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Accounting for the regulation of district heating (DH) system

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Abstract

The basic regulation formula (RF) based on direct-connection DH system is widely used to operate the DH systems, but the formula maybe not suitable for indirect-connection DH system. Here indirect connection means that the working fluid circulated in CHP and the primary network is not the same medium that flows in the secondary network. Therefore, this paper deduces the regulation formula for indirect-connection DH system. According to accuracy analysis, we find that the applicability of the regulation formula should be based on three conditions: 1) The design indoor temperature and volume specific heat load of all buildings are the same; 2) The same type of heating devices are used in the buildings after each substation or all heating devices are deemed as a big radiator with average performance; 3) The supply and return water temperatures in primary and secondary sides are the same for each substation. If the three conditions cannot hold true at the same time, then the accuracy of regulation formula should be analyzed first.

Keywords - district heating (DH); regulation; operation

1. Introduction

In a district heating (DH) system, heat is produced according to the heat demand which is always fluctuating with the outdoor temperatures [1,2], therefore the regulation is necessary to make the heating compatible with the changing heat demand, and thus to avoid the maladjustments.

The basic regulation formula [3,4] (RF) is widely used to operate the DH systems. In most cases, the formula is directly used in the DH systems, e.g. in China people usually use them without enough analysis on its applicability and accuracy, which however are very essential to operate the DH system to avoid the hydraulic and thermal maladjustments. Therefore, the detailed derivation of the basic regulation formula for DH systems with indirect connection heat users are presented in this paper. On this basis, the applicability conditions are also concluded for the formula. Here indirect connection means that the working fluid circulated in combined heat and power (CHP) plant and the primary network is not the same medium that flows in the secondary network. Therefore, heat exchangers lie in between the primary and secondary networks to transfer the heat. A typical indirect-connection heat user is shown as heat user 2 in Fig. 1.

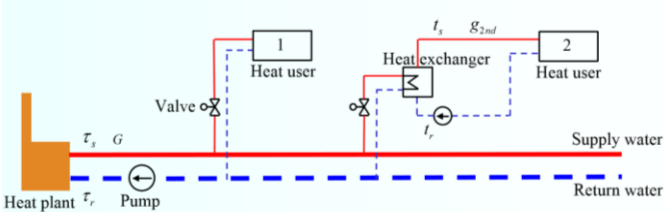

Fig. 1 The sketch of a direct-connection heat user (1) and an indirect-connection heat user (2) in a DH system. τ_s, τ_r – supply and return water temperatures in the primary network; t_s, t_r – supply and return water temperatures in the secondary network; G, g_{2nd} – flow rate in the primary and a secondary network.

The basic RF is obtained from a DH system only with direct-connection heat users (heat user 1 in Fig. 1). When the directly connected DH network is in a steady state and the heat loss of the network is so small that can be neglected, then the supplied heat from the plant equals the heating load of the heating devices, and they also equal to the heat demand of the heat users. According to this balance, the basic RF can finally take form [3]

$$\bar{Q} = \bar{G}\frac{\tau_s - \tau_r}{\tau_s' - \tau_r'} = \frac{\left(\tau_s + \tau_r - 2t_n\right)^{1+b}}{\left(\tau_s' + \tau_r' - 2t_n\right)^{1+b}} = \frac{t_{in} - t_{out}}{t_{in} - t_{out}'} \tag{1}$$

where $\bar{Q}$ is the relative heat load of the DH system; $\bar{G}$ is the relative flowrate of the DH network; τ_s and τ_r are the supply and return water temperatures at an outdoor temperature t_{out}, ℃; τ_s' and τ_r' are the design supply and return water temperatures, ℃; t_{in} is the design indoor temperature, ℃; t_{out}' is the design outdoor temperature, ℃; b is a characteristic coefficient of the heat exchanger. In section 2, we will introduce each term in detail.

The basic RF (1) is valid for the DH systems with only direct-connection heat users. However, the indirectly connected DH systems are more popular. It is not wise to utilize (1) in the indirectly connected DH systems without checking its applicability and accuracy. Many researchers have done studies on the control and regulation of different DH systems from different points of views [5-11]. Kuosa et al. [12] and Laajalehto et al. [13] studied the control method of a ring network in a DH system. Matthias Wissner examines the possibility of regulating DH systems in German market from an economic perspective. In addition, the smart and automatic technologies [14] are increasingly used in the DH substations to control the indoor temperature, but from the top-down point of view, this is only an auxiliary method to aid the DH regulation. Therefore, in this paper we mainly study the DH regulation in the heat plant and primary network, which is also the most important regulation method.

