Forecast of cut out events in Emanuelle Cambilargiu 20 MW wind Farm.

Alejandro Gutierrez Arce[1],Jose Cataldo[1],Gabriel Cazes[1],Santiago de Mello[2],
[1]Instituto de Mecánica de los Fluidos e Ingeniería Ambiental, Facultad de Ingeniería,
Universidad de la República, Montevideo Uruguay.
[2]Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE), Montevideo, Uruguay.

ABSTRACT: The present work analyzes the power out put of Emanuelle Cambilargiu wind farm installed in a complex terrain topography with a total power capacity of 20 MW composed of 10 Vestas V-80 wind turbine. There are particular storm events that can produce abruptly change in power production. Particular event can produce power ramps also with cut out, this happen when the control system of wind turbine composed with an anemometer installed in the nacelle of the wind turbine compute in the time integration that depends on the model of the machine a velocity higher than 25 m/s. Such kind of event are related with unstable condition in the atmosphere, in this work is defined a window time condition when there is forecast the power ramp, we define a alarm in this sense when the model forecast a gust that can change abruptly the production of the wind farm. The alarm is implemented with the ECMWF gust model. The work present results of WRF simulation with four different domain 30-10-3.3-1.1 km, was found that in terms of computational cost for a operational model the optimal horizontal size that has a reasonable skill cut out event forecast is 3 km.

KEY WORDS: wind farms; forecast; cut out.

1 INTRODUCTION

Wind farms analyzed in the present work are in the south-central region of South America (Uruguay). The data were provided by the national public utility of Uruguay (UTE). By 2016, the projected installed wind power capacity in the country will reach a penetration factor in the electrical system of 24 % . The present work addresses wind energy numerical forecasts for these operational wind farms over the last years. Electrical energy produced and input to the electrical grid is from the transformation of available kinetic energy in the atmospheric boundary. Thus, it is of interest to conduct numerical simulation of the near-surface atmosphere. Wind energy is a resource with significant fluctuation over short periods.

That is, there are substantial hourly variations of mean energy input to the grid, which indicates that wind energy must be complemented by other energy resources, such as those of a hydraulic or thermal power plant. A wind energy forecast gives information on the future to assist the dispatch of electrical power with minimal cost, using an objective function. There are particular storm events that can produce abruptly change in power production. In particular storm event can produce power ramps also with cut out, this happen when the control system of wind turbine composed with an anemometer installed in the nacelle of the wind turbine compute in the time integration that depends on the model of the machine. Such kind of event are related with unstable condition in the atmosphere, in this work is defined a window time condition when there is forecast the power ramp, we define a alarm in this sense when the model forecast a gust that can change abruptly the production of the wind farm.

1.1 *Emanuelle Cambilargiu wind farm.*

Emanuelle Cambilargiu farm is atop Caracoles Ridge in Maldonado. Its total installed power is 20 MW. There are 10 Vestas V80 2MW wind turbines aligned on the ridge, Figure 2, micro siting with the location of the ten wind turbine Vestas V-80 and power curve

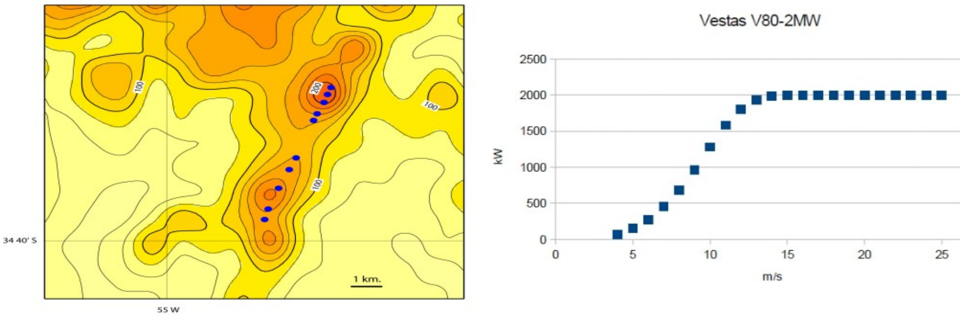

Figure 1. Emanuelle Cambilargiu wind farm micro siting

2 CUT OUT FORECAST

2.1 *Cut out and gust.*

Cut out velocity is defined in design of wind turbines in order to preserve the mechanical structure in the occurrence of extreme wind event, the value of this velocity and how is computed can vary form one model of wind turbine to other, the most common value presented by different wind turbine is a velocity of cut out 25 m/s. The control of the machine stop abruptly the production in when the cut out velocity is measured by anemometer installed in the nacelle, this a relevant event in terms of the electrical grid because the flux of energy come from nominal power production to zero, the cut out event could happen in one or more machine of the wind farms, in dependence of the scale of the event can impact in the total production, in a small lapse of time.

