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Bibliometric review of Energy Storage System for Grid connected Wind Power Plant

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Bibliometric Review of Energy Storage Systems for Grid Connected Wind Power Plant

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ABSTRACT

The integration of RESs like wind energy pose several problems for aggregators and grid operators majorly because of their intermittent and unstable behavior. The instability and intermittency can be reduced through accuracy in forecasting and reliable and effective storage and utilization. The main objective of this bibliometric review is to understand the extent of the available literature for the area of Energy Storage Systems for renewable energy resource specifically grid connected wind power plants. The bibliometric analysis is primarily based on Scopus, Research Gate, Mendeley and tools like GPS visualizer. It is revealed from the bibliometric analysis that major publications are from conference, journals and articles from Indian publications, followed by Chinese and publications from the US. The time series dataset started in 1976 till date. The major contribution is by the subject areas of Energy and Engineering followed by Environmental Science, Computer Science and Mathematics.

Keywords: Energy Storage System (ESS), Renewable Energy Sources (RESs), Wing Energy, Stochastic Dynamic Programming (SDP), Flexible Loads (FL)

1. INTRODUCTION

In the recent years the electric power systems have been revolutionized by the increase of power generators fed by wind and sun. Wind energy is that form of energy which is derived from solar energy. Moreover, there are numerous benefits of using wind turbines like they do not contribute to global warming as they do not produce greenhouse gases, they can be installed on farms thereby empowering the rural economy. The turbines occupy just a small fraction of the land in the farms so farmers and ranchers are not disturbed while doing their work in the farms. Renewable energy sources RESs provide clean energy with zero emission costs which is a major advantage of RESs

over conventional energy generation sources. The integration of RESs like wind energy pose many problems to aggregators and grid operators mainly because of their unstable and intermittent behaviors. Renewable resources like wind energy are intermittent. The problems caused due to unstable and intermittent behavior of RESs can be eliminated by the use of accurate forecasting and effective storage. Integrating large scale renewable resources like wind energy due to intermittency poses new problems during the operation of the power systems. As quoted by (Abinet Tesfaye Eseye, Matti Lehtonen, Toni Tukia, Semen Uimonen and R. John Millar, 2019) numerous solutions to the problem of forecasting renewable energy generation as suggested by (A.T. Eseye, J. Zhang and D. Zheng, 2018) can be found in the literature like particle swarm optimization and support vector machines, neuro fuzzy logic system, hybrid of genetic algorithm, integration of particle swarm optimization and neural networks and several others.

Different solutions for the storage of renewable energy according to (A. T. Eseye, J. Zhang, D. Zheng, and D. Wei, 2016) can also be found in the literature like pumped storage hydro units, multiple energy storage units (A.T. Eseye, D. Zheng, H. Li and J. Zhang, 2017), compressed air energy storage to eliminate unstable nature of renewable energy generation. Mitigation of variability of wind energy generation can be achieved using ESS. Combination of Wind energy conversion systems (WECS) with energy storage devices as suggested by (Ming-Shun Lu, Chung-Liang Chang Wei-Jen Lee and Li Wang, 2009) has tremendously enhanced and increased the capabilities of catering to the increased demand and varying load demand thus resulting in economic gain. To achieve trade-off between operation cost and revenue growth strategy of operation of the ESS plays a vital role. Use of ESS enhances the reliability and provides transmission congestion relief. ESS are employed for the wind power plants to improve the profits by implementation of energy time shifting.

ESS are employed for time shifting wind energy to maximize the profit for overcoming the intermittencies and instabilities. A way of handling this uncertainty problem is suggested by (Zhen Shu & Panida Jirutitijaroen, 2014) to use stochastic dynamic programming (SDP) framework and the computational efficiency of SDP is improved by objective approximation method. The case study of Electric Reliability Council of Texas has proven that the profits from SDP based approximation method are significantly more than the profits obtained by employing the deterministic policy. SDP approach provides policies that are highly adaptive to intermittencies in wind and price thereby enabling the wind companies to manage optimally the generation using ESS. According to the case study of Electric Reliability Council of Texas (ERCOT) the amount of wind energy is higher at night and lower during the day and pricing scenario is exactly reverse. In these cases, the wind energy is stored during the periods when price is less and fed back to the grid during the period when the price is higher which has resulted in higher profits and elimination of transmission congestion.

According to (Abinet Tesfaye Eseye, Matti Lehtonen, Toni Tukia, Semen Uimonen, and R. John Millar, 2019) Demand response capable load (DRCL) or flexible load (FL) is used in smart grid. The consumption of FL can be managed to be delayed, advanced, increased or decreased to eliminate the problem of deterioration of performance in ESS. This can be done without sacrificing comfort or its important functionality. FLs are generally used depending on the needs of the customer and its use also depends on production capability.

2. PRELIMINARY DATA COLLECTION

Publication databases can be accessed using the library portals of the Universities or by individually registering on the websites. Several methods are available to retrieve data from the popular databases like Scopus, Clarivate, Science Direct, Mendeley, Research gate, Google Scholar etc. Scopus database accessed on 13th December has been considered in this paper as it is the largest among the peer reviewed databases. List of the keywords used is given in the following section.

2.1 Important keywords

The important keywords required to carry out the search were "Energy Storage Systems (ESS)" and "Grid Connected Wind Power Plant". The other keywords are enumerated in table 1.

Table 1: List of keywords

Keywords	Number of Publications
Wind Power	137
Electric Power Transmission Networks	76
Energy Storage	70
Wind Turbines	45
Electric Utilities	37
Solar Energy	35
Electric Energy Storage	34
Optimization	31
Renewable Energy Resources	30
Electric Power Generation	26
Digital Storage	24
Energy Storage Systems	24
Renewable Energy Source	24
Photovoltaic Cells	23
Renewable Energies	23
Costs	22
Micro Grid	22
Solar Power Generation	21
Electric Batteries	20
Renewable Energy	20

Source: http://www.scopus.com (accessed on 13th December 2019)

The search was further restricted to English publications only. There were 227 English publications. Table 2. shows the publications of different languages like the Chinese, German three undefined.

