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Comparison of STATCOM and UPQC for compensation of Voltage Swell in Wind Farm to weak Grid Connection

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ABSTRACT

Wind power or wind energy is the use of wind to provide mechanical power through wind turbines to turn electric generators for electrical power. Wind power is a popular sustainable, renewable energy source that has a much smaller impact on the environment compared to burning fossil fuels.

Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electric power, competitive with, or in many places cheaper than, coal or gas plants. Onshore wind farms have a greater visual impact on the landscape than other power stations, as they need to be spread over more land and need to be built in rural areas, which can lead to "industrialization of the countryside" and habitat loss. Offshore wind is steadier and stronger than on land and offshore farms have less visual impact, but construction and maintenance costs are significantly higher. Small onshore wind farms can feed some energy into the grid or provide power to isolated off-grid locations. Wind power is an intermittent energy source, which cannot be dispatched on demand. Locally, it gives variable power, which is consistent from year to year but varies greatly over shorter time scales. Therefore, it must be used with other power sources to give a reliable supply. Power-management techniques such as having dispatch able power sources (often gas-fired power plant or hydroelectric power), excess capacity, geographically distributed turbines, exporting and importing power to neighboring areas, grid storage, reducing demand when wind production is low, and curtailing occasional excess wind power, are used to overcome these problems. As the proportion of wind power in a region increases, more conventional power sources are needed to back it up, and the grid may need to be upgraded. Weather forecasting permits the electric-power network to be readied for the predictable variations in production that occur.

1. Introduction

Electricity is an indication of comfortable life, and the demand for this energy source is increasing. Development in power industries increases the number of linear and nonlinear loads in each system. In nonlinear load conditions, many solid-state switching converters draw reactive power and current harmonics from the AC grid. These nonlinear loads generate harmonics, which produce disturbance and directly influence human life. Nowadays, each piece of equipment, power system, and service, such as furnaces, computer power supplies, communication systems, renewable energy systems, electrical power generations, and high-voltage systems, requires a continuous power supply. Researchers and different power companies are continuously exploring solutions to power quality problems [1], such as harmonics, system imbalance, load balancing, excess neutral current, and power system grid intrusions. Evidently, the increasing demand for nonlinear loads produces harmonics in the power system, thereby resulting in poor power quality. Flexible AC transmission system (FACTS) devices, such as static compensators (STATCOMs) and active power filters (APFs), are the most dominant technologies available for industrial and commercial purposes and are deemed the solution to this power quality problem.

In the past, harmonic grid problems were solved using passive filter (PF) devices [5]. These filters, together with low-cost solutions for power quality issues, are considered the initial stage of development in mitigating current harmonics [6,7]. APFs are considered the second stage of development and an effective solution to overcome the limitation of PFs. However, the size, cost, and rating of APFs are considerably increased by the increasing demand for power system capacity [8,9]. To overcome the issues of shunt APFs, a third stage of development consists of hybrid power filter (HPF) devices, which comprise hybrid combinations of PFs with shunt APFs [10]. Furthermore, HPF technology is evaluated in the fourth stage of development as a unified power quality conditioner (UPQC) [11]. Previous research [12,13] on power quality improvement has led to important developments in FACTS devices, namely, the static volt-ampere reactive (VAR) compensator (SVC), dynamic voltage restorer (DVR), and distribution STATCOM (DSTATCOM) [14–16]. Such improvements compensate for the mitigation problems related to power quality, including poor load power factor, load harmonics, imbalanced load conditions, and DC offset in loads.

2. Harmonics and International Standards

The amount or penetration of harmonics had previously been largely increasing, thereby affecting the performance and efficiency of the system [20]. Harmonics are generated in the system because of non-linear or critical loads. Harmonics exist in a power grid or power distribution network in the form of series and parallel resonances generated by harmonic current loads, which increase the source voltage and current total harmonic distortion. However, modern technologies in power quality improvement mitigate current, voltage, active and reactive power, voltage zero-crossing, and other

issues, such as harmonics, voltage sags and swells, notches and flickers, spikes and glitches, and voltage imbalance.

