Mapping the Academic Landscape of the Renewable Energy Field in Electrical and Electronic Disciplines

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Abstract: Research on renewable energy fields of electrical and electronic disciplines is key to promoting the efficient production and utilization of renewable energy, but its branches are numerous and development is uneven. This article examines the topic distribution and future development trajectory of this field, and aims to provide academic researchers with the clearest development context and organizational structure in this field. This study obtained all fields from 3743 articles in the field of renewable energy from the Web of Science (WoS) database, with a time span of 1992–2018. We applied statistical analysis, the latent dirichlet allocation (LDA) topic model, and the autoregressive integrated moving average (ARIMA) model to map topic landscapes in the field of renewable energy. By analyzing these fields, we discovered the digital characteristics of the field and divided the field into 29 different topics, such as “Power conversion technology”, “Micro-grid”, and “Electric vehicles and hybrid electric vehicles”, and analyzed the growth characteristics of topics in two time periods—1992–2005 and 2005–2018. Finally, based on the development trajectory of each topic, we predicted their future development enthusiasm, which was divided into cold, hot, and stable. We compiled statistics on the most popular outlets and citations for each topic, making it easy for researchers and journal editors to appreciate and apply them.

Keywords: renewable energy; latent dirichlet allocation (LDA); coherence score; autoregressive integrated moving average (ARIMA); engineering; electrical and electronic

1. Introduction

People’s pursuit of a higher standard of living and a growing world population have led to a sharp increase in global energy consumption. At present, most of the energy consumed by human beings comes from fossil fuels, which, when burnt, will cause global warming problems. Therefore, driven by an urgent desire to mitigate the effects of global warming and a foreseen end to the world’s fossil fuel resources, an increasing tendency toward renewable energies is fostered by the international community [1]. The use of environmentally friendly and clean renewable energy heavily relies on the development of power electronics technology. After decades of development, power electronics technology has made great progress in power semiconductor devices, converters, pulse width modulation (PWM) technology, motors, motor drives, advanced control and simulation technologies, etc. In the 21st century, we have seen that power electronics technology has not only been applied in global industrialization and the general energy system, but has also had a tremendous impact on energy saving, the renewable energy system, and electric/hybrid vehicles, and the impact of climate change mitigation is also significant [2]. Research in the field of renewable energy occupies an important position in the electrical and electronic disciplines. However, the multidisciplinary knowledge in this field is not only diverse and professional, but also decentralized and multifaceted [3].
Additionally, there is no relevant literature for a clear mapping of this increasingly complex subject. This article systematically reviews the literature in this field, including evolution, topic distribution, and dynamic prediction, to help researchers and students conduct efficient and effective literature reviews, and to make the academic development of renewable energy use and production more targeted and accurate. At the same time, the research in this paper also provides a reference for the optimal use of renewable energy in industry.

In the era of big data, most scientific documents and books are stored in databases electronically. In order to identify basic topics from massive data, topic modeling has emerged. Its core is a set of algorithms and the goal is to reveal, discover, and annotate the topic structure in the document set [4]. Latent dirichlet allocation (LDA) was proposed by Blei et al. in 2003, and is based on the assumption of the bag of words (BOW) model, ignoring the order of the documents in the corpus and the order between the words in a document. The LDA model believes that each document can be described as a mixed probability combination of $K$ topics in the corpus, where $K$ is determined by the modeler [5]. LDA simulates the process of generating a document based on a three-layer probability model, describes the document as a probability model of the likelihood function, and uses variational inference to solve the approximate likelihood and posterior distribution. The basis of the variational inference method is the use of Jensen inequality to approximate the LDA posterior distribution in order to optimize the calculation problem, so that the Expectation-Maximization (EM) algorithm can iteratively obtain the LDA prior parameters. Over the past two decades, topic modeling has been explored in various fields, including text mining in scientific literature, software engineering, bioinformatics and social network analysis, and many areas of information retrieval research, and thousands of papers have been written and models have been developed.

In this paper, the two methods of the topic coherence score and topic cosine similarity are used to help select the optimal number of topics for the LDA model. Michael et al. evaluated topic modeling by introducing the concept of topic coherence, and they were the first to propose a framework that allows existing word-based coherence measures to be constructed, as well as new ones, by combining elementary [6]. This is a qualitative method that automatically discovers the consistency of topics, and is divided into four parts: the segmentation of word subsets (S), probability estimation (P), confirmation measure (M), and aggregation ($\sum$). The final result of the entire measurement framework is the cross product of four parts, namely, $C = S \times M \times P \times \sum$. This method contains many metrics, such as $C_V$, $C_{UCI}$, $C_{UMass}$, and so on. $C_V$ is based on a sliding window, a one-set segmentation of the top words, and an indirect confirmation measure that uses normalized pointwise mutual information (NPMI) and the cosine similarity. Michael et al. proved, in experiments, that the $C_V$ measurement method performs the best, so this article uses the $C_V$ metric method. The visual tool pyLDavis provides us with the convenience of presenting a global view of the topic, as well as differences between topics, which is designed to help users interpret topics in the topic model that fits the text data corpus [7]. It is based on multi-dimensional scaling analysis, and shows the distance between topics in low-dimensional space by calculating the cosine similarity of the topic distribution learned by LDA [4].