Table 2: Trends in publishing language

Publication Type	Publication Count
English	227
Chinese	6
German	1
Undefined	3
Total	237

Source: http://www.scopus.com (accessed on 13th December 2019)

Researchers have published 44.72% papers in conference proceedings, 44.30% papers in journals, 6.75% in book series, 2.53% in trade publications and 1.68% in books as in table 3.

Table 3: Publication type

Publication Type	Number of Publications	Percentage from 237
Conference Proceedings	106	44.72%
Journals	105	44.30%
Book Series	16	6.75%
Trade Publications	6	2.53%
Books	4	1.68%

Source: http://www.scopus.com (accessed on 13th December 2019)

2.2 Highlights of preliminary data

In this paper the preliminary investigation is done based on the keywords that extracted 237 publications from the Scopus database. Documents like conference proceedings, journal papers, book series, trade publications and books were retrieved from 1976 to 2019 for the research area of ESS for grid based wind power plant. The publication count per year is as shown in table 4. Analysis based on number of publications per year is shown in figure 1.

Table 4: Publication count per year

Year	Publication Count	Year	Publication Count
2019	24	2006	3
2018	31	2005	3
2017	27	2003	3
2016	23	2000	1
2015	17	1999	2
2014	22	1995	2
2013	26	1985	1
2012	14	1980	1
2011	14	1976	1
2010	6	**Total**	**237**
2009	4		
2008	6		

Source: http://www.scopus.com (accessed on 13th December 2019)

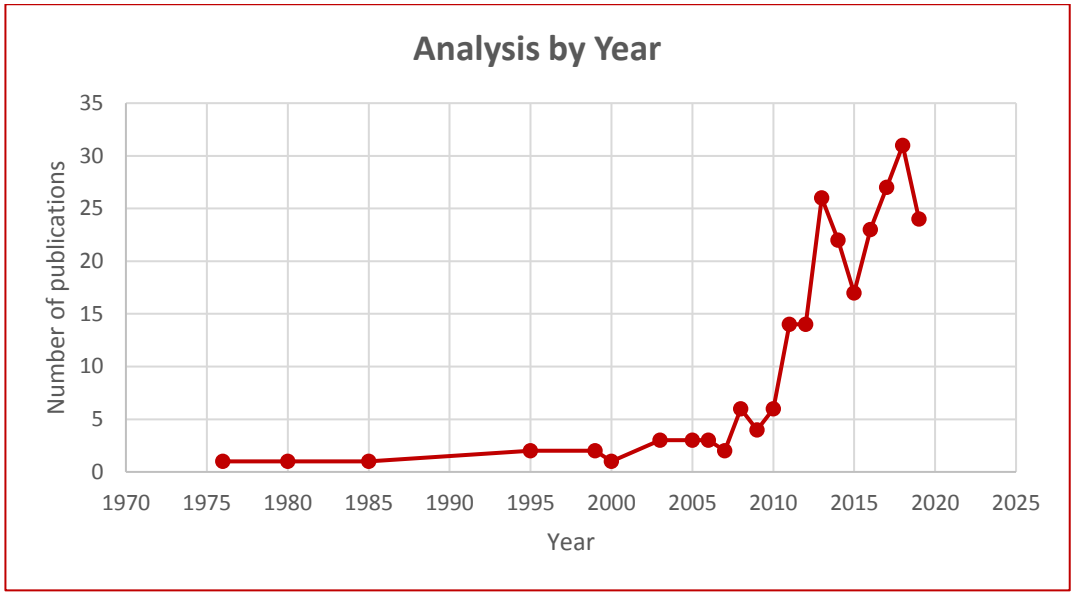

Figure 1: Yearly publishing trend

2.3 Data investigation

Through the conducted bibliometric review reveals about the type of literatures available in the next section which will highlight the distinctness of the available literature and using the geographical dispersion and the contributions by different authors, where the papers were published and the affiliation statistics.

3 BIBLIOMETRIC ANALYSIS

To perform the bibliometric analysis two ways were used

- Geographical region analysis

- Statistics of affiliations, subject area, author statistics, document type and citation analysis.

3.1 Geographical region analysis

The geographical regions of attentiveness of the published papers are shown in figure 2 which is drawn using GPS Visualizer tool from gpsvisualizer.com. Indian and Chinese publications are of the maximum number. Figure 3 shows the contribution in publications by different countries.

Figure 2: Geographic locations of the study of ESS for grid connected wind power plant

