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Title: # Appendix of Deliverable 1.1 "Creation of initial models and AVC control logic"

Synopsis: This document presents details of the initial voltage control logic of the LoVIA project.

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Appendix of Deliverable 1.1 “Creation of initial models and AVC control logic”

This document presents details of initial voltage control logic for the LoVIA project extracted (and extended) from the report of Deliverable 1.1 “Creation of initial models and AVC control logic”.

The LoVIA automatic voltage control (AVC) logic aims to change the busbar voltage target at different times of the day, considering voltages at the busbar as well as mid and end points. Based on analyses carried out for different control cycle lengths, it was decided to adopt a 30-minute control cycle. This means that the busbar voltage target is changed, if required by the logic, every 30 minutes.

For the logic, the busbar line-to-neutral (L-N) voltage will be considered as a reference (this can be derived from the voltage reference adopted by the TAPCON, which is L-L). A compensating voltage, V_{comp}, is calculated by a voltage control logic that takes into account the monitoring voltages. The new voltage target ($V_{new\ target}$) is then obtained by comparison with the monitored L-N busbar voltage (V_{busbar}) and the compensating voltage (V_{comp}).

$$V_{new\ target} = V_{busbar} - V_{comp} \qquad (1)$$

The determination of the compensating voltage (V_{comp}) is described in the following paragraphs.

The L-N voltage limits at the connection point of the customers are 253 and 216V, i.e., 1.10 and 0.94 p.u. With the OLTC, the lowest phase voltage at busbar would be 231V (tap position 9). This means that, assuming a voltage drop of no more than 6%, customers at the far end of the feeders would still see adequate voltages. However, this might not be the case for some feeders, hence the need of further flexibility (to be provided in this project by capacitor banks). On the other hand, the highest phase voltage at the busbar will be ultimately limited by the (unavoidable) presence of customers close to the substation, i.e., the busbar cannot exceed 253V (tap position 4).

The AVC logic has also considered scenarios when mid and end point voltages are close to the boundary: 2% near the boundary (i.e., from 248 to 253V and from 216 to 221V) are considered as orange zones. Based on the above, three voltage zones (red, orange and green) can be defined as shown in Figure A1.

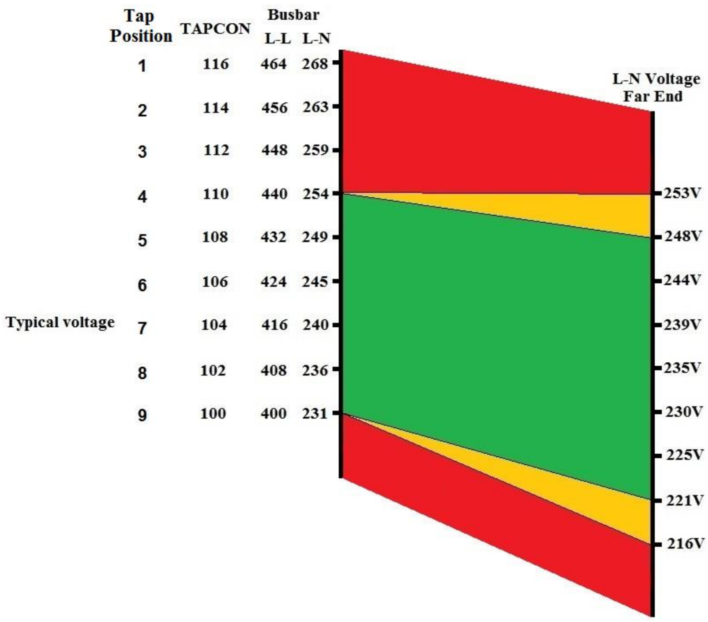


Figure A1 Voltage zones (integer values)

Every 30 minutes, the average busbar L-N voltage and the minimum and maximum L-N voltages of all the mid and end points of the LV feeders are monitored. These voltages are then compared to the voltage zones (Figure A1), i.e., green, orange and red. As shown in Table A1, the values (e.g., "- 2", "+ 1", etc.) correspond to a factor used to calculate the compensating voltage (V_{comp}). For instance, "- 2" means V_{comp} is equal to 2 multiplied by V_{unit}, where V_{unit} is the voltage change at the busbar when the tap changes one step. In the LoVIA project, one-step tap change corresponds to 2% voltage change at the busbar, i.e., 4.6V (L-N). Therefore, V_{unit} is equal to 4.6V.

