LOSSES ANALYSIS IN THE VIESGO POWER DISTRIBUTION SYSTEM

Losses analysis and key improvements

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1. INTRODUCTION

The purpose of this report is to evaluate the losses of VIESGO (From high voltage to medium voltage). The grid of analysis is limited by the following boundaries:

- Interconnections to the HV transmission grid
- The generation busbars connected to the distribution grid
- The MV busbars where the load demand has been aggregated. Consequently the grid of analysis does not include the radial lines from the MV busbars to the MV/LV distribution transformers

The cases of analysis are provided by VIESGO and correspond to different generation levels. The aim of the studies is the evaluation of the system losses variation depending on the generation level and the type of generation involved (hydro, wind, thermal). Additionally it is also evaluated the influence of the power demand depending on the case study.

Studies have been conducted with the PSS®E (Power Transmission System Planning) software in version [03]: 32.2.3 April 25, 2014

The document structure has the following main chapters:

1 Introduction. Studies and document introduction.

2 Cases of analysis. Short description of the considered study cases.

3 Losses analysis. It contains the analysis and results. Also includes the evaluation of the different sensitivity analysis.

4 Conclusions. A summary of the main observations.

1.1. REFERENCE DOCUMENTS

[01]. 14SV01306U01RA Oferta
[02]. 14SV01306M01R01 Resumen reunión lanzamiento
[03]. 14SV01306V01R00 Consideraciones y observaciones
[04]. CASOS_DE_ESTUDIO Resumen de zonas y casos de estudio
[05]. Estudio_ABB.zip Casos de estudio en formato .sav.
[06]. Mail 18/02/2015 RE: ABB Proyecto 14SV01306 Estudios de pérdidas EON: Teleconferencia 12/02/2015
[07]. GENERACION_CASOS_PSSE
[08]. 14SV01306M02R01 Acta reunión revisión del informe.
[09]. Mail 22/04/2015, Mail 18/05/2015
[10]. Estudio_ABB_0.sav

Figures list:

Tables list:

2. CASES OF ANALYSIS

The network under consideration corresponds to the current VIESGO distribution grid in Cantabria, Asturias, Castilla y Leon and Lugo. For the analysis in this study sixteen different generation scenarios are provided by VIESGO in a format valid for simulation in the program PSS®E (Power Transmission System Planning). See Appendix 14SV01306V02 for more details of the cases and other considerations.

The study cases correspond to sixteen operation and generation conditions of VIESGO grid in Cantabria, Asturias, Castilla y Leon and Lugo. These cases pretend to be representatives of usual operating scenarios of the VIESGO grid and they combine different degrees of each generation type installed in VIESGO grid: wind, hydroelectric and thermal. The following Table 1 and Figure 1 show a relation between the cases and the percentage of generation associated to each study case.

Table 1 Relation between each case of study, the generation in percentage and the type of generation.

(%) WIND	(%) HYDRAULIC	(%) TERMAL	CASE
0%	0%	100%	*1*
	30%	70%	*2*
	60%	50%	*3*
	100%	30%	*4*
30%	0%	70%	*5*
	30%	50%	*6*
	60%	30%	*7*
	100%	20%	*8*
60%	0%	50%	*9*
	30%	50%	*10*
	60%	30%	*11*
	100%	20%	*12*
100%	0%	50%	*13*
	30%	30%	*14*
	60%	20%	*15*
	100%	20%	*16*

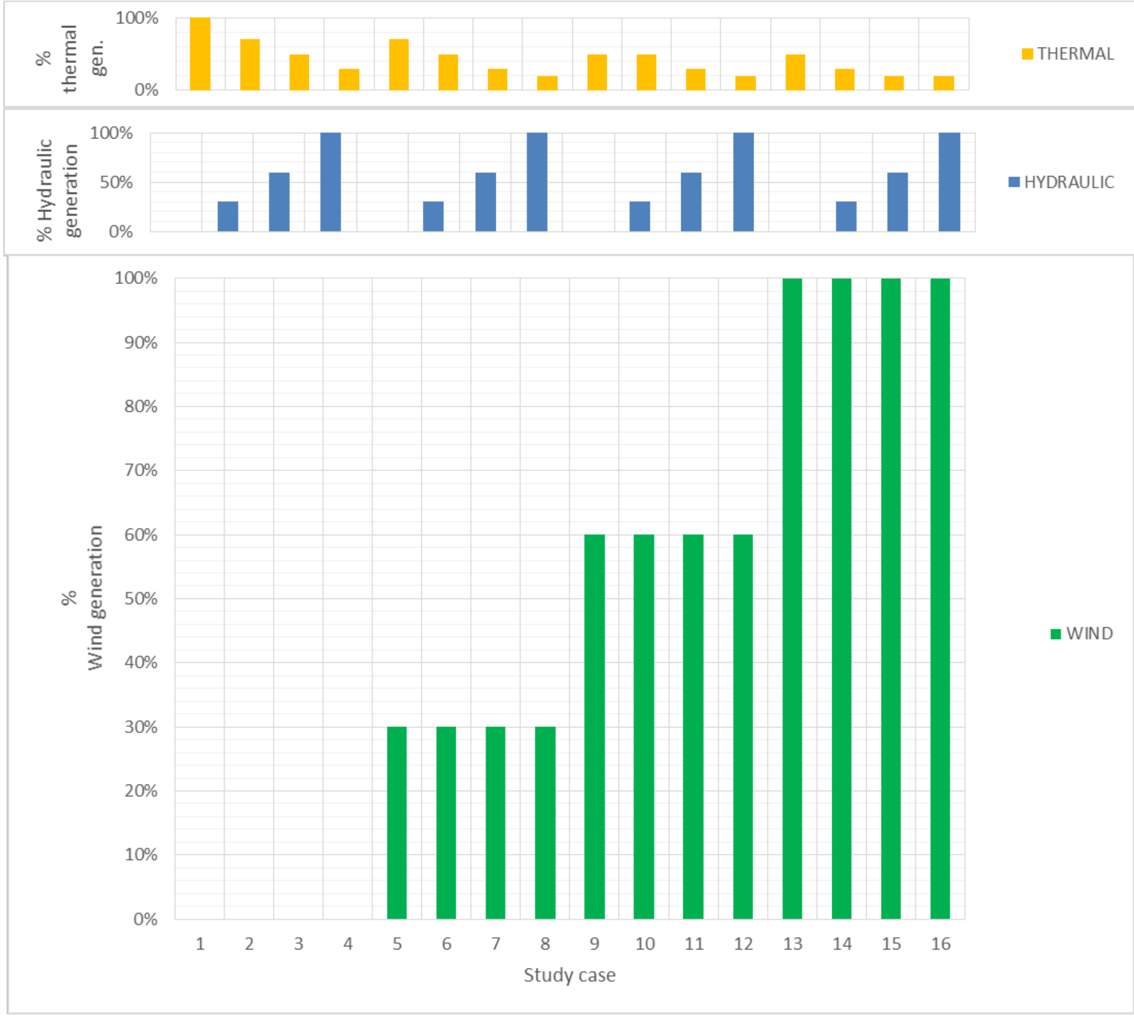


Figure 1 Representation of the generation for each case of study. Classification based on generation types according to Table 1.

In relation to the frontier interconnection points of the distribution grid with other systems a total of 26 points are considered, which can be divided in lines and transformers:

- Nine lines (eight 132 kV lines and one 55 kV line)
- Seventeen transformers (three 220/132 kV, six 400/132 kV, one 220/30 kV and six 220/55 kV).

For losses evaluation purposes it is considered as criteria that the interconnection losses are associated to the VIESGO grid (except for the Boimente 400/132 kV transformer). The appendix 14SV01306V02 includes the list and details of the considered interconnections.

In relation to the considered power demand at medium voltage side, as criteria it is considered a constant power demand for all cases with a value of 832 MW.

3. LOSSES ANALYSIS

Next sections detail the losses evaluation results considering different situations and sensitivities.

3.1. TOTAL LOSSES

VIESGO grid system has wind, hydro and thermal generation installed, it is also interconnected with other external networks mainly with the transmission network of REE.

The following Figure 2 shows, for each case study:

- The power from generation sources (MW),
- The power demand at the medium voltage level
- Power exchange with the external grids: Imported (negative values) / exported (positive values).

The figure shows that the higher the generation is the higher the power exported is. It is noted that from Case 8 on, the power flow through the interconnections change from import to export. For the reference Case 8 represents a total internal generation at VIESGO grid of 895 MW. Due to the consideration of constant power demand from medium voltage distribution for each study case, the power demand values are represented with a horizontal line.

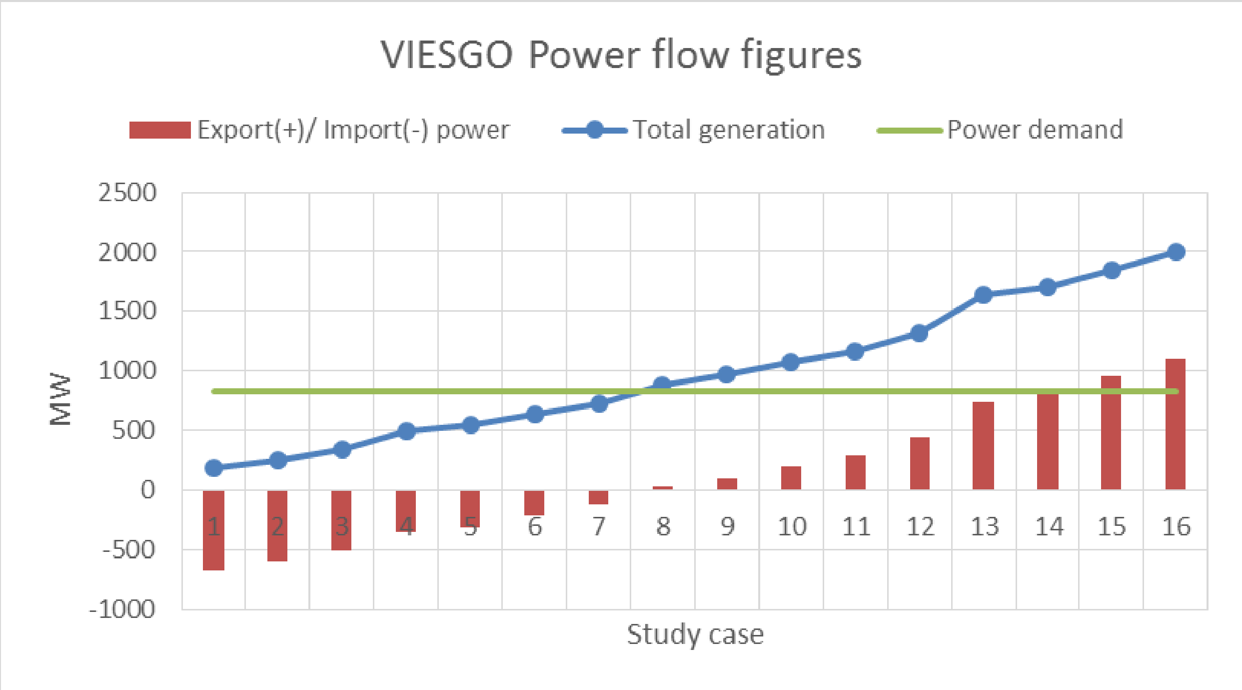


Figure 2 VIESGO Export, demand and generation power balance

The energy distribution from the generation points to the boundaries, i.e to the internal demand and/or to the interconnection points, causes losses associated to the distribution system. Since the considered power demand for the study is constant, the losses increase with the increase in generation.

