FEED-IN FROM DISTRIBUTED SOLAR THERMAL PLANTS IN DISTRICT HEATING SYSTEMS

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Abstract – A District heating (DH) feed-in system is connected to the DH system outside the main central pumps. There are four different ways to connect a feed-in system to the DH main line but the most frequently used are return/return (R/R) and return/supply (R/S). R/S is the most beneficial system since it influences the DH system the least. For an R/S feed-in system, there are two basic control concepts; a temperature controlled system and a flow controlled system. In the temperature controlled system there is always a shunt flow which the flow controlled system lacks. It is possible to build a combination feed-in system but the risk of poor performance increases. More field tests will be done during the summer 2017.

1. INTRODUCTION

There is a large potential to supply district heating systems with heat from small, distributed sources. One possible heat source is solar thermal (ST) systems. Some 20 DH-connected solar thermal facilities in Sweden were mapped out in a previous study and it was found that their performance was lower than expected [1]. There were signs that this was caused by fluctuations in the feed-in heat power and flow. In a study funded by the Swedish District Heating Association we have tried to find out why these fluctuations occur and how to avoid them [2].

2. ANALYS OF FEED-IN SYSTEM

2.1 Possible DH feed-in systems

One main findings is that a fundamental principle for a well-functioning feed-in is that the feed-in heat power must match the heat power generated by the ST system if no storage is used. It is often beneficial to avoid storage for practical and economic reasons.

A distributed heat source can be connected in four different ways.

- In a Return/Supply (R/S) system the water is withdrawn from the return pipe, heated to a correct temperature and fed back into the supply pipe.
- In a Return/Return (R/R) system the water is withdrawn from the return pipe, heated to any temperature higher than the temperature on the return line, and fed back into the return pipe.
- In a Supply/Return (S/R) system the water is withdrawn from the supply pipe, heated to any temperature, it has already a higher temperature than the temperature in the return line, and fed back into the return pipe.
- In a Supply/Supply (S/S) system the water is withdrawn from the supply pipe, heated to any temperature higher than the temperature on the supply line, and fed back into the supply pipe.

The use of S/R and S/S is rare since they feed the DH system with high temperature on the return line or a higher temperature than necessary on the supply line. They can be used some hours per year as an over heat protection system for a local heat source that can be hard to shut down.

R/R and S/S system cannot produce any flow on the DH main line. This disadvantage is very important to consider when the system is planned. On the other hand, R/S and S/R systems can produce the needed flow in the DH system both in the service pipe and on the main line.

A feed-in system never guarantees heat to all customers in the DH system. It is the central heat generation system that has the responsibility to provide heat to all customers.

2.2 Noisun R/S feed-in system

The most beneficial feed-in system is the R/S system. An R/S system does not affect the return temperature in the DH system but it reduces the heat power load from the central heat production unit in the same way as heat saving measures.

For about 16 years Solar Thermal (ST) plants have been installed as R/S feed-in systems in Sweden. [1] According to a study in 2012, many of these installations did not work in a proper way. The effects of the malfunction were possible to observe, on some readings, if the resolution time was short. The poor function appears as a variation in feed-in flow and heat power [3]. If the feed-in plant is small in comparison with the DH system, the DH operator cannot observe any influence on the DH system.

In January 2015, a new ST feed-in plant named Noisun was installed in Lerum, Sweden. The feed-in plant has a solar collector area of 860 m^2 and the DH system, which is rather small, has a yearly heat production of about 30 GWh. The central heat plant has heat production from biomass, wooden chips and pellets, and about 10 % natural gas. When the same feed-in flow variations occurred in this plant in the same way as in the other ST plants, this caused a lot of problems at the central heat plant. The biomass boiler could not reduce the heat power production as fast as the feed-in variations of heat power, which caused the central pumps a hard time to follow the feed-in flow. The feed-in flow variations were a bigger problem than the variations in heat power feed-in. This was the first time a DH company had complaints on a feed-in plant in Sweden and the message was very clear; stop the oscillations or otherwise the feed-in plant must stop.

