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MULTI-OBJECTIVE ACTIVE NETWORK MANAGEMENT SCHEME STUDIED IN SUNDOM SMART GRID WITH MV AND LV NETWORK CONNECTED DER UNITS

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ABSTRACT

Use of controllable, flexible, distributed energy resources (DER) in MV and LV networks will be in key role in order to improve local and system-wide grid resiliency and maximize utilization of renewable energy sources (RES). These resources will provide different technical services as part of future active network management (ANM) schemes. Therefore, future ANM and protection methods and solutions have to be adapted and developed so that active control and utilization of DER during both grid-connected and islanded operation modes is enabled. In this paper, multi-objective ANM scheme is studied by PSCAD simulations during grid-connected operation of Sundom Smart Grid. Based on the simulation results conclusions are stated, for example, related to preventing unwanted MV and LV network reactive power / voltage control interactions and potential mutual effects between voltage (U) and frequency (f) control functions (QU-, PU- and Pf -control) of DER units which are actively participating on studied multi-objective ANM scheme.

INTRODUCTION

In the future, utilization of distribution network (MV and LV) connected controllable and flexible DER resources i.e. flexibilities is needed to improve local and system-wide grid resiliency and maximize network DER hosting capacity. Flexibilities can consist of active (P) and reactive (Q) power control of flexible resources like controllable DG units, energy storages (ESs), controllable loads and electric vehicles (EVs) which are connected in DSOs grids. These flexibilities can provide different local and system-wide technical services as part of future active network management (ANM) schemes. Potentially these distribution grid connected flexibilities can provide different local (DSO) and system-wide (TSO) technical/ancillary flexibility services. However, potentially the use of, for example, active power flexibility for TSO purposes will have mutual impact in corresponding DSOs grid (and vice versa) and simultaneously the same flexibilities cannot be used for different TSO and DSO purposes. Therefore, transparent coordination and cooperation between TSOs and DSOs becomes increasingly important in the future. This will include, for example, data management and exchange related to grid/flexibilities data, control schemes, protection settings etc. In the future, due to increased DER, TSOs also need to more accurately estimate Q flows between DSO networks. Based on [1] the Q flow between HV and MV grid can be estimated with reasonable accuracy, but relative modelling errors are higher for distribution grids with QU-controlled DER than with cosφ(P) -controlled. In general, the local and system-wide technical flexibility services can be required by the grid codes and regulations or they can be offered by technical service / flexibility markets. Forthcoming DER unit grid code FRT requirements, like for example, operation time delays of different active Pf- and QU -control related technical ancillary services provided by flexibilities must be selective with islanding detection settings. [2]-[4]

Future ANM and protection methods and solutions have to be adapted and developed in a way which enables active control and utilization of DER based flexibilities during both grid-connected and islanded operation modes. In this paper, multi-objective ANM scheme is studied by simulations during grid-connected operation. The studied ANM scheme fulfills multiple targets / objectives (Fig. 1a) simultaneously by Q and P power control of both MV and LV network DER units.

