Journal of Engineering and Applied Sciences
MEDWELL PUBLICATIONS

A Bibliometric Analysis on the Progress of Hydroelectric Energy Research in the Last Decade

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Key words: Hydroelectric energy, renewable energy, bibliometrics, research trends, scientometry

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Page No.: 1912-1918
Volume: 15, Issue 8, 2020
ISSN: 1816-949X
Journal of Engineering and Applied Sciences

Abstract: To understand the history and progress of hydropower research, it was necessary to gather relevant information on the records of publications covering the years 2007-2016, through the Web of Science tool. Later, along with the HitsCite software, this information was used to analyze annual yields, countries, journals and institutions that showed interest in publishing on this subject, as well as the number of times these publications were cited. The results suggested that hydroelectric energy research has increased significantly over the past ten years. The country with the highest research output was China, followed by the United States, concluding that those who showed the most significant interest in hydroelectric energy research were developed countries, these countries also stood out for having a high value of TLCS (Total Local Citation Score) indicator that allows knowing the values of total score of citations by location. Furthermore, it should be noted that developed countries have more research advantages in this field than other countries. The first five institutions with the highest research results were Chinese where the first place was occupied by the Chinese Academy of Science. The journals highlighted for publishing articles in this area were Wasserwirtschaft and renewable and sustainable energy reviews while the journals with the highest FTAs were advances in water resources and computers and operations research.

INTRODUCTION

Hydropower is by far the world's first renewable source of energy; it has many advantages over most other sources of electricity (geothermal, tidal, wind and solar) including a high level of reliability, high-efficiency technology, lower operating and maintenance costs and great flexibility and storage capacity. It represents one-fifth of the world's electricity. Stable and affordable electricity supply is also critical to ending extreme

poverty and boosting economic growth. While the development of hydropower offers enormous opportunities, it also poses significant challenges and risks that vary significantly, depending on the type, location and scale of projects. Factors such as community resettlement, flooding of large areas of land and major changes in river ecosystems need to be considered carefully while mitigating risks. Hydroelectric energy comes from water at work, water on the move. In nature, energy cannot be created or destroyed but its form can change. When generating electricity, no new energy is created. In reality, one form of energy is converted to another form. To generate electricity, water must be moving. This is kinetic energy (in motion). When the flowing water turns the blades in a turbine, the shape changes to mechanical (machine) energy. The turbine rotates the rotor of the generator that then converts this mechanical energy into another form of energy, electricity. As water is the initial source of energy, we call this hydroelectric or hydroelectric power for short. In installations called hydroelectric power plants, hydropower is generated (US Department of the Interior Bureau of Reclamation Power Resources office 2005). The old Greeks had been using wooden water wheels to convert kinetic energy into mechanical energy for 2,000 years. In time, humans began creating dams to store water in the most convenient places to make better use of energy capacity. Additional engineering and structural changes have continued, providing a much more complicated process in the design of a hydroelectric power plant (Shortridge-Early-History-of-Hydroelectric-Power.pdf," n.d.; Castaldi *et al*., 2003). Many studies and advances have been presented over time to obtain a better use of this type of energy, in many of these econometric methods were used to evaluate the relationship between socio-economic indicators at the country level and hydroelectric energy in different countries such as Romania, China, Brazil and Afghanistan (Li *et al*., 2018; Danish *et al*., 2017; de Faria *et al*., 2017).

Although, much attention has been devoted to the development of hydropower in the literature, few of them collected systematic data and carried out a large-scale review of scientific articles, among the few found are (Jiang *et al*., 2016; Han *et al*., 2014) where publications have been found to maintain a rapid growth rate, English is the dominant language and the most critical points of hydroelectric energy research can be concluded as "fish", "species", "climate", "emission", "lake", "sediment", "Turkey", etc. A bibliometric approach is used in this study to quantitatively assess at the global level scientific research on the sustainable development of hydroelectric energy, by summarizing the keywords, the dominant key points of sustainable hydropower research could be concluded as "Turkey", "Eco-", "Small hydro-" and "Fish". Along with a comparable number of publications in the United States. Bibliometrics is a sub-discipline of science and provides information on the results of the research process, its volume, evolution, visibility and structure. In this way, they allow us to assess the scientific activity and the impact of both research and sources. According to this, the bibliometric indicators can be classified into two main groups, the activity and impact indicators. The activity indicators visualize the real state of science and within these are the number and distribution of publications, the average life of the citation or aging, connections between authors, among others (Cai, 2009). Impact indicators include the evaluation of widely cited papers and the impact factor h_idex, the latter being the best known (Tarlock, 2012).

