, the life cycle costs of BLS with extended primary network during 20 years to come make BLS very competitive to the traditional GS having troublesome secondary networks.

The network layout can be better optimized when having BLS instead of the traditional GS as illustrated in Fig 3. The GS is often in the middle of the connected buildings, which causes some pipes to follow the route back to the buildings that the primary network had already passed by. Moreover, installing two primary pipes is more flexible than 2–6 secondary pipes in between the densely constructed buildings and other technical infrastructure already in the ground, telecommunication and electric cabling, water and sewage piping.

### 1.2.3 Optimal Underground Piping

Introduction of BLS will both reduce the diameter and geographical length of the underground network, often also the number of the pipes to be installed. The reduced length is based on the new layout of the pipes as illustrated in Fig. 4.

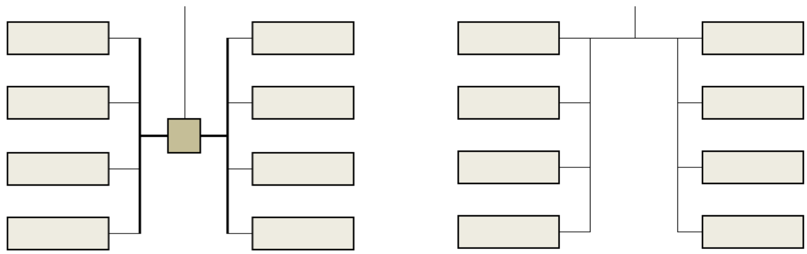


**Figure 4.** BLS helps reduce the piping route length.

As the water flow in the secondary network is large requiring several and large pipes, the BLS introduction will reduce the diameter and number of the pipelines when converting the secondary to the primary network. Reduced diameter implies lower investment costs on piping, usually the network being the largest component of the DH fixed assets.

The BLS will likely cause energy savings in the buildings as the temperature control is building specific and can be tuned according to the heating behavior of the particular building. This cannot be done with the traditional GS which serves 10–20 buildings collectively, and the heating quality needs to be adjusted to the most critical building, while the others will receive excess heat from time to time.

## 1.3 Improved Energy Efficiency

Some of the experiences from the heat energy savings after having had converted the GS to BLS have been:

- In Central Europe, conversion of old GS systems to modern BLS systems has reduced heat consumption by 15% on average, thus making DH more energy efficient and competitive on the market.
- In Weihai, Shandong, there have been indications that BLS systems use heat energy 12% less than GS systems.
- In Chengde, there are indications that the BLS saves 11% of the heat consumption compared with GS[1].

Remote communication may provide benefits in reduced maintenance and energy consumption.

Traditionally, only room space heating is used in Chinese DH. In other world, also domestic hot water is often integrated to DH. Introduction of BLS makes it possible to complement the DH with DHW afterwards at low incremental costs: a small

[1] District Heating 6/2014

heat exchanger and a small circulation pump as well as connection to the existing DHW and city water piping are needed.

## 1.4 Benefits of BLS

To the Heating Sector Reform the BLS introduction offers essential advantages such as:

- Each building gets exactly the heat it needs.
- Heat control inside the rooms works better when the heat supply is controlled for the particular building in the BLS.
- A professional body, the DH Company, will be responsible for the heat supply quality until the building entrance, not only to the GS.
- Heat losses (inside and outside the building) can be allocated unambiguously to either consumer or supplier. The building internal heat losses are clearly the responsibility of the customer, e.g. the building owner.
- Heat metering can be organized at low cost on building level.
- Thus, heat tariffs can be clearly defined: covering the costs of supplying heat up to the substation, either before or behind the heat exchanger of the BLS.
- Serial production is much more possible with BLS, thus providing lower investment costs than with tailored GS units.
- BLS with primary network connection is flexible for expansion: every new building will be equipped with a BLS whereas in a GS system a new building may either require capacity to be added to the GS or the secondary networks or such excess capacity had to be reserved in the design phase already, both being costly.
- Low return temperature due to tuned functioning of the BLS according to the heating needs of the particular building will be achieved, which improves the overall economy of the DH/CHP system.

The substations require room space depending on the size. A few examples are given in Table 1 about the substations of various capacities.

The maximum physical dimensions of the BLS is given in Table 2 in order to make it feasible to transfer the BLS to the final operation site, and to use as little room space as possible but to be easy to maintain anyway.

**Table 1.** Examples of physical sizes of real substations.

| SUBSTATION | DIMENSIONS lenght x width x height mm | Floor area substation m2 |
|---|---|---|
| WEIHAI 0,2 MW | 1500x600x1600 | 0,9 |
| ULAN BATAR 0,4MW | 2000x1000x1600 | 2,0 |
| HARBIN 1MW | 2500x2000x2300 | 5,0 |
| BAOTOU 7MW | 3000x4000x2300 | 12,0 |
| YANJI 9 MW | 6500x4000x2400 | 26,0 |
| YANJI 13 MW | 6000x3800x2300 | 22,8 |
| QINHUANGDAO 14MW | 7000x4000x2300 | 28,0 |
| YANJI 17MW | 6600x3900x2300 | 25,7 |

**Table 2.** Physical dimensions of BLS to design the room space needed in the building (mm).

| Capacity | Length | Breadth | Height |
|---|---|---|---|
| ≤200 kW | 1500 | 700 | 1600 |
| ≤400 kW | 1700 | 750 | 1650 |
| ≤600 kW | 1800 | 800 | 1700 |
| ≤800 kW | 1900 | 850 | 1800 |
| ≤1000 kW | 2000 | 900 | 1800 |
| ≤1200 kW | 2200 | 950 | 1900 |

The room size of the BLS should be large enough to leave at least 1 m on each side of the substation space free to walk and work.

The main components of the BLS are:

- Plate heat exchangers, the number depending on the types of heat consumptions such as space heating, DHW and ventilation.
- Heat meter
- A safety valve is in the secondary side to protect against high pressures.
- The circulation pump with control system
- A water flow sensor in the make-up water supply
- Temperature control components together with communication

- Circulation pump with frequency converter
- Pump box
- Shut-off valves
- Strainers

As the BLS product will be transferred as one integral unit from the factory to the final operation site without any disassembling/reassembling in between, there is no risk of noise or excess consumption of electricity, heat and room space, but the operation will be silent and optimal in the building.

The BLS can be carried through the normal doors of some 2.1 m high and 0.9 m breadth to the final operation site in the building (Fig. 5).

**Figure 5.** Small buildings heat exchanger unit.

There is no international standard about the BLS for the time being. There can be referred to "Plate heat exchanger unit" GB/T29466 and the "Guidelines for District Heating Substations" issued by Euroheat & Power, e.g. the DH Association in Europe, in October 2008. The guidelines are downloadable from the link: http://euroheat.org/Technical-guidelines-28.aspx.

## 1.5 Manufacturing BLS

The BLS shall be manufactured and tested at the factory as one integral unit, which then will be transported to the final site to be connected to the building and DH infrastructure.

At present, there are not many manufacturers of BLS in China, but as BLS becoming more common based on the pilots financed by the World Bank, for instance, it is certain that the numerous heat exchanger manufactures currently operating in China will add BLS to their product mix. This transition from imported to local manufacturing has happened in many other imported products before already: plate heat exchangers, fluidized bed boilers, frequency control of pumps, etc. that used to be imported but which now are mainly of Chinese origin. The same will happen with BLS after the prevailing barriers have been phased out.

# 2. Application in Finland and Global Trends

## 2.1 General Situation of Finnish District Heating

In Finland, the population living in the DH served buildings amounts to 2.7 million, about 50% of the population of 5.6 million in total. In year 2015, the average DH price was 75 €/MWh including all taxes, covering both the capacity and energy fees. The DH price varies among the almost 200 companies in a ratio ranging from 1 to 2 as each company has its own pricing policy. The total heat sales amounted to 33.0 TWh (118 PJ) in 2015[2], out of which 74% was based on CHP and the balance of 26% on industrial waste heat and heat only boilers.

In the fuel balance of the Finnish DH, the share of RES (33%, 2015) is expanding fast as presented in Figure 6 below. The RES expansion is to meet target of the DH sector to become carbon neutral (36%, 2015) by year 2050 latest (Fig. 7). Therefore it is very hard politically, if even impossible to build anymore fossil fuel fired sources in Finland. Discussions are underway even to forbid coal use completely by year 2030.

[2] District Heating statistic in Finland 2015 (www.energia.fi)

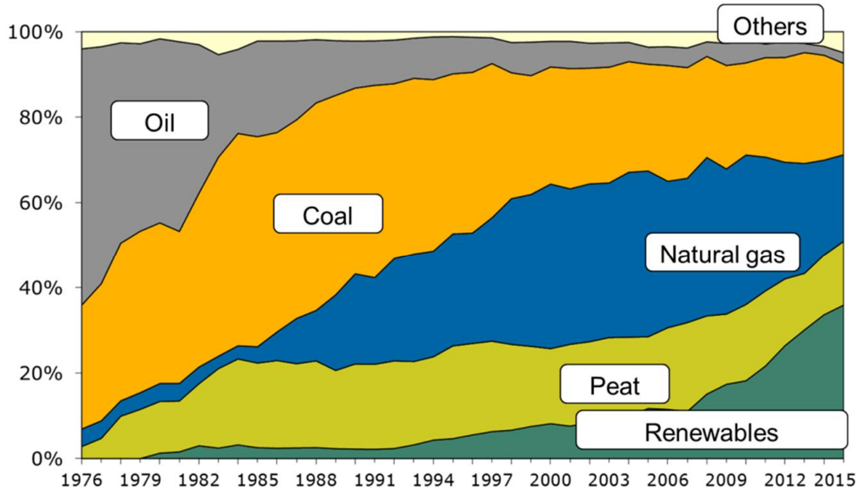


**Figure. 6.** Fuel balance of Finnish DH and related CHP since year 1976. Strong expansion of RES can be seen from year 2007 on (source: Finnish Energy, www.energia.fi).

The electricity used for the pumping at the heat source is about 6 kWh/MWh of the produced heat energy covering the heat delivery from the heat sources to the inlets of the BLS, e.g. the building walls.

The heat losses in the DH networks are typically 5–6% in large and up to 10% in small networks. In percentage terms, most heat losses take place in summer time when the heat sales are lowest but the temperature levels in the network are just some 20–30 °C and 10 °C degrees lower than in winter in the supply and return pipe, respectively. Therefore, the network heat losses in quantitative terms are almost constant throughout the year but the heat sales vary very much between the months.

The water losses in the DH systems are only 0.08% of the water flow equal only one replenishment of the network water volume a year on average. As the water losses are low, relatively small amount of the make-up water is needed. As the make-up water and consequently the network water quality is good, there is neither corrosion nor sedimentation inside the pipelines and armatures, and therefore the lifetime expectation is long and the maintenance costs are low.

