

**Grid Codes for Wind Power
Integration in Spain and Germany:
Use of Incentive Payments to
Encourage Grid-Friendly Wind
Power Plants**

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1. Summary

Against the background of an increasing share of renewable energy, improved grid integration of these plants is becoming more and more important. Because of intermittent generation dependent on wind conditions, improvements are also important for wind power plants. Therefore, some countries have developed grid integration standards for wind power plants, either through strict requirements and/or through financial incentives.

An overview for Spain and Germany is shown in **Table 1**.

| Measure | Spain | Germany |
|---------------------------------------|-----------|---|
| Frequency control | required | required (new plants), incentive (existing plants) |
| Voltage control | - | required (new plants) |
| Supply of reactive power | incentive | required (new plants) |
| Fault ride-through capability | incentive | required (new plants), incentive (existing plants) |
| Plant operation in line with forecast | incentive | - |

Table 1: Legislative framework in respect to grid integration of wind power

Spain provides incentives for the following measures to improve grid integration:

- Supply of reactive power; depending on the power factor of supplied electricity, a bonus or penalty is paid
- Plant design with fault ride-through capability; these plants receive an additional bonus
- Plant operation in line with the day-ahead forecast; in the case of deviations a penalty in line with hourly market deviation costs has to be paid.

Frequency control is mandatory for wind power plants. Wind power plant operators usually contract these services from other power plants against a respective remuneration.

Germany provides incentives to measures to refurbish existing wind power plants in respect to fault ride-through capability and frequency control. For new wind power plants, these measures and additionally voltage control and supply of reactive power are legally required.

Whereas in Spain separate bonuses are paid for each grid integration measure, in Germany a bonus is paid for a package of grid integration measures.

2. Introduction

This paper briefly describes the regulatory framework for grid codes in Spain and Germany which, on the one hand, defines requirements for wind power integration into an efficient grid operation and, on the other hand, gives economic incentives for such integration. This paper primarily focuses on grid codes and whether wind generators are given monetary incentives to comply with grid codes, or are simply required to comply with grid codes without additional compensation.

3. Why a grid code for wind power integration is required?

The operation of fossil fuel – fired power plants can be planned and controlled in order to meet the daily load curve of the electricity demand of the grid. However, the share of wind energy and other power plants using renewable energy is significantly increasing in recent years in many countries. The operation of these power plants is dependent on weather conditions. This brings about potential grid operational issues as the operation of these power plants can be controlled only in a limited way. There are also potential reliability concerns if a large amount of wind power trips off the grid because of grid faults. Finally, with a larger contribution expected from wind generation, there is some desire that wind contribute some grid support services such as reactive power or frequency and voltage control. For these reasons, a number of countries are pursuing requirements for wind plants to meet various grid standards, either through regulation, incentives, or both.

In order to mitigate grid problems, regulatory requirements and incentives for wind power and other renewable energy plants often include:

- frequency and voltage control
- supply of reactive power
- fault ride-through capability
- efforts to minimize the deviation between day-ahead forecasted generation and actual generation.

In the following sections the regulatory frameworks in Spain and Germany are briefly described, focusing not on the exact standards per se, but instead on the selective use of financial incentives to encourage compliance with those standards. Though most countries simply apply mandatory grid codes to new wind power plants, both Spain and Germany have also established financial incentives to encourage compliance with Grid Codes in certain circumstances. This paper focuses on the use of Grid Code incentives as these are less common and, in some circumstances, may be appropriate for consideration in China.

4. Regulatory framework in Spain

In May 2007 the Decree 661/2007 [Dec 661/2007] has been issued which defines conditions and remuneration of electricity generated by renewable energy and fed into the grid (i.e., the feed-in tariff). Operators of wind power plants can choose between the following two feed-in tariff options:

1. Participation directly in the Spanish wholesale electricity market; in this case, a feed-in tariff bonus is paid within the first 20 years additionally to the hourly price obtained in the wholesale market.
2. Electricity sales to distributors; in this case, a regulated full feed-in tariff is paid (the tariff within the first 20 years is higher than afterwards).

In both options, a bonus or penalty is paid depending on reactive power supplied as described at **Section 4.1**. In the case of fault ride-through capability of the wind power plant an additional bonus is paid as described at **Section 4.2**. In the case of deviations from forecasted generation a penalty is deducted as described at **Section Error! Reference source not found.**

4.1 Supply of reactive power

As incentive to supply reactive power a bonus or penalty is calculated as a percentage of a reference tariff which presently has a value of 78.441 €/MWh. The percentage rates are shown in **Table 2**. Alternatively, operators of wind power plants can participate in a reactive power market which, as of yet, has not been implemented.

| Power factor | Bonus (+) or penalty (-) as percentage of reference tariff | | |
|-------------------------|--|-------------------|---------------|
| | Peak load | Intermediate load | Off-peak load |
| Inductive power | | | |
| < 0.95 | -4% | -4% | +8% |
| 0.95 – 0.96 | -3% | 0% | +6% |
| 0.96 – 0.97 | -2% | 0% | +4% |
| 0.97 – 0.98 | -1% | 0% | +2% |
| 0.98 – 1.0 | 0% | +2% | 0% |
| 1 | 0% | +4% | 0% |
| Capacitive power | | | |
| 1.0 – 0.98 | 0% | +2% | 0% |
| 0.98 – 0.97 | +2% | 0% | -1% |
| 0.97 – 0.96 | +4% | 0% | -2% |
| 0.96 – 0.95 | +6% | 0% | -3% |
| < 0.95 | +8% | -4% | -4% |

Table 2: Bonus or penalty for reactive power as percentage of reference tariff; source: [Rodriguez 2008]

During peak load, there is an incentive to supply capacitive power, during off-peak load there is an incentive to supply inductive power.