MATERIALS AND METHODS

The methodology of this article is to collect all the information on research on hydroelectric energy, using the digital web science tool, taking only files reported in the period 2007-2017. The search yielded a total of 1504 records consisting of various standard documents, including journal articles, conference proceedings, reviews, editorial materials and letters. Data was subsequently imported into HistCite. Data such as year, country, institution and journal were summarized, we also analyzed high-impact articles, authors of high impact and research trends. The methodology of this article is to collect all the information on research on hydroelectric energy, using the digital web science tool, taking only files reported in the period 2007-2017. The search yielded a total of 1504 records consisting of various standard documents including journal articles, conference proceedings, reviews, editorial materials and letters. Data was subsequently imported into HistCite. Data such as year, country, institution and journal were summarized, we also analyzed high-impact articles, researchers of high impact and research trends.

RESULTS AND DISCUSSION

Focus on document type and language: Eight types of documents were identified in the 1504 files. Among the papers found, most were journal articles, representing 84% of the total records indicating that this is the predominant mode of study in hydroelectric energy research. It was followed by reviews and editorial material with 8.2 and 3.05%. Papers, book reviews and corrections were distributed the remaining 5.11%. The documents were written in 11 languages, in English 88.03%, German 10.03% to Turkish 0.06% of the total percentage. It should be noted that the predominance of

Table 1: Classification of the files, total score of citations according to location TLCS and TLCS/Files according to the countries

Countries	Archives	Countries	TLCS	Countries	TLCS/Archives
People's Republic of China	359	People's Republic of China	603	Turkey	4.140
USA	221	USA	440	Thailand	3.500
Germany	132	Turkey	273	Ireland	3.000
UK	70	India	150	India	2.083
Brazil	68	Germany	131	Chile	2.100
Turkey	66	UK	120	USA	1.990
Norway	63	Switzerland	116	Switzerland	1.900
Switzerland	61	Norway	108	Italy	1.740
Canada	57	Canada	90	UK	1.710
India	53	Brazil	67	Norway	1.710

the English language may be due to the fact that most researchers publish their articles in English as it is an international language for researchers.

Focus on annual research output: The analysis of the number of documents published per year for a specific topic is constructive in identifying the research impact it has had on a given subject over time as well as the interest of the scientific community and the need to conduct studies on that topic over time. In recent years, there has been a progressive increase in the elaboration and publication of research studies on hydroelectric energy. 2016 was reported as the year with the most extensive published studies based on data from the hites cite tool. During the periods 2011 and 2013 as well as 2014 and 2015, the increase in publications was found to be much higher as shown in Fig. 1.

Results-based distribution by country and number of citations: Analyzing country-specific research results helps to understand the country's capacity concerning others to produce publications on a specific topic. Since, 2007,97 countries have been interested in publishing, indicating that this issue attracted a lot of attention in all parts of the world. China is the country that has published the most of 359 documents, this is due to the fact that hydroelectric resource in China occupies an extremely important position, due to the fact that China is one of the countries with the most abundant water resources in the world and ranks first in the world, representing almost 1/6 of the earth as shown in Fig. 2. Hydroelectric resources play a decisive role in China's economic growth as well as in other countries (Suttmeier, 2006). It was found that this country also topped the list with a number of articles referenced, followed by the United States who reported a total of 221 documents published, these were 440 times referenced. The high interest of the United States in research on this issue is because hydropower provides approximately 96% of renewable energy in this country (Naciones Unidas, 2014). Other countries that top the list in terms of a number of publications are Germany (8.77%), United Kingdom (4.65%) and Brazil (4.52%) as can be seen in Table 1.

