DAILY HEAT LOAD VARIATION IN SWEDISH DISTRICT HEATING SYSTEMS

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ABSTRACT

If daily heat load variations could be eliminated in district heating-systems, it would make the operation of the district heating system less costly and more competitive . There would be several advantages in the operation such as:

- Less use of expensive peak load power where often expensive fuels are used.
- Less need for peak load power capacity.
- Easier to optimize the operation that leads to higher conversion efficiencies.
- Less need for maintenance because of more smooth operation of the plants

There are a number of ways to handle the daily variations of the heat load. Two often used are large heat storages or using the district heating network as temporary storage. If it would be possible to centrally control the customer substations, it would also be possible to use heavy buildings connected to the district heating system as heat storages.

To be able to find the best way to reduce or even eliminate the daily heat load variations, you need to understand the characteristics of the daily variations. This paper will describe a way of characterizing daily heat load variations in some Swedish district heating-systems.

INTRODUCTION

For all heat generation/distribution systems, heat load variations leads to inefficiencies. You need to design your system for the peak load even though you only need the top capacity for a very short period of time of the year. This is of cause expensive. The solution to this problem is heat storage. There are a number of possibilities to store heat in DH systems:

- Large heat storages at the heat generation plants
- Heat storage in district heating networks
- Heat storage in heavy buildings in by allowing small variation in indoor temperatures[1].

If it would be possible to extinguish daily variations it would lead to several profitable advantages such as:

- Less use of expensive peak load power where often expensive fuels are used.
- Less need for peak load power capacity.
- Easier to optimize the operation that leads to higher conversion efficiencies.
- Less need for maintenance because of more smooth operation of the plants

To do this some questions need to be answered:

- What input and output capacity to/from the heat storage is needed?
- What size of the heat storage is needed?
- Are the daily heat variations in the specific system large or small during a year?

METHOD

Nomenclature

P_h= Present hour value [MWh/h]

P_d= Mean hour value for the present day [MWh/h]

P_a= Mean hour value for the whole year [MWh/h]

S_h = Energy transfer capacity [MWh/h]

S_d = Size of heat storage [MWh/day]

S_a = Total annual daily heat load variation

τ_h = Momentary daily variation [h/h]

τ_d = Total daily variation [h/day]

τ_a = Total annual relative daily variation [h/year]

Variables

Measured data has been collected from some district heating systems in Sweden. The collected data is the heat power that is generated and fed into the district heating network. It is hour mean power that is used, i.e. 8 760 data points per year. Only whole years is used from 1 of January to 31 of December. To describe the daily variation three variables is defined.

1. Momentary daily variation (τ_h)
2. Total daily variation. (τ_d)
3. Total annual relative daily variation. (τ_a)

Three system examples are presented in this paper to exemplify the method to characterize district heating daily heat load variation:

System A: From a city in South of Sweden with an annual heat generation of 200 GWh.

System B: From a city in Southwest of Sweden with an annual heat generation of 64 GWh.

System C: From a city in the middle of Sweden with an annual heat generation of 1550 GWh.

Momentary daily variation (τ_h)

The momentary daily variation is proportional to the amount of heat that needs to be fed in or out to the DH network to extinguish the daily variation. This variable describe the heat power capacity needed for in and out put from and to the heat storage. For each district heating systems you will get 8 760 (8 784 during leap years) values per system and year.

The momentary daily variation is defined as the difference of each hourly measured value and the mean value of heat per hour of the same day divided by the mean heat per hour of the year.

$$\tau_h = \frac{P_h - P_d}{P_a}$$

The momentary daily variation is presented in Fig. 1 for the three example systems. The figure shows that the variations are more pronounced in the two smaller systems compared to the larger system.

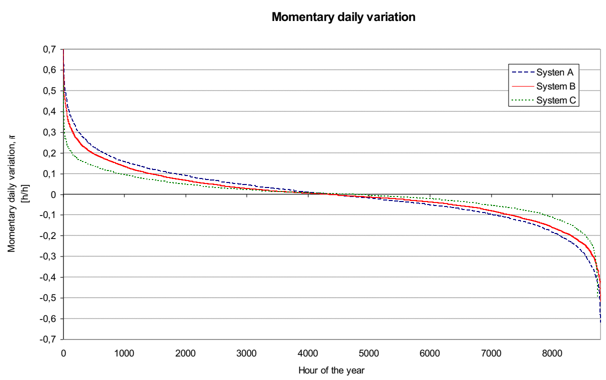

Fig. 1 Momentary daily variation sorted by size hour by hour for the three different district heating systems.

Total daily variation (τ_d)

Total daily variation is defined for each day and is a variable that is proportional to the amount of heat that divert from the daily mean heat load. If you want to extinguish the daily variation in a system this variable describe the size of the heat storage. For each DH systems you will get 365 (366 during leap years) values per system and year.

