Frequency-Conversion Transformation Plan for Nanning Sewage Treatment Plant

I. Introduction

Since the industrial revolution 200 years ago, people have attached more and more importance to urban sewage treatment. The rate of urban sewage treatment is an important symbol of the level of civilization in a region. In the last 200 years, urban sewage treatment has developed from the primitive natural treatment to simple primary treatment, then to in-depth treatment of the sewage water by using various advanced technologies and reuse. The treatment process has also developed from traditional activated sludge method and oxidation ditch process to various processes such as A/O, A2/O, AB and SBR (including CCAS process) to satisfy different requirements for effluent. Compared with advanced foreign countries, China's urban sewage treatment has a late start, and at present, the urban sewage treatment rate is only 6.7%. In addition to making efforts to introduce advanced foreign technology, equipment and experience, an urban sewage treatment system that applies to the actual situation in China must be explored by combining the local reality.

Combining the actual situation in China and by referring to advanced foreign technology and experience, the establishment of an urban sewage treatment plant should follow the following several directions of development:

1. Cost-effective total investment

As a developing country, China's economic development requires a large amount of funds, so it will benefit the national economy to a great extent to conduct strict control of the total investment.

2. Low operation expense

Operation expense is an important factor that decides whether the sewage treatment plant can have normal operation, and it is also one of major indices to determine the quality of a process.

3. Less occupation of land

With a huge population, China has a serious shortage in per capita land resources. Land resources are an important factor in the urban development and planning of many cities.

4. Great nitrogen and phosphorus removal effects

With eutrophication in a large area of the water environment in China, nitrogen and phosphorus removal in wastewater has become an urgent issue. The newly implemented national "Comprehensive Standards for Sewage Discharge" (GB8978-1996) have also explicitly specified that it applies to all sewage discharge units, and the discharge standards for phosphates and ammonia nitrogen have also been strictly specified, which means that in the future, most urban sewage treatment plants will have to consider the issue of nitrogen and phosphorus removal.

5. Combination of modern advanced technology and the environmental protection project

With the emergence and improvement of modern technology, especially the computer technology and the automatic control systems and equipment, it has provided strong support for the development of environmental protection. At present, most of the sewage treatment plants in developed foreign countries have adopted advanced computer management and automatic control systems to ensure normal operation and stable qualified effluent from the sewage treatment plants; while on the other hand, China has lagged behind on this aspect. Computer control and management will definitely become the direction of development for China's urban sewage treatment plants.

II. Sewage Treatment Process, Feasibility of Frequency-Conversion Transformation and the Principle of Frequency-Conversion Energy Conservation

1. Original sewage treatment system and process

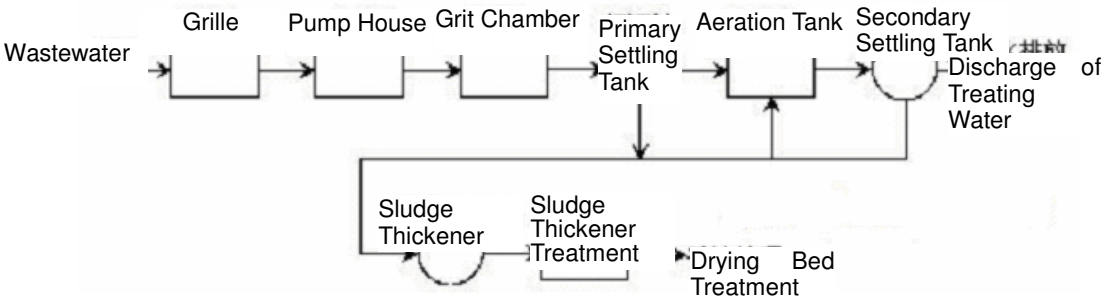
In order to choose an urban sewage treatment system with the most reliable process, most cost-effective investment and most convenient management, by combining local reality, we have investigated the mature experiences and development trends of sewage treatment plants in both China and abroad, and we have also made comparisons. At present, most Chinese and foreign sewage treatment plants have adopted primary and secondary processes.