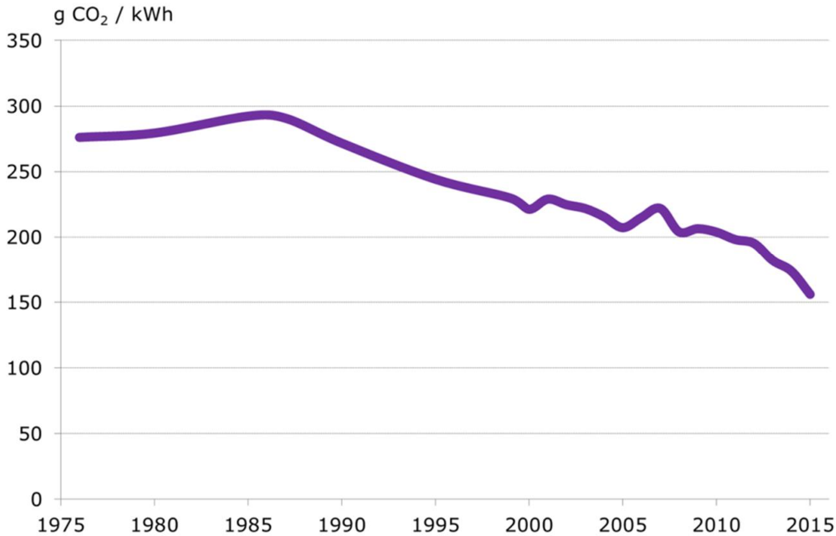


**Figure 7.** Carbon emissions of DH since year 1975 have declined due to constantly improving energy efficiency as well as conversion from fossil fuels to RES (source: Finnish Energy, www.energia.fi).

Only 0.5% of the Finnish DH networks are replaced annually, and this value has been constant for some decades already, and no indication has been recognized that the value would rise anytime soon. Thus, replacing only 0.5% of the networks per year would require as many as 200 years to replace all networks in Finland. Critical for such a long lifetime, and low maintenance costs, is the good water management: low water losses and high quality of circulation water.

The BLS is one of the technical approaches to help control water losses as the water losses will be measured on building level. Having high water losses in a building provides an indication that something is wrong there to be fixed.

## 2.2 BLS in Finland

DH in Finland has been awarded as the best DH system in the world with full five stars by the IEA, the International Energy Agency, mainly because of high level of integration and energy efficiency. Moreover, the DH and district cooling systems of Helsinki have been awarded as the best practice in the world by the IEA and the Euroheat & Power a number of times, for instance, Paris, France, 2009 and latest in New York 2013.

In Finland, the customer is always the building owner, never the individual apartment. Each building has its own substation (BLS) separating the responsibility border of the DH company and the building owner. The BLS is owned by the customer.

Apart from China, the BLS in Finland supplies heat both for SH and DHW. Therefore, there are always at least two heat exchangers and controllers in each substation, sometimes the third one for air conditioning.

Finland is a small country with the population of only 5.5 million and the territory of some 300 000 $km^2$, but located in the north with the highest heating requirements prevailing in Europe. The outdoor temperature used as the design basis of the DH systems ranges from -25 °C in the south to -35 °C in the north of Finland. Therefore, the heating systems have to be both reliable and adequate. The reliability of the DH supplies to the customers amounts to as high as 99.98% of the calendar time, and those less than 2 hours a year, the customer does not usually even recognize any break as the heat energy accumulated to the buildings and pipelines compensates the impacts. The Finnish Energy Industry Technology Association recommends that the back-up boiler capacity shall be sized to allow less than 10% lack of capacity in production for maximum 6 hours period at a time, when largest unit is out of operation and winter peak demand exist. The network and booster pump stations must be designed that not any customer is allowed to stay totally out of heat more than 3 hours. This recommendation takes into account the heat demand pattern and heat storage characteristics of buildings and DH networks as well as separated heat storages in some DH-systems.

Despite of northern location, the DH sales to customers, including both DHW and SH, amounted to 38 $kWh/m^3$ of heated volume in year 2014 on average. The value has been constantly declining due to energy efficiency improvements in the existing buildings and the new buildings being more or less passive or zero energy buildings already.

Moreover in Finland, DH has had to operate on the competitive market without much public support, which has made DH highly economic to be successful on the heating market. As competitors of DH during the past decades, oil and electric heating and lately individual heat pumps have appeared. Today, the half of the population is with DH, about 75% of DH produced by highly efficient CHP and the fuel mix ranging from fossil fuels to the constantly increasing share of renewable energy sources.

Most DH companies in Finland are owned by the municipalities. There are two main reasons to the municipal ownership such as (i) heating is local activity serving only the local people, which makes the governmental involvement unnecessary, and (ii) DH together with CHP is a profitable business to the owner, even though both electricity and heat function on open markets. As an example, the DH and CHP Company of Helsinki, the capital of Finland, generated €250 million profit with €900 million turnover in year 2014. A good share of the profit was used by the city as the owner to fund city development in favor of its citizens.

The DH industry by itself is not regulated in Finland, but the same customer right protection procedures apply to DH as to any other commercial product available on the market such as food, electric appliances, house renting, etc. Because of DH is regionally in a dominant market position due to DH share of 90% and more of the local heat market, the Finnish Energy Market Authority follows the pricing of DH companies that the heat price is not over sized including a fair profit. Due to competition on the market, the competitiveness and customer satisfaction, both constantly monitored by the DH companies, are the driving forces of DH management in the whole country.

The BLS is a rather standard product in Finland, but not officially standardized. The association Finnish Energy Industries[3] issues recommendations to its member companies, both utilities and manufacturers, about required water quality, substation structures, heat tariff systems, etc. The recommendations are not mandatory, but as the companies themselves have participated in preparing the recommendations, the recommendations are implemented in practice. Therefore, the DH systems in Finland both technically, institutionally and economically are rather uniform as designed, operated and maintained according to the mutually agreed recommendations. The association is based on voluntary membership of the energy companies in Finland. In practice, most DH companies are members of the Finnish Energy Industries as they benefit from lobbying with the government, participation in development work and information exchange.

The DH system is operated all year round because of continuous DHW supply, but SH is needed in the heating season only. All year round operation guarantees also better condition and reliability of DH systems compared to 3–4 months shutdown mode of the DH systems a year.

The connected buildings can switch on/off their heating individually as needed, because the DH system is in operation at all times.

An example of a Finnish DH system is given in the Fig. 8 below. In the city of Helsinki, the capital of Finland, some 92% of the building stock is connected to the DH. About 90% of the DH energy is produced by the CHP plants Vuosaari, Salmisaari and Hanasaari and the balance of 8% by the large heat only boilers (HoB) spread in the city area. The CHP energy is high as a base production even though the heat production capacities of CHP and the other sources are almost even, 1250 MW from CHP and 1350 MW from the HoBs and large heat pumps. The annual efficiency of the heat production is about 90% which is very high in the international context. The heat losses of the DH network are 6% of the annual heat production. The water losses of the DH systems are as low as some 0.08% of the circulation water flow on average.

[3] www.energia.fi

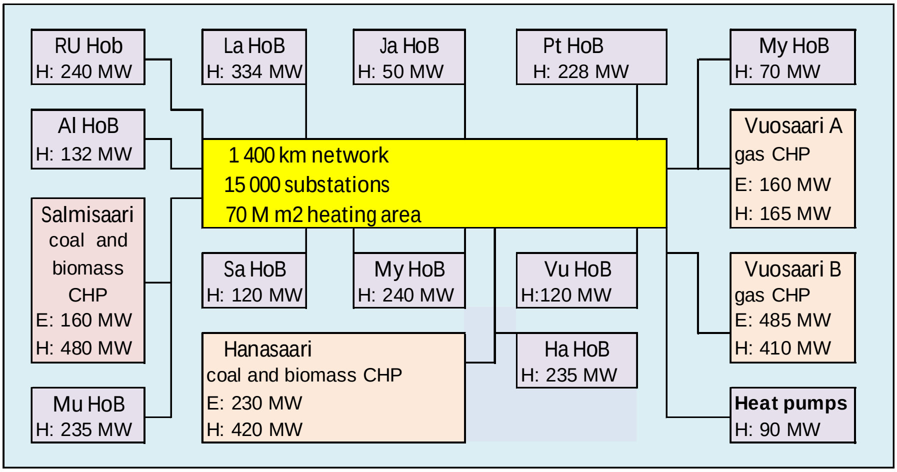


**Figure 8.** The various types of heat sources are interconnected to one integral ring-type DH network in the city of Helsinki, Finland (2015). All 15 000 substation units are BLS.

VTT has developed in co-operation with Helen a *Kopti* software system to help optimally operate the energy production system in Helsinki. Fuel consumption, capacity operation, including energy storing and unit annual service break time are optimized. Electricity trade in Nordic electricity trade market and local heat trade are also included in the systems operation.

Helen has automated customer information system collecting electricity and heat consumption data from remote read meters (ARM) at consumers, issues the customer electricity and heat bills according to the collected data. The data information system gives also to customer his own measured consumption history information in hourly/months level, if the customer wishes to have it.

## 2.3 Customer Connection Procedure in Finland

In Finland, the building owner is always the customer of DH, never the individual apartment. Therefore, the apartment level heat metering even being very rare and if possibly exists, is only used to allocate the total heat bill of the building to the apartment owners.

All buildings connected to the DH network have a BLS installed in the building basement to control the supply temperature and to measure the heat energy consumption of the building. Measuring consumption at the building level allows the heat supplier to issue the energy bills based on the actual consumption and the customer to monitor and control their heat consumption.

The process of joining a building property to the existing DH network and installing a BLS in the case of Turku Energia, typical to Finland in general, is described in the following steps:

1. Turku Energia (TE) carries out a technical and economic assessment on the property's connection readiness to the DH network (location of the property, other possible customers in the area, etc.) TE builds and covers the costs of the main DH network and the connecting pipe from the main network to the planned BLS in the building. The customer pays the fee for joining the network. The fee is based on the agreed heat capacity, either in terms of kW or $m^3$/h of ordered DH water flow.
2. Based on the assessment, TE estimates the initial costs and submits a heat sales offer to the customer. The initial offer includes:
    - Agreed water flow
    - BLS's location in the building and the requirements for the room space of the BLS
      - Estimated annual heat consumption (MWh)
    - Fees for joining the network (€)
    - Network user fee per annum (€/year)
    - Expert's fee for gathering necessary information to make the offer
    - A list of certified heat subcontractors is also provided to the potential client as the client (building owner) is responsible for the indoor installations.

   TE makes the cost estimate for the above mentioned equipment and services. The costs are paid by the customer once the customer approves the offer.

3. The customer estimates the investment costs within the building property needed to join the network.
   The expenses of the property, the surface work, insulation work in the building etc. are covered by the customer.
   The customer accepts/declines the offer.
   TE goes through the offer with the customer before the offer is accepted.
4. The property owner and TE agree on the heat distribution point, and both parties sign the heat distribution agreement. The heat distribution point divides the ownership and responsibilities of the maintenance etc. The heat supplier (TE) is responsible for the equipment from the heat source to the distribution point (left chart), the customer from the distribution point to the radiators in the property (right chart).

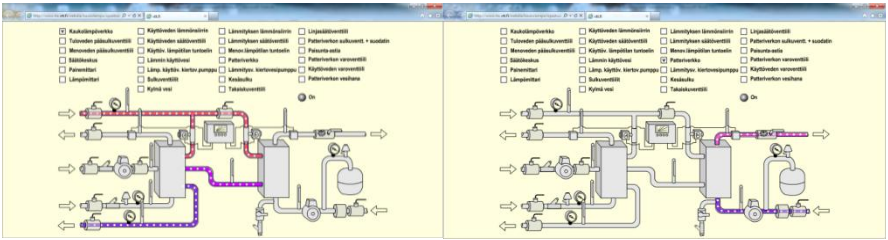

**Figure 9.** Borders of heat delivery in Finland (source: http://www.rte.vtt.fi/webdia/kaukolampo/opastus/animaatio/kaukol3.swf).

