ADAPTATION OF PROTECTIONS FOR COMPATIBILIZATION WITH FAULT RIDE – THROUGH CAPABILITY OF WIND FARMS

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ABSTRACT

The significant development of Distributed Generation (DG) using renewable energy sources can affect power system stability, in presence of a network disturbance which can lead to switch off a large amount of power installed in DG, since traditionally these power plants are disconnected from the network when a fault occurs.

However this reality has changed, so that Portuguese regulation reviewed Distribution Code Grid by introducing new requirements for DG, such as fault ride-through capability for wind farms, with the aim of promoting power system stability.

This paper describes network´s protection system changes that were introduced by Portuguese Distribution System Operator, in order to fit fault ride-through capability of some DG power plants. Towards interconnection protection, it is described changes in order to fit fault ride-through voltage characteristic. It is also described the functions needed at the Substation interconnection panel to allow auto-reclosure.

An example of an incident occurred in the Portuguese distribution network involving a wind farm with fault ride-through capability is also analysed.

INTRODUCTION

At the end of the year 2011, installed wind power capacity connected to Portuguese grid was 4603 MVA about 22% of the total installed power capacity. Of these 4603 MVA, 53% is connected to HV/ MV distribution grid and 47% to transmission grid. The sum of all renewable power capacity was about 54% of the total installed power capacity. [1]

The values referred above show the high weight of the renewable energies on the Portuguese network and particularly wind power.

In 2010, it was published a new regulation for DG power plants connected to Portuguese grid, which introduced requirements for low voltage ride-through capability of wind power plants.

This paper describes current Distribution Grid Code for wind power integration in Portugal on section 2, the adopted relay settings for the point of common coupling between distribution network and wind farms on section 3 and it is analysed the behaviour of a wind power station when faults occurred on its own feeder and on an adjacent line.

PORTUGUESE FAULT RIDE-THROUGH REGULATORY FRAMEWORK

Portuguese low voltage ride – through curve, a Voltage / Nominal Voltage vs. time characteristic, is represented in Figure 1 [2].

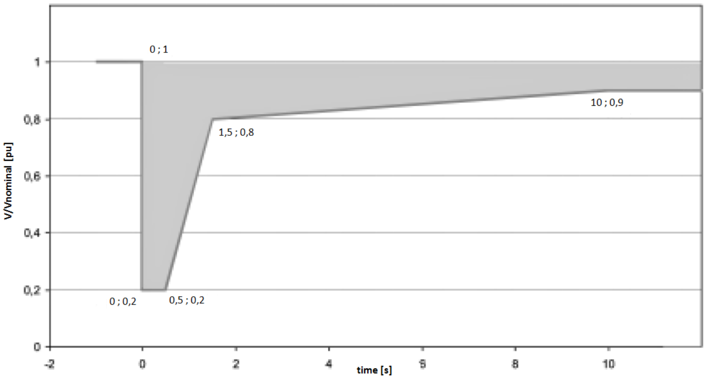

Figure 1 – Portuguese low voltage ride – through curve for distribution grid

Regulation defines that wind power stations with 6 MVA or more of installed power capacity that will connect to the distribution network after the regulation has been in force must follow the characteristic of Figure 1. Wind power stations that were already working before the new regulation must also follow the same voltage-time characteristic if its installed power capacity is equal or higher than 10 MVA.

Wind power plants that obey the conditions referred before, must be able to support single phase, biphasic or three phase faults, standing on-line whenever voltage on point of common coupling if above the specified curve.

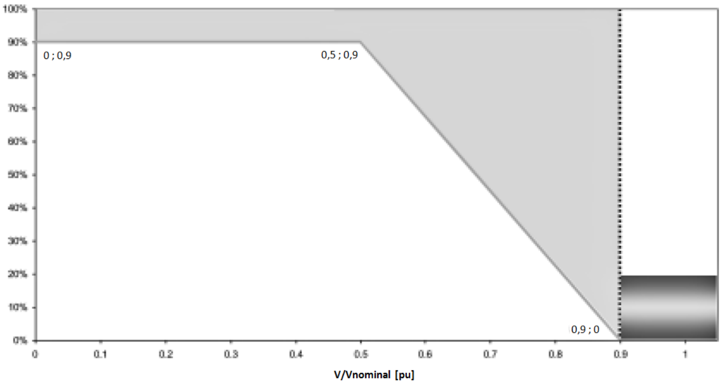

Figure 2 – Reactive current curve

In order to help the voltage recovery, wind generators must also supply reactive current according to Figure 2 [2]. This characteristic must start with a maximum delay of 50 ms after the fault be detected.