a. The Primary process mainly adopts physical methods

Big suspended solids and sand are removed from the wastewater mainly through interception by grilles and sedimentation. Both China and foreign countries have mature technology for the primary process, and there is no big difference.

b. The Secondary process mainly adopts biochemical methods

Suspended and soluble organics and nutrients such as nitrogen and phosphorus are removed from the wastewater mainly through methods in accordance with the movement of the microorganisms. At present, there are multiple methods for this treatment process. In summary, representative processes include the traditional activated sludge, oxidation ditch, A/O or A2/O process, SBR and CCAS process. At present, these representative processes have all been put into practical application in both China and abroad.



c. Aerator and submersible pumps are the core devices in sewage treatment, as well as the main operation and energy consumption devices. The air blower of the aerator in a sewage treatment plant operates all day long, and the main purpose of the aerator is to input air into the sewage water to be treated. The oxygen from the air is dissolved in the sewage, and the treatment effect of the sewage depends on the dissolved oxygen. The concentration of dissolved oxygen has a huge impact on the treatment result: if the concentration of dissolved oxygen is too low, the effluent of sewage won't be able to reach the standard; if the concentration is too high, it does not only waste energy, but may also makes the activated sludge float up, and as a result, the activated sludge won't be able to reach the standard. The concentration of dissolved oxygen is mainly regulated through the air volume blown by the air blower.

d. At present, the air volume of most air blowers is regulated by the air inlet valve and air outlet valve, and no speed regulation is conducted by the motor of the air blower. This kind of regulation has a limited energy-conservation effect. With different sewage volumes and in different stages of treatment process, although the required air volumes are different, the motor of the air blower consumes the same amount of electric energy, which has caused a huge waste of electric energy.

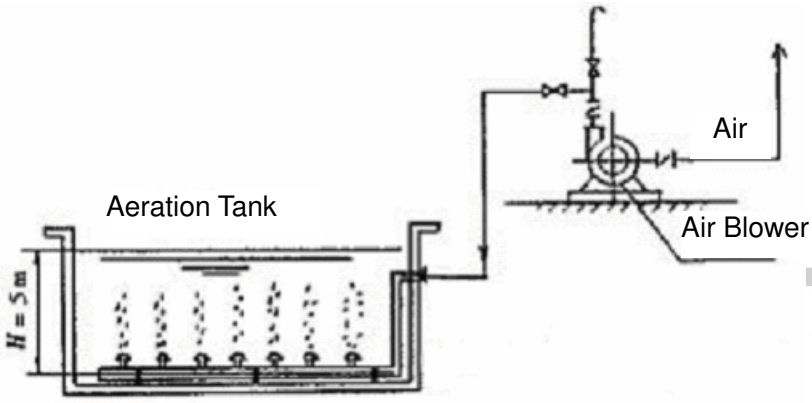


FIG. 1: Air Blowing and Aeration Schematic Diagram

2. Feasibility of frequency-conversion transformation

With the increasing popularization of AC frequency-conversion speed regulation, inverters have been widely used in various fields. The air blower of the aerator is installed with an inverter, and after frequency-conversion control of the air blower, the rotation speed of the air blower can be regulated in accordance with required air volume by different sewage volumes and different stages in the sewage treatment process, in this way controlling the volume of air supply, and the concentration of dissolved oxygen in the aeration tank can be controlled at the value required by the sewage treatment process.

Frequency-conversion speed regulation is an energy conservation and environment friendly technology. Devices in the sewage treatment plant generally have to operate all day long, and through frequency-conversion transformation, it has impressive energy conservation effects, the processing is stable and reliable, the operation is convenient, and real energy conservation and environment protection have been realized.

3. Principle of frequency-conversion energy conservation

With the constant development of technology, the AC (alternating current) motor speed regulation technology has been widely adopted. Through use of the new-generation full-control electronic components, inverter is used to change the rotation speed mode of AC motor to control the flow of the fan, which can significantly reduce energy loss caused by using the traditional mechanic method to regulate flow.

