DNV

Memo to:
Netbeheer Nederland

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From: Energy Systems
Date: 31-5-2021
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Explanation BLOS load flow tool Type B PGM revision 31-5-2021

1 INTRODUCTION

In the Netbeheer Nederland document "Power-Generating Modules compliance verification" for Type B, C and D, a simulation is prescribed to show that the Netcode requirements for reactive power capability are met. This BLOS tool (type **B LO**ad flow **S**imulation) has been developed as a tool in the Compliance process for Type B Power Park Modules. This can be used for this purpose if it concerns a "Basic Park Type B" (definition see below). Based on the rated capacities of the inverters (PV inverter, wind turbine), transformers and cables to be filled in, the tool calculates the active and reactive power (MW, Mvar) at the connection point and shows the results in table and graph form. This assesses whether the requirements of Netcode are met.

Note: The PPM owner/developer remains responsible for demonstrating Compliance to the network operator and cannot derive any rights or rely on the application or outcomes of this tool. DNV is not liable for any direct or indirect consequences when using this tool. It is not permitted to use this tool for purposes other than as a tool for Type B compliance activities, to copy and/or share with parties other than the network operator.

2 BLOS LOAD FLOW TOOL FOR BASIC PARK PPM TYPE B

In this tool a simple park grid configuration can be modeled if this grid meets the principles of a basic park, see chapter 3: Connection point - MS connection - MS installation - MS connection - MS/LS transformer – LS connection – inverters. An MS or LS connection consists of one or more parallel three-phase cables or, in the case of single-core cables, one or more parallel three-phase circuits. A MS connection between the Connection point and the central medium voltage distribution station on the park is modelled separately. Furthermore, the average length of the MS and LS connections to the transformers in the park is assumed. You specify the number of parallel cables between transformers and central MS installation in the model per transformer. The same applies to the LS connection, which connects the transformer to the inverters.

You specify the number of transformers. In the base park we assume identical transformers that are connected to an equal number of parallel MS cables to the central MS distribution station and an equal number of parallel LS cables to the inverters. Short LS cables from the individual inverter to a collection cabinet are neglected.

The total number of inverters to be specified is the total number in the entire PV park, not per transformer. The number of inverters per transformer is therefore determined by a calculation. Again, for the model, we assume that the number of inverters per transformer is the same. The rated data of the inverter to be filled in must come from inverter certificates/data sheets.

The transformers are usually equipped with tapping selector switch. We assume a switch with 5 positions with a voltage change on the medium voltage side of 2.5% per step. The position must correspond to the actual position in the installation. If no switch is present, select position 0. Position adjustment gives a change of 2.5% per step in the primary voltage and results in a shift of the Q-U window. This may be necessary to demonstrate compliance.

3 STARTING POINTS FOR USE

3.1 Basic park

Starting points for using this simple BLOS load flow tool and basic park configuration shown schematically in Figure 1 (top scheme) are:

- Inverters of one type
- Connection inverters to MS/LS transformers via LS cable (one or more parallel) (LS cables). Maximum length of LS cables: 500 meters
- One or more MS/LS transformers of one type, equipped with a tapping selector switch. If no switch is installed, select position 0
- Equal distribution of inverters over MS/LS transformers. A difference in distribution of up to 2 inverters per transformer is acceptable
- Connection of individual MS/LS transformers via MS cable (MS-TR) to a central MS distribution station (MS). One or more cables in parallel. Length MS cable up to 2 km
- Connection Central MS distribution station (MS) via MS cables (OP-MS) to the connection point (OP). One or more cables in parallel. Length MS cable up to 10 km
- Grid operator MS station (“inkoopstation”/överdrachtspunt”/connection point) (OP)
- Radial cable network, not meshed, no crossings
- No reactive power compensation

3.2 Sub parks and shared MS connection

It might be the case that a park configuration does not meet the starting points, but consists of sections ("sub parks") that do comply. In that case, a BLOS model can be used per sub park. If all sub parks comply, the entire park will also comply. The BLOS tool for all sub parks must then be submitted to the grid operator.