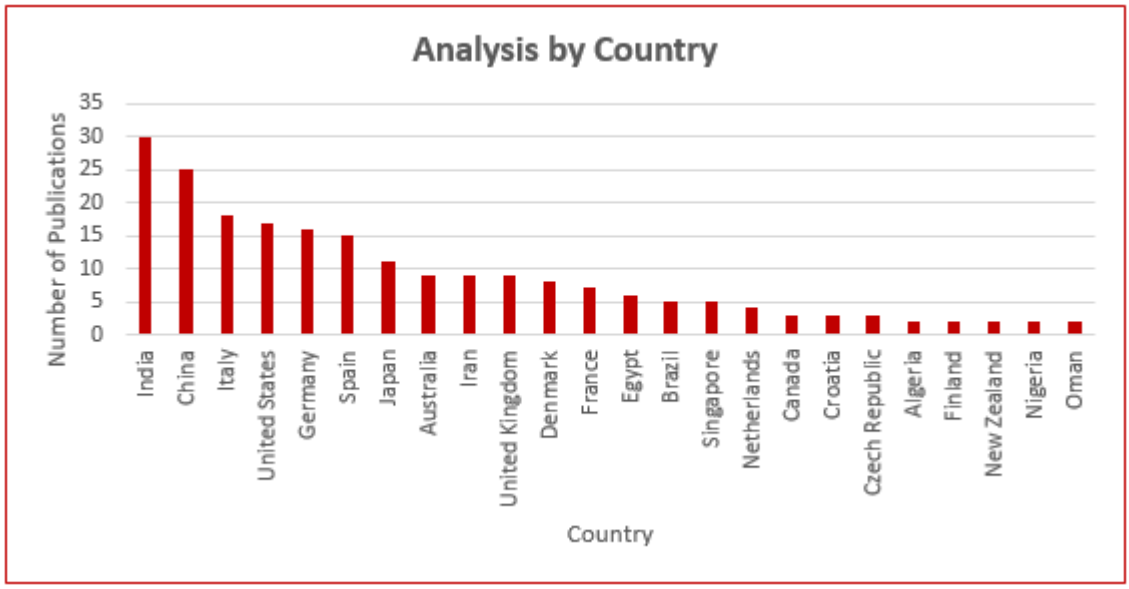

Figure 3: Analysis by country /Region

Source: http://www.scopus.com (accessed on 13th December 2019)

3.2 Analysis based on subject area

Categorization based on subject area is shown in figure 4. The analysis reveals that maximum number of research papers are published from the area of energy, Engineering followed by Environmental Science, Mathematics and Computer Science. The amount of research carried out in the areas of Decision Science and Economics and Finance is considerably less in the field of ESS.

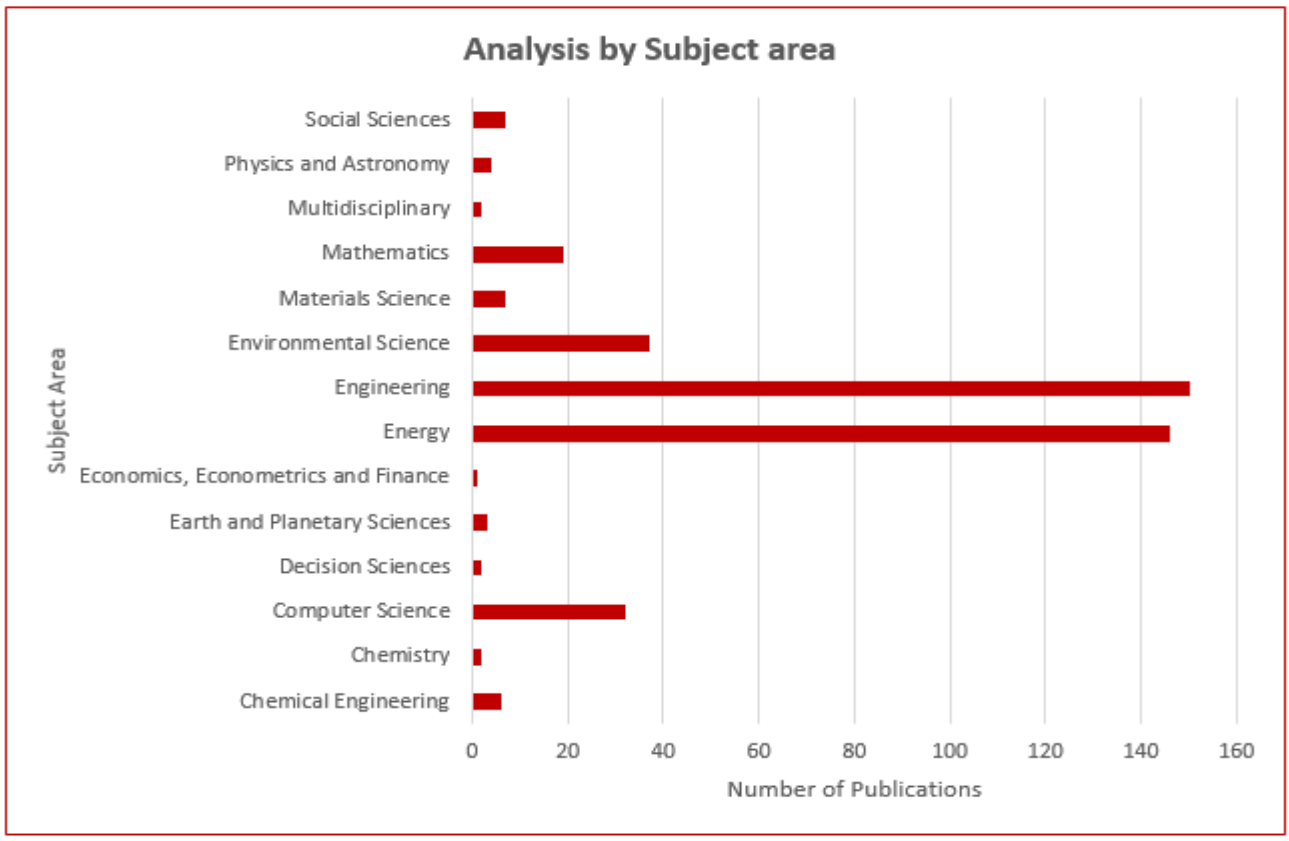

Figure 4: Analysis of papers published on ESS for grid connected wind power plant based on subject area

Source: http://www.scopus.com (accessed on 13th December 2019)

3.3 Analysis based on affiliation

Contributions by different Universities worldwide in publishing research papers in the field of ESS for grid based wind power plant is shown in figure 5. The research area of ESS for grid connected wind power plant is dominated by the Indian and Chinese Universities listed in figure 5. Top twenty Universities publishing in this field have been shown.

