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Viewpoints on the Experiences and Challenges of Fishery Energy Internet

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INTRODUCTION

It is noteworthy that energy-related carbon dioxide emissions have aroused great concern around the world. In this regard, the renewable energy trend has intensified during recent decades due to its extremely low carbon footprint. Photovoltaic (PV) power generation and wind power generation have become the primary sources of renewable energy (Fu et al., 2020), and hydrogen fueling stations have increased during the last decades due to their high energy efficiency. Zhang et al. presented a novel coordinated control method for hydrogen fueling stations, and the results of the experiment indicated that their method can greatly improve energy economy and efficiency (Zhang et al., 2021a). The installation of renewable energy needs to consider land and other practical issues. Rural roof, fishery, and greenhouse PV generation systems provide a variety of feasible schemes for renewable energy installations. Considering the economy of installing renewable energy in rural areas and the rapid increase in electricity demand brought on by agricultural electrification, agricultural energy internet (AEI) has become a valuable topic of integrated energy systems (Fu et al., 2021). It must also be mentioned that multi-energy complementarity is the key to the rapid development of integrated energy systems in recent years (Mu et al., 2020), and rural energy systems are suitable for applications of cascade utilization of various types of renewable energy resources. Harish et al. found that renewable energy such as PV generation, wind energy, and small hydropower had improved the level of electrification in rural areas and significantly affected the economy of rural energy systems. Their view is that the Internet of Things (IoT) should be applied to rural energy systems; the microgrid solution based on IoT is a smart solution to improve rural electrification (Harish et al., 2022).

The chief aim of this study is to express the author's viewpoints on the experiences and challenges of fishery energy internet (FEI) in China. The importance of FEI lies in its economic and environmental benefits to integrated energy systems. First, a fishery has high energy consumption and carbon emissions because it consumes plenty of nonrenewable resources for fishing activities (Schau et al., 2009). It has been calculated that offshore fisheries accounted for 24% of Korean energy needs, and active gears consumed 20 percent more energy than passive gears (Lee et al., 2018). Second, the fish pond provides available space for renewable energy installation (Li et al., 2022), and the space and its cost are essential in planning and structuring renewable energy systems. The dependence of fisheries on energy and their space sharing require the development of FEI technologies. In addition, the establishment of a fishery informatization system also provides a foundation for the construction of FEI.

The remaining article has three main parts. First, we propose a concept (FEI) that consists of renewable energy and fish farming in *Concept*. Second, we share the experiences of combining a fishery with PV power generation in *Experiences*. Then, we address the most common challenges of FEI in *Hard Problems*. Finally, we give a discussion and a conclusion in *Discussion and Conclusion*.
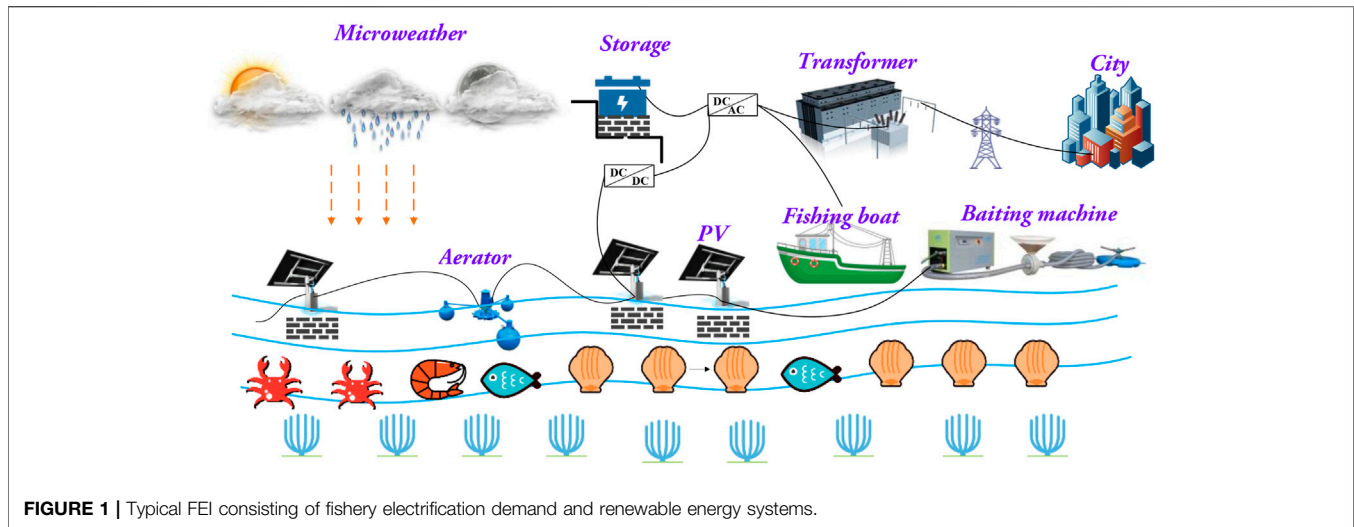
FIGURE 1 | Typical FEI consisting of fishery electrification demand and renewable energy systems.

