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SUPER ENGINEERING

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Xinjiang Energy-Based Desert Management Project

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Xinjiang is an important area connecting China with other Central Asian countries and a strategic location for safeguarding national security. Its economic development is the core and key of China's "the Belt and Road Initiative" strategy. However, there are existing problems in Xinjiang, such as water resource shortages, agricultural inefficiency, increasing desertification, and an imbalance in regional economic development. In response to these problems, the project team innovatively proposed a strategic concept of using energy to develop modern agriculture facilities in Xinjiang to control desertification.

The Xinjiang Energy-Based Desert Management Project is guided by the concept of ecological civilization, and the promotion of Xinjiang's desert governance system and modernization of governance capacity. The project is based on the new energy utilization system and is focused on the efficient utilization of water resources. By focusing on the development of modern facilities and efficient agriculture, we will continue to build a green economic industrial system in Xinjiang's desert areas, promote forward-looking development of Xinjiang and long-term stability, and explore the development model of new rural towns in arid and semi-arid regions that are resource-saving, eco-friendly, and using green energy.

1 Status of agriculture and energy development in Xinjiang

The climate in Xinjiang is extremely dry, the ecological environment is fragile, and natural disasters occur frequently. The strong focus on the agricultural industry, unbalanced regional development, scattered production patterns, extensive management methods, declining soil productivity, declining soil quality, and pollution of the agricultural environment have significantly affected the sustainable development of agricultural production.

The trend of desertification is intensifying, threatening the ecological security of the northwest region. By the end of 2014, the area of desertified land in Xinjiang was 1.0706×10^6 km^2, accounting for 64.31% of the total land area of Xinjiang. Compared with 2009, the area of desertified land in Xinjiang increased by 3.6718×10^6 km^2, with an average annual increase of 0.734×10^6 km^2. The desertification of the land in Xinjiang is still expanding every year.

Xinjiang has abundant wind and solar resources. As a result of the development of new energy wells, Xinjiang's new energy faces problems such as insufficient market consumption, limited power transmission capacity, and abandonment of wind and solar energy production, which affect the healthy development of the new energy industry.

The water used for agricultural production in Xinjiang accounts for more than 90% of the total water consumption. In some areas, the large number of wilderness in the upper and middle reaches of the river and the excessive development of water resources have resulted in significant water shortages, interruptions in the downstream flow, environmental deterioration, large-scale desertification, and secondary salinization.

2 Strategy and goals

Based on the theoretical and practical background, the Xinjiang Energy-Based Desert Management Project draws on the experiences of desertification researches at home and abroad. Based on an in-depth understanding of the current situation of desert governance in Xinjiang, we will adopt the concept of ecological civilization development and investigate the energy industry based on the concepts of new energy and renewable energy as related to the problems in Xinjiang desert management. We will focus on

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modern eco-agriculture, which is a three-dimensional industrial system consisting of grassland management, animal husbandry, and aquaculture, to achieve a self-sufficient new green economy desert management model and to explore resources based on the efficient use of water resources in arid regions. A new type of rural/urban development model that focuses on conservation, eco-friendliness, and green energy is proposed to develop a scientific and economically viable green recycling development path for desert management and modern agricultural development in China's arid regions. This model provides a contribution to the development of China's green economy and ecological civilization, as well as national security. The "New Energy Towing Desert Reconstruction/Utilization Plan" was launched for the project, as shown in Fig. 1.

Fig. 1 "New Energy Towing Desert Reconstruction/Utilization Plan" kick-off meeting.

3 Content and layout

3.1 Energy security

The "13th Five-Year Plan" for electric power stated that in 2020, the national installed wind power capacity will reach 210 million kilowatts or more and photovoltaic power stations will be laid out on the principle of decentralized development and near-end consumption to vigorously promote major technological breakthroughs in solar thermal power generation. In 2020, the installed capacity of solar power will reach 110 million kilowatts, including more than 60 million kilowatts of distributed photovoltaics and 5 million kilowatts of solar thermal power. The installed solar power generation unit is shown in Fig. 2.