5. The customer submits the DH connection plan to TE for approval. The DH connection plan has to be designed to meet the building's heat energy and capacity needs. The plan is drawn and designed by a professional technical designer. The information shown in the plan is used e.g. to define the agreed capacity and water flow, to estimate the energy consumption, etc. The plan is handed to TE for inspection and approval.
6. The customer chooses the subcontractor for installing the BLS
   TE purchases and installs the heat meter, heat supplier's shut-off valves and the strainer. The customer purchases the BLS. The BLS has to be installed and connected to the TE's network by the subcontractor certified by TE. A list of certified heat subcontractors that have proven to have sufficient expertise and experiences is maintained by TE.
7. Checking of the installed DH equipment.
   TE conducts the installation check to make sure the equipment and the installation fill the technical requirements before the start of heat distribution.
8. Heat distribution starts.
9. Operations test and final check of the equipment. Guidance will be provided by TE to the customer on how to use and maintain the BLS and the indoor heating system.

## 2.4 BLS Worldwide

The trend elsewhere in the world appears to either stay with BLS or to convert GS towards BLS as presented in the Table 3 below.

A number of countries use BLS already, and some of the countries are turning from GS to BLS. Nevertheless, none are moving other way round from BLS to GS.

In some cases, such as Russia and Denmark, for instance, not only group substations and even direct connections are used but also BLS.

The heat exchangers of space heating can be either mountable, when opening and remounting of the heat exchanger plates is possible, or brazed, when the entire heat exchanger has to be replaced if broken or leaking. The latter brazed ones are reliable and much cheaper and smaller than the mountable ones, thus having had gained market dominance in the world, as presented in Table 4 below.

**Table 3.** Countries with main practice on substations.

| **Common practice** | **List of countries** |
|---|---|
| Countries using GS | Belarus, China, Denmark, Romania, Russia, Ukraine |
| Countries using BLS | Austria, Bulgaria, Canada, Croatia, Czech Republic, Estonia, Finland, France, Germany, Italy, Norway, Serbia, Sweden, Switzerland, United Kingdom, USA |
| **Countries in transition** | |
| Countries moving from GS to BLS | Poland, Hungary, Lithuania |
| Countries moving from BLS to GS | There are NONE. |

The trend elsewhere in the world appears to either stay with BLS or to convert GS towards BLS as presented in Table 4.

**Table 4.** Countries using mountable or brazed heat exchangers in SH circuits.

| **Heat exchanger type in space heating** | **Countries** |
|---|---|
| Only mountable | China |
| Brazed | Austria, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Norway, Serbia, Sweden, Switzerland, United Kingdom, USA |
| Both brazed and mountable | Belarus, Russia, Ukraine |

# 3. Application Status of Building Level Substation in China

## 3.1 Background

Traditional group substation (GS) and large secondary network system are used in Chinese heating area for a long time. The advantages appeared one by one in the process of application and there are mainly four problems. First of all, the pipe network would require a tremendous investment because the large diameter of pipeline with large flowrate and small temperature difference are forced to use, causing by the long transmission distance and large heating scale of secondary network system. Secondly, it is difficult to lay secondary network pipelines. Mostly, new communities are high-rise buildings, which interior design adopts loop system, needed to lay two or three circuits of secondary network pipelines within the buildings. As a result, four to six heating pipelines in parallel are installed in the community. Besides, other pipes such as water pipe, gas pipe, sewage water pipe, etc., must be laid at the same time, resulting in the difficulty of laying pipelines. The third is the serious hydraulic imbalance, which is inevitable (due to the long transmission distance and large heating scale) and hard to effectively regulate, leading to uneven heat for users, high heat consumption and huge power consumption of distribution. Last but not least, even though each building's heat parameters may be different, they can't be targeted regulating, because those parameters of the whole secondary network are constant.

In order to change the status of huge building energy consumption, the Chinese government vigorously promotes the renovation work of heat metering. The end user dynamic adjustment bringing by household heat metering reform exposes the severe problems of hydraulic imbalance and poor targeted regulation of traditional group substation. The building level substation (BLS) supply heating for every building after the primary network directly extends to the building, eliminating the secondary network of traditional heating system. It can effectively solve the problems caused by group substation and is a key technology of variable flow metering for heating and controlling.

However, because of the lack of design guideline related to building heat transfer technology, some heating companies don't dare to break through obstacles and other issues at the implementation level, so this technology has not been widely accepted in China. Currently, only a few demonstration projects have been implemented. For example, in 2005, the city of Weihai in Shangdong Province firstly adopted the building level substation (BLS) and household heat metering in its central heating cogeneration projects with the loan from the World Bank. The test results revealed that heating efficiency was improved significantly and 12% heating load was saved compared to traditional group substation (GS). In 2013, the building level substation units, covering 16 million square meters area, were installed in the city of Chengde, Heibei Province, under co-financing of the grant from the Global Environmental Facility administrated by the World Bank. After one year of trial operation, the actual heating load of the substation was 34 $W/m^2$, 10.5% lower than the average heating load of other group substations (38 $W/m^2$), which are constructed at the same period.

## 3.2 Demonstration Project in Jiahe Community's Building Level Substation Project in Chengde

Jiahe Residential Community's building level substation and household metering demonstration project is a pilot project of "China Heat Reform and Building Energy Efficiency Project", executed by the Ministry of Housing and Urban-Rural Development and the World Bank, under co-financing of the grant from the Global Environmental Facility administrated by the World Bank.

### 3.2.1 Project Overview

The project is located in southern part of Airport District in the city of Chengdu, and it is an integrated building complex including five-star hotels, commercial buildings, office buildings and communities. The demonstration project is implemented in the community with a gross floor area 16 million square meters, which is composed of 10 high-rise residential buildings. Besides, all of those buildings are designed and constructed in accordance with the three-step energy-saving standards in Hebei Province.

The project mainly includes three parts: building level substations, floor heating temperature control valves, heat meters and remote meter-reading devices. 9 building level substation (BLS) units and 18 building heat exchange units are installed in the community. Total number of 1655 heating temperature control valves, ultrasonic heat meters and remote meter-reading systems are installed in users' room.

### 3.2.2 Investment Analysis

The total investment cost of substations and pipe network is CNY 7.89 million, of which the primary network investment is CNY 1.43 million, secondary network investment is 1.30 million and the substations are invested CNY 5.16 million. The total investment increases 28.97% higher than other traditional community substations with the same scale, as shown in Table 5 and Fig. 10.

**Table 5**. Comparing investment cost of the building level substations traditional group substations.

| Compare Item investment | BLS ($CNY/m^2$) | GS ($CNY/m^2$) | Difference ($CNY/m^2$) | Percentage (%) |
|---|---|---|---|---|
| Primary net investment | 8.93 | 2.23 | 6.7 | 300.45 |
| Substation investment | 32.25 | 6.85 | 25.4 | 370.8 |
| Secondary network investment | 8.15 | 29.17 | -21.02 | -72.06 |
| Total investment | 49.33 | 38.25 | 11.08 | 28.97 |

1) The length of primary network pipeline increases after adopting the building level substation technology, causing the investment is 300.45% higher than that of traditional substation.

2) Only the pipeline connected the substation's exit and building's thermal entrance are needed, leading the investment of this part saving 72.06% compared to the traditional one.

3) The adoption of imported equipment which is highly integrated automation systems increases the initial cost, 370.8% higher than the traditional one.

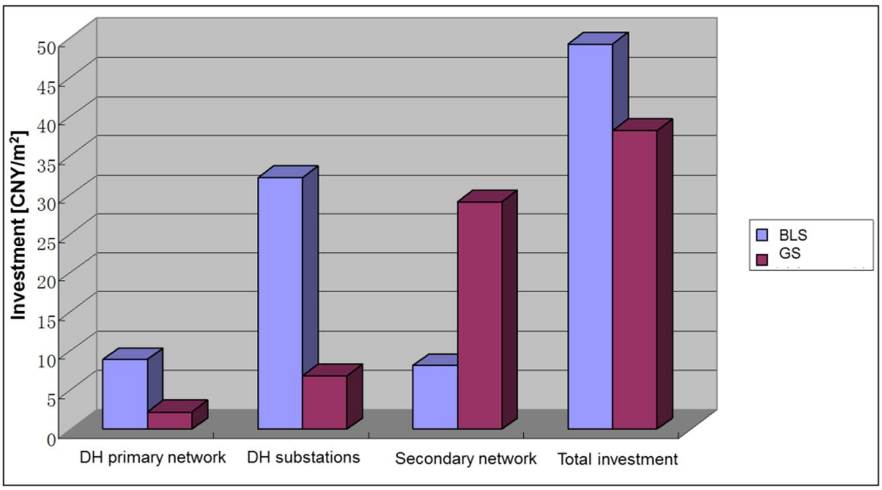


**Figure 10.** The heat exchange station building investment comparison with conventional heat transfer station ($CNY/m^2$).

### 3.2.3 Energy Saving Analysis

Energy saving analysis is divided is in three parts (Fig. 11):

1) Heat-saving analysis: The building level substation system basically eliminates the hydraulic imbalance after cancelling the secondary network. Meanwhile, each building can adjust the heating parameters independently in accordance with its heating effect which significantly increases energy efficiency and reduces the heating load. The actual heating load is 34 W/m$^2$, 10.5% lower than the average heating load of other group substations (38 W/m$^2$), which are constructed at the same period.

2) Electricity-saving analysis: The resistance of secondary network pipelines is greatly reduced and the ability of adopting more economical operation method – low flow and large temperature difference – heavily decreases the consumption of electricity. The project consumes 0.84 kWh/m$^2$ electricity, 13.5% lower than 0.97 kWh/m$^2$ compared to the average electricity consumption of other stations.

3) Water-saving analysis: There is no need of water except the basic debugging water after eliminating the secondary network system. The actual water consumption is 3.02Kg/m$^2$, saving 68.57% comparing to other traditional systems' average water usage (9.61 Kg/m$^2$).

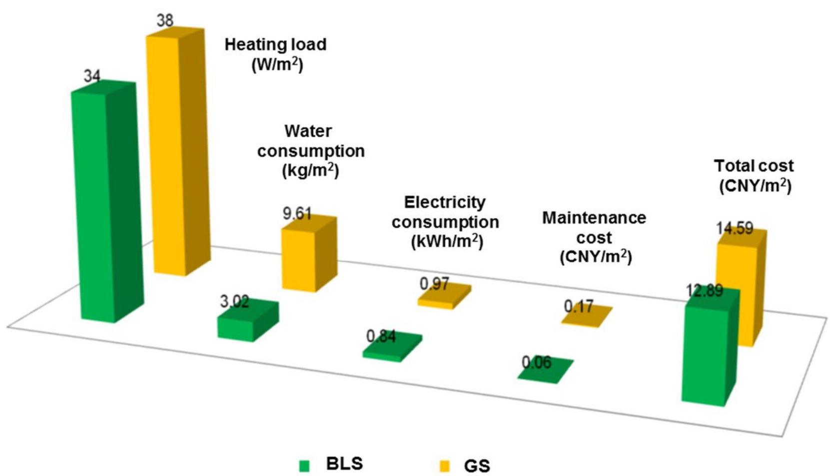


**Figure 11.** Comparison of Group Station (GS) and Building level substation (BLS) [x/m$^2$].

### 3.2.4 Comprehensive Analysis

1) Depending on the operation data, the comprehensive operation cost of the building level substation is 12.89 CNY/$m^2$, 11% lower than that of other newly built substations (14.59 CNY/$m^2$). As the total gross heating area is 16 million square meters in Jiahe community, the operation cost can reduce CNY 234.3 thousand per year.

