
“Recent Trends in Wind Technology”

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Abstract

Wind power now represents a major and growing source of renewable energy. Large wind turbines (with capacities of up to 6-8 MW) are widely installed in power distribution networks. Increasing numbers of onshore and offshore wind farms, acting as power plants, are connected directly to power transmission networks at the scale of hundreds of megawatts. As its level of grid penetration has begun to increase dramatically, wind power is starting to have a significant impact on the operation of the modern grid system. Advanced power electronics technologies are being introduced to improve the characteristics of the wind turbines, and make them more suitable for integration into the power grid. Meanwhile, there are some emerging challenges that still need to be addressed. This paper provides an overview and discusses some trends in the power electronics technologies used for wind power generation. First, the state-of-the-art technology and global market are generally discussed. Several important wind turbine concepts are discussed, along with power electronics solutions either for individual wind turbines or for entire wind farms. Some technology challenges and future solutions for power electronics in wind turbine systems are also addressed.

Keywords: *Wind energy, Wind turbines, Power generation economics, Power system economics, Stability, Aerodynamics, Renewable energy resources, Power engineering and energy, Production, Tiles Introduction*

INTRODUCTION

The cumulative installation of wind turbines has grown at a fast pace over the last two decades. Installed wind power generation, which is currently larger than 440 GW, is expected to exceed 760 GW by 2020, making this form of renewable energy a significant component of the modern and future energy supply systems. Along with the fast-growing capacity, the power electronics technologies used for wind turbine systems (WTSs) have also changed dramatically in the last 30 years.

In the 1980s, the power electronics in wind turbines was simply a soft-starter, which is used to initially interconnect a squirrel-cage induction generator (SCIG) with the power grid when the wind turbine starts to produce power. Because power electronics did not need to carry power continuously, simple power semiconductor device such as thyristors were applied. In this solution, the rotational speed of the generator is fixed; thus, the wind-speed fluctuations are directly reflected as mechanical-torque fluctuations and then current fluctuations of the generator. Therefore, this solution requires a “stiff” power grid, and its mechanical construction must be able to support the high mechanical stress caused by wind gusts.

Moreover, the wind turbine cannot operate at its maximum efficiency in a broad range of wind speeds, and thereby has reduced energy yield.

In the 1990s, power electronics technology was mainly used for rotor resistance control of wound-rotor induction generators (WRIGs), in which more advanced power electronics devices such as diode bridges and choppers were used to control the rotor resistance for the generator. In this solution, the rotational speed of the wind turbine can vary in a limited range, especially at the nominal power operation of the wind turbine (typically 0%–10% above the generator’s synchronous speed); thus, the mechanical stress in the system can be relieved.

THE CONCEPT OF LIFE-CYCLE ASSESSMENT

The life cycle assessment (LCA) is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released to the environment and to evaluate and implement opportunities to affect environmental improvements (ISO, 1999).

The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use and maintenance; recycling; and final disposal (the so called 'cradle to grave' concept).

According to the ISO 14040 and 14044 standards, a LCA is carried out in four phases:

- Goal and scope definition;

- Inventory analysis: compiling the relevant inputs and outputs of a product system;
- Impact assessment: evaluating the potential environmental impacts associated with those inputs and outputs; and
- Interpretation: the procedure to identify, qualify, check and evaluate the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