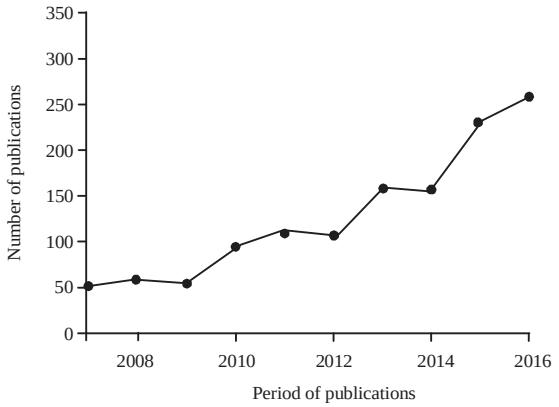

Fig. 1: Number of records per year

Distribution based on institution and appointment results: The distribution of institution-based research can help to understand the research capacity and activities of institutions around the world as well as help to identify institutions whose focus is on hydroelectric energy research. Chinese Academy of Science, noted for its excellent contributions in scientific research, tops the list with 43 publications, contributing 2.85% of the total articles. Wuhan University has obtained in the last ten almost 3,000 million RMB of funding from government and industrial sectors for research and development of high technology, this justifies its high activity in the publication of 39 documents and contributing 2.59% to the total of publications worldwide. The top 5 institutions highlighted for their hydroelectric energy research are Chinese institutions including the two mentioned above, Hohai University (2.32%), Dalian University Technology (2.26%) and Sichuan University (2.26%) are among them, shown in Table 2. When talking about research quality, the TLCS indicator is the most relevant one in this case. Not always the number of published documents is equal to the number of times that these are referenced, many times this value usually increases or decreases depending on the institution. An example of this is that Chinese academy of science is the instruction with the most documents published but Dalian university technology is the one that has the largest TLCS, 99 articles of 1504