The next Figure 3 shows the values of the losses that were found in the area of analysis. The losses values are represented versus the values of the total generation. It is included the values associated to the provided case: Estudio_ABB_0.sav that represents an internal generation in VIESGO grid of near zero MW.

In next sections 3.2 and section 3.3, it will be analysed and represented the losses by different voltage levels and different VIESGO areas.

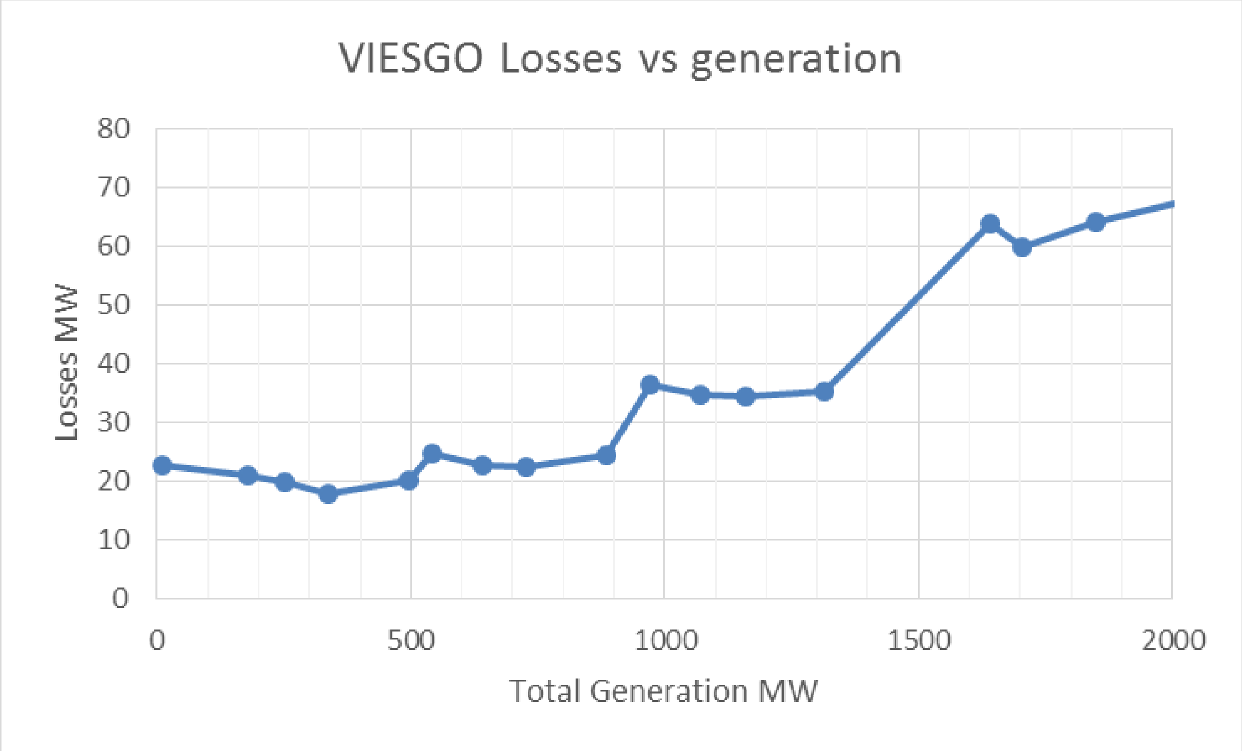


Figure 3 VIESGO Losses versus generation

As seen in Figure 3 above, the progressive increase in the generation marks a general trend of increase in the system losses.

Four situations are also seen with an increase and subsequent slight decrease in the losses. These peaks correspond to different generation levels of 191 MW (Case 1), 554 MW (Case5), 981 MW (Case 9) and 1652 MW (Case 13). The aforementioned cases correspond to generation cases where wind generation suffers an increase considering the correspondent case number sequence and hydro generation is at minimum. e.g. in the sequence of study cases: Case1, case 2 case 3 and case 4, case 1 represents the maximum wind generation and minimum hydraulic generation and next cases 2 to 4 represent an hydraulic generation increase.

Considering the cases of analysis when hydraulic generation increases and wind generation remains constant the losses are slightly reduced. See Table 1 for identifying generation levels by case.

As a summary it can be highlighted the following observations:

- The general trend in the level of losses is an increasing trend with increasing level of generation.
- Increasing wind generation leads to a losses increase.
- For each level of wind generation, the presence of hydraulic generation in service slightly decreases the losses in the grid system.

The following Figure 4 shows the percentage of losses based on internal power demand from VIESGO (% absolute losses divided by total internal power demand). The percentage in losses is represented versus the export/import power flows with the external grid. For the interpretation of the values represented it has been considered that: negative horizontal values correspond to import power (power from the external grid into VIESGO), while positive horizontal values indicate export power (power from inside the VIESGO grid to the external grid). Similarly to Figure 3 above, Figure 4 represents an upward trend in the percentage values depending on the power export level

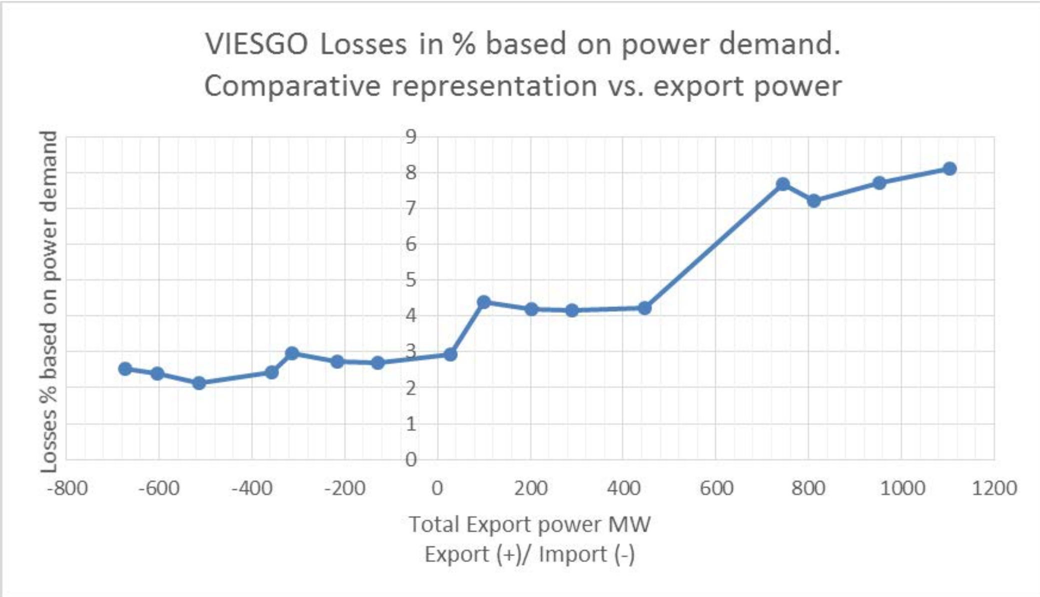


Figure 4 VIESGO Losses in percentage based on power demand. Comparative representation with export power

Regarding to study cases Case 1 to Case 16, these represent an upward trend of total generation. The following Figure 5 shows the percentage of losses based on power demand for each of the study cases: (% of total losses divided by internal power demand at VIESGO grid).

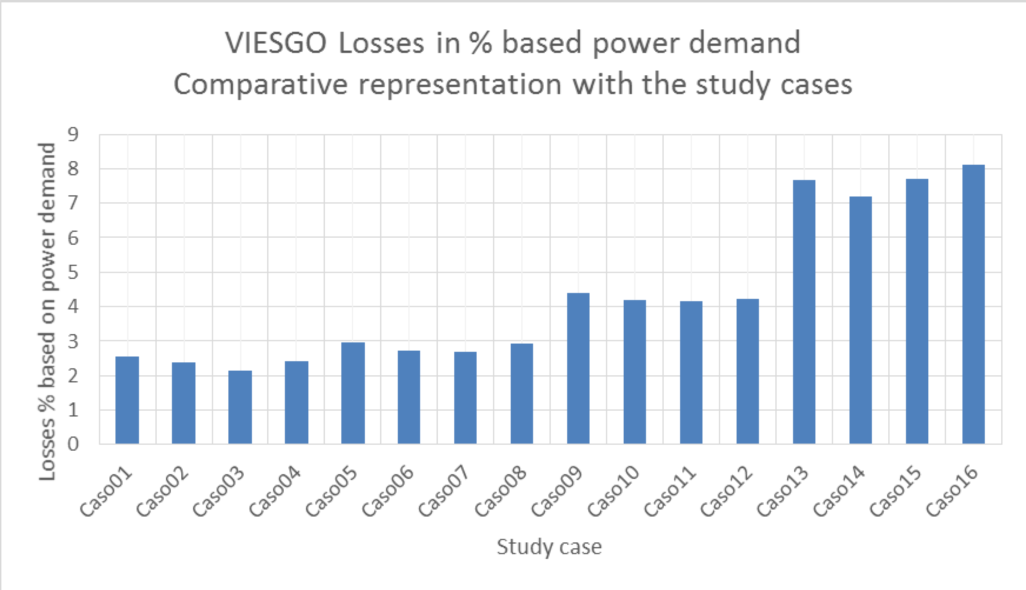


Figure 5 VIESGO Losses in percentage based on power demand. Comparative representation with the study cases

The previous Figure 3, Figure 4 and Figure 5 represent the trend of losses and the losses in percentage based on power demand. Since it has been considered that the internal power demand does not vary for each study case, both the absolute values of losses and the percentage value of losses relative to power demand, follow the same trend.

