Scholar Publishing Group
Academic Journal of Energy
https://doi.org/10.38007/RE.2022.030206
ISSN 2790-2714 Vol. 3, Issue 2: 48-56

New Energy Based on Superconducting Energy Storage Technology in Central Heating

Odsuren Batdelger*

Vytautas Magnus University, Lithuania

**corresponding author*

Keywords: Superconducting Storage, New Energy, Central Heating, Cost Control

Abstract: As a country with a large population, with the growth of national economy and the improvement of people's living standards, its consumption of energy is getting bigger and bigger, and the total consumption has ranked first in the world. In the numerous energy consumption, the load energy consumption of the northern central heating occupies a considerable part. In the north, where the demand for central heating is extremely increasing dramatically, there are many large wind farms, and the large area of "wind curtailing" phenomenon is getting more and more attention by the society.This paper aims to study the application of new energy sources based on superconducting energy storage technology in central heating. This paper first discusses the principle and classification of superconducting energy storage technology. According to the arrangement form, installation position and connection form of superconducting energy storage device in the heat network, and the various characteristics of superconducting energy storage and traditional heat storage are compared and analyzed, and the best use conditions and form of superconducting energy storage device are sought. At the planning level of the system, the annual total cost model of superconducting energy storage is established, which includes the system thermal model and the system economy model, and the particle swarm algorithm is taken as the solution method of the optimal solution of the model. At the level of daily operation scheduling, the dynamic model and daily operation optimization model of the hot user system are established. The former is based on the aggregate parameter method, including the envelope structure dynamic model, the heating system heat conduction model and the building air dynamic heat balance model; the latter includes the uniform supply model and the heterogeneous supply model. The experiment proved that the central heating system constructed in this paper has higher human efficiency, and the upper heating temperature reached 22℃, making the room more comfortable and pleasant, and reducing the carbon emission.

1 Introduction

Heating system is an essential part of residential projects in northern China. With the acceleration of urbanization, the scale of urban heat network cannot meet the demand. Secondly, central heating not only occupies a large amount of investment, but also puts forward higher technical requirements for heating system operators. Property companies generally do not have the ability to operate on such a large scale. Central heating, especially primary energy-saving cogeneration heating, is important to improve the environment and improve people's living standards; Central heating also fully demonstrates the convenience, comfort, safety, reliability and beauty of modern cities, so it is widely used in Europe and other countries. In the coal, oil, natural gas and other resources saving, improve the quality of life, improve the urban infrastructure such as health, environmental protection, and other aspects of the modern city construction, the development prospect of urban central heating will be very broad [1-2].

In the research on the application of new energy based on superconducting energy storage technology in central heating, many scholars have studied it and achieved good results. For example, Zappatore A evaluated the impact of different energy storage substances on the micro-cogeneration system, and proposed that the performance of the phase change heat storage system depends heavily on the power of the cogeneration system of [3]. Eshraghi A studied the effect of applying heat storage devices in the central heating system on primary energy conservation. By simulating the proposed heat storage tank model, the primary energy consumption and its economic [4] is predicted.

This paper first discusses the principle and classification of superconducting energy storage technology. According to the arrangement form, installation position and connection form of superconducting energy storage device in the heat network, and the various characteristics of superconducting energy storage and traditional heat storage are compared and analyzed, and the best use conditions and form of superconducting energy storage device are sought. At the planning level of the system, the annual total cost model of superconducting energy storage is established, which includes the system thermal model and the system economy model, and the particle swarm algorithm is taken as the solution method of the optimal solution of the model. At the level of daily operation scheduling, the dynamic model and daily operation optimization model of the hot user system are established. The former is based on the aggregate parameter method, including the envelope structure dynamic model, the heating system heat conduction model and the building air dynamic heat balance model; the latter includes the uniform supply model and the heterogeneous supply model.