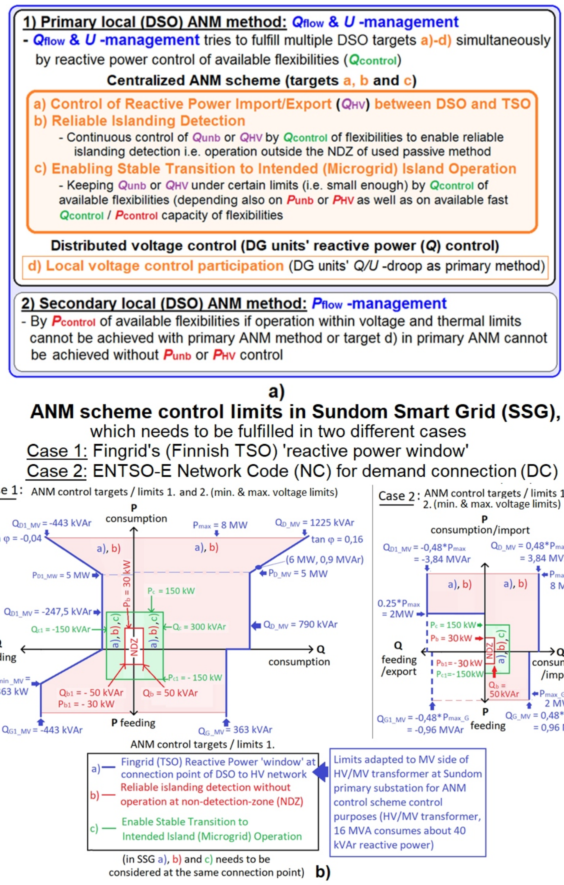

Figure 1. a) Multi-objective ANM scheme targets and b) ANM scheme target a) control limits in SSG (see [3]).

PSCAD simulations are done for a local smart grid pilot Sundom Smart Grid (SSG). Reactive power control limits of multi-objective ANM scheme in SSG are studied in two different cases (Fig. 1b): Case 1 with Fingrid's (Finnish TSO) 'reactive power window' (requirement today) and Case 2 with ENTSO-E network code for demand connection (NC DC, future requirement) [5]. The studied ANM scheme which, in addition to other simultaneous Q_{flow} & U -management objectives / targets (Fig. 1a), utilizes reactive power unbalance control based Q_{flow} & U -management also, for example, to ensure reliable islanding detection [3], [4]. Today there are two DG units connected to SSG (Fig. 2). One 3.6 MW full-power-converter based wind turbine (WT) connected to MV network with own MV feeder J08 (Fig. 2) and another LV network connected inverter based Photovoltaic (PV) unit (33 kW) at MV/LV substation TR4318 (Fig. 2).

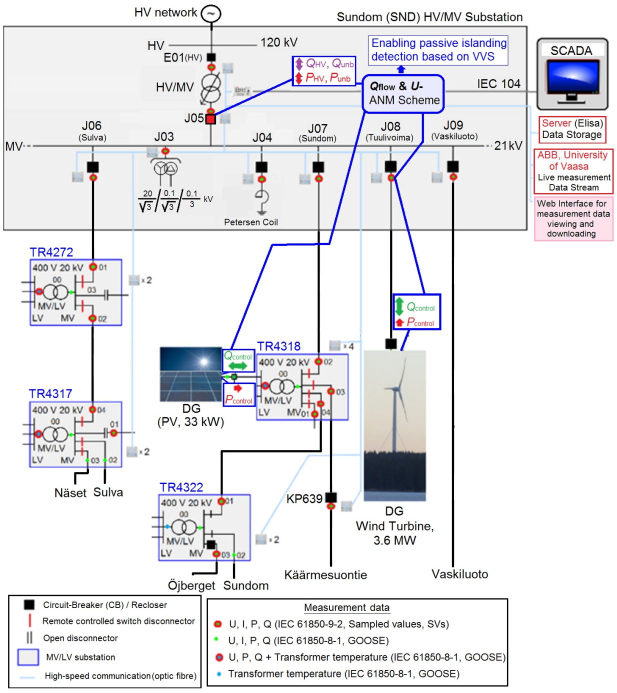

Figure 2. Sundom Smart Grid (SSG) real-life pilot network in which multi-objective ANM scheme presented in Fig. 1 is studied.

In addition to traditional IEC 61850-8-1 GOOSE measurements, in SSG IEEE 1588 time-synchronized current and voltage measurements from multiple points are sent by IEDs and transferred to a data center / storage using the IEC 61850-9-2 standard protocol (Fig. 2). Additional IEDs have also been installed to secondary substations. This system sends its data in real time through the optical fiber network (Fig. 2). All the data are sent to a centralized server (Fig. 2). In total, 20 IEDs are sending IEC 61850-9-2 SV streams with a sampling rate of 4 kHz as well as GOOSE data. So far this data has been also utilized e.g. for real-time power quality monitoring [6] and in the future these time-synchronized measurements can be used e.g. for improved real-time state-estimation in order to enable the utilization of new ANM scheme functionalities.

