

A Systematic Literature Review on Engineering Technology and Management Challenge of Micro Wind Turbine

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Abstract—The development of micro wind turbine is involving many aspect such as engineering technology and management aspect. Both of this approach is important while the priority would be different for each implementation. The study undertaken is to understand the issues during micro wind turbine implementation and found the priority that can be used as foundation for further research in the micro wind turbine area. Our literature review found that micro wind turbine is most effective to be implemented in rural/remote area. While the implementation for urban and domestic consumption face many challenge in social and management aspect. Furthermore it is found that the technology aspect is improving from the rotor, electrical control and battery in the last of seven years of micro wind turbine study.

I. INTRODUCTION

Micro wind energy, a type of wind energy that has the capacity below 10 KW is one of the solutions for energy crisis, an alternative generation of clean energy. This study focused on the research that has been undertaken in the area of micro wind energy, especially Micro Wind Turbine (MWT) for micro generation on rural and remote area.

It can be argued that many aspects might affect the development of wind energy from the management aspect such as economy, efficiency and environment. The technical aspect such as MWT rotor, battery, wind and thermodynamic aspect also plays important roles during MWT development.

The result of this study will help as foundation for further study in wind energy. Also to help prioritize which aspect of the wind energy that might be explored. The study also can be used as framework to develop further research question in the area of micro wind energy in rural and remote area.

II. METHODOLOGY

The methodology for literature review is by explore the 19 latest peer review journal related with MWT, and analyzing trend in latest 10 year. The journal sorted using

Scopus, according to most cited journal. The keyword that used in this methodology is “Micro Wind Turbine” [1-20].

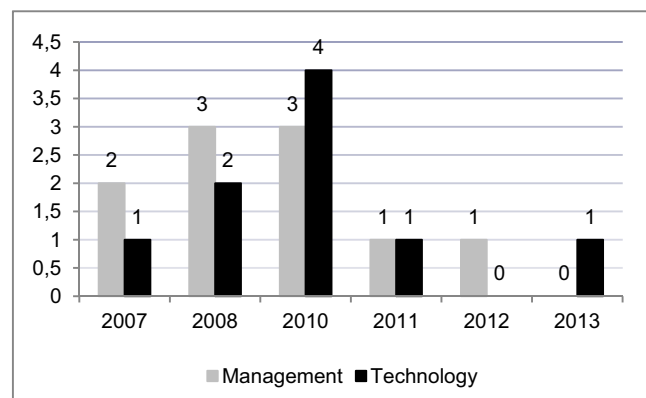


Fig.1. Number of Research in Management and Technology Aspect of MWT

The research in the area of micro wind energy in the urban and rural/remote area also considered to be reviewed as the similarity of the energy consumption. The development on latest technology in the wind energy included to find the effective strategy to develop the wind energy turbine.

A. Journal profile

The journal that being reviewed is from the Journal of Energy and Buildings, Energy Efficiency, Energy Policy, Renewable and Sustainable Energy Reviews, Applied Energy, Energy Policy, Energy, Journal of Power and Energy, Energy, Renewable Energy, IEEE Transactions on Power Systems, IEEE Transactions on Energy Conversion, Renewable Energy, with key point in the area as in the table. It can be seen from the list of journal above that the research for MWT is involving of both management and technical dimension.

The IEEE journal would be reference to technical aspect of MWT while the management aspect can be seen from the energy policy and efficiency related journal.

B. Research profile

The background of the researcher also plays an important role in the MWT research. As the wind energy researcher can be from electrical, mechanical, civil or architecture study. The background of researcher might drive the methodology and focus of the research. The variety of researcher background is gives an advantage as the MWT study is involving multi discipline field of study.

Challenge in this study is that each researcher study is specific in each location. UK researcher which tend to focus on implementation aspect, in general has the windiest area to be performed research.

The variety of researcher is important especially on regionalization. The results of MWT in one location might be different compare to conclusion in the different area.

C. Key question in MWT research

What the future of energy is a basic question that leads the research on the renewable energy (RE) to be used to replace the fossil fuel, which predicted will be run out. To overcome with the situation there are many possibility that the use of RE will plays a significant roles in the future. The question that might arise is how we can use the potential resources that available.

The question on RE research can be started from the location centric, such as urban electricity generation in urban location which technology most effective, whether using large scale wind turbine, or using small scale wind turbine. The location centric plays important role in early MWT research since the researcher tend to analysis the use of MWT in the urban area. The main assumption is whether the MWT can be implemented in urban area, the analyzing the factor that affecting the implementation process.

Another question can be on focusing on the technology it self such as, by using micro wind turbine, which location is the most effective to be implemented. By using the technology approach, researcher can focused on the component of MWT that provide the highest efficiency and optimization.