The objective of this paper is to account for the applicability and accuracy of the basic RF in the indirectly connected DH system and to provide a guidance for the regulation and operation of different DH systems. This paper is organized as follows. Section 2 presents the regulation formula for DH systems with only indirect-connection heat users. Section 3 discusses the accuracy and applicability of the basic RF. Conclusions are drawn in Section 4.

2. Regulation formula for DH systems with only indirect-connection heat users

In some big DH systems, heat users are usually indirectly connected to the DH network through heat exchangers, so that the hydraulic and pressure conditions in primary and secondary networks are independent with each other. This also makes the system safer and easier to operate.

2.1 Heat balance of each indirectly connected substation

For the indirectly connected substation, such as the heat user 2 in Fig. 1, if the same type of heating devices are used in the buildings after this substation or all heating devices are deemed as a big radiator with average performance; and the volume specific heat load (used to calculate the heat demand) of the buildings is stable, then the relative heat load of the substation takes form

$$\bar{q}_i = \frac{q_{hx,i}}{q'_{hx,i}} = \frac{q_{3,i}}{q'_{3,i}} = \frac{q_{2,i}}{q'_{2,i}} = \frac{q_{1,i}}{q'_{1,i}} \tag{2}$$

where $\bar{q}_i$ is the relative heat load of substation i; $q_{1,i}$ is the building heat demand calculated using the volume specific heat load after substation i, W; $q_{2,i}$ is the heat radiating load of the heating devices in the buildings after substation i, W; $q_{3,i}$ is the supplied heat load from the primary network to substation i, W; $q_{hx,i}$ is the heat load of the heat exchanger in substation i, W. These heat loads correspond to an arbitrary outdoor temperature t_{out}, and the corresponding design parameters can be expressed as

$$q'_{1,i} = \tilde{q} V_i (t_{in} - t'_{out}) \tag{3}$$

$$q'_{2,i} = aF_i \left(\frac{t'_{s,i} + t'_{r,i}}{2} - t_{in} \right)^{1+b} \tag{4}$$

$$q'_{3,i} = g'_{2nd,i} c_w \left(t'_{s,i} - t'_{r,i} \right) \tag{5}$$

$$q'_{hx,i} = K'_i F_{hx,i} \Delta t'_i \tag{6}$$

where $\tilde{q}$ is the volume specific heat load of the buildings after substation i, W/m^3; V_i is the volume of the buildings after substation i, m^3; a and b are the coefficients of the radiator equation; F_i is the radiator's area after substation i, m^2; $g'_{2nd,i}$ is the design flowrate of the secondary network after substation i, m^3/s; c_w is the specific heat capacity of water, J/(kg·K); $t'_{s,i}$ and $t'_{r,i}$ are the design supply and return water temperatures in the secondary network after substation i, ℃; K'_i is the design heat transfer coefficient of the heat exchanger in substation i, w/(m^2·K); $F_{hx,i}$ is the heat exchange area of the heat exchanger in substation i. $\Delta t'_i$ is the design logarithmic mean temperature difference (LMTD) in the heat exchanger in substation i, ℃.

It is usually assumed that the indoor design temperatures t_{in} in all buildings are the same, then the relative heat loads of all substations are equal

$$\bar{q}_1 = \bar{q}_2 = \cdots = \bar{q}_i \tag{7}$$

The RF for substation i can be obtained from (2)-(7)

$$\bar{q}_i = \bar{K}_i \frac{\Delta t_i}{\Delta t'_i} = \bar{g}_{2nd,i} \frac{t_{s,i} - t_{r,i}}{t'_{s,i} - t'_{r,i}} = \frac{(t_{s,i} + t_{r,i} - 2t_{in})^{1+b}}{(t'_{s,i} + t'_{r,i} - 2t_{in})^{1+b}} = \frac{t_{in} - t_{out}}{t_{in} - t'_{out}} \tag{8}$$

where $\bar{K}_i$ is the relative heat transfer coefficient of the heat exchanger in substation i; $\bar{g}_{2nd,i}$ is the relative flowrate of the secondary network after substation i.

