Trend Analysis of Hybrid Small-hydro Generation Systems in Rural Areas

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Abstract. The hybrid power generation technology of small hydropower and wind or solar energy is one of the trends of small hydropower technology transfer, which can effectively improve the quality of power generation and enhance the permeability of renewable energy. This paper proposes a document mining system, which uses Citespace to visually analyse the keywords of small hydropower, and selects the small hydropower hybrid power generation system to occupy an important position in the current power generation technology. Secondly, using the same method to construct the keyword network diagram of small-scale hydro-wind complementary power generation technology and small-scale hydroelectric hybrid power generation technology, it is found that these two kinds of technologies are the focus of research in recent years, and they are still in the stage of fierce competition, it is hoped that more in-depth research can be carried out through a variety of clustering methods.

1. Research background

As the price of natural gas, new coal and nuclear power generation costs continue to rise, under the dual pressure of economic development and environmental destruction, people are not satisfied with a single renewable energy generation, and instead conduct research on complementary power generation technologies. Small hydropower is one of the most important renewable energy in the world. According to the relevant data of the World small Hydropower Development report 2016, the global installed capacity of small hydropower is about 78GW, accounting for 1.9% of the total global capacity and 7% of the total renewable energy capacity. However, the resource development rate of small hydropower is still relatively low, accounting for about 36%, and there are still problems of insufficient power and unstable power in many remote areas. Hybrid systems consisting of small hydropower stations and other renewable and sustainable energy is considered to be the most promising development technology. [1].

A hybrid system composed of a mixture of small hydropower and other power systems has greater advantages than a single small hydropower system. When combined with wind turbines or solar photovoltaic systems, hybrid renewable energy systems are more cost-effective and environmentally friendly [2].

Because the installed capacity and generating capacity of the hydroelectric power station are related to the water head and discharge of the river, and the water flow changes every day. The power
generation of the wind farm is determined by the type of wind turbine and the local wind speed. Compared with the flow of water from the river, the short-term fluctuation of wind speed is greater. The output of photovoltaic power generation is mainly determined by the working current and voltage of photovoltaic panels. The process of converting solar energy into electricity in photovoltaic panels is continuous, and the intermittence of photovoltaic power generation is mainly reflected between day and night. The advantages of using small hydro-photovoltaic hybrid power generation system are mainly reflected in solving the contradiction between agricultural water use and power generation in irrigation period, solving the shortage of small hydropower supply and peak regulation in low water period.

Wind energy and photovoltaic power generation are renewable green power that has developed rapidly in recent years, but the independent wind power generation system has higher requirements for the capacity of energy storage system [3]. Therefore, the use of wind, solar and hydropower complementary power generation can further improve the permeability of renewable energy, and optimize the power structure.

2. Present situation of small hydropower development

Systematic literature analysis method through comprehensive and complete literature summary and objective evaluation as far as possible, the incompleteness and non-objectivity of traditional literature review can be overcome, and more accurate conclusions can be obtained [4-5].

This paper draws lessons from the literature mining system on keyword research built by Xu et al, and can analyse these documents systematically. The system is shown in figure 1, in the collection of the whole literature of small hydropower, the retrieval type is designed as B_i+C_j. Among them, B_i stands for "small/micro/mini/pico", while C_j contains four different expressions of "hydropower/hydro power/hydroelectric/hydroelectricity". Using Boolean search in the Web of Science™ core collection database, 2395 downloads are obtained in the subject range. Data analysis uses the software CiteSpace, which is a Java application, which effectively combines cluster analysis, social network analysis and multi-dimensional scale analysis to analyse the contents of scientific literature. Finally, the analysis results are visualized in the form of knowledge graph. In order to understand the research trend and evolution [6-7]. The publication time of the literature is from 1996 to 2018, the network construction uses the minimum spanning tree pruning method, the node type is selected as keywords, and keyword analysis, as a kind of co-occurrence analysis, plays an important role in understanding the dynamics of knowledge development [8]. In the visualization module, different network analysis views: clustering and time zone, as shown in figure 2, reveal the internal relationship between keywords, thus studying the development process in this field.