2) Imported equipment is adopted in this demonstration project. Hence, the investment of devices can be further reduced if realizing localization, then the initial cost of systems can be roughly equal to that of traditional substations.

3) The demonstration project fully validates that the building level substation has standing technical advantages and obvious energy-saving effect, which enables the heating companies to obtain long-term benefit.

# 4. Technical Requirements of Planning, Design, Installation, and Operation

## 4.1 Technical Requirements of Energy Planning of New City Area Applying with BLS

A new city area will be designed by the city planning office of the municipality. The planning office co-operates (meetings, phone calls, emails) with the local utilities such as electricity, water and waste water and heating. In case DH can be made available in the new area, due to a short distance from the existing networks and high heat load density in terms of the new heat load (MWh/m) of connecting network as is usually the case, the local DH Company participates in the new city area planning.

The city planning office designs the streets, locations and sizes of the buildings, services to be provided in the new area, parking places, parks, etc.

When the building location plan has been preliminarily approved between the city planning office and the utilities, the DH Company determines the initial peak heat load of the buildings, and designs the network extension to connect the new buildings to the existing network. The DH Company uses their hydraulic analysis software to design the pipes and assess the possibility, if a booster pump or a network looping (network ring) is needed to secure the adequate water pressure levels in the new building area.

The building location plan including the utilities and streets will be discussed in the politically elected city planning committee. If the committee does not require any amendments to the plan, the plan will be approved. Otherwise, a revised planning has to be produced, and a new approval shall be sought from the committee.

After the location plan and utilities have been approved, the privately owned technical design companies shall produce a HVAC (heating-ventilation-air-conditioning) plan for the construction of each building. The same plan will be used for sizing the substation and the DH connection.

The DH Company will use the data from the HVAC plan to size the heat exchangers and the control valve of the substation, and insert the substation data to a standard data form. The data form will be attached to the bid to be submitted from the DH Company to the potential customer, e.g. the owner of the new building, to connect to the DH system. Together with the data form there is also an introductory letter and the General Terms and Conditions to connect to DH.

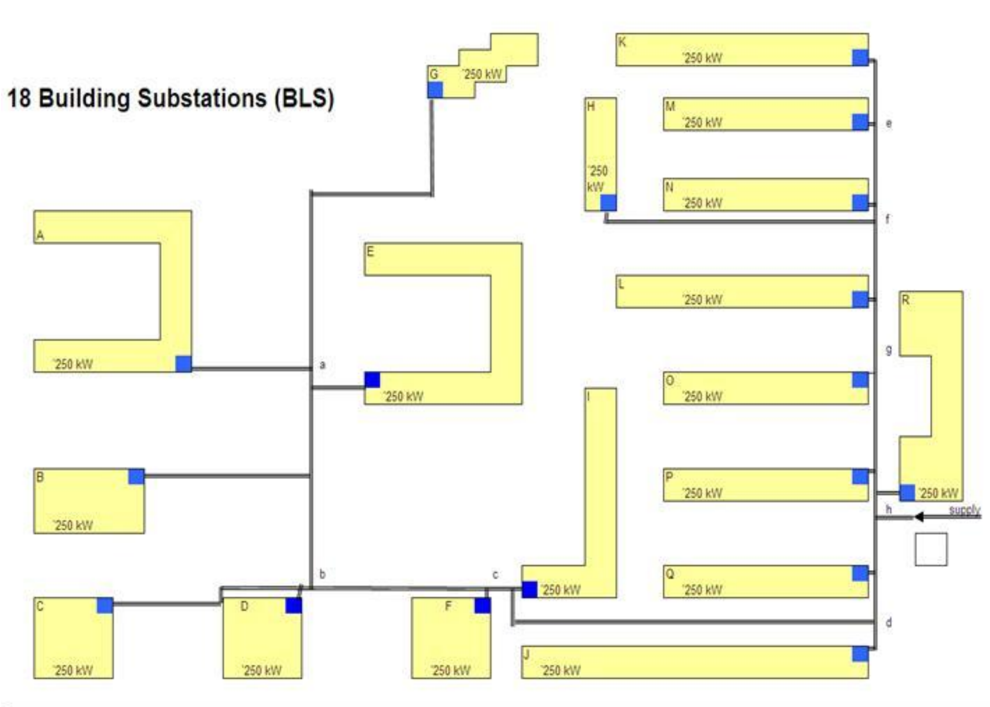


**Figure 12.** Network design with 18 BLS units (blue squares) when the heat supply comes from the right (east).

The example illustrated in the above Fig. 12, there are 18 buildings each with a BLS unit of 250 kW each, and 4500 kW in total. In Finnish conditions the annual heat sales would be some 11 000 MWh. Here the length of the added network is 3200 m in trench length from the BLS units to the existing network. Therefore, the heat load density amounts to 3.4 MWh/m (=11000/3200), which is well above 2 MWh/m threshold, thus economically justifying the DH connection.

The threshold value of 2 MWh/m is a rule of thumb, which is based on a large number of feasibility studies having analyzed whether DH is the least cost solution to be built/ rehabilitated or not. The values higher than 2 MWh/m are like sustainable DH cases, whereas the densities below 1 MWh/m rarely are. The values between 1 and 2 require a detailed analysis whether DH is economically justified or not in the particular case.

In Finland, for instance, the country wide average was 2.2 MWh/m in year 2014 for reference (source: Finnish Energy).

The capacity of the BLS and its connection pipeline are determined in the following ways:

1) The heat exchanger for space heating is based on the heat load of the building plus 30% back up in terms of $W/m^2$ excluding DHW. Thus, if the design heat load of the building is 100 kW, for example, the heat exchanger will be 130 kW as the oversizing does not cost much but offers safety margin in case there is a temporary problem with the inadequate supply water temperature in the DH network.

2) The heat exchanger for DHW is designed according to the recommendations of the Finnish Energy. The following examples are given to the DHW heat exchanger capacity depending on the number of apartments: 1 apartment: 60 kW; 50 apartments: 330 kW; 200 apartments: 630 kW.

3) The control valve has to have at least 2/3 of the pressure difference prevailing over the substation in order to be able to control. Usually the pressure difference over the heat exchangers is 0.2 bar (20 kPa) and the difference over the substation about 0.6 bar (60 kPa). With the example of the 100 kW building, the control valve shall be sized according to the real maximum water flow corresponding to the 100 kW design load and 50 $^{o}$C temperature difference. In addition the heat meter causes some pressure loss.

4) The pressure difference requirement of the BLS unit, including the heat meter, the control valve and the heat exchanger(s) is 1 bar (100 kPa) in total. If the pressure difference is usually more than 4 bar, there should be a pressure difference control valve to “kill” the excess pressure difference and to enable the smooth operation of the BLS.

5) The diameter of the connecting pipe, according to the Finnish District Heating Handbook from year 2006, is based only on the heat load of the space heating (W) and the 50–70 °C water temperature difference, the difference depending on the age and type the particular building, and the pressure loss. The pressure loss of the connection pipeline is normally 2 bar/km for pipe, equal to 4 bar/km of pipeline (1 pipeline = two pipes), In cases when the customers will be connected to the end of the network branches, it means far away from the nearest heat source, 1 bar/km (2 bar km for pipeline) is used for the connection pipe design.

6) The DHW load is taken into account by selecting the standard connecting pipe one category larger than without DHW. For instance, if the design shows the space heating would require DN50, then DN65 will be chosen to cover the DHW load as well.

The BLS shall be purchased and owned by the customer. The DH company often maintains a list of accredited contractors that are certified to install BLS units and connect them to indoor and DH networks. The customer shall organize competition amongst some of them to detect the lowest price. Anyway, the DC company expert will install the heat energy meter (ARM[4]-meters) to the front of the BLS with a

[4] Automatic remote read meters

sealed fuse; check the technical connection, thermal insulation, the existence of a drainage chamber in the floor, and tuning of the control system and the overall performance of the BLS during the commissioning stage.

**Regional piping**

The regional piping layout design will be done in a way to minimize the length of the network. The length is critical because of investment costs and operation and maintenance costs. The heat losses, for instance, are proportional to the length of the pipeline.

Traditionally, when constructing a new DH system in China, the heating company is responsible for the primary network and the GS, whereas the real estate developer for the secondary network and the indoor heating installations. Now, introduction of the BLS would change the responsibility border, and the associated cost allocation.

- The heating company should extend the primary network from the avoided GS up to the building entrances.
- The real estate developer does not need to install the underground secondary network but should install the BLS into building basements where room space should be reserved for BLS.

## 4.2 Technical Requirement of the BLS Connected with Existing Heating Network

The pressure difference at the gate valves of the BLS has to be about 1 bar (100 kPa) at minimum for the BLS to function properly. The 1 bar pressure difference is needed for the pressure losses in the water flow sensor of the heat meter, the heat exchanger(s) and the control valve. On the other hand, if the pressure difference is very high about 4 bar or more, as the BLS will be near to the heat source, a pressure difference control valve is suggested to the inlet of the BLS to prevent too much pressure difference for the control valve to control.

The diameter of the connection pipe of usually PN16 (or sometimes PN10) shall be sized according to the pressure loss; normally 2 bar/km for pipe and equal to 4 bar/km of pipeline. In special cases when the customers will be connected to the end of the network branches 1 bar/km (2 bar/km for pipeline) is used instead for the connection pipe design.

The water temperature requirements are the same as with group substations connected to the same primary network.

Based on the calculations and experiences, the costs of the two parties do not change much, when the BLS system will be chosen instead of the traditional GS system in a new construction area. Therefore, there seems not to be any substantial financial barrier to introduce BLS. Rather the problem seems to be how to find room space in the building to install the BLS. Sometimes, as in Weihai, Shandong province, the BLS units were installed in separate steel plate covered boxes near to the heated buildings.

Nevertheless, the investment cost sharing between the DH Company and the developer should be clear. The current responsibilities seem simple and fair: The DH Company invests in primary network extension to the room of the BLS and the developer invests in the BLS and the indoor heating system.

In Europe various cost sharing ways are applied, even in one company. The customer may choose whether he wishes to own the substation or not. If yes, his annual payments to the DH Company will be lower than if the DH Company would own the BLS.

## 4.3 Transition from the GS to BLS

There is vast experience in Central Europe in converting the GS to BLS since year 1993 already. The first conversions were made in the World Bank funded projects in Estonia and Poland as well as in the German financed projects in East Germany (previous DDR). Thereafter, numerous conversions have materialized in Europe, and the conversion has become a rather standard requirement of many international financing institutions (WB, EBRD, EIB, NEFCO).

Actually, the technical conversion is not complicated. The BLS units will be mounted to the buildings, either in the special technical room, or on the inner or outer wall of the building. A physical restriction may appear as there is no basement typically in the apartment buildings in China. Having no basement, the BLS can be installed outside the building, either hanging on the outer wall of the building up to some 200 kW capacity, or larger capacity BLS units in to a separate cabin to be installed near to the building wall. In either case, the BLS has to be covered with thermally insulated (polyurethane plates) steel walls. The cabin has to be equipped with a locked door, to which the key is given to a very few certified persons. An example of the BLS installed to the cabin is given in Fig. 13.

The primary network with high pressure and temperature will be extended from the current network to the building walls to connect the BLS unit. The existing secondary network can be left idle or removed. In case the existing secondary network will be removed, the underground trench may be used for the primary network extension. If the network layout can be revised to have the total pipeline length shortened, some additional digging is needed for the new trenches. In Europe, sometimes the existing secondary pipeline could remain untouched in the ground and become a primary pipe. This was possible if the design pressure class of the secondary network was adequate PN16, for instance, thermal compensation was done and the pipeline was still rather new.