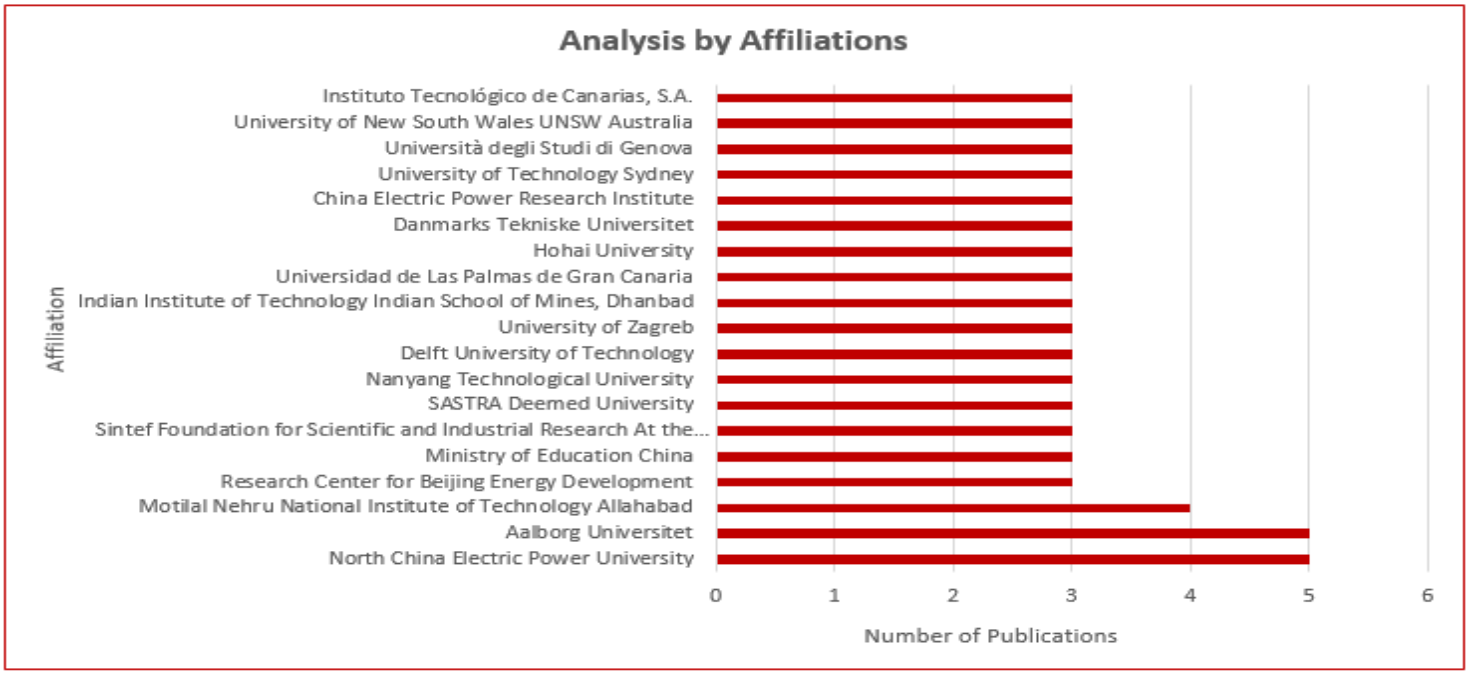

Figure 5: Analysis based on affiliations for publications contributing in the field of ESS for grid connected wind power plant

Source: http://www.scopus.com (accessed on 13th December 2019)

3.4 Analysis based on number of publications per author

Key authors contributing in the field of ESS for grid connected wind power plant are depicted in figure 6. First ten authors were considered from the available accessed data from the Scopus database.

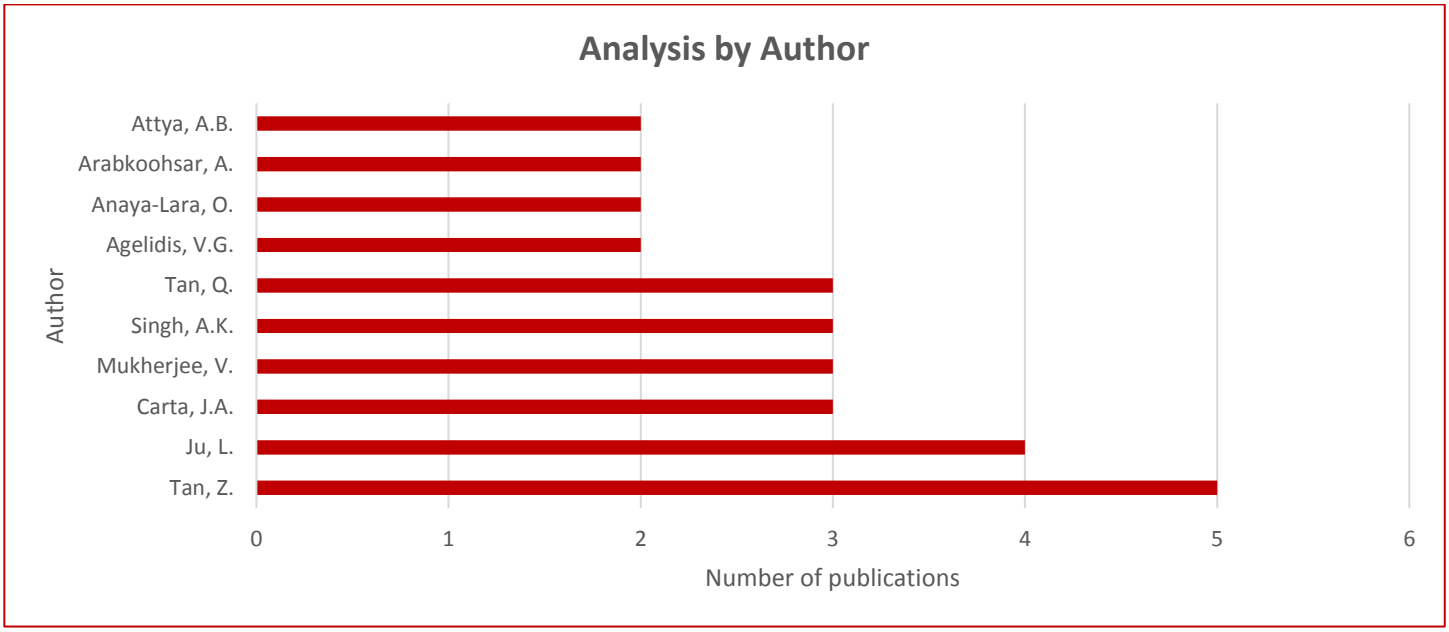

Figure:6 Key contributors in publishing

Source: http://www.scopus.com (accessed on 13th December 2019)

3.5 Journal Statistics

The publication source types are shown in figure 7. It is clear from figure 7 that 45% publications are conference proceedings, 44% publications are from journal, 7% from book series and 2% are books and trade publications.

