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Dynamic balancing for dynamic networks

Advanced hydraulic networks have to ensure energy-efficient, economical and fault-free operation, compensate for deviations from the original planning values, permit future upgrades and have low installation costs. And yet how can we efficiently control increasingly more complex networks in all partial load states? Dynamic solutions for dynamic operation are the answer.

Hydraulic networks are an important component of any building. Not only are they used for heating and air conditioning, but they also represent a significant cost factor when it comes to operation with the help of electric pumps.

$$P_{el} = \frac{\Delta p \cdot \dot{V}}{\eta}$$

To operate a hydraulic network energy-efficiently and economically, it is necessary to vary the transported volumetric flow. The formula for calculating the electric pumping power demonstrates that adapting the circulating volumetric flow, in particular, makes it possible to save a substantial amount of the pump's energy. The use of systems with a constant volumetric flow seems to be an outmoded approach.
Although it is already customary today to use controlled pumps and to adapt the delivered volumetric flow as well as to reduce the pump pressure differential provided, the downstream network is still largely controlled on the basis of static control intervention. It is common practice to balance hydraulic networks using static balancing throttles, presettable control valves or circuit control valves. Of course, these interventions are carried out only once and only for the specific calculated state: the design state under full load. However, the design state occurs very rarely during later operation of the hydraulic network since the installation is under partial load in nearly all operating situations. So the question arises whether not only the pump but also network control

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should be adapted to the different partial load states and whether static balancing in a variable installation might even be a hindrance.

It's all a matter of synchronicity

Static hydraulic balancing ultimately means the additional introduction of substantial resistances in order to bring the pressure loss of each flow path in line with the least favorable one in the system when the installation is under design state. This is also necessary for fault-free operation under these conditions. As described above, however, this applies only to the design state and thus only to a fraction of the operating states since a hydraulic network is in the partial load state most of the time. In examining these partial load states, a distinction must nevertheless be made between two different situations. On the one hand, the network as a whole is subjected to a very uniform load, which means that the behavior of all consumers is similar. In this situation, a static control intervention can offer helpful support to the control valve even in the partial load state because the resistances are proportional to the volumetric flow and thus change uniformly with a similar variation in the volumetric flows.

However, if the hydraulic network is subjected to an uneven load, for example when supplying the north and south sides of a building at the same time, or when supplying areas of varying use, the static hydraulic balance may quickly become a hindrance. In buildings with this type of use, the least favorable flow path cannot be determined by calculating the design state. Depending on the current usage and internal and external loads, the least favorable flow path varies continuously. The network behavior is dynamic. The installed static balancing throttles are then not only superfluous but also represent a substantial hydraulic resistance, which is both unnecessary and can even impair network control, depending on the utilization.

Since the hydraulic networks in buildings are almost always in partial load states, the problem arises that the pump must continuously overcome unnecessary resistances in installations with variable volumetric flows and conventional static hydraulic balancing. These resistances do not help improve controllability since they are not designed for this operating state. Depending on the pump control, this situation can even lead to undersupply of individual flow paths because it may not be possible to overcome the additional resistance of the static balancing throttle. For example, this would be conceivable in an installation with end-point pump control, i.e. one where the pressure is measured over the consumer in the least favorable flow path of the installation, calculated on the basis of the design state. If we take a look at a partial load state in which all flow paths are closed and only the pump-proximate flow path having the largest static throttling requires full power, it quickly becomes clear that the available pump pressure differential may under certain circumstances be insufficient for the requested flow path. [Figure 1]

Figure 1 shows a classic network with static balancing. A partial load state can be described by way of an example in which flow paths 2 through 5 are closed and only flow path 1 is in operation.

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While static balancing is designed for the least favorable flow path 6, flow path 1, which is actually the most favorable one in this operating state, turns out to be the least favorable flow path in the current hydraulic state. The static balancing throttle generates an enormous pressure loss in this case, even though the throttle is not needed. Although a noticeable undersupply doesn’t always occur, it should nevertheless be clear that static balancing in today’s networks with variable volumetric flows is not expedient even from an energy perspective. Dynamic adjustment of the balancing throttle is necessary in order to correctly balance a dynamic network with variable volumetric flows. Combi valves may be a solution.

As much resistance as necessary and as little as possible

[Figure 2]

Combi valves essentially consist of two components. The first of these is the usual control valve, and the other component is a differential pressure controller that is connected in series and operates depending on the pressure differential over the control valve.