In recent years, in order to grasp the development status of various disciplines, relevant scholars have discussed the development process of the discipline from the perspective of the whole or part of each subject area. For example, based on LDA analysis, Tran et al. classified peer-reviewed papers in the research field of global research on interventions supporting quality of life among people with diabetes, and completed a quantitative review of the literature in this field [8]. Additionally, Guo et al. drew a thematic map of social class and inequality based on LDA, providing a powerful reference for researchers in social disciplines [9]. This article will also use the LDA method to study the field of renewable energy in the electrical and electronic disciplines, which few scholars have analyzed.

The rest of this paper is organized as follows. Section 2 describes the research procedure in brief. Section 3 illustrates the experimental process and results. In Section 4, we summarize our research and propose some future research directions.
2. Materials and Methods

2.1. Search Strategy

This paper used the following criteria to extract all the fields of an article from the core collection of the Web of Science (WoS) database: articles published in English from January 1980 to December 2018, in areas including “Engineering, Electrical and Electronic” and with the theme “Renewable energy” or “Renewable power”. In the journals indexed by Science Citation Index (SCI), a total of 4080 articles were found and downloaded. After deleting the articles without keywords and abstracts, 3743 articles were left, spanning from 1992 to 2018.

2.2. Data Extraction and Preprocessing

We used Python 3.7 to compile data in the PyCharm 2017 integration environment. The abstract can be regarded as a concise representation of the article and has been successfully used to identify and explain subject topics. In addition, Shaheen et al. proposed that, for a small dataset, abstract topic distributions capture broader topics [10]. This study first built a corpus containing the titles, keywords, and abstracts of all sample articles. As shown in Table 1, taking the following short text as an example, the natural language processing method was used to preprocess the corpus, and the results of text preprocessing were used for the input of the LDA model in Section 3.2:

Table 1. Text preprocessing.

| ID | Process | Result |
|----|---------|--------|
| 1  | Converted to lowercase. | [economic impact of investments in weather forecasts for distribution system operators: the Italian case.] |
| 1  | Removed symbols. | [economic impact of investments in weather forecasts for distribution system operators the Italian case] |
| 2  | Tokenized each sentence into a list of words. | [economic, impact, of, investments, in, weather, forecasts, for, distribution, system, operators, the, Italian, case] |
| 3  | Removed non-emotional English stop words, such as “a”, “an”, “can”, “are”, etc. | [economic, impact, investments, weather, forecasts, distribution, system, operators, Italian, case] |
| 4  | Used the n-gram model to form frequently-occurring word pairs as phrases. | [economic, impact, investments, weather, forecasts, distribution-system, operators, Italian, case] |
| 5  | Lemmatization. | [economic, impact, investment, weather, forecast, distribution-system, operator, Italian, case] |
| 6  | Used tf-idf to extract important words. | [economic, impact, investment, weather, forecast, distribution-system, operator, case] |
| 7  | Created the dictionary and word vectors: A dictionary is a collection of information about words or phrases. The word vector creates a unique ID for each word in the document and converts it into a vector. | dictionary: [0,1,2,3,4,5,6,7] vectors: [[0,1],[1,1],[2,1],[3,1],[4,1],[5,1],[6,1],[7,1]] |
3. Results

3.1. Statistical Analysis of the Sample

This study analyzed the annual growth rate of articles in the field of renewable energy and the proportion of articles with respect to all SCI articles in the WoS classification as “Engineering, Electrical and Electronic” in that year. As shown in Figure 1, the growth rate remained above 0, indicating that the number of articles has increased significantly over time. In 1992, only three articles (0.0197%) were published, but this number changed to 767 (1.005%) in 2018, indicating that the field developed rapidly in this period of 27 years.

![Figure 1. The publication percentage and its growth rate of renewable energy fields in electrical and electronic disciplines.](image)

The authors of these articles come from 86 countries, of which China, the United States, and India are the top three. In addition, the three most common schools in the sample are Slovak University of Technology (3.77%), Tsinghua University (1.23%), and Shanghai Jiao Tong University (1.05%). See Figure 2 for details. The articles have been published in 166 journals, and the five most frequent outlets in the field can be seen in Table 2.