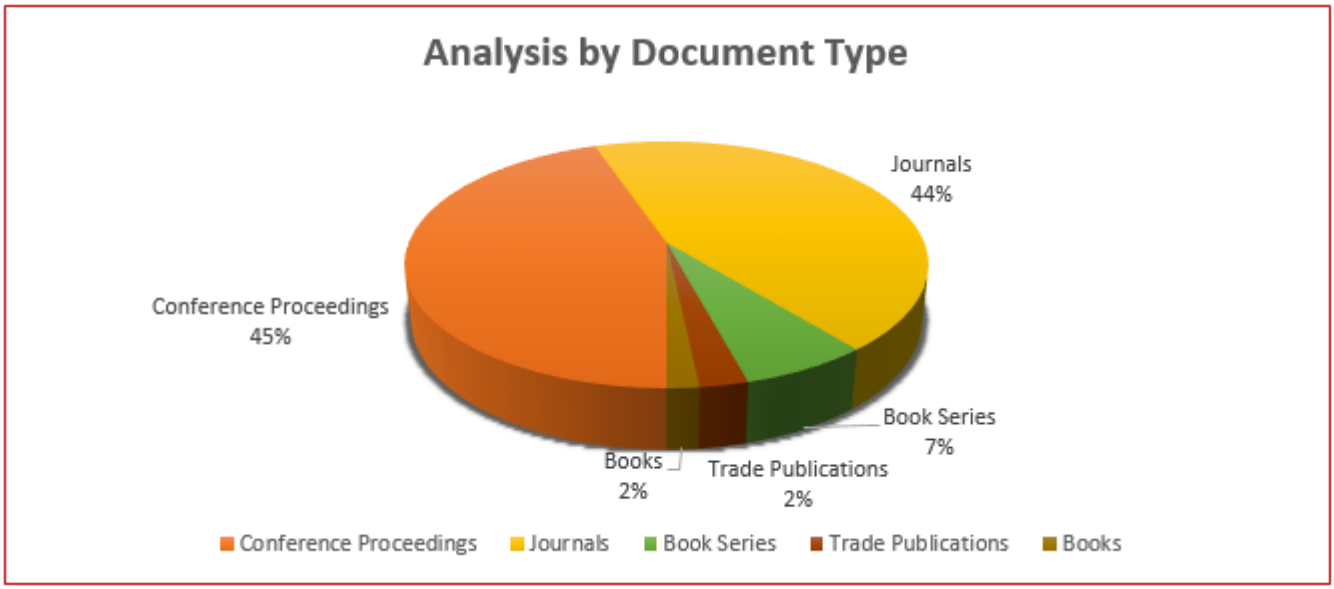

Figure 7: Analysis based on document type.

Source: http://www.scopus.com (accessed on 13th December 2019)

3.6 Network Analysis

The interrelation between the various statistical quantities is depicted using the network analysis that is carried out using the tool 'Gephi'. Gephi is basically an open source software that is used for clustering and manipulation of the available data. Keywords, source type, publication title, year of publication, affiliations, author are represented by nodes and edges. Different parametric combinations of data extracted from Scopus are used for creating the clusters shown in figures 8-10. Fruchterman Reingold layout was used along with manual adjustments for the layout while clustering. Figure 8 shows a network based on the affiliations, language and publication type. It has 184 nodes and 182 edges. Figure 9 shows a cluster of year and subject area. It has 59 nodes and 57 edges. Figure 10 shows a cluster of keyword and source title. It has 351nodes and 482 edges. The layout used for this cluster is Yifan Hu.