2. Research on the Application of New Energy Based on Superconducting Energy Storage Technology in Central Heating

2.1. Development of Superconducting Energy Storage Technology

Superconducting magnetic energy Storage (SMES) combines the high-density and high-efficiency energy storage characteristics of superconducting magnets and the millisecond-level rapid response characteristics of heating electronic devices, enabling rapid power regulation in the four-quadrant range of active power and reactive power. In the modern heating system with the large-scale application of intermittent renewable energy, SMES, as a new heating system stabilizer based on the energy storage principle, has the potential to break through the "passive stabilization" mode of the traditional heating system and realize the "active stabilization". SMES is widely used for the stability control of heating system and improving the central heating quality in various countries. As early as 1982, Pollieville Heating Company (BPA) successfully applied a 30MJ / 10MW SMES to suppress low-frequency power oscillations on the 500kV contact line between the

West coast of the Pacific Ocean and Southern California, whose functions also include central heating pressure support and frequency control.The early SMES mainly uses the low-temperature superconducting technology, the need to soak the superconducting magnet in liquid helium or liquid nitrogen to cool to the working temperature area, low refrigeration efficiency; and the SMES operation needs to supplement the refrigerant at any time, it is not convenient to use. Therefore, the main users are concentrated in semiconductor chip production companies, data processing centers, paper mills and plastic factories and other enterprises with high power quality requirements, as well as [5-6] s such as strong magnetic field and nuclear physics laboratories.

The development of high temperature superconducting (HTS) material technology makes the manufacturing process of bismuth (Bi) and yttrium (Y) superconducting strip increasingly mature. At the same time, along with the progress of refrigeration machine technology, the high temperature superconducting SMES (HT-SMES) using conduction cooling has attracted more and more attention. Japan New Energy Development Organization (NEDO), together with Tokyo Heating Company and Kyushu Heating, has jointly carried out commercial utilization value HT-SMES research and development work since 1999, mainly used to enhance the stability of the heating system (15kWh / 100MW) and load fluctuation compensation and frequency control (500kWh / 100MW). HT-SMES has been applied in the fields of system voltage support and uninterrupted central heating, with a maximum capacity of MJ magnitude. Compared with the low-temperature superconducting SMES, the HT-SMES increases the operating temperature of the magnet from 4.2K to above 20K, greatly improving the magnet cooling efficiency.

From the current technical economy perspective, the small and medium-sized SMES with decentralized layout is the basic mode suitable for the practical application of SMES. Mobile high temperature superconducting SMES can flexibly choose the installation site, which has the advantages of meeting the decentralized layout and wide application, and has a good application prospect in the heating system, [7-8].

2.2. Status Quo of Central Heating

China's energy utilization rate is relatively low, and because of the large base, the energy waste is very serious, in the "12th Five-Year" Plan ", it is clear to save 670 million tons of standard coal energy, energy-saving transformation is imperative. Building energy consumption accounts for about 30% of the national energy consumption, and heating and air conditioning account for another 30% of the building energy consumption. Therefore, the energy conservation of the heating system is very important in the energy conservation of the whole building.

Because China's central heating system scale is huge, the level of automatic control is not high, causing the phenomenon of uneven cold and heat is very common, energy waste is serious. For a long time, professionals have attributed the uneven loss of cold and heat to the heat loss of the pipe network, which is not only in the wrong direction, but also the amount of loss is difficult to count accurately. We must realize that the uneven heat loss caused by cold and heat is sent to the heat user, only because the room is overheat, the excess heat is lost through the window.

It can be seen that in 1980, because of the underdeveloped science and technology, the whole heating system was less inefficient, of which the power consumption accounted for only about 1%. However, with the progress of science and technology, the energy efficiency of heating system has been significantly improved, and the proportion of power consumption has also increased. Even in some heating systems, the energy consumption reaches about 10% of the system energy efficiency. It can be seen that under the background of national energy conservation and emission reduction targets, it is more and more important to improve the power transmission efficiency of heating system

Through the above analysis, we can clearly understand the energy consumption of each link of the heating system, and master the energy saving space of the whole heating system. In the ideal energy saving stage, the energy efficiency of the heating system is about 70%, while China is still in the second energy stage of the heating energy efficiency is about 30%, among which the energy saving potential is about 40%, and the energy saving space is huge [9-10].