2.2 Heat balance of the whole DH system and the regulation formula

For the whole DH system, the relative heat load is

$$\bar{Q} = \frac{Q_{hx}}{Q'_{hx}} = \frac{Q_3}{Q'_3} = \frac{Q_2}{Q'_2} = \frac{Q_1}{Q'_1} \tag{9}$$

where Q_1 is the heat demand of all buildings, W; Q_2 is the heat radiating load of all heating devices, W; Q_3 is the provided heat load of the DH network, W; Q_{hx} is the heat load of the heat exchangers in all substations, W. Similarly, these heat loads correspond to an arbitrary outdoor temperature t_{out}, the corresponding design parameters are marked with a comma and can be written as the summation of all substations using (3)-(6). Therefore, we can obtain

$$\bar{Q} = \frac{\sum_i q_{hx,i}}{\sum_i q'_{hx,i}} = \frac{\sum_i g_{2nd,i} c_w (t_{s,i} - t_{r,i})}{\sum_i g'_{2nd,i} c_w (t'_{s,i} - t'_{r,i})} = \frac{\sum_i aF_i \left(\frac{t_{s,i} + t_{r,i}}{2} - t_{in} \right)^{1+b}}{\sum_i aF_i \left(\frac{t'_{s,i} + t'_{r,i}}{2} - t_{in} \right)^{1+b}} = \frac{\sum_j qV_j (t_{in} - t_{out})}{\sum_j qV_j (t_{in} - t'_{out})} \tag{10}$$

If the following three conditions hold, then (10) can be written as in (11).

1) The design indoor temperature and volume specific heat load of all buildings are the same.
2) The same type of heating devices are used in the buildings after this substation or all heating devices are deemed as a big radiator with average performance;
3) The supply and return water temperatures in primary and secondary sides are the same for each substation.

$$\bar{Q}=\underset{①}{\frac{\sum_i q_{hx,i}}{\sum_i q'_{hx,i}}}=\underset{②}{\frac{\sum_i g_{2nd,i}c_w(t_{s,i}-t_{r,i})}{\sum_i g'_{2nd,i}c_w(t'_s-t'_r)}}=\underset{③}{\frac{\sum_i aF_i\left(\frac{t_{s,i}+t_{r,i}}{2}-t_{in}\right)^{1+b}}{\sum_i aF_i\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}}}=\frac{t_{in}-t_{out}}{t_{in}-t'_{out}} \tag{11}$$

therefore, we can get (12) from (7), (8) and (11).

$$\bar{q}_1=\bar{q}_2=\cdots=\bar{q}_i=\bar{Q} \tag{12}$$

Next, we will discuss each term in (11) and make the equation more clear for DH regulation. According to (6)

$$q'_{hx,i}=K'_iF_{hx,i}\Delta t'_i \tag{13}$$

Substitute (13) into term ① of (11), we derive

$$\bar{Q}_{hx}=\frac{\sum_i q_{hx,i}}{\sum_i q'_{hx,i}}=\frac{\sum_i K_iF_{hx,i}\Delta t_i}{\sum_i K'_iF_{hx,i}\Delta t'_i} \tag{14}$$

Meanwhile, the heat exchange area of a heat exchanger in substation *i* can take form

$$F_{hx,i}=\frac{q'_{hx,i}}{K'_i\Delta t'_i} \tag{15}$$

Substitute (15) into (14), we derive

$$\bar{Q}_{hx}=\frac{\sum_i K_i\left(\frac{q'_{hx,i}}{K'_i\Delta t'_i}\right)\Delta t_i}{\sum_i K'_i\left(\frac{q'_{hx,i}}{K'_i\Delta t'_i}\right)\Delta t'_i}=\frac{\sum_i\left(\frac{K_i}{K'_i}\right)\left(\frac{q'_{hx,i}}{\Delta t'_i}\right)\Delta t_i}{\sum_i\left(\frac{K'_i}{K'_i}\right)\left(\frac{q'_{hx,i}}{\Delta t'_i}\right)\Delta t'_i} \tag{16}$$

if the LMTD under design condition is the same in each heat exchanger, namely $\Delta t'_1=\Delta t'_2=\ldots=\Delta t'_i=\ldots\Delta t'$, then (16) can take form

$$\bar{Q}_{hx}=\frac{\sum_i\left(\frac{K_i}{K'_i}\right)\Delta t_i}{\sum_i \Delta t'}=\frac{\sum_i \bar{K}_i\Delta t_i}{\sum_i \Delta t'} \tag{17}$$

