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Research on Key Technologies of CCUS Supply Chain Digital Twin System for Smart Agriculture

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ABSTRACT

CO_2 capture, transportation, storage and utilization in agriculture (CCUS) technology is a new technology with the potential to reduce CO_2 emissions on a large scale. Considering the immature technology of CO_2 pipeline long-distance transmission and the lack of relevant utilization technologies, it is necessary to develop a reproducible and efficient CCUS digital system. The research shows that different concentrations of CO_2 have a promotion mechanism for plants in photosynthesis. On this basis, through various sensors, actuators and intelligent twin platforms, the problems of poor information communication and extensive management of CCUS in all aspects of agricultural application can be solved, giving new answers to the low-cost CO_2 pipeline transportation and utilization of CCUS technology at the emerging stage. In this study, through the introduction of artificial intelligence and digital twin related technologies, the data of farmland soil physical and chemical properties are collected by using nitrogen, phosphorus, potassium, conductivity, PH value, temperature, humidity and other sensors, and the impact of exogenous carbon dioxide on plant photosynthesis, plant physiology and biochemistry, and plant growth yield is comprehensively analyzed. The demand for carbon dioxide is predicted through artificial intelligence technology, and carbon capture is conducted according to the prediction results, The carbon dioxide sensor can accurately measure the concentration and content of captured carbon dioxide; The captured carbon dioxide will be timely and accurately distributed to the corresponding farmland for soil improvement and crop yield increase. Visual modeling of the above process can visually see the overall operation process online. This research combines the virtual and real aspects of CCUS, and realizes the accurate evaluation, standardized management, visual real-time early warning, personalized analysis, intelligent decision-making and fine control of the whole process of agricultural CCUS supply chain. It has improved the intelligence and informatization level of the supply chain, as well as the intelligent service capability and circulation efficiency. In the future, we will modularize the components used in the above process to facilitate personalized configuration according to customer needs.

Keywords: CCUS, carbon capture, soil improvement, vegetable income increase, digital twins

1. INTRODUCTION

Global climate change has become a major challenge on a global scale, with extensive impacts on human society, economy and ecosystem. The massive emission of greenhouse gases is one of the main causes of climate change[1]. In order to mitigate the effects of climate change, the international community generally recognizes the importance of carbon capture and agricultural carbon use. Carbon capture technologies aim to capture and store greenhouse gases such as carbon dioxide from the atmosphere, while agricultural carbon use refers to the fixation of carbon dioxide in soil through agricultural and land management practices to increase carbon storage and improve soil quality.

As a technology that integrates virtual and real worlds, digital twin systems can simulate and optimize complex physical systems, providing new opportunities and challenges for carbon capture and agricultural carbon utilization. The aim is to apply digital twinning to improve the efficiency, sustainability and decision support of carbon capture and agricultural carbon use processes. The specific objectives include: 1. Simulation and optimization of carbon capture system: Through the establishment of digital twin model, accurate modeling and simulation of carbon capture process is carried out

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to optimize equipment design, operational parameters and operational strategies, improve carbon capture efficiency and reduce costs. 2. Monitoring and maintenance of carbon capture equipment: digital twin system is used to monitor and predict the operating status of carbon capture equipment, identify potential

problems and failures in advance, and conduct intelligent maintenance and optimization to ensure the stable operation and life of equipment. 3. Support agricultural carbon use decisions: Digital twinning technology is applied to model and simulate agricultural carbon use systems, so as to provide assessment and optimization of agricultural carbon use strategies for farmers and decision makers, including soil management measures, crop selection and breeding methods. 4. Comprehensive optimization of carbon capture and agricultural carbon utilization: Integrate the digital twin models of carbon capture and agricultural carbon utilization system to realize effective utilization and conversion of carbon dioxide generated by carbon capture and improve the overall benefits and sustainability of carbon capture and agricultural carbon utilization.