Alternatively to the losses evaluated in the previous figures, in the following Figure 6 the losses are calculated in percentage as follows absolute losses divided by: the values of total power demand plus export/import power exchange with the external grid.

The following Figure 6 shows in the vertical axis the absolute value of the equation: 100*losses/(power demand+Net exchange). Where net power exchange will be positive if net power is exported and negative if net power is imported.

On the horizontal axis the net power exchanged of VIESGO grid with the external network is shown. Positive values represent power export ie from VIESGO grid to external grid, and negative values represent power import ie from external grid to VIESGO grid

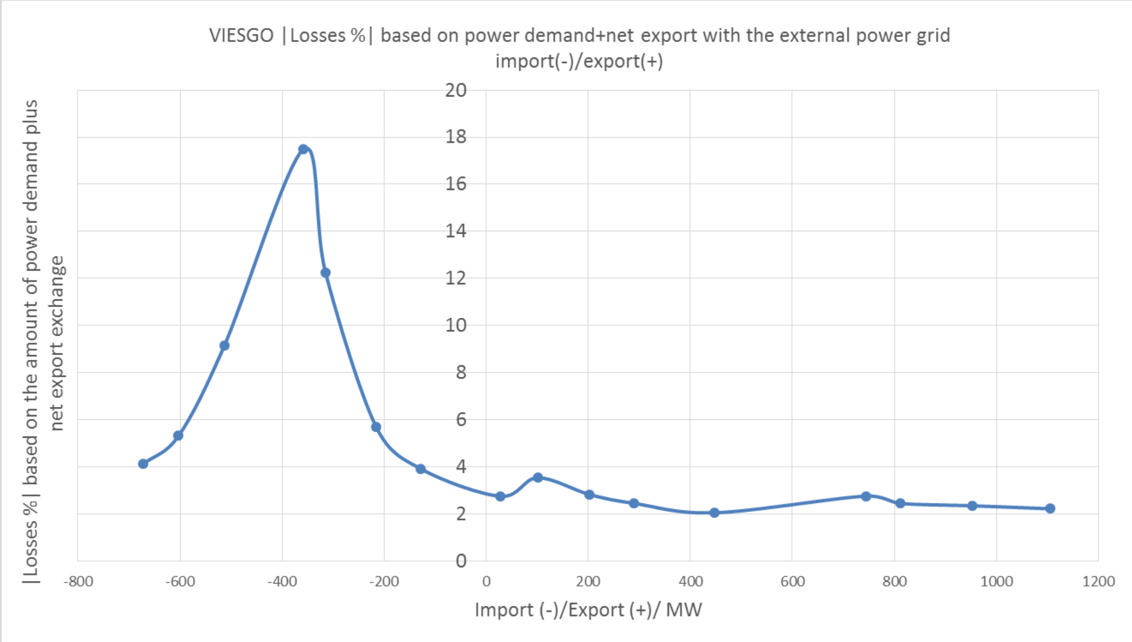


Figure 6 VIESGO Absolute value of losses in percentage base on power demand+net export. Comparative representation with export power demand

Figure 6 shows that with net exporting power flows, the losses level are between 2 to 4% (% values relative to consumption plus net exports). By contrast with values for net importing power flows, the losses in percentage are very high, even with absolute values of around 18% for some scenarios of study.

3.2. LOSSES BY VOLTAGE LEVELS

In this section the level of losses in VIESGO distribution grid for each voltage level is analysed. The voltage levels to be considered are grouped into the following classes:

- 220 kV: Corresponds to the 220 kV transmission level assigned to VIESGO.
- 132 kV: Corresponds to the distribution level. Distribution power flows as well as power demand power flows goes through this voltage level.
- 55 kV: Corresponds to the distribution level. Distribution power flows as well as power demand power flows goes through this voltage level.
- 30&20 kV: This voltage level contains several 30 kV lines and transformers with 20 kV voltage level according to the cases of analysis. According to the initial considerations for the study, the losses associated to the medium voltage level for distribution purposes to the transformers MV/LV are not included. The only medium voltage system considered in the losses evaluation corresponds to the transformers for generation units and some 30 kV lines.
- <20 kV: Level corresponding to the generation plants, their ancillary services or other supplies associated to generation plants, according to the provided studies cases.

In Figure 7 two magnitudes are represented. On the one hand in a bar chart lists the results of the percentage of losses, associated with each voltage level considered. 100% is the total value of the losses. The values are associated to the left vertical axis.

With a solid line by each case study (Case 1 to Case 16) the absolute values of total losses are represented. Different curves represent the absolute losses by each voltage levels are. Values are associated with the right vertical axis.

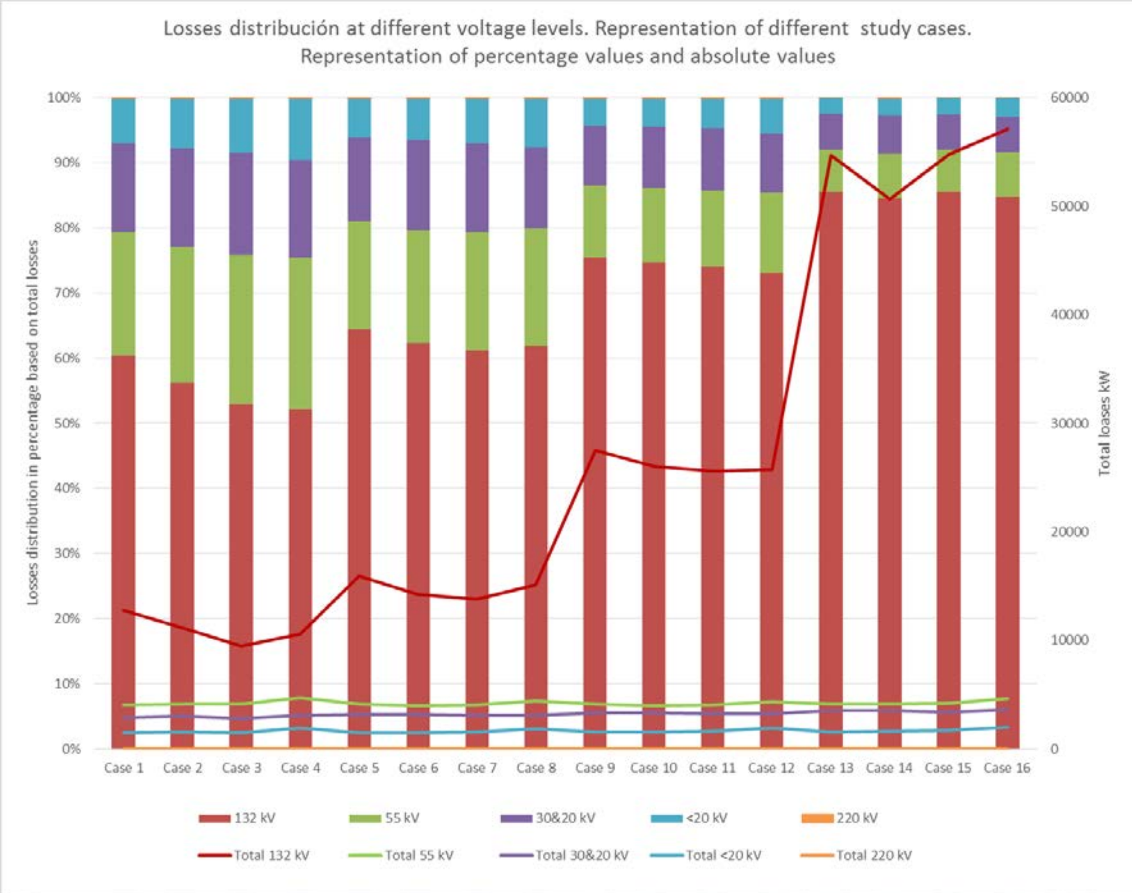


Figure 7 Distribution in percentage of losses by voltage levels. Representation of losses distribution for each case of study

Next Table 2 represents the values of the losses (kW) associate to the Figure 7

Table 2 Losses classified by each case of study and by each voltage level

	Losses kW by each cases of study and by each voltage level					
	220 kV	132 kV	55 kV	30&20 kV	<20 kV	Total
Case 1	9	12779	4012	2897	1456	21153
Case 2	10	11184	4146	3024	1528	19893
Case 3	10	9427	4083	2798	1491	17809
Case 4	10	10551	4671	3053	1915	20200
Case 5	9	15900	4094	3170	1503	24676
Case 6	10	14203	3968	3121	1484	22786
Case 7	10	13765	4061	3086	1566	22488
Case 8	10	15074	4411	3050	1830	24375
Case 9	10	27514	4091	3337	1551	36502
Case 10	10	26042	3982	3294	1525	34853
Case 11	10	25581	4046	3256	1617	34510
Case 12	10	25751	4367	3206	1915	35248
Case 13	10	54684	4128	3501	1561	63883

	Losses kW by each cases of study and by each voltage level					
	220 kV	132 kV	55 kV	30&20 kV	<20 kV	Total
Case 14	13	50700	4107	3507	1623	59951
Case 15	10	54787	4188	3412	1682	64077
Case 16	10	57106	4625	3587	2018	67345

From the results shown in the Figure 7, it can be observed that the 132 kV level is the one that represents the greatest losses compared to other voltage levels. This 132 kV level represents between 53 to 86 percent of total losses. The absolute values of losses are greater with higher wind generation. The next voltage level with significant losses contribution is 55 kV, the losses values for 55 kV are between 6 to 23 percent.

If we compare the different cases, it can be observed that the higher wind generation (Cases 13, 14, 15, 16) is the higher the percentage of loss in the level of 132 kV (85%) is. In case of low wind generation or zero (e.g. Cases 1 , 2, 3, 4) the levels of losses at 132 kV represents between 53-65%.