Exceptionally, the BLOS tool can also be used for a park, where the transformers are connected to the connection point by a common medium voltage connection (shared MS connection). This is shown in the lower diagram in Figure 1 for the connections MS cable #1-2/#2-3/#3-4. However, the total length of the connection between 1st transformer (MS#1) and last transformer (MS#4) shall not exceed 2000 meters. When entering cable connection OP-MS, the cable type connected to the connection point (purchasing station) must be chosen with a length from the grid operator station to the first transformer station (MS#1) plus half of the total length of the connection from the transformer station MS#1 to MS#4 (maximum 1000 meters). Set the MS-TR cable to 0 meters in this case.

If the PV/wind turbine park does not meet these principles, you must use a dedicated load flow simulation package.

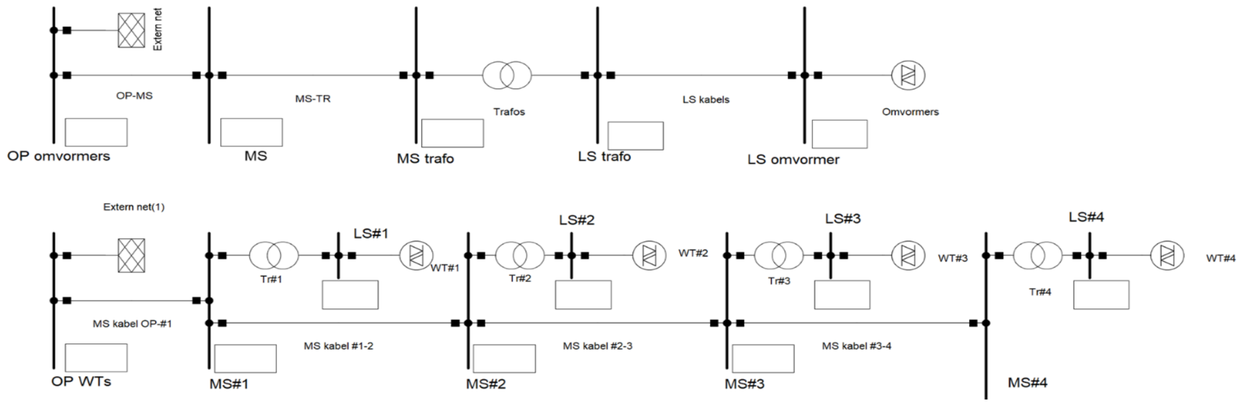


Figure 1 Schematic representation of the base parks

4 SHEETS IN BLOS TOOL

4.1 Input and Results sheet

In the "Invoer en resultaten" sheet, the data of the park must be entered: inverters/wind turbines, low and medium voltage cables and transformers. The input cells are shown in Figure 2. There is an internal library with cables and transformers, from which you can choose. In addition, it is possible to add medium voltage cables (2 types), low-voltage cables (1 type) and transformer (1 type) with corresponding parameters yourself. The white colored fields are to be used to enter the corresponding data yourselves.

The block OP-MS cables concerns the cables from the connection point to the central MS installation. The block MS-TR cables concerns the cables from the central MS park installation to the transformer(s). If the connection point is located on the central MS park installation, fill in a length of 0 meters for the OP-MS cables, but choose a (random) type.

Fill in the rated primary and secondary voltage at the transformer. A tap selector switch with 5 positions (respectively +2, +1, 0, -1, -2) has been assumed. The selected position must correspond to the actual position in the installation. Position adjustment gives a change of 2.5% per step in the primary voltage and results in a shift of the Q-U window. This may be necessary to achieve compliance.

Each input field is accompanied by a note with a brief explanation. The text becomes visible when the cell is clicked.

Details:

- For inverters and wind turbines, enter values according to manufacturer's information. At maximum and minimum voltage, take into account the actual settings over and under voltage protection
- MS-TR cables and LS cables to transformers can have different lengths. Assume the average length of the cables
- If there is no OP-MS cable, because there is a connection point at the central MS installation of the park, to which the transformers are also connected, then choose a type for OP-MS cable but fill in length of 0 meters.
- If no tap selection switch is installed, select position 0.