Noisun is not connected to a specific customer or installed together with a load substation.

To get a correct feed-in temperature a 3-way valve, SV3 in the figure 1, was used. To work properly, a 3-way valve needs about the same pressure difference on the two regulating ports. Two pressure sensors and one 2-way valve, SV4, are included in the feed-in station to give a good function on SV3. These extra control functions were not enough to eliminate the feed-in flow variations.

To stop the oscillations in the feed-in flow, the control system was modified. The temperature up to the solar collectors, at sensor GT5, was set to be a function of the solar irradiation. This solved the problem.

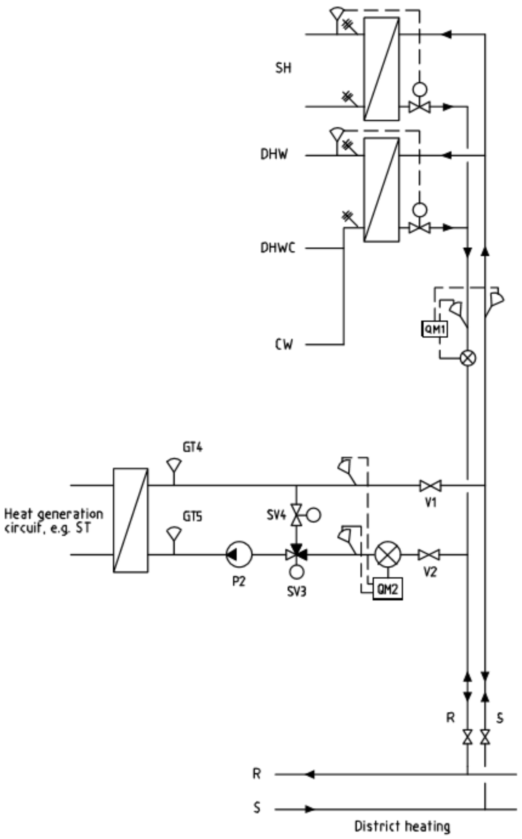

Figure 1. Simplified drawing of the feed-in substation at Noisun. The feed-in pump P2 is given a speed relative to the DH differential pressure and SV3 is supposed to give the correct feed-in temperature and flow. SV4 and two pressure sensors give SV3 the possibility of work properly.

2.3 Ödåkra R/S feed-in system

36 apartments in 7 buildings were built in a small community outside Helsingborg, Ödåkra in 2009. The buildings have passive house standard and should to a large extent be heated by an ST system. The ST system would interact with a DH system. The first attempt was to only use ST on the DH substation secondary side but there was no space for storage tanks and it was not possible to change the drawings. Instead an ST R/S feed-in plant was built. The heat power and temperature variations were identified already during the system test run but no action was taken. A simplified drawing of the feed-in system is shown in figure 2. The feed-in pump, P2, should work together with a 2-way valve, SV2, to get a correct feed-in temperature at GT4.

There are about 10 ST feed-in plants in Sweden with the same feed-in substation layout and control system function.

