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Design and Development of Airfoil for Small Capacity Wind Turbine: A Review

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Abstract— Renewable energy sources wind, solar is fast growing potential power across the world. Energy consumption and need is increasing day by day. Dependency on fossil fuel is not trail solution. Wind energy is one of the easy available renewable sources. Utilization of this energy into power generation will become good solution in futuristic energy crisis. We have named this as our final time design so as to begin allowing towards power generation through clean sources similar as wind. Power generation in our country is veritably low at present. In metropolises like Mumbai-India region are suffering from power cuts. The design of Wind Turbine blades, QBlade, solid work is used. It includes specific post processing and life assessment of blade. We take an occasion to present this report on design of airfoil and put before outline some useful information regarding this design. This work of art is motivated by the significant part of blades in the performance of wind turbine. This review helps researchers those who are working in the domain of micro-small capacity wind turbine.
Keywords— Wind Turbine, Aerodynamics, Blade design, Airfoil, Micro-Small Capacity, QBlade

I. INTRODUCTION

Energy need and its utilization is key aspect for civilization. Statistical Review of World Energy report states that nearly eighty four percent of world's energy comes from fossil fuel [1]. Increase in the emissions of CO_2 from the conventional energy sources causes more pollution as well as this all sources is non-renewable to overcome this demand of alternate energy source i.e. Renewable (Wind, Solar) needed. Wind Energy is one of the most cleanest and free source of energy. It is abundance in nature, so the generation of electrical energy with the help of generator is easily possible. Kinetic energy of wind is used to convert electrical by means of electrical generator. Fig. 1 Shows Wind energy installed capacity is expanded in each year since from 2001-2019. In year 2019 wind energy installed capacity expanded by 19% with newly added capacity of around 60 GW [2]. PR Chaina has 188,392 MW installed capacity of wind energy shares 35% of total wind energy generation by world followed by USA, Germany, India which generated 89,077 MW, 56,135 MW, 32,848 respectively as shown in the Fig. 2 [3].