3.3. LOSSES BY VIESGO AREAS

Before analysing the losses associated to each VIESGO grid area, the amount of generation associated with each region will be detailed. The following Figure 8 shows a comparison, based on the study cases, of the evolution of the total generation amount in each VIESGO area. It is noted that the Galicia region has a greater amount of generation compared to others. Cantabria and Castilla areas have less generation.

Study cases Case 1 to Case 16, on which the study has been performed, represent a progression in the total generation levels. In particular each group of four study cases (i.e: group of cases 1 to 4, group cases 5 to 8, case group 9 to 12 and case group 13 to 16) they have the same level of wind power each group. Each group of commented four cases has different combinations of hydraulic and thermal generation. Moreover wind energy is constant in the same group of four cases and increase in study cases with higher number. (See Table 1).

With the above consideration it can be seen in Figure 8 that particularly in Galicia the increase of wind energy sets the trend of increasing the total generation. Therefore it is observed that in Galicia the generation increases every four study cases. In the region of Asturias generation also increases with the increase in wind generation. In Asturias the presence of other generations causes that the total generation does not follow the trend of the wind generation, and there are variation in the generation values depending on the amount of other type of generations. In Figure 8 it can be seen that Asturias generation fluctuate in cycles of four cases, and at the beginning of each cycle there is a decrease trend depending mainly on the hydraulic variations.

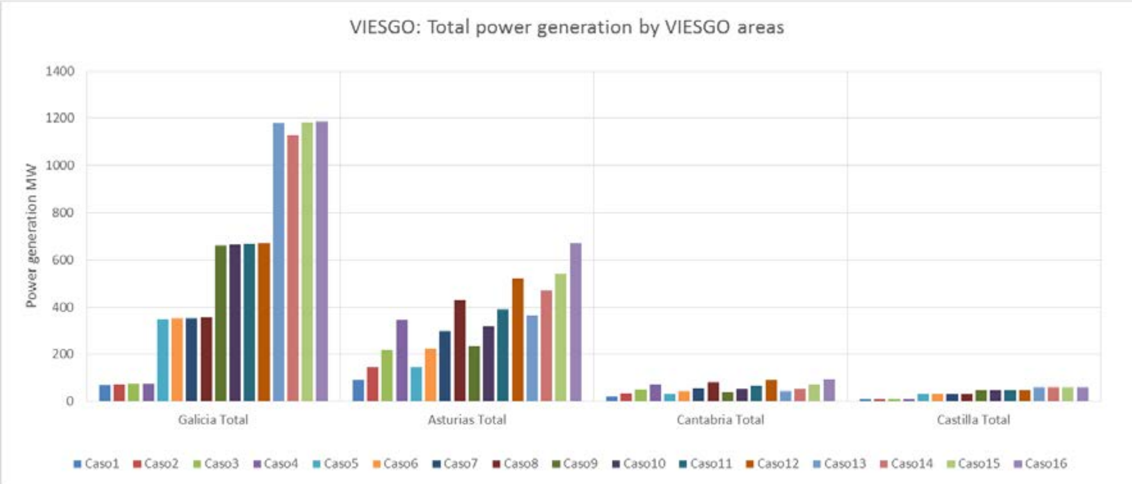


Figure 8 Representation of generations associated to each VIESGO areas and to each case of study

The losses distribution in percentage is shown in Figure 9. In the Figure 9 is also shown the absolutes values of the losses for the entire grid and their growing trend depending on the study case.

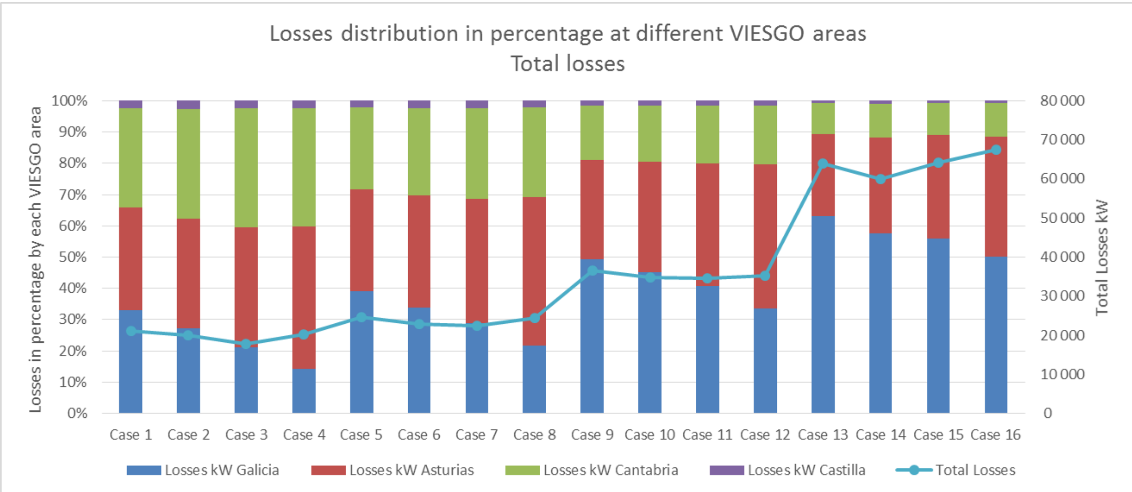


Figure 9 Distribution in percentage of losses and by VIESGO areas. Representation of total losses

It is seen in the Figure 9 that for high levels of wind generation (e.g. cases 13, 14, 15, 16) the proportion of losses associated with other areas of Cantabria and Castilla is much lower than the others. For low wind generation (example cases 1, 2, 3, 4), the percentage of losses associated to Galicia, Asturias and Cantabria are of the same order. In any case the contribution given by Castilla grid is always less than the other regions, due to its extension.

The numerical values associated to the previous figures are represented in the next Table 3. In this table it is represented the absolute losses values based on the study cases of analysis. Also there is a representation by each VIESGO area and each study case.

Table 3 Losses (kW) by VIESGO areas and by study cases.

	Losses (kW)				
	Galicia	**Asturias**	**Cantabria**	**Castilla**	**Total**
Case 1	7010	6929	6771	486	21195
Case 2	5418	7023	6990	505	19935
Case 3	3764	6860	6773	451	17848
Case 4	2855	9220	7665	496	20235
Case 5	9652	8039	6511	518	24720
Case 6	7742	8182	6365	538	22827

	Losses (kW)				
	Galicia	**Asturias**	**Cantabria**	**Castilla**	**Total**
Case 7	6501	8972	6520	534	22527
Case 8	5295	11587	7002	529	24412
Case 9	18065	11602	6338	544	36549
Case 10	15740	12377	6243	538	34898
Case 11	14083	13577	6358	535	34553
Case 12	11871	16205	6685	530	35291
Case 13	40370	16741	6283	545	63939
Case 14	34631	18297	6541	537	60005
Case 15	35874	21170	6550	538	64132
Case 16	33736	25897	7187	580	67400

Next the absolute value of losses is represented by each electrical area (Galicia, Asturias, Cantabria and Castilla). The following figures: Figure 10, Figure 11, Figure 12 and Figure 13 correspond to the losses associated to the four areas (Galicia, Asturias, Cantabria and Castilla). At each graphic the following three quantities are shown:

- A bar chart with the values of absolute losses kW for each case study.
- A curve representing the percentage of loss values in percent relative to the inner region power demand for each case study.
- A curve representing the percentage of loss values. These loss values are calculated as: absolute losses (unsigned) divided by the sum of domestic power demand in the area plus net power export of the region through its borders. The graphic shows the values for each case of study.