It is also defined on the regulation that wind farms must support frequency offsets between 47,5 Hz and 51,5 Hz.

RELAY SETTINGS TO MATCH FAULT RIDE-THROUGH

After the regulation about fault ride-throught applied to wind farms was published, Distribution System Operator defined the settings for point of common coupling. Such as indicated in Table 1, it was defined that undervoltage protection function must have three levels of operation. The voltage-time characteristic that resulted from these three levels is bellow the required low voltage ride-through curve, thus stricter.
Relay settings of Table 1 are applied for point of common coupling of a wind power plant connected to a medium voltage network for both cases of own line or shared line with another loads.

Protection Function		Setting	Trip Time
Ground Overvoltage	Level 1	10% (Impedance Neutral)	Maximum neutral time overcurrent of substation + 0,5s
		50% (Ungrounded Neutral)	2 x Maximum neutral time overcurrent of substation + 0,65s
	Level 2	70% (Impedance Neutral)	Instantaneous
Undervoltage	Level 1	80%	1,6s
	Level 2	25%	0,6s
	Level 3	18%	Instantaneous
Overvoltage	Level 1	115%	Instantaneous
Under Frequency	Level 1	49,5 Hz	Maximum time overcurrent of substation + 0,5s
	Level 2	47,5 Hz	Instantaneous
Over Frequency	Level 1	50,5 Hz	Maximum time overcurrent of substation + 0,5s
	Level 2	51,5 Hz	Instantaneous
Overcurrent	Level 1	130%Ilicensed	Maximum time overcurrent of substation + 0,5s
	Level 2	400%Ilicensed	Instantaneous

Table 1

In what concerns high voltage network, relay settings are similar to the ones presented on Table 1, however considering a different earthing system (solidly grounding).

On the other hand, main earthing system present in medium voltage is reactance grounding.

For comparison it is represented in Table 2 relay settings for a common DG power station that has not to obey low voltage ride-through curve and in case of being connected to an overhead line shared with another loads (explored with automatic reclosing, conditioned to voltage-check).

Protection Function		Setting	Trip Time
Ground Overvoltage	Level 1	10% (Impedance Neutral)	Maximum neutral time overcurrent of substation + 0,5s
		50% (Ungrounded Neutral)	2 x Maximum neutral time overcurrent of substation + 0,65s
	Level 2	70% (Impedance Neutral)	Instantaneous
Undervoltage	Level 1	85%	Maximum time overcurrent of substation + 0,5s
	Level 2	21%	Instantaneous
	Level 3	-	-
Overvoltage	Level 1	115%	Instantaneous
Under Frequency	Level 1	49,5 Hz	Instantaneous
	Level 2	-	-
Over Frequency	Level 1	50,5 Hz	Instantaneous
	Level 2	-	-
Overcurrent	Level 1	130%Ilicensed	Maximum time overcurrent of substation + 0,5s
	Level 2	400%Ilicensed	Instantaneous

Table 2

This reality introduced new challenges to Distribution System Operator, in order to ensure that protection system requirements of distribution network are not affected by the presence of a wind farm with ride-through fault capability, considering the following preventions:

i. Accidental islanding on the network;
ii. Out-of-phase reclosing;
iii. Increasing of unsuccessful automatic reclosing rate.

To meet these requirements, wind power stations, that started its operation after the publication of new regulation and which have that conditions (> 6 MVA), must receive a signal that order the open of interconnection breaker whenever the breaker of substation opens. This intertripping scheme guarantees that wind power station do not remain feeding a fault located on its own line.

However, older wind power stations which have adopted fault ride-through (> 10 MVA) are not required to have intertripping scheme. If this case happens, automatic reclosing on the substation can be impaired. It is possible to maintain automatic reclosing if substation panel has synchro-check relay for high voltage network or voltage-check relay for medium voltage network. Otherwise fast reclosing (isolation time of 300 ms) must be out of service.

INCIDENT ANALYSIS

At past day 24 November occurred two faults in the adjacent network of a wind farm with fault ride-through capability. This wind farm is connected to 15kV network on a dedicated line.

The first fault occured at 5 a.m. and was located on wind farm's line. The oscillographic records of the wind power station on point of common coupling are represented in Figure 3.

