Wind and Solar Curtailment

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***Abstract*—High penetrations of wind and solar generation on power systems are resulting in increasing curtailment. Wind and solar integration studies predict increased curtailment as penetration levels grow. This paper examines experiences with curtailment on bulk power systems internationally. It discusses how much curtailment is occurring, how it is occurring, why it is occurring, and what is being done to reduce curtailment. This summary is produced as part of the International Energy Agency Wind Task 25 on Design and Operation of Power Systems with Large Amounts of Wind Power.**

Keywords-wind; solar; curtailment; transmission congestion

I. Introduction

In many regions, wind and solar generation are preferred instead of conventional generation because of their emissions benefits; policy, legislation, and/or incentives may be established to encourage the use of wind and solar instead of conventional generation. Additionally, wind and solar have zero or very low marginal costs, which means that as long as a system operates within transmission and operating constraints, wind and solar tend to displace conventional generation. However, increasing wind and solar penetration levels may drive a system to encounter transmission or operational constraints, forcing the system operator to accept less wind or solar than is available. High levels of wind and solar power can be challenging to integrate into power systems because of their variability and limits in predictability. When high levels are planned, infrastructural, operational, or institutional changes to the grid may be necessary. During this transition phase, curtailment may be higher than after the changes are made. We use the term *curtailment* broadly to refer to the use of less wind or solar power than is potentially available at that time.

There are many reasons for curtailment, and system operators may distinguish between these reasons for compensation and accounting purposes. The main reasons for wind and solar curtailment are listed below.

Transmission congestion, or local network constraints, is a common reason for system operators to utilize higher marginal-priced resources instead of less expensive resources. Related to congestion is insufficient transmission availability. Because of the mismatch in construction times, wind power plants may be built somewhat in advance of the necessary transmission to transport those energy resources to load centers. These new wind power plants may be curtailed until transmission infrastructure is commissioned.

Minimum operating levels on thermal generators are another driver for curtailment. Wind, in particular, is often stronger at night, when loads are low and thermal units are pushed down against their minimum operating constraints. A related issue is the requirement for downward reserves. If wind and solar are unable to provide downward reserves, then sufficient downward capability may need to be held on thermal units, raising their operating levels.

Hydro plants may also have minimum operating levels because of environmental, recreational, or irrigation constraints. For example, to comply with limits on dissolved gases to protect fish, operators may be required to run water through their turbines rather than spill water over a dam.

Curtailment can also occur in the distribution system to avoid high penetrations or back-feeding, in which a feeder produces more energy than it consumes, of distributed generation on feeders, which can lead to voltage control issues as a result of variability of the wind or solar resource. Back-feeding can be problematic if protection devices and other infrastructure were not designed or are not yet adapted for this type of operation.

Finally, limits may be placed on nonsynchronous generation levels to maintain frequency requirements and stability issues, especially on small, isolated grids. Modern wind and solar power plants interconnect to the grid through power electronics. Because they displace conventional synchronous generation, which provides inertia and may provide governor response, system frequency response might suffer if a contingency event occurs when there is a high penetration of nonsynchronous generation.