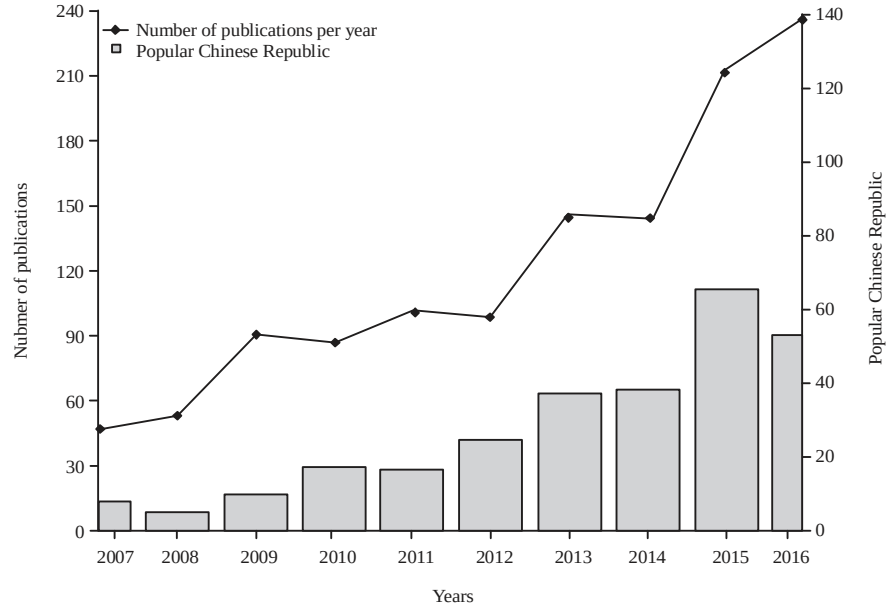

Fig. 2: Number of publications per year vs. publications per year of China

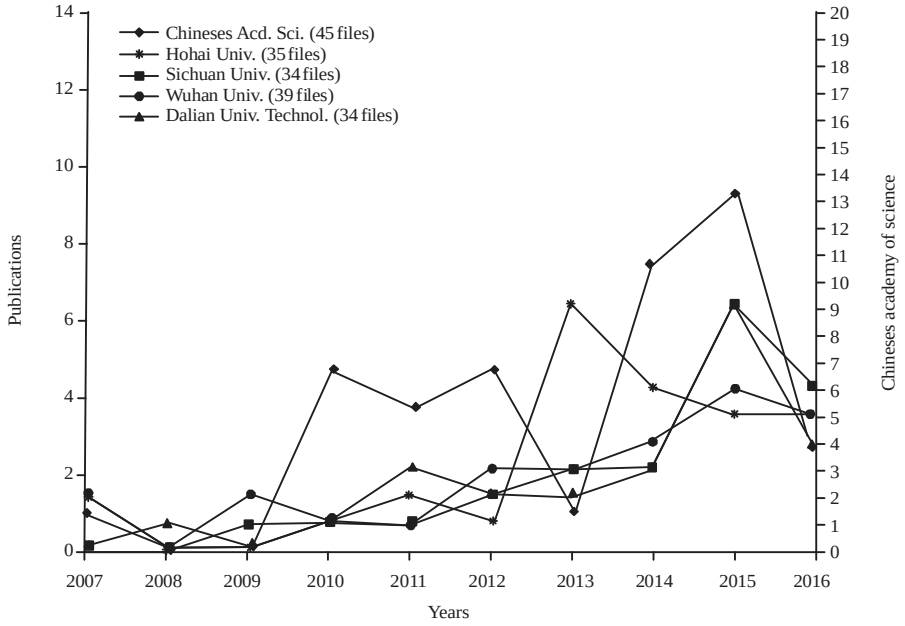

Fig. 3: Number of records of each institution per year

reference articles from this institution, on the other hand one must also take into account a TLCS/Records ratio, to identify which schools have a higher quotient, in this specific case Norwegian university of science and technology, this Norwegian institution has 24 publications with a TLCS (Total Local Citation) of 76 as shown in Fig. 3, this also represents the production of documents from the first 5 institutions per year.

Distribution of central journals and citations: A total of 441 journals were interested in publishing 1504 articles in the area of hydropower. All journals were sorted in descending order by their respective number of published articles. Next, the number of articles from the first analysis was summarized, a total of 30 journals were identified as basic journals for hydroelectric energy research. Initially, the ten journals with enormous

Table 2: Records of the first ten institutions according to archives, TLCS and TLCS/Archives

Institution	Archives	Institutions	TLCS	Institutions	TLCS/Archives
Chinese Acad. Sci.	43	Dalian Univ. Technol.	99	Norwegian Univ. Sci. and Technol.	3.17
Wuhan Univ.	39	Chinese Acad. Sci.	86	Univ Calif Davis	3.04
Hohai Univ.	35	Sakarya Univ.	86	Dalian Univ. Technol.	2.91
Dalian Univ. Technol.	34	Norwegian Univ. Sci. & Technol.	76	Beijing Normal Univ.	2.83
Sichuan Univ.	34	Univ Calif Davis	70	Chinese Acad. Sci.	2.0
Tsinghua Univ.	27	Beijing Normal Univ.	65	Huazhong Univ. Sci. and Technol.	1.73
Huazhong Univ. Sci. and Technol.	26	Natl Inst Technol	63	Tsinghua Univ.	1.56
Norwegian Univ. Sci. and Technol.	24	Wuhan Univ.	56	Wuhan Univ.	1.44
Beijing Normal Univ.	23	Indian Inst. Technol.	53	Hohai Univ.	0.83
Univ. calif davis	23	Karadeniz Tech. Univ.	52	Sichuan Univ.	0.59

Table 3: Top five high impact articles

Researchers	Title	Journals	Years	TLCS
Kibler KM, Tullos DD	Cumulative biophysical impact of small and large hydropower development in Nu River, China	Water resources research	2013	22
Yuksel I	As renewable energy hydropower for sustainable development in Turkey	Renewable and sustainable energy reviews	2010	19
Yuksel I	Hydropower in Turkey for a clean and sustainable energy future	Renewable and sustainable energy reviews	2008	15
Kaygusuz K	The role of hydropower for sustainable energy development	Energy sources part b-economics planning and policy	2009	7
Kumar D, Katoch SS	Sustainability suspense of small hydropower projects: A study from Western Himalayan region of India	Renewable energy	2015	6

research impact were analyzed. The journals with the highest performance were Wasserwirtschaft with 9.7%, renewable and sustainable energy reviews with 6.6%, water resources management 3.1% and representative percentage of total registration. It is not guaranteed that journals that publish more articles are those that have the highest values of TLCS, for example, renewable and sustainable. Energy reports a TLCS of 540 with a relatively fewer than 100 publications, ranks first in sometimes cited but second in a number of publications. A high TLCS means a more considerable influence on the development of hydroelectric energy research, most of these journals are primarily focused on this topic or related topics. It should be noted that the major Journals cited globally for this specific topic is renewable and sustainable energy reviews with a TGCS (Total Global Citation Score) indicator of 1382 and a TGCS/t 211.29 where the time unit in which this score is evaluated is the year. Therefore, it can be concluded that this is the most influential Journals in general when it comes to this type of research as shown in Fig. 4.