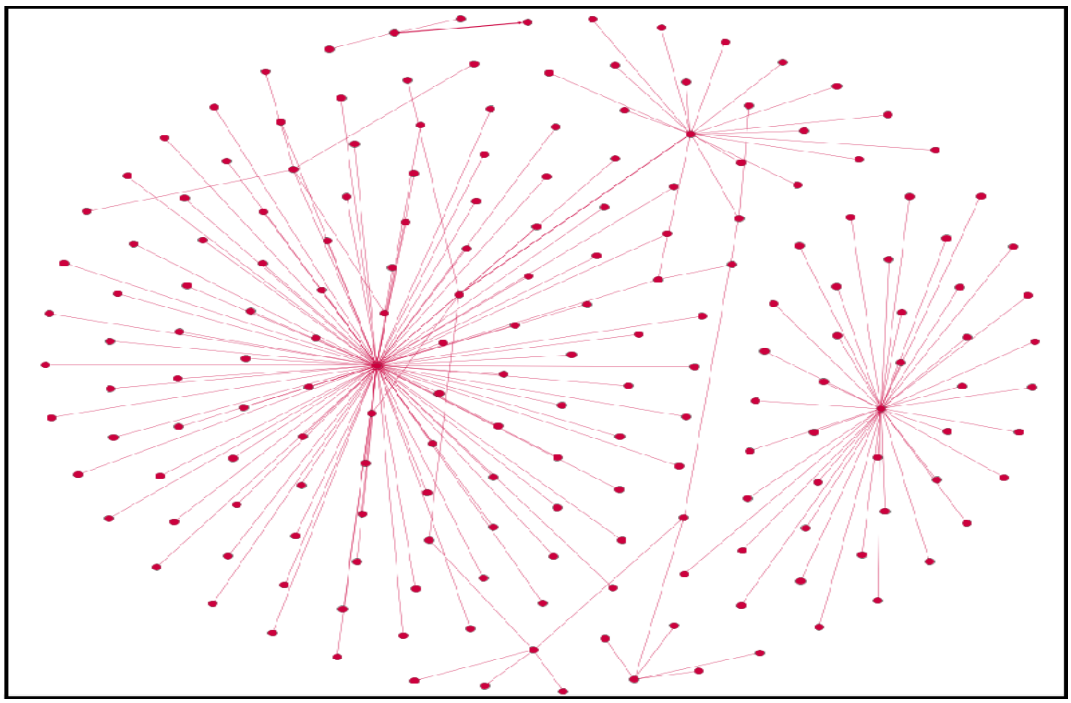

Figure: 8 Cluster of affiliations, language and publication type

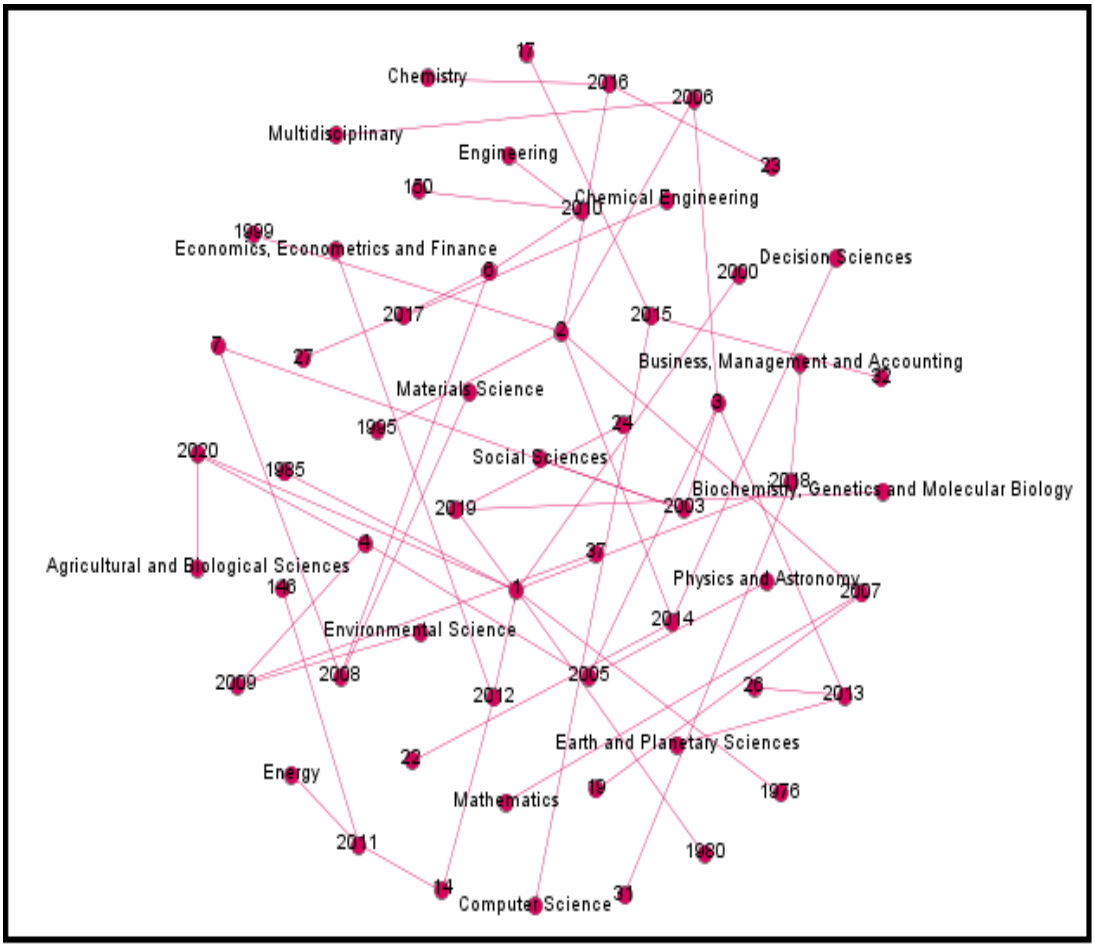

Figure:9 Cluster of Subject area and year

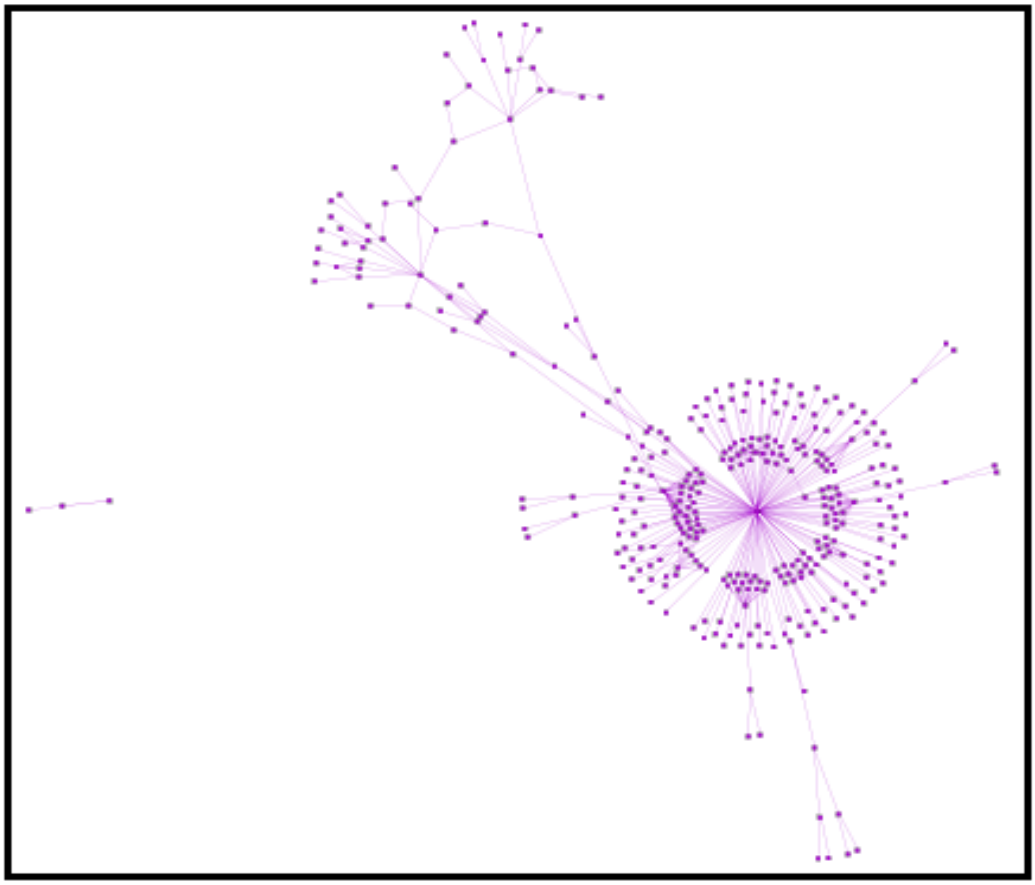

Figure:10 Cluster of keyword and source title

3.7 Citation Analysis

The citations obtained per author (first ten considered) in the area of ESS for grid connected power plant are given in table 5. Authors and their citations till date of the extracted data are shown.

Table 5: Citations per author with maximum citations in the area of ESS for grid based wind power plant

Author	<2015	2015	2016	2017	2018	2019	Total
Ju L., Tan Z., Yuan J., Tan Q., Li H., Dong F.	0	0	5	19	29	37	90
Hasanien H.M.	0	6	9	9	13	20	57
Bortolini M., Gamberi M., Graziani A.	1	18	25	31	36	25	136
Grillo S., Marinelli M., Massucco S., Silvestro F.	30	12	18	16	17	10	103
Niknam T., Golestaneh F., Malekpour A.	38	20	24	16	20	27	145