SIMULATION STUDY CASES

As presented in Fig. 2 today there are today two distributed generation (DG) units in SSG. However, in the study cases of this paper also future scenario with higher amount of PV units connected in LV network of SSG (Fig. 3 and Table 1) will be evaluated in order to study potential MV and LV network interactions related to fulfilling targets of multi-objective ANM scheme (Fig. 1a) by active Q and P control of MV and LV network connected DER units. In addition, potential mutual effects between QU-, PU- and Pf-control functions of DER units, for example when same DG unit is simultaneously used to provide both local and system-wide services (if possible), are studied in the PSCAD simulations.

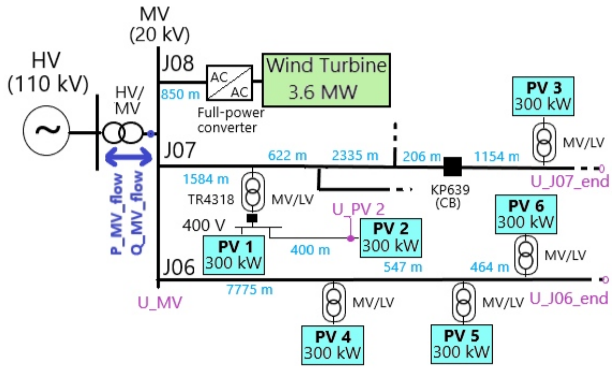

Figure 3. SSG future scenario with more PV units in LV network.

Table 1. Simulation study cases (see Fig. 1-3).

Cases	Number of WTs / PVs*)	Participation on ANM	RWP limit in ANM by WT or PVs**)	Over- / Under-voltage limits (pu)
0 (Base case, situation today)	1 (3.6 MW) / 1 (33 kW)	NO	-	0.95 / 1.05 (MV and LV)
1	1 (3.6 MW) / 1 (33 kW)	YES	WT	0.95 / 1.05 (MV and LV)
2a	1 (3.6 MW) / 6 (300 kW)	YES	WT	0.95 / 1.05 (MV and LV)
2b	1 (3.6 MW) / 6 (300 kW)	YES	PVs	0.95 / 1.05 (MV and LV)
2c	1 (3.6 MW) / 6 (300 kW)	YES	PVs	0.95 / 1.05 (MV and LV)
2d	1 (3.6 MW) / 6 (300 kW)	YES	WT	0.95 / 1.05 (MV) 0.9 / 1.1 (LV)

*) WT is Wind Turbine, PV is Photovoltaic Unit, **) 'Reactive Power Window' (RPW) limits are fulfilled by reactive power control of only WT or PVs (Fig. 1-3)

Fig. 4 shows a simplified flow-chart about determination of WT P- and Q- control set-point values when WT participates in ANM (Fig. 1-3, Table 1).

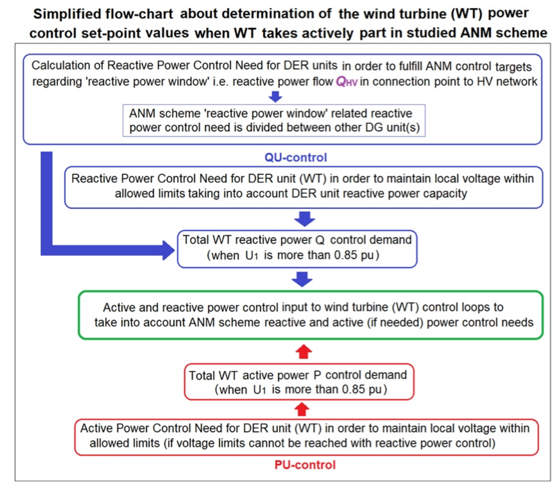

Figure 4. Flow-chart about determination of WT P- and Q- control set-point values when WT participates in ANM (Fig. 1-3, Table 1).

WT and PV unit *QU*-, *PU*- and *Pf*-droops which were used in the simulations are shown in Fig. 5 and Table 2.

