DISTRIBUTED GENERATION FORECAST AS INPUT TO CAPACITOR BANKS MANAGEMENT IN DISTRIBUTION NETWORKS

Ana Carina MORAIS
EDP Distribuição – Portugal
anacarina.morais@edp.pt

José Alexandre PASCOAL
EDP Distribuição – Portugal
josealexandre.pascoal@edp.pt

Paulo CRUZ
EDP Distribuição – Portugal
paulo.cruz@edp.pt

ABSTRACT

Reactive energy control has an important role in the electric system, once it is a tool which enables a more efficient management of the Distribution Network (DN). Nowadays, in Portugal, the balance between active and reactive energy is performed daily at REN EHV/HV substations fulfilling ERSE (Portuguese Regulator) rules. Failure to comply these rules implies financial penalties for the Portuguese DSO, EDP Distribuição.

Up to now, the capacitor banks management model used by Portuguese DSO was based on local historical demand at the HV/MV substations. This methodology is only valid for passive networks with no DG. This paper aims to check the feasibility of including DG forecasting into the proposed capacitor banks management model at networks with large concentration of DG.

To validate this study, a comparison (considering actual generation patterns) between the results obtained by both the historical and the proposed model will be conducted.

INTRODUCTION

In the last decade, Portugal became a worldwide reference concerning electrical production based on renewable sources. These production facilities spread throughout all voltage levels and widely vary in dimension, representing a new challenge for the Portuguese DSO.

In this context, DN power flow has undergone deep changes, since no longer it is a mainly consumption network, but it has turned an active network, attending the increase of DG. As a result, there is an increased complexity and a larger number of variables to be considered in optimization at managing DN.

By the end of 2011 DG installed capacity was around 5,9 GVA in DN (Fig.1).

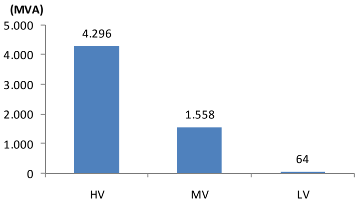


Fig. 1 – Portuguese DG installed capacity (end of 2011)

Out of the actual DG renewable energy technologies interconnected to DN (small-Hydro, wind, solar and Waste - Solid and Forestry), wind generation means about 75% of the total. Therefore, wind variability brings new challenges into the management of capacitor banks installed in HV/MV distribution substations.

REACTIVE POWER COMPENSATION FRAMEWORK

Reactive power compensation has benefits for the DSO, namely reduction in losses, in voltage drops and voltage fluctuations, in energy penalties and in overloads. Hence, it increases facility equipment useful life and decreases maintenance operations. All those benefits have ultimately practical effects on quality of service performance level.

To encourage a better management of reactive power, penalties have been recently changed (January 2011) by ERSE.

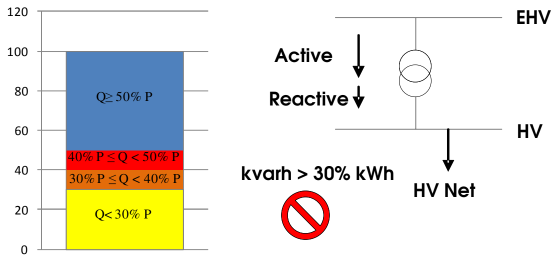


Fig. 2. Current Peak periods penalties

Regarding DG, different levels of reactive power injection have been set for peak periods. Producers connected to HV or MV (P>6MW) can chose either not to inject any reactive power or maintain a tan φ = 0,3. Producers connected to MV (P≤6MW) should maintain a tan φ ≥ 0,3. In off-peak periods, no reactive power should be injected.

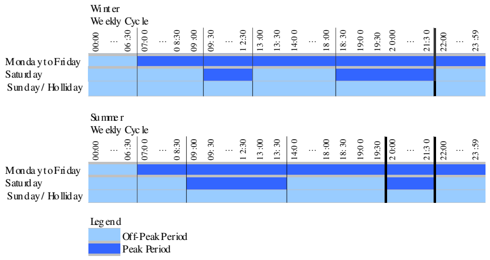


Fig. 3 – Peak and off-Peak schedule

It is up to the DSO to evaluate the impact of such framework in the management and control of reactive power, since the DSO continues to have obligations to fulfil the TSO reactive power requirements (Fig. 2).