III. ANALYSIS OF MWT

A. History of MWT Research

History of MWT research is related with the history of renewable energy and especially the wind energy research itself. Traditionally the research of wind energy is developed a long time ago, with main topic can be from the large scale wind turbine or on the grid system of wind turbine. It can be argued that preliminary research on wind turbine is baseline for MWT development.

For the latest 10 year, the development of MWT is a attracting various researcher. The topic is ranging from different aspect such as management and technology. The power generation in the urban area is attracting that researcher is analyzing on how is the role of MWT in the urban area, and how can it be implemented effective.

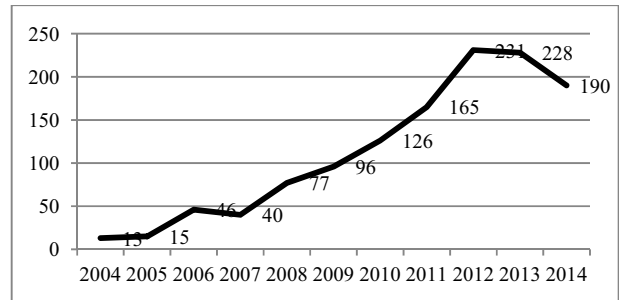


Fig.2. Number of MWT Research in latest 10 year

Refer to Fig.1 above, it can be seen that the development of MWT begin increasingly in the 2007 period where the growth rate increasingly

One of the preliminary research that cited the most on MWT in urban area is a study from Bahaj et al in 2007 that begin analyzing the electricity demand versus the ability of MWT to fulfill the demand [1]. This also followed in 2008 by Peacock et all mention on electricity demand and the performance of MWT [2]. This also increasing the trend of micro energy generation using MWT from the management aspect such as from the consumer approach which are consumer adoption [3] and consumer motivation [8].

On the other side, researcher also begins to focus on the technology aspect. How to produce more effective MWT is analyzed. It begins with area of wind such as distribution arrangement of MWT [7], wind aerodynamics [5], and roof mounting site analysis [6].

As the literature review taken, the topic of MWT is develop overtime. It is indicated that the effort of doing research on management and technology aspect is taken. Although it can be argue that the latest research is emphasis on the technology aspect instead of management aspect [4-7, 10, 11, 13, 17, 20]. One of the reason why this trend happened is because in 2007 the preliminary research on the energy management dimension mention that “is unlikely to be realized unless an adequate method is found for more accurately predicting energy yield” [2].

IV. MANAGEMENT ASPECT OF MWT

There are many aspects that impacting the successful implementation of wind energy, from management aspect to technology aspect. Management aspect can be from energy analysis, economy and ecology. While technology aspects can be from the performance, roof top design to thermodynamic aspects.

From the management aspect for example, literature review shown that the energy demand from the customer is the key factor that should be considered. As the use of the energy in the family or urban area is tend to minimal. The study also classifies the various electricity demands by occupancy such as couple with children or single person [1]. Also it can be indicated that the successful implementation of MWT can be seen in the rural area [15] compare to the urban area.

Sub Area	Paper
Supply and Demand of Production	2
Consumer Approach (Motivation & Adoption)	2
Energy Production	6

Fig. 3. Number of MWT management focus area

From the figure 3 above, it can be argued that the focus of the management study of MWT is vary from the supply and demand of production to consumer approach.

A. MWT will not be effectively implemented in urban and domestic area.

Some researcher tends to begin the research by emphasizing on electricity micro generation in urban area or in domestic sector. This research found that MWT will not be effectively implemented in urban area [1] [2]. Although it is believed that the MWT may have potential to make significant impact, if it's located on the suitable location [1]. The aspect that might support this conclusion is based on analysis of domestic electricity demand, turbine performance, financial and carbon savings analysis and matching the generation with demand [1].

B. MWT will have challenge in economic, social and lifecycle

Another management aspect that might affect the MWT implementation is from Economic, Social, Adoption and Lifecycle. More detail on economic challenge might comes capital cost and inadequate fuel savings and payback [3], where the social challenge in the aspect of social risk, issues on safety and noise within neighborhood [8].

The economic and social area is the most challenging area that the researcher found that variety results come from this area. There are a lot of dependency such as the location that being research and the type of technology that used to analyzed.

One of the research that indicating this condition is on 2006 which by performing 400 online questionnaire that indicating the priority should not on the renewable energy only, but the priority should be on energy efficiency [3].

Lifecycle implementation challenge also important issues during the MWT implementation, life cycle system performances also very sensitive to climatic and geographic

conditions [14]. It also can be argued that during the lifecycle process which are:

- Production,
- Distribution & Installation,
- Operation,
- End of Life.

The lifecycle approach used to evaluate potential environmental impacts of a MWT from the production to end of life stage [14].

To sum up, the recent research in 2010 also in align that the MWT implementation is complex and the comparison between RE is poorly understood [16].