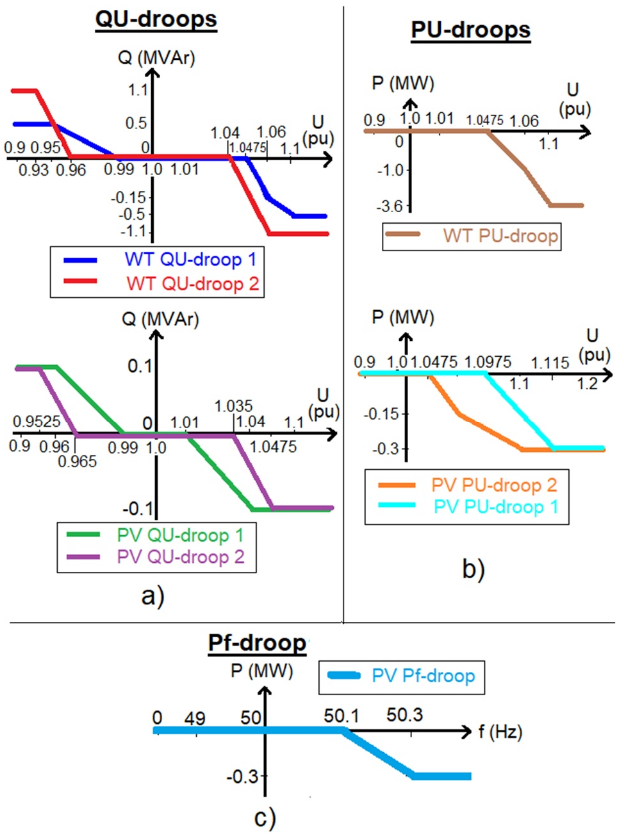

Figure 5. a) WT and PV *QU*-droops, b) WT and PV *PU*-droops and c) PV *Pf*-droop in simulations (Fig. 1-3, Table 1).

Table 2. *QU*- & *PU*- and *Pf*-droops of DG units in study cases (see Table 1 and Fig. 3 and 5).

Cases	*QU*-droop of WT / PVs	*PU*-droop of PVs
0	1 / 1	1
1	1 / 1	1
2a	1 / 1	1
2b	1 / 1	1
2c	1 / 2	1
2d	2 / 2	2 (only PV 2), 1 (other PVs)

Table 3 shows the sub-cases of study cases presented in Table 1.

Table 3. Sub-cases of study cases (see tables 1 & 2 and Fig. 1-3).

Sub-cases*)	**OLTC****) **set value (kV)**	**Load level**	**Total load (kW, KVAr),** (including also *P* losses and *Q* produced/consumed by cables & overhead lines)
Fingrid_1	*20.7*	Very low	1033, -690
Fingrid_2	20.0	Very low	978, -665
Fingrid_3	*20.7*	Very high	6993, 325
Fingrid_4	20.0	Very high	6583, 290
ENTSO_1	*20.7*	Very low	1033, -690
ENTSO_2	20.0	Very low	978, -665
ENTSO_3	*20.7*	Very high	6993, 325
ENTSO_4	20.0	Very high	6583, 290

*) Fingrid or ENTSO refers to used 'reactive power window' (RPW) limits (Fig. 1b),
**) HV/MV transformer On-Load-Tap-Changer (OLTC) *setting is today 20.7 kV*

In Table 4 used simulation sequence and other issues regarding study cases (Tables 1-3) are presented.

Table 4. Simulation sequence actions and other issues in study cases (see tables 1 -3 and Fig. 2 & 3). Total simulation time t = 120 s.

Time (s)	**Initial Condition / Action**
t = 0 - 120	PV unit active power (P_{PV}) is at nominal (if voltage at PV unit connection point is between min. & max. limits) i.e. 33 kW or 300 kW
t = 10.5	WT active power (P_{WT}) increases from initial 0.5 to 1.5 MW (if voltage at WT connection point is between min. & max. limits)
t = 30.0	WT active power (P_{WT}) increases from initial 1.5 to 2.5 MW (if voltage at WT connection point is between min. & max. limits)
t = 45.0	WT active power (P_{WT}) increases from initial 2.5 to 3.6 MW (if voltage at WT connection point is between min. & max. limits)
t = 70 - 80	Over-frequency situation (50.25 Hz), *Pf*-control of PVs reduces their active power output (P_{PV}) according to their Pf-droop in study cases 2a-d
t = 100 - 110	Under-frequency situation (49.8 Hz), Part of the load participates on demand response and disconnects from the LV network in very low load sub-cases (Table 3)
Other issues	- In all study cases of Table 1 and 2 (except Case 0) WT and PVs *QU*-droop is primary and PU-droop secondary local voltage control method - HV/MV substation On-Load-Tap-Changer (OLTC) operation time delay is 60 or 20 s in studied cases