- PFs require a separate filter for each harmonic current, and their filtering range is limited.
- PFs allow only one component (either a harmonic or a fundamental current component) to pass at a time.
- Large amounts of harmonic current saturate or overload the filter and cause series resonance with the AC source, thereby resulting in excessive harmonic flow into the PFs.
- PFs amplify source-side harmonic contents because of the impedance in the source of parallel and series negative resonances between the grid and the filter .
- The design parameters of PFs in an AC system depend on the system operating frequency, which changes around its nominal value according to variable load conditions.
- PFs only eliminate frequencies to which they are tuned, thus resulting in limited compensation, large size, and tuning issues.

2.1 Shunt APFs

APFs were introduced and investigated as a solution to the limitations of PFs. An APF consists of an active switching device and passive-energy storage devices, such as inductors and capacitors, which provide superior compensation characteristics, including voltage and current harmonics, voltage imbalance compensation for utilities, and current imbalance compensation for consumers. APFs mitigate reactive power, neutral current, changing line impedance, frequency variation, voltage notch, sudden voltage distortion, transient disturbance, and voltage balance and improve the power factor of voltage and current in medium-power systems.

Different APF topologies and control methodologies have been proposed and progressively investigated as a perceived solution to critical issues in high-power load

applications [31,32]. APFs are classified into many categories in accordance to subsequent measures. The circuit structure of an APF commonly includes a voltage-source PWM inverter with a DC-link capacitor. Evidently, current-source APFs are superior in terms of compensating current dynamics. However, voltage-source APFs perform better than current-source APFs in terms of filter losses and PWM carrier harmonic reduction. Table 1 shows the survey results for shunt and series APFs

3. Literature Review

A wind farm is a group of wind turbines in the same location used for the production of electric power. A large wind farm may consist of several hundred individual wind turbines distributed over an extended area. Wind turbines use around 0.3 hectares of land per MW, but the land between the turbines may be used for agricultural or other purposes. For example, Gansu Wind Farm, the largest wind farm in the world, has several thousand turbines. A wind farm may also be located offshore.
Almost all large wind turbines have the same design — a horizontal axis wind turbine having an upwind rotor with 3 blades, attached to a nacelle on top of a tall tubular tower.
In a wind farm, individual turbines are interconnected with a medium voltage (often 34.5 kV) power collection system and communications network. In general, a distance of 7D (7 times the rotor diameter of the wind turbine) is set between each turbine in a fully developed wind farm. At a substation, this medium-voltage electric current is increased in voltage with a transformer for connection to the high voltage electric power transmission system.

3.1 Generator characteristics and stability

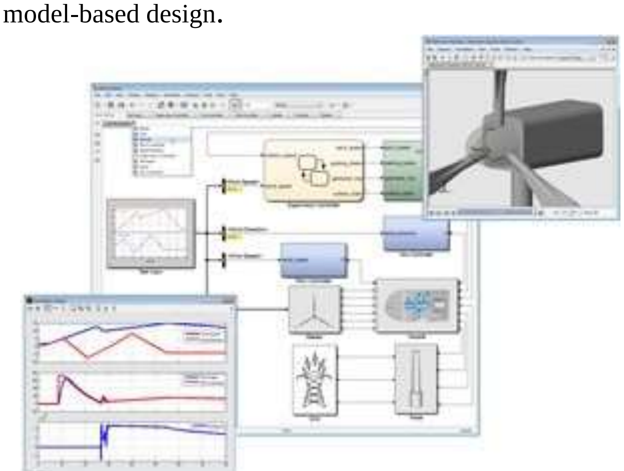
Induction generators, which were often used for wind power projects in the 1980s and 1990s, require reactive powerfor excitation, so electrical substations used in wind-power collection systems include substantial capacitor banks for power factor correction. Different types of wind turbine generators behave differently during transmission grid disturbances, so extensive modeling of the dynamic electromechanical characteristics of a new wind farm is required by transmission system operators to ensure predictable

stable behavior during system faults (see wind energy software). In particular, induction generators cannot support the system voltage during faults, unlike steam or hydro turbine-driven synchronous generators.

4. Methodology

4.1 Simulink

Simulink is a MATLAB-based graphical programming environment for modeling, simulating and analyzing multidomain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation and model-based design.