In real-life operation of the indirect-connection DH system, the LMTD in each heat exchanger Δt_i is rarely the same. However, if we assume the supply and return water temperatures in primary and all secondary networks are the same for each substation, namely $\Delta t_1=\Delta t_2=\ldots=\Delta t_i=\ldots\Delta t$, then (17) can then take form

$$\bar{Q}_{hx}=\frac{\sum_i \bar{K}_i \Delta t_i}{\sum_i \Delta t'}=\frac{\Delta t}{\Delta t'}\frac{\sum_i \bar{K}_i}{\sum_i 1}=\frac{\sum_i \bar{K}_i}{i}\frac{\Delta t}{\Delta t'} \tag{18}$$

where

$$\bar{K}_i=\bar{g}_i^{0.5}\bar{g}_{2nd,i}^{0.5} \tag{19}$$

$\bar{g}_i$ and $\bar{g}_{2nd,i}$ are the relative flowrates in the primary and secondary sides of substation i

$$\bar{g}_i=\frac{g_i}{g_i'};\quad \bar{g}_{2nd,i}=\frac{g_{2nd,i}}{g_{2nd,i}'} \tag{20}$$

g_i', g_i are the flowrates in design condition and other operating conditions in the primary side, m^3/s, calculated by

$$\begin{aligned}\frac{g_i'}{G'}&=\frac{q_{hx,i}'}{Q'}\Rightarrow g_i'=\frac{q_{hx,i}'}{Q'}G'\\ \frac{g_i}{G}&=\frac{q_{hx,i}'}{Q'}\Rightarrow g_i=\frac{q_{hx,i}'}{Q'}G\end{aligned} \tag{21}$$

$g_{2nd,i}'$, $g_{2nd,i}$ are flowrates in design condition and other operating conditions in the secondary side m^3/s, calculated by

$$\frac{q_{hx,i}'}{Q'}=\frac{g_{2nd,i}'c_w(t_{s,i}'-t_{r,i}')}{\sum_i g_{2nd,i}'c_w(t_s'-t_r')}=\frac{g_{2nd,i}'}{\sum_i g_{2nd,i}'}\Rightarrow g_{2nd,i}'=\frac{q_{hx,i}'}{Q'}\sum_i g_{2nd,i}';\quad g_{2nd,i}=\frac{q_{hx,i}'}{Q'}\sum_i g_{2nd,i} \tag{22}$$

Substitute (21) and (22) into (20), we derive

$$\bar{K}_i=\bar{g}_i^{0.5}\bar{g}_{2nd,i}^{0.5}=\left(\frac{g_i}{g_i'}\right)^{0.5}\left(\frac{g_{2nd,i}}{g_{2nd,i}'}\right)^{0.5}=\left(\frac{\frac{q_{hx,i}'}{Q'}G}{\frac{q_{hx,i}'}{Q'}G'}\right)^{0.5}\left(\frac{\frac{q_{hx,i}'}{Q'}\sum_i g_{2nd,i}}{\frac{q_{hx,i}'}{Q'}\sum_i g_{2nd,i}'}\right)^{0.5}=\left(\frac{G}{G'}\right)^{0.5}\left(\frac{\sum_i g_{2nd,i}}{\sum_i g_{2nd,i}'}\right)^{0.5} \tag{23}$$

and according to (22)

$$\frac{\sum_i g_{2nd,i}}{\sum_i g_{2nd,i}'}=\frac{g_{2nd,i}}{g_{2nd,i}'}=\bar{g}_{2nd,i}\Rightarrow \bar{g}_{2nd,1}=\bar{g}_{2nd,2}=\cdots=\bar{g}_{2nd,i}=\bar{G}_{2nd} \tag{24}$$

Therefore

$$\bar{K}_i=\bar{g}_i^{0.5}\bar{g}_{2nd,i}^{0.5}=\left(\frac{G}{G'}\right)^{0.5}\left(\frac{\sum_i g_{2nd,i}}{\sum_i g_{2nd,i}'}\right)^{0.5}=\bar{G}^{0.5}\bar{G}_{2nd}^{0.5} \tag{25}$$

It can be concluded from (25) that the relative heat transfer coefficient in all heat exchangers are the same, $\bar{K}_1=\bar{K}_2=\ldots=\bar{K}_i=\ldots\bar{K}$, that is to say, the relative heat transfer coefficient in any heat exchanger can represent that of the whole DH system under the given conditions. Thus, (18) can be simplified as

$$\bar{Q}_{hx}=\frac{\sum_i \bar{K}_i}{i}\frac{\Delta t}{\Delta t'}=\frac{\sum_i \bar{K}}{i}\frac{\Delta t}{\Delta t'}=\frac{\bar{K}\sum_i 1}{i}\frac{\Delta t}{\Delta t'}=\bar{K}\frac{\Delta t}{\Delta t'} \tag{26}$$