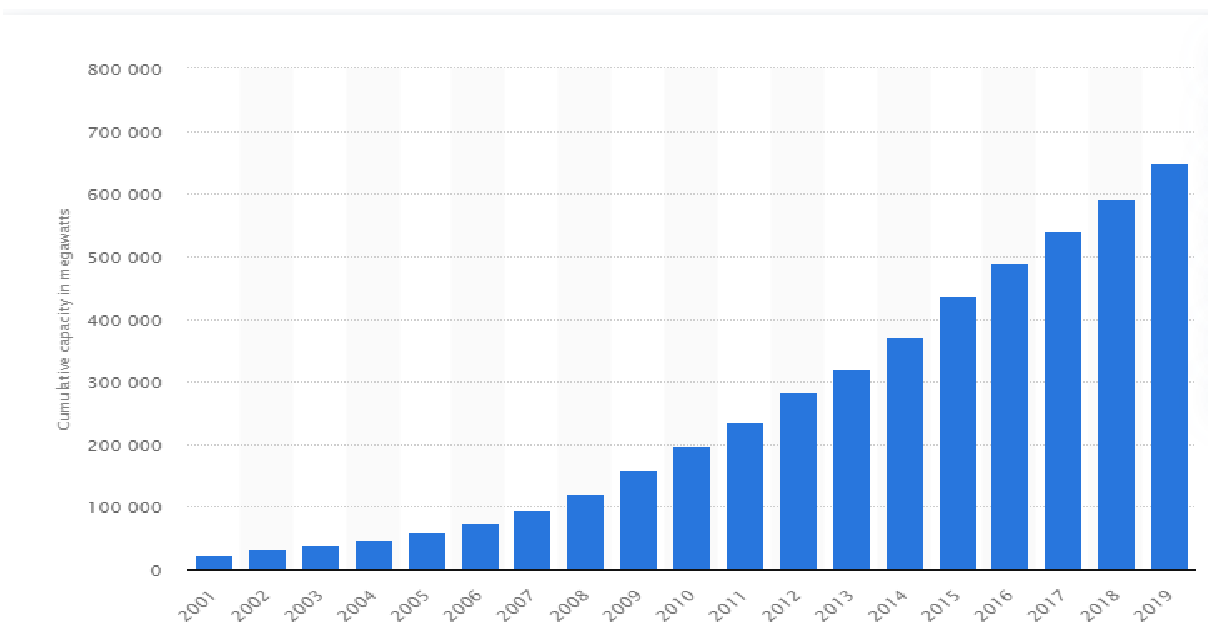

Fig. 1 Global cumulative wind power installed capacity, 2001-2019 [2].

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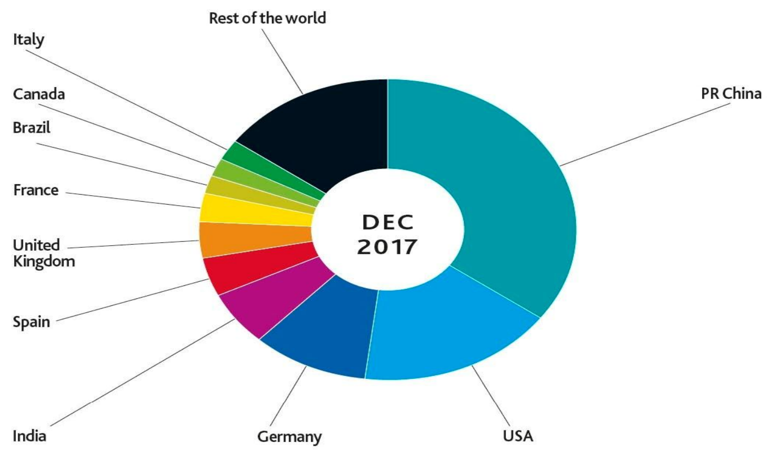
TOP 10 CUMULATIVE CAPACITY DEC 2017



Country	MW	% Share
PR China	188,392	35
USA	89,077	17
Germany	56,132	10
India	32,848	6
Spain	23,170	4
United Kingdom	18,872	4
France	13,759	3
Brazil	12,763	2
Canada	12,239	2
Italy	9,479	2
Rest of the world	82,391	15
Total TO P10	**456,732**	**85**
World Total	**539,123**	**100**

Source: GWEC

Fig. 2 Top cumulative capacity in dec-2017 [3]

Wind turbines classification done on the basis of, numbers of blades, axis of rotation power capacity, concept of tower, direction of operation, different gearbox mechanism. Horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT) are commonly known classification based on lift and drag phenomenon respectively. (Johari MK, et al., 2018) proposed that, HAWT is most popular and efficient than VAWT [4]. (Surve M.L., et al., 2021) performed computational studies of micro-capacity wind turbine. Novelty of their work represents simulation of newly design airfoil for micro-capacity wind turbine [5].

II. MICRO CAPACITY WIND TURBINE

Design small capacity wind turbine, selection of air foil task and optimum design of turbine is obligatory (Manwell J.F et.al. 2002) [6]. Development of Roof mounted turbines of capacity from 400 Watt to 2.5 kW considered under micro-small capacity types for domestic application [7]. (Rodrigues et al., 2016) described piece of advice for development of micro-small capacity wind turbine using scrap material [8]. Micro-small capacity wind turbines are located in built-up area where wind velocity is very extent. To gain good start up for wind turbines at extent wind speed conditions, design of airfoil must be done at low Reynolds number [9]. (Surve M.L., 2017) performed extensive literature review on micro capacity horizontal axis wind turbines, author mentioned that design and construction requires less amount of funding. It can be used for domestic applications, such as charging of batteries, street lights. Large capacity wind turbines changes the global weather conditions and have calamitous effects on the atmosphere [10].

A. Simulation tools:(QBlade)

Design of wind turbine blade or turbine simulation it is important to use deliberate airfoil to extract more amount of energy from it. Design of new Airfoil QBlade is one of the powerful tools. It is free available software under the General Public License [5, 10, 11, and 12].