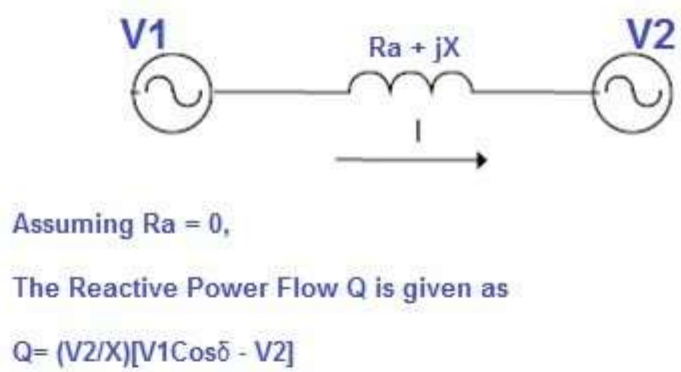


4.2 Statcom Functionality

STATCOM or Static Synchronous Compensator is a power electronic device using force commutated devices like IGBT, GTO etc. to control the reactive power flow through a power network and thereby increasing the stability of power network. STATCOM is a shunt device i.e. it is connected in shunt with the line. A Static Synchronous Compensator (STATCOM) is also known as a Static Synchronous Condenser (STATCON). It is a member of the

Flexible AC Transmission System (FACTS) family of devices.
The terms Synchronous in STATCOM mean that it can either absorb or generate reactive power in synchronization with the demand to stabilize the voltage of the power network**.**

4.3 Working Principle of STATCOM:



To understand the working principle of STATCOM, we will first have a look at the reactive power transfer equation. Let us consider two sources V1 and V2 are connected through an impedance Z = Ra + jX as shown in figure below.

In the above reactive power flow equation, angle δ is the angle between V1 and V2. Thus if we maintain angle δ = 0 then Reactive power flow will become

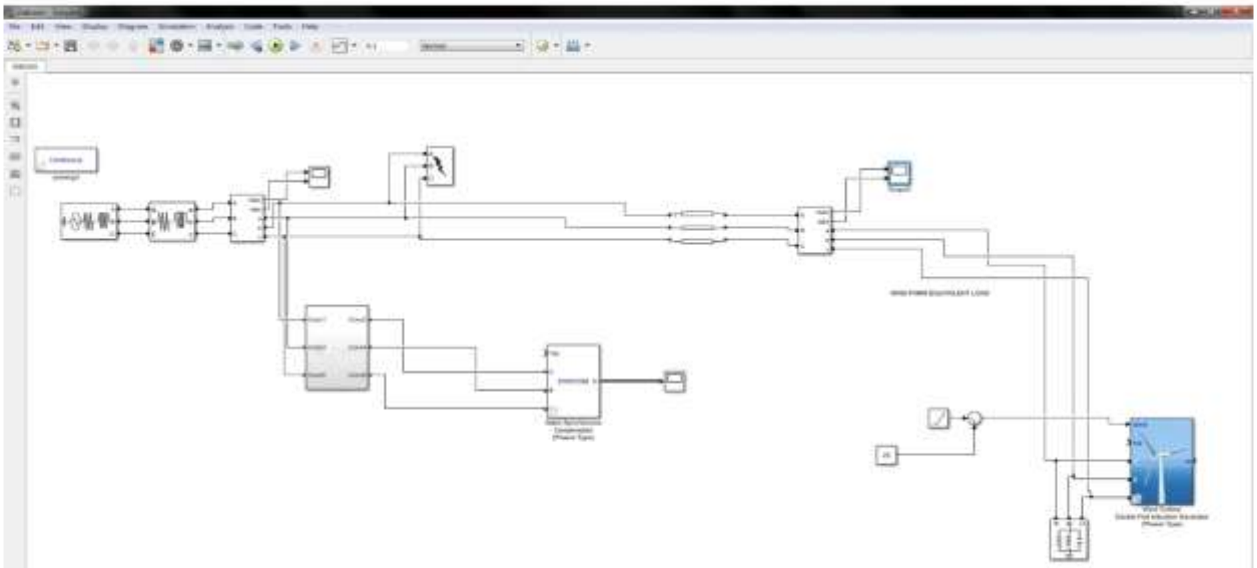
Q = (V2/X)[V1-V2]

To summarize, we can say that if the angle between V1 and V2 is zero, the flow ofactive power becomes zero and the flow of reactive power depends on (V1 – V2). Thus for flow of reactive power there are two possibilities.

