Increasing Integration of Wind Power through Voltage Control in Medium Voltage Grid Using Smart Transformers

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Introduction

Nowadays, an increasing amount of wind power is produced and injected into power grid. The wind power from distributed wind generators (WGs), whose generation capacity is up to MW size, is usually injected into distribution grids [1]. However, the injection of wind power is variable due to the nature of wind. A higher integration of wind power from distributed WGs induces variations of feeder voltage, to which the WGs are connected to. So feeder voltage control becomes an important topic in distribution grid in order to integrate more and more wind power.

Traditional methods of feeder voltage control use high voltage (HV)/ medium voltage (MV) transformer with Load Tap Changer (LTC). This kind of transformer can change the set-point of LTC to modify voltage magnitude discretely, but it is not able to provide reactive power compensation [2]. The capability of feeder voltage control using the transformer with LTC is limited.

The smart transformer (ST) is a type of power electronics based transformer, which interfaces the medium voltage (MV) and low voltage (LV) grids [3]. Besides adapting voltage level as the conventional power transformer (CPT) at MV/LV interface, ST provides other services, like reactive power compensation [3]-[5]. It is proposed to use ST assisting feeder voltage control.

This paper aims to demonstrate that the hosting capacity of distributed WGs in distribution gird can be increased in terms of feeder voltage control provided by STs. The focus is on reducing the voltage variations in MV feeders using ST during wind power injection.

Approach

In order to identify the voltage variations during wind power injection, and to prove the features of ST, a distribution grid, which contains 3 MV feeders with unbalanced loads, and 5 distributed WGs, is modeled in PSCAD. There are 5 case studies. Case 1 and case 2 demonstrate the variations of voltage amplitudes in MV feeders without/with wind power injection. Case 3 and case 4 analyze voltage variations with the same amount wind power injection as case 2, while 1 and 4 STs are connected to the grid respectively. In case 5, there are 4 STs connected to the grid with double amount wind power injection compared to case 4. Case 1, case 2 and case 3 are presented in the abstract, while the other 2 cases will be presented in the final version of the paper.

Main body of abstract

Model setup

The work has been carried out from modeling the distribution grid. The structure of the distribution grid modeled in PSCAD is shown in Fig.1. The Utility Grid in Fig.1 connects to the 3 MV feeders through the HV/ MV substation, where bus 0 represents the MV bus of the substation. There are 12 feeder buses (Bus 1-12), 9 loads (L1-L9) and 5 distributed WGs (D1-D5) in the model. The WGs use Type 1 wind turbine generator. Either CPTs or STs can be used to connect loads or WGs to the feeder buses. The data of the model shown in Table 1-3 are selected according to [6].

