A multi-criteria analysis of bidirectional solar district heating substation architecture

Nicolas Lamaison[1, 2], Roland Bavière[1, 2], David Chèze[1, 2], Cédric Paulus[1, 2]

[1] CEA LITEN - 17 Rue des Martyrs, 38054 Grenoble (France)

[2] INES - 50 Avenue du Lac Léman, 73375 Le Bourget du Lac (France)

Abstract

Decentralized surplus feed-in of solar heat into a District Heating Network (DHN) is here addressed. The heat collected from solar panels located on rooftops of DHN connected buildings may either be used locally for domestic hot water and space heating or fed into the heating network. Two-way substations able to transfer heat from and into the network seem then to be required utilities of future DHN. In that context, two equally important questions were identified: i) what should be the specifications and architecture of such solar fed bidirectional substations? and ii) what is the impact of decentralized reinjection on the network operation? The former is addressed in the present paper while the latter is an ongoing study not presented here. In the present work, first a discussion on the specifications and architecture of such bidirectional substations led to the conclusion that architectures for which the solar heat is entirely reinjected into the DHN without local consumption seem more feasible. Second, a Modelica-based modeling framework of the bidirectional substation is presented and preliminary results highlight the potential of reinjection on the DHN. The results presented here are part of the first year work in the frame of the European project 'THERMOSS'.

Keywords: Solar Feed-In, Decentralized, Substation, District Heating, Dynamic Modeling, Modelica, Prosumers

1. Introduction

In the "2way District Heating" course of action from the 4GDH concept (Lund et al., 2014), decentralized feed-in of solar heat from prosumers, i.e. customers reinjecting heat into a district heating network (DHN), seems to be a promising solution to increase the share of renewable energy of DHNs. The latter is especially true in dense urban areas with limited ground surface. Reinjection of solar heat will maximize the use of well-exposed customers' rooftops while minimizing the cost by mutualizing the equipment via the DHN.

However, when scattered heat reinjections occur in a DHN, new problematics arise. Among the most decisive ones, prosumers must decide whether it is interesting to consume or feed-in the collected solar energy, they must control their reinjection temperature in a context of variable differential pressure and the DHN operating company must deal with distributed reinjection points.

Among the various reinjection principles (see Fig. 1), the Return to Supply line (R/S) variant highlighted in Fig. 1a, seems to be the best option since it leads to the lowest temperature in the solar panels without modifying the network return temperature (Lennermo and Lauenburg, 2016; Schäfer et al., 2014). However, R/S feed-in implies to overcome the local differential pressure between the return and supply lines, which usually exhibits significant variations due to rapid load fluctuations. Moreover, the feed-in temperature must be superior or equal to the local network supply line value. The latter constraints on the local differential pressure and the local supply temperature involve at the bidirectional substation level the use of at least a variable speed pump and a finely tuned control strategy.

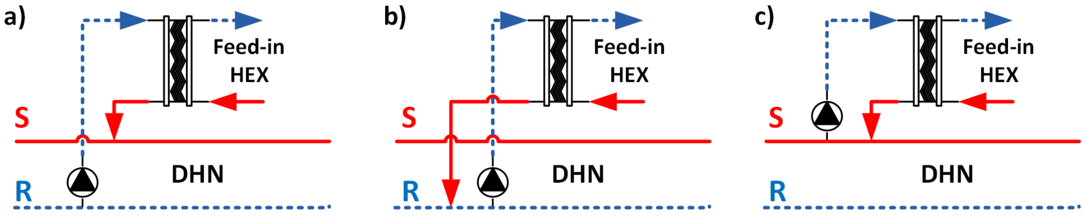

Fig. 1: Schematic of two-way substation feed-in strategies into a DHN – a) Return/Supply (R/S), b) Return/Return (R/R) and c) Supply/Supply (S/S)

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More than only considering decentralized reinjection like in Brange et al. (2016) or Heymann et al. (2017), it is of great importance to consider both the local consumption and reinjection of the excess heat as in Paulus and Papillon (2014) and Pietra et al. (2015). The local consumption possibility together with the local differential pressure and supply temperature constraints presented previously lead to the requirement of innovative control algorithm at the substation level (Rosemann et al., 2017). At the network level, the operation with multiple prosumers also becomes more challenging with the creation of new pressure cones for example (Brand et al., 2014) that may lead to flow stagnation in some parts of the network and even possible flow reversal at the main generator (Heymann et al., 2017). Additionally, the traditional critical differential pressure driven operation becomes more difficult to implement (Hassine and Eicker, 2014).

In this context, it seems necessary to address the question of bidirectional substation at both the substation and network levels. Thus, on the one hand, the present study addresses the specifications, architectures, and modeling of a two-way substation for a multi-family building including the possibility of local consumption. On the other hand, work on the influence of decentralized reinjection on the network's performance is ongoing but not presented here. These two studies are meant to be connected in future work by implementing the model developed in the first task into the network of the second task.