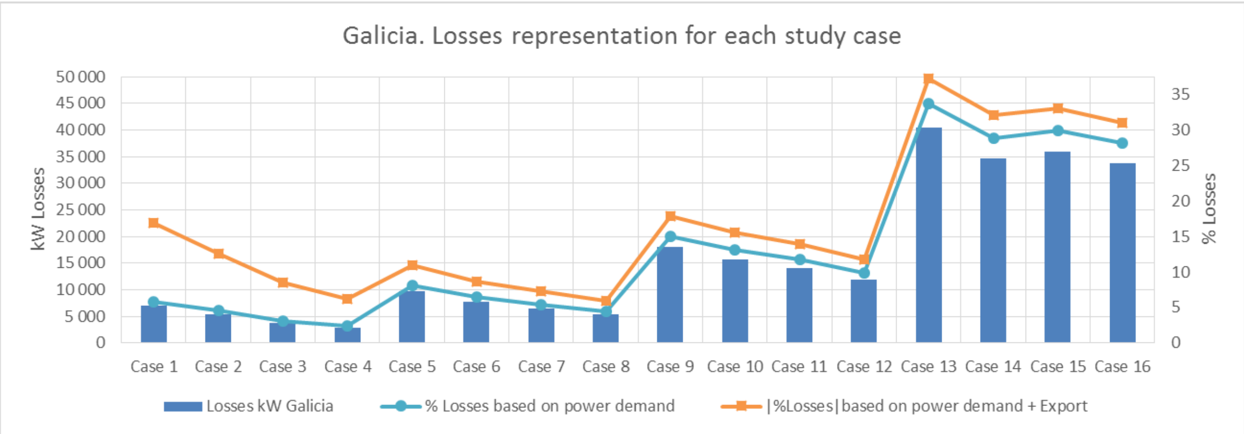


Figure 10 Representation of losses in Galicia and by each study case

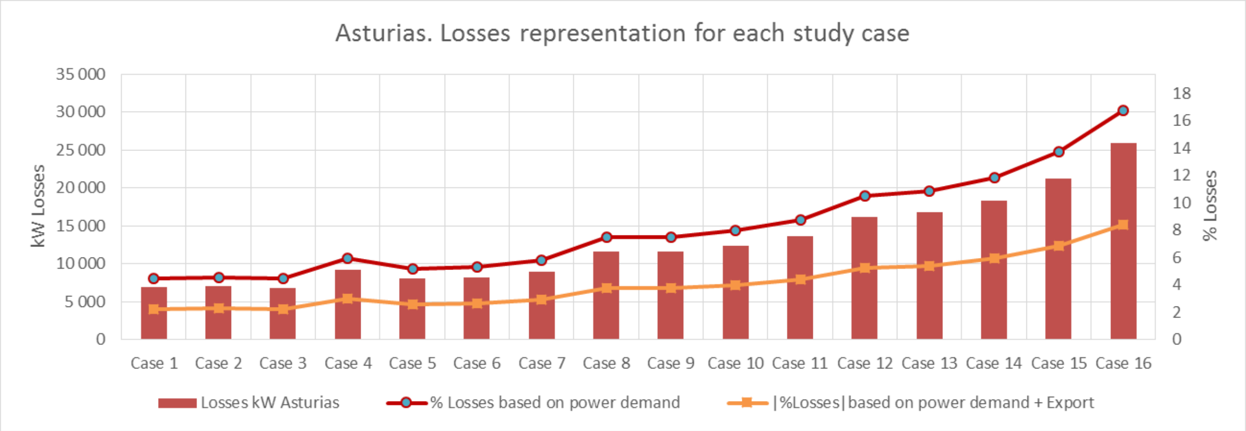
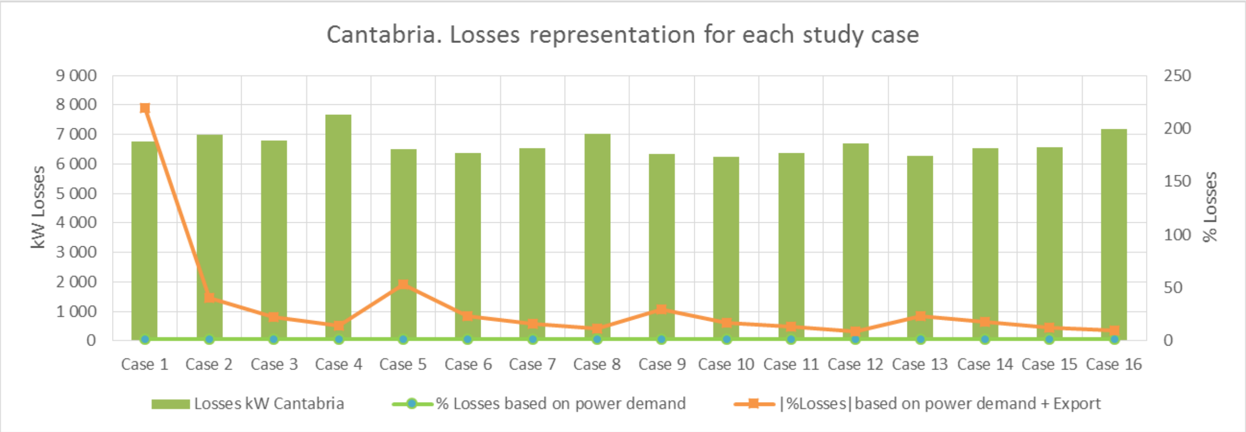


Figure 11 Representation of losses in Asturias and by each study case



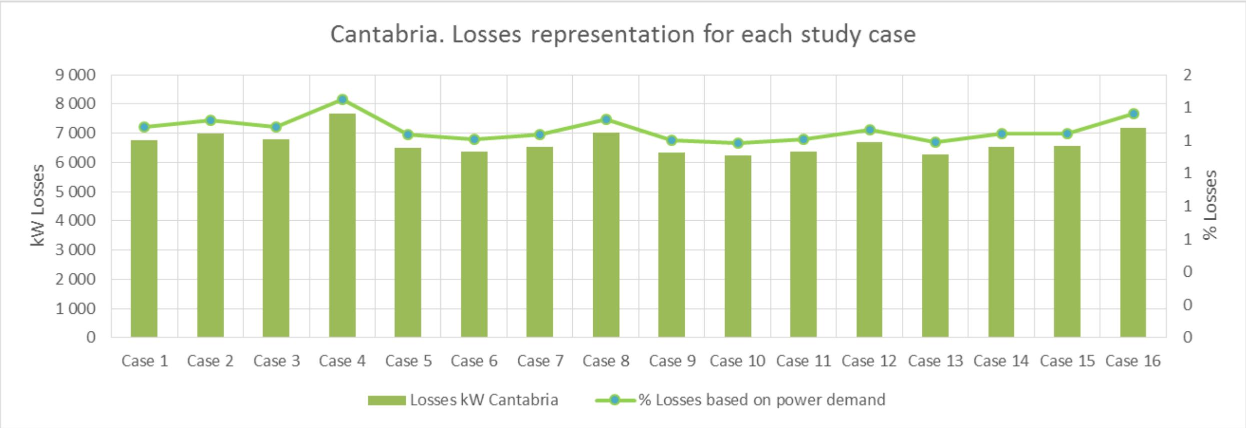


Figure 12 Representation of losses in Cantabria and by each study case

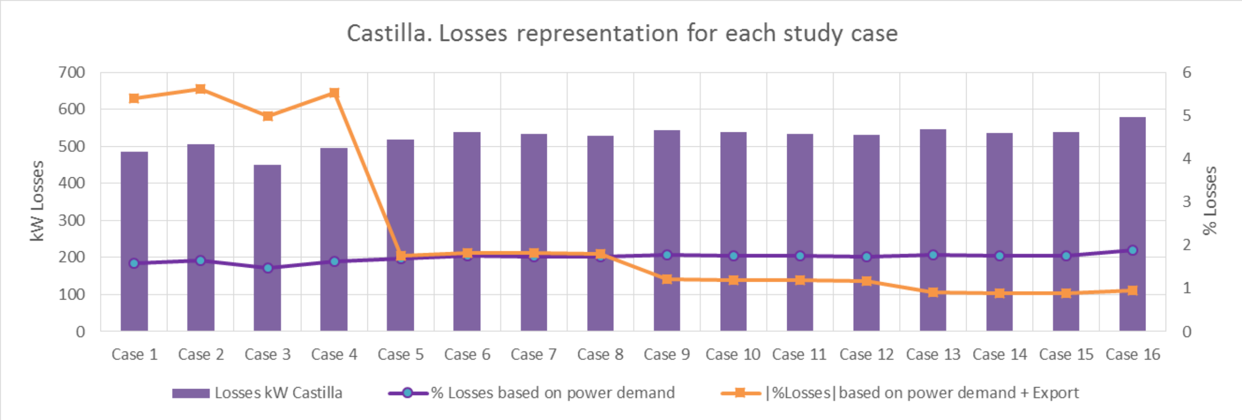


Figure 13 Representation of losses in Castilla and by each study case

It is noted in the previous figures that losses values in the area of Galicia have a cyclical pattern for every four study cases (according to wind generation values detailed in Table 1). This cyclical pattern presents a peak value and a subsequent decreasing evolution. This evolution is first justified by the influence of wind generation and secondly by the influence of the hydraulic generation, for each level of wind generation. The presence of hydraulic generation reduce the losses in the total grid system.

In Asturias area the behavior in general is an increasing total generation pattern. In contrast for the regions of Cantabria and Castilla absolute losses are less dependent on generation levels and maintain a more stable behavior in absolute values, even with increasing total generation (Case 1 to Case 16). This behavior is explained by the low presence of generation in the area and by the constant power demand as consideration for all the cases of study.

In all cases it is observed a difference in perceptual values between those calculated based on power demand only or based on power demand plus net power export. This difference is more important in Cantabria and Castilla areas and even more in cases with low internal generation (hydraulic and thermal). These cases correspond to high power import levels.

3.4. SENSITIVITY ANALYSIS: LOAD VARIATIONS

According to the considerations for this study, power demand in all study cases is considered as constant. This section evaluates the variation of losses in the VIESGO grid with the change in domestic power demand. For this purpose study cases (Case 1 to Case 16) are tested considering power demand increments of ± 10% of the initial case. The changes are both active and reactive power, but the generation level are held constant. For each study case is obtained three values of losses: the loss value of the original case, the value of losses with an increase in consumption with + 10% and the value of losses with a decrease of 10%.

In next Figure 14 the results of absolute losses (kW) are shown in three curves, associated with the study cases:

- Curve of losses in VIESGO grid according to the original cases and consumption.
- Curve of losses corresponding to changes in consumption of the original cases by + 10%.
- Curve of losses corresponding to changes in consumption in the original cases by -10%.

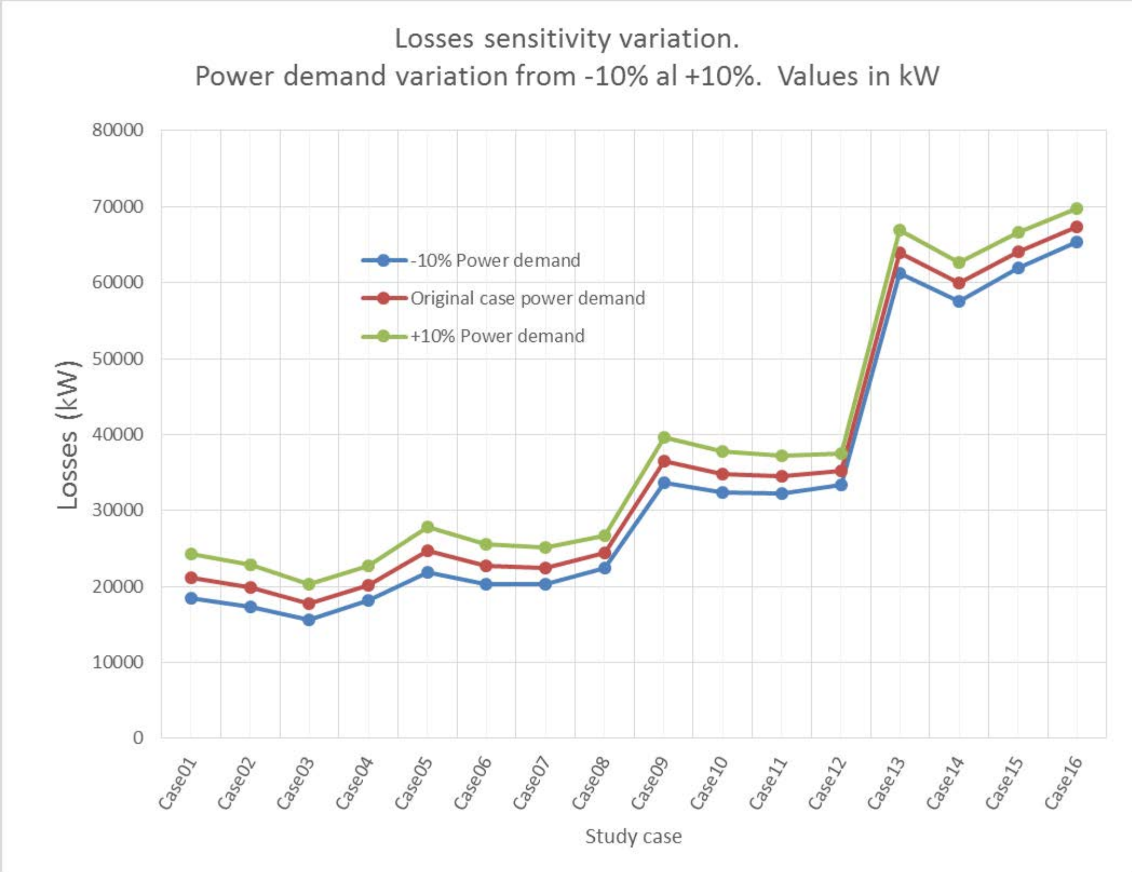


Figure 14 Representation of losses sensitivity variation with power demand. Values of power demand variation considering ±10% power demand variations