Strictly speaking, only wind fluctuations with periods shorter than a given sampling period T should be taken into account; i.e., a gust should be determined with reference to a stationary average speed. For this work is computed and used in the analysis a hourly mean and gust with WRF [1] and European Center for Medium-Range Weather Forecasts (ECMWF) [2]. This work considers the gust:

$$g = max[V(t)] \tag{1}$$

The ECMWF presented a model of gust based on [3], the resulting wind gust as a function of mean velocity $\bar{V}$ and friction velocity ust was,

$$g = \bar{V} + 7.71\, ust \tag{2}$$

2.2 *Cut out event forecast with WRF- ECMWF*

WRF model was running with four, by each tower, two-way nesting are used with grid spacings of 30-km, 10-km, 3.3-km, and 1.1-km [3]. The 30-km domain covers the most a significant region of South America, centered in Rio de la Plata, and the 10-km domain covers the tower location, the 3.3-km and 1.1-km domain covers the tower location. All simulations utilize 53 vertical layers with the model top at 100 hPa. The lowest model sigma levels are at 1, 0.9987, 0.9974, 0.9948, 0.9922, 0.9896, 0.98693, 0.9843 and 0.9777. The physical parameterization schemes used in all model domains include in Radiation longwave and short wave the NCAR Community Atmosphere Model CAM [4] , Purdue Lin microphysics [5], and the Noah land surface scheme [6]. A cumulus scheme is not used on the 3.3 km fine domains while in 30-km and 10-km domain are used the Kain-Fritsch [7], and MYJ PBL scheme [8] . The National Centers for Environmental Prediction (NCEP) global forecast system (GFS) operational global analyses are used for initial conditions and boundary conditions.

In this work is defined a forecast of cut out event in terms of and alarm when gust forecast by WRF-ECMWF is greater than an gust that define the Alarm g_{Alarm},this parameter need to by calibrated with historical information related with event in each wind farm to obtain the optimal value. The alarm is defined in terms of a window of time than could happen the event to give the information to technical personal who work in the dispatch of the electrical grid, that strong event who could change the flux of electric energy in the region of wind farm have a True Event probability. A event of cut out is defined when at less one wind turbine stop and report in the SCADA a cut out. The window of time to count as a True Event success is defined in this work when the Alarm is activated at 12 hours or less before $\bar{V}+7{,}71ust>g_{Alarm}$, 12 hours or less after $\bar{V}+7{,}71ust<g_{Alarm}$, the skill of grid resolution is computed with a telescopic WRF simulation in four different grid domain 30-km, 10-km, 3.3-km, and 1.1-km . Alarm is activated, as follow in (3)

If

$$\bar{V}+7{,}71ust>g_{Alarm} \tag{3}$$

Alarm is activated at start time $t=t_{g>g_{Alarm}}-12h$ Alarm=1

Alarm is activated at finish time $t=t_{g<g_{Alarm}}+12h$ Alarm=1

else

Alarm=0

end

A event of cut out is defined when at less one wind turbine stop and report in the SCADA a cut out. The window of time to count as a True Event success is defined in this work when the Alarm is activated at 12 hours or less before $\bar{V}+7{,}71ust>g_{Alarm}$, 12 hours or less after $\bar{V}+7{,}71ust<g_{Alarm}$, the skill of grid resolution is computed with a telescopic WRF simulation in four different grid domain 30-km, 10-km, 3.3-km, and 1.1-km . Also is computed the False Alarm events when the Alarm is activated and the cut out event did not happen.