![Figure 2. The nine most common schools.](image)
Table 2. The five most frequent outlets in the field.

| Outlets                                      | Percentage |
|----------------------------------------------|------------|
| IEEE Transactions on Power Systems           | 8.58%      |
| IEEE Transactions on Smart Grid              | 7.16%      |
| International Journal of Electrical Power & Energy Systems | 6.81%      |
| IEEE Transactions on Sustainable Energy      | 5.82%      |
| IEEE Transactions on Power Electronics       | 5.56%      |

In addition to the “Engineering” research area, the sample includes 21 other WoS research areas. As shown in Table 3, “Energy & Fuels” is the second largest research area, accounting for 13.01%, and covering 29 topics (in Section 3.2). “Computer Science” (9.30%) and “Science & Technology—Other Topics” (8.79%) cover 28 topics (in Section 3.2).

Table 3. Top ten Web of Science (WoS) research areas.

| Research                                      | Percentage | Counts of Topics Covered |
|-----------------------------------------------|------------|--------------------------|
| Engineering                                   | 100.00%    | 29                       |
| Energy & Fuels                                | 13.01%     | 29                       |
| Computer Science                              | 9.30%      | 28                       |
| Science & Technology—Other Topics             | 8.79%      | 28                       |
| Telecommunications                            | 8.68%      | 27                       |
| Automation & Control Systems                  | 7.10%      | 26                       |
| Instruments & Instrumentation                 | 5.98%      | 23                       |
| Physics                                       | 2.83%      | 23                       |
| Operations Research & Management Science      | 1.52%      | 19                       |
| Transportation                                | 1.26%      | 17                       |

3.2. LDA Topic Classification

3.2.1. Grid Search of the Optimal Number of Topics

LDA requires modelers to specify the number of topics. In this study, an optimal topic number should result in the model having the highest topic coherence score and the largest cosine similarity distance between topics. A two-stage grid search was used to find the optimal number of topics in the 3743 articles. In the first stage, the model set was calculated in steps of 10 in the range of 3–93 (i.e., 3, 13, 23 … 93), and each topic was repeated 30 times to avoid the influence of random resampling in the LDA. Each model was evaluated by topic coherence measures. As shown in Figure 3, the first-stage grid search program shows that when the number of topics is 33, the coherence score is the largest (0.3680), and the second largest value is achieved with 23 topics, with a score of 0.3667. Based on the two largest topics obtained in the first stage, we carried out the grid search process in the second stage with a topic range of 13–43 and step size of 1 (i.e., 13, 14, 15, …, 42, 43). Figure 4 shows that in the second stage of the grid search process, when the number of topics is 29, the topic coherence score reaches the maximum (0.387), and the optimal numbers of topics seem to be 29, 31, and 34.

Next, we evaluated the quality of the topic modeling to select the optimal number of topics. We used K for 29, 31, and 34 to draw the pyLDAvis plots of the LDA model for comparison. As shown in Figure 5, each bubble in the figure represents a topic, and the larger the bubble is, the more common the topic is. A good topic model will display quite large non-overlapping bubbles throughout the chart, rather than being clustered in one quadrant. Models with too many topics usually have a lot of overlap, and small-sized bubbles are concentrated in one area of the chart. The words and bars on the right represent the most salient terms in the corpus. When K = 29, pyLDAvis bubbles are more evenly distributed in the quadrant with less overlap, which shows that 29 is the optimal number of topics we are looking for.
3.2.2. Assessing Topic Diversity

Since LDA represents a collection of topics in a document, each topic is represented as a word distribution in the vocabulary, so we assigned each article to the topic with the highest topic load value and each article was only assigned to one topic. Our modeling results are shown in Table 4. The highest loading value for each topic is between 0.24 and 0.86 (mean = 0.57, std = 0.16). Antons et al. considered that if the loading of the topic is less than 0.10, the article does not contain meaningful topics [11]. Therefore, the highest topic loading for all articles is valid.
Table 4. Topic modeling results.