The present paper thus addresses the problem at the substation level. It firstly deals with the specifications and architectures of bidirectional substations. Features such as the location of the hydraulic separation between the network and the building, local consumption of the heat or total feed-in and control strategies are combined to build an exhaustive list of possible configurations. Secondly, a promising setup is chosen from that table based on a multi-criteria analysis. Finally, a modeling framework for the simulation of bidirectional substations is presented with preliminary results. Contrarily to most publications on this topic in the open literature, Modelica programming language is here used rather than TRNSYS (Paulus and Papillon, 2014), NetSim (Brand et al., 2014) or in-house tools (Pietra et al., 2015) since it has native multi-physical modeling capabilities (i.e. thermo-hydraulic) and allows for implementing new components. Both the details of the two-way substation and the impact of these prosumers on the network are thus studied using the Modelica "Standard" Library, together with the "Buildings" (Wetter et al., 2014) and the "DistrictHeating" (Giraud et al., 2015) libraries.

2. Bidirectional Substation Specifications

2.1. Initial Considerations

As previously discussed, the problem here addressed is the decentralized reinjection of solar heat on a DHN using R/S feed-in (see Fig. 1). The solar collectors are assumed to be on the rooftop of a multi-family building, equipped with a unique bidirectional substation (see Fig. 2). Variants relying on individual bidirectional stations at the apartment level have been discarded from this study due to prohibitive cost and increased complexity. Indeed, solar bidirectional substations seem more appropriate for multi-family buildings rather than for individual apartments (Rosemann et al., 2017) since it simplifies the hydraulic connections at the building level while reducing the costs. It also reduces the number of reinjection points in the DHN, aggregate heat inputs and thus simplifies the operation of the network.

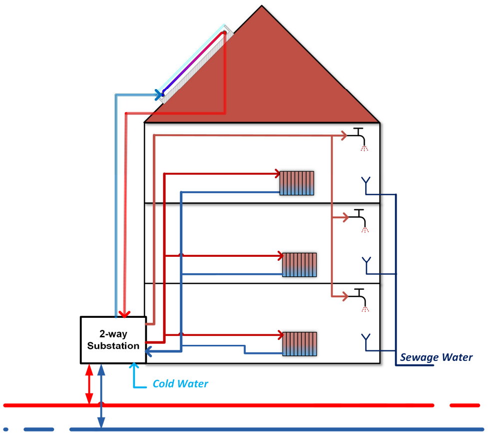


Fig. 2 Two-way substation in multi-family building prosumers

The multi-family building considered in the present study consists in 3 floors with 2 apartments of 3 people per floor. Each apartment has a height, width and length of respectively 2.5m x 10m x 7m leading to an overall footprint of the building of 7.5m x 10m x 14m. A preliminary calculation leads to an overall space heating (SH) nominal power of about 42kW based on a consumption of 100W/m² (poorly insulated buildings built in the 80’s in western European climate) and an overall domestic hot water (DHW) nominal power of 60kW. The latter is obtained using the daily draw-offs from COSTIC (2016), i.e. about 150 liters for an apartment of 3 people, and the “DHWcalc” calculator (Jordan and Vajen, 2005) to obtain distributed daily or yearly profiles. The maximum 10 minutes average from this profile is 16kW/apartment leading to the 60kW for the entire building when accounting for a simultaneity coefficient of 0.62. The solar collector field has an area of 80m², which covers one side of the rooftop with a 30° of inclination angle. The building solar production would reach 56kW with an assumption of 700W/m² of production based on IEA SHC recommendations (IEA SHC, 2004).

The rest of the present section is dedicated to the question of the architecture of such two-way substation. Fig. 3 summarizes schematically the challenge posed here with the bidirectional substation connected to the DHN, to the SH and the DHW loops, and to the solar collector field. The question to address in the following parts is how to do so.

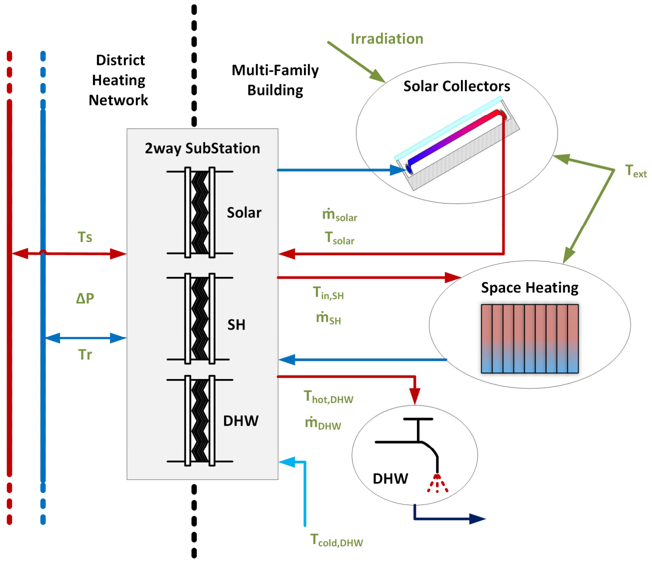


Fig. 3: Overview of the boundary conditions to account for in the design of the two-way substation

2.2. Selection of Features

In the present section, an exhaustive list of possibilities regarding the architecture of the substation will be established through the combinations of three features. Then, the purpose will be to select the most promising ones based on various criteria. The three selected features to characterize the bidirectional substations are the following:

- Feature 1: Type of connection to the DHN, i.e. location of the hydraulic separations for SH and DHW
- Feature 2: Possibility or not to reuse the heat locally, i.e. connection with the solar field
- Feature 3: Control strategy associated to the reinjection of heat.