2.3. Algorithm Selection

Both voltage and current SMES can be decoupling control active and reactive power in real time in the P-Q plane four quadrant. The CSC has a filter capacitance on the AC side, allowing it to provide more capacitance and reactive power to the power grid; the VSC must be connected to the power grid through a set of large numerical reactors to ensure its normal operation and proper performance. Therefore, under the same active capacity, its ability to provide capacitably reactive power to the grid is weaker than the current type.

The energy storage Esm on a superconducting magnet can be represented as [11-12]

$$E_{sm} = \frac{1}{2} L I_d^2 \tag{1}$$

In the formula, L is the inductance size of the superconducting coil, and Ld represents the direct current flowing through the superconducting coil. When the magnet inductor L

At large times, the rate of change of the DC current Id is very small. Let Psm be the active power output by SMES to the system, then the change of Id can be written as

$$I_d(t) = \sqrt{I_{d0}^2 - \frac{2\int_0^t (1+\zeta) P_{sm} dt}{L}} \tag{2}$$

ζ Is the loss coefficient of the converter.

3. Research and Design Experiment of New Energy Application Based on Superconducting Energy Storage Technology in Central Heating

3.1. Thermal Model of Superconducting Storage Heating System

This paper studies the application of the superconducting energy storage system in the central heating system. Above, the form, arrangement position and connection form of the superconducting energy storage system in the heating system have been analyzed. Considering that the superconducting energy storage system is a distributed heat storage mode, it is arranged at each heat exchange station of the heating system. Therefore, the model is based on the heat exchange station, considering only the basic heat source, superconducting energy storage device and peak heat exchange station; the economic equipment cost only considers the purchase and installation cost of the heat exchange station, and the operation cost only considers the fuel cost of the basic heat source, heat storage device and spike heat exchange station.

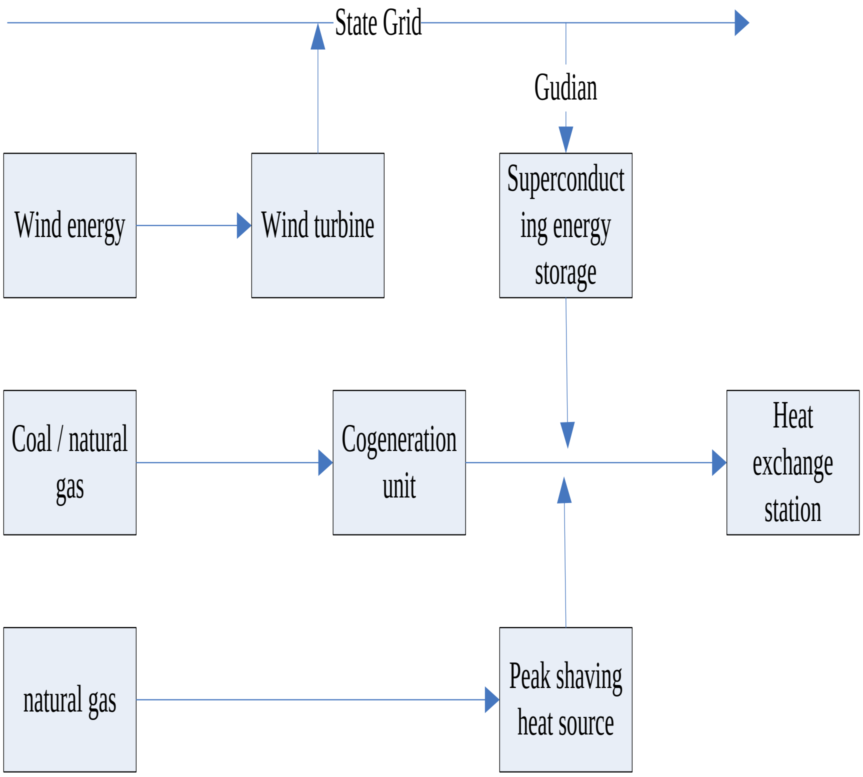

Figure 1. Schematic diagram of the operation principle of the thermoelectric integrated system

The combined heat and power generation system is the basic heat source, the superconducting energy storage system is arranged, and the integrated thermal power system takes the peak-regulating boiler as the peak heat source. The operation principle is shown in Figure 1.