**Figure 13.** A BLS installed outside the building in a thermally insulated cabin in Weihai, Shandong province in year 2007 (source: A. Nuorkivi).

As the result of the conversion, the GS building remains empty and can be used for other purposes: indoor sports, small industry, a meeting room, etc. or be removed to have free land area for children or parking, for instance. Thus, the conversion of GS to BLS would improve the living comfort in the area.

# 5. Issues and Resolutions

## 5.1 Challenges to the Heating System

There have been BLS units in operation for several years in various parts of China, but still very little analysed information is available on their real performance in terms of energy efficiency.

So far, there have been challenges to commission and analyse BLS in China due to institutional resistance, which has been seen in the following forms:

- The BLS changes the responsibility border between the parties, the DH company and the real estate developer. The parties do not see an incentive to work over the traditional border to facilitate BLS.
- The technical design institute has little or no experience in the BLS concept, its design, requirements and benefits. Therefore, it rather designs traditional solutions.
- DH operators have had little or no trust in the independent and automatic operation of the BLS, but the automation may have been switched off and the BLS has been operated manually. Therefore, the collected data is not completely relevant for analyses.

The DH companies, after the international financing is over, have not always shown interest in recording and giving metered data for the analysis to be carried out by an external body.

## 5.2 Ownership and Maintenance of BLS

Traditionally, when constructing a new DH system in China, the heating company is responsible for the primary network and the GS, whereas the real estate developer for the secondary network and the indoor heating installations. Now, introduction of the BLS would change the responsibility border, and the associated cost allocation.

- The heating company should extend the primary network from the avoided GS up to the building entrances.

- The real estate developer does not need to install the underground secondary network but should install the BLS into building basements where room space should be reserved for BLS.

Currently in China, the developer would be responsible for financing the BLS if implemented. The responsibility of operating should be with the DH Company as there is no market yet specific to operation and maintenance of the BLS outside the DH Company. Therefore, the DH Company would have the know-how to maintain the BLS and interest in it as well, because the technical performance of the substation, both BLS and GS, reflects to economy of the entire DH system.

The BLS ownership could be transferred from the developer, or the customer, to the DH Company as is currently done with secondary networks already.

In Europe, the ownership of the BLS varies even in a country. Either the DH Company or the heat customer can be the BLS owner.

Regardless who the owner is, the authorized customer representative, the property management company, should have access to the BLS room to tune the BLS operation according to the building specific needs.

## 5.3 Institutional Barriers and Responding Measures

An institutional barrier concerns the interest of the heating company and the developer:

- Heating company may wish to minimize the life cycle costs as it will be responsible for operation of the system in the future. Given that, the operation costs including water, heat and electricity losses as well as repair costs are important to run the business. The lower the costs are, the higher the profit would be unless the regulator distributes the cost savings to the end-user tariffs.
- Real estate developer wishes to sell the apartments at high profit. Therefore, it tries to minimize the investment cost related to heat supply, thus often yielding to poor materials and poor construction quality.

Then, after the building has been commissioned, usually the heating company has to take over the operation of the secondary network, the construction of which was out of the company's quality control.

## 5.4 Cost Sharing

The heat customer, paying a lump sum for DH regardless the quality and energy he has received, is not interested in energy saving.

The DH Company having a constant cash flow, based on the lump sum tariff, has an incentive to minimize the fuel costs as a means to gain profit. From time to time, this may compromise the heating quality of the customers. The customers being at the far end of the distribution network suffer more for the inadequate heating quality whereas the other ones being closer to the heat source, the GS, may have even excess heat to be ventilated out from the windows. Typically, there prevails imbalance of heating quality in the secondary networks at present.

Based on the calculations and experiences, the costs of the two parties do not change much, when the BLS system will be chosen instead of the traditional GS system in a new construction area. Therefore, there seems not to be any substantial financial barrier to introduce BLS. Rather the problem seems to be how to find room space in the building to install the BLS. Sometimes, as in Weihai, Shandong province, the BLS units were installed in separate steel plate covered boxes near to the heated buildings.

Nevertheless, the investment cost sharing between the DH Company and the developer should be clear. The current responsibilities seem simple and fair: The DH Company invests in primary network extension to the room of the BLS and the developer invests in the BLS and the indoor heating system.

In Europe various cost sharing ways are applied, even in one company. The customer may choose whether he wishes to own the substation or not. If yes, his annual payments to the DH Company will be lower than if the DH company would own the BLS.

# 6. Technical Issues

## 6.1 Make-up Water

There are three alternatives to supply make-up water to the indoor heating system, as follows:

- First, city water will be taken and stored in an open basin and softened before supply to the heating system. The water storage basin and the softening system need relatively much room space which is costly. On the other hand, the price of the city water is lower than the price of the treated primary network water.
- Second, the primary network water can be tapped to the indoor heating system. As the treated water is relatively more expensive, the water management in the indoor heating systems should be good: no water losses and expansion tank.
- Third, the city water is taken directly from the city water network and led to the indoor heating system without any open air basin. Typically in Europe and America, mainly this third alternative is used which leads to make-up water savings.

The most used material in the water systems is steel, and its corrosion rate depends on the content of oxygen in the water. In closed systems, where the oxygen content is constant, the corrosion rate increases straight as a function of temperature. When the steel reacts with oxygen, it can produce an oxide layer on the surface of steel. If the oxide layer is tight, it can be protective. If the oxide layer is porous, it is not protective. Corrosion can perpetuate in the pores and the local effect can be severe, because the anodic area versus cathodic area is small. Chlorides have deleterious effects. They can diffuse through the passivation layer pitting and crevice corrosion. The solid particles in the water can cause erosion corrosion by abrasive wear of the surfaces. Erosion corrosion is said to have its maximum around 150 °C temperature.

The actions concerning the make-up water are to soften the water and to remove salt by an ion-exchanger in the first place. Removing of oxygen is intended to carry out as a side circulation for both the additive water and the water in the network chemically or thermally. Also the pH value should be raised to a level 9–10, where the corrosion due to oxygen has its minimum.

## 6.2 Expansion Compensation

Based on water physics, both water volume and density change along with the temperature variations. At present, the expansion is compensated by the overflow valve. As the pressure increases, the valve opens and releases excess water to the sewage or the open-type make-up water tank.

In China for the time being, the water losses in the secondary side are so high that there is no possibility to closed water circulation in the secondary side. Make-up water flow is constant ranging from 1 to 3% of the secondary circulation water flow.

As the BLS will become more common, and the make-up water flow will substantially reduce, expansion tanks can be installed to the BLS. In such a way, the water losses will reduce even more, and almost vanish. Thus, the indoor piping system would become a closed loop without constant make-up water need.

## 6.3 One- or Two-Way Control

In China, the communication functions in two-ways. Measured data can be collected both into controller of the substation or remotely to the control centre. The control centre may locate either at the main heat source or at the headquarters of the DH company. Second, by means of remote control system, the operator can remote manipulate the set values of the pumps and valves at the substation, thus bypassing the local automation of the substation.

Moreover, if the number of the substations is high, the operator staff is not able to manage the substations other than relying on the electronic automation systems functioning in the substations already.

In China, there have been examples that the set value manipulation, while bypassing the automation of the substation, has caused excess heating costs.

While analysing the remote metered data, the operator can identify those substations in which the measured data seem abnormal, and if so, send a maintenance staff to check the substation functioning. Such indicators of abnormal operation compared to measured date from the other substations are, for instance:

- The difference of supply and return temperature is very low, which may indicate there is excess pumping in the secondary side. This can be corrected by reduced pumping.
- The make-up water losses are high. Either there is a leakage to be repaired or the customer illegally taps water for his own needs.
- Heat consumption is high/low per heated area, which indicates there is a need to adjust the temperature values of the control systems of the substation.
- Alarms of unexpected events of doubtful data.

## 6.4 Heat Exchanger Design

Often the rubber sealed heat exchangers are undersized, which is one reason to small temperature difference on the secondary side. Another reason is excess pumping caused by too powerful pumps.

In order to have the heat exchangers adequately sized, there is a non-profit standardization institute AHRI based in the USA. AHRI is the only third party heat exchanger verification institute in the world. Most international heat exchanger manufacturers are members of AHRI (Fig. 14).

AHRI Standard 400 is a global standard stipulating the verification of thermal performance of liquid-to-liquid heat exchangers.


**Figure 14.** Label and contact information of AHRI.

AHRI uses the "AHRI Liquid To Liquid Heat Exchangers (LLHE) Certification Program" to verify the heat exchanger performance.

The manufacturers are forced to deliver their heat exchanger design software programs to AHRI. Whenever there is any doubt the heat exchanger does not meet the required temperature values, AHRI can be asked to test the particular heat exchanger. The costs of the testing shall be paid by the manufacturer in case the heat exchangers failed, or the requestor, if the heat exchanger met the set requirements.

## 6.5 Heat Meter Reading Combined with Remote Controlling

Regular heat meter reading is vital in case consumption based billing is used.
In China, the consumption based billing is still to expand outside the already existing pilot cities.

As ways to collect metered heat consumption, the following options are available:

- Automatic remote reading through the SCADA.
- Mobile remote reading by means of car driving in the neighborhood of the buildings.

- Manual recording on the paper cards that the customer shall fill-in and mail to the DH company at the end of each month.

Consumption based billing is used 100% in the EU, North-America, and South-Korea on the building level. Apartment level metering is rarely applied as billing as there are both excess costs and inaccuracies related to apartment level heat metering. Those apartment level meters already existing are often used to allocate the heat consumption of the building to the apartments. Specific heat cost allocators are used often to allocate the heating costs of the building to the apartments.

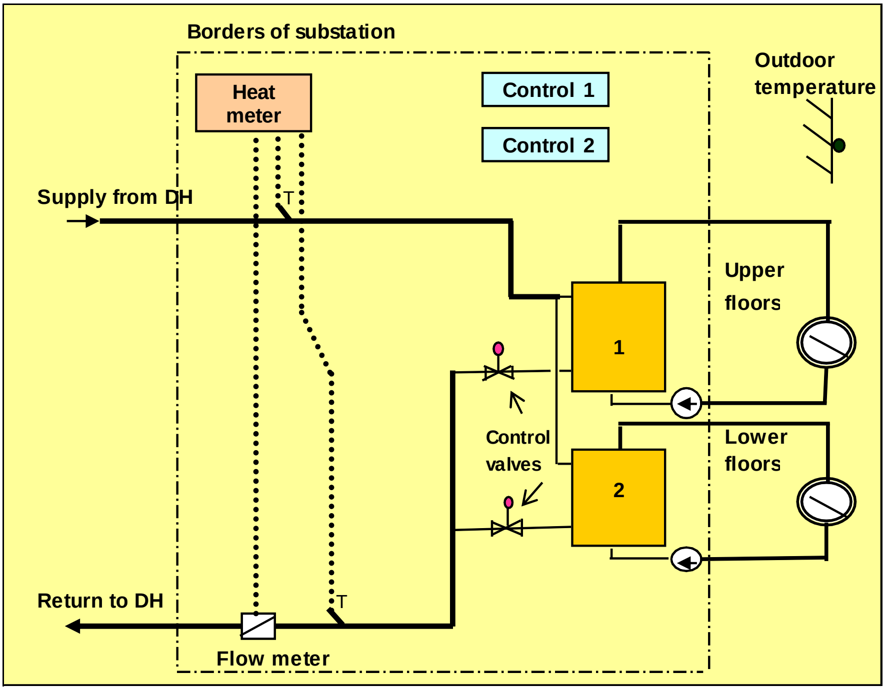


**Figure 15.** The BLS for up to 24 floors in building with two heat exchangers and control systems, one for floors 1–12 and the other one for 13–24. More heat exchangers and control systems can be added if more floors exist in the particular building. No changes in the primary network are needed.