However, regarding study cases (Tables 1-4) it should be noted that in Finland very high load situation simultaneously with maximum PV generation is unrealistic. However, maximum WT generation may happen also during very high-loading and simultaneous max. PV production might be realistic in some other countries.

SIMULATION RESULTS

In following Tables 5-14 main simulation results from different simulation cases are presented.

Table 5. Active and reactive power flow between HV and MV network (P_MV_flow, Q_MV_flow) measured from MV side of primary transformer in cases 0 and 1 (see Tables 1-3 and Fig. 1-3).

Sub-case	**P_MV_flow (kW), Q_MV_flow (kVAr)** (at t = 65.0s)		**Inside 'Reactive Power Window' -limits** (Fig. 1b) (YES / NO)	
	Case 0	**Case 1**	**Case 0**	**Case 1**
Fingrid_1	-2600, *-690*	-2600, -240	NO	YES
Fingrid_2	-2655, *-665*	-2660, -245	NO	YES
Fingrid_3	3360, 325	3360, 322	YES	YES
Fingrid_4	2950, 290	2950, 290	YES	YES
ENTSO_1	-2600, *-690*	-2605, 30	NO	YES
ENTSO_2	-2655, *-665*	-2665, 25	NO	YES
ENTSO_3	3360, 322	3360, 322	YES	YES
ENTSO_4	2950, 290	2950, 290	YES	YES

Table 6. Active and reactive power flow between HV and MV network (P_MV_flow, Q_MV_flow) measured from MV side of primary transformer in cases 2a and 2b (see Tables 1-3 and Fig. 1-3).

Sub-case	**P_MV_flow (kW), Q_MV_flow (kVAr)** (at t = 65.0s)		**Inside 'Reactive Power Window' - limits** (Fig. 1b) (YES / NO)	
	Case 2a	**Case 2b**	**Case 2a**	**Case 2b**
Fingrid_1	-4250, 100	-4250, -30	YES	YES
Fingrid_2	-4350, 30	-4350, -80	YES	YES
Fingrid_3	1580, 787	1585, 760	YES	YES
Fingrid_4	1206, 550	1205, 550	YES	YES
ENTSO_1	-4250, 570	-4250, *-30**)	YES	NO
ENTSO_2	-4350, 430	-4350, 10	YES	YES
ENTSO_3	1570, 860	1570, 860	YES	YES
ENTSO_4	1205, 550	1205, 550	YES	YES

*) All PV units take max. reactive power (-100 kVAr / PV), but it is not enough in this case => WT is not simultaneously with WT *QU*-droop 1 settings (Fig. 5a) taking reactive power at all and therefore 'reactive power window' limits are exceeded

Table 7. Active and reactive power flow between HV and MV network (P_MV_flow, Q_MV_flow) measured from MV side of primary transformer in case 2c at *t*=65 s and *t*=75 s (see Tables 1-3 and Fig. 1-3).