Fig. 2 Solar panel power generation unit.

By studying the development of Xinjiang's energy industry, the status and layout of new energy power generation, the problems in development, planning, and utilization, as well as the foundation, mode, and layout of the new energy security system are defined; new energy-driven desert management is explored and existing problems are addressed or resolved. In this manner, the conditions of the development model of photovoltaic agriculture integration in representative areas (Hami, Yili, and Kashgar) are analyzed and demonstrated targetedly. This investigation will support the important role of the renewable energy industry in managing deserts and protecting the ecological environment.

3.2 Sustainable and safe utilization of water resources

The rational development, utilization, and protection of water resources are the basis for Xinjiang's economic development and ecological security, as well as the lifeline. The development and utilization mode of water resources based on the regulation and storage of underground water reservoirs and the unified scheduling of groundwater and surface water ensures the appropriate development and utilization of water resources adapted to regional sustainable development. Through the flow of new energy, we will make full use of new technologies such as water-saving irrigation, sewage treatment, and salt water desalination to ensure the safe distribution of water resources, maintain the protection of regional ecological assets, and ensure sustainable development in Xinjiang's arid regions.

3.3 New energy-driven modern facility-based agriculture

Modern facility-based agricultural production uses substrate cultivation or hydroponics, which does not require soil and can be implemented in desert areas. The layout of the project depends on the regional distribution of desertified areas and solar and wind resources in Xinjiang. In addition, the layout of the project also considers the need for certain labor resources and agricultural technology resources; therefore, the layout of the Xinjiang Construction Corps is integrated. Finally, in order to facilitate the export of agricultural products produced by this project, the distribution of major trading ports in Xinjiang and the traffic conditions of major public railways and airports in Xinjiang were also considered.

The comprehensive analysis and project layout selection focus on the Karamay, Yili, Altay, and Tacheng areas in northern Xinjiang, Aksu, Kashgar, Korla, and Hotan in southern Xinjiang, and Hami in eastern Xinjiang, among others. With regard to ports, there are Red Flag Lapu Port, Kazakh La Sou Port, Irkistan Port, Turkut Port, Muzate Port, Durata Port, Khorgos Port, Alashan Port, Dostik Port, Bhaktu Port, Aqe Buick Port, and Kanas port, among others. Modern intelligent factory-based agriculture considers three models: a thousand-acre unit model, a five-acre unit model, and a hundred-acre unit model. The layout of the 1000-acre unit focuses on the adjacent ports and 20 units are proposed; the layout of the 500-acre unit focuses on the adjacent airport and 30 units are proposed; the 100-acre unit focuses on the adjacent large and medium-sized cities and 50 units are recommended.

We choose areas with abundant solar, thermal, and wind resources, use modern solar and wind energy storage technology, convert the resources locally into electric energy, and use it locally to ensure that the demand for automated equipment and environmental control energy in intelligent factory-based agricultural production is met. From the aspect of energy supply, this approach provides a guarantee for modern intelligent factory-based agriculture in the Xinjiang Energy-Based Desert Management Project. The agricultural production green house based on intelligent factory is shown in Fig. 3.

The climate in most parts of Xinjiang is characterized by abundant sunshine, wind, and sand, but the differences between southern and northern Xinjiang as well as eastern and western Xinjiang are large. Northern Xinjiang is cold in winter and cool in summer, while southern Xinjiang is hot in summer and temperatures in winter are not very low. Therefore, the industrialized agricultural facilities have to be adapted to local conditions and different greenhouse types are selected according to the characteristics of climate and topography. Greenhouses in southern Xinjiang require ventilation and cooling in summer and greenhouses in northern Xinjiang require insulation and heating in winter. Greenhouses in both southern and northern Xinjiang have to be resistant to sand infiltration. Northern Xinjiang also experiences considerable snowfall in winter, therefore, in the design of greenhouses, snow-related problems have to be considered.