The main components of the BLS (Fig. 15) comprise the heat exchanger (orange color) separating the primary and the secondary water networks, the temperature control valves (pink), outdoor temperature controller (light blue) and the heat energy meter (light red) with two temperature sensors and one water flow sensor. The water flow sensor is installed in the return pipe on the primary side.

The substation automation is the same in GS and BLS, but within BLS it works more accurately as being specific to the individual building. The automation regulates the heat supply by means of two measurements, as follows:

- The outdoor temperature measurement tells to the temperature controller how much heat is needed.
- The supply temperature of the secondary/indoor piping tells to the controller how much heat is currently supplied to the buildings or buildings.
- The controller regulates the control valve by opening if more heat is need and throttling if less heating is needed.

The automation system shall be tuned according to the requirements of the connected heat load. Basically, the tuning is very simple: The set value of the supply water temperature will be given respective both to the outdoor temperature starting the heating, let us say +17 °C, and the nominal design temperature, let us say –20 °C. The supply water temperature set values depend linearly on the actual outdoor temperature.

As an ECO-function, the circulation pump may stop temporarily when the outdoor temperature is very high, usually in day time during sunny spring and autumn.

The flow sensor of the heat energy meter should be installed in primary side of the BLS either:

- in to the return pipe where the water temperature is more stable than in the primary side, and the meter reading therefore more accurate as used in Finland; or,
- on the supply side in case the water losses inside the building are relatively high as often in China, and there is a need to charge the water losses in the heating bill at least in some extent.

## 6.6 Automation

The old DH system scheme is illustrated in Fig. 16 left below having had prevailed in the past in China and Russia. There was neither control at GS nor in buildings, but only manual temperature control at the heat source. The old case is used here as the reference case with zero energy savings.

The current practice in China is to equip the GS with temperature control systems (right), which save 7–15% heat energy compared to the old practice with no control at all. The GS controls the supply temperature of the secondary network according to the outdoor temperature. Those buildings being close to the GS may receive excess heat whereas the others being at the end of the network less than needed as the secondary network may not be in balance at all times.

The heat energy savings mentioned in the Figures assume that the required room temperature is the same in all cases.

The closer the temperature control is to the customer, the more accurate is the control quality for the end-user at the apartment. Based on the accurate control, the problems with over and under heating of apartments will substantially fade, thus reducing heat losses in buildings.

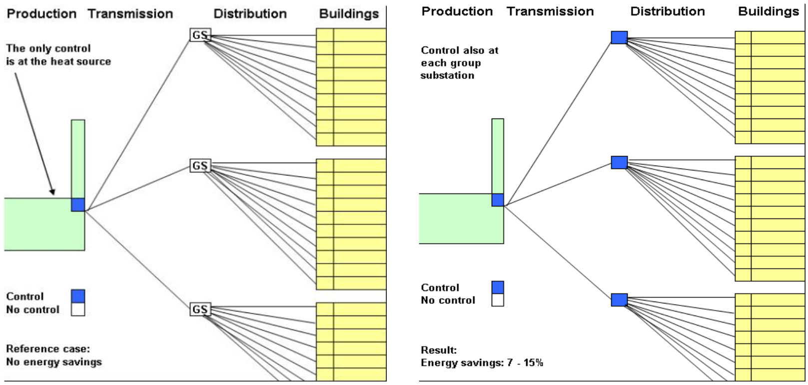


**Figure 16.** Reference case with manual control at heat source only (left) and the current Chinese practice to have the automatic temperature control at each GS (right). The energy savings of the automatic GS reach from 7% to 15% relative to the reference case. The blue squares indicate temperature control whereas the white squares without such control.

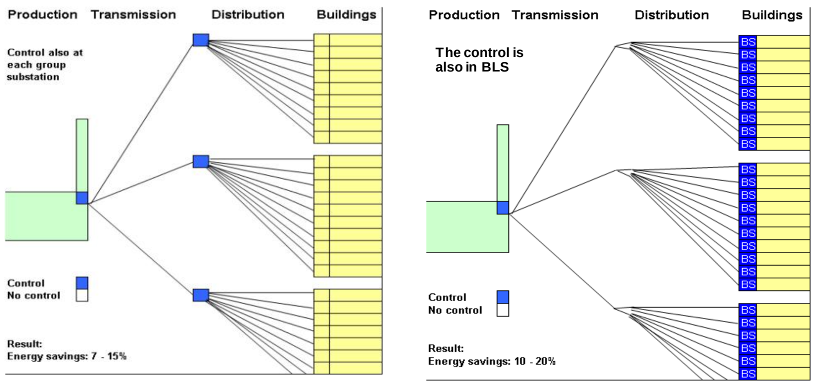


**Figure 17.** The GS (left) is replaced by BLS (right). Simultaneously, the temperature control has moved from GS to each BLS, where the temperature control can be tuned to reflect the behaviour of the particular building. The heat energy savings range from 10 to 20% compared to the reference case.

In China, as in all countries in the world, people want to have a constant improvement on the living quality. It may mean better or more food, better possibilities to travel, larger variety of entertainment, etc. Improving quality of heating is certainly one of those trends of wanting. The heating quality means that room temperatures must stay adequate and stable to meet the increasing requirements of living comfort. To meet the requirements, the BLS offers a response better than the current GS (Fig. 17).

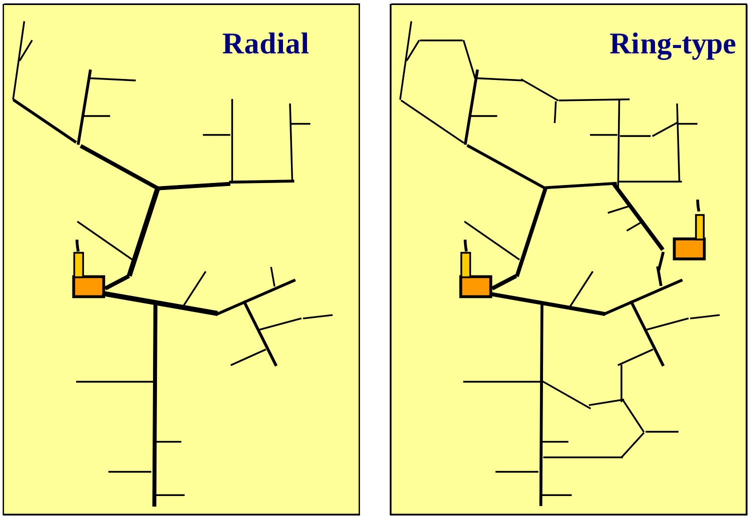


**Figure 18.** One heat source per network in the radial (China) versus two or more heat sources in the ring-type network (Finland).

The ring-type primary network becomes possible when all substations, regardless whether GS or BLS type, are equipped with temperature control (Fig. 18). The temperature control makes the substations automatic and independent. In practice this means that the substation functions if there is adequate pressure different on the primary side, about 1 bar (0.1 MPa), and the supply temperature is on the level required by the actual outdoor temperature. Thus, the automatic substation is independent on the direction from where the heat comes to the substation. Therefore, the substation can be connected to a ring (e.g. a loop) of the primary network having two possible directions to receive heat. Two directions improve the reliability of heat supply compared to the radial type. Moreover, the looped network allows economic load dispatch which sets the CHP to be a base heat source and the HoBs to remain as peak and back-up heat sources, as demonstrated in the Helsinki example above.

A new requirement shows up when the DH network operation will be converted from the radial to ring-type operation. Hydraulic analysis of ring-type networks is not possible any more to be carried out by manual calculation but the analysis requires a sophisticated software designed for ring-type network analyses.

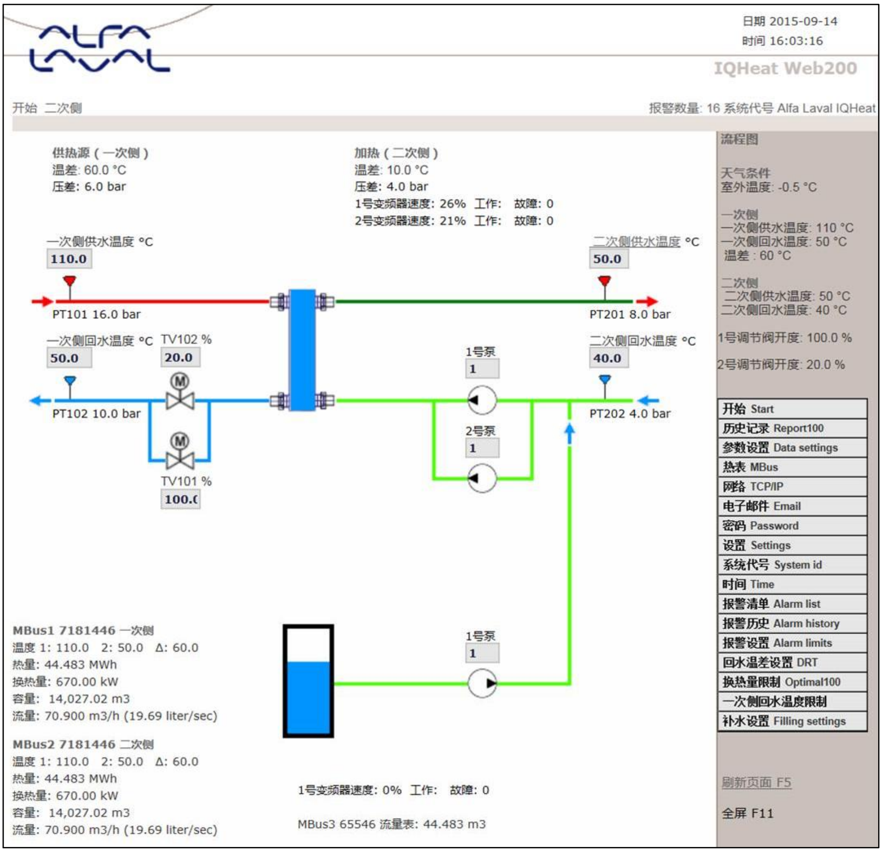


**Figure 19.** Control screen of substation.

## 6.7 IT Tools for Optimization

Appropriate software helps district heating companies improve energy efficiency, increase security of supply and save on costs. Two internationally used software tools of Enoro are mentioned here (Fig. 20).

Enoro's GRADES Heating software is a network calculation and simulation tool that is used to improve overall network design and operation. The graphical user interface includes a map view for visual network design and simulation calculations. When the design of a DH network must be changed – for example to add BLS units, heating consumers, or network areas – GRADES Heating helps find the optimal new network dimensioning (sizing for pipes, pumps and valves), to increase energy efficiency and save on costs without reducing security of supply. In daily DH operations, GRADES Heating can be used to evaluate different scenarios to find the best network operation plan for the coming days.

The GENERIS energy information system provides a measurement data warehouse for the centralized management of all measurement data measured from DH networks. Collection of measurement data from as many network locations as possible provides valuable information about the status and dynamics of the entire DH network. In addition, measurement data can be used to improve the accuracy of network simulations. When GENERIS is also given data about the costs of heat production (e.g. production plants and fuel costs) and about sales models (i.e. sales contracts and tariffs), the system will provide the heating company with a complete and detailed overview of their entire heating business as a basis for planning future business operations.