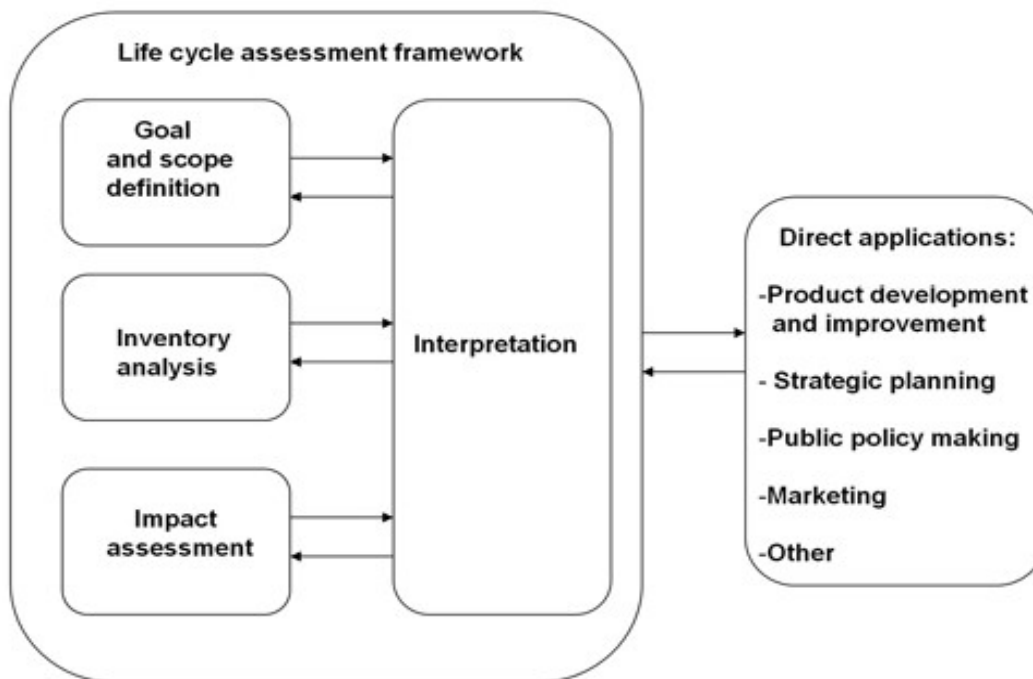


Figure 1 Conceptual Framework on LCA

In the phase dealing with the goal and scope definition, the aim, the breadth and the depth of the study are established.

The inventory analysis (also called life-cycle inventory - LCI), is the phase of LCA involving the compilation and quantification of inputs and outputs for a given product system throughout its life cycle. LCI establishes demarcation between what is included in the product system and what is excluded. In LCI, each product, material or service should be followed until it has been translated into elementary flows (emissions, natural resource extractions, land use and so on).

The third phase, life-cycle impact assessment, aims to understand and evaluate the magnitude and significance of the potential environmental impacts of a product system. This phase is further divided into four steps. The first two steps are termed classification and characterization, and impact potentials are calculated based on the LCI results.

LCA IN WIND ENERGY: ENVIRONMENTAL IMPACTS THROUGH THE WHOLE CHAIN

The LCA approach provides a conceptual framework for a detailed and comprehensive comparative evaluation of

environmental impacts as important sustainability indicators.

Recently, several LCAs have been conducted to evaluate the environmental impact of wind energy. Different studies may use different assumptions and methodologies, and this could produce important discrepancies in the results among them. However, the comparison with other sources of energy generation can provide a clear picture about the environmental comparative performance of wind energy.

An LCA considers not only the direct emissions from wind farm construction, operation and dismantling, but also the environmental burdens and resources requirement associated with the entire lifetime of all relevant upstream and downstream processes within the energy chain. Furthermore, an LCA permits quantifying the contribution of the different life stages of a wind farm to the priority environmental problems.

Wind energy LCAs are usually divided into five phases:

- 1. Construction** comprises the raw material production (concrete, aluminium, steel, glass fibre and so on) needed to manufacture the tower, nacelle, hub,

blades, foundations and grid connection cables.

2. On-site erection and assembling includes the work of erecting the wind turbine. This stage used to be included in the construction or transport phases.

3. Transport takes into account the transportation systems needed to provide the raw materials to produce the different components of the wind turbine, the transport of turbine components to the wind farm site and transport during operation.

4. Operation is related to the maintenance of the turbines, including oil changes, lubrication and transport for maintenance, usually by truck in an onshore scheme.