The numerical values associated to the Figure 14 are represented in next Table 4:

Table 4 Losses considering a power demand variation, and by each study case

	Losses (kW) for the original case, and for the cases with ±10% variation in power demand.			
Study case	(-10%) kW	Original kW	(+10%) kW	Delta o power demand: (+10%) minus (-10%) power demand (kW)
Case01	18424	21153	24246	5821
Case02	17283	19893	22880	5596
Case03	15587	17809	20351	4764
Case04	18115	20200	22663	4548
Case05	21931	24675	27800	5868
Case06	20344	22785	25600	5256
Case07	20242	22487	25083	4841
Case08	22479	24374	26631	4153
Case09	33696	36498	39699	6003
Case10	32351	34848	37723	5372
Case11	32214	34505	37175	4961
Case12	33308	35244	37556	4248

	Losses (kW) for the original case, and for the cases with ±10% variation in power demand.			
Study case	(-10%) kW	Original kW	(+10%) kW	Delta o power demand: (+10%) minus (-10%) power demand (kW)
Case13	61212	63869	66920	5708
Case14	57547	59938	62716	5169
Case15	61872	64064	66636	4764
Case16	65346	67331	69724	4379

The values shown in Figure 14 and Table 4 show that the absolute losses, at any studies power demand, increases with generation levels. (The Cases 1 to 16 represent a progression of the amount generated).

In the following Figure 15 the variation of the losses in absolute values (kW) is shown. This variation considers the difference of the losses in VIESGO grid considering the case with a + 10% of the original consumption, less the losses of the original case -10% of the original consumption.

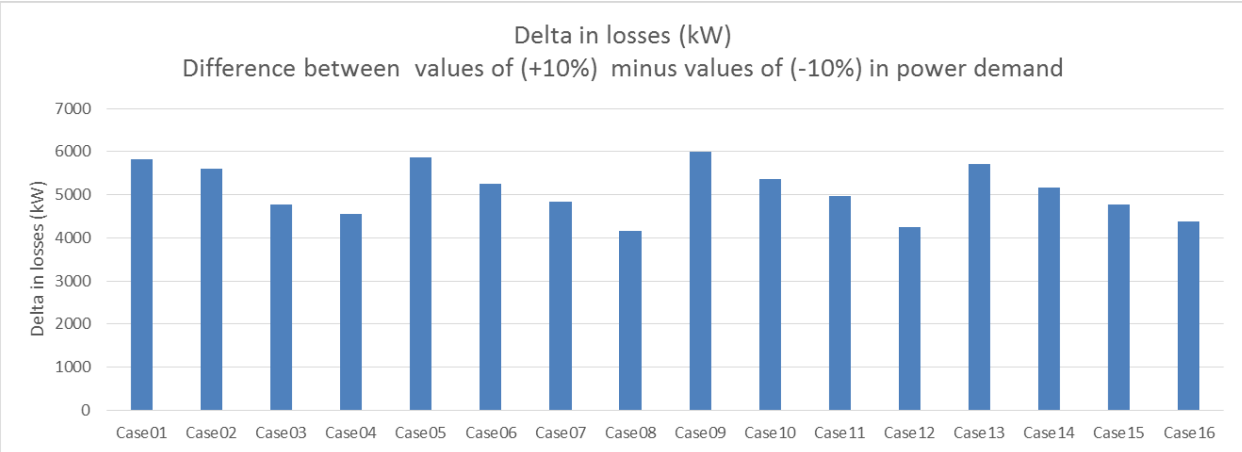


Figure 15 Delta in losses considering the end values +10% and +10% in power demand

Figure 15 shows that the variations in the losses present a cyclical pattern every group of four study cases. For example the four group are Cases 1 to 4, Cases 5 to 8, Case 9 to 12 and cases 13 to 16. Each all study cases of one group represent the same wind generation (e.g. the win generation in Cases 1 to 4 are the same). It is noted that variations of losses decrease in each sequence of four cases in a group. This is because of the impact of hydraulic and thermal generations. These generations increase in the study cases of each group (e.g. the sequence of cases Case 1, 2, 3 and 4 represent also increasing sequence in hydraulic and thermal generations). The hydraulic generation and/or thermal are closer to power demand points but wind generation is far, this why they hydraulic and thermal generation represent a reduction in losses. Also their increase reduces the sensitivity in power demand variations, because they are closer to the power demand points.

3.5. SENSITIVITY ANALYSIS: GENERATION VARIATIONS

In this section the variations of losses with variations of the generation are observed. First it is shown the presence of generation for each type (wind, hydraulic and thermal). In Figure 16 is shown the power generation by different generation types for the entire distribution VIESGO grid. The representation includes three types of generation for each of the sixteen cases of study.

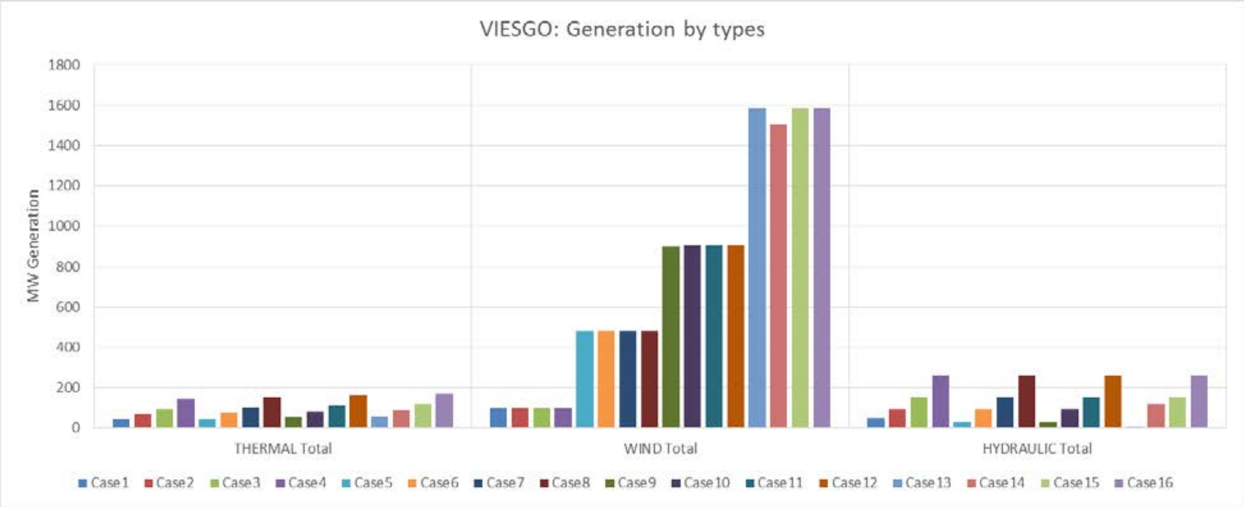
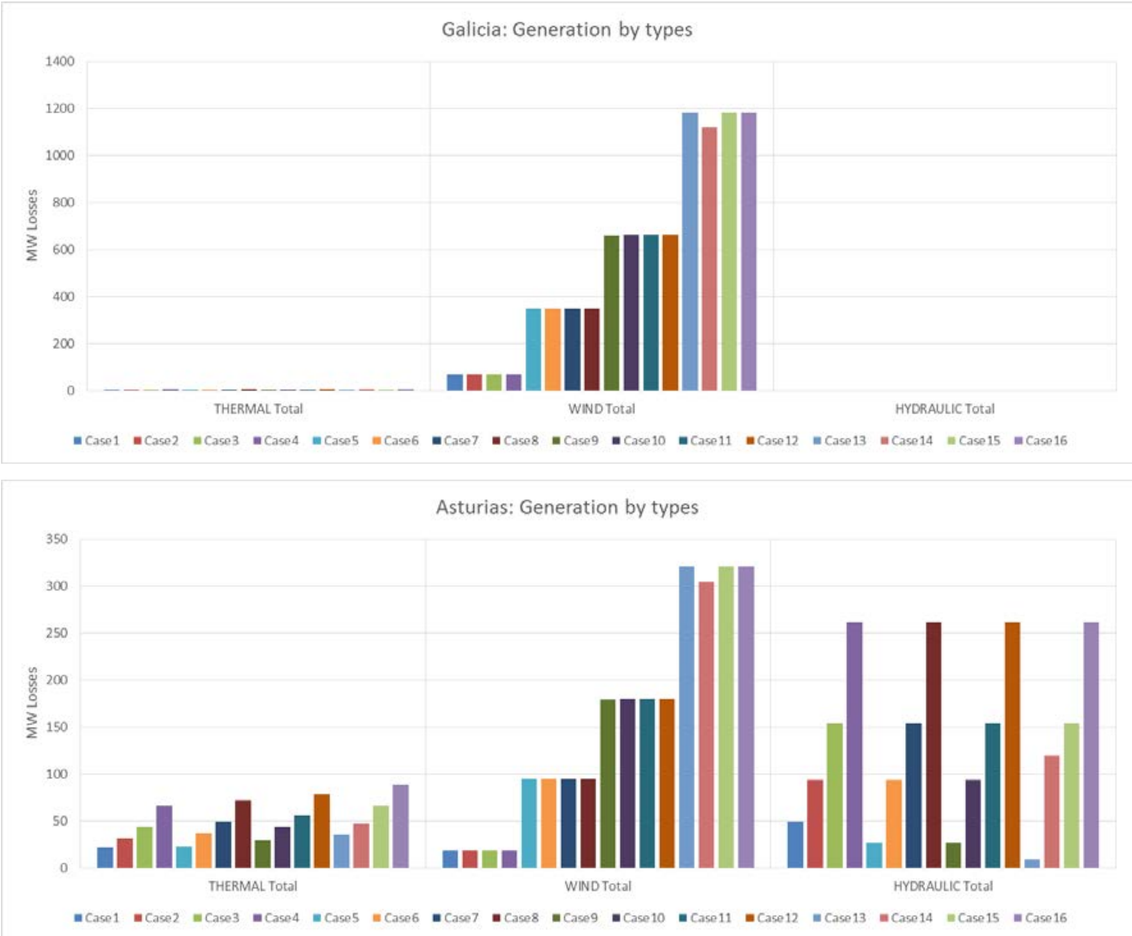


Figure 16 Representation of different generation types of VIESGO, and by each study case

As it can be observed the presence of wind generation represent a significant amount compared to the amount of other generations (thermal and hydraulic). Also it can be noted that the fluctuations of wind generation are higher that other fluctuation for other generations.