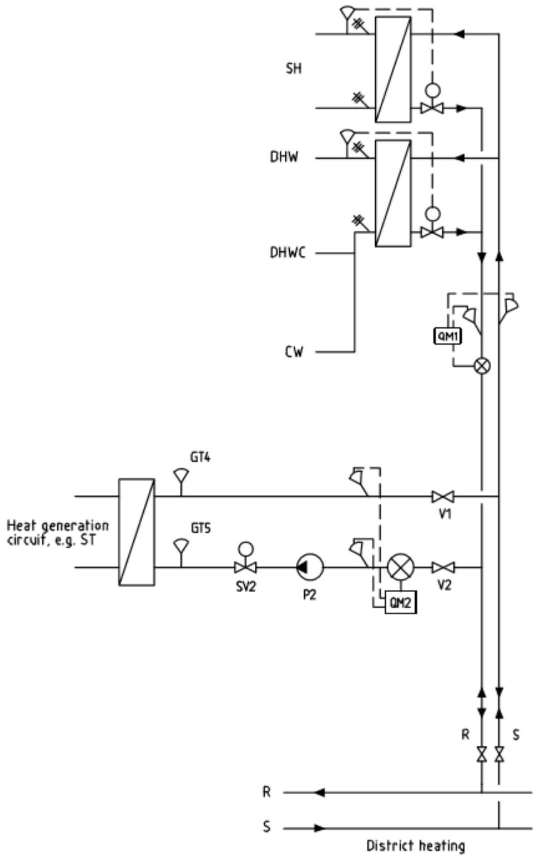

Figure 2. Simplified drawing of the feed-in station at Ödåkra. The feed-in pump, P2, should work together with a 2-way valve, SV2, to get a correct feed-in temperature.

Some experiments have been performed at the Ödåkra plant. The differential pressure has been measured with a mobile test unit. Measurement from 5 days are shown in figure 3. The minimum difference occurred in the evening of 7 November and maximum difference occurred in the morning of 11 November. The most common difference was between 1,8 and 2,5 bars (18- and 25-meter water pillars).

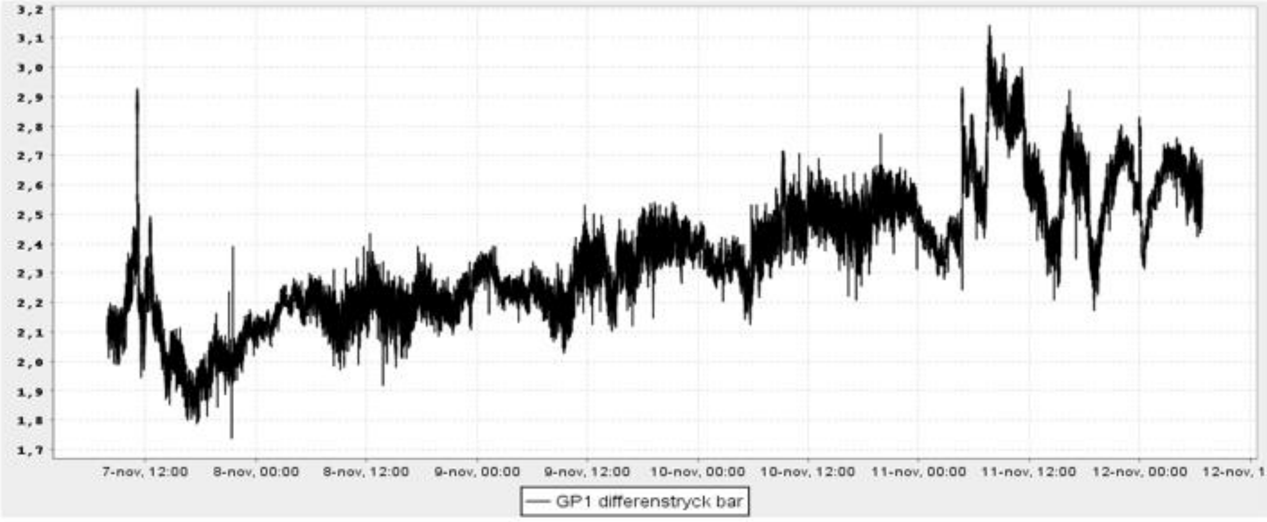

Figure 3. Differential pressure, DP, at the Ödåkra R/S feed-in plant. The differential pressure was measured with 10 seconds resolution. In the graph DP is shown from 7 November 2014 until 12 November 2014. The minimum DP difference was 1,75 bar and the maximum difference is 3,15 bar but most of the time the difference was between 1,8 and 2,5 bar (or 18- until 25-meter water pillar)

Set speed in the controll system, %	Speed on the feed-in pump, %	Feed-in flow, m³/h
0	25	0
5	28	0
10	32	0
15	36	0
20	40	0,8
25	44	1,2
30	48	1,6
35	52	1,8
40	56	2,1
45	59	2,4
50	63	2,6
60	71	3,1
70	79	3,3
80	87	3,3
90	93	3,3
100	100	3,3

Table 1. The flow test with SV2 100 % open. The speed is changed from the control computer with an on/off-digital signal and an 0 – 10 V analogue signal for speed variation. The feed-in flow is measured with the feed-in station flow meter. The theoretical maximum feed-in flow is 1,6 m³/h

A flow test with pump speed variation was performed on the 17 March 2016. SV2 was 100% open and the flow was measured with the flowmeter in the heat meter that is integrated in the feed-in station. The used flow meter needs some time to show the correct flow as it has an integrated function. The theoretical maximum feed-in flow is 1,6 m³/h. Measured values are shown in table 1.