| ID | Topic Labels                                      | #Articles | Loading |
|----|---------------------------------------------------|-----------|---------|
| 1  | Research on battery energy storage                | 115 (3.07%) | 0.28 (0.8) |
| 2  | Hybrid energy generation system                   | 293 (7.83%) | 0.3 (0.65) |
| 3  | Research on electric vehicles and hybrid electric vehicles | 113 (3.02%) | 0.25 (0.4) |
| 4  | Photovoltaic power generation system              | 190 (5.08%) | 0.27 (0.73) |
| 5  | Micro-grid                                        | 325 (8.68%) | 0.28 (0.66) |
| 6  | Energy storage or reserve system                  | 228 (6.09%) | 0.41 (0.86) |
| 7  | Power conversion technology                       | 361 (9.64%) | 0.31 (0.7) |
| 8  | Research on dc circuit breaker and fault current limiter | 76 (2.03%) | 0.25 (0.49) |
| 9  | Inverter and grid-connected inverter              | 209 (5.58%) | 0.27 (0.81) |
| 10 | Bidding and development strategies for the electricity market | 136 (3.63%) | 0.28 (0.45) |
| 11 | Power flow analysis                               | 47 (1.26%) | 0.24 (0.33) |
| 12 | Optimal dispatch and manage for power systems     | 116 (3.10%) | 0.26 (0.41) |
| 13 | Wind power generation system                      | 70 (1.87%) | 0.26 (0.64) |
| 14 | Research on generator                             | 182 (4.86%) | 0.28 (0.45) |
| 15 | Smart grid                                        | 173 (4.62%) | 0.27 (0.49) |
| 16 | Control technology and some systems               | 72 (1.92%) | 0.27 (0.49) |
| 17 | Energy harvesting                                 | 70 (1.87%) | 0.27 (0.62) |
| 18 | Transmission line and transmission congestion control | 23 (0.61%) | 0.26 (0.62) |
| 19 | New renewable energy                              | 35 (0.94%) | 0.23 (0.29) |
| 20 | Prediction and management of renewable resources   | 348 (9.30%) | 0.32 (0.8) |
| 21 | Study on power system stability                   | 184 (4.92%) | 0.28 (0.52) |
| 22 | Power system in teaching                          | 14 (0.37%) | 0.22 (0.34) |
| 23 | Network communication technology                  | 29 (0.78%) | 0.3 (0.7) |
| 24 | Power quality control                             | 46 (1.23%) | 0.31 (0.79) |
| 25 | Peak power management                             | 12 (0.32%) | 0.23 (0.34) |
| 26 | Power management                                  | 108 (2.89%) | 0.25 (0.6) |
| 27 | Fuel cell power generation system                 | 40 (1.07%) | 0.27 (0.67) |
| 28 | Study on the damping characteristics of reactance | 23 (0.61%) | 0.24 (0.48) |
| 29 | Research on distributed systems                   | 105 (2.81%) | 0.28 (0.53) |

This study used the Herfindahl–Hirschman index (HHI) to assess the diversity of topics. The index is a measurement used to understand the level of competition that exists within a market or industry. It refers to the sum of the squares of the total revenue or total assets of the industry’s competitors in each market, which is used to calculate the dispersion of the size of the manufacturers in the market. According to experience, markets with an HHI of less than 0.10 are competitive or diverse markets, markets with an HHI in the range of 0.10 to 0.25 are moderately concentrated markets, and markets with an HHI greater than or equal to 0.25 are highly concentrated or monopolistic markets. Similarly, we calculated the HHI value of each article, that is, the sum of the squares of the topic load for each topic of each article, which ranges from close to zero to one, for evaluating the topic diversity of the article. We determined that if an article has an HHI of less than 0.10, it contains diverse topics; if the HHI is 0.10 to 0.18, the article contains a few important topics; and if the HHI is 0.18 or higher, the article contains a salient topic. The calculation results obtained by the above measurement methods in this paper indicate that 63.67% of the articles have an HHI value in the range of 0.10–0.18, meaning that they contain a few important topics, and 36.33% of the articles have an HHI value greater than 0.18, meaning that they contain a salient topic. The HHI value of 0% articles is less than 0.01, indicating that there are no articles that have diverse topics in the sample. This shows that the number of topics selected is reasonable, which means that LDA can extract dominant topics from other topics.

In order to further verify the classification results, this study obtained data from the SCOPUS scientific database for additional verification by selecting 1000 articles that belong to the subject area of “Engineering” and “Energy”, and titles, keywords, and abstracts containing the words “renewable energy” or “renewable power” or “electrical” or “electronics”. The type of research included was a journal article, and the time span was guaranteed to be 1993–2018. In this research, the optimal number
of topics was selected for 1000 validation sets through text preprocessing and LDA topic modeling and evaluation methods. The results are shown in Figure 6. This study used a two-stage grid search method. In the first stage, the topic coherence score for the number of topics in the range of 3–93 was searched with 10 steps, and the two largest topic coherence scores of 0.4188 (k = 23) and 0.4371 (k = 33) were obtained. In the second stage, the search was performed in the range of 13–43, with 1 as the step size. When k = 29, the maximum topic coherence score was 0.4382, which proved that the classification results of the literature in this field were correct.