2. *MATERIAL AND METHODS*

A whole-system digital enabling method applied in CCUS field to improve industrial efficiency is mainly applied in the intelligent optimization method of carbon capture and carbon recovery in different scenarios in the whole industrial field. Deep reinforcement learning technology is used to establish a systematic self-learning system， Fig 1. Through the digital monitoring of the entire carbon capture process and the analysis of different working conditions and flue gas composition, Through this method, the optimal ratio and scheme of the whole system can be generated to reduce energy consumption, monitor anomalies, reduce losses, and realize the lowest comprehensive carbon capture cost. Finally, the multi-scenario application of this method in the field of carbon capture can be realized. Meanwhile, this method can analyze experimental errors and actual industrial error sources on the basis of optimization. In order to understand the causes of errors in CCUS experiment and production process, it can reduce the difficulty of implementing CCUS related technologies in the future, and provide a theoretical basis for the improvement of CCUS technology.In this paper, a typical model of deep reinforcement learning, namely deep Q learning network (DQN), is used as the basis. To enable the DQN controller to meet control requirements, the DQN controller needs to constantly interact with the thermal process environment to generate trajectory data to train the Q network in the controller. In order to obtain a control strategy that meets control requirements and goals, and ensure that the controller system meets corresponding control requirements and achieves control goals.

Step 1: Build the sample pool. The trajectory data is continuously generated during the interaction between the controller and the CO_2 capture system environment. The trajectory data is added to the sample pool. The quantity and quality of the samples determine the quality of the Q network weight parameter training effect, and then affect the control performance of the whole control system[2].

Step 2: Train the Q-value network. First, the agent randomly selects a certain number of samples in the sample pool. Then, according to the target Q-value network, the current Q-value network, the DQN error function, and the corresponding interactive data, the random gradient descent algorithm is used to update the weight parameters of the Q-value network, and every training period (N steps), The weight parameter of the current Q-value network is directly assigned to the target Q-value network.

1. Record the real-time gas working condition data, the ratio of ammonia liquid and the loss amount through the sensor, and the data amount of each cycle running of the system can be recorded in the server without manual participation in the process

2. Based on the overall working condition coefficient of the system, the thermal conversion efficiency and ammonia liquid escape rate were evaluated, and the optimization of efficiency and the minimization of escape rate were realized by adjusting the working condition

3. The simulation system has the lowest distortion rate compared with the actual equipment, and can analyze and solve theoretical and experimental error sources, experimental and actual error sources, theoretical and actual error sources on the basis of theoretical, experimental and actual data, and add relevant error analysis mechanism into the self-learning system. Based on the above system, It can realize the replacement and experiment of the new technology of CCUS-related modules on the basis of low investment, and the experimental data obtained by it can be calculated to the actual data with high accuracy.

