Bibliometrical Analysis of the Smart Grid Research

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Abstract. Based on the information of 1924 articles collected from China Academic Journal Network Publishing Database (CAJD), bibliometrical analysis methods are used to analyze the smart grid research. The results showed that: 1) the smart grid has got the attention of many researchers, core authors have been initially presented; 2) The main research institutes of this field are the professional institute in electric power field and universities with electricity professional; 3) *Automation of Electric Power Systems*, *East China Electric Power* and *Electrotechnical Application* are the main journals publishing the articles about the smart grid; 4) "Demand response", "Power system" and "Internet of things" are the keywords frequently appeared, which are the research focuses in the field of smart grid.

Introduction

The smart grid has got the attention of many researchers and periodicals. They have discussed both the meaning and basic concept of the smart grid[1, 2], and analyzed the relevant standard system [3].

For deep understanding of the smart grid research status and providing a reference for future research in this field, this article uses the bibliometrical method to analyze the related literature in China Academic Journal Network Publishing Database, which include the distribution of publishing year, core authors, core research institutions, core journals, the high frequency keywords, etc.

Data Sources and Processing

This paper is based on the platform of China Academic Journal Network Publishing Database (CAJD). When seeking the effective information, journals sources are "core journals" and "CSSCI journals", search word is "smart grid", field is "subject", the match method is "precise", time span is "until 2015". Based on the retrieval on March 10, 2016, a total of 2638 records are found. Excluding the articles without author and signed by "editorial board", "this Journal Dispatch", finally 1924 effective records are collected.

Figure 1 Smart Grid Research Paper Growth Line

The smart grid research publications in each year are shown in table 1. Table 1 indicates that the research paper quantity of the smart grid in the first 11 years is very small, only 0 ~ 1 article for every year. In 2009, the publication number soared to 91. From 2010 to 2015, it was stable at

around 300 articles each year. This indicates that this field has got more and more attention of the researchers, and it has gained steady development. The line chart of publications in each year is shown in figure 1.

Table 1 Quantity Statistics of the Smart Grid Research Publications in Each Year

Year	Paper number	Year	Paper number
1996	1	2006	0
1997	0	2007	3
1998	0	2008	5
1999	0	2009	91
2000	0	2010	261
2001	0	2011	282
2002	1	2012	317
2003	1	2013	324
2004	1	2014	329
2005	0	2015	308

The analysis of authors, institutions, and journals

The Core Author Analysis. Statistics shows that there are 6578 authors in all 1924 articles, cooperative degree is 3.42. These papers involved 4545 authors (This article did not consider the duplicate of names). Ming Zeng is the author that has the most publications with 31 articles, the second and third respectively are Xinjie Li (18 articles), and Junyong Liu (17 articles). The authors with 11 published articles or above are shown in table 2. In addition, there are 3524 authors only published 1 article, and it accounts for 77.5% of the total number of authors.

Table 2. Core Authors in the Smart Grid Study

No.	Author	Paper number	No.	Author	Paper number
1	Ming Zeng	31	10	Dong Liu	12
2	Xinjie Li	18	11	Yang Cao	12
3	Junyong Liu	17	12	ShengWei Mei	12
4	Jianguo Yao	16	13	Yusheng Xue	12
5	Hongbin Sun	15	14	Chuangxin Guo	12
6	Zheng Yan	13	15	Guangyu He	11
7	Fushuan Wen	13	16	Yijia Cao	11
8	Peng Li	13	17	Qian Ai	11
9	Shengchun Yang	13	18	Song Xue	11

If the first author is the only consideration, core author distribution is shown in table 3. From the comparison between table 3 and table 2, if the first authors are the only consideration, the most publication authors are still Ming Zeng and Xinjie Li, but the list after them will be more different. There are only 5 authors in table 2 appeared in table 3.