Invoergegevens		
Naam PGM	Demo park	
Type omvormers	Fabricaat/type	
Omvormers	Totaal aantal omvormers	50
	Schijnbaar vermogen per omvormer Snom (kVA)	250
	Werkzaam vermogen per omvormer Pnom (kW)	250
	Maximaal blindvermogen levering per omvormer (kvar)	250
	Maximaal blindvermogen opname per omvormer (kvar)	-250
	Nominale spanning Unom (V)	550
	Maximale stroom I max (A)	262
	Maximale spanning Umax (V)	630
	Minimale spanning Umin (V)	480
	Maximale kortsluitstroom (A)	270
LS kabels Omvormers naar transformatoren	aantal (driefasen)parallel per transformator	10
	Lengte (km)	0.20
	Geleider kabel (mm2 Al)	240 Al
MS trafos Transformatoren	aantal transformatoren	5
	Schijnbaar vermogen S (kVA)	2500
	Nominale spanning primair Ums (kV)	10.50
	Nominale spanning secundair Uls (kV)	0.55
	Positie aftakschakelaar (0=nominale overzetverhouding)	+1
MS TR kabel Transformatoren naar MS verzamelstation	aantal (driefasen)kabels parallel per trafo	1
	lengte per kabel (km)	0.50
	Doorsnede geleider kabel (mm2 Al)	95 Al
OP-MS kabels MS verzamelstation naar overdrachtspunt	aantal (driefasen)kabels parallel naar overdrachtspunt	1
	lengte per kabel (km)	5.00
	Doorsnede geleider kabel (mm2 Al)	800 Al
NET	Toegekende netspanning Uc (kV):	10.50

Rechts kan 1 eigen typen LS-kabel ingevoerd worden	Ruimte voor 1 type eigen LS kabel			
	Geleider (mm2)	Weerstand R (Ohm/km)	Reactantie X (Ohm/km)	Belastbaarheid (A)
	95test	0.322	0.069	230

Rechts kan 1 eigen type transformator ingevoerd worden	Ruimte voor 1 type eigen Transformator			
	Vermogen (kVA)	Nullastverlies (kW)	Kortsluitverlies (kW)	Kortsluitspanning (%)
	5200	4.00	42.50	10.00

Rechts kunnen 2 eigen typen MS-kabels ingevoerd worden	Ruimte voor 2 typen eigen MS kabels				
	Geleider (mm2)	Weerstand R (Ohm/km)	Reactantie X (Ohm/km)	Capaciteit C (microFarad/km)	Belastbaarheid (A)
	830test	0.053	0.106	0.470	580
	95test	0.322	0.110	0.230	245

