CONTROL OF SMART GRIDS WITH RENEWABLE ENERGY SOURCES

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ABSTRACT

The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. At that time, economic issues were the most important factors, hence interest in such processes decreased when oil prices fell. The current resurgence of interest in the use of renewable energy is driven by the need to reduce the high environmental impact of fossil-based energy systems. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time. Future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades. Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not "dispatchable"—the power output cannot be controlled. Control is one of the key enabling technologies for the deployment of renewable energy systems. Solar and wind power require effective use of advanced control techniques. In addition, smart grids cannot be achieved without extensive use of control technologies at all levels. This section of the report will concentrate on one form of renewable energy—wind—and on the role of smart grids in addressing the problems associated with the efficient and reliable delivery and use of electricity and with the integration of renewable sources

Keyword: *smart grids[1], renewable energy[2], wind turbine[3]*

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1. INTRODUCTION

The term smart grid implies that the existing grid is dumb, which is far from true. The current grid structure reflects carefully considered trade-offs between cost and reliability. The responsiveness achievable through smart grid concepts will, however, play a vital role in achieving large-scale integration of new forms of generation and demand. Renewable generation will make an increasingly important contribution to electric energy production into the future. Integration of these highly variable, widely distributed resources will call for new approaches to power system operation and control. Likewise, new types of loads, such as plug-in electric vehicles and their associated vehicle-to-grid potential, will offer challenges and opportunities. Establishing a cyber infrastructure that provides ubiquitous sensing and actuation capabilities will be vital to achieving the responsiveness needed for future grid operations. Sensing and actuation will be pointless, though, without appropriate controls.

Far better than in the old days, when the design of any machine was carried out under a rigid and sequential strategy, starting from the pure aerodynamics and following with the mechanical, the electrical, and finally the control system design, the new tools have opened the door to a more central role for control engineers.

The new philosophy brings a concurrent engineering approach, where all the engineering teams work simultaneously to achieve the optimum wind turbine design. This strategy allows the control engineers to interact with designers from the other fields from the very beginning, discussing and changing the aerodynamics, mechanics, and electrical systems to improve the dynamic behavior, efficiency, reliability, availability, and cost, and finally to design the most appropriate controllers for the machine.

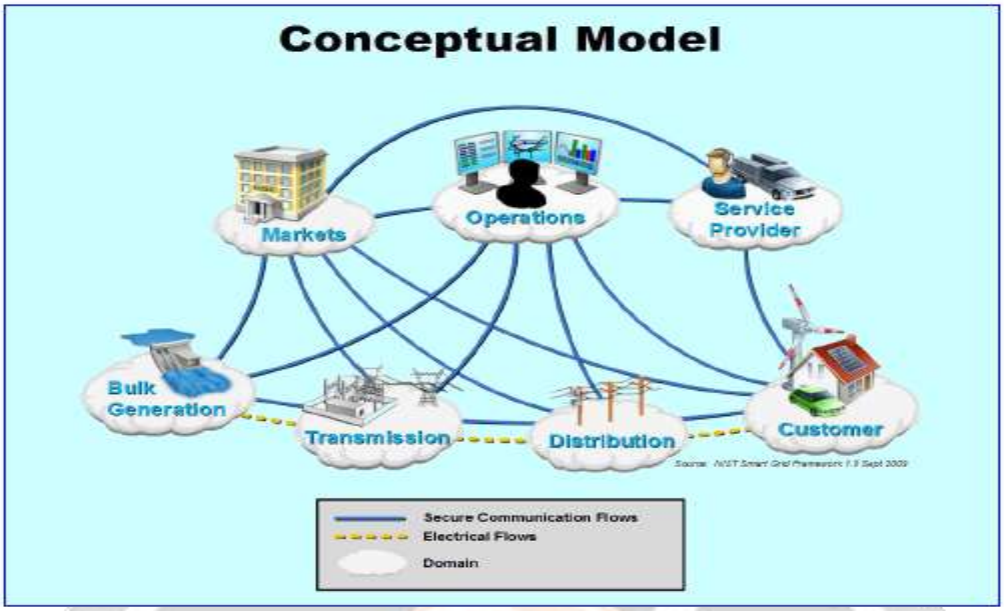

Fig-1 : Depiction of the NIST smart grid conceptual model

2. MULTIDISCIPLINARY COMPUTER DESIGN TOOLS

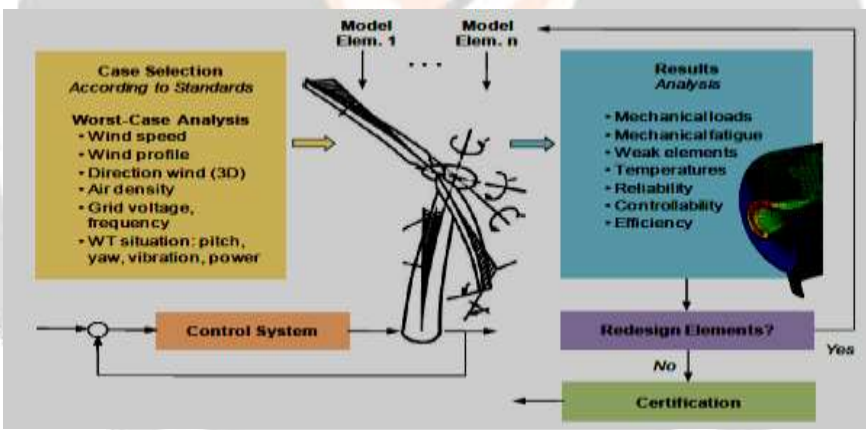

Fig-2 : Multidisciplinary computer design tools for wind turbine design

Nowadays, there are essentially two types of wind turbines: constant-speed and variable-speed machines. Until the late nineties, the constant-speed concept dominated the market. Today, it still represents a significant share of the operating wind turbines, but newer requirements have led to the emergence of variable-speed designs . Three main alternative strategies are used for regulating the amount of power captured by the rotor: passive stall control or fixed pitch, variable pitch control, and active stall control.