![Figure 6. Coherence score of the two-stage grid search.](image)

3.2.3. Topic Labeling

We manually labeled each topic in the following ways. First, we used the top 15 words with the highest load value as the topic words and downloaded the full text of the top 20 articles and topic words in each topic. We invited 58 volunteers from different schools in different regions to read 20 random articles and topic words carefully, and marked each topic according to the understanding. We made sure that each article was read by at least two students. The author read 580 articles and topic words. We discussed controversial topics and finally finished by labeling the topics.

As shown in Table 4, the four most popular topics are “Power conversion technology” (Topic 7), “Prediction and management of renewable resources” (Topic 20), “Micro-grid” (Topic 5), and “Hybrid energy generation system” (Topic 2). These results are reasonable. As we all know, the common feature of energy power systems is the need for power conversion. That is, the power output from the power generation equipment is matched in form with the requirements of the existing power equipment through the power conversion device, so that the quality of the power can meet the needs of users. In addition, in order to reduce the impact of intermittent energy on the network security, it is necessary to predict the change of renewable energy with a reasonable accuracy [12]. A micro-grid is being developed to run modern power distribution systems in a more economical and efficient manner, benefiting both system operators and consumers [13]. Similarly, the hybrid energy generation system is a promising technology for clean and sustainable development [14]. It can make up for the shortcomings of the low reliability caused by the intermittent instability of wind and solar resources, and provide stable and reliable electricity. The four least popular topics are “Peak power management” (Topic 25), “Power system in teaching” (Topic 22), “Transmission line and transmission congestion control” (Topic 18), and “Study on the damping characteristics of reactance” (Topic 28).
3.3. Topic Dynamics

3.3.1. Prediction Based on Autoregressive Integrated Moving Average Technology (ARIMA)

Because the article count sequence shows strong autocorrelation, we chose autoregressive integrated moving average technology (ARIMA) to determine trends across the entire field and each topic. In ARIMA $(p, d, q)$, the AR part can be regarded as the linear regression of the previous $p$ period time series; the MA part is regarded as the linear regression of the current time series with respect to the random disturbance of the previous $q$ period; and the $d$ part represents “difference”, that is, in order to obtain data on the stationary series, the non-stationary data values are replaced by the difference between their values and one or more previous values. In this study, 30-time series were constructed based on ARIMA, and the appropriate parameters of ARIMA were determined following the conventional Baux Jenkins methodology [15].

Taking the whole field as an example, first, the text was divided into a training set (90%) and a test set (10%). We used the data from 1992 to 2015 as a training set and the data from 2015 to 2018 as a test set. Then, the time sequence diagram (part of the curve in Figure 1) of the percentage of publications in this field (1992–2018) was drawn. We found that it has a strong growth trend and poor stability. Because the ARIMA model requires the time series to be stable, this study took the logarithm and first-order difference to obtain the stable series. At the same time, the results of the Dickey fuller test of the first-order difference sequence also meet the requirements of stationarity. Then, the AR order of the training sequence was estimated by the partial autocorrelation function (PACF) graph; the MA order of the training sequence was estimated by the autocorrelation function (ACF) graph; and the most appropriate $p, q$ combination value was selected by combining the Akaike information (AIC), Bayesian information (BIC), and Hannan and Quinn information standard (HQIC). For the time series of the whole field, when $(p, q) = (3, 2)$, the standard statistics of AIC, BIC, and HQIC are the smallest, and are $-298.89$, $-292.42$, and $-296.97$, respectively. In order to verify the quality of the model, we drew the residual to see whether it was white noise, and checked whether the residual was non-autocorrelation by applying the Durbin Watson test and Ljung box test [16]. The Durbin Watson test value was 1.71, close to 2, indicating that there was no autocorrelation. Finally, through the comparison of the prediction results and the test set, it was found that the results were relatively similar, indicating that the prediction model fitted well.

As shown in Figure 1, this study placed the predicted results on the same map as the historical data. In addition, as shown in Table 5, this research found the ARIMA model parameters $(p, d, q)$ for each topic and calculated the annual average of the predicted growth rate.