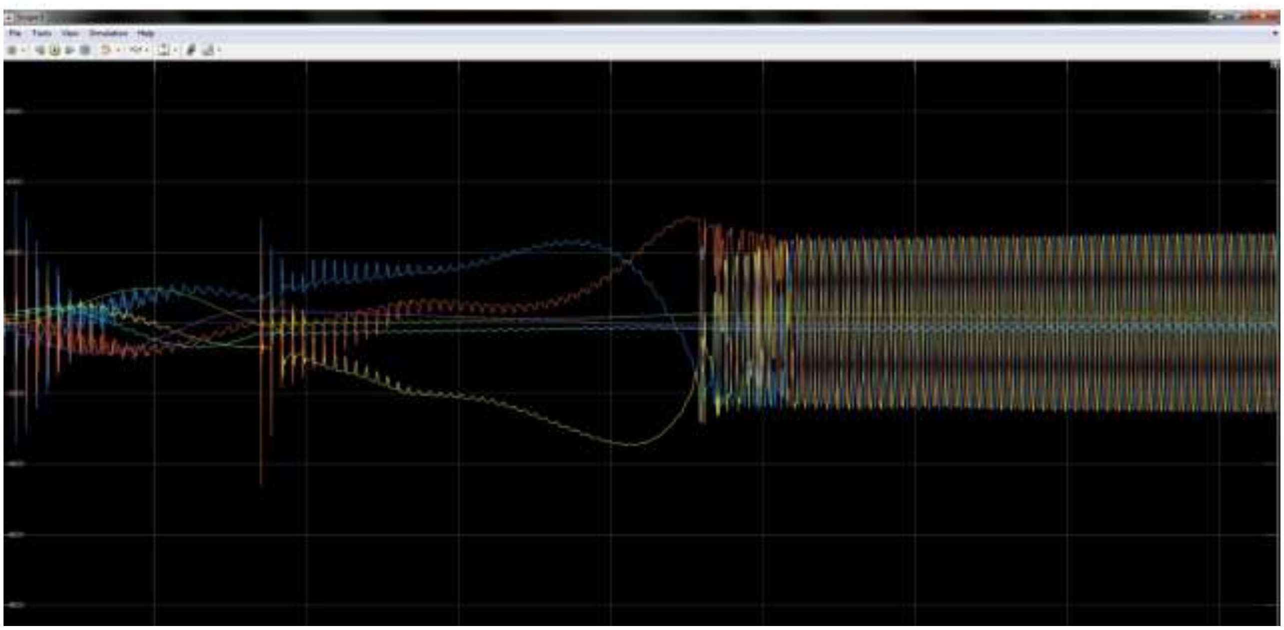
1) If the magnitude of V1 is more than V2, then reactive power will flow fromsource V1 to V2.
2) If the magnitude of V2 is more than V1, reactive power will flow from source V2to V1.

This principle is used in STATCOM for reactive power control. Now we will discuss about the design of STATCOM for better correlation of working principle and **design.**

You may like to read Reactive Power and Voltage Control of a Transmission Line.