CONCEPT

FEI has resulted in the solution of the vitalization of rural regions. The purpose of the FEI project is to promote the economic transformation and technology upgrading of fishery integrated energy systems with digital technology. FEI is the incorporation of digital fishery and energy internet, which is the result of the implementation of IoT with integrated energy systems. A fishery IoT regulates fishery equipment and facilities through intelligent sensors, such as dissolved oxygen, hydrogen ion concentration, temperature, conductivity, water level, and turbidity sensors. The information interaction between power and fishery IoTs can realize the perception of fishery equipment demand and energy network operation. FEI is the deep integration of IoT and fishery energy systems. The aerators are equipped with direct current frequency conversion motor technology, including a floating water pump, impeller pump, and waterwheel pump. Using PV generation means FEI will reduce fishery electricity bills. Advanced fishery electrification technologies have ignited the development of renewable energy and storage devices at unmanned fish farms, as shown in **Figure 1**. FEI takes electrification as a guarantee to realize the modernization and intellectualization of fishery breeding. It uses a series of electrical devices to replace traditional breeding devices, such as oxygenation pumps, electrical water purification systems, electric auto fish food timer dispensers, electrical brush machines, electric packers, and so on. An energy management system for FEI is made up of energy management functions, which are oxygenation, physical filtration, feeding, water quality monitoring, and nutrition monitoring.

Another interesting finding is that both fisheries and renewable energy are sensitive to sudden weather changes, that is to say, power supply and demand can be disturbed by changes in extreme weather and climate events. A summary of FEI benefits is provided as follows. 1) FEI can realize data communication and cooperative control between renewable energy and fishery energy load using IoT. 2) FEI finds a win-win solution for the fisheries sector and integrated energy systems. 3) This future FEI can promote the consumption of renewable energy and reduce carbon emissions.

EXPERIENCES

China's National Energy Administration encourages the development of various solar projects, including the fishery and PV complementary power project. Local governments are encouraged to introduce policies to actively support renewable energy development projects with environmental protection objectives. On the premise of ensuring the safety of water resources and environmental protection, China vigorously supports the transformation of clean and low-carbon energy and developing solar and smart energy systems. The construction of FEI in Guangdong has a good physical foundation, including rich fishery resources and advanced energy internet technology. Guangdong province is the manufacturing base of PV production equipment and grid-connected inverters, which have laid the foundations of the fishery and PV complementary power project. Guangdong has a long coastline and many offshore wind farms, resulting in a high proportion of PV and offshore wind power in Guangdong FEI. China's experience in FEI is worth learning from, and we have summarized key points in developing FEI. a) The shading rate control of PV panels should consider the tradeoff between fishery harvest and PV power generation. PV shading lowers water temperature, which has significant effects on plankton and fishery production. It is important to highlight that the dual benefits of fishery and renewable energy are the benefits of FEI. Only a single benefit may seriously weaken the advantages of FEI. b) Fishery meteorological services mean much to FEI. Rainfall, sunshine, and temperature will not only affect fishery breeding but also affect PV power generation. In other words, the weather can directly affect the source and load of FEI, and the weather sensitivity of energy networks is inevitable. IoT-based fishery and oceanographic monitoring systems are identified as a central technology for energy information systems. c) Another form of novel FEI technology in China is a technology called aquaponics, which combines aquaculture and hydroponics to produce more agricultural economic benefits with

high energy efficiency (Zhang et al., 2021b). Aquaponics is a potential technology that can realize the integrated development of renewable energy, fishery, and planting.

HARD PROBLEMS

From a technical point of view, a weak rural distribution grid finds it difficult to cope with the rising electricity demand for fish and fishery products. Extremely sensitive motors driven by frequency converters, such as aerators, baits, and fishery robots, suffer from power quality issues in three-phase imbalance, voltage, and frequency quality. The consequence of the power outage of the oxygenation pump is that the lack of oxygen in the breeding pond leads to the death of fish and shrimp in a large area. Aquaculture electricity consumption is regarded as an industrial power consumption, whose price is expensive in China. From an economic point of view, the electricity bill accounts for most of the aquaculture cost, and the financial burden has become a stumbling block to fishery electrification, which is a basic of FEI. In addition, fishery and PV complementary power projects bring new problems to electric utilities. First, water vapor easily accumulates on the water surface and erodes PV modules in the humid and high-temperature environment. Thus, the potential induced attenuation effect causes serious loss of PV power generation. Second, the existing fishery and PV complementary power projects rarely consider the transmission capacity of energy networks.

Large-scale disorderly de-networking of PV generation has a serious impact on the safe operation of the energy networks, and the problem of PV power abandonment is also very serious in China. Considering the requirements of power quality, profitability, and renewable energy integration, there is therefore an urgent need, but it is still a significant challenge to further develop the FEI theory and improve technical and economic benefits.