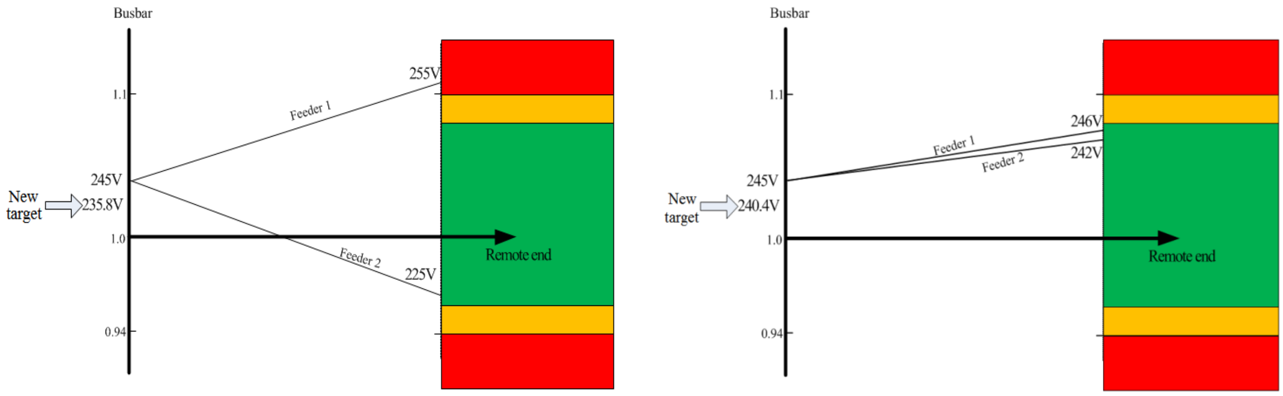
Examples of the calculation of compensating voltages (V_{comp}) and the new voltage targets are illustrated in Table A2 and Figure A2. A detailed flow chart containing the actual values adopted in this initially proposed voltage control logic is presented in Figure A3.

Table A1 Determination of V_{comp} by Monitored Mid and End Point Voltages

<table>
<tr><th colspan="3"></th><th colspan="6">Maximum</th></tr>
<tr><th colspan="3"></th><th>Red</th><th>Orange</th><th colspan="2">Green</th><th>Orange</th><th>Red</th></tr>
<tr><th colspan="3"></th><th>>253V</th><th>253V≥. ≥248V</th><th>248V>. ≥239V</th><th>239V>. ≥221V</th><th>221V>. ≥216V</th><th><216V</th></tr>
<tr><td rowspan="6">Minimum</td><td>Red</td><td>>253V</td><td>- 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Orange</td><td>253V≥. ≥248V</td><td rowspan="3">- 2</td><td>- 2</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Green</td><td>248V>. ≥239V</td><td rowspan="2">- 1</td><td>If V_{busbar}≥ 424V - 1</td><td></td><td></td><td></td></tr>
<tr><td>239V>. ≥221V</td><td>0</td><td>If V_{busbar}≤ 408V + 1</td><td></td><td></td></tr>
<tr><td>Orange</td><td>221V>. ≥216V</td><td>- 1</td><td>0</td><td>+ 1</td><td>+ 1</td><td>+ 1</td><td></td></tr>
<tr><td>Red</td><td><216V</td><td>0</td><td>+ 1</td><td>+ 2</td><td>+ 2</td><td>+ 2</td><td>+ 3</td></tr>
</table>