- It is made by TU Berlin
- Airfoil design and analysis
- Uses X-Foil tool to analysis airfoils.
- Uses the BEM theory for blade design and optimization

- Turbine definition and simulation
- Extrapolation of Lift and drag polar
- QBLADE working model includes:

It is easy to simulate various important parameters with the help of QBlade tool. One can check maximum power coefficient (Cp)max for new design airfoil. Optimization of turbine can be easily done with the help of QBlade tool. weibull distribution is entered in the software helps to determine annual energy production in (GWh). The main accomplish is to discover pressure and velocity variation and boundary layers formation across various angle of attack (AOA) range. CFD tool it is easy to detect CL/CD ratio for various ranges of AOA. Spalart-Allmaras (one equation) model is second-hand for CFD analysis of blade and airfoil. Simulation tool provides us outputs and these parameters plays essential in manufacturing blade or optimal power extraction from it [5].

B. Design of Airfoil

Fig. 3 Flow Chart for New Design Airfoil

Fig. 3 Represents stages of design of airfoil in QBlade software, Selection of suitable airfoil depends on comparison of all airfoils results. One can easily check turbine simulation and optimum power coefficient Cp(max). QBlade tool becomes easy to operate and accessible for new users. Design of HAWT & VAWT can be done by using QBlade tool.

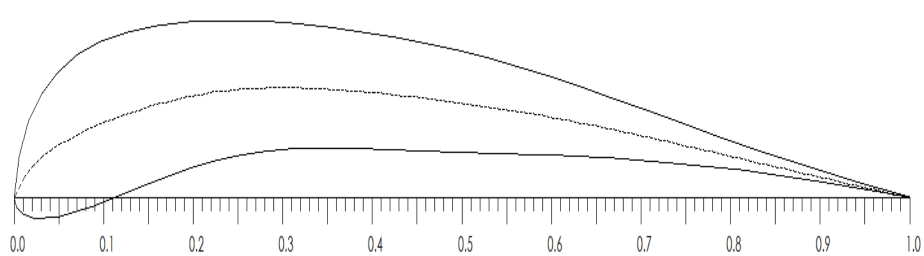


Fig. 4 New Design Airfoil INDTH8

Figure 4. Shows new design airfoil INDTH8 by using QBlade tool. Author has design and develops his own new airfoil. New design airfoil compare with previous NACA airfoils. It shows better result Max CL/CD ratio 89.86 for AOA 7. The designed airfoil is analyzed for various parameters like lift coefficient, drag coefficient, lift o drag ratio, thrust, and power coefficient. The simulation is carried out an average wind speed of 12 m/s here cut in and cut out wind speed for installation site was taken into account for simulation at Reynolds number Re = 500000. The angles of attack (AOA) range from 0◦ to 15◦, for different tip speed ratios (TSR). Here, tip speed ratio refers to the ratio of linear velocity of tip of the blade to average wind velocity [5]. Mass density 1.225 kg/m3 and kinematic viscosity 1.647 X 10-5 m2/s of air are considered for simulation at an ambient temperature of 300 K and pressure of 1 atmosphere.

TABLE I
CHARACTERISTICS OF AIRFOIL

Sr. No	Airfoils	Thickness %	Max. Thick. pos%	Camber %	Max. Camber pos%
1	INDTH8	8.87	9.70	6.07	30.60

Table1 represents Characteristics of newly design Airfoil INDTH8. The new airfoil has maximum thickness of 8.87% of chord length at 9.70 % of the chord. And maximum thickness of camber is 6.07% of chord length at 30.60% of the chord.