DISCUSSION

Relationship Between AEI and FEI

It is important to highlight that AEI refers to an intelligent integrated energy system providing farmers with access to low- and no-carbon energy sources, and electrification has significantly improved the energy efficiency of agricultural systems (Fu and Yang, 2022). It is well established that agriculture includes crops, animal husbandry, forestry, fisheries, and the food industry. Thus, AEI can be classified into multiple categories depending upon the agriculture subsectors. It is worth mentioning that FEI is one of the fastest growing forms of AEI.

Advantages and Uniqueness

First, we discuss the advantages of developing FEI in China. It is commonly known that China's energy demand is mainly concentrated in the eastern and southern regions due to

economic growth and economic development. Basically, the southern and eastern coastal regions of China are rich in water resources, whose development has been the basis for the fishery and PV complementary power project. FEI can connect the electricity demand and solar PV-fishery plant in these areas, and this will help solve the problems of energy shortage and renewable energy consumption. Second, we discuss the uniqueness of FEI. FEI is a unique integrated energy system, which can realize the cross-border integration of renewable energy and aquaculture. FEI can include multiple types of low-carbon energy: wave power generation, offshore wind power, and PV. Another interesting finding is that FEI includes various types of energy consumption, such as power consumption of automatic baiting machines, aerators, water pumps and refrigerated stores, power machinery of fishing vessels, aquaculture heating, etc. Financing renewable energy options for developing FEI will help China reach its goal of hitting carbon emission reductions.

CONCLUSION

This article introduces the novel concept of FEI, which integrates a renewable energy system and IoT. From the perspective of energy, PV power generation offers no pollution and clean energy for aquaculture facilities and equipment. It is important to highlight that the average monthly electricity bill is always a primary cost element. From the perspective of information, aquaculture IoT is integrated with power IoT to increase the reliability of power supply and energy efficiency of the aquaculture industry. FEI makes full use of one land for two purposes. FEI can greatly help realize the sustainable development of economic, ecological, and social benefits *via* combining PV power generation and fish farming. FEI has become the development direction of renewable energy systems in China's coastal areas. FEI changes the traditional modes of fishery production *via* realizing industrialization, electrification, and informatization, and provides a promising solution for the construction of centralized PV power plants. With the development of digital fishery and energy internet, FEI will become more energy efficient, low-carbon, intelligent, and reliable.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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REFERENCES

Fu, X., Guo, Q., and Sun, H. (2020). Statistical Machine Learning Model for Stochastic Optimal Planning of Distribution Networks Considering a Dynamic Correlation and Dimension Reduction. *IEEE Trans. Smart Grid* 11 (4), 2904–2917. doi:10.1109/TSG.2020.2974021

Fu, X., and Yang, F. (2022). Viewpoints on the Theory of Agricultural Energy Internet. *Front. Energ. Res.* 10, 839108. doi:10.3389/fenrg.2022.871772

Fu, X., Zhou, Y., Yang, F., Ma, L., Long, H., Zhong, Y., et al. (2021). A Review of Key Technologies and Trends in the Development of Integrated Heating and Power Systems in Agriculture. *Entropy* 23, 260. doi:10.3390/e23020260

Harish, V. S. K. V., Anwer, N., and Kumar, A. (2022). Applications, Planning and Socio-Techno-Economic Analysis of Distributed Energy Systems for Rural Electrification in India and Other Countries: A Review. *Sustainable Energ. Tech. Assessments* 52, 102032. doi:10.1016/j.seta.2022.102032

Lee, J., Kim, T., Ellingsen, H., Hognes, E. S., and Hwang, B. (2018). Energy Consumption and Greenhouse Gas Emission of Korean Offshore Fisheries. *J. Ocean Univ. China* 17, 675–682. doi:10.1007/s11802-018-3511-0

Li, P., Gao, X., Li, Z., Ye, T., and Zhou, X. (2022). Effects of Fishery Complementary Photovoltaic Power Plant on Near-Surface Meteorology and Energy Balance. *Renew. Energ.* 187, 698–709. doi:10.1016/j.renene.2022.01.118

Mu, C., Ding, T., Qu, M., Zhou, Q., Li, F., and Shahidehpour, M. (2020). Decentralized Optimization Operation for the Multiple Integrated Energy Systems with Energy cascade Utilization. *Appl. Energ.* 280, 115989. doi:10.1016/j.apenergy.2020.115989

Schau, E. M., Ellingsen, H., Endal, A., and Aanondsen, S. A. (2009). Energy Consumption in the Norwegian Fisheries. *J. Clean. Prod.* 17 (Issue 3), 325–334. doi:10.1016/j.jclepro.2008.08.015

Zhang, K., Zhou, B., Or, S. W., Li, C., Chung, C. Y., and Voropai, N. I. (2021). Optimal Coordinated Control of Multi-Renewable-To-Hydrogen Production System for Hydrogen Fueling Stations. *IEEE Trans. Ind. Applicat.* 1, 1. doi:10.1109/TIA.2021.3093841

Zhang, S., Guo, Y., Li, S., Ke, Z., Zhao, H., Yang, J., et al. (2021). Investigation on Environment Monitoring System for a Combination of Hydroponics and Aquaculture in Greenhouse. *Inf. Process. Agric.* 2021, 1. doi:10.1016/j.inpa.2021.06.006