Figure 1. Document mining system for small hydropower

![Figure 1. Document mining system for small hydropower](image-url)
The keywords are presented in a clustering pattern, as shown in figure 2a, in which there are 356 nodes and 809 edges, the network density is 0.0128, the degree of modularization is 0.531, the average S is 0.4851, and there are 15 kinds of effective clustering. The Q value is about 0.5, indicating that the integrity of the network structure is general, while the S value is less than 0.5, the clustering effect is not very good. In figure 2b, there are ten scaffold nodes of different sizes, each node represents a keyword, and the higher the frequency of keyword occurrence, the greater the ten scaffolds. Renewable energy, hydropower and system are the top three key words of frequency, concentrated from 2000 to 2004, while the main node keywords after 2006 are technology optimization, environmental impact and so on. Therefore, 2005 can be regarded as a turning point in the whole development process of small hydropower. First of all, before 2005, small hydropower began to develop vigorously, while wind energy appeared. After that, the technology transfer of small hydropower, considering the technical cost and economic benefits, hybrid power systems began to appear.

### 3. The complementary grid-connected path of water and wind.

In the power generation technology map of small hydropower stations, water-wind complementary power generation technology is an important direction in the transfer stage, and it is likely to become the leading technology in the next stage of small hydropower. Therefore, it is necessary to make an in-depth study on the small-scale water-wind complementary technology through the literature mining system.

In order to fully cover the relevant research literature, the retrieval type is designed as different expressions of wind power and small hydropower. Among them, wind power is represented by wind, and small hydropower is a different combination of "small/micro/mini/pico" and "hydropower/hydro power/hydroelectric/ hydroelectricity". 467 related articles were retrieved from the Web of Science™ core database.

In the document mining system, the keyword clustering network is constructed by using CitespaceIII software. Taking keywords as nodes, it mainly reflects the internal relationship between keywords. The routing network method is used to analyse all the literatures in the Citespace III software, and each interval and the merged network are pruned with 2 years as the time interval. The resulting keyword network consists of 167nodes and 307edges, and the network density is 0.0221. The Q value of modularization degree is 0.5407, which indicates that the network integrity is general, and the average silhouette value is 0.4107, which indicates that the degree of clustering in the network is
very low, indicating that the research in the field of small-scale water-wind complementary technology is relatively scattered and is in the primary stage of development. There are no research results of a certain scale to form effective clustering.

By presenting the keyword network in a clustering pattern, we can see the distribution of different clusters and the relationship between clusters, as shown in figure 3. Along the path of clustering distribution, it can be found that starting from the cluster 0 where the renewable energy is located, it spreads from inside to outside, and there are a lot of crossover, so the development of the relationship between clusters is not very obvious. Combined with Timeline View, we can also see that renewable energy is the earliest and most frequent keyword in the network, the cross-shaped annual ring distribution indicates that this node is a research hotspot in this field in recent years. According to the distribution of key words, the whole development trend can be divided into three stages. The first stage is that by about 2006, wind energy and small hydropower, the main participants of complementary small water and wind, have appeared one after another, as well as biomass energy (biomass) and solar energy. The second stage and the third stage are demarcated by 2012, in which the second stage is a large number of studies on complementary power generation of small hydropower and renewable energy, involving technology optimization, energy utilization costs and environmental protection issues. The mainstream of the last stage is the utilization and management of the small-scale hydro-wind complementary power generation model, as well as the obstacles faced by the model at this stage.

Through the analysis of literature mining system, it is concluded that the path of small-scale hydro-wind complementary power generation technology is in the primary stage of development. Therefore, considering that the cutting-edge of technology can usually be reflected in academic papers and patent documents, analyzing the growth path of related academic papers and patent documents on small hydro-wind complementary power generation technology can reflect the development status and trends of the technology to a certain extent [9].