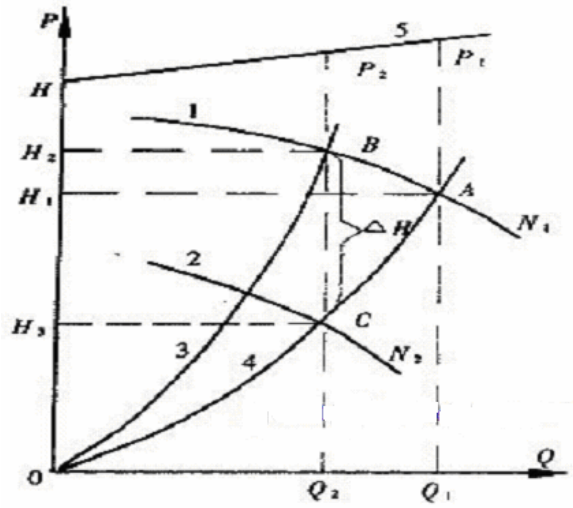


FIG. 2 Performance Curve of the Fan during Frequency-Conversion Regulation

In FIG. 2:

Curve 1 and 3 refer to the pressure-flow curves during speed regulation;
Curve 3 and 4 refer to resistance characteristic curves of the pipeline during throttling regulation;
Curve 5 represents the constant-speed power-flow curve.

Assume point A is the biggest operating point of the fan. When air volume has to be reduced from Q1 to Q2, if throttling regulation is adopted, from operating point A to B, the air pressure will be increased to H2; from the FIG. we can see that the shaft power P2 is also reduced, but the decrease is not much. If frequency conversion regulation is adopted, when fan operating point moves from A to C, we can see that under the situation of satisfying the same air volume Q2, air pressure H3 will have significant decrease, and subsequently, power P3 is also reduced significantly. The saved power loss △P＝△HQ2 is in proportion to the area BH2H3C in the FIG.

a. From the above analysis we can see that frequency conversion regulation is a highly efficient regulation method.

Adoption of frequency conversion regulation in the fan won't generate additional loss of pressure, the energy conservation effect is significant, and the regulation range of air volume is 0%～100%, which applies to the situation which requires a wide regulation range and frequent operation under low load. However, when the rotation speed of the fan and the air volume decreases, it will cause huge change to the air pressure. From the law of proportionality of the fan:

Q1/Q2＝(n1/n2)，H1/H2＝(n1/n2)2，P1/P2＝(n1/n2)3

We know that:

When the rotation speed has decreased to half of the original rated rotation speed, the flow, pressure and shaft power of corresponding operating point will decrease to 1/2, 1/4 and 1/8 of their original values respectively. This is the reason while frequency conversion regulation can significantly reduce consumption of power.

① Assume rotation speed of the water pump decreases by 10% (when the output power is 45Hz), then the power

P2=（0.9）×P1=0.73P1, 27% energy will be saved

②Assume rotation speed of the water pump decreases by 20% (when the output power is 40Hz), then the power

P2=（0.8）^{3}×P1=0.51P1, 49% energy will be saved

b. Because power is in proportion to the cube of the rotation speed, therefore, the bigger change of the rotation speed, the even bigger reduction of power consumption with geometric progression.

c. Energy conservation is analyzed in accordance with the calculation formula in the Mandatory National Standards Implementation and Monitoring Manual in GB12497 "Cost-Effective Operation of Three-Phase Asynchronous Motor", i.e.:

The fan and pump have adopted a baffle to regulate the flow. The corresponding input power of motor PL and flow Q has the following relation:

$$P_L = \left[0.45 + 0.55\left(\frac{Q}{Q_N}\right)\right] Pe(KW)$$

Where: Pe—Input power KW of the motor under rated flow
QN—Rated flow

$$Ki = \frac{P_1}{P_L} = \frac{P_L - Pe\left(\frac{Q}{QN}\right)^3}{P_L} = 1 - \frac{\left(\frac{Q}{Q_N}\right)^3}{0.45 + 0.55\left(\frac{Q}{Q_N}\right)^2}$$

Where: Ki refers to the energy conservation rate, and P1 refers to the saved power.