4 Analysis of energy demand of modern agricultural facilities in Xinjiang

Xinjiang is an arid area with few clouds and rains, a lot of sandstorms, and many alpine basins, deserts, and oases. Its geographical features and climatic conditions are significantly different from those in Northern China. To this end, the Dutch energy-saving glass greenhouse (Fig. 4) is used as the facility structure and an energy analysis of long-season tomato cultivation is conducted. Equipment such as a multi-source (ground/water/air) heat pump, insulation layer to prevent freezing, and external shading are considered. Intelligent energy-saving environmental control technology and other energy-saving technologies are investigated to address needs related to lighting, heating, cooling, and ventilation. Calculations are conducted for the equipment load and operating characteristics for electricity demand accounting and seasonal power consumption forecasting. The calculations of the greenhouse equipment load and power consumption forecast are based on the design parameters and operational data of the Dutch greenhouse.

The meteorological and solar radiation data and seasonal temperature changes in Kashgar, Aksu, Korla, Hami, Karamay, Yili, and other areas in Xinjiang were used for the calculation of the external environment and an analysis of long-season tomato cultivation in Dutch energy-saving greenhouses of 3 hectares was conducted. For electricity

Fig. 3 Intelligent factory-based agricultural production greenhouse.

Fig. 4 Energy-saving glass greenhouse.

demand, a Wenluo greenhouse is considered with 9.6 m long and 4 m wide. The light intensity is 150 W/m^2, the heating load is 150 W/m^2, the ventilation load is 30 W/m^2, and the additional load is 20 W/m^2 according to seasonal demand. The environmental control targets of the greenhouse are day/night temperatures of 20–22 °C/15–18 °C and the daily cumulative radiation amount is 1500 J/cm^2. The facility uses LED lighting and an air–water source composite heat pump for heating and cooling, and the cover material of the greenhouse is AR (Anti-Reflection)-scattering light glass. The multi-source heat pump has external shading and uses ground/water/air source for heating or cooling. It is installed 60 cm below the greenhouse for heat treatment and ground heat utilization and intelligent energy-saving control technology is used to improve the energy efficiency.

In the Kashgar area of Xinjiang, a Dutch-type energy-saving glass greenhouse was constructed. The electrical load is 280 W/m^2. The power consumption demand is higher during nighttime for lighting and heating and during summertime for daytime cooling. The maximum power load of the facility is 8400 kW, which means that a total power supply of 8500 kW is required to meet the operating power demand of the energy-saving glass greenhouses. The greenhouse electricity consumption is predicted based on the energy consumption of greenhouse tomato cultivation. The energy consumption of the energy-saving glass greenhouse in winter will be at least 1.248×10^5 kWh, the daily electricity consumption in spring will be at least 0.888×10^5 kWh, the minimum daily electricity consumption in summer will be 0.888×10^5 kWh, and the daily power consumption in autumn will be at least 0.648×10^5 kWh, thereby the annual power consumption will be 3.672×10^5 kWh (equivalent to 1102 kWh/m^2 power consumption, i.e., 126 W/m^2 per unit power consumption).

In Aksu, a Dutch energy-saving glass greenhouse was constructed with an electrical load of 380 W/m^2, a maximum facility power load of 1.14×10^4 kW, and annual power consumption of 3218 kWh. In the Korla region, the Dutch energy-saving glass greenhouse has an electrical load of 330 W/m^2, a maximum facility power load of 9900 kW, and annual power consumption of 2.927×10^7 kWh. In the Hami area, the Dutch energy-saving glass greenhouse has an electric load of 290 W/m^2, a maximum facility power load of 8700 kW, and annual electricity consumption of 3.089×10^7 kWh. The Dutch energy-saving glass greenhouse in the Karamay area has an electric load of 280 W/m^2, a maximum facility power load of 8400 kW, and annual power consumption of 3.359×10^7 kWh. The Dutch energy-saving glass greenhouse in the Yili area has an electrical load of 330 W/m^2, a maximum facility power load of 9900 kW, and annual power consumption of 3.251×10^7 kWh.