Term ② in (11) can be written as in (27), if the supply and return water temperatures in the secondary network are the same for each substation.

$$\bar{Q}_3=\frac{\sum_i g_{2nd,i}c_w(t_{s,i}-t_{r,i})}{\sum_i g'_{2nd,i}c_w(t'_s-t'_r)}=\bar{g}_{2nd,i}\frac{t_s-t_r}{t'_s-t'_r}=\bar{G}_{2nd}\frac{t_s-t_r}{t'_s-t'_r} \tag{27}$$

For term ③ in (11), if the same type of heating devices are used in the buildings after all substations or all heating devices are deemed as a big radiator with average performance, then the radiator's area is calculated by

$$F_i=\frac{q'_{2,i}}{a\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}} \tag{28}$$

Substitute (28) into (11), then

$$\bar{Q}_2=\frac{\sum_i aF_i\left(\frac{t_{s,i}+t_{r,i}}{2}-t_{in}\right)^{1+b}}{\sum_i aF_i\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}}=\frac{\sum_i \frac{q'_{2,i}}{a\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}}a\left(\frac{t_{s,i}+t_{r,i}}{2}-t_n\right)^{1+b}}{\sum_i \frac{q'_{2,i}}{a\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}}a\left(\frac{t'_s+t'_r}{2}-t_{in}\right)^{1+b}}=\frac{\sum_i q'_{2,i}\left[\frac{(t_{s,i}+t_{r,i}-2t_{in})^{1+b}}{(t'_s+t'_r-2t_{in})^{1+b}}\right]}{\sum_i q'_{2,i}} \tag{29}$$

If the supply and return water temperatures in the secondary network are the same for each substation, (29) can take form

$$\bar{Q}_2=\frac{(t_s+t_r-2t_{in})^{1+b}}{(t'_s+t'_r-2t_{in})^{1+b}}\frac{\sum_i q'_{2,i}}{\sum_i q'_{2,i}}=\frac{(t_s+t_r-2t_{in})^{1+b}}{(t'_s+t'_r-2t_{in})^{1+b}} \tag{30}$$

In all, only if the aforementioned three conditions (1) – (3) hold true at the same time, basic RF of indirect-connection DH systems can be written as

$$\bar{Q}=\bar{K}\frac{\Delta t}{\Delta t'}=\bar{G}_{2nd}\frac{t_s-t_r}{t'_s-t'_r}=\frac{(t_s+t_r-2t_{in})^{1+b}}{(t'_s+t'_r-2t_{in})^{1+b}}=\frac{t_{in}-t_{out}}{t_{in}-t'_{out}} \tag{31}$$

Conditions (1) and (2) can be satisfied at the design phase of the DH system. Condition (3) is a common condition that must be satisfied to make all three terms in (11) take the form in (31). However, only the supply temperatures in primary sides (τ_s) of all substations can be the same. The return temperatures in primary sides (τ_r) and the supply and return temperatures in secondary sides of all substations t_s and t_r are rarely the same in real-life operation conditions. Therefore, the accuracy of the regulation formula should be analyzed.

3. Accuracy and applicability of the regulation formula

As discussed in section 2, only τ_s can be equal for all substations, but τ_r, t_s and t_r are rarely equal for different substations. That is to say, in the real-life DH regulation, there still exist some differences between the results of (31) and the theoretically results when all the three conditions hold true. In this section, we will discuss these differences when τ_r, t_s and t_r vary from the theoretically values, provided that there are not severe hydraulic and thermal maladjustments in the DH network.

We find that the three variables τ_r, t_s and t_r cannot change arbitrarily, because if τ_s is equal in all substations, then at most two variables can vary arbitrarily within a certain scope (±5% is used in this paper according to some real monitoring data of many substations in a big DH system) and the remaning one is restricted by the first and second law of thermodynamics. In this paper, we assume that t_s and t_r can vary arbitrarily within the scope and use a DH system with five indirectly connected substations under design condition (t'_s and t'_r are 85 ℃ and 60 ℃) to demonstrate the accuracy analysis of the RF. Design indoor and outdoor temperatures are 18 ℃ and -26 ℃, respectively. The combinations of t_s and t_r for the accuracy analysis is shown in Table 1 and the accuracy analysis results are shown in Fig. 2.