1.1 STATCOM MODEL



1.2 STATCOM OUTPUT

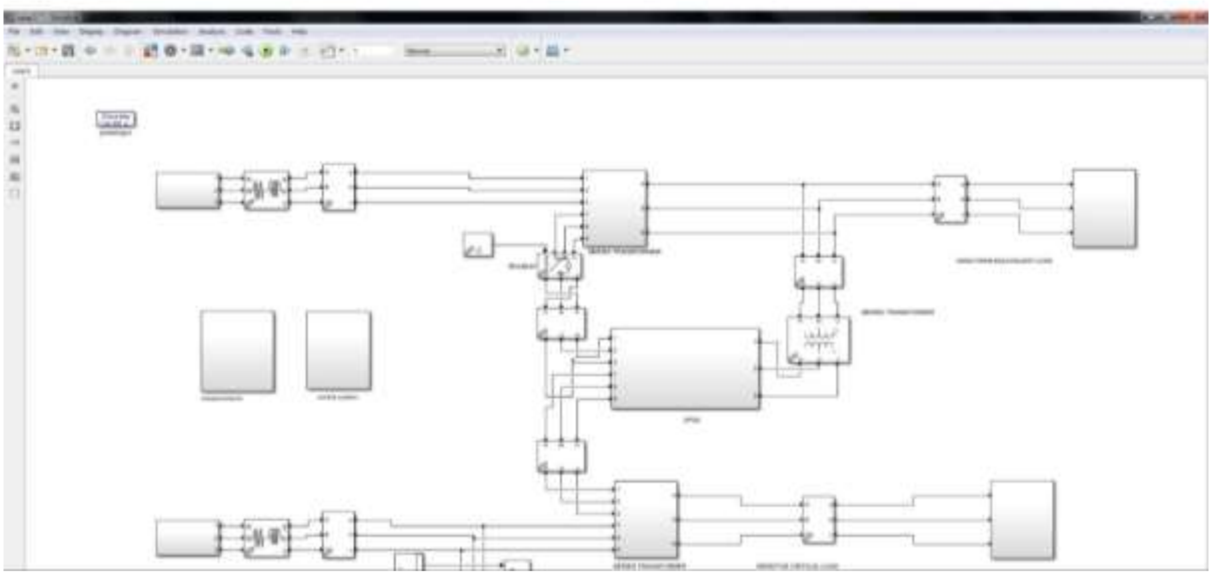
4.4 Application of STATCOM:

Voltage stability is one of the biggest problems in power systems. Engineers and researchers are trying to consolidate a definition regarding to voltage stability, besides proposing techniques and methodologies for their analysis. *Most of these techniques are based on the search of the point in which the system's Jacobian becomes singular, this point is referred as the point of voltage collapse or maximum load ability point. (we will discuss point of voltage collapse in next post)*The series and shunt compensation are able to increase the maximum transfer capabilities of power network .Concerning to voltage stability, such compensation has the purpose of injecting reactive power to maintain the voltage magnitude in the nodes close to the nominal values, besides, to reduce line currents and therefore the total system losses. Today due the development in the power electronics devices, the voltage magnitude in some node of the system can be adjusted through sophisticated and versatile devices named FACTS. One of them is the static synchronous compensator (STATCOM).

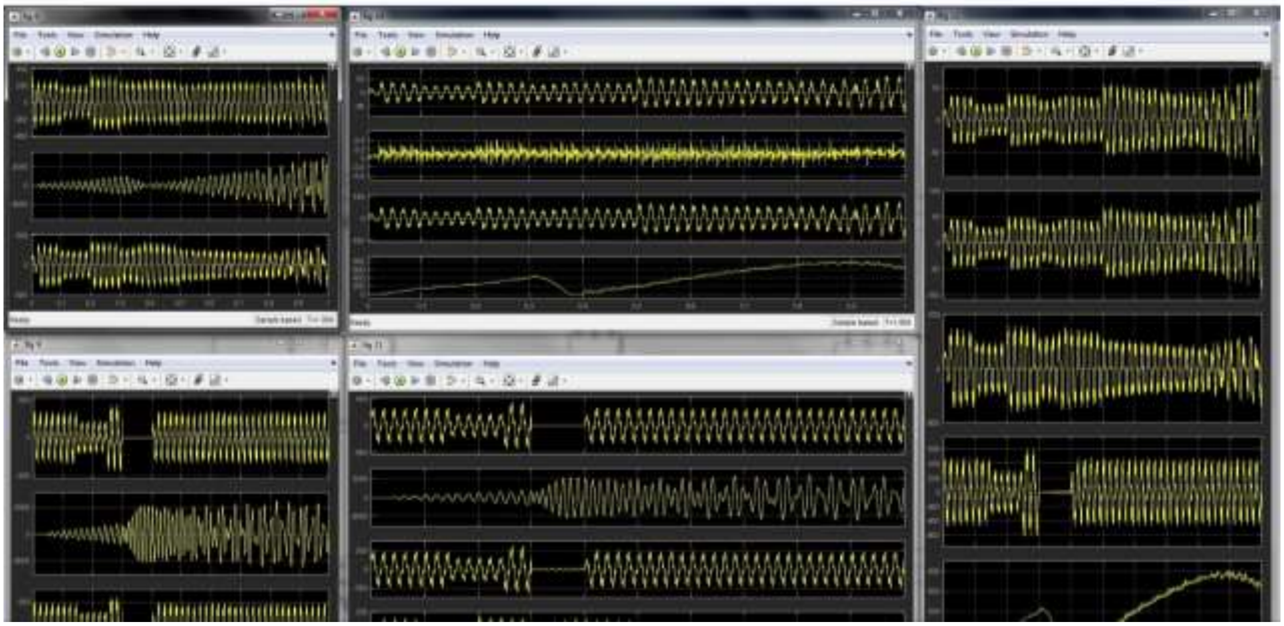
Usually a STATCOM is installed to support electrical networks that have a poor power factor and often poor voltage regulation. The most common use of STATCOM is for voltage stability. A STATCOM is a voltage source converter (VSC) based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacity.