Analysing the detail for each VIESGO area, Figure 17 shows the generation types for each VIESGO areas (Galicia, Asturias, Cantabria and Castilla).



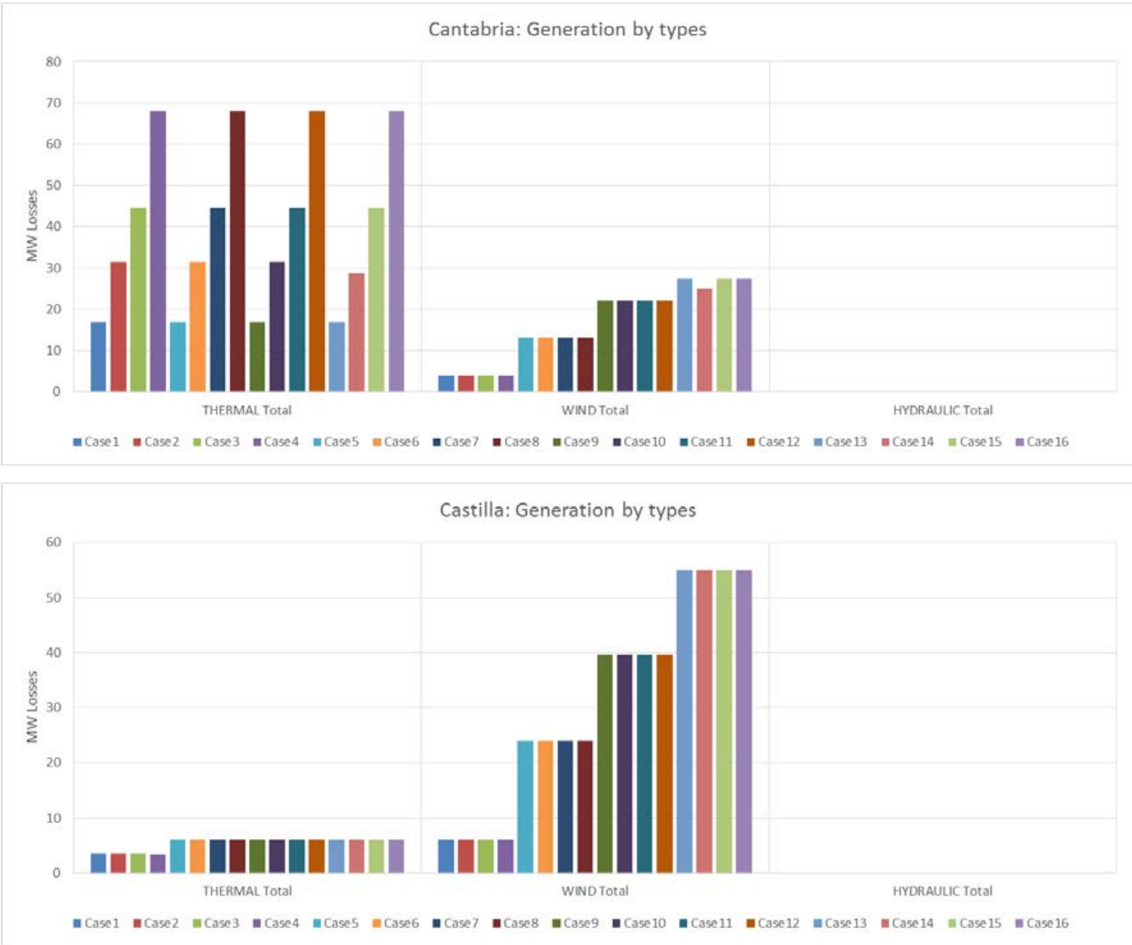


Figure 17 Representation of different generation types of VIESGO, at each VIESGO area

By areas it can be observed that:

- Galicia has a large amount of wind generation, and almost zero from other generation types. In addition the maximum amount of wind generation is almost four times more than the sum of wind maximums in the other regions.
- In Asturias the presence of hydraulic and wind generation are predominant and to a lesser extent from thermal.
- Cantabria and Castilla the presence of generation is much lower than that in Asturias and Galicia.

Furthermore the power demand points inside the VIESGO grid are distributed according to next Figure 18. It the figure can be shown that Cantabria is the area of greatest power demand followed by Asturias. In addition when Figure 18 is compared with the generation shown in Figure 17, it is found that Galicia is an energy-exporting area, Asturias and Castilla consume or export depending on wind levels, and Cantabria in most of the cases imports power to give supply to the power demands.

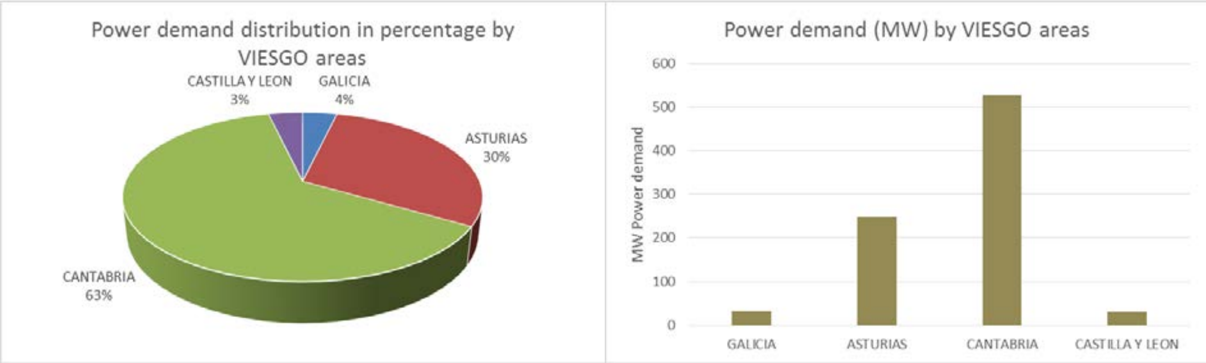


Figure 18 Power demand distribution in the VIESGO power grid

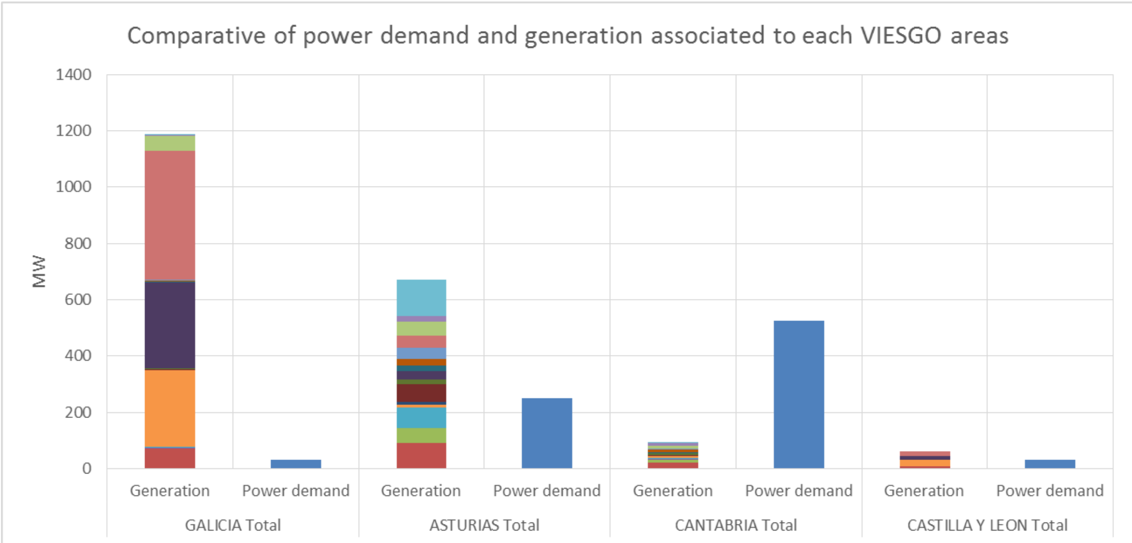


Figure 19 Comparative of power demand and generation associated to each VIESGO areas

Next, the losses associated with each type of generation will be evaluated. Generally increasing wind generation contributes to an increased level of losses regardless of the level of other generation types (hydraulic and thermal). The study cases include situations with different degrees of wind generation according to Table 1 (Wind 99 MW, 480 MW, 904 MW, 1584 MW approximately). For each of these cases different situations in the degree of generation of other types are combined. See Table 1. It is noted that for each increase in the degree in wind generation differentially increases the level of losses in absolute values.

Next Figure 20 represents the absolute losses for each generation range. Different curves represent the wind generation power ranges of 99 MW, 480 MW, 904 MW, 1584 MW. At the same time the same study cases with same wind generation can present difference in losses as it is shown in the figure.