Tab. 1 presents the three possibilities listed for Feature 1 ‘Network Connection’, Feature 2 ‘Local Usage’ and Feature 3 ‘Control Strategy’. In this Table, the substation is represented by a grey rectangle. More specifically, the section of the substation dedicated to SH and DHW production is highlighted by a ‘SH/DHW’ tag while the section dedicated to the solar heat is referred by a ‘Solar’ tag. The different features will be combined in the next section.

Feature ‘1’, referred as C for Connection, deals with the location of the hydraulic separation between the DHN and the consumer (SH and DHW). Here is the list of possibilities for Feature ‘1’:

- C0: There is no hydraulic separation between the DHN and the consumer inside the bidirectional substation;
- C1: A single heat exchanger in the bidirectional substation performs the hydraulic separation between the DHN on one side and the DHW and SH loops of the consumer on the other side. C1’ indicates that

DHW production is then collective for the entire building while C1'' indicates that DHW production is decentralized at the apartment level;

- C2: Two heat exchangers in the bidirectional substation perform the hydraulic separation respectively between the DHN and the DHW loop and between the DHN and the SH loop of the consumer.

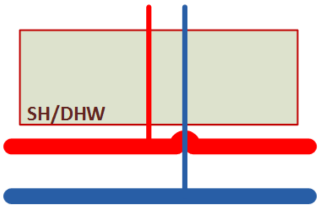
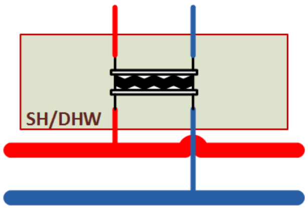
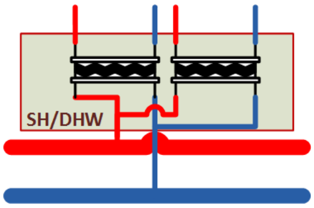
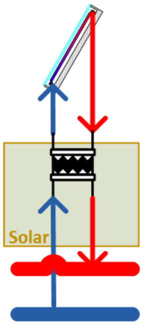
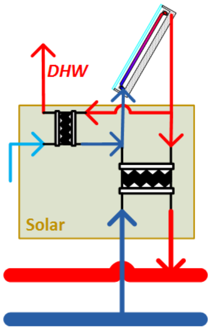
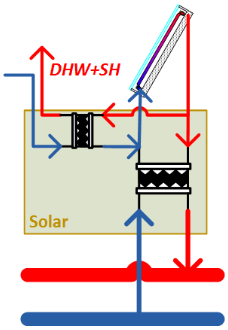
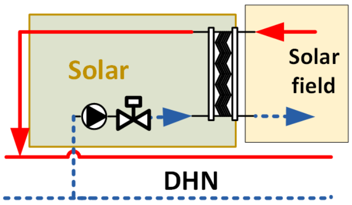
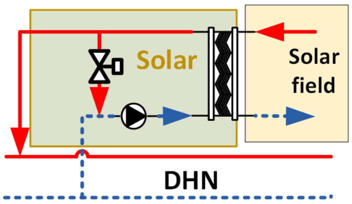
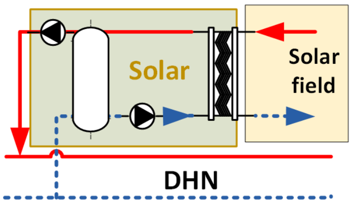
Feature '2', referred as U for Usage, deals with the local consumption of the produced heat, i.e. the connection between the consumer and the solar field. It is worth mentioning here that the hydraulic separation between the solar field and the DHN will always be performed with a heat exchanger in the two-way substation:

- U0: The produced heat is entirely reinjected into the DHN;
- U1: The produced heat is partly used locally for DHW preparation and partly reinjected in the DHN;
- U2: The produced heat is partly used locally for DHW preparation and SH and partly reinjected in the DHN.

Feature '3', referred as S for Strategy, deals with the strategy/control associated to the reinjection (feed-in), i.e. the link between the substation and the DHN. The following possibilities are further detailed later:

- S0: A pump and a 2-way valve in series;
- S1: A pump and a 2-way valve as bypass;
- S2: Two pumps and a hydraulic separator.