3.2. Experimental Design

This paper experiments on the new energy central heating system based on superconducting energy storage technology constructed in this paper. It first explores the dynamic performance index of superconducting storage technology, studies the dynamic performance index of the system under different energy storage capacity, and by comparing whether the performance index change of AWC is included. Secondly, we compare the central heating efficiency of the central heating system and the traditional heating system, and judge the superiority of the central heating system in this paper.

4. Experimental Research and Analysis of New Energy Application Based on Superconducting Energy Storage Technology in Central Heating

4.1. Dynamic Performance Indicators

In this paper, the superconducting energy storage technology used in this paper explores the dynamic performance indexes of the system under different energy storage capacity in the three cases. By recording the changes of the three cases, the experimental data are shown in Table 1.

Table 1. Energy storage capacity changes of superconducting energy storage technology

	2	4	6	8	10
Without AWC	1.5	1	0.6	0.5	0.45
With AWC	0.75	0.6	0.5	0.47	0.43
No saturation	0.4	0.4	0.4	0.4	0.4

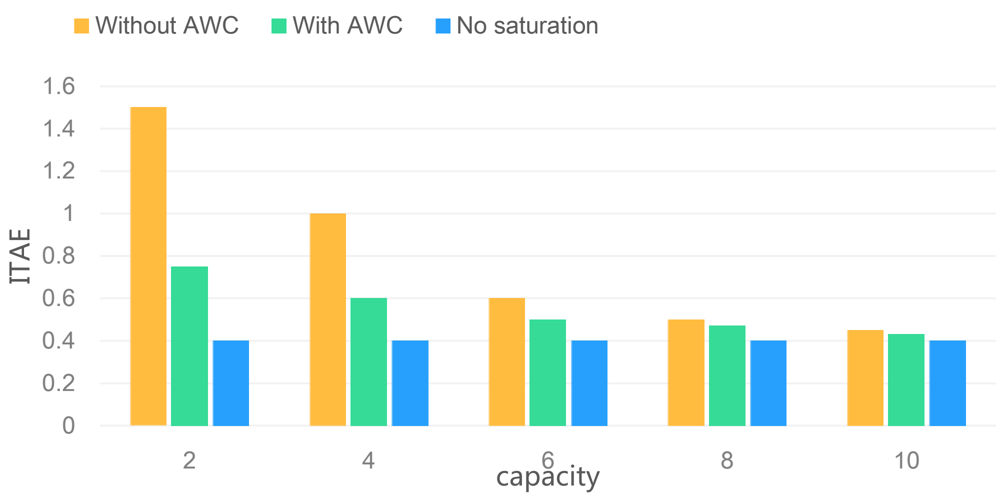

Figure 2. Dynamic performance index of the system under different energy storage capacity

As can be seen from Figure 2, although AWC cannot completely eliminate the adverse effects caused by the saturation link on the system, it can effectively compensate for it, and the more obvious the smaller the energy storage capacity is.However, with the increase of the energy storage capacity, the dynamic performance indicators of the three different energy storage technologies are getting closer and closer, and they are stable at about 0.4.

4.2 Central Heating Efficiency

This paper explores the central heating efficiency of the central heating system of this paper, compares the traditional central heating system with a certain 0℃ room, and records the temperature change of each hour. The experimental data are shown in Table 2.