Sub-case	**P_MV_flow (kW), Q_MV_flow (kVAr)**		**Inside 'Reactive Power Window' - limits** (Fig. 1b) (YES / NO)	
	Case 2c (*t* = 65.0 s)	**Case 2c** (*t* = 75.0 s)	**Case 2c** (*t* = 65 s)	**Case 2c** (*t* = 75 s)
Fingrid_1	-4250, -30	-3020, -90	YES	YES
Fingrid_2	-4330, -400	-3080, -330	YES	YES
Fingrid_3	1615, 605	2910, 550	YES	YES
Fingrid_4	1250, 300	2560, 250	YES	YES
ENTSO_1	-4250, *-30*[*)]	-3020, *-220*[*)]	NO	NO
ENTSO_2	-4350, 10	-3080, *-345*[*)]	YES	NO
ENTSO_3	1615, 605	2910, 550	YES	YES
ENTSO_4	1250, 300	2560, 250	YES	YES

[*)] Same conclusions / reasons for 'reactive power window' limit violations

Table 8. Active and reactive power flow between HV and MV network (P_MV_flow, Q_MV_flow) measured from MV side of primary transformer in case 2d at *t*=65 s and *t*=75 s (see Tables 1-3 and Fig. 1-3).

Sub-case	**P_MV_flow (kW), Q_MV_flow (kVAr)**		**Inside 'Reactive Power Window' - limits** (Fig. 1b) (YES / NO)	
	Case 2d (*t* = 65.0 s)	**Case 2d** (*t* = 75.0 s)	**Case 2d** (*t* = 65 s)	**Case 2d** (*t* = 75 s)
Fingrid_1	-4320, 120	-3020, 40	YES	YES
Fingrid_2	-4370, -240	-3080, -320	YES	YES
Fingrid_3	1600, *795*[*)]	2900, 750	NO	YES
Fingrid_4	1250, 300	2555, 235	YES	YES

[*)] Q_MV_flow cannot be maintained inside 'reactive power window' limits due to WT *QU*-droop 2 settings (Fig. 5a) and conflicting requirements between WT *QU*-droop and 'reactive power window' limits fulfillment

Table 9. Wind turbine (WT) reactive power (Q_WT) in cases 0, 1, 2a, 2b and 2c at *t*=65 s, P_WT = 3.6 MW (see Tables 1-3 and Fig. 1-3).

Sub-case	**Q_WT (kVAr)** (at *t* = 65.0s)		
	Case 0 / 2b / 2c	**Case 1**	**Case 2a**
Fingrid_1	0	-448	-130
Fingrid_2	0	-414	-120
Fingrid_3	0	0	73
Fingrid_4	0	0	0
ENTSO_1	0	-715	-595
ENTSO_2	0	-685	-560
ENTSO_3	0	0	0
ENTSO_4	0	0	0

Table 10. Wind turbine (WT) reactive power (Q_WT) in case 2d at *t* = 65 s, *t* = 75 and *t* =105 s, P_WT = 3.6 MW (see Tables 1-3 and Fig. 1-3).

Sub-case	**Q_WT (kVAr)**		
	Case 2d (*t* = 65 s)	**Case 2d** (*t* = 75 s)	**Case 2d** (*t* = 105 s)
Fingrid_1	-132	-132	-144
Fingrid_2	-158	-158	-158
Fingrid_3	*-210*	-230	-210
Fingrid_4	0	0	0

It can be seen from simulation results of Table 6 and 7 that ENTSO-E 'reactive power window' (RPW) limits cannot be fulfilled in all cases (cases 2b and 2c) during very low load (*sub-case ENTSO_1*) because in these cases all PV units take max. reactive power (-100 kVAr / PV) and WT is not simultaneously taking reactive power at all with WT *QU*-droop 1 settings (Fig. 5a). Also Table 8 shows that in case 2d Fingrid RPW -limits cannot be fulfilled in *sub-case Fingrid 3* during very high-load due to WT *QU*-droop 2 settings (Fig. 5a) and conflicting requirements between WT *QU*-droop 2 (Fig. 5 and Table 10) and RPW-limits fulfillment. As expected Table 9 shows that ENTSO-E RPW -limits require more reactive to be consumed by WT than Fingrid RPW -limits in cases 1 and 2a during very low load conditions. In addition, regarding ENTSO-E requirement (Fig. 1b) 2 MW limit for *P* feeding, it can be seen from Tables 5-7 that the limit is exceeded in very low load cases.