Figure 2 Overview of the input sheet of the BLOS tool

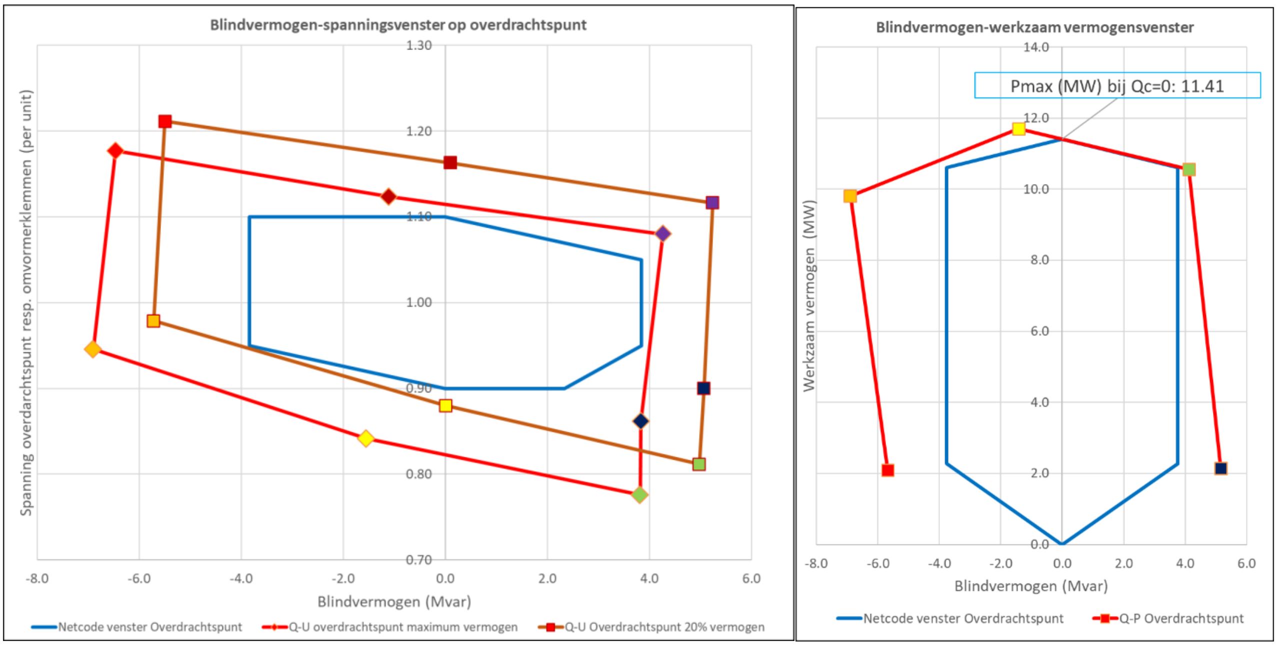
4.2 Sheet Q-you and Q-P window

Next it is necessary to check in the sheet "Q-U en Q-P vensters" whether the calculated Q-U windows of the park (red and brown) completely enclose the window with grid code requirements (blue). The Q-U and Q-P windows determine whether the network code requirements are met. The calculated Q-U and Q-P windows are given as an example in Figure 3

The blue window corresponds to the minimum requirements of the grid code. The red and brown window are calculated values of the park at the connection point, based on the data entered, at maximum and at 20% of the maximum active power of the park. The red and brown window in the “Blindvermogen-spanningsvenster op overdrachtspunt” shall completely cover the blue window. If not, the requirements of the grid code are not met.

What possibilities are there to adjust the Q-U window so that the grid code is met:

- Adjust the tap position of the transformer. This shifts red and brown windows up or down.
- Increase the reactive power limits of the inverter, if according to the supplier this is possible. This can be at the expense of the active power output.
- Reduce the active power of the inverters, allowing more reactive power to be supplied and/or absorbed. If the total maximum capacity of the park should not be reduced (Pmax), more inverters should be installed.



	In blindvermogen-spanningsdiagram dienen rode en bruine venster het blauwe venster geheel af te dekken															Blindvermogen-werkzaamvermogen				
Uc netspanning (p.u.)	1.18	0.95	0.84	0.78	0.86	1.08	1.12	1.21	0.98	0.88	0.81	0.90	1.12	1.16		1.00	0.99	1.00	1.02	1.01
Pc overdrachtspunt (MW)	10.63	9.04	10.06	8.64	9.74	10.63	11.84	2.16	2.09	2.28	2.07	2.11	2.16	2.28		2.10	9.81	11.70	10.56	2.14
Qc overdrachtspunt (Mvar)	-6.47	-6.90	-1.55	3.82	3.84	4.27	-1.10	-5.49	-5.71	0.01	4.97	5.06	5.23	0.09		-5.69	-6.89	-1.42	4.12	5.16
Uomv (p.u.)	1.15	0.90	0.87	0.87	0.95	1.15	1.15	1.15	0.90	0.87	0.87	0.95	1.15	1.15		0.92	0.95	1.03	1.09	1.05
Pomv omvormers totaal (MW)	11.29	9.89	10.91	9.49	10.59	11.29	12.50	2.33	2.33	2.33	2.33	2.33	2.33	2.33		2.33	10.65	12.50	11.29	2.33
Qomv omvormers totaal (Mvar)	-5.37	-5.37	0.00	5.37	5.37	5.37	0.00	-5.37	-5.37	0.00	5.37	5.37	5.37	0.00		-5.37	-5.37	0.00	5.37	5.37
Uc (p.u.)	1.18	0.95	0.84	0.78	0.86	1.08	1.12	1.21	0.98	0.88	0.81	0.90	1.12	1.16		1.00	0.99	1.00	1.02	1.01
Pc/Pmax (p.u.)	0.91	0.78	0.86	0.74	0.84	0.91	1.02	0.19	0.18	0.20	0.18	0.18	0.19	0.20		0.18	0.84	1.00	0.91	0.18
Qc/Pmax(p.u.)	-0.56	-0.59	-0.13	0.33	0.33	0.37	-0.09	-0.47	-0.49	0.00	0.43	0.43	0.45	0.01		-0.49	-0.59	-0.12	0.35	0.44