The total daily variation is defined as the sum over the day of the difference of each hourly measuring value and the mean value of energy per hour of the same day divided by two times the mean energy per hour of the year.

$$\tau_d = \frac{\frac{1}{2}\sum_{h=1}^{24}\left|P_h - P_d\right|}{P_a}$$

The total daily variation is presented in Fig. 2 for the three example systems. The figure verifies that the variations are more pronounced in the two smaller systems compared to the larger system. Another implication is that the highest day values are very few, giving an incentive to construct heat storages somewhat smaller than the peaks in the figure. Hence, the investment costs will be reduced more the lost benefits from the storage, giving a more optimised heat storage.

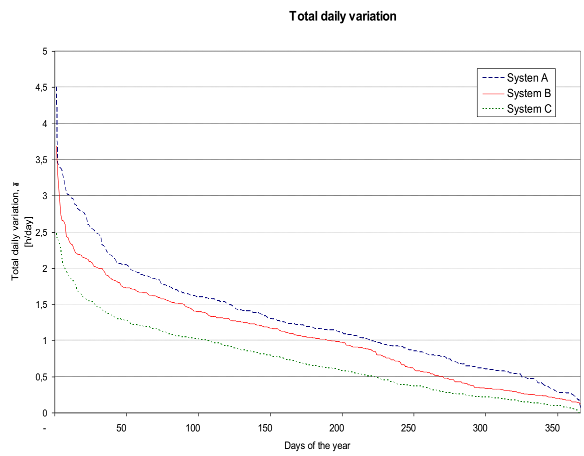

Fig. 2 Total daily variation sorted by size day by day for the three different district heating systems.

Total annual relative daily variation (τ_a)

Total annual daily variation is a variable that is proportional to the total amount of energy that at daily basis divert from the mean value accumulated for a period of one year. It is used to compare different systems between themselves. For each DH systems you will get 1 value per system and year.

Total annual daily variation is defined as the sum over the year of the difference between each hourly measuring value and the mean value of energy per hour of the same day divided by two times the mean energy per hour of the year.

$$\tau_a = \frac{\frac{1}{2}\sum_{h=1,d=1}^{8760,365}\left|P_h - P_d\right|}{P_a}$$

The annual daily variation is presented in Fig. 3 for 10 different Swedish district heating systems. Since the annual daily load variation has a magnitude of 250–500 h, only 3–6% of the annual heat load is generated above the daily average heat loads. Hence, it is the seasonal variations that dominate the heat load variations in the Swedish district heating systems.

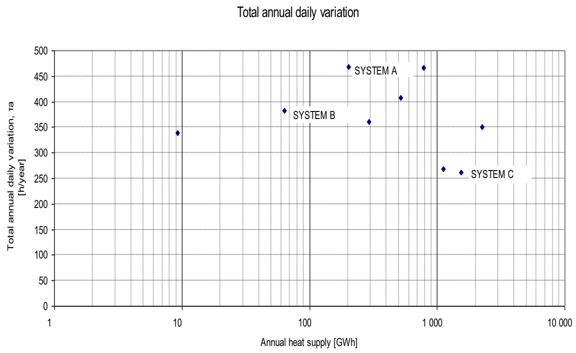

Fig. 3 Total annual daily variation for 10 different district heating systems in Sweden.

RESULTS

To characterize daily heat load variations in district heating systems three variables have been defined.

τ_h = Momentary daily variation

τ_d = Total daily variation

τ_a = Total annual daily variation

Together with the mean annual heat per hour (P_a) and the energy transfer capacity in and out of the heat storage, size of storage to extinguish the systems daily variation and the total daily variation and can be determined according to the expressions below.

Energy transfer capacity:

$S_h = \tau_h \cdot P_a$ [MWh/h]

Size of heat storage:

$S_d = \tau_d \cdot P_a$ [MWh/day]

Total annual daily heat load variation:

$S_a = \tau_a \cdot P_a$ [MWh/year]

CONCLUSIONS

An expected conclusion would be that large district heating systems have smaller relative daily variations (τ_a) than small district heating systems. There are two reasons for that:

1. In a large district heating system, the use of heat power is spread on different distances from the heat plant, i e the chilled water in the return pipe return back to the heat generation at different time compared to when the return water left ach substation (geographical diversity)

2. In large district heating networks, you would expect that the operators have more active operation of the heat distribution network with respect to temporary heat storage.

But as can be observed in the Fig. 3 there does not seem to be such a trend. One explanation could be that the heat users differ in different systems. e.g. in the system in Fig 3 with an annual heat supply of 9 GWh, mostly single and multi family houses are connected and very few industry or office buildings are connected.

Since there is a large diversity among the annual daily variation more data need to be collected to be able to make any further conclusions.

REFERENCES

[1] Olsson L, Werner S: “Building mass used as short term heat storage”, The 11th International Symposium on District Heating and Cooling Reykjavik 2008.