Probability of True Event is Skill computed as follow in (3), and probability of False Alarm is computed as follow in (4)

$$True\ Event\ Skill=\frac{Number\ of\ cases\ True\ Event\ Cut\ Out\ Alarm\ Forecast\ Sucess}{Total\ Cut\ Out\ Event} \tag{4}$$

$$False\ Alarm\ Probability=\frac{Number\ of\ False\ Alarm}{Total\ Alarm\ Activated\left(True\wedge False\right)} \tag{5}$$

Difference of time defined as Δt_{Begin} is computed as the difference between the Event begin and time when $g>g_{Alarm}$, (5)

$$\Delta t_{Begin}=t_{Start\ cut\ out}-t_{g>g_{Alarm}} \tag{6}$$

Difference of time defined as Δt_{End} is computed as the difference between the event finish and time when $g<g_{Alarm}$, (6)

$$\Delta t_{End}=t_{Finish cut\ out}-t_{g>g_{Alarm}} \tag{7}$$

In table 1 is presented the result for Alarm Forecast for full year of forecast running 2012 in E. Cambilargiu Wind Farm.

	Cut Out Begin (DD/MM/YY hh:mm)	Total Duration (hh:mm)	Wind Turbines Afected (#)	Alarm 30km	Δt 30km Begin (h)	Δt 30km End (h)	Alarm 10km	Δt 10km Begin (h)	Δt 10km End (h)	Alarm 3.3km	Δt 3.3km Begin (h)	Δt 3.3km End (h)	Alarm 1.1km	Δt 1.1km Begin (h)	Δt 1.1km End (h)
Event_1	31/01/12 03:33	**01:33**	7;6;8;9;10;10	0	---	---	0	---	---	1	0	-2	1	0	-2
Event_2	05/03/12 20:41	**03:39**	9;1;4;6;5;2;10;3;1;6;7;2;8;10;4;3	0	---	---	0	---	---	0	---	---	0	---	---
Event_3	08/08/12 02:54	**04:38**	7;8;10;9;4;6;10;10;9;6;4;10;9;6;4;10;10	0	---	---	0	---	---	1	0	-2	1	4	4
Event_4	11/08/12 23:36	**00:25**	7;8	0	---	---	0	---	---	0	---	---	0	---	---
Event_5	14/08/12 22:33	**09:03**	7;9;10;8;8;8	1			0	---	---	1	0	1	1	0	0
Event_6	22/08/12 22:12	**06:58**	7;8;8;10;9;6;6;4;8;8	0	---	---	0	---	---	1	2	-10	1	5	-11
Event_7	24/08/12 05:54	**00:58**	7;	1			0	---	---	1	-10	0	1	-11	0
Event_8	04/09/12 05:33	**05:41**	7;8	0	---	---	0	---	---	1	1	6	1	-11	-11
Event_9	19/09/12 01:42	**00:42**	7;10;4;9;7;9	1			1	10	-2	1	-13	-13	1	-13	-13
Event_10	19/09/12 10:51	**08:55**	7;4;1;4;7;5;4;1;7;8;8;10;2;4;7;7;7;4;7;4;4;10;10;7;4;10;7;9;8;4;8;5;1;2;3;6;3;7;10;1;2;7;9	1	-3	-4	1	2	-1	1	-5	-2	1	-4	-4
Event_11	23/10/12 02:45	**12:31**	4;10;7;9;9;5;2;1;3;10;4;2;9;3;5;7;7;7;7;7;7;8;7;7;3;2;7;9;10;7;7	1	-1	-3	1	-3	1	1	3	-14	1	3	-4
Event_12	30/10/12 11:12	**00:33**	7;4;8	0	---	---	0	---	---	0	---	---	0	---	---
Event_13	09/11/12 16:33	**00:17**	7;7;1;4	0	---	---	0	---	---	0	---	---	1	5	7
Event_14	07/12/12 00:22	**00:56**	7;10;9;1;4;8;2;3;5	1			0	---	---	1			1	1	3
Event_15	16/12/12 15:51	**00:09**	2;	0	---	---	0	---	---	0	---	---	0	---	---
Event_16	25/12/12 04:56	**00:29**	10;10	1	-8	-8	0	---	---	1	-2	-11	1	1	-11
Event_17	31/12/12 16:33	**00:24**	4;3;2;10;9;1;6;8;7;5;6;7	0	---	---	0	---	---	1	-1	0	1	-1	0
		N°False Alarm		5			2			14			15		
		True Event Skill (%)		**41%**			**18%**			**71%**			**76%**		
		False Alarm Probability (%)		**42%**			**40%**			**54%**			**54%**		

Table 1. Alarm Forecast for full year of forecast running 2012 in Emanuelle Cambilargiu Wind Farm

In Figure 2 is presented for Cut Out Event 3 mean velocity forecast in continuous, semi continuous WRF- ECMWF gust, green 30 km, blue 10 km, magenta 3.3 km, red 1.1 km, power out put of wind farm in black