Table 1. Combinations of t_s and t_r for analyzing the accuracy of the regulation formula in a DH system with only indirectly connected substations

Substation	1#	2#	3#	4#	5#
t_s variation	5%	3%	1%	-3%	-5%
t_s	89.25 ℃	87.55 ℃	85.85 ℃	82.45 ℃	80.75 ℃
t_r variation	5%	3%	3%	-3%	-5%
t_r	63 ℃	61.8 ℃	61.8 ℃	58.2 ℃	57 ℃
t_s-t_r	26.25 ℃	25.75 ℃	24.05 ℃	24.25 ℃	23.75 ℃

Fig. 2 shows that the calculated relative heat loads of each substation using the three different terms of the regulation formula in (8). The difference of relative heat load calculated by $\bar{q}_{hx,i} = \bar{K}_i \Delta t_i / \Delta t'$ is the biggest, up to ±15%; the difference of $\bar{q}_{2,i} = (t_{s,i} + t_{r,i} - 2t_{in})^{1+b} / (t'_s + t'_r - 2t_{in})^{1+b}$ is ±8%, and the difference of $\bar{q}_{3,i} = \bar{g}_{2nd,i} (t_{s,i} - t_{r,i}) / (t'_s - t'_r)$ is only ±5%, which is the smallest. If we want to use (31) in a real life DH regulation, then the difference of relative het load should be less than ±10% or even smaller. Therefore, the corresponding variation scope of t_s and t_r should be less than ± 3% as indicated from Fig. 2. From this point of view, the central regulation and on-site regulation in the substations or buildings should coordinate to control the DH system better and reduce thermal maladjustments between different heat users.

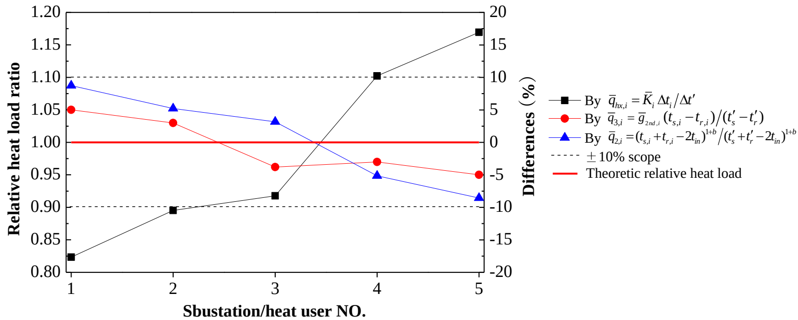

Fig. 2 Accuracy of the regulation formula when t_s and t_r vary ±5% in a DH system with only indirectly connected substations.

4. Conclusions

The basic regulation formula is based on the direct-connection DH systems and thus cannot be used in the indirect-connection DH system without accuracy analysis. This paper deduces the regulation formula for indirect-connection DH system, and according to accuracy analysis, we find that the applicability of the regulation formula should be based on three conditions: 1) The design indoor temperature and volume specific heat load of all buildings are the same; 2) The same type of heating devices are used in the buildings after each substation or all heating devices are deemed as a big radiator with average performance; 3) The supply and return water temperatures in primary and secondary sides are the same for each substation.

If the three conditions cannot hold true at the same time, then the accuracy of regulation formula should be analyzed first. If the difference of theoretical relative heat load ratio and the ratio calculated by regulation formula should be less than ±10%, then the corresponding variation scope of t_s and t_r should be less than ±3%. Otherwise, the central regulation and on-site regulation in the substations or buildings should coordinate to operate the DH system better and reduce thermal maladjustments between different heat users.

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Paper 358
Manuscript Title: Accounting for the regulation of district heating (DH) system

Dear Reviewer,

Thank you very much for your comments. We carefully read them and revised the manuscript accordingly. Questions are answered below point by point:

Some of the formulas have been distorted in the editing system and have to be restored before final acceptance can be issued.

- ✓ We have restored the equations in the manuscript. PDF version is provided.

One more round of proof reading would be beneficial.

- ✓ The proof reading has been done.

A follow up question is if it had been beneficial to simulate a system with different degree of variability of the users to investigate the influence of the variability of the users on the applicability of the formula for indirect systems.

- ✓ Yes, It is beneficial, because the basic regulation formula is derived from the direct connection DH system, and it cannot be directly used in the DH system with indirect connection heat users and/or DH system with different end-node heating systems (e.g. radiators and floor heating system, where the temperature requirements is different). In order to use the right formula in the right DH system and increase the reliability of the central control of DH, we have to study the applicability and accuracy of the basic regulation formula and determine the regulation formula for each kind of DH system.

Sincerely yours,

Dr. Haichao Wang