5. Dismantling: once the wind turbine is out of service, the works of dismantling the turbines and the transportation (by truck) from the erection area to the final disposal site; the current scenario includes recycling some components, depositing inert components in landfills and recovering other material such as lubricant oil.

OFFSHORE

1. LCI Results: Offshore Wind Farms

Results extracted from the reviewed LCA studies for offshore wind farms regarding several of the most relevant emissions are shown in Figure 2.0 Bars show the variability of the results when several wind farm configurations are considered in a single study.

Carbon dioxide emissions vary from 6.4 to 12.3 g/kWh in the consulted references. Methane emissions range from 2.8 to 16.9 mg/kWh. Nitrogen oxides emissions range from 18 to 56.4 mg/kWh. NMVOCs are emitted in quantities that range from 1.7 to mg/kWh, particulates range from 10.5 to 54.4 mg/kWh and, finally, sulphur dioxide emissions range from 22.1 to 44.7 mg/kWh. All of these quantities, are quite similar to those obtained for onshore wind farms, with the only exception being that particulates are far below the emissions of conventional technologies such as natural gas (see Figure 2).

In Figure 3, the contribution of different life cycle phases to the emissions is depicted. In an offshore context, the contribution of the construction phase is even more important, accounting for around 85 per cent of the emissions and hence of the impacts.

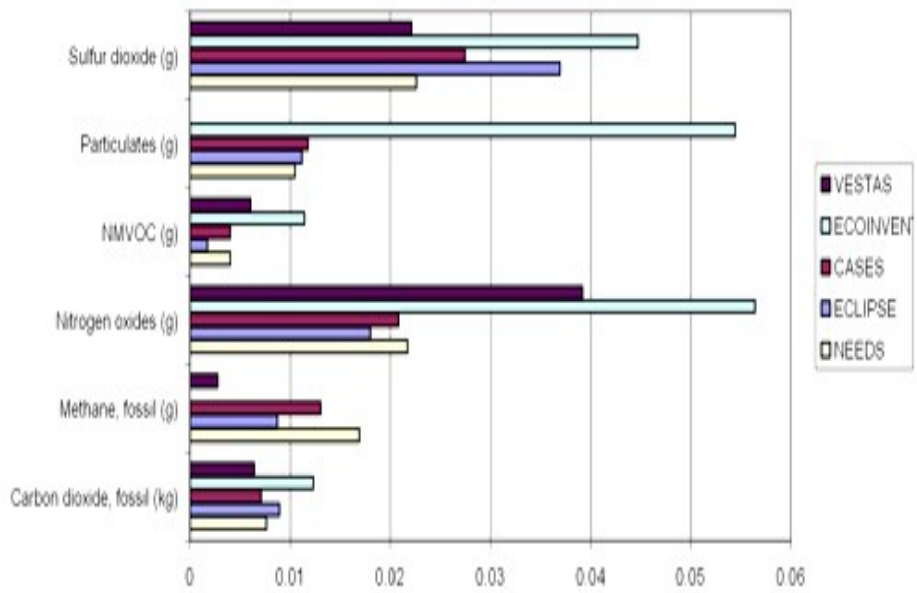


Figure 2 Emissions from the Production of 1kWh in Offshore Wind Farms throughout the Whole Life Cycle