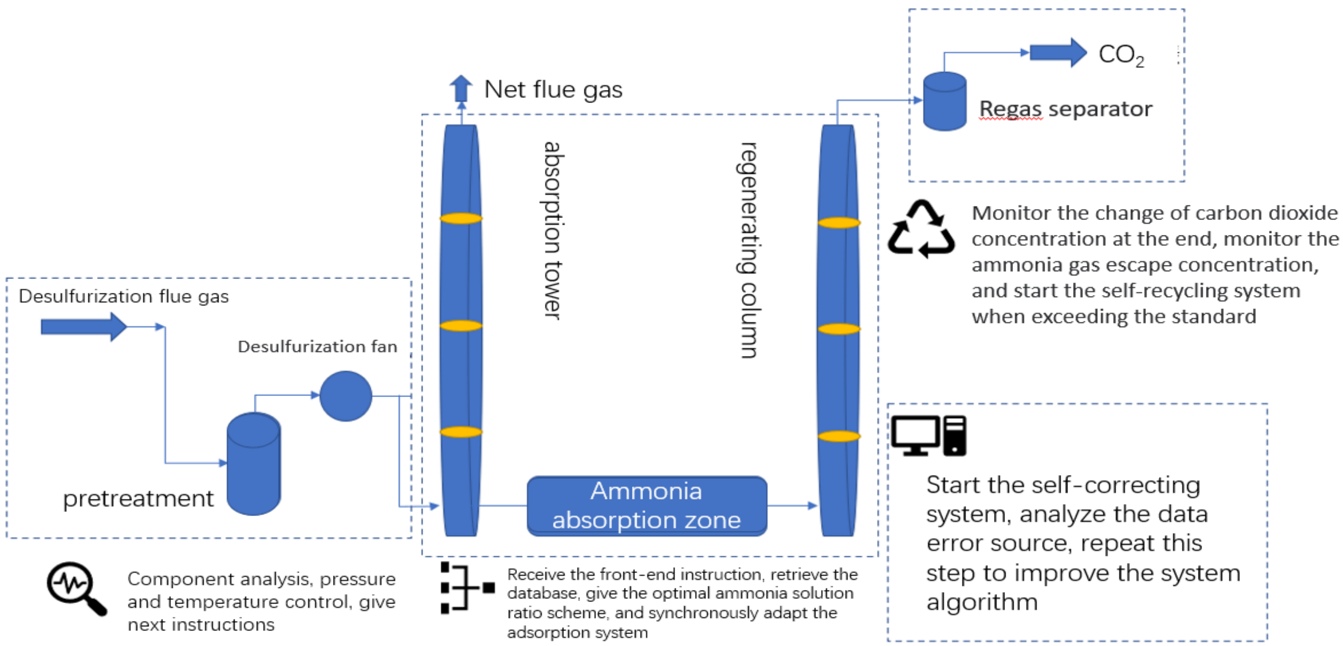

FIG 1. The workflow of digital twinning in the whole system of CCUS

3. *RESULTS*

The purpose of this design is to provide a self-learning and self-deployment system based on the field of CCUS, real-time data collection of different modules, and through the self-analysis ability to give the optimization scheme, in the process of data collection inverse calculation system, improve the source of system error，Our design 3D image is shown in Fig 2.

Simulation and optimization: Digital twinning can create a virtual CCUS system model that closely matches the real system. By simulating and optimizing the digital twin model, the performance of the system can be predicted under different conditions, and the operating parameters and configuration can be optimized to maximize the efficiency and performance of the CCUS system.

Real-time monitoring and prediction: By connecting the real CCUS system to the digital twin model, the health of the system can be monitored and predicted in real time. The digital twin model can receive real-time data, predict system response and performance, and provide early warning and fault diagnosis, as well as timely adjustment and optimization of operational strategies.

Energy conservation and emission reduction: Digital twinning can optimize the energy consumption and emission reduction of CCUS systems by simulating different operational schemes and strategies. Through prediction and optimization, energy consumption of the system can be reduced, energy efficiency can be improved, and carbon dioxide emissions can be minimized.

Construction and Maintenance support: Digital Twin technology can also provide support during the construction and maintenance phase of CCUS systems. By simulating and optimizing the construction scheme in the digital twin model, the errors and costs in the actual construction can be reduced. In the aspect of system maintenance, the digital twin model can help predict and optimize the maintenance plan, improve the reliability and maintenance efficiency of the system.

Decision support: Digital twinning technology provides comprehensive data and analog analysis to help decision makers make more informed decisions. The digital twin model enables decision makers to evaluate different investment strategies, policy measures and operational options to support the long-term planning and development of the CCUS system.

FIG 2. CCUS digital twin rendering

4. DISCUSSION

Digital twinning can be used to monitor carbon dioxide in agriculture. Here are some ways to monitor CO_2 in agriculture through digital twinning. CO_2 concentration monitoring: Measuring CO_2 concentration in real time by installing CO_2 sensors and monitoring equipment in agricultural environments. These sensors can transmit the collected data to digital twin models, which can analyze and record changes in CO_2 concentration and provide visual monitoring results.

CO_2 emission simulation: Digital twin models can simulate and predict CO_2 emissions in agricultural systems. Based on crop type, fertilization, pesticide use and other parameters, the model can estimate the amount of CO_2 produced in the system. This can help agricultural decision makers understand and manage CO_2 emissions and develop mitigation strategies.

CO_2 uptake and utilization optimization: Digital twinning technology can optimize CO_2 uptake and utilization processes in agricultural systems. By establishing the digital twin model, the growth, photosynthesis and CO_2 absorption efficiency of crops can be simulated and optimized. Models can predict the effects of CO_2 uptake under different conditions and help agricultural producers optimize planting schemes and environmental control strategies to maximize the use of CO_2 resources.

CO_2 emission reduction strategies: Based on the simulation and optimization results of the digital twin model, CO_2 emission reduction strategies can be developed and evaluated. The model can simulate different agricultural management practices, such as irrigation, fertilization, crop rotation, etc[3].And predict their effects on CO_2 emissions. This can help agricultural decision makers select and implement mitigation measures to reduce the carbon footprint of agricultural systems.

5. CONCLUSIONS

In the process of experimental design and verification, we found that digital empowerment is extremely advantageous in this field. Digital empowerment brings many benefits and advantages to the CCUS system, including the following: Simulation and optimization, real-time monitoring and control, decision support, fault diagnosis and prevention, construction and maintenance support, and most importantly, in the context of China's open carbon trading in the future, through the advantages of artificial intelligence self-learning, to realize the prediction of the future carbon price, so as to provide users with the most accurate economic analysis.

DECLARATION OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this

paper. All authors read and approved the final manuscript.

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