Tab. 1: Possibilities for Features 1, 2 and 3 - The gray rectangle represents the bidirectional substation perimeter, the 'SH/DHW' tag represents the substation part dedicated to SH and DHW while the 'Solar' tag represents the substation part dedicated to the solar heat

FEATURE 1: HYDRAULIC SEPARATION between DHN and SH+DHW (Network Connection)		
C0	**C1**	**C2**
		
FEATURE 2: SOLAR FIELD CONNECTION (Local Consumption)		
U0	**U1**	**U2**
		
FEATURE 3: FEED-IN ARCHITECTURE (Control Strategy)		
S0	**S1**	**S2**
		

2.3. Features Combinations

As a first step, the two Features ('C' and 'U') are combined resulting in the configuration table Tab. 2. Fig. 4 Fig. 5 show examples of such combined configurations with the two parts 'SH/DHW' and 'Solar' inside the bidirectional substation. Additionally, here are the considerations to account for when combining these first two features:

- If there is no hydraulic separation between the DHN and the building in the bidirectional substation (C0), then each apartment is equipped with an individual small scale one-way substation with a DHW heat exchanger and a SH heat exchanger in parallel, as highlighted in configuration C0U0 of Fig. 4
- If there is no hydraulic separation between the DHW and SH loops in the bidirectional substation but they are themselves separated from the DHN (C1), then if the DHW production is individual, each apartment is equipped with an individual small scale one-way substation with only a DHW heat exchanger (C1''), as highlighted in configuration C1''U0 of Fig. 5

Tab. 2: Possible configurations for solar source bidirectional substation based on Features 1 and 2

DHN Connection	Local usage		
	U0	U1	U2
C0	V	X	X
C1'	V	V	V
C1''	V	X	V
C2	V	V	V

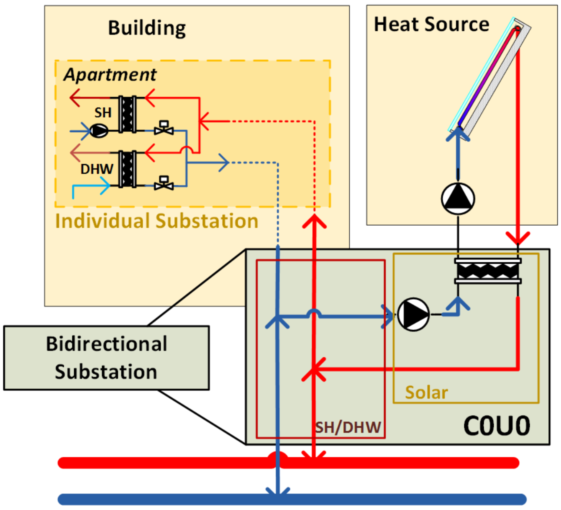


Fig. 4: C0U0 configuration with <u>individual SH/DHW substation</u> in each apartment

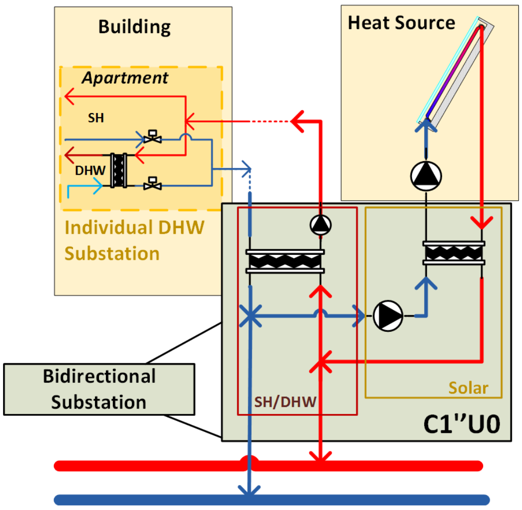


Fig. 5: C1''U0 configuration with <u>individual DHW substation</u> in each apartment

It is observed in Tab. 2 that three configurations, namely C0U1, C0U2 and C1''U1 are unrealistic. Indeed, for the first two, since in configuration C0 the bidirectional substation has no heat exchanger separating the network from the building, individual one-way substations (from network to consumer) are needed in each apartment. Thus, if local usage is implemented, it means that each individual substation needs to handle the solar heat produced. The latter seems inappropriate as explained in Section 2.1 (cost and complexity issues). Similarly in configuration C1''U1, since DHW is not separated from SH at the substation level and is produced individually in each apartment, it means that in order to be able to reuse the solar heat for DHW preheating, an extra heat exchanger is needed in each apartment, which is again rather costly.

For all the other feasible combinations, various criteria listed below have been considered and Tab. 3 summarizes the performance of each of these configurations for these criteria:

- <u>Cost</u>: Related to i) the pressure and temperature levels in the building (lower if hydraulic separation present in the substation), ii) the necessary equipment in the two-way substation (amount of pumps, valves, heat exchangers), and ii) the necessary equipment in the building (extra individual substation for DHW production or indirect space heating)

- Operation: Related to the operation of the solar field with respect to the DHN and the consumers. Simpler if the solar production is decoupled from the consumer part (U0 solutions)
- Ownership: Related to who owns what in the overall system, i.e. is the barrier between the DHN operating company and the consumer clear? In the case of local consumption (U1 and U2), it is clear if the solar field belongs to the consumer but not clear if it belongs to the DHN company.
- Extra DHW production in the apartments: Related to the requirement of an extra hydraulic separation between SH or DHN water and DHW water outside of the two-way substation. This is linked to the location of the hydraulic separation.
- Sanitary loop Requirement: Related to the requirement of a sanitary loop for DHW production. If individual DHW substations are used, sanitary loop is not needed.

