Application of Ejector Afflux Technology in Peak Load Unit

Jun Liu, Wei Zheng, Lingkai Zhu, Ying Guo, Yue Hang, Pangfeng Shang
Jinxu Lao
State Grid Shandong Electric Power Research Institute Jinan, China.

*Corresponding author e-mail: 971705556@qq.com

Abstract. Taking Shandong new energy development as background, this paper expounds new energy development and consumption and studies the application of Ejector Afflux Technology in heat-supplying unit, so as to bring the peak unit regulation ability and realize the effect of energy saving and consumption reduction.

1. Introduction
In the report of the 19th National Congress of the Party, General Secretary Xi Jinping puts forward an important statement that "socialism with Chinese characteristics has entered a new era after long-term efforts." Through long-term efforts, profound changes have taken place; people's living standards have continued to improve; industry has developed rapidly and the power industry has also made rapid progress. The new energy power generation technologies such as photovoltaic power generation, wind power generation, and nuclear power generation have gradually matured, effectively solving problems such as dumping wind, dumping light, and environmental pollution. Throughout China's power grid, it mainly is thermal power, leading to limited peak adjustment capacity. With the development of new energy, the question concerning how to consume new energy generation has been brought about. In response to the call of the state, we will promote the production and consumption of energy revolution, build a clean, low-carbon, safe and efficient energy system, improve the regulation capacity of the power grid, and speed up the improvement of the power supply side regulation capacity. In addition, the flexibility transformation of thermal units has been carried out all over the country so as to improve the ability of peak regulation, thus giving way to new energy generation.

2. Development of Shandong power grid
New era, new kinetic energy, new Shandong. In 2018, Shandong promulgated the "new and old energy conversion plan", followed by its electric power industry. We have eliminated many high energy-consumption units and vigorously developed new energy sources. By the end of 2017, Shandong grid-connected new energy had been 20.545 million kilowatts, rising by 61.27% year-on-year, accounting for 21% of the total installed power grid. The installed capacity of new energy is increasing year by year, Shandong has become a large province regarding new energy installed capacity (and also a large consumer of new energy); in 2018, Shandong plans to put into production 6.21 million kilowatts, including 1.2 million kilowatts of direct-fired generating units, 1.25 million kilowatts of nuclear power, 89 million kilowatts of wind power, 1.22 million kilowatts of centralized photovoltaic, and 1.65 million kilowatts of distributed photovoltaic. By the end of 2018, wind and photovoltaic installations are expected to reach 115 and 13 million kilowatts. With the increase of the installed capacity of new energy, the generation capacity is also increasing, and the utilization hours of thermal power units will be further
reduced. Zhaoyi UHVDC has been put into operation, and Shandong external power receives further increase; at the same time, with the operation of nuclear power units, thermal power unit start-up capacity in the province has further reduced, and the contradiction between peak load regulation, new energy consumption and livelihood heating supply will be more prominent.

Flexibility transformation of thermal power units is one of the effective measures to improve peak load regulation capacity and consume new energy. Shandong has a total installed capacity of 104 million kilowatts, of which 63.47 million kilowatts, accounting for 61.6% of the total installed capacity. The installed capacity of pumped storage power station with peak shaving and valley filling function is only 1 million kilowatt, accounting for 1.0% of the total installed capacity. However, facing the increasingly severe peak shaving problem of power grid, pumped storage couldn’t be the main solution, so the flexibility transformation of thermal power unit is an essential way.

In recent years, society has been progressing day by day, industry developing rapidly, and thus the demand for energy is increasing day by day. The rapid development of industry drives the demand for industrial steam to increase. Many pure condensing units are transformed to heat supply. As an energy conversion plant, power plants consume a large amount of coal resources, while producing a variety of steam with different qualities, the correct use of which can improve the efficiency of energy use, achieving the purpose of energy saving and consumption reduction. In the new era, Shandong's energy saving and consumption reduction are parallel to peak shaving under the transformation of new and old energy.