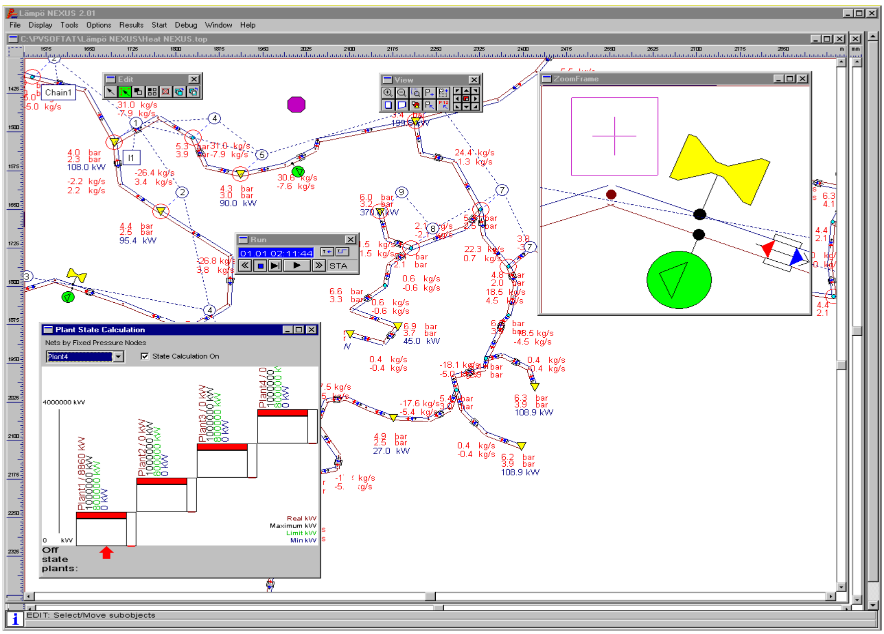

**Figure 20.** Example of looped network optimization with GRADES software.

## 6.8 Noise

The BLS units are silent as they are both designed and tested in the factory already to be installed in the living environment not to disturb anybody. The smallest substations can be installed in the living rooms, when the substations are apartment level substations, as show in Figure 21 below.

The noise level of BLS is below 35 dB, which is mainly caused by the water flowing in the pipes. Also some little noise comes from the controller as it is knocking when doing the controlling work. As wet pumps are used, the pumps are silent and noiseless.

**Figure 21.** Two apartment level substations for 150 m$^2$ (left) and 300 m$^2$ (right) heated areas including both DHW and SH services.

## 6.9 Safety

The BLS is equipped with an excess pressure valve, e.g. a safety valve, which releases the excess pressure out of the BLS and the DH system.

The high pressure and temperature up to some 10 bar and 120$^o$C, respectively, can temporarily prevail in the primary network in the entrance of the substation. The pipes are from steel usually of PN16, which is designed for normal use in 16 bar pressure.

If problems occur, they start with small leakages in seams, which will be detected by the moist sensor located in the substation room or by the visual inspection regularly, once a week, for instance, carried out by the operation staff in the substation room.

# Annex 1: Sino-Fin Comparison of DH

The main differences between Finland, and typical to many countries in the EU, and China are collected to the table below.

**Table 5.** Comparison.

| Issue | China | Finland |
|---|---|---|
| Climatic conditions | 35–55° latitude;<br>-10...-35 °C minimum temperature | 60–70° latitude;<br>-25...-35 °C minimum temperature |
| New building code | New buildings with 50% energy reduction from the 1980–1982 building code | Low energy buildings from 2012 on |
| Status of DH | Strongly expanding 13–18% /a | Rather saturated market, 1%/a growth |
| Products of DH | Only room heating: DH system runs during heating season only (5–7 months); DHW usually with solar collectors | Both room and DHW heating: DH runs<br>all year round |
| Type of room heating | Either radiator or floor heating | Radiator heating mainly |
| Heat metering | Rather common in group substations already, but rarely in buildings | Always in buildings |
| Number of enterprises | Several per city (In Tianjin used be 420 DH companies 10 years ago) | Usually one DH company per city but not<br>regulated by anybody |
| Heat tariffs | Fixed Yuan/$m^2$ | Two tier tariffs based on metered heat consumption |
| Basis of heat billing | Building norms | Metered heat consumption |

| | | |
|---|---|---|
| Heat distribution | DH company delivers via primary network to group substations, from which further on vie secondary networks to buildings | DH company delivers via primary network directly to the buildings, where building level substations |
| DH sector regulation | Strictly regulated, socially motivated | Almost no regulation but market based business |
| Specific heat consumption | 100–200 kWh/$m^2$ | 130 kWh/$m^2$ including domestic hot water<br>130 kWh/$m^2$ |
| Quality of heating services | No heating in early autumn and late spring, sometimes inadequate room temperatures in winter (World Bank customer surveys) | Comfortable heating services all year round, customers are highly satisfied according to the surveys carried out. |
| Type of networks | Branched: one heat source per network | Looped: several heat sources in one network |
| Expected lifetime of the network pipelines | 10–30 years. The main problem is the corrosion in the secondary networks | Longer than 50 years. At present, only 0.5% of the networks country wide are replaced annually (equals to 200 years lifetime) |
| Circulation water losses | The water losses are typical high 1–3% of the water flow. | Water losses are low: 0.08% of the water flow. |
| Circulation water quality | Water quality is poor and corrosive in the secondary side. | Good quality of water and no corrosion. |
| Heat production | About 35% from huge CHP plants and the rest 65% from coal fired water boilers of 29 to 64 MW and a little from industrial processes | 70% from CHP, 30% from industry and heat only boiler sources |
| Heat production capacity | About 100% of peak load, no back up | 120...200% of peak load including back-up |
| Fuel | More than 95% domestic coal | Mix of bio mass (31% in 2014), natural gas (22%), coal (24%), peat (13%); oil (3%), waste heat and other (7%) |
| Corporate structure | CHP state owned, DH city owned, secondary networks owned by customers | DH and CHP mainly city owned in one company, no secondary networks |
| DH company | Operation and maintenance focused utilities | Full scale business units |

# Annex 2: Global Trends

## District Cooling

As the heat loads decline, due to constantly improving energy efficiency of the buildings, the DH companies have started looking for new products. As a major new product, district cooling (DC) has shown up. District cooling can be integrated with district heating to form DHC.

DC can be developed as a complementary product to CHP and DH as the cooling demand will increase both due to climate change and the energy efficient buildings, and perhaps even more due to increasing indoor air quality requirements that have a big impact on human health and comfort. The modern energy efficient buildings have substantial indoor heating sources as both the increasing number of electric appliances, even though the new ones being more energy efficient than the old ones, and the inhabitants emit heat. Therefore, heating needs tend to decline while the cooling will increase. Using heat pumps for combining DH and DC is a good idea that has been adopted already successfully in many cities in BSR, for instance, in 8 cities in Finland (Helsinki, Espoo, Vantaa, Turku, Heinola, Lahti, Tampere, Kuopio), and in as many as 35 cities in Sweden. The largest DC suppliers are FORTUM in Stockholm, the Tekniska Verken (Technical Works) in Linköping and HELEN in Helsinki. An absorption chiller connected to CHP power plant is also good way to support CHP production to reach CHP's minimum heat load especially in summer time when district heating demand is not so high. Free cooling from see and lakes are also used for DC.

Advanced use of waste heat and cooling sources with heat pumps and integration of DH and DC systems increase the overall efficiency and reduce emissions. The optimum temperature level of the heat source will depend on the actual conditions at the power plant, and consequently, a feasibility analysis is required in each individual case to determine the optimum plant configuration.

Many customers having both DH and DC use both products in parallel around the year: DH to deliver DHW in summer and DC to chill IT server rooms in winter time. In future, due to global warming and highly energy efficient buildings, the cooling needs may increase whereas the heating needs will decline. Today in the office buildings the need of cooling is already higher than the need of heating. Surprisingly, in many modern buildings even as north as in Finland, the cooling peak load is already higher than the heating peak load.

DC integrated to DH is the only way to use solar energy in densely built urban centres to produce DHW. Integration of solar to DC proceeds in three steps is as follows:

- In summer time, the buildings are naturally heated by solar radiation.
- The DC system absorbs the excess heat from the buildings and transfers the waste heat to the DH system by means of heat pumps.
- In DH, the waste heat recovered from the DC system is used for DHW heating to substitute fossil fuels. Thus, the solar radiation in the 1st step was converted to DHW heating in the 3rd step.
- Also active solar driven absorption chillers are used for cooling. Then production and demand will meet each other.

Let us imagine that in case the DHC system would not exist at all but the DHW should be produced with individual solar collectors. In Helsinki, for instance, the capacity of the solar collectors would require a surface area equivalent to the size of 30 football courts to be located in the already densely built Helsinki peninsula. It is obvious that it would be difficult if not impossible to find such a large surface available for solar collectors in a densely built city center, but the integral DHC solves the surface problem in an optimal way.

The DC system of Helsinki as an integral part of CHP, DH, solar heat recovery and cold storing has been several times awarded by the international organizations such as Euroheat & Power, International Energy Agency (IEA) and International District Energy Association (IDEA) due to its high level of innovations and system integration, the latest award dating April 2015 titled *Global District Energy Climate Awards*.

## 4th Generation of DH[5]

The DH environment is constantly changing: First, the buildings consume less and less heat energy, which creates challenges to the capital intensive DH and CHP to remain competitive and economic in the future. Second, fighting Climate Change requires RES to substitute fossil fuels. Many RES types benefit from low temperatures in the DH.

In general, there are three basic possibilities to replace the current use of fossil fuels: (i) energy efficiency measures that reduce the need of primary energy in general, (ii) renewables that can substitute fossil fuels, and (iii) heat recoveries that can substitute any fuels.

[5] Prof. Sven Werner, Halmstad University, Sweden in 8th Cold Climate Conference, Dalian, Oct. 2015

Here is list of changes in the supply side that encourages a new type of DH, let us say the 4th generation DH, to gradually come into place:

- Biomass and waste used in HoBs and in steam driven CHP plants with flue gas condensation allow the overall heat production energy efficiency to rise, even above 100% as the moist content of the flue gases will be condensed, and the condensing heat will be recovered to the DH return water pipe of the system.
- Heat can be recycled from biomass and waste refineries
- Heat can be recycled from energy intensive industrial processes
- Heat can be recycled from electricity intensive users, such as large data processing centres
- Natural geothermal deep heat resources will become increasing important as the depth of drilling increases
- Thermal solar collectors as already used in China in large scale could supply excess heat to the DH network if the BLS will be constructed in a two-way supply mode.
- Excess electricity generated by fluctuating solar and wind power can be used in large heat pumps and electric boilers.
- Heat storages for both daily and seasonal purposes can smooth the heat load variations, thus improving overall economy and reducing the need of fossil fuels.

All the new supply technologies become more efficient and competitive if the DH supply temperatures become lower than today. Hereby, the network temperatures become a very important performance indicator for the 4th generation DH systems.

How could lower network temperatures be reached? There are two main strategies to reduce DH network temperatures:

1. Elimination of all current temperature faults in distribution networks, substations, and customer heating systems (about half of the required efficiency change from 3rd generation to the 4th generation DH)
2. Reduced heat demands in both new and existing buildings or increasing radiator surfaces (about the other half of the required change)

Hence,

- The HVAC[6], heat pump, and district heating communities should co-operate in order to get low temperature space heating systems in the future.
- The low temperature systems should be the main global strategy to increase the profitability of renewables and heat recovery in both heat pumps and DH systems.