Tab. 3: Performance criteria for the selection of the most promising architecture

	C0U0	C1’U0	C1’’U0	C2U0	C1’U1	C2U1	C1’U2	C1’’U2	C2U2
Cost	+/-	+/-	-	+	+/-	+	+/-	--	+
Ownership	+	+	+	+	+/-	+/-	+/-	+/-	+/-
Operation	+	+	+	+	+/-	+/-	+/-	+/-	-
Extra DHW production needed	Yes	Yes	Yes	**No**	Yes	Yes	Yes	Yes	No
Sanitary loop required	No	Yes	No	**Yes**	Yes	Yes	Yes	No	Yes

In general, operation and ownership are easier if there is no local usage of the produced solar heat (U0 solutions) since the DHN could then own the decentralized solar fields and operate them at wish, as common generators (but of small size). Solutions involving additional individual substations (C0 and C1’’) are more costly but do not require sanitary loops and allow for individual metering. C2U1 also seems interesting since it does not increase drastically the number of components while allowing self-consumption of the locally generated heat. However, that configuration is more complex to operate.

2.4. Selected Architecture

For the continuation of the present study, configuration C2U0, i.e. with the hydraulic separation for both the space heating and the DHW performed in the bidirectional substation and with no local consumption, has been selected for the following reasons:

- In this configuration, the DHN operator could rent the building’s rooftop to install the collector field and would then operate it at wish to suit the entire DHN operation;
- In this configuration, the operation of the consumer part of the substation remains as usual;
- It is cost efficient since the hydraulic separation is performed at the building scale and thus individual one-way substations are not necessary. Additionally, since the hydraulic separation is performed at the building scale, the building’s piping would run at lower pressure and temperature;
- It presents the simplest operational scheme / control strategy.

The selected configuration C2U0 is shown on Fig. 6. On this Figure, control strategy S0 (see Tab. 1) of the last feature, i.e. Feature ‘3’, has been superimposed to the C2U0 configuration. In general, the main objective of the control strategy is to obtain a feed-in temperature level above the local supply temperature in the DHN, while fulfilling the following constraints:

- Obtain the lowest temperature in the solar field to reach high efficiencies;
- Overcome the strongly varying local flow resistance, i.e. differential pressure drop;
- Well adjust the feed-in flow rate so that the feed-in rate matches the strongly varying heat rate produced by the solar field.

As highlighted in Schäfer et al. (2014), the challenge here lies in the combination of two parameters with strong and fast variations, i.e. the solar heat production and the local differential pressure drop. In general, if a speed controlled pump alone is used to maintain the targeted temperature, too many startup/shutdown cycles are noticed when the differential pressure exhibits strong variations.

In control strategy S0 (see Tab. 1), the pump is responsible for the pressure differential while the valve is applied to regulate the flow in order to meet the targeted temperature. This method exhibits good performance but the control valve results in higher electricity demand for the pump. In control strategy S1 (see Tab. 1), the pump is responsible for the pressure differential and the 2way valve used as shunt is responsible for the feed-in flow and temperature. The feed-in pump, shall only have enough pressure head to exceed the differential pressure. The cold temperature on the hot side of the heat exchanger is higher than it needs to be resulting in lower solar field efficiency. Finally, in control strategy S2 (see Tab. 1), the hydraulic separator divides the system into two hydraulic loops. The pump located after the extraction is used for temperature control while the other one targets a pressure differential set point. The solution turns out to be a good approach for solving the problems. However, the cost is high as the use of additional components (extra pump and hydraulic separator).

A 3-way valve solution is also possible but was not selected here because of the fast-varying differential pressure, impossible to handle using a 3-way valve (Lennermo et al. (2014).

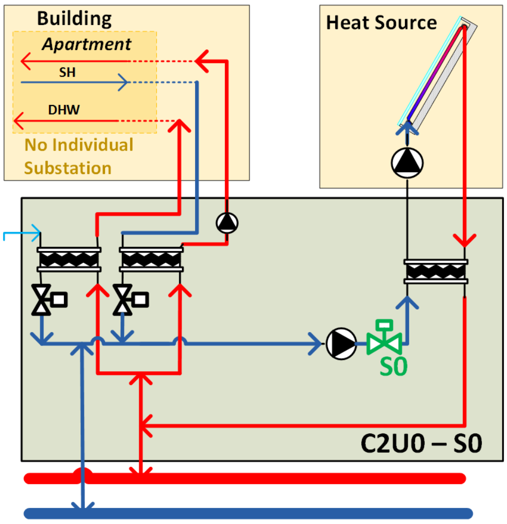


Fig. 6: Bidirectional Substation configuration C2U0 with control strategy S0

As a conclusion of the present section, the performed assessment led to the selection of configuration C2U0 as promising architecture for a bidirectional substation. In this configuration, the hydraulic separation between both the building SH and SHW loops and the DHN is performed in the substation and the solar heat is entirely reinjected in the DHN. Three control strategies have been identified and will be compared in future work. The next section presents the modeling framework developed and the associated preliminary results obtained.