Fig. 5 Hami Shichengzi Photovoltaic Industrial Park.

5 Xinjiang energy-based modern agricultural development, utilization model, and distribution pattern

Due to different energy resources in different regions of Xinjiang, different energy supply modes for the greenhouses are used, including photovoltaic power in the Aksu area, wind power in the Karamay area, and a combination of wind, solar, and gas in the Hami area. Figure 5 shows the Hami Shichengzi Photovoltaic Industrial Park. Kuitun is used as an example of the design of a 50-acre modern greenhouse facility.

Due to its location in the interior of the Asia-Europe continent, Kuitun has a northern temperate continental climate. The high altitude area is affected by westerly wind and subtropical weather systems. In addition, the barrier of the Tianshan Mountains, which are a source of cold air from the north, and the flat surface of the Gobi desert result in hot summers and cold winters with four distinct seasons.

The greenhouse area is 34312.8 m^2, with an east-west length of 204 m and a north-south width of 168.2 m. The supporting nursery greenhouse area is 4656 m^2, with an east-west length of 97 m and a north-south width of 48 m. The grading and packaging workshop (including temporary storage and cold storage) has an area of 4656 m^2, of which the east-west length is 97 m and the north-south width is 48 m. The area of the two-story management room is 2880 m^2, of which the east-west length is 30 m and the north-south width is 48 m. There are nutrient solution mixing room and control room on the first floor, and the management room and conference room on the second floor; there is also a glass-separated visitor area for people to see the greenhouse cultivation area without risk of introducing diseases.

The cultivated greenhouse has a height of 7 m and a top height of 8 m. The grading and packaging workshop has a height of 7 m and a top height of 9 m. The nursery greenhouse has a height of 7 m and a top height of 8 m. The total height of the two-story management area is 9 m.

Additional buildings include grading and packaging workshops and management rooms. These are constructed using light steel sandwich plates and are located on the north side of the greenhouses so that greenhouse lighting is not affected, and the greenhouses are protected from the north wind.

6 Economic evaluation and benefit analysis

The 50-acre modern greenhouse is operated by purchasing locally built wind power and photovoltaic power plants. The plan includes construction of multi-span greenhouse and related equipment facilities and purchase of supporting machinery. The total construction period is estimated to be one year and the total investment of the project is 103 million yuan, including 85.5 million yuan for the construction of the multi-span greenhouse and 15 million yuan for the supporting facilities. The construction period interest is 2.3238 millon yuan.

80% of the investment required for this project comes from bank loans and 20% comes from local enterprises. The construction period loan interest is calculated based on the current 5-year or more loan interest rate of the People's Bank of China, which is 5.65%. 70% of the working capital is short-term bank loans with a loan interest rate of 5.1% and the remaining 30% is from the initial capital. The investment profit rate is 4.74%, the asset-liability ratio is 80.57%, the break-even point described by capacity utilization rate is 54.02%, and the break-even point described by annual output is 3106.26 tons.

The Xinjiang Energy-Based Desert Management Project utilizes wind power and photovoltaic energy that cannot be transported and exported from Xinjiang and the project does not compete with local needs for electricity. There is also no competition with the local people for agricultural production because the Gobi desert is not suitable for traditional cultivation. This project greatly improves the water use efficiency and the utilization of underground brackish water and domestic sewage. By adhering to the five development concepts of "innovation, coordination, green, openness, and sharing", the project is in line with the fourth industrial revolutionary trend of cross-border integration of energy and information (Internet, big data). Moreover, the project represents a change in traditional desert management and adopts new energy types and new technologies to drive desert transformation/utilization. There is also an urgent need for Xinjiang to promote "the Belt and Road Initiative", stimulate economic growth, promote the transformation of the economic structure, and realize the Xinjiang strategy. Therefore, the project represents an integration of global innovation concepts and innovative technologies.