In the simulations (cases 2a-d, Table 1) PV unit PV 2 was the only one which was connected further away from MV/LV substation (Fig. 3) and therefore potential need for active power curtailment with PV *PU*-droop control (Fig. 5b and Table 2) due to overvoltage limit violations was most probable. In order to study PV 2 *QU*-control and voltage limit effects on PV 2 active power feeding capability (i.e. active power curtailment needs) two additional cases 2a_I and 2a_II were simulated (Table 11).

Table 11. Simulation study cases 2a_I and 2a_II to study PV 2 *QU*-control and voltage limits effects on PV 2 active power feeding capability in different sub-cases (see Tables 1-3 and Fig. 3).

Cases (Modified from case 2a)	**Differences to case 2a** (Table 1)
2a_I	PV 2 without *QU*-control
2a_II	PV 2 without *QU*-control & max. voltage limit in LV network is 1.1 pu & min. voltage limit 0.9 pu, PV 2 with *PU*-droop 2, *QU*- and *PU*-control of other PVs similar to case 2a

Table 12. PV unit PV 2 active and reactive power (P_PV 2, Q_PV 2) in cases 2a_I, 2a_II, 2a and 2b at *t*=65 s (see Tables 1-3 and 11and Fig. 3).

Sub-case	**P_PV 2 (kW), Q_PV 2 (kVAr)** (at *t* = 65.0s)			
	Case 2a_I	**Case 2a_II**	**Case 2a**	**Case 2b**
Fingrid_1	96, 0	193, 0	220, -100	213, -100
Fingrid_2	148, 0	246, 0	270, -100	267, -100
Fingrid_3	283, 0	300, 0	300, -100	300, -72
Fingrid_4	300, 0	300, 0	300, -62	300, -62

Table 13. PV unit PV 2 active and reactive power (P_PV 2, Q_PV 2) in cases 2c and 2d at *t*=65 s (see Tables 1-3 and 11and Fig. 3).

Sub-case	**P_PV 2 (kW), Q_PV 2 (kVAr)** (at *t* = 65.0s)	
	Case 2c	**Case 2d**
Fingrid_1	213, -100	300, -100
Fingrid_2	251, -100	300, -100
Fingrid_3	300, -65	300, -62
Fingrid_4	300, -16	300, -16

Table 14. Reactive power (Q_PV) of PV units 1-6 in cases 2a, 2b, 2c and 2d at *t*=65 s (see Tables 11-13 and Fig. 3).

Sub-case Fingrid_3	**Q_PV (kVAr)** (at *t* = 65.0s)					
	PV 1	**PV 2**	**PV 3**	**PV 4**	**PV 5**	**PV 6**
Case 2a	-100	-100	-100	-100	-100	-100
Case 2b	-100	-72	-94	-78	-78	-84
Case 2c	-100	-65	-56	-42	-40	-50
Case 2d	-100	-62	-51	-38	-35	-46

Tables 12-14 show how reactive power *QU*-droop control, different PV and WT *QU*-droop settings and max. voltage limit changes affect on PV 2 unit active power curtailment needs. The effect of OLTC set value, 20.7 or 20.0 kV can be also seen from simulation results i.e. typically less reactive power is needed from DER units to fulfill RPW -limits with lower set value (cases 1 and 2a in Table 9) and less active power also needs to be curtailed by PV 2 (Tables 12 and 13) with 20.0 kV setting.

Simulations with New WT *QU*-droop Settings

In previous simulations ENTSO-E (Cases 2b and 2c, sub-case ENTSO_1) and Fingrid (Case 2d, sub-case 3) RPW-limits could not be achieved due to WT *QU*-droop 1 (ENTSO_1) settings and mutual / conflicting requirements between WT control functions) (*QU*-droop 2 & *Q*-control to fulfill RPW-limits) in case 2d / sub-case Fingrid 3. To solve these issues new simulations from these cases were done with modified WT *QU*-droops (Table 15 and Fig. 6). Simulation results in Table 16 show that now with different WT *QU*-droop settings in these cases RPW-limits can be fulfilled.

Table 15. New simulations from two challenging study cases with modified WT *QU*-droops (Fig. 5 and 6).