Analysis of high impact articles and researchers: The articles with the most significant research impact were selected using the indicator TLCS. It can be seen in Table 3. That the ten best articles were written by 12 researchers where the author Yusek I was highlighted by publishing three articles. The article, based on the cumulative biophysical impact of hydroelectric river development, obtained a TLCS of 22, the highest score in this last period. The article with the greatest impact by the researchers Yuksel I reported a local Total citation score of 19 having as a central theme the study of hydropower from renewable energy for sustainable development in Turkey. Hydroelectric energy research in Turkey for a clean and sustainable energy future reported a total citation score of 15. The closest and most impactful article to date was that of Kumar D, Katoch SS who studied the sustainability of small hydropower projects: a study of the western Himalayan region of India, publishing the article in 2015. The data of articles with the greatest impact are reported in the 2009-2015 period which indicates that in this period the acceptance on the part of the companies with the highest impact is the following was much greater. In 2016 and what has been published this year, no articles of great impact and influence have been found in this area. Among the outstanding authors in the areais Yuksel I with eight publications and TLCS of 86, Cheng CT with 18 publications and TLCS equal to 71, Chau Cw has three publications and a Score of 45 (Fig. 5).

Analysis of appointment display: The hits cite tool was used to generate a visualized chronological table of quotes on hydroelectric energy research work. Table 4 shows the first ten articles with the highest TLCS, classified by researchers, title and year of publication, each article