3. Modelling Framework

3.1. Modelling

This section aims at presenting the framework developed for the comparison of the bidirectional substation architectures and control strategies in the frame of the 'THERMOSS' project. It is based on the open source modelling language Modelica used in the commercial simulation environment Dymola. Modelica is an acausal (equation-base) and object-oriented programming language with a large and fast-growing community both for industrial and academic applications (Schweiger et al., 2017). Modelica has native multi-physical modelling capabilities (thermo-hydraulic), is structured in libraries enabling exchange of methods in the scientific community and allows for implementing new components. Moreover, the Annex 60 project from the IEA (Wetter, et al., 2015) promotes the development of computational tools for building and community energy systems based on Modelica and FMI standards, motivating the choice of this modelling framework. As mentioned in the introduction, the Modelica "Standard" Library for its common connectors and fluid ports, the "Buildings" library

(Wetter et al., 2014) for its general building and solar panels models and the "DistrictHeating" library (Giraud et al., 2015) for its heat exchanger and piping models will be used.

As highlighted previously in Fig. 3, the bidirectional substation is surrounded by four boundary conditions blocks, namely the space heating needs, the domestic hot water draw-offs, the solar gains and the network operating conditions. Thus, the present section begins with the core model of the bidirectional substation and then continues with the description of these four boundary conditions blocks.

Bidirectional substation

It is composed of three heat exchangers and associated valves, two pumps (for SH circulation and for the reinjection) and connection piping as shown in Fig. 6. The heat exchangers are discretized in nz elements and the heat exchange in each element 'i' is calculated as $\dot{Q}_i = (UA/nz).\Delta T$ with a constant overall heat transfer capacitance UA and the local temperature difference ΔT between the hot and cold streams. The overall heat transfer capacitance for each heat exchanger is obtained based on nominal operating conditions (see Tab.4). It is worth mentioning that the network side is the hot side for both the DHW and the SH heat exchangers while it is the cold side for the Solar heat exchanger The heat exchangers are modeled with no flow resistance, the pressure drop being entirely considered in the associated valves model. For the latter, a quadratic model is assumed. Finally, regarding the pumps, they are both considered to run at constant speed with the flow rate modulation being performed by the feed-in valve (see S0 in Fig. 6) in the case of the feed-in pump and a thermostatic valve for the SH, as explained in the next paragraph.

Tab. 4: Nominal operating conditions for the Heat Exchangers of the bidirectional substation

Heat Exchanger	$T_{hot,in}$ [°C]	$T_{hot,out}$ [°C]	$T_{cold,in}$ [°C]	$T_{cold,out}$ [°C]	DTLM [°C]	Power [kW]	UA [kW/K]
Solar	90	60	50	85	7.2	56	7.8
DHW	80	50	10	55	31.9	60	1.9
SH	80	50	45	70	7.2	42	5.8

SH needs

The boundary condition dealing with the space heating demand is modeled with i) a heating system and ii) a mono-zone building. For the former, it is connected to the SH pump and is composed of a thermostatic valve and a radiator modelled using the "RadiatorEN442_2" model from the library "Buildings" (Wetter et al., 2014). In this model, the transferred heat is computed using a discretization along the water flow path, and heat is exchanged between each compartment and a uniform room air and radiation temperature. The mono-zone building is modeled using the "mixed air" model (Wetter et al., 2011) from the library "Buildings" (Wetter et al., 2014). The latter considers a perfectly mixed air in the room and takes into account heat exchange through convection, conduction, infrared radiation and solar radiation. Internal heat gains due to occupation (latent heat), lighting (radiation) and home appliances (convection) are included in the model. Constant single-flow ventilation is considered with a flow-rate of about 0.4 room volume per hour. For the present study, the dimension of the building considered were listed in Section 2.1. The total glazed area for the building represents 1/6 of the building living area, shared as follows, 50% on the South wall, 15% on the West wall and 35% on the East wall. The envelope of the building (layers composition and infiltration) can be set to follow various French thermal regulations (RT2000, RT2005, RT2012).

DHW draw offs

For now, the water draw-off system is considered without sanitary loop. As explained initially, the daily or annual (depending on the simulation) profile of draw-offs are obtained from the software DHW calc (Jordan and Vajen, 2005) from Task 26 of IEA which distributes DHW draw-offs throughout the year or the day with statistical means, according to a probability function. The mean daily DHW consumption was obtained from a report of COSTIC (2016) based on the type of apartment and the number of people living in it. Additionally, a correction of the cold water temperature is also included in the simulations using the model of Burch and Christensen (2007).