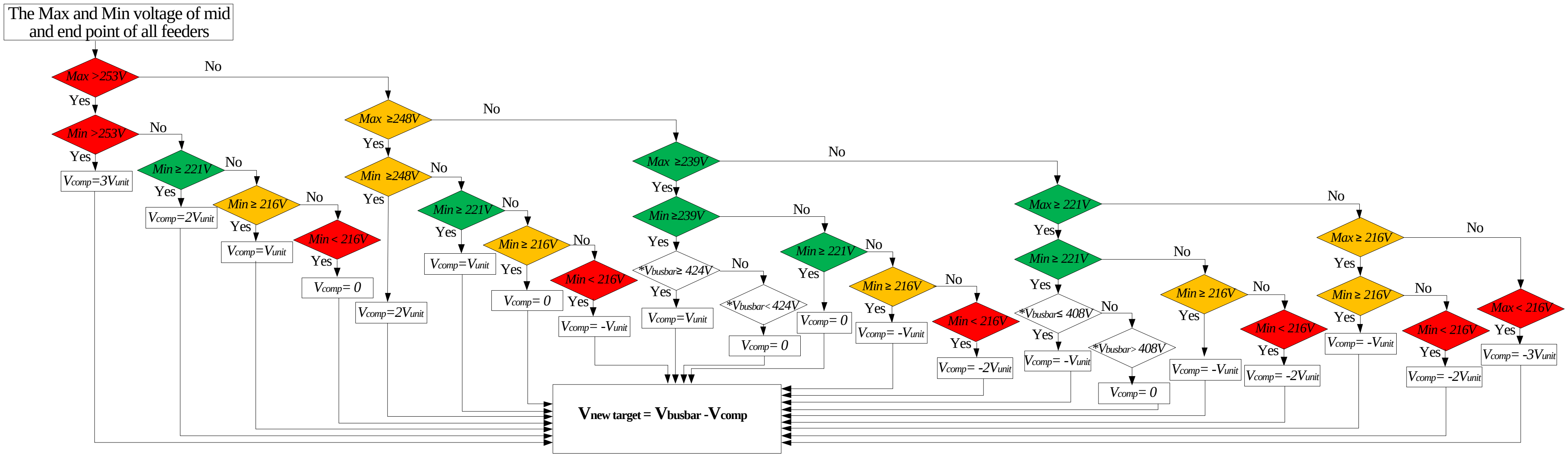
Table A2 Examples of New Voltage Target Calculation

Example	Busbar voltage L-N (V)	Mid and end point voltage L-N (V)		V_{comp} (V)	New voltage target (V)
		Maximum	Minimum		$V_{new\ target}=V_{busbar}-V_{comp}$
1	245	255	225	2*4.6	235.8
2	236	245	210	-1*4.6	240.6
3	235	249	219	0	235
4	245	246	242	1*4.6	240.4



(a) Example 1 (b) Example 4

Figure A2 New Voltage Target Calculations for Two Examples



* denotes the voltage is line-to-line voltage

Vunit = 4.6V

Figure A3 Detailed Flow Chart of the Voltage Control Logic

The main RTU (USP20) code corresponding to the above proposed logic is shown in Figure A4 and Figure A5. This code is essentially to determine the new voltage target as presented in Table A1. In the code, “FDR_MAX” and “FDR_MIN” represent the maximum and minimum of voltages at all mid and end points. “BUSBAR_MNTR_V” represents the average of the monitored busbar voltage (L-L). “AO_DESIRED_V” is the new voltage target. It is important to highlight that this code is only the main part of the algorithm and other aspects such as data processing, fall back settings and interoperability with other devices need to be incorporated.