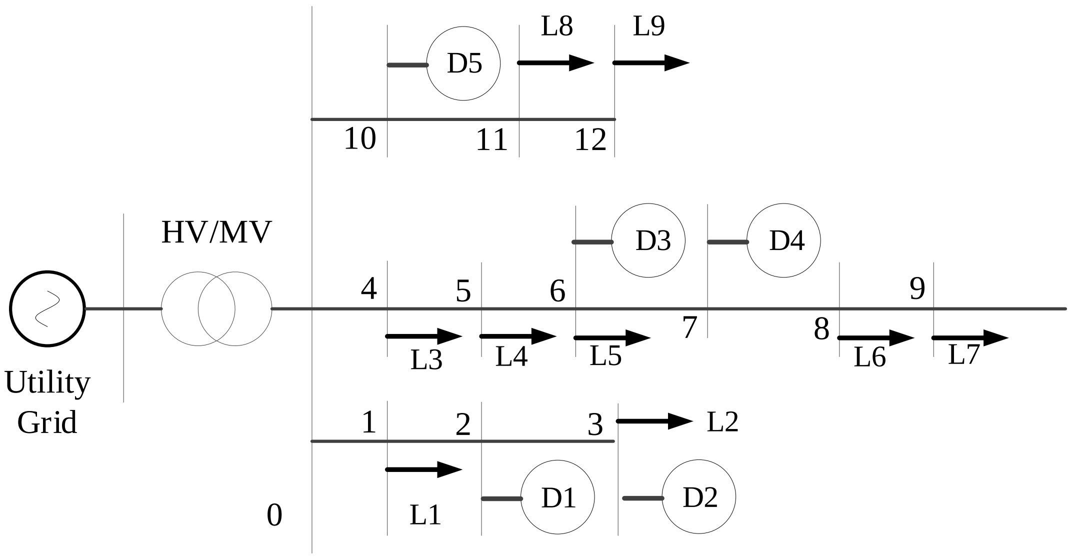

Fig. 1. Structure of simulation grid

Table 1. Parameters of lines of MV feeders

Bus No.	Bus No.	*r* *(Ohm/km)*	*x* *(Ohm/km)*	*l* *(km)*	Bus No.	Bus No.	*r* *(Ohm/km)*	*x* *(Ohm/km)*	*l* *(km)*
0	1	0.213	0.284	8.69	6	7	0.056	0.041	1.14
1	2	0.091	0.121	3.71	7	8	0.045	0.02	0.46
2	3	0.056	0.041	1.14	8	9	0.045	0.02	0.46
0	4	0.213	0.284	8.69	0	10	0.213	0.284	8.69
4	5	0.128	0.094	2.75	10	11	0.091	0.121	3.71
5	6	0.091	0.121	3.71	11	12	0.056	0.041	1.14

Table 2. Installed capacity of WGs

WG No.	Bus No.	Installed capacity (kVA)	WG No.	Bus No.	Installed capacity (kVA)
D1	2	300	D4	7	300
D2	3	300	D5	10	500
D3	6	300			

Table 3. Data of loads

Load No.	Bus No.	Phase A		Phase B		Phase C	
		P(kW)	Q(kVar)	P(kW)	Q(kVar)	P(kW)	Q(kVar)
L1	1	200	80	430	175	140	50
L2	3	50	10	50	10	50	10
L3	4	630	210	0	0	315	60
L4	5	380	40	330	30	260	40
L5	6	160	40	160	40	160	40
L6	8	110	25	110	25	110	9
L7	9	90	25	100	20	100	35
L8	11	500	100	480	120	480	140
L9	12	250	80	100	35	110	25

Case Studies

Case 1, case 2 and case 3 are presented in this section. In case 1 there is no wind power injection and no STs, in case 2 there is a total of 1.7 MW wind power injection but no STs, and in case 3, a ST replaces the CPT between load 2 and feeder bus 3 with the same wind power injection as case 2. The voltage amplitudes of feeder buses which connect to WGs are shown in Fig.2.

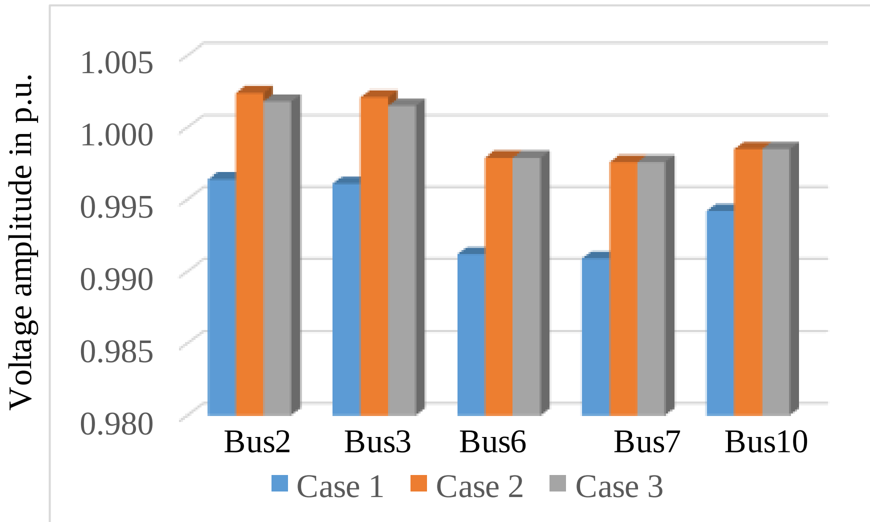

Fig. 2. Voltage of the buses connected DWUs

From Fig. 2, comparing case 1 and case 2, the changes of voltage amplitudes due to the injection of wind power is observed. Comparing case 2 and case 3, it confirms that

ST has reduced the variations of voltage amplitude along the MV feeder where ST is connected to.

CONCLUSION

This paper focuses on using voltage control of ST, e.g. reactive power compensation, to reduce voltage variations in MV feeders of distribution gird, so the capacity of wind power integration can be increased. The model for simulation is described and 3 case studies are presented. The final paper will provide the comprehensive theoretical analysis and detailed results from simulations. The voltage control strategy of ST will be explained. Case studies 4 and 5 will be presented as well. The improvement of voltage profiles will be shown by means of simulation.

LEARNING OBJECTIVES

In the paper, the reader will be able to understand how ST can help increase integration capacity of distributed WGs by providing voltage control in MV feeders. The results from simulation will be compared and will confirm the capability of ST.

REFERENCES

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