Network

The network side inputs are the local differential pressure and supply temperature. It was explained beforehand that these two variables are decisive regarding the control scheme of the two-way substation. In the present model, these two variables can either be set to constants to study specific operational conditions or set to follow real DHN variations. For the latter, data were collected in the frame of the THERMOSS project at the DHN of San Sebastian, Spain. Fig. 7 below presents these data for three days with a time step of 15 minutes.

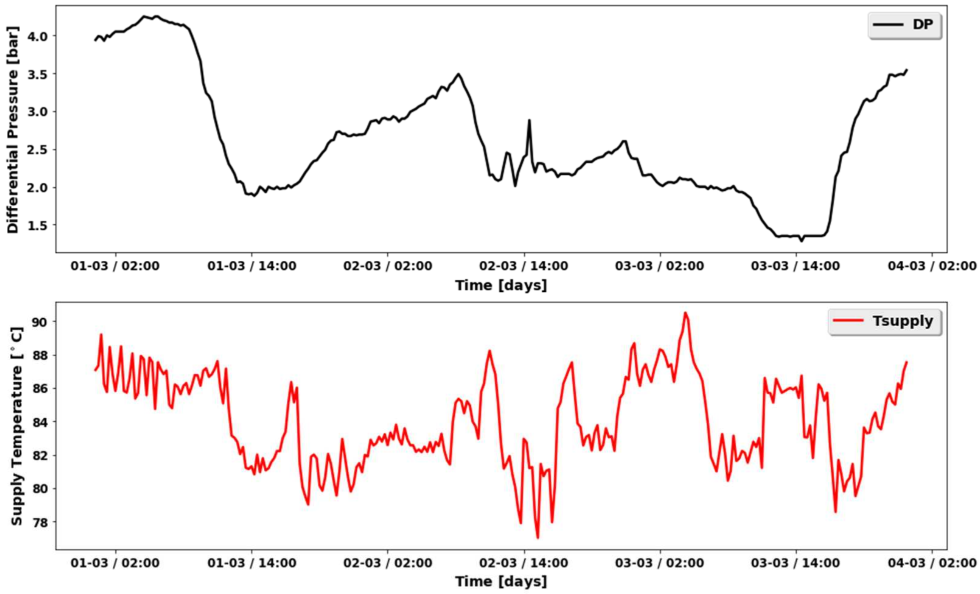


Fig. 7: Differential pressure and Supply Temperature variations in the DHN of Giroa-Veolia in San Sebastian

Solar field

The solar field on the rooftop is modeled using the ‘SolarCollectors’ package from the Buildings library which models a solar thermal collector according to the ASHRAE93 test standard (ASHRAE93, 2010). The package proposes different pre-defined solar panels set of characteristics. The flat plate panel Guandong Fivestar Solar Energy Co, FS-PTY95-2.0 (area of 2m²) is thus used together with Glycol47 as working fluid. The collector area is discretized and considered to be 80m² for a tilt of 30° as explained in Section 2.1. A solar pump with variable speed is considered. That pump is set to start above a given level of solar irradiance (100W/m²) and is controlled so that the outlet temperature from the solar field remains around 85°C.

Overall model

Fig. 8 presents the final Modelica-based framework built for the bidirectional substation simulations. The core block, i.e. the bidirectional substation, is surrounded by the four boundary conditions blocks described previously, i.e. the network inlets, SH needs, DHW draw-offs and solar gains.