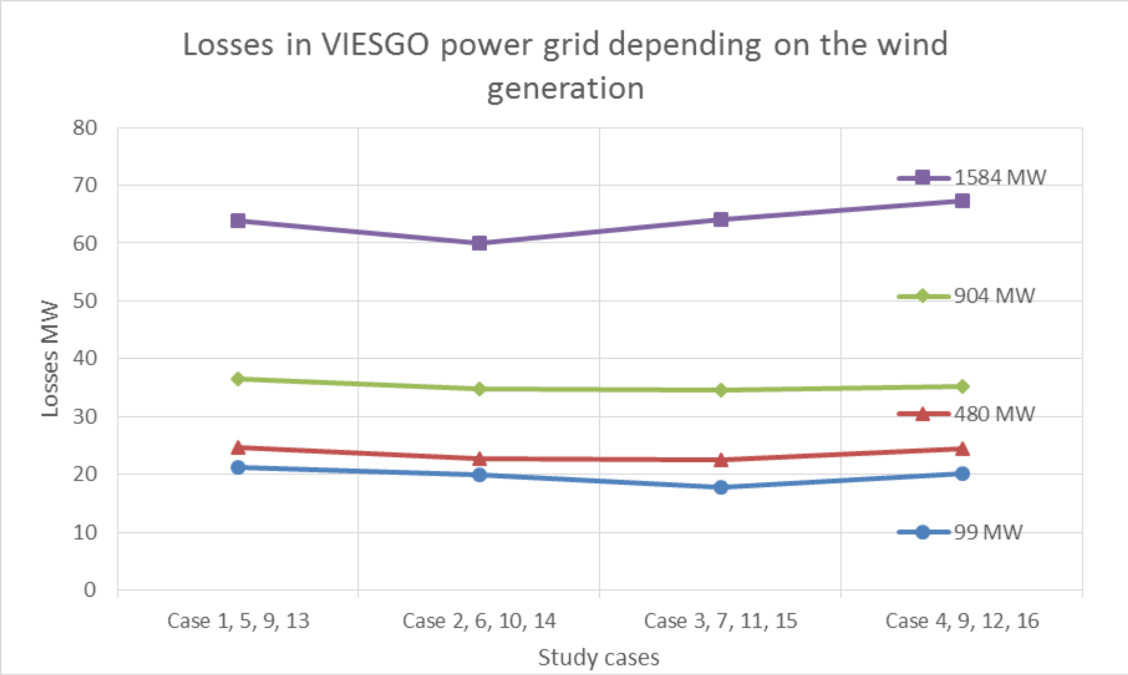


Figure 20 Losses in VIESGO power grid depending on the wind generation

In similar analysis as in Figure 20 above, Figure 21 has grouped case of study with the same level of hydraulic generation. The groups of hydraulic generation are: values in the range of [9-49 MW], values in the range of [94-120 MW], value of 154 MW and value 262 MW of hydraulic generation. Next Figure 21 shows the total losses in the VIESGO grid associated at the case studies with similar levels of hydraulic generation. There is a curve for each generation range or value. Each curve shows the evolution of total losses in the system with increase in wind generation.

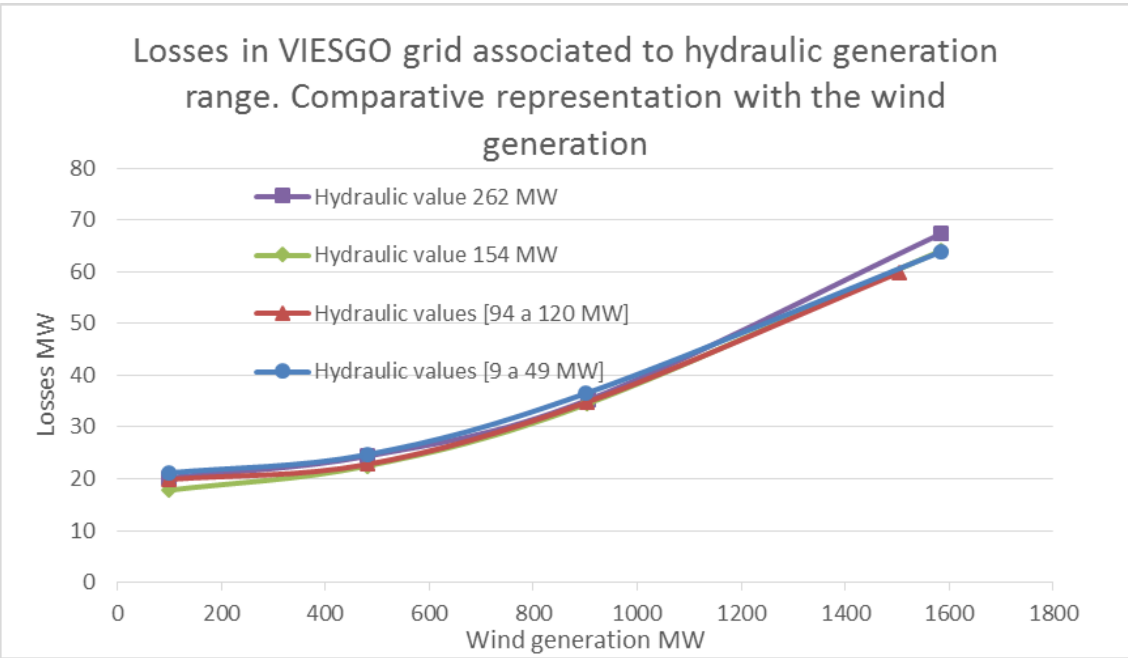


Figure 21 Losses in VIESGO grid associated to each hydraulic power generation range. Representation of the influence of the wind power generation

As shown in Figure 21 all curves appear almost overlapped. This represents that the sensitivity of the losses, for the considered generation levels, is insignificant compared to the increase caused by the wind generation increase.

Performing similar analysis as the hydraulic sensitivity analysis, but with thermal sensitivity, it can be observed similar behavior. Figure 22 shows the losses in the VIESGO grid grouping different cases with the same degree of thermal generation. At the same time the increase of losses with the wind generation increase is represented. The findings are similar to those with hydraulic generation: the sensitivity of the system losses due to changes in thermal energy is insignificant. Wind generation variation drives the losses trend.

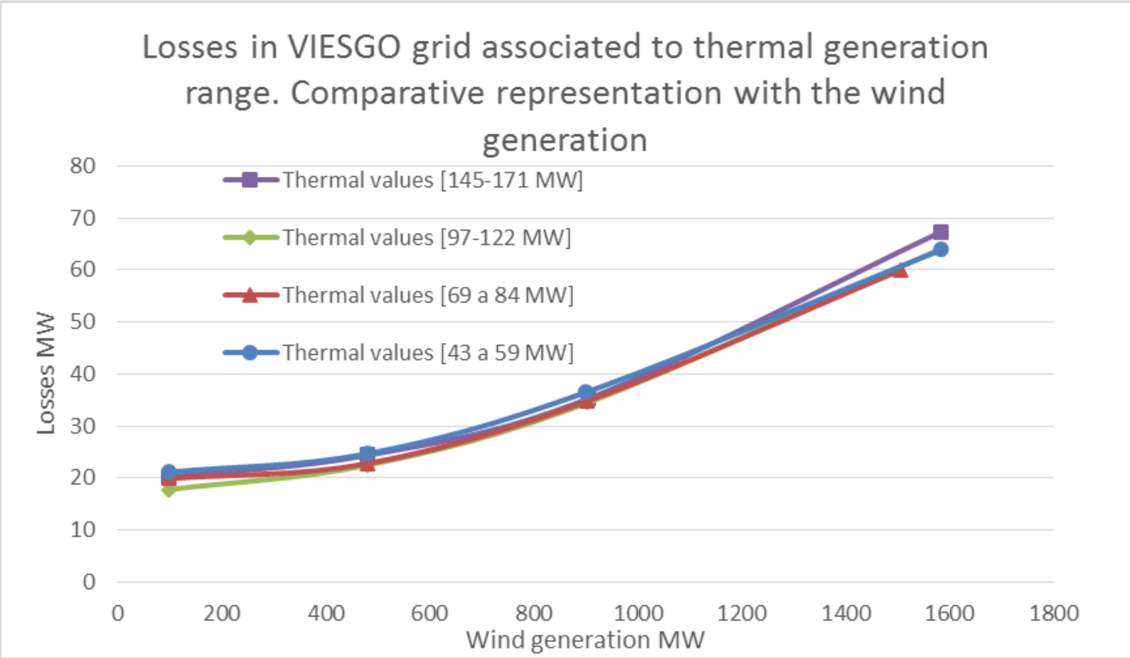


Figure 22 Losses in VIESGO grid associated to each thermal power generation range. Representation of the influence of the wind power generation

4. CONCLUSIONS

This study analysed the losses associated to VIESGO distribution grid. The losses associated to the medium voltage level, as well as MV/LV transformer to power demand supply are not included. Sixteen study cases have been provided and analysed. These cases pretended to be representatives of usual operational scenarios. These scenarios include minimum and maximum generation situations, and a combination of different degrees of generation types: wind, hydraulic and thermal generations. The degree of distribution power demand was considered constant for each scenario.

Next analyses have been evaluated for the losses study, considering the study cases:

- Analysis of different generation levels and different power demand. Results has evaluated the entire VIESGO grid and also the different VIESGO areas (Galicia, Asturias, Castilla and Cantabria).
- Analysis of different generation types. The evaluation has considered the entire grid and the different areas.
- Analysis of losses values considering different generation levels. It has been evaluated the entire grid, different areas and different voltage levels.
- Sensitivity losses analysis considering power demand variations.
- Sensitivity losses analysis considering different generation types.

To summarize, VIESGO distribution system of study has interconnection points mainly with REE transmission system. The VIESGO grid is composed of several areas (Galicia, Asturias, Cantabria and Castilla) with particular characteristics. Wind generation represents the highest generation degree. This is several times the maximum capacity of hydraulic and thermal power.

By areas Galicia has a large presence of wind power and is an energy-exporting area, while on the other side Cantabria region is a net-importer. Cantabria has insufficient internal generation to meet internal power demand. Asturias and Castilla can be clearly exporting or importing areas depending on the available wind power.

In relation to the entire VIESGO grid, losses increase with the increase in wind generation. This is because the wind increase represents an increase in the exporting power to the transmission grid, and an increase in the power flows to other VIESGO areas to meet their power demand. Furthermore the variation of conventional generation has almost no impact on the variation of losses compared to the increase in wind power.

By voltage levels, 132 kV level represents the greatest contribution to losses, followed by the 55kV level. The total losses are in the range of 20 to 67 MW considering particular study cases and all the voltage levels.

The power demand variation is associated with a variation of losses. The lower level of generation, the higher is the sensitivity of the losses due to power demand variations. This is because of the need to import energy in low generation situations.