Yao D.L., Choi S.S., Tseng K.J., Lie T.T.	27	18	16	16	11	6	94
Iwanski G., Koczara W.	91	11	15	11	10	6	144
Korpas M., Greiner C.J.	44	6	11	3	3	3	70
Bueno C., Carta J.A.	122	22	31	26	27	17	245
Meurer C., Barthels H., Brocke W.A., Emonts B., Groehn H.G.	45	2	2	3	2	6	60

Source: http://www.scopus.com (accessed on 13th December 2019)

3.8 Statistics by document source

Figure 11 shows the statistics for publications in ESS for grid connected power plant. From the available extracted data, it is apparent that maximum number of publications are from the applied energy journal.

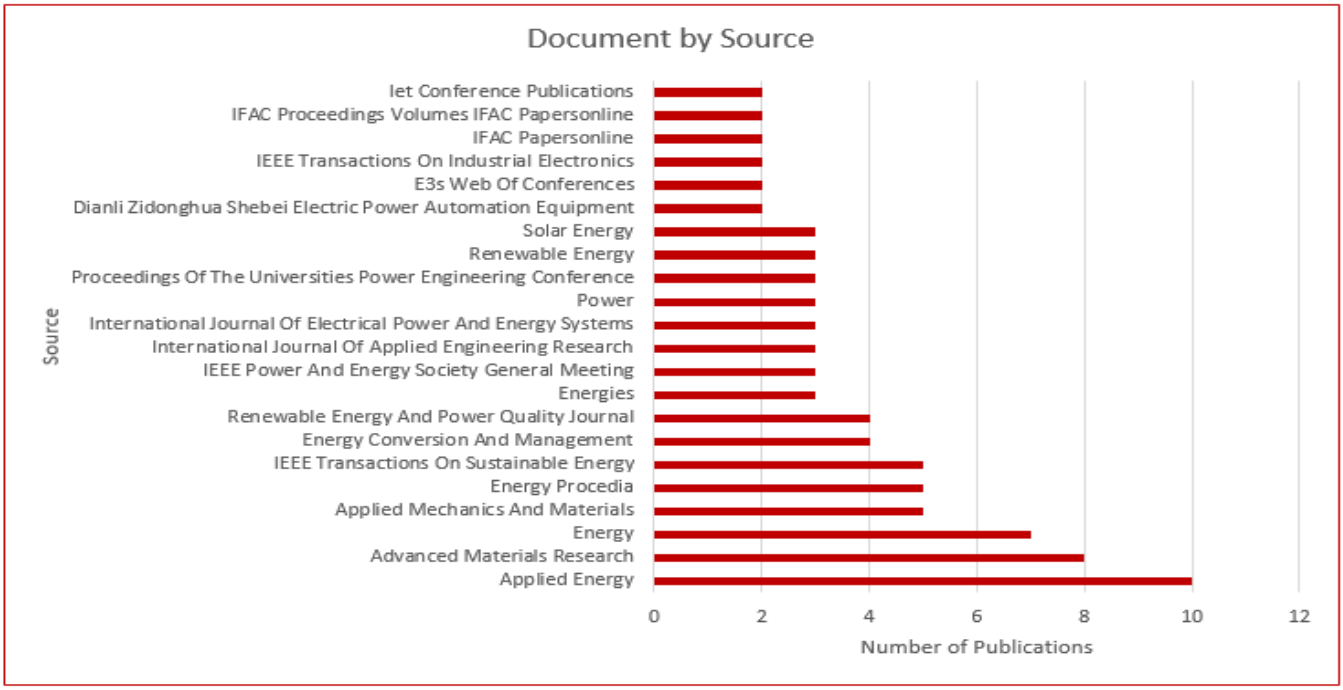

Figure 11. Statistics by document source

Source: http://www.scopus.com (accessed on 13th December 2019)

4. LIMITATIONS OF THIS STUDY

Different combinations of keywords were used to explore the Scopus database for the purpose of bibliometric review. A few important journals and articles which were not available in Scopus database could not be incorporated in this study.