4.5 UPQC VOLTAGE CONTROLLER:

The regulation of the DC bus voltage has been assigned to the shunt converter. Voltage sag compensation action produce an increment of active power draw by series converter, thus causing an increase in DC bus voltage. Based on deviation from reference DC bus voltage, the shunt converter injects appropriate active current at PCC.
So, Ed reference voltage for shunt converter, contains the control action for the DC bus voltage control loop. This control action is calculated using a PI controller type. The control loop is tuned to obtain a slow response compared with phase jump compensation dynamics, avoiding PCC voltage phase variation due to active power injection



1.3 UPQC MODEL



1.4 UPQC OUTPUT

5. Result:

Simulation results for 0 < t < 6: At t = 0.5" begins the cyclical power pulsation produced by the tower shadow effect. As was mentioned, the tower shadow produces variation in torque, and hence in the active and reactive WF generated power. For nominal wind speed condition, the power fluctuation frequency is f = 3.4Hz, and the amplitude of the resulting voltage variation at PCC, expressed as a percentage is:Δ/= 1.50 %.
Voltage fluctuation for 0.5 < t < 3. The fluctuation value is higher. This means that even in normal operation, the WF impacts negatively on the System Power Quality. At t = 3.0" the active and reactive power pulsations are attenuated because the P and Q controllers come into action.

5. Conclusion:

In the proposed dissertation work the strategy for voltage sag generation by fault in the line which will be compensation is presented with magnitude restoration and phase jump compensation. SImulation model showa the better wind farm performance in proposed strategy than that found in magnitude only compensated method. Moreover, the proposed strategy does not need converters with higher power rating than that found in other schemes. Thus, considering the improvement in performance, the proposed strategy is recommended in retrofitting the existing Induction Generator based Wind Farms.

6. Reference :

1. Dragoon K, Milligan M. Assessing wind integration costs with dispatch models: a case study. Windpower 2003. 2003. Austin, TX: AWEA.
2. Kirby B, Hirst E. Customer-specific metrics for the regulation and load following ancillary services. 2000, Oak Ridge National Laboratory: Oak Ridge, TN.
3. NERC, NERC Operating Manual. 2002: Princeton, N.J.
4. Hirst E, Kirby B. Ancillary-service details: dynamic scheduling. 1997, Oak Ridge National Laboratory: Oak Ridge.
5. Hirst E. Integrating wind output with bulk power operations and wholesale electricity markets. Wind Energy 2002; 5 (1): 19-36.

6. Wan Y. Wind power plant monitoring project annual report. 2001, National Renewable Energy Laboratory: Golden, CO.
7. Milligan M. Wind power plants and system operation in the hourly time domain. Windpower 2003. 2003. Austin, TX: AWEA.
8. Milligan M, Factor T. Optimizing the geographic distribution of wind plants in Iowa for maximum economic benefit and reliability. Journal of Wind Engineering 2000. 24(4): 271-290.
9. Brooks EDL, Smith J, Pease J, McGree M. Assessing the impact of wind generation on system operations at Xcel Energy-North and Bonneville Power Administration. Windpower 2002. 2002. Washington, D.C.: American Wind Energy Association.
10. PacifiCorp. Integrated Resource Plan 2003.
11. http://www.pacificorp.com/Navigation/Navigation23807.html. 2003.