We analyzed the overall growth in this field, which experienced a volatility increase before 2005 and began to grow steadily after 2005. We discussed the dynamics of each topic in the 1992–2005 and 2005–2018 time periods. We constructed 30 time series (the field and 29 topics). The percentage of publications in this field has increased significantly in both time periods, with an average growth rate of 23.98% before 2005 and 25.49% after 2005. However, there were only eight topics before 2005, and six of them had a decline in the growth rate before 2005, but then exhibited an increase after 2005. For example, the publication percentage of “Energy storage or reserve system” (Topic 6) shrank (on average, $-0.31\%$ per year) before 2005, but expanded (on average, 111.0% per year) in the second period. “Prediction and management of renewable resources” (Topic 20) declined by an average of 33.6% per year before 2005, but increased by an average of 46.0% per year during the second period. After 2005, only one topic (Topic 13, Wind power generation system) experienced a decline, and the rest of the topics experienced an increase. In particular, “Fuel cell power generation system” (Topic 27) increased, on average, 96.55% per year; “Smart grid” (Topic 15) increased, on average, 89.4%; and “Study on power system stability” (Topic 21) increased, on average, 54.3%. We searched for new topics that emerged after 2011 and found three topics: “Network communication technology” (Topic 23), “Power system in teaching” (Topic 22), and “New renewable energy” (Topic 19). By analyzing
emerging topics, researchers will be able to access new changes in research in the field in a timely manner, making their research novel and full of potential.

By comparing the average annual growth rate in this field, we set the development trend of each topic as three levels: hot, stable, and cold. We set the topics with a high growth rate in the field as hot topics, those with a negative growth rate as cold topics, and the rest as stable topics. From Table 5, we can clearly see that topic 3, 4, 5, 11, 12, 15, 21, and 23 are hot topics. The top five are “Micro-grid” (30.74%), “Smart grid” (30.0%), “Research on electric vehicles and hybrid electric vehicles” (27.71%), “Network communication technology” (23.86%), and “Study on power system stability” (22.6%). With the advocacy of energy conservation and emission reduction, electric vehicles have become the most environmentally friendly choice for people to travel. Therefore, electric vehicles and related micro-grid and energy dispatch topics will become valuable research content in the future. The development of network communication has not only provided convenience for people’s lives, but has also become an important engine for economic and social development. Therefore, the integration of network communication technology and power grid technology is particularly important. At the same time, research topics such as “the stability and safety of power system operation” and “Power flow analysis” still need to be researched in the future.

Table 5. The results of autoregressive integrated moving average technology (ARIMA) and forecasting.

| Topic Order | AIC | BIC | HQIC | Ljung-Box (p-Value) | Pre | Post | Avg Future Gth | Category |
|-------------|-----|-----|------|---------------------|-----|------|---------------|----------|
| The Field   | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 1     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 2     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 3     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 4     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 5     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 6     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 7     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 8     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 9     | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 10    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 11    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 12    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 13    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 14    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 15    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 16    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 17    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 18    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 19    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 20    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 21    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 22    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 23    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 24    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 25    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 26    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 27    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 28    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |
| Topic 29    | 1   | 1   | 0.56 | 0.29  | 2.48 | 0.15 | 0.38 | Benchmark |

3.3.2. Verification Based on Different Segments

In addition, we divided the 1992–2018 data set into different segments with different lengths and compared their individualized results with the overall results. Specifically, due to the large fluctuation of the growth rate around 2005, we selected several special years, with 2005 as the reference point. 1993 and 1995 represent the initial state of development; 2016 and 2018 represent the latest state of development; and 2000 and 2013 are the middle years of the period with large fluctuation and small fluctuation, respectively. Then, we set up the time series of the growth rate of the percentage of publications in this field in different periods to predict the growth rate from 2019 to 2020. As shown in Table 6, the predicted average growth rate of the 10 different time periods is 16.29%, which is only 0.45% different from the overall prediction result, and does not affect the predicted topic enthusiasm results, proving that the prediction result is accurate.
Table 6. The prediction results in different segments.

| ID | Segments (Year) | Prediction of Growth (%) |
|----|----------------|--------------------------|
| 1  | 1993–2005      | 72.14                    |
| 2  | 1993–2013      | 20.30                    |
| 3  | 1993–2016      | 25.13                    |
| 4  | 1995–2005      | 34.00                    |
| 5  | 1995–2016      | 07.18                    |
| 6  | 1995–2018      | 17.15                    |
| 7  | 2000–2013      | 21.34                    |
| 8  | 2000–2018      | −18.89                   |
| 9  | 2005–2016      | −18.03                   |
| 10 | 2005–2018      | 2.59                     |

average 16.29

3.4. Extracting Important Results

Tables 7 and 8 show the three most frequently cited references and the three most popular published outlets for each topic in order to provide a reference for researchers. There are 166 outlets included in the field. The outlet with the largest number of topics is IEEE Transactions on Industrial Electronics, covering 26 topics in the field, followed by International Estate of Electrical Power & Energy Systems, which covers 25 topics. These outlets cover a wide range of topics, and the two outlets published a large number of articles in the field.