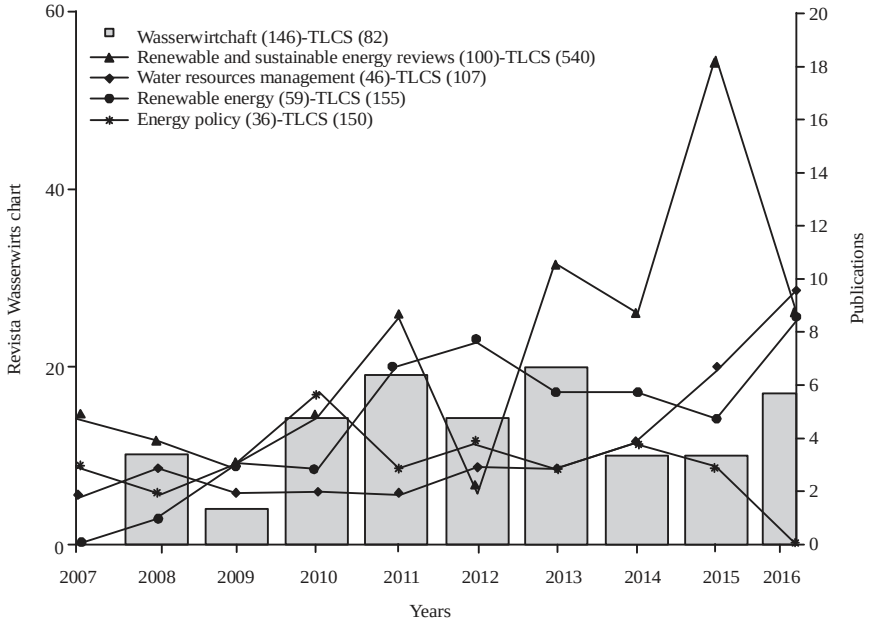

Fig. 4: Number of publications per year of the five leading journals

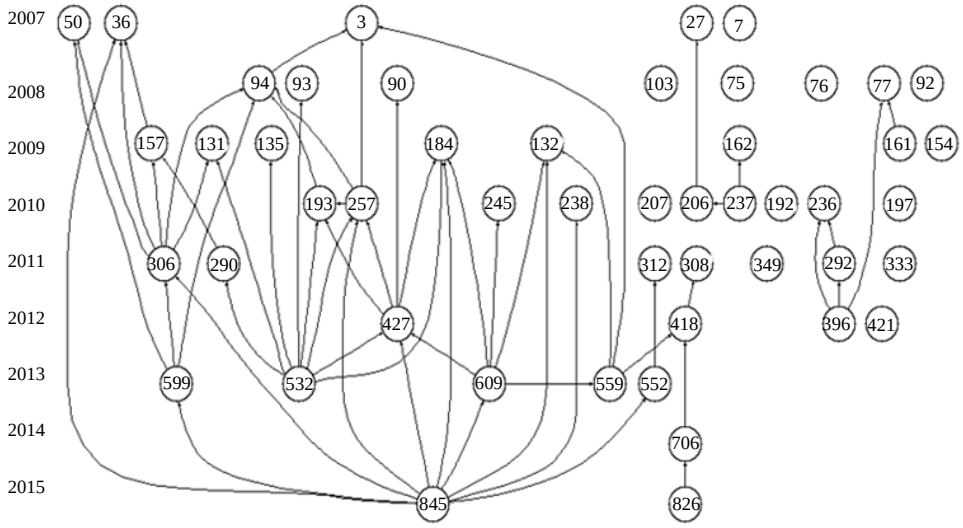

Fig. 5: Chronological citations chart

Table 4: Classification of the first ten articles with the highest TLCS

Numbers	Researchers, Title, Years	TLCS
245	Chang XL, Liuxh, Zhou W. hydropower in China at present and its further development energy. 2010	32
148	Huang HL, Yan Z. present situation and future prospect of hydropower in China, renewable and sustainabl e energy reviews. 2009	31
396	Hamudunub, killingtveit a. assessing climate change impacts on global hydropower energies. 2012	28
306	Dursun B, Gokcol C. the role of hydroelectric power and contribution of small hydropower plants for sustainable development in turkey, renewable energy. 2011	26
193	Yukseli. hydropower for sustainable water and energy development, renewable and sustainable energy reviews. 2010	25
236	Madani K, Lundjr. estimated impacts of climate warming on california's high-elevation hydropower, climatic change. 2010	24
418	Ziv g, Baran E, Nam S, rodriguez-iturbei, levinsa. trading-off fish biodiversity, food security and hydropower in the mekong river basin, proceedings of the national academy of sciences of the united states of America. 2012	24
192	Renofaltbm, Jansson R, Nilsson C. effects of hydropower generation and opportunities for environmental flow management in swedish riverine ecosystems, reshwater biology. 2010	22

Table 4: Continue

Numbers	Researchers, Title, Years	TLCS
559	Kibler KM, Tullos DD. cumulative biophysical impact of small and large hydropower development in nu river, China, water resources research. 2013	22
157	Kucukali S, Baris K. assessment of small hydropower (shp) development in turkey: laws, regulations and EU policy perspective	21

corresponds to a number in Fig. 5. There are 50 nodes, some related to each other, the maximum value of TLCS is held by node 245. The relative sizes of the nodes in the figure show the number of documents quoted while the arrows point to the papers quoted. Article 245 had a significant impact on hydroelectric energy research, published in Chinese and interested in the study of China's energy development and its current influence, this article was published in 2010. Other influential articles on this topic were also published by Chinese authors, such as 148 interested in studying the current and future situation of hydroelectric energy in China. Those articles with a high TLCS value were published from 2009-2013.

CONCLUSION

The results obtained in hydroelectric energy research show a significant growth trend over the period evaluated. This trend is motivated by the fact that this type of energy is renewable and clean, so, it does not contribute to the increase in environmental pollution, recalling that the issues tackling climate change have received more considerable attention during the last decade, mainly those world powers that stand out for their role in promoting policies that benefit the environment. A total of 93 countries showed their investigative capacity addressing the issue of hydropower 441 journals published papers, Wasserwirtschaft reported larger published papers while renewable and sustainable energy reviews stood out for presenting higher values in the TLCS and TGCS indicators. Some 1423 institutions were evaluated and once again Chinese institutions played an important role in contributing greatly to the study of hydropower but most of these documents were produced in English, the official language of research papers. In the analysis of authors as expected those with the greatest number of publications were Chinese authors, Cheng CT registered 18 publications but it was Yuksel I who with eight publications obtained the highest score of citations with a TLCS of 86. Hydroelectric energy is currently the world's largest renewable source of electricity generation and in 2010 it covered 16% of the world's electricity needs. It is expected that its contribution to total electricity generation will be around 15% by 2035 and it can, therefore, be concluded that the interest of many countries and young researchers as well as instructions and journals will continue to increase due to the importance of this subject and the indispensable use it has been given during the past decade.

ACKNOWLEDGEMENTS

This research was supported by the Mechanical Engineering Department of Universidad del Atlántico, with G. Valencia and Z. De La Peña supported by the Kai Research Group and A. Rodriguez supported by the IMTEF Research Group.

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