Figure 3 Calculated Q-U and Q-P windows including requirements from the network code.

4.3 Sheet LF model

An example of the presentation of the calculation results is shown in Figure 4. The main results of the calculations in columns L to AC in sheet "LF model" are automatically provided with a cell color. Its meaning is explained below the table. With an orange color, the operating point of the inverters is exactly on the limit or the limiter is active. If a cell is coloured red, the inverters, transformer or cable are overloaded. In this case, the component in question must be adjusted by installing more inverters, cables or transformers or a substantiated explanation must be given as to why the calculated overload will not be problematic. The calculations are based on interpretation of the requirements in Netcode.

The 1st block, with indices "c", refers to the calculated values at the connection point.

The 2nd block with indices "ms-op" concerns the kW and kvar losses in the cables from the connection point to the MS park installation. The relative load of the cables is also indicated. The transformers are connected to the MS park installation via MS-TR cables (3rd block, indices ms-tr). Of these, the kW and kvar losses and the relative load of the cables are also calculated. The kvar figure can be negative: in that case, the MS cable generates more reactive power than it consumes.

The 4th block with indices "tr", concerns kW and kvar losses and the relative load of the transformers. The relative voltage on MS resp. LS side of the transformers is presented above (Ums) resp. below (Uls) this block.

The 5th block, with indices "ls", concerns kW and kvar losses and the relative load of the cables between transformers and inverters/wind turbines.

The 6th and 7th block, with indices "omv", concern the generated active, reactive and apparent capacities of all inverters/wind turbines together resp. of the individual inverter/wind turbine. Below this are presented the absolute (Uomv (V)) and relative (Uomv (p.u.) voltage and the relative current (Iomv (p.u.)) of the inverter/wind turbine.

Finally, the calculated contribution to the short circuit current at the connection point. This is determined by dividing the specified maximum short circuit current of the joint inverters/wind turbines on the low voltage side by the transfer ratio of the transformers.

The calculations have also been carried out for 20% of the maximum active power. These results are also presented in the BLOS tool. An example of this presentation is shown in Figure 5.