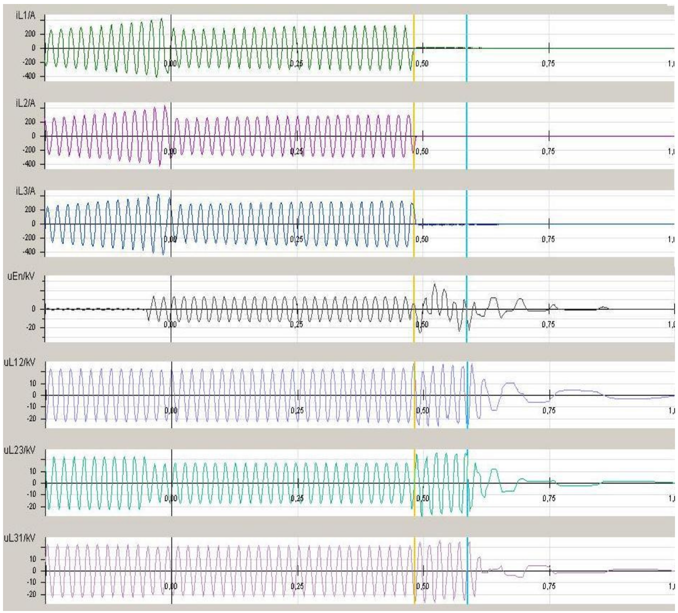

Figure 3 – Oscillographic records of 24 Novembre 5 a.m.

From the curves above it is possible to conclude that the fault was single line ground because of uEn (neutral voltage).
Initially, there was a relay pickup from ground overvoltage. This function has a trip time of 1s. However 480ms later the substation breaker opened and line current went to zero. After that, the neutral became ungrounding as only is grounded on substation side and for this reason voltage between phases started to increase. Voltage between phases 1 and 2 reached 17,3kV and 105ms later the relay tripped and the breaker opened.

The second fault occured at 6 a.m. and was located on a line connected to the same substation than the wind farm. The oscillographic records of wind power station on point of common coupling of this event are represented in Figure 4. Like the previous incident, this fault is also single line ground.
Initially there was a relay pickup from ground overvoltage. After 16ms the undervoltage function pickuped and maintained during 52ms. After 114ms from its pickup ground overvoltage function also normalized like happened with the voltage of the three phases. The fault was cleared at this time on the substation.

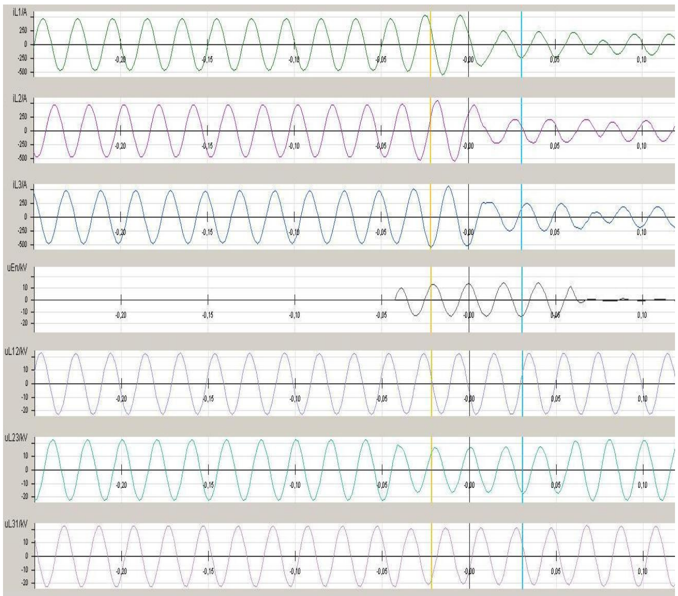

Figure 4 – Oscillographic records of 24 Novembre 6 a.m.

In these two incidents the wind power station behaved like expected, it remained on-line when the fault was not in its feeder and switched off when the fault was in its own line. So the low voltage ride – through curve was obeyed.

CONCLUSIONS

This paper showed in what way fault ride–through capability was implemented on wind farms connected to Portuguese distribution network regarding interconnection protection system. It was described the regulatory framework and the necessary protection system adaptation. Finally it was analyzed two incidents involving a wind farm with fault ride–through capability, which followed time-voltage characteristic successfully.
At the end of the year 2012, around 770 MVA of power capacity is installed on wind farms with fault ride-through capability connected Portuguese distribution network.

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