The above formula can be used to estimate the saved electric power after transformation. In accordance with the original operating mode, for fan which has adopted inlet guide vane, when the inlet guide vane has a small opening, it has similar energy conservation effect with the inverter, i.e., when the opening is 10%, it has similar energy conservation effect with that by adoption of frequency conversion control, which can be ignored.

4. Actual generated economic value and estimation

a. When the bypass opening is 30% and the flow is 70%, estimation of the energy conservation rate is:

1-（(0.7)3/0.45+0.55×(0.7)2）＝52%

b. Under original power frequency, the estimated power consumption of each machine in every month is:

160×0.7×24×30＝80640 KWH

c. After frequency conversion transformation, the power consumption of each machine in every month is:

80640×52%＝41933 KWH

d. After frequency conversion transformation, the saved electricity cost of each machine in every month is:

41933×0.8＝ RMB 33546.4 Yuan

Conclusion:

Price of each unit of frequency-conversion energy-conservation cubicle is: RMB 192,000 Yuan; ROI (return on investment) cycle: about 6 months.

IV. Operating condition of the original equipment

1. Equipment parameters

a. Nanning Sewage Treatment Plant has 3 centrifugal air blowers, model: 1TYC27;

b. Model of the auxiliary three-phase asynchronous motor: Y2-315L1-2-160KW, 2-pole motor, rated rotation speed is 2975RPM.

c. Original start mode is soft start (no frequency-conversion start).

2. Operating mode of the air blower during sewage treatment

The air blower has adopted an inlet guide vane, outlet valve and bypass vent valve to regulate the air volume. During operation, the inlet guide vane has an opening of 10%, the inlet flow temperature is 25.2°C and the pressure is 0.1KPA; the outlet valve is fully open, the outlet temperature is 91.7°C and the pressure is 60KPA; the outlet bypass vent valve has an opening of 30%.

3. Damage of the start current to the motor and equipment

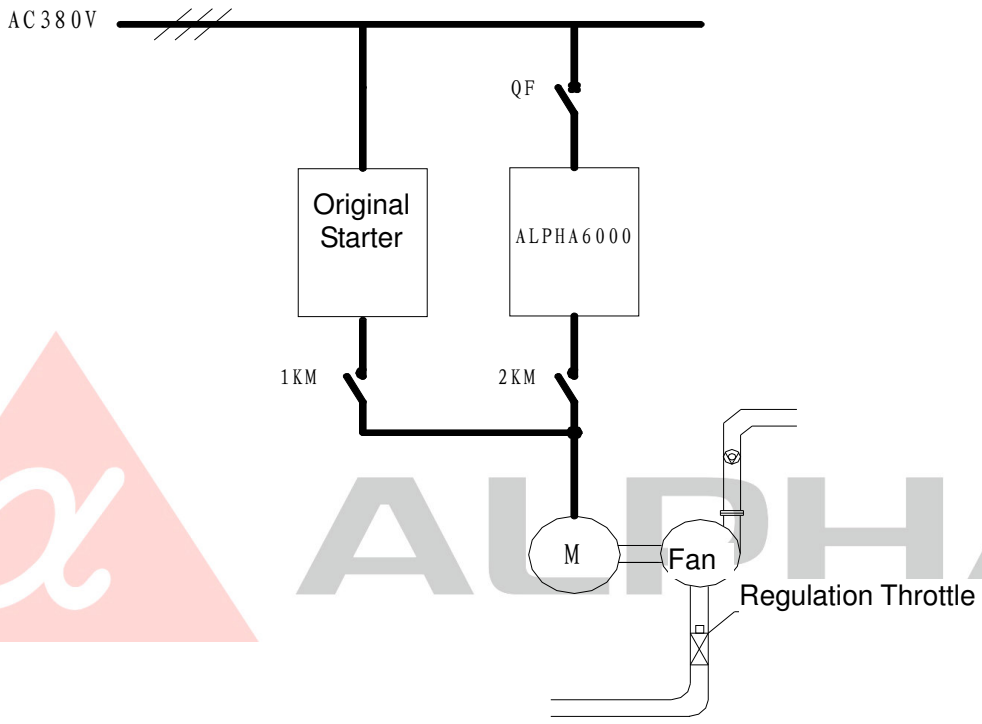
The motor has adopted the start mode of reduced-voltage soft start. Although this mode can reduce the damage of the start current to the motor, due to the high inertia of the air blower, there is a high requirement for start torque, and the start current is still as high as 2—3 times that of the rated current, which tends to reduce the service life of the motor, water pump, check valve and the pipeline system.