4.2 Fault ride-through capability

In the case of a fault of the grid (voltage sag) a power plant can be forced to shut down. This behavior increases the fault of the grid. Therefore, an incentive is given to wind power plant operators to provide fault ride-through capability so that the plant is not shut down in the case of a fault.

In the case that the wind power plant provides fault ride-through capability, a bonus of 3.8 €/MWh is paid. This is applied if the wind power plant has been installed before January 1st, 2008 and will be applied for 5 years [Rodriguez 2008].

4.3 Wind power forecast

An incentive is given that the actual electricity generation of the wind power plant is in line with the forecast for electricity generation prepared one day before. In the case of deviations the amount of electricity which deviates from the forecast is imposed with a penalty. This penalty is equivalent to the hourly market deviation costs. In the case of electricity sales to distributors, this penalty is applied only if the deviation is more than 5% of the electricity generation [Rodriguez 2008].

Wind power plant operators have to bear balancing responsibility and the balancing costs. This is different to Germany where wind power plant operators have no balancing responsibility [Hiroux 2010]. In Germany, balancing of power is entirely in the responsibility of the four transmission grid operators who themselves have to rely on the short term spot market for handling deviations.

4.4 Frequency control

Frequency control is mandatory for wind power plants. All generators have to be operated with a reserve margin of 1.5%. The power plant operators are not paid for this service. Alternatively, the frequency control service can be contracted from other resources, e.g. fossil fuel – fired power plants. In this case the wind power plant operator is released from frequency control obligation. This makes sense as frequency control is expensive for wind power plants to provide.

As an experience it can be said that wind power plant operators usually buy the release from frequency control obligation from other power plants [Pease 2008].

5. Regulatory framework in Germany

On October 25th, 2008 a Renewable Energy Law [EEG 2009] has been issued. It has been updated on December 22nd, 2009. Former versions of this law are from the years 2000 and 2004.

At Annex 5 of this law a reference electricity generation output is defined for a defined reference site. This depends on the wind power plant type and hub height.

The remuneration of electricity generated by wind power plants and supplied to the grid is 92 €/MWh for the first 5 years and 50.2 €/MWh thereafter. The first 5 years period is prolonged by 2 months for each 0.75 % of the reference output, by which the actual output of the plant is lower than the reference output. This compensates for poor sites.

§ 64 of the Renewable Energy Law entitles the German government to issue ordinances to improve grid integration of wind power plants. A system service ordinance [SDLWindV 2010] has been issued in 2009 and updated in June 16th, 2010.

It is distinguished between the following categories:

- Refurbishment of existing wind power plants commissioned after December 31st, 2001 and before January 1st, 2009 (§66 of Renewable Energy Law)
- Existing plants commissioned between January 1st, 2009 and July 1st, 2010
- New wind power plants commissioned after July 1st, 2010

For all categories, the ordinance includes, among others:

- Requirements on plant behavior in the case of a fault (fault ride-through capability)
- Requirements on frequency control.

For new plants requirements on voltage control and supply of reactive power are included additionally. New plants have to meet the requirements of the technical guidelines for generators connected to the intermediate voltage [MV Code 2008] or high voltage [Transmission Code 2007] grid respectively in respect to grid integration.

After April 1st, 2011 all new plants will need a certificate that they strictly meet the grid integration requirements: the grid code is required for these new plants. Therefore, it can be said that new plants are legally required to meet the standards, whereas for existing plants incentives are given.

For existing plants, incentives are offered for the plants to upgrade their equipment in order to meet the more-stringent new grid codes. In particular, existing plants (§66) receive a bonus of 7 €/MWh over a time period of five years if they meet the requirements for BOTH fault ride through and frequency control through refurbishment that is completed before January 1st, 2011.

In addition, new wind power plants that are commissioned prior to April 1st, 2011 will receive a temporary bonus of 5 €/MWh if they meet these requirements.

6. Implications for China

Mandatory grid codes have emerged as a best practice in many countries. Often, these are mandatory requirements that, at a minimum, must be met by new wind power plants. Both Germany and Spain, however, have also selectively used financial incentives to meet grid code requirements.

Spain has, historically, primarily relied on financial incentives for the provision of grid-friendly services from wind companies.

Germany, on the other hand, has relied more heavily on mandatory compliance requirements, although Germany does offer monetary incentives for early compliance with these requirements and to encourage existing wind plants to upgrade to the new standards.

Offering financial incentives to wind companies for complying with grid integration requirements may be a sensible option under certain restricted conditions, including:

- To encourage existing wind plants to meet newer and more stringent grid integration requirements, as a strict requirement that older plants meet the new standards may result in significant and unexpected costs for existing wind plants, and may result in contract abrogation or termination or even in the wind power plants ceasing operations
- To encourage early compliance with grid integration requirements that will strictly apply to wind power plants at a future date
- To encourage grid services that may not be required but that would be valuable for the grid (e.g., frequency control, up ramping); effectively, to encourage wind power plants to go beyond the strictly-required grid codes and meet even higher standards
- To encourage the use of grid-friendly turbines when it is difficult politically to implement a strong grid integration requirement

Policymakers in China may wish to consider whether paying financial incentives to wind generators may make sense under some of the specific conditions noted above, such as early compliance or for existing wind power plants, or whether a strict grid integration requirement is the preferred option under all circumstances.

7. References

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