Table 2. Comparison of the heating efficiency of the two central heating systems

	1	2	3	4	5
Traditional heating	**10**	**14**	**18**	**18**	**20**
This article focuses on heating	**14**	**20**	**22**	**22**	**22**

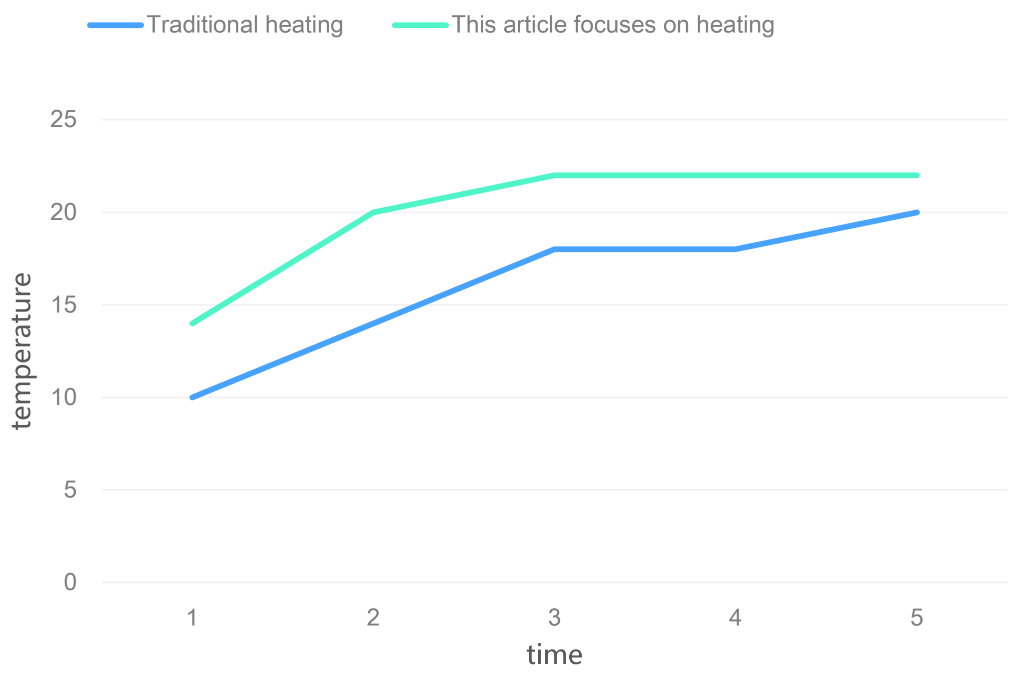

Figure 3. Room temperature change curve under two heating modes

It can be clearly seen from Figure 3 that the heating efficiency of the central heating system constructed in this paper is greatly improved, the heating speed is faster, and the temperature upper limit is higher, making the room more comfortable and pleasant. Through the application of superconducting energy storage technology and new energy, the central heating system is also more energy saving and environmental protection, and the carbon emission is greatly reduced.

5. Conclusion

With the increasing scale of renewable energy generation in the power system, the contradiction between power supply and demand balance in the large power system is gradually becoming prominent, which not only greatly increases the risk of low-frequency oscillation in the interconnected power grid, but also easily leads to large-scale power failure accidents. Energy storage technology has developed rapidly in recent years: not only the existing energy storage forms have made great progress, but also some emerging energy storage devices have emerged, providing an effective means for the active stabilization of the power system.This paper mainly studies the application of superconducting energy storage device in the central heating system, analyzes the heat storage form, location and heat network connection mode in the heating system, establishes the mathematical model for the application of the system planning level, and finds the optimal strategy and daily operation optimization model of the heating system with superconducting energy storage.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Ojemaye M O , Okoh A I .Global research direction on Pt and Pt based electro‐catalysts for fuel cells application between 1990 and 2019: A bibliometric analysis.International Journal of Energy Research, 2021, 45(11):15783-15796. https://doi.org/10.1002/er.6907

[2] Advancement of Research on Application of Microbial Mineralization Technology in Remediation of Arsenic Contaminated Environment.Acta Pedologica Sinica, 2021, 58(4):862-875.

[3] Zappatore A , Heller R , Savoldi L , et al.A new model for the analysis of quench in HTS cable-in-conduit conductors based on the twisted-stacked-tape cable concept for fusion applications.Superconductor Science and Technology, 2020, 33(6):065004 (13pp). https://doi.org/10.1088/1361-6668/ab895b

[4] Eshraghi A , Salehi G , Heibati S , et al.An enhanced operation model for energy storage system of a typical combined cool, heat and power based on demand response program: The application of mixed integer linear programming.Building Services Engineering Research & Technology, 2019, 40(1):47-74.