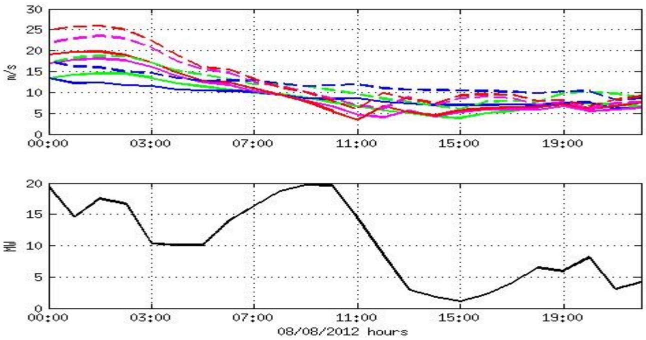

Figure 2. Cut Out Event 3 in Emanuelle Cambilargiu Wind Farm

As can be seen also when the cut out event has gone after 07:32 there is abruptly change in power production, there is wind power ramp event related with gusty condition in planetary boundary layer wind flux. The grid domain with higher resolution can catch the cut out condition, there are scale of the physical process associated with the unstable condition that can be better respresented by the model with a resolution of 3.3 km and 1.1 km, the optimal grid resolution in terms of computational cost for a operational model is 3.3 km.

CONCLUSION

The present work analyzes the power out put of Emanuelle Cambilargiu wind farm installed in a complex terrain topography with a total power capacity of 20 MW composed of 10 Vestas V-80 wind turbine. There are particular storm events that can produce abruptly change in power production. Particular event can produce power ramps also with cut out, this happen when the control system of wind turbine composed with an anemometer installed in the nacelle of the wind turbine compute in the time integration that depends on the model of the machine a velocity higher than 25 m/s. Such kind of event are related with unstable condition in the atmosphere, in this work is defined a window time condition when there is forecast the power ramp, we define a alarm in this sense when the model forecast a gust that can change abruptly the production of the wind farm. The alarm is implemented with the ECMWF gust model. Also when the cut out event has gone after there is abruptly change in power production, there is wind power ramp event related with gusty condition in planetary boundary layer wind flux. The grid domain with higher resolution can catch the cut out condition, there are scale of the physical process associated with the unstable condition that can be better represented by the model with a resolution of 3.3 km and 1.1 km.

The work present results of WRF simulation with four different domain 30-10-3.3-1.1 km, was found that in terms of computational cost for a operational model the optimal horizontal size that has a reasonable skill cut out event forecast is 3 km.

ACKNOWLEDGMENTS

The present results were from the development of project ANII FSE-2009-29 and recent advances of an agreement for implementation of a forecast system of wind energy power input to the national grid between the Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE), and School of Engineering UdelaR, and project ANII FSE-2011-6562.

REFERENCES

[1] Skamarock, 2008 NCAR/TN 475+STRNCAR TECHNICAL NOTE June 2008 A Description of the Advanced Research WRF Version 3
[2] IFS DOCUMENTATION Cy37r2Operational implementation 18 May 2011 PART IV: PHYSICAL PROCESSES
[3] Cornalino Eliana, Martín Draper. Planning the distribution of wind farms in Uruguay in order to optimize the operability of large amounts of wind power. EWEA 2012 Annual Event Monday 16 - Thursday 19 April 2012 | Bella Center, Copenhagen, Denmark http://www.ewea.org/annual2012/
[4] Collins W.D et al 2004: Description of the NCAR Community Atmosphere Model (CAM 3.0), NCAR Technical Note, NCAR/TN-464+STR, 226pp
[5] Lin, Y.-L., R. D. Farley, and H. D. Orville, 1983: Bulk parameterization of the snow field in a cloud model. J. Climate Appl. Meteor., 22, 1065-1092.
[6] Chen, F., and J. Dudhia, 2001: Coupling an advanced land-surface/ hydrology model with the Penn State/ NCAR MM5 modeling system. Part I: Model description and implementation.Mon. Wea. Rev., 129, 569?585.
[7] Kain, J. S., 2004: The Kain-Fritsch convective parameterization: An update. J. Appl. Meteor., 43, 170?181.
[8] Mellor, G. L., and T. Yamada, 1982: Development of a turbulence closure model for geophysical fluid problems. Rev. Geophys. Space Phys., 20, 851-875.