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[6] Heating, ventilation and air conditioning

# Annex 3: Substation for Connecting the Building to Heating Networks

## Integrated meter section

Prefabricated meter section, integrated in the substation
Complete for metering of energy, except meter.
Vertical meter section with 10X before and 5X meter-DN after, in straight line
Pressure class PN 16 (or PN 25 bar)
Connection DN 50

Consisting of:

Strainer with draining valve
Thermometers 0–160 °C
2-point metering of pressure and differential pressure over strainer.
Manometer in return line 16 bar.
Temperature sensor connection DN15
Dummy flow meter threaded DN32 L=260 mm
Draining valve in return pipe
Connection for letting off air DN15 in supply line

## Heat exchanger system

Unit including programmable computerized control equipment. Unit is delivered mounted, wired and fully functional.

1. Heat exchanger system
2. Computerized programmable controller
3. Options to Controller

**1. Heat exchanger system**

Unit for heating of heating circuits. Stainless acid proof steel in heat exchangers.
Unit made and marked according to PED 97/23.
Prefabricated Heat Exchanger Unit,
Weight about: 180 kg

Unit equipped with sensors for measuring of temperature of incoming primary and secondary media.

Sensors replace thermometers for temperature reading.
Primary supply equipped with a summer shut off valve for Heating 1
Needed deration connections is included and draining with sealed flush valves.
The heat exchanger is insulated with CFC-free PU-foam, with an ABS surface. The insulation is easy to mount and dismount.
Steel pipes in the system are painted.

**Heating 1** secondary side with:

- Ball valve in return pipe
- Balancing valve in supply line DN80
- Safety pressure relief valve, DN25, 6.0 bar
- Filling of secondary side of type EN1717 EA.
- Connection for expansion line DN25
- Strainer in return line

Manometer for pressure and differential pressure reading 3 points, 0–6 bar

*Circulation pump*

Flow 6.09 l/s, lifting height 85 kPa

The pump has alarm signal, is prepared for external on/ off control, and has control input for 0–10V.
External pipe connection DN80

**2. Computerised controller**

Hardware is mounted in an electrical cabinet. It includes applications and functions for control and monitoring of the heating unit.
Controler has an inbuilt display, and can even in simplest version communicate via WEB, OPC and ModBus both RTU and IP, without options and add-ons. A modem port is also included.
M-Bus, Lon, advanced WEB, BacNet and other options included in delivery are listed under “3. Options” below.
Controller can be integrated and communicate with most Building Management Systems (BMS) and supports open communication standard like TCP/IP OPC and LON.
Optional communication module can be installed also afterwards, not needed to be part of initial delivery. The software can be replaced by use of the inbuilt SD-card reader.
Controller shall be completely installed, programmed and wired. Basic function of hardware and software, as well as sensors, actuators, pump control functions shall be tested before shipment.

**Control functions**

*Heating*

Outdoor compensated heating supply temperature is used. An outdoor sensor and a heating curve determines the wanted supply temperature of the heating supply. The heating curve is a 5 points curve + min and max value, adjustable at different temperatures.

*ECO-function heating*

Need- based control of control valves and pumps. At warm outside temperature all control valves closes, and the pump stops. Pump and valve exercise is performed at adjustable times.

**The controller shall be always prepared for the following functions:**

Reading of pulses from energy meter and/ or cold water meter.

Limiting/ control of difference between the primary return and the secondary return temperatures. When this difference is too high, this function limits the opening of the control valve, in order not to use more than necessary capacity and limit primary flow.

Limiting of return temperature primary side. Different settings depending on season.

Capacity or flow limitation.

**Alarm functions**

Controller has alarms for temperature deviations, sensor faults, pump alarms and external alarm inputs. Alarm message can be sent as E-Mail or SMS if unit is connected to internet, or via an optional Modem.

**Commissioning**

Startup is made according to instructions in the manual in the shipping documentation. Support available via internet (contact of the manufacturer).

**3. Options included in delivery**

These options are ordered and are part of the delivery:

**- Advanced webserver**

Advanced WEB- function, built in web server. Gives a graphical interface over the units functions. A large memory holds historical data (>20 years!) that can be presented in the user interface. All settings, optimizations and alarm handling can be made via this user interface. No licenses, no programs needed, no web-hotels etc. Only a PC with a web browser program is needed. Internet connection on both the Controller and the PC is needed.

Alarms as SMS to mobile phones via TCP/IP is prepares, as well as e-mail alarm.

A report function shall be included in Controller. It is a function monitoring system for historical data of the unit. The Report component shall have several loggers,

with different time horizons. In the user interface can be monitored 1, 2, 3 or 8 days of values in a graph, or as values in a table.
It shall be possible to download all stored data since the Controler was started up 8 every 10 minutes a value- set is saved. This data shall be accessible in an Excel file automatically created on demand.
The electrical cabinet shall be prepared with a 2 meter TCP/IP net work cable, that should be connected to the internet-supplier's network socket. Internet connection, subscription and socket are not part of this delivery.

**- Meter value communication**
Transmitting of meter values from energy meter and/ or cold water meter with M-Bus. Values gathered from the energy meter are volume, energy, capacity, flow and temperatures.

**- Pressure sensor 0–10 bar**
Pressure sensor 0–10 bar, output 0–10 V (24 V AC supply) for measuring of pressure in secondary side heating.

**Design data:**

| | |
|---|---|
| Available differential pressure min: | 100 kPa |
| Pressure Norm | |
| PN 16 (or PN 25) | |
| *Heating 1* | |
| Capacity | 500 kW |
| Temperature | 120-63.8 / 60-80 °C |
| Flow | 2.24 / 6.09 l/s |
| Pressure drop | 2 / 14 kPa |

**Control equipment:**

| | |
|---|---|
| Controller | |
| Heating 1 | |
| Temperature sensor | QAZ21.5220-150 |
| Sec. return sensor | QAD21/209 |
| Prim. Return sensor | QAD21/209 |
| Outdoor sensor | QAC 22 |
| 2-way control valve | VVF53 DN40 Kvs |
| 16.00, 25 kPa | |
| Actuator | SKD 60 |
| *Sensors primary side* | |
| Sensor primary return | QAD21/209 |
| Sensor primary supply | QAD21/209 |

Control equipment with sensors and actuators are internally wired. Outdoor sensor is supplied but not wired. Commissioning not included.

Supplied pumps are electrically wired. For 1-phase pumps for heating >6 A, Hot Water Circulation pumps > 2 A, double pumps and all 3-phase pumps only alarm and control wiring is made. Electrical main supply for pumps must then be done on site according to local regulations.

## TECHNICAL SPECIFICATION TABLE

| **HEAT EXCHANGERS** | **Unit** | | | **Heating 1** | | |
|---|---|---|---|---|---|---|
| Manufacturer | | | | | | |
| Type | | | | | | |
| Load | kW | | | 500 | | |
| | | | | **Prim.** | **Sec.** | |
| Temperature | °C | | | 120-63.8 | 60-80 | |
| Flow | l/s | | | 2.24 | 6.09 | |
| Pressure drop | kPa | | | 2 | 14 | |
| PED - category | | | | Cat 1 | | |
| Material | | | | AISI 316 | | |
| **Control equipment** | | | | **Heating 1** | | |
| Manufacturer | | | | | | |
| Controller | | | | | | |
| Control Valve | | | | | | |
| Flow | l/s | | | 2.24 | | |
| Pressure drop | kPa | | | 25 | | |
| Size / kvs | DN/kvs | | | 40/16.00 | | |
| Actuator | | | | SKD 60 | | |
| Control signal/Voltage | V | | | 24V / 0-10V | | |
| **PUMPS** | | | | **Heating 1** | | |
| Manufacturer | | | | | | |
| Type | | | | | | |
| Flow | l/s | | | 6.09 | | |
| Head | kPa | | | 70 | | |
| Power / Current | W / A | | | 769/ 3.38 | | |
| Voltage | V | | | 230, 1 phase | | |

| NETWORK, EXPANSION- AND SAFETY EQUIPMENT | | Heating 1 | |
|---|---|---|---|
| Network volume / lifting head for network | l/kPa | / 50 | |
| Expansion tank volume / prepressure | l/kPa | / | |
| Safety valve size / relief pressure | DN/bar | DN25/6.0 | |
| **SECONDARY SIDE PIPE EQUIPMENT** | | **Heating 1** | |
| Pressure drop | kPa | | |
| **PIPE SIZES** | | | |
| District heating flow/return | | DN50 | |
| Heating flow-return, pressure drop for pipes and components | | DN80 | |
| **OPTIONAL COMPONENTS:** | | **Measurements and calculation values** | |
| Balancing valve for heating / Pressure Drop (kPa) | | | |
| Manometer module for heating / secondary side | | 3 points, 0–6 bar | |
| Filling H1 | | | |
| Summer Shut Off Valve Heating1 | | | |
| Painting of steel Pipes | | | |
| | | | |
| Pressure sensor 0-10 bar, 0-10 V, 24V AC<br>IQ Web200 ( Incl. WEB Server, Report, E-mail alarm)<br>IQ Meter 200 ( M-Bus, meter communication) | | | |
| **ADDITIONAL INFORMATION:** Temperatures read from control centre. | | | |
| PED-category for substation Cat 1 | | | |
| Calculated available differential pressure of primary heating network min 100 kPa /max 600 kPa | | | |
| Integrated meter section with inlet strainer, sensor pockets and thermometers. Vertical return line with meter dummy Threaded, DN 32, 260 mm. Pressure metering in 3 points, 16 bar. | | | |

*Sponsors:*

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*http://www.energy.fi*

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*Enoro*
*http://www.enoro.fi*

*Kollmeks*
*http://www.kolmeks.fi*

*Högfors valves*
*http://www.hogfors.fi*

*Vexve*
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Series title and number

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| Title | **The building level substation – the innovation of district heating system** Version II |
|---|---|
| Author(s) | Kari Sipilä, Arto Nuorkivi & Jorma Pietiläinen |
| Abstract | The building level substation (BLS) is suggested here as an innovation to the District Heating (DH) sector development in China. Introduction of the BLS would provide obvious benefits in improved energy efficiency and living comfort, but it also faces institutional barriers to overcome. CHP concept will be described, and the economic, institutional and technical issues associated to BLS will be addressed.<br><br>The BLS units are prefabricated compact products that are designed, manufactured and tested at the factory ready for transportation to the construction site, where the complete BLS unit will be mounted to the floor, connected to the existing indoor piping of heating and water, the remote communication facilities as well as to power supplies of the building.<br><br>The BLS as an integrated plate heat exchange unit shall be prefabricated and assembled and successfully tested both hydraulically and electrically in the factory already to meet the high functional and low noise requirements, and if he so wishes, at the presence of the Borrower's representative. Its base and brazed structures should have sufficient intensity and stability.<br><br>Domestic hot water (DHW) can also be integrated to DH. BLS makes it possible to complement the DH with DHW afterwards at low incremental costs: a small heat exchanger and a small circulation pump as well as connection to the existing DHW and city water piping are needed. BLS can be also equipped with an automatic remote red meter (ARM) to follow energy consumption.<br><br>This BLS manual is updated from the 1st version done in Oct. 2015 (VTT Technology 231, available at: www.vtt.fi/inf/pdf/technology/2015/T231.pdf). Chapter 2 and 3 are added into the 2nd version. Also some parts of the text are reorganized in new order and some text is added and some taken off. The text called "Global trends" is added in Annex 2. |
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# The building level substation – the innovation of district heating system

## Version II

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