Under some special conditions, negotiation of the above is possible, both with DG and/or with TSO.

ACTIVE NETWORKS MANAGEMENT

Variability in generation from renewable sources, wind and small-hydro, brings new challenges into the management of capacitor banks installed in HV/MV distribution substations.
Recent load diagrams reveal that reactive power turned less variable, not following the active power behaviour (Fig. 4). This is a consequence of the new legal framework for DG reactive power control.

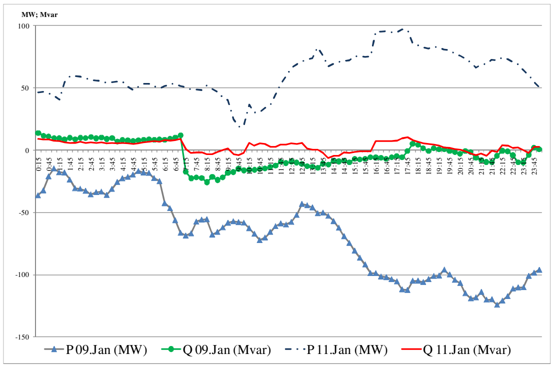


Fig. 4 – Active and Reactive flow of a EHV/HV substation, regarding HV network links

This stability allows the medium/long term MV capacitor banks time schedules definition.
In a EHV/HV substation with a significant DG penetration, the problem is no longer how to deal with penalties, but controlling momentary reactive power flow sudden changes at times of high DG production and low loads.

MODEL AND RESULTS

To analyse the practical implications of the variables at stake, namely DG and reactive power, a real distribution network with a high level of wind power and small-hydro generation, both in HV and MV, was chosen (Fig. 6 / Table 1).
In order to simplify the model, an equivalent load and generator was calculated for each HV/MV substation. The capacitor banks available in the MV side were aggregated. The effect of DSO lines was not considered.

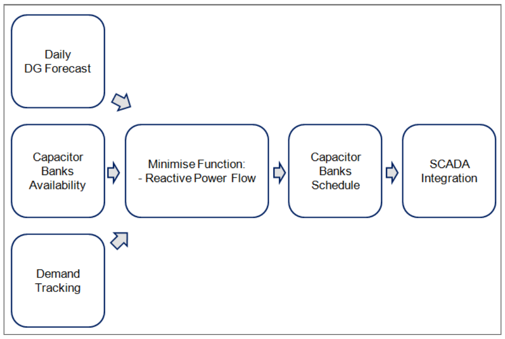
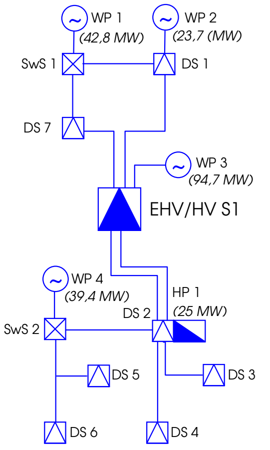


Fig. 5. Methodology Diagram

On a first stage and using historical data, demand was separated from generation to forecast demand. Then, taking advantage of current development in DG power forecasts, generation diagrams for the days ahead were obtained (Fig. 5).



Legend:
DS - Distribution Substation
SwS - Switching Substation
HP – Hydro Power
WP – Wind power
EHV/HV S – Extra High Voltage Substation

Fig. 6. HV Distribution Test Network

Table 1

DG CHARACTERIZATION

HV DG	Inst. P (MW)	tan φ
Wind Power 1	18,2	0,3
	24,6	0,0
Wind Power 2	23,7	0,3
Wind Power 3	40,9	0,3
	53,9	0,0
Wind Power 4	39,4	0,3
Hydro Power 1	25,0	0,4
Total	**225,5**	

HV DG	Tech	Inst. P (MW)	tan φ
DS 1	Wind	2,5	0,3
	Small Hydro	25,8	0,3
DS 2	Wind	38,0	0,3
	Small Hydro	10,7	0,3
DS 3	-	-	-
DS 4	Wind	10,8	0,3
		11,2	0,0
	Small Hydro	10,2	0,3
DS 5	Wind	12,5	0,3
	Small Hydro	2,2	0,3
DS 6	CHP	5,8	0,4
	Small Hydro	0,6	0,3
DS 7	Wind	28,7	0,0
Total		**158,9**	