Table 7. The three most cited references per topic.

| Topic | Articles |
|-------|----------|
| 1     | Teleke et al. [17]; Zhao et al. [18]; Gee et al. [19] |
| 2     | Carrasco et al. [20]; Liserre et al. [21]; Jiang et al. [22] |
| 3     | Saber et al. [23]; OTA et al. [24]; Khodayar et al. [25] |
| 4     | Sun et al. [26]; Alajmi et al. [27]; Shi et al. [28] |
| 5     | Rocabert et al. [29]; Trends in Microgrid Control [30]; Tsikalakis et al. [31] |
| 6     | Barton et al. [32]; Huang et al. [33]; Vazquez et al. [34] |
| 7     | Rodriguez et al. [35]; Blaabjerg et al. [36]; Maharjan et al. [37] |
| 8     | Franck et al. [38]; Li et al. [39]; Reyes et al. [40] |
| 9     | Zhong et al. [41]; Daher et al. [42]; Alepuz et al. [43] |
| 10    | Keane et al. [44]; Lopez-Higuera et al. [45]; Zhao et al. [46] |
| 11    | Williams et al. [47]; Cao et al. [48]; Abdedlaziz et al. [49] |
| 12    | Battistelli et al. [50]; Nguyen et al. [51]; Lora et al. [52] |
| 13    | Blaabjerg et al. [53]; Teodorescu et al. [54]; Huang et al. [55] |
| 14    | Li et al. [56]; Muljadi et al. [57]; Karki et al. [58] |
| 15    | Wang et al. [59]; Varaiya et al. [60]; Sauter et al. [61] |
| 16    | Mu et al. [62]; Aunedi et al. [63]; Samadi et al. [64] |
| 17    | Park et al. [65]; Zhang et al. [66]; Mao et al. [67] |
| 18    | Verzijlbergh et al. [68]; Hammons et al. [69]; Chen et al. [70] |
| 19    | Pearson et al. [71]; Ursua et al. [72]; Careri et al. [73] |
| 20    | ATWA et al. [74]; Bull et al. [75]; Singh et al. [76] |
| 21    | Blaabjerg et al. [77]; Short et al. [78]; Lee et al. [79] |
| 22    | Rasheduzzaman et al. [80]; Hong et al. [81]; BESSAjR et al. [82] |
| 23    | Liu et al. [83]; Baccarelli et al. [84]; Liu et al. [85] |
| 24    | Muljadi et al. [86]; Hadjimetriou et al. [87]; Basu et al. [88] |
| 25    | Vesti et al. [89]; Zhao et al. [90]; Dudhani et al. [91] |
| 26    | Whittingham [92]; Chakraborty et al. [93]; Xie et al. [94] |
| 27    | Han et al. [95]; Chen et al. [96]; Xu et al. [97] |
| 28    | Liu et al. [98]; Liu et al. [99]; Du et al. [100] |
| 29    | Blaabjerg et al. [101]; Zhang et al. [102]; Conti [103] |
Table 8. The three most popular outlets per topic.