The dominant pressure drop of feed-in pump P2 is the differential pressure. The DP is not flow dependent and P2 must exceed DP in order to generate a flow. When the speed and flow were indicated in the pump flow chart it became very clear that there is no flow before the DH network DP is exceeded. The numbers are shown in table 1. The pump is controlled by a 0 – 10 V signal from the control computer. The standard is that the pump is started by a digital signal, on/off, and if the 0 – 10 V analogue speed signal is at 0 V the pump starts on the lowest recommended speed, 25 %.

It is almost impossible to get a correct feed-in flow with only pump-speed regulation. The higher the pressure drop (eg DP) the more difficult it is to get a correct flow if the flow is low.

In the third test the pump speed was fixed. The pump speed was so high that the DP was exceeded, the pump could make a feed-in flow if SV2 was 100 % opened.

Instead of reducing the P2 speed, SV2 was closed. Even if SV2 was not dimensioned for this function it was possible to get a correct flow.

In table 2 the speed of P2 and the opening degree of SV2 is shown. The amount of extra electricity the pump needs is not calculated. Most important with this test was to see if it was possible to get a correct feed-in flow with this function and the result is very clear. It is easier to get a correct flow with controlling the opening degree on a 2-way valve than with a pump speed control.

Set speed in the controll system, %	Opening degree on SV2, %	Feed-in flow, m³/h
30/48	100	1,6
30/48	90	1,6
30/48	80	1,57
30/48	70	1,55
30/48	60	1,45
30/48	50	1,30
30/48	40	1,13
30/48	30	0,79
30/48	20	0,44
30/48	10	0,11
30/48	9	0,077
30/48	7	0,048
30/48	5	0,043

Table 2. P2 is given a fixed speed, high enough to exceed DP. The flow is controlled with SV2. It is much easier to get a correct flow with a change of the opening degree on SV2 than with P2, especially at high DP and low flows.

3 CONCLUTIONS

3.1 Two R/S feed-in possibilities

A feed-in system needs to deal with these two conditions.

- The system must know how much flow and/or heat power to feed-in.
- The control system must be able to feed in the correct flow and/or heat power.

The first part is solved in ST system by measuring the solar irradiation and some temperatures. Heat power or flow can then be determined by calculations. For other types of local heat sources than solar, it can be more difficult.

For the second part, how the feed-in system can give the correct feed in flow, two base concepts have been developed, on the basis of the two plants reported above:

- Temperature controlled system with a shunt flow
- Flow controlled system with no shunt flow.

3.2 A temperature controlled system

In a temperature controlled system, it is important that there is always a shunt flow. The feed-in flow has two alternative flow paths, through the shunt or as a feed-in flow. The DP is the dominating pressure drop for the feed-in flow and the easiest way to balance this pressure drop in the shunt pipe is with a 2-way valve.

Figure 4 shows a simplified drawing of a temperature controlled feed-in system. The pressure drop over SV4 is balancing the DP so that a correct feed-in flow can be obtained.

P2 only needs to give a high enough pressure head so that it is possible to obtain a feed-in flow. The pump speed can be fixed or obtained from a set point given by the DP. A pressure sensor is then needed.