Resultaten loadflow	Load flow bij maximaal werkzaam vermogen											
Uc netspanning (p.u.)	0.970	1.177	0.946	0.841	0.776	0.861	1.080	1.123	1.177	0.994	1.003	1.016
Pc overdrachtspunt (MW)	11.65	10.63	9.04	10.06	8.64	9.74	10.63	11.84	10.63	9.81	11.70	10.56
Qc overdrachtspunt (p.u.)	-0.13	-0.61	-0.76	-0.15	0.44	0.39	0.40	-0.09	-0.61	-0.70	-0.12	0.39
Qc overdrachtspunt (Mvar)	-1.52	-6.47	-6.90	-1.55	3.82	3.84	4.27	-1.10	-6.47	-6.89	-1.42	4.12
Sc overdrachtspunt (MVA)	11.75	12.44	11.37	10.18	9.45	10.47	11.45	11.89	12.44	11.98	11.78	11.34
Ic overdrachtspunt (A)	666	581	661	665	670	668	583	582	581	663	646	613
Pms-op (kW)	351.7	270.2	349.8	351.3	354.3	352.3	267.4	268.6	270.2	351.4	330.8	296.1
Qms-op (kVAr)	622.9	428.0	628.3	641.7	653.0	636.9	431.7	430.0	428.0	623.5	575.6	500.3
Ims-op kabelstroom (p.u.)	1.15	1.01	1.14	1.15	1.15	1.15	1.00	1.00	1.01	1.15	1.11	1.05
Pms-tr (kW)	55.0	42.2	54.7	55.0	55.5	55.2	41.7	41.9	42.2	54.9	51.7	46.2
Qms-tr (kVar)	0.3	-11.6	2.3	4.9	6.3	3.4	-9.6	-10.5	-11.6	0.6	-2.1	-5.4
Ims-tr kabelstroom (p.u.)	0.58	0.51	0.58	0.58	0.58	0.58	0.51	0.51	0.51	0.58	0.56	0.53
Ums (p.u.)	0.995	1.175	0.936	0.865	0.828	0.912	1.125	1.147	1.175	0.987	1.028	1.063
Ptr (kW)	112.9	97.9	109.3	107.9	107.8	110.7	97.5	97.6	97.9	111.4	108.7	102.3
Qtr (kVAr)	750.1	571.8	750.5	750.1	750.0	750.0	571.6	571.7	571.8	750.4	705.1	632.9
Itransformer (p.u.)	1.00	0.87	1.00	1.00	1.00	1.00	0.87	0.87	0.87	1.00	0.97	0.92
Uls (p.u.)	0.974	1.129	0.882	0.846	0.844	0.921	1.120	1.122	1.129	0.936	1.006	1.062
Pls (kW)	331.2	252.4	331.2	331.2	331.2	331.2	252.4	252.4	252.4	331.2	311.3	279.4
Qls (kVAr)	148.8	113.4	148.8	148.8	148.8	148.8	113.4	113.4	113.4	148.8	139.8	125.5
Ils-kabelstroom (p.u.)	0.55	0.48	0.55	0.55	0.55	0.55	0.48	0.48	0.48	0.55	0.54	0.51
Pomv omvormers totaal (MW)	12.50	11.29	9.89	10.91	9.49	10.59	11.29	12.50	11.29	10.65	12.50	11.29
Qomv omvormers totaal (Mvar)	0.00	-5.37	-5.37	0.00	5.37	5.37	5.37	0.00	-5.37	-5.37	0.00	5.37
Somv omvormers totaal (MVA)	12.50	12.50	11.25	10.91	10.91	11.88	12.50	12.50	12.50	11.93	12.50	12.50
Pomv omvormer (kW)	250	226	198	218	190	212	226	250	226	213	250	226
Qomv omvormer (kVar)	0	-107	-107	0	107	107	107	0	-107	-107	0	107
Somv omvormer (kVA)	250	250	225	218	218	238	250	250	250	239	250	250
Uomv (V)	550	630	495	480	480	523	630	630	630	525	567	599
Uomv (p.u.)	1.00	1.15	0.90	0.87	0.87	0.95	1.15	1.15	1.15	0.95	1.03	1.09
Iomv (p.u.)	1.00	0.87	1.00	1.00	1.00	1.00	0.87	0.87	0.87	1.00	0.97	0.92
Kortsluitbijdrage overdrachtspunt (A)	690											