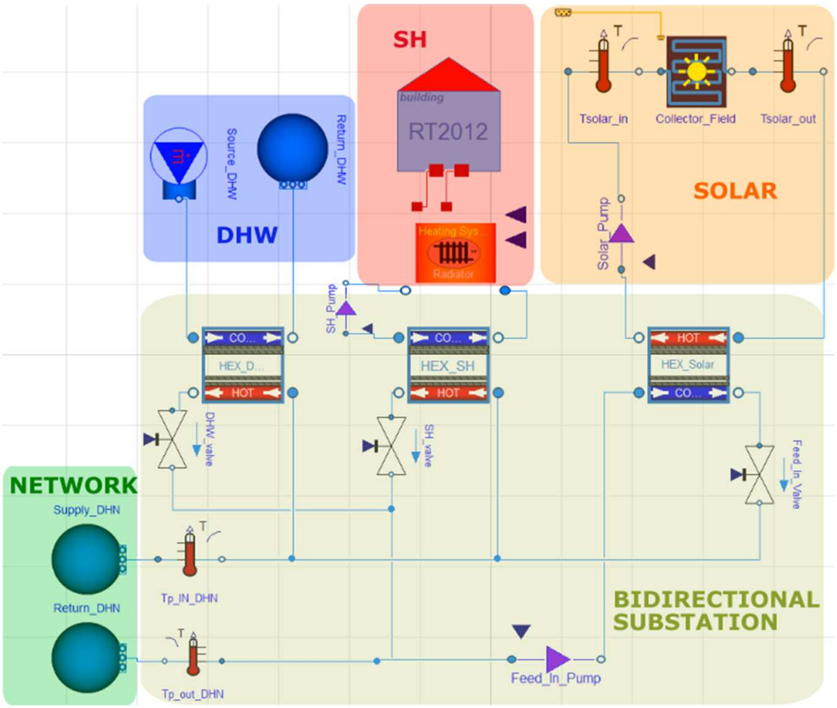


Fig. 8: Overall Modelica-based framework developed

3.2. Preliminary results

In the present study, the modeling framework discussed in the previous section is used to highlight the potential of solar heat reinjection from the multi-family building described in section 2.1. For that preliminary results, only the SH, DHW and Solar boundary conditions blocks were simulated. The location selected for the simulation is San Sebastian, Spain. Monthly energy gains/consumptions results are shown in Fig. 9. From this Figure, it can be calculated that if a configuration allowing for local consumption (U1 or U2) is chosen, up to 19.7MWh/yr could be consumed locally by the building while up to 41.2MWh/yr could be reinjected in the DHN. If a configuration with no local consumption is chosen as C2U0 for example, up to 60.9MWh/yr could be reinjected in the DHN. Future detailed simulations including the bidirectional substation together with the different control strategies discussed in section 2.4 will allow calculating which part of these potential amounts can effectively be used locally and reinjected into the DHN.

At this point, it is worth mentioning that at the level of the DHN, the usage of bidirectional substation is rational energetically speaking in two different situations. The first one is in the case that an inter-seasonal storage is installed on the DHN so that the decentralized contributions from excess heat of different prosumers are collected during summer (see Fig. 9) and reinjected in the DHN during winter. The second one is in the case where the reinjection from few prosumers allow reducing the centralized heat production for the DHW of all the consumers of the DHN, even during summer.

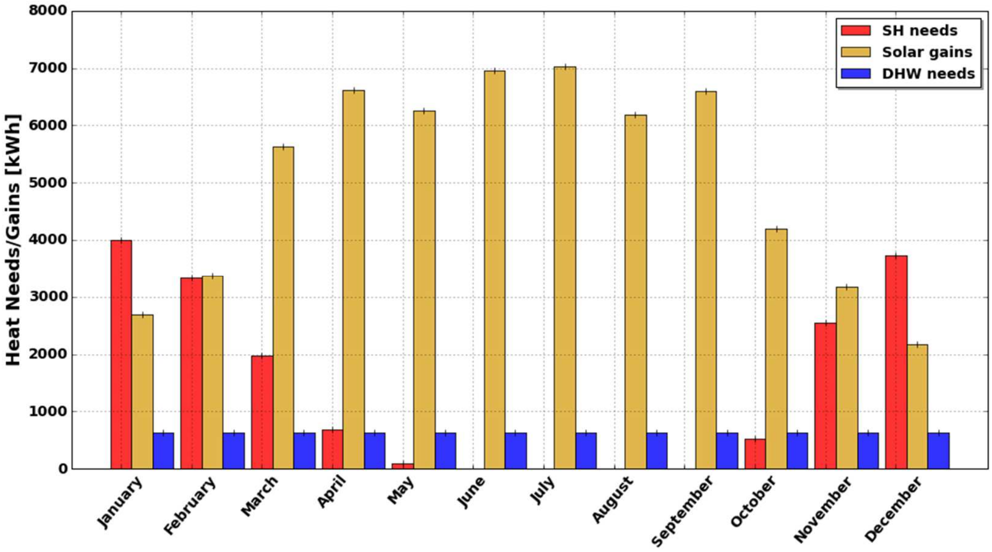


Fig. 9: Simulated solar production and SH and DHW needs for a multi-family building of 6 apartments and a flat plate solar collector area of 80m² located in San Sebastian

4. Conclusion

The present paper has set the basis towards the development of a solar bidirectional substation able to reinject/consume heat on/from a district heating network. Firstly, the main specifications of this bidirectional substation were established, i.e. Return to Supply decentralized feed-in, multi-family building scale, both able to consume and reinject heat. Secondly, features such as the type of connection to the network and the type of local consumption were combined to build an exhaustive list of potential architectures, and the most promising one was selected from a multi-criteria analysis. For this architecture, the hydraulic separation between both the building SH and SHW loops and the DHN is performed in the substation and the solar heat is entirely reinjected in the DHN. Finally, a modeling framework built to study and compare different architectures and control strategies was presented together with preliminary results highlighting the reinjection potential from multi-family building equipped with solar bidirectional substation.

In the frame of the European project 'THERMOSS', variants of the selected architecture with the various control strategies discussed will be compared using the presented modeling framework. Additionally, the impact of multiple reinjection points on the DHN operation will be studied at the network scale in order to have a complete picture of the development of bidirectional substations.

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