3. Application of Ejector Afflux in Heating and Peak-Regulating Units

With the continuous development of new energy, the peak load regulation pressure of power grid is increasing, causing a "revolution" of flexible transformation of thermal power units. Many technologies have emerged at home and abroad, such as low-pressure cylinder zero-output, the transformation of steam turbine through-flow part, heat storage technology and so on. Shandong Province has been experimenting on peak shaving of renewable energy units since 2016 and carried out in-depth regulation of several selective units. Several units have been selected through peak shaving test to carry out deep peak shaving. One plant has two heating units, and one of them was selected to participate in peak shaving of renewable energy. The unit was originally designed as a heating unit. The heating and extracting steam are extracted from the middle exhaust. The rated extracting steam pressure is 0.45 MPa (adjusting range: 0.35-0.6 MPa) and the rated extracting steam is 300 t/h. The extracting steam is supplied to the outside through a DN800 pipeline by opening two DN1200 outlets under the middle pressure exhaust cylinder. After the unit is put into operation, the main heat users are industrial steam. The industrial steam parameters are 1.0MPa, 230 C, and there is no heating user. Because the original design parameters of heat supply and extraction cannot meet the demand, so heat supply is transformed. The boiler reheater outlet reheats section of steam extraction and supplies external heating after reducing temperature and pressure; desuperheated water is provided by the booster pump, offering heat supply water directly to supplement condenser. After retrofitting, the high exhaust pressure decreases with the increase of exhaust steam volume. In order to prevent the damage of last stage blade and diaphragm caused by the excessive decrease of exhaust pressure of high pressure cylinder, the inlet valve of medium pressure cylinder is used to adjust the high exhaust pressure, which inevitably leads to throttling loss and the efficiency of medium pressure cylinder. The larger the heating capacity is, the lower the electric load will be, and the greater the throttling loss will be. At the same time, after reducing temperature and pressure, the reheat steam with high parameters forms low quality steam for external heating, which makes the steam with high quality heat without work, causing a large amount of energy waste and reducing the efficiency of the unit.

In order to find a more economical way of external heating, the ejection afflux technology is adopted. The reheat cold section is used as the driving steam source, and the five-stage extraction steam is ejected. After mixing the two kinds of steam, an intermediate quality steam is supplied to the heat user. In order to meet the requirement of steam parameter operation, the unit is equipped with pressure matcher. The pressure matching system is shown in Figure 1.
3.1. Working principle of pressure matching device
Steam ejection pressure matcher is a kind of steam ejector which uses Laval gas ejection principle to eject low pressure steam or low pressure residual heat steam from steam turbine partial extraction and back pressure unit through high-speed steam ejection, so as to increase the pressure to meet the needs of various steam pressure users. Each matcher is equipped with three ejectors; each ejector is composed of a nozzle and a common diffuser corresponding to the mixing chamber. Each nozzle is equipped with an independent automatic control device to control the pressure and flow of a matcher in a unified manner, which can be used when the steam flow rate of the user varies greatly (30%-100%). The problem that the flow rate of the injector cannot be adjusted is solved, thus meeting the requirements of the new construction of the heating system of power plants, thermal power plants and enterprises and the transformation of waste heat recovery.

3.2. Energy saving and consumption reduction effect
The simulation unit runs under peak load regulation. Through the thermal performance test, the data of two heating modes are obtained through field test, and the energy saving and consumption reduction effect of the unit is calculated and analyzed. On the premise that the parameters are adjusted and the system isolation meets the requirements of the test program, the system is stabilized for half an hour and the test record is kept for one hour. The summary of the relevant experimental data and calculation results under the two heating modes is shown in Table 1 and Table 2.

A new steam supply is formed by injecting a part of low quality steam, i.e. five-stage extraction steam, instead of a part of reheat steam, and mixing the reheat steam with five-stage extraction steam. Reasonable use of different-quality steam produced in the electric power production process can be realized, avoiding high-quality steam in the absence of work into low-quality steam, and resulting in "high-energy and low-use" phenomenon; ejection confluence has achieved high-quality steam substituting low-quality steam, and improved the economy of the unit; through field test and
measurement, it is concluded that the energy saving effect of converging under different loads is shown in Table 3.

In summary, the introduction of ejector afflux technology has changed the original heating mode of the unit, reduced the heat consumption rate of the unit, and the energy saving effect is obvious.

| Table 1. Main data and calculation results of ejection confluence heating mode |
|---------------------------------------------------------------|
| Name                          | Unit | 250MW | 230MW | 210MW |
| Generator power               | MW   | 251.09 | 229.85 | 210.65 |
| Reheat cold extraction steam flow rate | t/h  | 64.65  | 61.42  | 57.68  |
| Reheat cold extraction steam pressure | MPa | 3.09   | 2.80   | 2.55   |
| Reheat cold extraction temperature | ℃  | 315.18 | 309.25 | 312.02 |
| Five stage extraction steam flow rate | t/h  | 18.44  | 11.37  | 9.15   |
| Five stage steam extraction pressure | MPa | 0.74   | 0.70   | 0.64   |
| Five stage extraction temperature | ℃  | 349.10 | 340.82 | 344.80 |
| Pressure behind the pressure matching device | MPa | 1.02   | 0.97   | 0.90   |
| Unit total heat flux           | t/h  | 83.08  | 72.79  | 66.82  |
| Unit heat consumption rate     | kJ/(kW·h) | 7702.4 | 7715.8 | 7744.5 |
| Power supply coal consumption  | g/(kW·h) | 311.22 | 310.24 | 312.14 |