Resultaten loadflow	Load flow bij 20% van maximaal werkzaam vermogen										
Uc netspanning (p.u.)	1.212	0.979	0.880	0.812	0.900	1.116	1.163	1.212	0.998	1.005	1.012
Pc overdrachtspunt (MW)	2.16	2.09	2.28	2.07	2.11	2.16	2.28	2.16	2.10	2.28	2.14
Qc overdrachtspunt (p.u.)	-2.54	-2.74	0.00	2.40	2.40	2.42	0.04	-2.54	-2.71	0.02	2.41
Qc overdrachtspunt (Mvar)	-5.49	-5.71	0.01	4.97	5.06	5.23	0.09	-5.49	-5.69	0.05	5.16
Sc overdrachtspunt (MVA)	5.91	6.08	2.28	5.39	5.49	5.66	2.28	5.91	6.06	2.28	5.58
Ic overdrachtspunt (A)	268	342	142	365	335	279	108	268	334	125	304
Pms-op (kW)	59.2	95.1	16.0	103.7	87.0	59.6	9.2	59.2	90.9	12.4	71.0
Qms-op (kVAr)	2.4	116.0	-31.9	148.9	103.2	12.6	-92.7	2.4	104.3	-58.5	53.6
Ims-op kabelstroom (p.u.)	0.47	0.60	0.24	0.62	0.57	0.47	0.19	0.47	0.58	0.21	0.52
Pms-tr (kW)	9.3	14.8	2.5	16.1	13.5	9.2	1.4	9.3	14.2	1.9	11.0
Qms-tr (kVar)	-23.9	-12.2	-14.1	-8.1	-11.9	-21.7	-25.5	-23.9	-13.2	-18.8	-16.9
Ims-tr kabelstroom (p.u.)	0.24	0.30	0.12	0.31	0.29	0.24	0.09	0.24	0.29	0.11	0.26
Ums (p.u.)	1.194	0.955	0.887	0.847	0.933	1.144	1.169	1.194	0.976	1.011	1.042
Ptr (kW)	43.7	42.4	20.4	42.6	41.5	43.3	30.4	43.7	42.1	24.2	41.7
Qtr (kVAr)	125.2	202.9	34.2	216.3	182.5	125.5	19.9	125.2	193.5	26.4	149.4
Itransformer (p.u.)	0.41	0.52	0.21	0.54	0.49	0.41	0.16	0.41	0.51	0.19	0.45
Uls (p.u..)	1.146	0.900	0.867	0.861	0.939	1.137	1.141	1.146	0.922	0.988	1.041
Pls (kW)	55.3	89.6	15.1	95.5	80.6	55.4	8.8	55.3	85.4	11.7	65.9
Qls (kVAr)	24.8	40.2	6.8	42.9	36.2	24.9	3.9	24.8	38.4	5.2	29.6
Ils-kabelstroom (p.u.)	0.23	0.29	0.12	0.30	0.27	0.23	0.09	0.23	0.28	0.10	0.25
Pomv omvormers totaal (MW)	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33
Qomv omvormers totaal (Mvar)	-5.37	-5.37	0.00	5.37	5.37	5.37	0.00	-5.37	-5.37	0.00	5.37
Somv omvormers totaal (MVA)	5.85	5.85	2.33	5.86	5.86	5.86	2.33	5.85	5.85	2.33	5.86
Pomv omvormer (kW)	47	47	47	47	47	47	47	47	47	47	47
Qomv omvormer (kVar)	-107	-107	0	107	107	107	0	-107	-107	0	107
Somv omvormer (kVA)	117	117	47	117	117	117	47	117	117	47	117
Uomv (V)	630	495	480	480	523	630	630	630	507	546	578
Uomv (p.u.)	1.15	0.90	0.87	0.87	0.95	1.15	1.15	1.15	0.92	0.99	1.05
Iomv (p.u.)	0.41	0.52	0.21	0.54	0.49	0.41	0.16	0.41	0.51	0.19	0.45

Kleurcodering		
	(groen)	Geen overschrijding van de grenzen van de omvormers, transformatoren of kabels
	(oranje)	Bedrijfspunt op nominale of grenswaarde van de omvormer, transformator of kabel
	(rood)	Overschrijding van de grenzen van de omvormers, transformatoren of kabels
	(blauw)	Berekend blindvermogen, werkzaam vermogen en relatieve spanning op het overdrachtspunt

Figure 4 Presentation of the calculation results at a maximum and 20% of the maximum active power.