5. CONCLUSIONS

The bibliometric review of energy storage systems for grid based wind power plant is purely based on the data extracted from Scopus. The review highlights that maximum contribution in this area in terms of research publications is from the areas of Energy and Engineering followed by Environmental Science, Computer Science and Mathematics. It is revealed from this bibliometric analysis that major publications are from conference, journals and articles from Indian publications, followed by Chinese and publications from the US. The instability and intermittency of renewable energy sources like wind energy can be eliminated by the use of reliable and effective energy storage systems. Use of ESS enhances the reliability and are employed for the wind power plants to implement energy time shifting that provides higher profits thereby making wind integration attractive. Based on the bibliometric review done in this study researchers in countries like India and China who are the key research contributors in this area of research can help in the enhancement of the utility and generation of the valuable renewable energy.

REFERENCES

Oudalov, A., Chartouni, D., & Ohler, C. (2007). Optimizing a battery energy storage system for primary frequency control. *IEEE Transactions on Power Systems*, *22*(3), 1259-1266.

Grillo, S., Marinelli, M., Massucco, S., & Silvestro, F. (2012). Optimal management strategy of a battery-based storage system to improve renewable energy integration in distribution networks. *IEEE Transactions on Smart Grid*, *3*(2), 950-958.

Ahmed, H., & Bhattacharya, A. (2018). PMSG-based VS-WECS for constant active power delivery to standalone load using direct matrix converter-based SST with BESS. *IET Generation, Transmission & Distribution*, *13*(10), 1757-1767.

Arduini, F. R., Martins, D. D. B., Júnior, B. R., & Asada, E. N. (2019, September). BESS Support to DFIG-based Wind Turbines connected to medium-voltage distribution networks. *IEEE PES Innovative Smart Grid Technologies Conference-Latin America (ISGT Latin America)* (pp. 1-6). IEEE.

Eseye, A. T., Lehtonen, M., Tukia, T., Uimonen, S., & Millar, R. J. (2019). Optimal energy trading for renewable energy integrated building microgrids containing electric vehicles and energy storage batteries. *IEEE Access*, *7*, 106092-106101.

Shu, Z., & Jirutitijaroen, P. (2013). Optimal operation strategy of energy storage system for grid-connected wind power plants. *IEEE Transactions on Sustainable Energy*, *5*(1), 190-199.

Stuyts, J., Horn, G., Vandermeulen, W., Driesen, J., & Diehl, M. (2014). Effect of the electrical energy conversion on optimal cycles for pumping airborne wind energy. *IEEE Transactions on Sustainable Energy*, *6*(1), 2-10.

Chen, Z., Yin, M., Zou, Y., Meng, K., & Dong, Z. (2016). Maximum wind energy extraction for variable speed wind turbines with slow dynamic behavior. *IEEE Transactions on Power Systems*, *32*(4), 3321-3322.

Nguyen-Hong, N., Nguyen-Duc, H., & Nakanishi, Y. (2018). Optimal sizing of energy storage devices in isolated wind-diesel systems considering load growth uncertainty. *IEEE Transactions on Industry Applications*, *54*(3), 1983-1991.

Watson, D., Hastie, C., & Rodgers, M. (2017). Comparing different regulation offerings from a battery in a wind R&D park. *IEEE Transactions on Power Systems*, *33*(3), 2331-2338.

Arraño-Vargas, F., & Konstantinou, G. (2019, June). Real-Time Models of Advanced Energy Conversion Systems for Large-Scale Integration Studies. *IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG)* (pp. 756-761). IEEE.

Babarit, A., Body, E., Gilloteaux, J. C., & Hétet, J. F. (2019, May). Energy and economic performance of the FARWIND energy system for sustainable fuel production from the far-offshore wind energy resource. *Fourteenth International Conference on Ecological Vehicles and Renewable Energies (EVER)* (pp. 1-10). IEEE.

Chaudhari, A., Joshi, R. R., Mulay, P., Kotecha, K., & Kulkarni, P. (2019). Bibliometric Survey on Incremental Clustering Algorithms. *Library Philosophy and Practice*, 1-23.

Oudalov, A., Chartouni, D., Ohler, C., & Linhofer, G. (2006, October). Value analysis of battery energy storage applications in power systems. *IEEE PES Power Systems Conference and Exposition* (pp. 2206-2211). IEEE.

Pasca, E., Petretto, G., Grillo, S., Marinelli, M., & Silvestro, F. (2009, September). Characterization of wind and solar generation and their influence on distribution network performances. *44th International Universities Power Engineering Conference (UPEC)* (pp. 1-6). IEEE.

Eseye, A. T., Zhang, J., Zheng, D., Li, H., & Jingfu, G. (2017, April). A double-stage hierarchical hybrid PSO-ANN model for short-term wind power prediction. *IEEE 2nd International Conference on Cloud Computing and Big Data Analysis (ICCCBDA)* (pp. 489-493). IEEE.

Eseye, A. T., Zhang, J., Zheng, D., Li, H., & Jingfu, G. (2017, April). Short-term wind power forecasting using a double-stage hierarchical hybrid GA-ANFIS approach. *IEEE 2nd international conference on cloud computing and*

big data analysis (ICCCBDA) (pp. 499-503). IEEE.

Eseye, A. T., Zheng, D., Zhang, J., & Wei, D. (2016, October). Optimal energy management strategy for an isolated industrial microgrid using a modified particle swarm optimization. *IEEE International Conference on Power and Renewable Energy (ICPRE)* (pp. 494-498). IEEE.

Garcia-Gonzalez, J., de la Muela, R. M. R., Santos, L. M., & Gonzalez, A. M. (2008). Stochastic joint optimization of wind generation and pumped-storage units in an electricity market. *IEEE Transactions on Power Systems*, *23*(2), 460-468.