setpoint

```
IF((FDR_MAX>253)AND(FDR_MIN>253)) THEN
COMP_V := 3*VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN>=221)) THEN
COMP_V := 2*VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN>=216)) THEN
COMP_V :=VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN<216)) THEN
COMP_V :=0;
END_IF;

IF((FDR_MAX>=248)AND(FDR_MIN>=248)) THEN
COMP_V :=2*VUNIT;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN>=221)) THEN
COMP_V :=VUNIT;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN>=216)) THEN
COMP_V :=0;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN<216)) THEN
COMP_V :=-VUNIT;
END_IF;

IF((FDR_MAX>=239)AND(FDR_MIN>=239)AND(BUSBAR_MNTR_V>=424)) THEN
COMP_V :=VUNIT;
END_IF;
  IF((FDR_MAX>=239)AND(FDR_MIN>=239)AND(BUSBAR_MNTR_V<424)) THEN
  COMP_V :=0;
  END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN>=221)) THEN
COMP_V :=0;
END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN>=216)) THEN
COMP_V :=-VUNIT;
END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN<216)) THEN
COMP_V := -2*VUNIT;
END_IF;

IF((FDR_MAX>=221)AND(FDR_MIN>=221)AND(BUSBAR_MNTR_V<=408)) THEN
COMP_V := -1*VUNIT;
END_IF;
  IF((FDR_MAX>=221)AND(FDR_MIN>=221)AND(BUSBAR_MNTR_V>408)) THEN
  COMP_V :=0;
  END_IF;
IF((FDR_MAX>=221)AND(FDR_MIN>=216)) THEN
COMP_V :=-1*VUNIT;
END_IF;
IF((FDR_MAX>=221)AND(FDR_MIN<216)) THEN
COMP_V :=-2*VUNIT;
END_IF;

IF((FDR_MAX>=216)AND(FDR_MIN>=216)) THEN
COMP_V :=-VUNIT;
END_IF;
IF((FDR_MAX>=216)AND(FDR_MIN<216)) THEN
COMP_V :=-2*VUNIT;
END_IF;

IF FDR_MAX<216 THEN
COMP_V :=-3*VUNIT;
END_IF;

AO_DESIRED_V := (BUSBAR_MNTR_V/1.732) - COMP_V;

IF AO_DESIRED_V<231 THEN
AO_DESIRED_V :=231;
END_IF;
IF AO_DESIRED_V>253 THEN
AO_DESIRED_V :=253;
END_IF;
```

Maximum and Minimum of voltages at all mid and end points

Monitored busbar voltage

New voltage target

Figure A4 RTU USP20 main code of the proposed logic (screenshot)

```
IF((FDR_MAX>253)AND(FDR_MIN>253)) THEN
COMP_V := 3*VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN>=221)) THEN
COMP_V := 2*VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN>=216)) THEN
COMP_V :=VUNIT;
END_IF;
IF((FDR_MAX>253)AND(FDR_MIN<216)) THEN
COMP_V :=0;
END_IF;

IF((FDR_MAX>=248)AND(FDR_MIN>=248)) THEN
COMP_V :=2*VUNIT;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN>=221)) THEN
COMP_V :=VUNIT;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN>=216)) THEN
COMP_V :=0;
END_IF;
IF((FDR_MAX>=248)AND(FDR_MIN<216)) THEN
COMP_V :=-VUNIT;
END_IF;

IF((FDR_MAX>=239)AND(FDR_MIN>=239)AND(BUSBAR_MNTR_V>=424)) THEN
COMP_V :=VUNIT;
END_IF;
  IF((FDR_MAX>=239)AND(FDR_MIN>=239)AND(BUSBAR_MNTR_V<424)) THEN
  COMP_V :=0;
  END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN>=221)) THEN
COMP_V :=0;
END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN>=216)) THEN
COMP_V :=-VUNIT;
END_IF;
IF((FDR_MAX>=239)AND(FDR_MIN<216)) THEN
COMP_V := -2*VUNIT;
END_IF;

IF((FDR_MAX>=221)AND(FDR_MIN>=221)AND(BUSBAR_MNTR_V<=408)) THEN
COMP_V := -1*VUNIT;
END_IF;
  IF((FDR_MAX>=221)AND(FDR_MIN>=221)AND(BUSBAR_MNTR_V>408)) THEN
  COMP_V :=0;
  END_IF;
IF((FDR_MAX>=221)AND(FDR_MIN>=216)) THEN
COMP_V :=-1*VUNIT;
END_IF;
IF((FDR_MAX>=221)AND(FDR_MIN<216)) THEN
COMP_V :=-2*VUNIT;
END_IF;

IF((FDR_MAX>=216)AND(FDR_MIN>=216)) THEN
COMP_V :=-VUNIT;
END_IF;
IF((FDR_MAX>=216)AND(FDR_MIN<216)) THEN
COMP_V :=-2*VUNIT;
END_IF;

IF FDR_MAX<216 THEN
COMP_V :=-3*VUNIT;
END_IF;

AO_DESIRED_V := BUSBAR_MNTR_V - COMP_V;

IF AO_DESIRED_V<231 THEN
AO_DESIRED_V :=231;
END_IF;
IF AO_DESIRED_V>253 THEN
AO_DESIRED_V :=253;
END_IF;
```

Figure A5 RTU USP20 main code of the proposed logic (text)