4. Noise, vibration and water hammering problems during equipment operation

During the start, operation and stop process of the equipment, due to lack of timely and efficient regulation, there tends to be phenomena such as serious water hammering, increase of mechanical noise and aggravated vibration, and all these phenomena are very destructive, which tends to cause ruptures or concavity in pipes as well as damaged valves and fixtures, and it may also increase the load of the inlet wire transformer. Since adoption of frequency conversion regulation, the start or stop process can be extended by increasing the acceleration or deceleration time. Even during the operation, the operating points that tend to cause equipment resonance can be skipped through selection of the operating frequency points, so that the stress on the vane, check valve and pipeline system of the water pump can be significantly reduced, abrasion of the bearing will also be reduced, and the service life of the equipment will be significantly increased.

V. Frequency-Conversion Transformation Plan

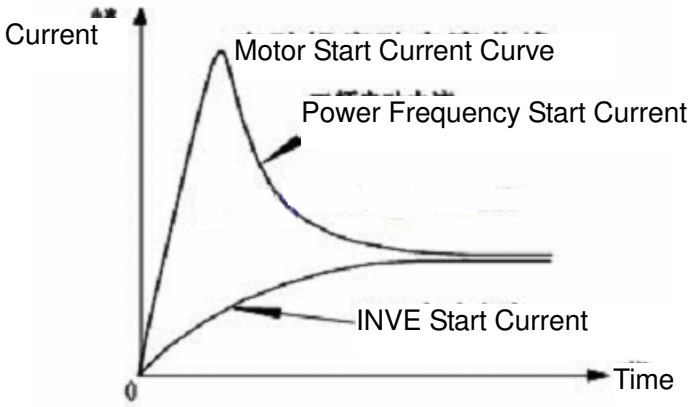
In accordance with operation mode of the original equipment, considering reliability and flexibility of configuration, the plan in which one machine driven by one motor is adopted. Each motor of the air blower is equipped with one unit of frequency-conversion energy-conservation cubicle, and the original soft start device is saved as the spare device in case the frequency-conversion energy-conservation cubicle has failure to ensure smooth production. The frequency-conversion energy-conservation cubicle includes inverters, changeover contactor, indicators, indicating lamp and button switches. The system diagram is as the following:



VI. Benefits for the Users

1. Highly efficient and energy-conservation operation, impressive effects of energy conservation, short ROI (return on investment) cycle
   After frequency conversion transformation, the air blower can regulate the air supply volume in accordance with the technical demands, and it is more energy efficient after frequency conversion speed regulation.

2. The motor has realized real loaded soft start, and the impact is reduced.
   After adoption of frequency conversion regulation, due to use of the SPWM technology, actual soft start and buffer stop have been realized, which has fundamentally eliminated the damage of start current to the motor and other equipment, and the service life of the equipment will be significantly increased.



3. Increase the service life of the equipment

After adoption of frequency conversion regulation, the start or stop process can be extended through increase of acceleration and deceleration time. Even during the operation, the operating points that tend to cause equipment resonance can be skipped through selection of the operating frequency points, so that the stress on the vane, check valve and pipeline system of the water pump can be significantly reduced, abrasion of the bearing will also be reduced, and the service life of the equipment will be significantly increased.