4. Water-light hybrid off-grid path
The comprehensive development of water and light includes two cases: complementary and independent. For areas far away from the large grid in a state of no or lack of power, the local small hydropower resources and solar energy are used to establish a hybrid independent power generation system. Figure 4 shows a typical independent hydro-photovoltaic hybrid power generation system.
Through figure 2, the hybrid power generation system has appeared in the second stage of the development of small hydropower technology, and small-scale hydroelectric power generation technology has become a direction of small hydropower technology transfer.

4.1 Data preparation
In order to accurately retrieve the relevant literature of small-scale hydro-photovoltaic hybrid power generation, in the advanced retrieval of Web of Science™ core collection database, the retrieval type is designed as a combination of small-scale hydropower and photovoltaic power generation. Solar photovoltaic power generation is represented by "PV OR solar OR photovoltaic". Finally, 360 related literatures are obtained, which are recorded as the literature collection $K_{CS4}=360$. The Citespace III data set consists of 360 full records.

4.2 Cluster analysis
The pathfinding network method is used to analyse the literature collection $K_{CS4}$ in Citespace III software. From 1996 to 2018, one year is taken as the time interval, and PathFinder pruning is used for each interval and the merged network respectively. The final keyword network consists of 178 nodes and 590 edges, and the network density is 0.0375. The $Q$ value of modularization degree is 0.502, indicating that the integrity of the network is general; the average silhouette value is 0.5771, indicating that the clustering of the network is reasonable, indicating that the research of small hydro-photovoltaic hybrid power generation system has been concentrated.

The time zone visualization pattern, shown in figure 4, can reflect the generation of hot spots and inflection points from the time series. Renewable energy, which appeared in 2001, is the earliest inflection point in the network, and it is also the keyword with the highest frequency. Solar, which appeared in 2007, is the second inflection point in the network. Hybrid, which emerged in 2013, is the third inflection point. In terms of time distribution, the relevant research is focused on after 2009. Therefore, 22 years of development can be divided into three stages. Before 2007, small hydropower and photovoltaic power generation developed respectively, during which other renewable energy also appeared, among which wind energy is the key word with higher frequency, and its emergence time is earlier than solar energy. Photovoltaic power generation developed vigorously in the next few years, and after 2013, small-scale hydro-photovoltaic hybrid power generation system began to attract the attention of researchers. The clustering model, shown in figure 4, is used to analyze the distribution of different clusters and the relationship between clusters. It can be seen from the figure that the research in the field of small-scale water-light mixing technology is relatively concentrated, indicating that the
technology path has a good development trend. The distribution of inflection points in clustering is more uniform, which is distributed in cluster 0, cluster 1 and cluster 4 respectively. There are 8 effective clusters in all 12 clusters.

Figure 5. Time zone view analysis of small hydro-photovoltaic hybrid power system

Figure 6. Cluster analysis of small hydro-photovoltaic hybrid power generation system

5. Conclusion

At present, the resource development rate of small hydropower is still low. With the development of technology, economy, and policy, the hybrid generating system of small hydro has become the research hot spot. By means of experiment design to study the technology development within boundary, and analysis on key words, it can find the related research about complementary technology of small hydro has been wildly focused since 2005, which is still in the developing stage in total, and various small energy technologies is the possible development direction of this field.

Small independent water-light hybrid system is also one of the technical paths for the future development of small hydro, and there are complementary and independent two patterns for its development. Constructing keywords clustering network graph and time-zone view, and comparison and analysis, it can find independent system is the mainstream model of small water-light hybrid technology, which is mainly focused on system composition and optimization; the visual result shows that the new technology path has water-wind-light hybrid system and composed utilization of biomass energy with pumped-storage power station.
The related research about small water-wind complementary power generating system and small water-light hybrid power generating system has become the research hotspot in recent five years, which is still competed fiercely. It is feasible to stimulate the growth path of related academic thesis, patent literature, and wind-power market of small water-wind technology with the combination of dual model, and then, in accordance of comparison and analysis on simulated growth path, it can analyze the dynamic development trend and status of technology horizontally and vertically to have further deep research.

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