So far, over the entire range of wind turbine sizes, no one of these strategies has taken the lead over the others. However, as machines get larger and power production increases, the trend is toward pitch control and active stall control. The configuration of a fixed-speed wind turbine is based on a gearbox and an asynchronous generator, which is usually a squirrel-cage induction generator to reduce costs.

The gearbox links the wind turbine shaft with the rotor of a fixed-speed generator, providing the high rotational speed required by the generator. The generator produces electricity through a direct grid connection, and a set of capacitors is used to compensate reactive power. Due to lack of a frequency converter, the generator speed is dictated by the grid frequency.

One disadvantage of fixed-speed operation is poor aerodynamic efficiency, particularly at partial-load operation. From the electrical system's standpoint, another disadvantage is that this type of operation has a detrimental effect on voltage because asynchronous generators demand reactive power from the grid.

New multidisciplinary computer design tools able to simulate, analyze, and redesign in a concurrent engineering way the aerodynamics, mechanics, and electrical and control systems under several conditions and external scenarios have extended the capability to develop more complex and efficient wind turbines. In this new approach, the control system designs, and the designers' understanding of the system's dynamics from the control standpoint, are playing a central role in new engineering achievements.

3. POWER CURVE OF A WIND TURBINE

A generic qualitative power curve for a variable-speed pitch-controlled wind turbine is shown in Fig. 3. Four zones and two areas are indicated in it. The rated power Pr of the wind turbine (that is, the actual power supplied to the grid at wind speed greater than Vr) separates the graph into two main areas. Below rated power, the wind turbine produces only a fraction of its total design power, and therefore an optimization control strategy needs to be performed. Conversely, above rated power, a limitation control strategy is required.

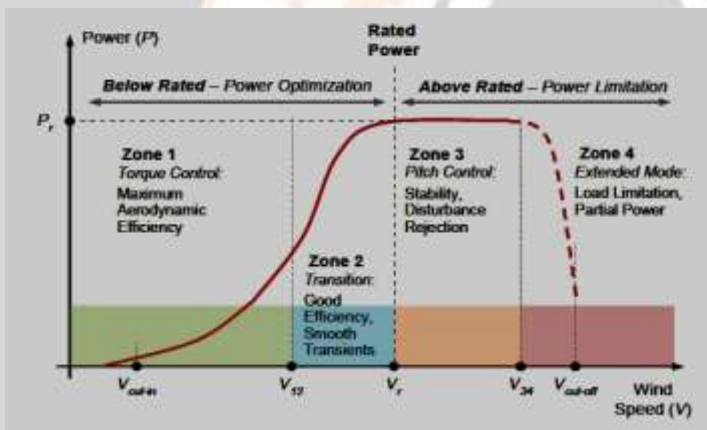

Fig-3: Power curve of a wind turbine and control zones

For passive-stall-controlled wind turbines, in which the rotor blades are fixed to the hub at a specific angle, the generator reaction torque regulates rotor speed below rated operation to maximize energy capture. Above a specific wind speed, the geometry of the rotor induces stall. In this manner, the power delivered by the rotor is limited in high wind conditions thanks to a particular design of the blades that provoke loss of efficiency.

In pitch control, the power delivered by the rotor is regulated either by pitching the blades toward the wind to maximize energy capture or by pitching to feather to discard the excess power and ensure that the mechanical limitations are not exceeded. At rated operation, the aim is to maintain power and rotor speed at their rated value. To achieve this, the torque is held constant and the pitch is continually changed following the demands of a closed-loop rotor speed controller that optimizes energy capture and follows wind speed variations.

In contrast, below rated operation there is no pitch control; the blade is set to a fine pitch position to yield higher power capture values while the generator torque itself regulates the rotor speed. Active stall control is a combination of stall and pitch control. It offers the same regulation possibilities as the pitch-regulated turbine but uses the stall properties of the blades. Above rated operation, the control system pitches the blades to induce stall instead of feathering. In this technique, the blades are rotated only by small amounts and less frequently than for pitch control.

4. CONCLUSIONS

An alternative energy source: In 1789, Martin Heinrich Klaproth, a German chemist, discovered uranium in the mineral pitchblende. Eugène -Melchior P é ligot, a French chemist, was the first person to isolate the metal, but it was Antoine Becquerel, a French physicist, who recognized its radioactive properties almost 100 years later. In 1934, Enrico Fermi used the nuclear fuel to produce steam for the power industry.

Later, he participated in building the fi rst nuclear weapon used in World War II. The U.S. Department of Energy estimates worldwide uranium resources are generally considered to be sufficient for at least several decades. The amount of energy contained in a mass of hydrocarbon fuel such as gasoline is substantially lower in much less mass of nuclear fuel.

This higher density of nuclear fission makes it an important source of energy; however, the fusion process causes additional radioactive waste products. The radioactive products will remain for a long time giving rise to a nuclear waste problem. The counterbalance to a low carbon footprint of fission as an energy source is the concern about radioactive nuclear waste accumulation and the potential for nuclear destruction in a politically unstable world.

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