TABLE II
DESIGN PARAMETER OF AIRFOIL

Sr. No	Airfoil	Optimum Angle of Attack	Max. CL/CD	Optimum CL
1	INDTH8	7	89.8678	1.29137

C. Materials and Manufacturing Methods

Wind turbine rotor blades made from different materials, wood, metals, composites, plastics [6]. (Kazumasa Ameku et.al, 2008) used Glass Fiber reinforced plastic sheet for design of a 3 kW wind turbine [13]. (Surve M.L., 2017) manufacttured 1 m length of blade by using composite fibre glass and epoxy resin maerial. Auhor furher mentioned that hand lay-up process required skill operators as preperation of pattern & mould making both are difficult job [14]. (Onder Ozgener et.al, 2006) used epoxy carbon fiber reinforced plastics for a small wind turbine system [15]. The small and medium blades are commonly made by manual process viz. hand or wet lay-up. In this process fibre in the form of fabric woven roving mat, is placed in the tool and impregnated with the resign by hand. The standard of the product depends on expertise of the workers [16].

D. Wind Tunnel & Field Testing

Wind tunnel is mainly used to measure ratio of Lift /Drag Force. Coefficient of lift and drag is calculated from obtained force components [17].

Lift Coefficient

$$C_L = \frac{2 \times F_L}{\rho \times A \times V^2}$$

Drag Coefficient-

$$C_D = \frac{2 \times F_D}{\rho \times A \times V^2}$$

Where,
FL/FD- Lift/Drag Forces (N)
A- Cross Section Area of Airfoil (m2)
V- Stream velocity (m/s)
ρ- Density of Air (kg/m3)

Fig. 5 Wind tunnel set-up (Test Section)

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Fig. 5 shows wind tunnel set-up available in New Horizon Institute of Technology, Thane Mumbai India in Civil Engineering Department.

Fig. 6 Airfoil AF2016 test model [17].

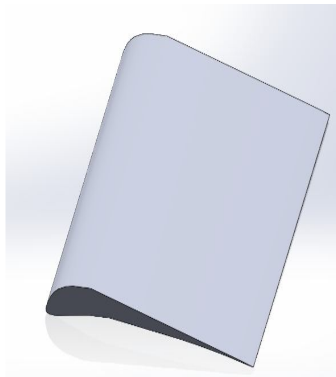

Fig. 8: Solid work design Model INDTH8

Fig 7 Test Section [17].

Fabricated rotor blade will be trial experimentally in a wind tunnel. Fig. 6 shows one element of rotor blade manufactured by using 3D printing technology by (Dhurpate P. & Sutar K.B., 2016) [17]. Test section of wind tunnel is too small so it is required to test only shorter span of blade (i.e. one element) instead of entire blade. Aerodynamic behaviour of airfoil or rotor blade tested under real conditions. 3D element of rotor blade mounted in test section shown in fig.7. Experiments on rotor blades are conducted to validate CFD results. Fig. 8 shows solid work design model by author for INDTH8 airfoil which is discussed in this literature. Sing and Ahmed [9] designed and tested a new air foil author found that the, performance of two bladed system at wind speed of range 3-6 m/s for a height of 8.22 m obtained power coefficient at wind velocity of 6 m/s was 0.29. (Kwansu, et al. 2014; 15) suggested that wind tunnel testing is worth to use among any testing methodology [18]. (Surve M.L., et al., 2021) found out there was discrepancy in 3D CFD results for wind turbine blade and experimental results for an airfoil, conducted in the wind tunnel test section [5].

E. Future Scope

To reinforce the above topic, wind tunnel as well as field testing of the wind turbine blades, designed using the new airfoil will be commanded.

III. CONCLUSION

Author proposed a path for new researchers in this field by doing not only extensive literature but also well contribution in QBlade design and simulation of new airfoil, turbine simulation, testing techniques, material and manufacturing methods, different simulation tools. Author mentioned that design and construction requires less amount of funding. It can be used for domestic applications, such as charging of batteries, street lights. How micro-capacity worthwhile for domestic need was revel by author impressively? Brief literature on current energy scenario in wind sector discussed very well by author with details of reference link. Expensive literature studies on Importance of QBlade tool and limitation or discrepancy found in 3D CFD results for wind turbine blade and experimental results for an airfoil, conducted in the wind tunnel test section will be helpful for future scope in topic of wind tunnel testing of the wind turbine blades.

