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Analysis and comparison of wind farm reactive power capabilities considering wind turbine level on-load tap-changer transformers

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Abstract

Some of the challenges that new onshore wind farm (WF) installations are facing are, on one side, the more and more demanding grid codes and, on the other side, the weaker grids at the point of common coupling (PCC). The combined effect of these conditions typically leads to an increasing need of static synchronous compensator (STATCOM) installations in new WFs where doubly-fed induction generators (DFIGs) or full converter (FC) based wind turbines (WTs) are commissioned, thus increasing the overall WF cost. One alternative to STATCOMs for compensating the aforementioned issues are fast on-load tap-changer (OLTC) transformers integrated at WT level. The use of fast OLTC WT transformers can significantly reduce costs by allowing the WT to operate at optimum voltage levels.

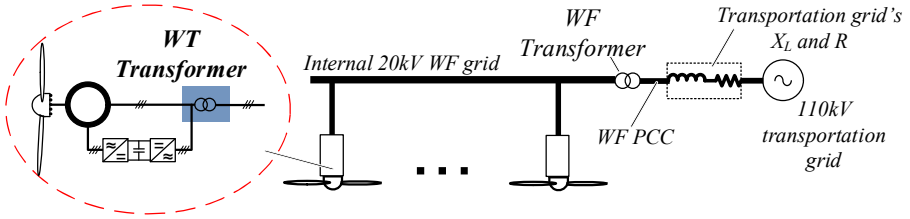
In this research work, the advantages of using fast OLTC WT transformers are analysed and evaluated. Two different WF configurations are evaluated under various grid conditions to determine the benefits in terms of reactive power capabilities and cost that these OLTC transformers provide to the overall WF.

Methodology

Two different WF configurations have been evaluated with DigSilent simulation platform. As described in figure below, the simulated WF scenario is composed of a 110kV transportation grid, a power transformer at the WF PCC, an internal 20kV WF grid and several WTs, each equipped with a 20kV/0,69kV transformer with or without OLTC capabilities, and a DFIG. The OLTC transformer has a regulation capability of ±4%, i.e. a total transformer regulation capability of 8%. First WF configuration consists of 9 WTs of 4.65MW (case A), while the second considers 7 WTs of 6MW (case B). By changing the transportation grid's short circuit ratio (SCR) and X/R ratio, the WFs reactive power capabilities have been assessed under 12 different cases (see Table 2). Thus, the need of a STATCOM has been calculated and compared for all the assessed cases.

Table 1. Analysed wind farm case studies.

Wind farm case studies	
A	9 wind turbines of 4,65MW
B	7 wind turbines of 6MW



Results

The results in Table 2 and 3 show that the use of an OLTC at WT level allows the WF to provide between 20 to 30 percent more inductive reactive power than when the WT is equipped with a conventional transformer. The capacitive reactive power capability is increased at any case varying from 15% increase to 211% increase depending on the SCR and X/R ratios. In both scenarios, the lower the X/R ratio and the weaker the grid, the greater the benefits of the use of an OLTC transformer. Furthermore, the reactive power capability increases when the rated power of the WT is higher. In this sense, for guaranteeing a power factor of 0,95 at WF PCC (13,66MVAr are required in total), the use of an OLTC transformer allows to avoid the need of a STATCOM for case B, whereas additional 632kVAr are needed for the worst case in the scenario A. Assuming 120k€/MVAr as a STATCOM cost reference and an extra cost of 36k€ at the WT due to the OLTC, the cost savings in the WF level STATCOM due to the use of the OLTC technology can reach up to about 0.8M€.

Table 2. Outcome of the case study A based on nine WTs of 4,65MW each.

GRID		WF REACTIVE POWER PRODUCTION CAPABILITY AT THE PCC AT RATED POWER						STATCOM REQUIRED FOR PF=0,95			COST SAVINGS DUE TO THE USE OF A WT OLTC	
		MAX CAPACITIVE			MAX INDUCTIVE			MAX CAPACITIVE				
		NO OLCT	FAST OLTC		NO OLCT	FAST OLTC		NO OLCT	FAST OLTC			
X/R	SCR	MVAR	MVAR	%	MVAR	MVAR	%	MVAR	MVAR	Cutback	PER WT	PER WF
10	20	11,378	12,976	+14%	-21,710	-29,986	+38%	2,23	0,632	1,60	-14.693 €	-132.240 €
	10	9,764	13,286	+36%	-19,674	-26,389	+34%	3,84	0,322	3,52	10.960 €	98.640 €
	5	8,065	13,787	+71%	-23,651	-22,074	-7%	5,54	0,000	5,54	37.907 €	341.160 €
3	20	10,129	13,157	+30%	-22,890	-31,360	+37%	3,48	0,451	3,03	4.373 €	39.360 €
	10	7,521	13,631	+81%	-21,486	-28,731	+34%	6,09	0,000	6,09	45.160 €	406.440 €
	5	4,342	13,494	+211%	-20,186	-24,101	+19%	9,27	0,114	9,15	86.027 €	774.240 €

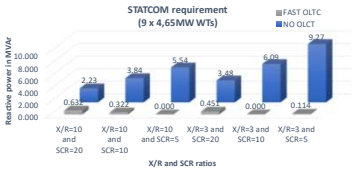
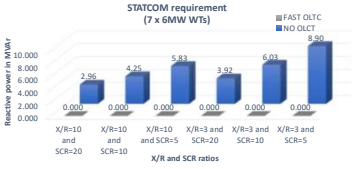


Table 3. Outcome of the case study B based on seven WTs of 6MW each.

GRID		WF REACTIVE POWER PRODUCTION CAPABILITY AT THE PCC AT RATED POWER						STATCOM REQUIRED FOR PF=0,95			COST SAVINGS DUE TO THE USE OF A WT OLTC	
		MAX CAPACITIVE			MAX INDUCTIVE			MAX CAPACITIVE				
		NO OLCT	FAST OLTC		NO OLCT	FAST OLTC		NO OLCT	FAST OLTC			
X/R	SCR	MVAR	MVAR	%	MVAR	MVAR	%	MVAR	MVAR	Cutback	PER WT	PER WF
10	20	10,847	20,551	+89%	-24,424	-31,965	+31%	2,76	0,000	2,76	11.331 €	79.320 €
	10	9,553	23,214	+143%	-22,163	-29,625	+34%	4,06	0,000	4,06	33.514 €	234.600 €
	5	7,975	17,355	+118%	-18,294	-24,459	+34%	5,63	0,000	5,63	60.566 €	423.960 €
3	20	9,883	20,914	+112%	-25,489	-32,786	+29%	3,73	0,000	3,73	27.857 €	195.000 €
	10	7,774	21,185	+173%	-24,063	-31,124	+29%	5,83	0,000	5,83	64.011 €	448.080 €
	5	4,905	14,648	+199%	-21,393	-27,860	+30%	8,70	0,000	8,70	113.194 €	792.360 €



Conclusions

The WT solution that considers a transformer without OLTC capabilities is the solution that higher STATCOM needs have. Considering the STATCOM cost, the commissioning of WFs with WT level OLTC technology provides cost saves up to 0.8M€ in weak grids with low X/R ratio. The weaker the grid the higher the benefits (see figures below the Tables 2 and 3). Furthermore, the higher the WT power the higher is the cost saving thanks to the use of the OLTC. Hence, it can be concluded that this solution will allow the commissioning of WFs with weak grids at its PCC.

References

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