| Topic | Outlets |
|-------|---------|
| 1     | IEEE Transactions on Sustainable Energy; International Journal of Electrical Power & Energy Systems; IEEE Transactions on Industrial Electronics |
| 2     | IEEE Transactions on Sustainable Energy; IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems |
| 3     | IEEE Transactions on Smart Grid; IEEE Transactions on Vehicular Technology; Electric Power Systems Research |
| 4     | IEEE Transactions on Energy Conversion; IEEE Transactions on Industrial Electronics; International Journal of Electrical Power & Energy Systems |
| 5     | IEEE Transactions on Smart Grid; International Journal of Electrical Power & Energy Systems; IET Generation Transmission & Distribution |
| 6     | IEEE Transactions on Sustainable Energy; IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems |
| 7     | IEEE Transactions on Power Electronics; IEEE Transactions on Industrial Electronics; IEEE Transactions on Industry Applications |
| 8     | IEEE Transactions on Applied Superconductivity; IEEE Transactions on Power Electronics; IEEE Transactions on Industrial Electronics |
| 9     | IEEE Transactions on Industrial Electronics; IEEE Transactions on Power Electronics; IEEE Transactions on Industry Applications |
| 10    | IEEE Transactions on Power Systems; IEEE Transactions on Smart Grid; IEEE Transactions on Sustainable Energy |
| 11    | IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems; IET Generation Transmission & Distribution |
| 12    | IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems; IEEE Transactions on Sustainable Energy |
| 13    | IEEE Transactions on Sustainable Energy; IEEE Journal of Emerging and Selected Topics in Power Electronics; IEEE Transactions on Industrial Electronics |
| 14    | IEEE Transactions on Energy Conversion; IEEE Transactions on Industry Applications; Electric Power Components and Systems |
| 15    | IEEE Transactions on Smart Grid; International Journal of Electrical Power & Energy Systems; Proceedings of the IEEE |
| 16    | IEEE Transactions on Smart Grid; International Journal of Electrical Power & Energy Systems; IET Generation Transmission & Distribution |
| 17    | IEEE Transactions on Wireless Communications; IEEE Journal on Selected Areas in Communications; IEEE Transactions on Communications |
| 18    | IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems; IEEE Transactions on Smart Grid |
| 19    | IET Renewable Power Generation; IEEE Transactions on Power Systems; IEEE Transactions on Applied Superconductivity |
| 20    | IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems; IEEE Transactions on Sustainable Energy |
| 21    | IEEE Transactions on Power Systems; International Journal of Electrical Power & Energy Systems; Electric Power Systems Research |
| 22    | IEEE Transactions on Power Systems; International Journal of Electrical Engineering Education; European Transactions on Electrical Power |
| 23    | IEEE Access; IEEE Transactions on Vehicular Technology; International Journal of Electrical Power & Energy Systems |
| 24    | International Journal of Electrical Power & Energy Systems; Electric Power Systems Research; IEEE Transactions on Power Electronics |
| 25    | International Journal of Electrical Power & Energy Systems; Journal of Modern Power Systems and Clean Energy; IEEE Transactions on Power Electronics |
| 26    | IEEE Transactions on Smart Grid; IEEE Transactions on Industrial Electronics; IEEE Access |
| 27    | IEEE Transactions on Sustainable Energy; Electric Power Systems Research; IEEE Transactions on Industry Applications |
| 28    | IEEE Transactions on Industry Applications; IEEE Transactions on Energy Conversion; IEEE Transactions on Industrial Electronics |
| 29    | International Journal of Electrical Power & Energy Systems; IEEE Transactions on Smart Grid; IEEE Transactions on Power Systems |
4. Discussion and Conclusions

This paper provides a systematic review of 3743 articles published in renewable energy fields of electrical and electronic disciplines from 1992 to 2018, including evolution, topic distribution, and dynamic prediction. The results show that this field is technology-oriented, improving the efficiency of renewable energy production and utilization through the establishment of multiple energy systems. In the next few years, research on renewable energy technologies will continue to grow substantially, with a growth rate of 16.74%. It entered the preliminary research stage in 1995 and has continued to grow since 2005. Twenty one topics have been added since 2005, indicating that the renewable energy field has developed rapidly in the past 15 years. This article examined 29 topics. The topics related to the stability of renewable energy are “Optimal dispatch and manage for power systems” (topic 12), “Study on power system stability” (topic 21) and “Power quality control” (topic 24), etc., and the topics on the economics of renewable energy are “Bidding and development strategies for the electricity market” (topic 10) and topic 12. Additionally, the topics related to the availability of renewable energy are “Hybrid energy generation system” (topic 2), “Photovoltaic power generation system” (topic 4), and “Wind power generation system” (topic 13). Most of the topics have a large or stable growth trend in the future, which shows that as a field with a short research period (relative to the economic and financial fields), renewable energy has significant deficiencies in the above three aspects, and future research on these aspects also has growth potential.

We found that the development in this field is not balanced. For example, research on new energy sources has made breakthrough progress in tidal energy and wave energy [104], but there are few articles in this field and the research enthusiasm in the future is cold, so more researchers should be called on to pay more attention to this topic. Similarly, the topics of “Power system in teaching”, “Research on dc circuit breaker and fault current limiter”, and “Control technology and some systems” need to be addressed. In addition, each country has a set of specific standards for the conductor temperature and current carrying value of transmission lines. The smaller examination of the transmission potential of transmission lines will not change the national standards, which may be the reason why the topic of “Transmission line and transmission congestion control” will become cold in the future.

In summary, this paper describes the renewable energy field in the electrical and electronic disciplines at a more detailed level. For readers, it can help them gain a deeper understanding of the field and obtain the relative saliency of the topics of interest. For researchers, it can help them to summarize studies. For students and teachers, it can provide teachers with information for targeted teaching and help students choose course design themes. For editors, it provides important results for them to appreciate and apply.

Our research may have some limitations. First, we analyzed only nine of 56 fields per article. In the future, we will focus on using these fields as much as possible to learn more about potential information. Second, we classified each article into a single topic, without considering the correlation between topics. Some articles may belong to multiple topics. Future research may focus on multi-label source text classification research.

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