Several simulations were run on the case study network, analyzing days where power generation was greater than 60% of the DG installed capacity (in the analysed period - January 2012). These days are characterized by an imbalance between the production and consumption of reactive power, being production exceeded consumption. The results should define the capacitor banks time schedules for those days, in order to minimize the injection of reactive power in the EHV/HV substation.
Two critical moments, depending on the generation diagram, can be identified in a day with high DG generation forecast:

Moment 1 - Beginning of the day (around 7 am)
  - Load still low;
  - Clients capacitor banks connected (Fig. 3);
  - High level of DG generation

Moment 2 - End of the day (around 10 pm)
  - Load begins to decrease;
  - Clients capacitor banks still connected (Fig. 3);
  - High level of DG generation

For the days not identified as critical the capacitor banks time schedules are the same defined for local compensation of DN (Table 2), ensuring the accomplishment of reactive power compensation rules.

Table 2

MEDIUM TERM CAPACITOR BANKS TIME SCHEDULE

	Qn (Mvar)	Day	1st period in	1st period out	2st period in	2st period out
DS 2 (CB 1)	3,4	Monday to Friday	07:00	23:59	-	-
		Saturday	09:30	13:00	20:00	09:30
DS 2 (CB 2)	3,4	Monday to Friday	07:00	23:59	-	-
		Saturday	09:30	13:00	20:00	09:30
DS 4	3,4	Monday to Friday	07:00	23:59	-	-
		Saturday	09:30	13:00	20:00	09:30
DS 6 (CB 1)	3,4	Monday to Friday	Allways ON			
		Saturday				
DS 6 (CB 2)	3,4	Monday to Friday	07:00	23:59	-	-
		Saturday	09:30	13:00	20:00	09:30
DS 7 (CB 1)	3,4	Monday to Friday	07:00	23:59	-	-
		Saturday	-	-	-	-
DS 7 (CB 2)	3,4	Monday to Friday	-	-	-	-
		Saturday	-	-	-	-

Using generation forecast and the aforementioned 60% condition, four days were identified: 2, 9, 24, and 27 of January 2012.

Each of the four days identified were analysed.

Data analysis for 02 Jan load diagram

The wind generation forecast predicts, for the first hours of the day, a high production in the HV and MV network fed by the EHV/HV S1 substation, reaching 250 MW. This configures a Moment 1 situation.

Thus the reactive power forecast highlights the need to delay the connection of the capacitor bank in almost every HV/MV substation, as described in Table 3.

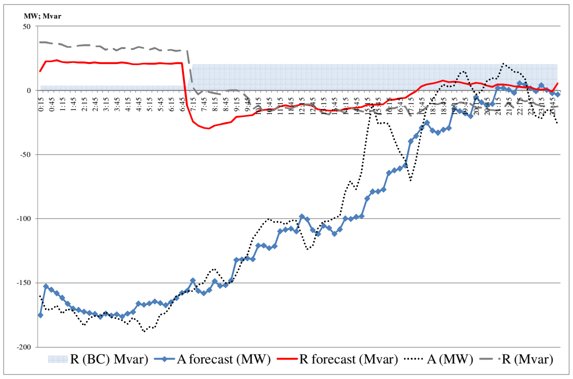


Fig. 7 – Load diagram with conventional capacitor bank management

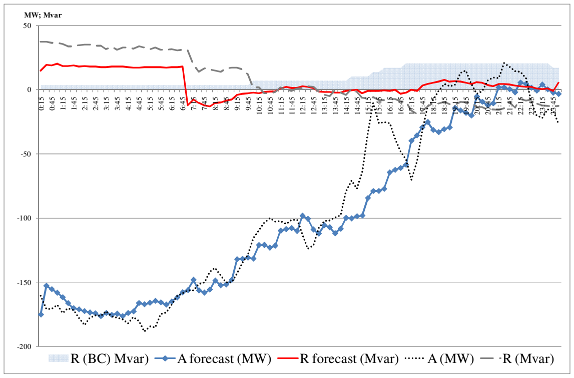


Fig. 8 – Load diagram with capacitor bank schedule adapted (Table 3)

Table 3

CAPACITOR BANKS TIME SCHEDULE (02.JAN.2012)

	Qn (Mvar)	1st period in	1st period out
DS 2 (CB 1)	3,4	15:30	23:50
DS 2 (CB 2)	3,4	16:00	23:45
DS 4	3,4	14:30	23:55
DS 6 (CB 1)	3,4	Allways ON	
DS 6 (CB 2)	3,4	10:00	23:59
DS 7 (CB 1)	3,4	17:00	23:40
DS 7 (CB 2)	3,4	-	-

Comparing Fig. 7 and Fig. 8 it can be seen that, despite the error between reactive power forecast and real values, the decision of delaying the capacitor bank connections was a good decision, helping to control reactive power flow.