[Figure 3]

The control valve is activated according to a request in the network and changes its stroke, for example with the aid of an actuator. At the same time, the differential pressure controller maintains a constant pressure differential over this very control valve. Due to this type of combination, the control valve remains independent of pressure as long as a certain minimum pressure differential is maintained.

$$\Delta p = C \cdot V^2$$

Any operating point may be selected for illustration. For example, if the valve is open all the way, a certain volumetric flow forms in the flow path which is dependent on all hydraulic resistances and the available pressure differential through the pump. The differential pressure controller plays an important role among the resistances. By changing the position of the differential pressure controller, the resistance of the flow path is changed in such a way that a volumetric flow forms which generates a constant pressure drop over the constant resistance of the fully open control valve. The control valve cone is thus a type of orifice plate of the differential pressure valve. If the available pressure is then increased, for example by changing the pump characteristic curve, the differential pressure controller would close until the volumetric flow in the control valve, and thus the pressure differential over the valve cone, is constant again. Of course, this also works in reverse, when reducing the available pressure differential. The differential pressure controller opens until the flow path resistance is weak enough to again maintain the volumetric flow in the control valve. The result is a flow path with a constant volumetric flow and variable total resistance, regardless of the available pressure differential. The use of this system is, of course, limited to the

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permitted maximum pressure differential and to the minimum pressure differential required when the differential pressure controller is open all the way in order to maintain the relevant volumetric flow.
In addition to changing the available pressure differential, changing the valve stroke must also be considered. If the volumetric flow in the flow path is changed, the valve can be closed, for example. The pressure differential over the valve cone is, of course, held constant even in this situation. If the valve closes, the valve cone resistance increases. Due to the correlation between pressure, volumetric flow and hydraulic resistance, this means that changing the valve stroke at a constant pressure differential acts in proportion with the volumetric flow. The correlation between volumetric flow and stroke can thus be determined by the design of the valve cone and the resulting hydraulic resistance. [Figure 4]
Based on this characteristic, not only does the network behavior change but also the way in which such control valves are designed. While kvs values and the valve authority are used when working with conventional control valves, the design of a pressure-independent control valve is based entirely on volumetric flows. The valve has to be selected only according to the maximum volumetric flow and can then ensure the desired flow with a sufficient pressure differential. *[Figure 5]*
The characteristic of the constant volumetric flow also affects the problems and requirements of today's hydraulic networks mentioned above. Due to their dynamic behavior, combi valves can compensate for minor deviations between planning and assembly at the construction site. It is also possible to upgrade a hydraulic network relatively easily using combi valves since the valves compensate for the new hydraulic states.
Despite the drastically reduced amount of planning and installation, it is still necessary to design a network properly. The desire for energy-efficient hydraulic networks, in particular, necessitates flawless and well thought-out planning. Although pressure-independent valves can compensate for many deviations and errors, they should not be improperly used as a way to make up for inadequate planning since a dynamic and economical network with few pressure losses is also directly linked to a well thought-out topology.

Optimizing pumping power and the least favorable flow path

If one compares combi valves to conventional control valves without taking the hydraulic network or a possible installation situation into account, it becomes apparent that the resistance, and thus the pressure loss over a pressure-independent control valve, is higher than with a conventional valve. To ensure fault-free operation, combi valves have a necessary minimum pressure differential of approximately 15 – 20 kPa. By comparison, this figure is only 9 kPA for a conventional radiator valve, i.e. the pressure-independent control valve thus doubles the necessary pressure differential. So how does this relate to energy efficiency when combi valves are used?

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The entire network and the valve’s specific installation situation must always be taken into account when considering the effect the valves have on pump energy. Any additional pressure loss is irrelevant in all flow paths since the balancing throttle is integrated into the pressure-independent control valve, and an increased pressure loss is required in any case. The minimum pressure differential is of no interest in this case. Only the least favorable flow path does not require a balancing throttle in the conventional network, which makes the minimum pressure differential noticeable since it must be maintained and thus also affects the entire volumetric flow within the network. However, is the required pressure differential actually higher than that of a conventional control valve? Not necessarily!
In a dynamic network, the least favorable flow path can vary depending on use. For example a formerly “favorable” flow path with a static balancing throttle can suddenly become the least favorable flow path due to different heating or cooling requirements. A comparison with a pressure-independent control valve must take into account not only the valve's pressure loss but also the pressure loss over the balancing throttle. Since with static balancing the balancing throttle is set to a constant resistance and it is not adapted to the operating situation, the pressure loss in the least favorable flow path can be significantly lower with a pressure-independent control valve than is the case with a conventional control valve and a static balancing throttle.

Conclusion

[Figure 6]

In today’s hydraulic networks, the volumetric flow varies depending on the actual demand. Dynamic networks of this type are currently balanced primarily using static control elements and calculated to the relevant design state. Due to the fact that hydraulic networks in buildings operate primarily in the partial load range, this circumstance is expedient only to a limited extent. Ideally, hydraulic networks should be optimally balanced in any operating state and have a high degree of flexibility. Combi valves can be one solution. They simplify planning, compensate for minor deviations during the construction phase, continuously balance the network and play a significant role in making hydraulic networks transparent. At the same time, the assumption that this type of valve generates higher pressure losses in a dynamic network is incorrect when viewed holistically. Of course, the potential for increasing comfort and thermal energy efficiency must also be taken into account. After all, what network is really balanced in practice even if this was provided for in the planning stage?

References:

Avery, Gil: “Balancing A Variable Flow Water System Will Ruin the Control System,” ASHRAE Journal, issue: October 1990

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