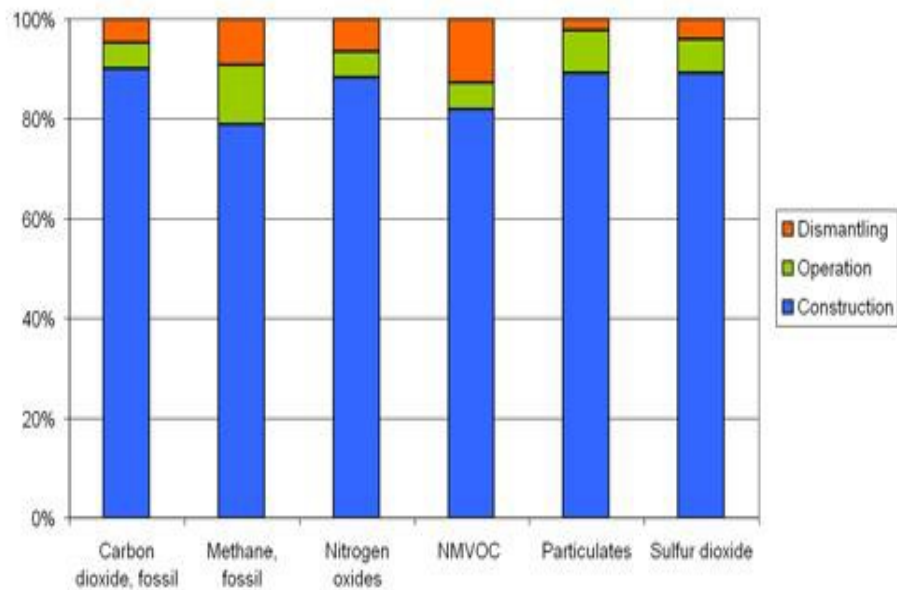


Figure 3 Contribution of the Different Life Cycle Phases of an Offshore Wind Farm to the Relevant Emissions

AVAILABILITY, RELIABILITY AND ACCESS

High availability is crucial for the economics of any wind farm. This depends primarily on high system reliability and adequate maintenance capability, with both being achieved within economic constraints on capital and operational costs.

Key issues to be addressed for good economics of an offshore wind farm are:

- Minimization of maintenance requirements
- Maximization of access feasibility.

The dilemma for the designer is how best to trade the cost of minimizing maintenance by increasing reliability - often at added cost in redundant systems or greater design margins - against the cost systems for facilitating and increasing maintenance capability. Previous studies within the EU research programmers, such as OptiOWECS, have considered a range of strategies from zero maintenance (abandonment of faulty offshore turbines) to highly facilitated maintenance.

Access is critical as, in spite of the direct cost of component or system replacement

in the difficult offshore conditions, lost production is often the greatest cost penalty of a wind turbine fault. For that reason much attention is given to access. Related to the means of access is the feasibility of various types of maintenance activities and the need or not for support systems (cranes and so on) and other provisions in the wind turbine nacelle systems.

IMPACT ON NACELLE DESIGN

The impacts of maintenance strategy on nacelle design relate to:

- Provision for access to the nacelle;
- Systems in the nacelle for handling components; and
- The strategic choice between whether the nacelle systems should be (a) designed for long life and reliability in an integrated design that is not particularly sympathetic to local maintenance and partial removal of sub-systems or (b) designed in a less cost-effective modular way for easy access to components

LOCATION OF EQUIPMENT

Transformers may be located in the nacelle or inside the tower base. Transformer

failures have occurred in offshore turbines, but it is not clear that there is any fundamental problem with location either in the nacelle or the tower base.

IMPORTANCE OF TOWER TOP MASS

The tower top mass is an important influence on foundation design. In order to achieve an acceptable natural frequency, greater tower top mass may require higher foundation stiffness, which could significantly affect the foundation cost for larger machines.

- Offshore wind speeds tend to be faster than on land.

ADVANTAGES

- Small increases in wind speed yield large increases in energy production.
- Offshore wind speeds tend to be steadier than on land.

DISADVANTAGES

- Offshore wind farms can be expensive and difficult to build and maintain.
- Effects of offshore wind farms on marine animals and birds are not fully understood.

CONCLUSION

When electrical connection to the offshore installation is not already established and cable installation is not economically viable we have identified an alternative method of storage / distribution of this energy, in the form of potable water. It has been established that the conversion of seawater by desalination to produce water for storage or distribution through the existing pipeline appears to be a viable alternative, especially in areas where brackish water supplies are low. The production of Hydrogen offshore using electrolysis appears to be worth further investigation due to the global developments in clean fuel and fuel cell technology.

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