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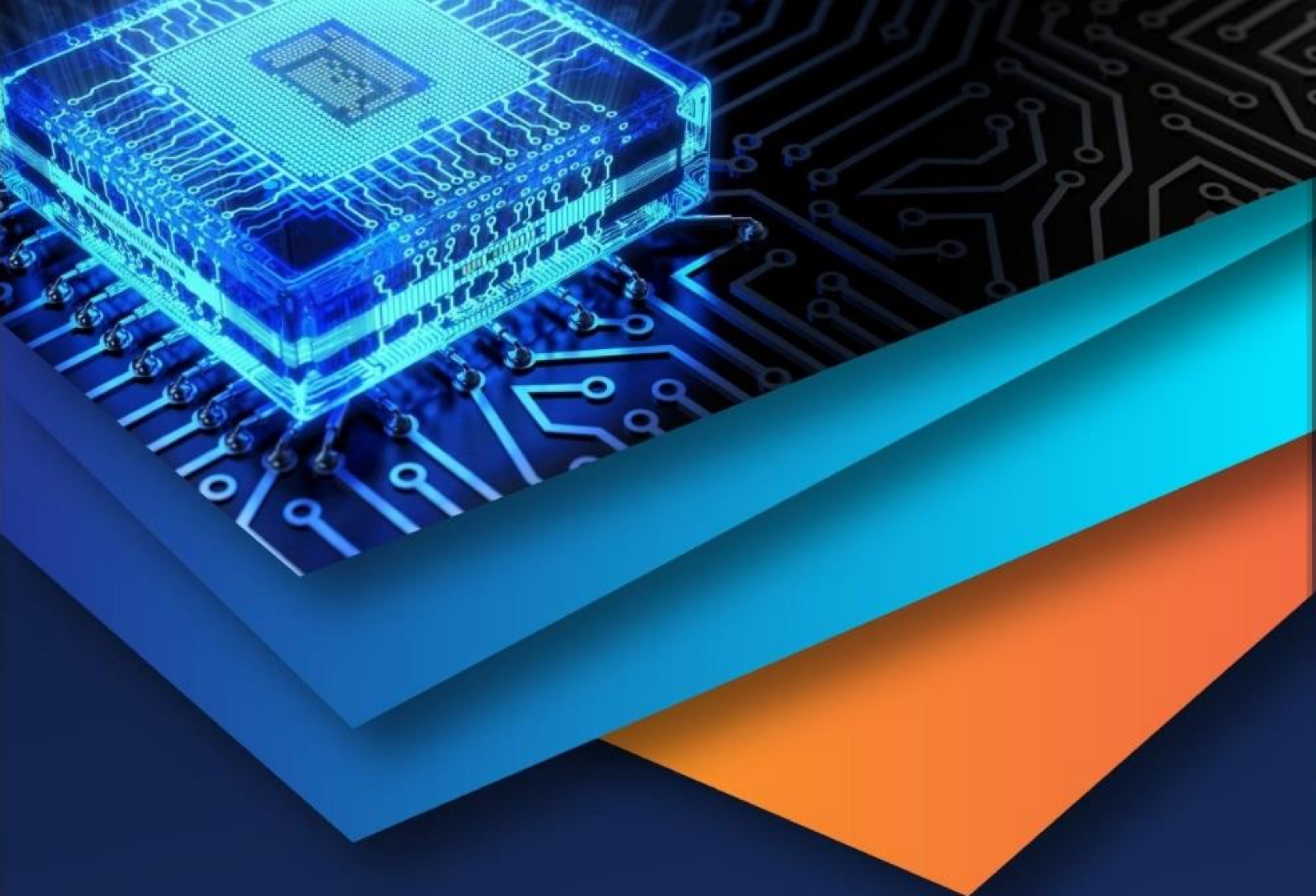

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