Efficiency of wind turbine generator

For decades, utilization of energy has increased remarkably all over the world. Significant efforts were carried out by most of the developing countries to mitigate and minimize the impact of climate change through the optimization of energy use [1]. Moreover, owing to the large combustion of fossil fuels, large quantities of greenhouse gases, carbon dioxide (CO2), and carbon monoxide (CO) are being released into the atmosphere, which increases the risks of global warming and climate change. Whereas the energy generation of fossil fuels is obtained with only 30-40% of efficiency [2], thus, more than half of the energy is lost as waste heat, which has a detrimental impact on the economy and environment.

Nowadays, the urgent need for alternative energy sources is to cut down the total energy consumption of fossil fuels and greenhouse gas emissions as a result of increasing energy demand. However, global total energy demand increased by about 160% from 1990 to 2017, increasing 1.6 times in 27 years [3]. Thus, continuous efforts and studies focus on a more attractive energy technology that enhances the performance, economic aspect, and climate change with a common strategy adopted by several countries [4]. Moreover, renewable energy sources are crucial and important for the industrial and commercial sectors to run appliances at homes or offices and to run factories [5]. Figure 1 shows the consumption energy rate of fossil fuels and renewable energies in 2017 [6].

Flowchart of review process

This paper is structured as follows, after this introduction. Section 2 deliberates the energy consumption. In Sect. 3, the wind turbine is discussed. The parameters involved in the performance of wind turbines are discussed in Sect. 4. In Sect. 5, the environmental impacts of wind turbines are illustrated. We finish in Sect. 6 with the conclusions. The aim of this paper is to illustrate and elaborate on the principle parameters affecting wind turbines, and the environmental impacts of wind energy harnessing.

World''s primary energy consumption (million tons oil equivalent) [28]

Worldwide cumulative wind installed capacity [44]

where Pv is power (W), A = pR2 denotes swept area, and (v) stands for wind speed. The cut-in and cutoff speed limits of a turbine are set at 3 m/s and 25 m/s, respectively [52]. The mathematical model of the mechanical power (Pm) output or rotor shaft power is computed by the following relation [53, 54]:

where Cp is the coefficient of performance or the turbine efficiency, which is a nonlinear function of tip speed ratio l and the blade pitch angle v (0 <= CP <= 1). The relationship between the power coefficient (Cp) and the torque coefficient (CT) is given by Eq. (4) [55]:

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Because wind speed is variable with time, wind turbines operating at its rated speed are very rare [56]. In this case, the capacity factor is useful to estimate the average power generated by the turbine. The dimensionless CF is expressed as [57]:

The performance of VAWT is mainly exhibited by the coefficient of torque (Ct) and power (Cp). Following Eqs. (8) and (9) are useful to compute Ct and Cp of the Darrieus-type VAWT [43]:

where T(t) shows the instantaneous torque, P(t) stands for the power produced by the turbine. Further, r denotes air density, V? denotes the free-stream velocity, and swept area is computed by A = DH [11, 43, 57].

The manufacturers in the wind energy industry always focus to design the turbine that performs with better efficiency for a longer period. To help manufacturers with this aim, researchers always investigate the characteristics that are associated with wind turbine performance during shorter and longer periods [58]. One of the methods to improve its performance is the maximizing annual energy production, generally expressed as [59]

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