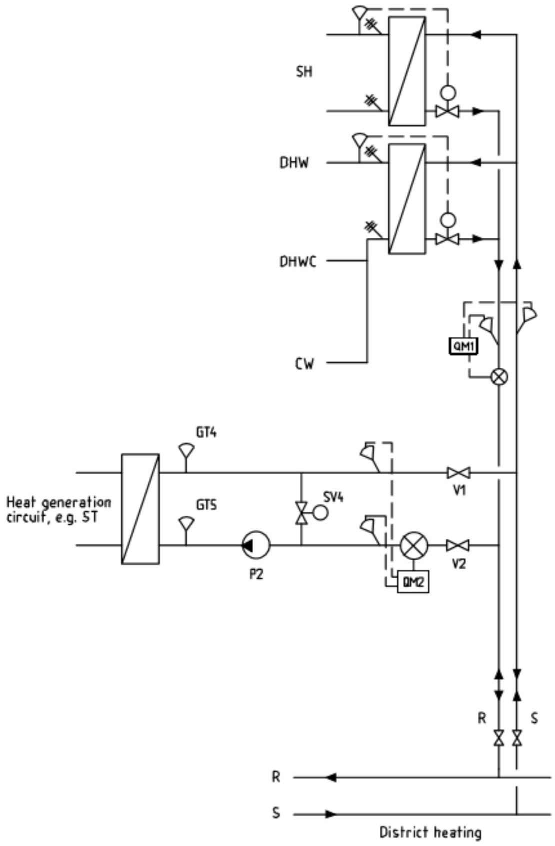

Figure 4. Simplified drawing of the feed-in substation with a temperature control layout. SV4 balances the DP pressure and can give the correct feed in flow. P2 only needs to give high enough pressure head so that it is possible to get a feed in flow.

One disadvantage with a temperature controlled system, is that the temperature at GT5 is always higher than the DH return temperature This in turn means that the cold temperature on the other side of the heat exchanger is a little bit higher than necessary.

One advantage with a temperature controlled system is that P2 can work with a better and acceptable flow.

3.3 A flow controlled system

In a flow controlled system no shunt flow is used. A correct feed-in flow is created with speed variations on P2, a fixed speed on P2 and variated varied opening degree on SV2 or a combination of the two alternatives.

The largest disadvantage is that P2 must, for a shorter or longer time, work with a flow lower than what the pump manufacturer has recommended. If the time operated at a low flow is long, it could affect the guarantee.

As there is no shunt flow the temperature at GT5, se figure 2, is always the same as the temperature on the DH return line. The cold temperature at the other side of the heat exchanger can be colder in a flow controlled system than in a temperature controlled system.

3.4 A mixed feed in system

It is possible to design a feed-in system with a mixture of a temperature and a flow controlled systems. When the heat-power production is low the feed-in system can work as a temperature controlled system with a high enough flow on P2 with help of a shunt flow. When the feed-in flow is high enough the control system can switch to a flow control system.

To make a combination system running in a real plant can be difficult.

4. FUTURE WORK

4.1 Test plant in Düsseldorf

A test plant with a solar collector area of little more than 200 m² is under construction in Düsseldorf. The feed-in substation with the control unit is prepared to test different R/S feed-in possibilities.

More information and results will be reported in the coming year.

4.2 Rebuilding of Swedish feed-in plants

The Swedish ST feed-in plants do not [1] perform as well as expected. A possible reason for this is the poor feed-in function. One plant is already under discussion of reconstruction and others are going to be informed about the new findings. How many that will be rebuilt before summer 2017 is uncertain.

4.3 New plant in south of Sweden

A new ST feed-in plant is planned in southern Sweden. The collector area is a little more than 200 m². The R/S feed-in system is not yet decided, but this plant will be using both R/R and R/S connections.

4.4 Summary

There is still a lot of research on feed-in systems needed. A longer article that more fully describes the basic principles is under way. The field tests that will be done during summer 2017 can provide a deeper understanding of the feed-in problem. Already performed tests show that the local circumstances can affect the feed-in layout and control system considerably.

REFERENCES

(The references here are enclosed to serve as an example of Reference formatting in various cases)

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[3] Lennermo, G., Lauenburg, P. & Brand, L., 2014. Decentralized heat supply in district heating systems - implications of varying differential pressure. *14th International Symposium on DH and Cooling*.