| Table 2. Main data and calculation results of reheated hot section heating mode |
|---------------------------------------------------------------|
| Name                          | Unit | 250MW | 230MW | 210MW |
| Generator power               | MW   | 251.23 | 230.81 | 211.04 |
| Reheat steam extraction flow   | t/h  | 68.77  | 69.70  | 74.39  |
| Reheat steam extraction pressure | MPa | 2.88   | 2.63   | 2.39   |
| Extraction temperature of reheated hot section | ℃  | 536.00 | 535.44 | 535.20 |
| External heating pressure      | MPa  | 1.01   | 1.01   | 1.00   |
| Unit total heat flux           | t/h  | 68.77  | 69.70  | 74.39  |
| Unit heat consumption rate     | kJ/(kW·h) | 7752.9 | 7727.2 | 7750.8 |
| Power supply coal consumption  | g/(kW·h) | 314.01 | 312.10 | 312.92 |

| Table 3. Energy saving effect of ejection confluence under different loads |
|---------------------------------------------------------------|
| Name                          | Unit | 250MW | 230MW | 210MW |
| Reduction of heat consumption rate | kJ/(kW·h) | 50.56  | 11.42  | 6.30   |
| Reduction of coal consumption in power supply | g/(kW·h) | 2.79   | 1.86   | 0.78   |
| Annual saving of standard coal | ton  | 8070  | 5364  | 2256   |
| Annual cost saving            | Ten thousand yuan | 404   | 268   | 113    |

3.3. The influence of ejector afflux technology on peak regulation units.
For peak load regulation of thermal power units, many factors restrict regulation ability and safe operation of the peak-load units, such as the ability of boiler system not to put oil into the minimum stable combustion, fuel quality, temperature limit of desulfurization and denitrification system, minimum steam intake of low pressure cylinder, etc. Some important parameters, such as the deviation from the design value, may easily cause the steam temperature to decrease, the tube wall metal overtemperature and some important auxiliaries are in the safe and stable boundary. In order to avoid affecting the safe operation of the unit during peak shaving, it is necessary to solve the difficult problem of peak shaving of the unit by proper means or revamping the necessary equipment from various aspects such as boiler, steam turbine and auxiliary equipment.
During peak load regulation, the heating unit should not only meet the electrical load requirements, but also meet the needs of the thermal users. By introducing jet confluence, the plant has changed the heating mode of the unit and participated in the peak shaving test of renewable energy units in Shandong Province. Under the condition of minimum electric load and maximum extraction capacity, the industrial extraction steam is poured from #1 to #2, and the auxiliary header steam is poured from #1 to #2. The exhaust temperature of the high pressure cylinder, the exhaust pressure of the high pressure cylinder and the exhaust pressure of the high pressure cylinder are closely monitored. In order to increase the industrial extraction flow rate and gradually reduce the opening of the middle regulating valve, the limit value of the middle regulating valve opening is 20% to ensure the minimum intake flow rate of the low pressure cylinder. When the opening pressure of the middle regulating valve reaches 27%, the industrial extraction flow rate has reached about 95t/h. During the test period, the average industrial extraction steam flow of #2 unit is 94.03 t/h, the average active power of generator recorded in EMS of dispatching center is 121 MW, which is 36.7% of rated capacity of unit (330 MW), the average reactive power is 79 MVar, and the average power factor is 0.837. Under this working condition, the boiler combustion is stable, without any combustion-supporting operation; the environmental protection devices work normally; the environmental protection indicators are qualified; the operation parameters of the unit are normal; the boiler has not found the heating surface overheating, coking, large area slagging and other abnormal conditions, the auxiliary units work normally. With the restriction of heating users, the flow rate cannot continue to increase. Under this load, the unit has the ability to further improve the flow rate of industrial extraction steam.

The application of ejector afflux technology can change the heating mode of the unit, optimize the configuration of steam of different quality produced in the production process of the unit, and supply the heat users. Compared with the traditional heating mode, the adjustment is more flexible, which improves the flexibility of the heating unit to a certain extent.

4. Conclusion
The development of new energy has effectively solved the problems of wind, light and water abandonment, and gradually improved the environmental pollution problem to a cleaner and more efficient direction. Accordingly, the instability of new energy power generation increases the peak load regulation pressure of the power grid, and promotes the flexible transformation of thermal power units to make way for new energy generation. On the premise of energy-saving and peak-shaving, the application of ejector afflux technology in thermal power units can rationally utilize different quality steam produced in the production process, thus avoiding "high energy and low use". The effect of energy-saving and consumption is obvious, and it also plays an auxiliary role in peak regulation.

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