Data analysis for 09 Jan load diagram

The forecast for this day indicated that wind generation in the first hours of the day could reach 200 MW.

This configures a Moment 1 situation.

Following the wind generation forecast, adjustments were made to the capacitors banks time schedule (Table 4).

Table 4

CAPACITOR BANKS TIME SCHEDULE (09.JAN.2012)

	Qn (Mvar)	1st period in	1st period out
DS 2 (CB 1)	3,4	15:30	23:50
DS 2 (CB 2)	3,4	16:00	23:45
DS 4	3,4	14:30	23:55
DS 6 (CB 1)	3,4	Allways ON	
DS 6 (CB 2)	3,4	10:00	23:59
DS 7 (CB 1)	3,4	17:00	23:40
DS 7 (CB 2)	3,4	-	-

In this case there was a significant difference between forecast and real DG production. Despite that, adjustments made to the capacitor banks schedule incurred in no penalties for the DSO.

Data analysis for 24 Jan load diagram

This day had a Moment 1 situation, resulting from a wind generation forecast of nearly 250 MW from midnight until 10 am.

The reactive power forecast revealed the need to delay the connection of the capacitor bank as described in Table 5.

Table 5

CAPACITOR BANKS TIME SCHEDULE (24.JAN.2012)

	Qn (Mvar)	1st period in	out
DS 2 (CB 1)	3,4	07:30	23:59
DS 2 (CB 2)	3,4	07:45	23:59
DS 4	3,4	07:15	23:59
DS 6 (CB 1)	3,4	Allways ON	
DS 6 (CB 2)	3,4	07:00	23:59
DS 7 (CB 1)	3,4	08:00	23:59
DS 7 (CB 2)	3,4	-	-

The decision of delaying the capacitor bank connections reduced reactive power flow.

Data analysis for 27 Jan load diagram

Wind production forecast and load diagrams analysis lead to a Moment 2 situation. The forecast indicated high DG production after 7 PM, reaching 250 MW. In this case it is advisory to gradually bring forward the capacitor bank switching off, as described in Table 6.

Table 6

CAPACITOR BANKS TIME SCHEDULE (27.JAN.2012)

	Qn (Mvar)	1st period in	out
DS 2 (CB 1)	3,4	07:30	23:00
DS 2 (CB 2)	3,4	07:45	22:00
DS 4	3,4	07:15	22:30
DS 6 (CB 1)	3,4	Allways ON	
DS 6 (CB 2)	3,4	07:00	22:15
DS 7 (CB 1)	3,4	08:00	21:45
DS 7 (CB 2)	3,4	-	-

As it can be seen, during the analysis period, the use of DG production forecast proved to be very helpful in minimizing the reactive power flow, especially in critical periods such as low consumption, high level of DG generation and reactive power injection.

CONCLUSIONS

The MV capacitor banks time schedules for the HV/MV substation with a high level of DG, both in HV and MV level, can be adjusted considering DG production forecast. This forecast can be used as a complementary analysis to the medium term schedule and it might used to make adjustments to that schedule.

The case study presented enhances that the medium term schedule fits most of the days; however when there is high DG production, the DSO can anticipate constraints and act accordingly to prevent them.

A local approach, based on local actuation concept (at a HV/MV substation level), thinking globally (at a EHV/HV substation level) can only be used in networks without DG, or with DG connected only in the MV network. Whenever DG is present in the HV network, the approach must be made considering the group of HV/MV substations connected to the EHV/HV substation: as global optimum does not result from local optimum. With this new approach reactive power flows in the DN and in the EHV/HV substation are minimized. Further studies must be developed in close collaboration with all parts involved.

REFERENCES

[1] Ministry of Economy and Ministry of the Environmental and Spatial Planning, "*Decreto-Lei n.º 339-C/2001*", Dec. 29, 2001.

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[3] Ministry of Economy, Innovation and Development, "*Portaria n.º 596/2010*", Jul. 30, 2010.