New 2e Sub-cases	Differences to original / New WT QU-droops (Table 2)
ENTSO_1 (Modified from case 2b)	WT *QU*-droop 4
Fingrid_3a (Modified from case 2d)	WT *QU*-droop 1
Fingrid_3b (Modified from case 2d)	WT *QU*-droop 3

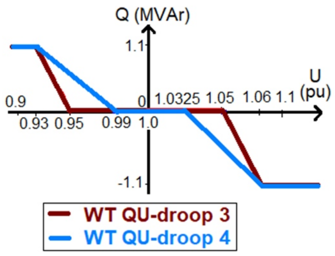

Figure 6. Modified WT *QU*-droops for two challenging cases (Fig. 1-3, Table 1).

Table 16. Active and reactive power flow between HV and MV network (P_MV_flow, Q_MV_flow) and WT reactive power (Q_WT) in case 2e sub-cases at *t*=65 s (see Tables 7-10 and 15).

Sub-case	Case 2e (*t* = 65.0 s)		
	P_MV_flow (kW), Q_MV_flow (kVAr)	**Inside 'Reactive Power Window' - limits** (Fig. 1b) (YES / NO)	**Q_WT (kVAr)** (at *t* = 65.0s)
ENTSO_1	-4254, 245	YES	-273
Fingrid_3a	1600, 607	YES	0
Fingrid_3b	1600, 607	YES	0

DISCUSSION AND CONCLUSIONS

In the future reactive power (*Q*) control of distribution network connected DER could be increasingly used for ANM instead of traditional *Q* compensation devices (like reactors, capacitors and STATCOMs). However, contribution of DER on different reactive power and voltage control methods at different voltage levels (HV, MV and LV) needs to be planned and operated in a feasible way in order to avoid unwanted interactions between voltage levels as well as potential mutual effects between *QU*-, *PU*- and *Pf* -control funtions of DER units. Regarding these issues e.g. in [7] interaction between OLTCs and DER unit *QU*-control has been studied and one recommendation in [7] was that *QU*-control dead-zone /-band should be between 0.97 and 1.03 pu in order to prevent oscillating interactions. Paper [7] also underlined the importance of *QU*-control correct time delays and control stability during transient disturbances. On the other hand, in [8] it was stated that *QU*-control parameters in the German standard "VDE-AR-N-4105" [9] are feasible and utilization of *QU*-control is not a problem from stability point of view. Paper [10] suggested also that in order to take the advantages of both centralized and local controls, the parameters of *PU*- and *QU*-droops could be tuned every 15 minutes in order to minimize network losses and *P* curtailment due to voltage limit violations. In addition, optimal parametrization of *QU*-droops was considered in [11] taking into account DER units (PV) penetration level and weather conditions.

This paper studied the new multi-objective ANM scheme by PSCAD simulations of real-life Smart Grid pilot SSG. Simulations showed that unwanted effects and mutual conflicting requirements are possible if unfeasible *QU*-droop settings are used. In addition to *QU*-droop settings, also operation time delays of different voltage control functions needs to be carefully planned. Other main conclusions based on the simulations are:

1) Setting value of OLTCs and DER unit local *QU*-droops could be in the future adaptive so that short- (time of day) and long-term (seasonal) forecasts and locational aspects would be considered in centralized multi-objective ANM scheme operation in coordinated way.

- For example regarding OLTC setting value in SSG it could be (instead of todays 20.7 kV) in the future either
  - *I)* 20.3 kV during whole year (now),
  - *II)* In the near future if large amount of PV increases in LV network, 20.3 kV during winter (October-April) and 20.0 kV during summer (May-September) or
  - *III)* If in the future amount of both PVs and charging of electric vehicles (EVs) increases substantially then real-time weekly / daily / hourly voltage level (incl. OLTC setting value) optimisation could be then more relevant (e.g. between 20.0–20.5 kV in SSG) through ANM.

2) As part of studied ANM scheme only reactive power *Q* of DER unit(s) close to HV/MV substation, where RPW targets must to be fulfilled, should be controlled for RPW purpose (WT in SSG) and leave *Q* control capacity of other DER units which are further from the HV/MV substation point for local distribution network voltage control (PVs in SSG).

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