[5] Tyrala D , Pawlowski B .Failure Analysis of Premature Corrosion of HF Seam-Welded Steel Pipe in Central Heating System.Journal of Failure Analysis and Prevention, 2021, 21(3):1-7.

[6] Yang C , Gunay B , Shi Z , et al.Machine Learning-Based Prognostics for Central Heating and Cooling Plant Equipment Health Monitoring.IEEE Transactions on Automation Science and Engineering, 2020, PP(99):1-10.

[7] Dale-Derks C .When A Failure Strikes: Decentralizing A Central Heating System.Engineered systems, 2019, 36(6):24-24,26-27.

[8] Chervenkov H , Ivanov V , Gadzhev G , et al.Degree-Day Climatology over Central and

Southeast Europe for the Period 1961-2018 -Evaluation in High Resolution.Cybernetics and Information Technologies, 2021, 20(6):166-174. https://doi.org/10.2478/cait-2020-0070

[9] Tulus V , Hany Abokersh M , Cabeza L F , et al.Economic and environmental potential for solar assisted central heating plants in the EU residential sector: Contribution to the 2030 climate and energy EU agenda.Applied Energy, 2019, 236(FEB.15):318-339.

[10] Muzyka R , Chrubasik M , Pogoda M , et al.Py–GC–MS and PCA Analysis Approach for the Detection of Illegal Waste Combustion Processes In Central Heating Furnaces.Chromatographia, 2019, 82(7):1-9.

[11] Ma D C , Lan F .Numerical simulation analysis on multi-layer low-temperature heating method of asphalt pavement in hot in-place recycling.Journal of Central South University, 2020, 27(12):3793-3806. https://doi.org/10.1007/s11771-020-4577-6

[12] Biglarian H , Sharfabadi M M , Alizadeh M , et al.Performance investigation of solar thermal collector with auxiliary heater for space heating.Journal of Central South University, 2021, 28(11):3466-3476. https://doi.org/10.1007/s11771-021-4868-6

[13] Magdy G , Bakeer A , Alhasheem M .Superconducting energy storage technology-based synthetic inertia system control to enhance frequency dynamic performance in microgrids with high renewable penetration.Protection and Control of Modern Power Systems, 2021, 6(1):1-13. https://doi.org/10.1186/s41601-021-00212-z

[14] Kesgin I , Gluskin E , Kasa M , et al.Fabrication and Testing of 10-Pole Short-Period Nb3Sn Superconducting Undulator Magnets.IEEE Transactions on Applied Superconductivity, 2020, PP(99):1-1. https://doi.org/10.1109/TASC.2020.2964193

[15] Mbam S O , Nwonu S E , Orelaja O A , et al.Thin-film coating; historical evolution, conventional deposition technologies, stress-state micro/nano-level measurement/models and prospects projection: a critical review.Materials Research Express, 2019, 6(12):122001 (28pp). https://doi.org/10.1088/2053-1591/ab52cd

[16] Rath M , Miryala M , Murakami M , et al.Controlled piezotronic properties on recoverable energy storage density in rare-earth ions doped epitaxial PZT thin films.Journal of Physics D: Applied Physics, 2019, 52(30):304001 (7pp). https://doi.org/10.1088/1361-6463/ab1b08

[17] Niladri, Chakraborty, Syamasree, et al.Hybrid SMES Based Reactive Power Dispatch by Cuckoo Search Algorithm.IEEE Transactions on Industry Applications, 2019, 55(1):907-917. https://doi.org/10.1109/TIA.2018.2866575

[18] Murayama M , Kato S , Fujisawa A , et al.Design and Implementation of DC Pulsed Power Supply Employing Self-Excited Induction Generators and Flywheels for Toroidal Field Coils of a Tokamak Device, PLATO.IEEE Transactions on Applied Superconductivity, 2020, 30(4):1-5. https://doi.org/10.1109/TASC.2020.2981075