Table 3. Core Authors in the Smart Grid Study (First Author)

No.	Author	Paper number	No.	Author	Paper number
1	Ming Zeng	22	11	Xiangping Meng	5
2	Xinjie Li	18	12	Baohui Zhang	5
3	Haijiang Shi	7	13	Hui Xu	5
4	Jiaqing Zhao	7	14	Fan Yang	5
5	Lisha Zhou	6	15	ShengWei Mei	5
6	Peng Li	6	16	Xingzhi Wang	5
7	Guan Xiao	6	17	Bin Wang	5
8	Yixin Yu	5	18	Dewen Wang	5
9	Jing Lu	5	19	Mingjun Wang	5
10	Jianguo Yao	5	20	Jia Ju	5

The Institution Distribution. Considering only the first institution of each article, China Electric Power Research Institute is the number 1 institution that has the most publications in the field of smart grid research with 150 articles, secondly and thirdly, respectively, are North China Electric Power University (147 articles), and Tsinghua University (74 articles). Institutions in the top 16 of publication list are shown in table 4. Table 4 indicates that the core research institutions are mainly professional institutes in electric power field and excellent professional power universities. At the same time, some electric power enterprises also play important roles.

Table 4. TOP16 Institution List of Smart Grid Research Publications

No.	Institution	Paper number	No.	Institution	Paper number
1	China Electric Power Research Institute	150	9	Tianjin University	31
2	North China Electric Power University	147	10	Xi'an Jiaotong University	30
3	Tsinghua University	74	11	Zhejiang University	27
4	Shanghai Jiaotong University	56	12	Wuhan University.	27
5	Shanghai Municipal Electric Power Company	47	13	Southeast University	26
6	State Grid Electric Power Research Institute	46	14	Chinese Academy of Science	24
7	Sichuan University	33	15	Shanghai University of Electric Power	21
8	East China power grid co., LTD	32	16	State Grid Energy Research Institute	19

The Journal Distribution. Statistics show that 1924 articles were published in 225 journals, which demonstrates that smart grid research has gained the attention of many journals. The *Automation of Electric Power Systems* has the most publications (245 articles), followed by *East China Electric Power* (214 articles), and *Electrotechnical Application* (191 articles). Journals publishing above 22 articles are shown in table 5, these journals published totally 1388 articles, accounting for 72% of the total number of 1924 articles, indicating that smart grid research has formed special stable group in periodicals. The top 6 journals issued 1006 articles, accounting for 22% of all smart grid research articles, the proportion is very high, and they are the core journals in this field.

Table 5 Journal Distribution of Smart Grid Research Articles (≥ 22)

Journal Name	Number of Publications	Journal Name	Number of Publications
Automation of Electric Power Systems	245	Electric Power	90
East China Electric Power	214	Electric Power Automation Equipment	62
Electrotechnical Application	191	High Voltage Apparatus	36
Power System Technology	135	Chinese Journal of Power Sources	28
Power System Protection and Control	118	Transactions of China Electrotechnical Society	26
Electrical Measurement & Instrumentation	103	Low Voltage Apparatus	23
Proceedings of the Chinese Society for Electrical Engineering	95	High Voltage Engineering	22

The Keywords Analysis

From all the 1924 articles, a total of 4434 keywords appeared. Since using "smart grid" as the keyword to retrieve and obtain data, therefore the word "smart grid" occurrences is certainly the most, and it appeared totally 956 times. The top 14 high frequency keywords are shown in table 6. Table 6 shows that "demand response", "power system" and "Internet of things" appeared more than 50 times, which are the research focuses in the field of smart grid.

Table 6 The High Frequency Keywords of the Smart Grid Research (Top 14)

No.	Keywords	Frequency	No.	Keywords	Frequency
1	The smart grid	956	8	Cloud computing	44
2	Demand response	57	9	Intelligent power distribution network	40
3	Electric Power Systems	53	10	The smart electricity meter	39
4	The Internet of things	51	11	power distribution network	39
5	Intelligent substation	48	12	Renewable energy	36
6	Distributed power	47	13	Distributed generation	34
7	The electric car	47	14	Micro power grid	31

Conclusion

Through the bibliometric analysis of journal articles in the field of smart grid, the following characteristics can be found in the study of this field:

- 1) The smart grid research has got the attention of many researchers and core authors initially presented.
- 2) The main research institutions are professional institutes in electric power field and excellent professional power universities. At the same time, some electric power enterprises also play important roles.
- 3) The *Automation of Electric Power Systems*, *East China Electric Power* and *Electrotechnical Application* are the main journals published the articles about the smart grid.
- 4) The frequency of the keywords "Demand response", "Power system" and "Internet of things" is very high, which are the research focuses in the field of smart grid.

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