C. MWT is effective used for micro generation in rural and remote area

Although most of the research tend to perform the research within urban area, which the main priority is to reduced the fossil fuel usage. There are some research indicated that the MWT is effective to be used for micro generation in rural and remote area [15] [18] [19]. It is also known that remote rural communities are especially vulnerable to the reliability of conventional electricity supply methods [15]

Although the prospect of MWT in the rural area is promising, the other location specific aspect need to be undertaken carefully. For example, The study of MWT that using case study in Mongolia, Peru and Nicaragua for example mention that the locations of MWT must be carefully chosen with among others, the following place-specific factors [18]:

- Viability of other power generation technologies,
- Wind resource,
- External environment,
- Needs of the community,
- Ability to pay for energy services.

V. TECHNOLOGY ASPECT OF MWT

There are three aspect of technical MWT research that found during literature review, which are the development of battery, electrical control, rotor and the wind flow. Based on literature review each of the researchers has their own method for each topic.

The wind flow analysis for example, the method that used is using computational model [5] [6], which can be using mathematical model or to setup an experiment for the model using wind tunnel model. The research focusing on the wind flow analysis, try to have better performance for the MWT.

For example, the study indicating on how the wind flow characteristics are strongly dependent on the profile of the roofs [6]. It also mentioned that "It is found that turbines

mounted on flat roofs are likely to yield higher and more consistent power for the same turbine hub elevation than the other roof profiles” [6]. This study will help to improve the performance of MWT by enhancing the roof top design.

It is suggested that researcher study into the complex flow field developing around a Savonius wind rotor and to evaluate its performance [5]. Also it is mentioned that a mathematical model of the interaction between the flow field and the rotor blades was developed and validated. This technical approach would be a foundation of MWT wind flow analysis [5].

The electrical control can be from many point of view such as generator reliability [17], develop power saving architecture [4] or develop stability enhancement for MWT [13]. The enhancement of electrical control can be useful in the future development of MWT, as it will be independent from location or the wind flow. Another important electrical aspect of MWT is development of battery. The research try to find the optimum size batteries that can be used [10].

In the electrical control research the efficiency is the main priority to be achieved. It can be seen from the study that the maximum efficiency over a wide range of operating conditions is expected [4]. The electrical control study is important since MWT may operate in various condition

The design of rotor for MWT, also researched in area of developing method to control the power curve [11] and also to develop a Horizontal Axis Wind Turbine (HAWT) which performed analysis to indicate which model that most effective to be used for MWT [20].

VI. LIMITATION AND FUTURE WORK

The literature study undertaken is tries to cover both of technology and management challenge of MWT. However the review has a limitation, such as on:

- Energy mix and the combination with non-renewable energy.
- Comparison of MWT with other renewable micro generation technology such as Solar PV or Solar Heater.
- Environmental impact.

The energy mix and the environment impact of MWT.

The energy mix should play an important role by combining MWT together with another form of RE such as Solar PV or Biomass and Non RE such as Gas or Coal.

As per figure above, it can be seen that the hybrid approach by combining the other source of renewable micro generation is important to maintain the balance of energy mic.

Analyzing on the environmental impact of the MWT also is not explored detail in the MWT research. Another

area that is not covered in the study is the use bigger scale of MWT such as medium or larger scale of wind turbine.

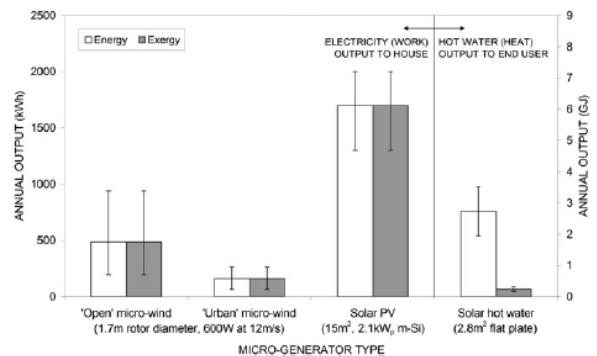


Fig. 4. Estimated micro-generator annual output (source [19])

For the future work that required is on the analysis of the study in the combination of MWT with other micro generation energy. The need to cover other aspect such as environment also should be covered in the future research.

VII. CONCLUSION

From the literature review, it can be summarized in regard to the recent development in electricity micro generation using MWT as below:

- 1) Current MWT is not effectively to be used for electricity micro generation in urban area
- 2) The difficulty of MWT adoption can be caused by economic, social and lifecycle
- 3) MWT is effective used for micro generation in rural and remote area
- 4) Future enhancement of MWT can be from many aspects such as rotor design, electrical control, placement who can improve the MWT performance.

Also, it can be suggested that further classification and taxonomy on renewable energy especially on MWT is established. So the researcher can be easy to understand what interrelated and interdependent topic that might give advantage during the research.

As the development of MWT would be very sensitive with the location, the importance of having specific and measured location is a key in the MWT research. The management and technology factor will be depending on the location that chosen.

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