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***Abstract*—In this paper, the solution of the power flow for unbalanced three phase micrograms systems is proposed. The study aims at the integration of inverter interfaced units using the control law used for primary voltage and frequency regulation, so as to take into account possible small variations of these parameters to account for sudden load changes. The proposed study deals with unbalanced systems which is the typical case of small distribution systems and shows how the power losses term varies as the regulators parameters vary as well, thus showing that these are sensitive parameters that could have an important role in optimal management of such systems.**

***Keywords*—Islanded power flow, unbalanced systems, three phase, microgrids.**

I. INTRODUCTION

According to traditional method, we have to use slack bus which is considered as an infinite bus capable of holding the system frequency and its local bus voltage constant, and it is called balanced bus. This method is not suitable for islanded microgrids systems having small and comparable capacity generators and there is no generator that can be physically regarded as a slack bus. In order to face the problem above, inverter interfaced generation units are modeled using the control law used for primary voltage and frequency regulation and a power flow calculation method without a slack bus has been recently studied. In this formulation also loads have to be considered with power depending on voltage and on frequency and not, as it is commonly done, with a constant power model (P, Q). This model indeed may lead to inconsistent and misleading results about loss reduction and other subsequent calculation.

Authors in [1] proposed a power flow calculation method for islanded power network. In this paper, the authors proposed a calculation method without slack bus. However, the loads in this study only depend on voltage, not on frequency and the application is devoted to balanced transmission systems. Therefore the proposed model, it is not suitable for power flow calculations in microgrids, which typically show unbalanced loads.

The power flow formulation in three phase unbalanced micro-grid with voltage and frequency dependent load modeling may causes trouble with traditional methods, such as the Newton Raphson method, due to the presence of sparse matrices. Authors in [2] propose a new method that can solve this problem: the Newton Trust Region Method. The method is designed by a combination of Newton Raphson Method and Trust Region Method. The paper shows that this new method is a helpful tool to perform accurate steady state studies of islanded microgrid and the solution for a 25 bus test system is achieved after a few iterations.

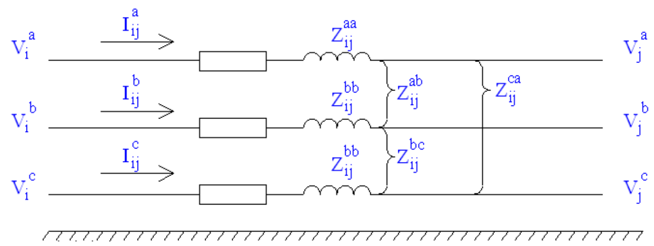

Fig. 1. Model of 3 phase line

In this paper, the solution of the power flow for unbalanced three phase microgrids systems using algorithm Trust Region Method is used to perform a parametric study. The speed of this solution is not as quick as the one in [2] (the solution is achieved after a few more iterations with the same test system), but the aim of this paper is primarily to show that it is possible to obtain improved quality results (lower power losses) if the primary regulators parameters are modified. Therefore, by means of the Trust Region Method, many extensive power flow calculations have been carried out with different regulators parameters, giving rise to different values of the power losses. Of course, since flows are affected such regulation allows the attainment of other operational objectives connected to the power flows distribution.

In the applications section, the power flow in the 25 bus test system has been thus carried out with many scenarios to show how the power losses term varies as the regulators parameters vary as well, therefore showing that these are sensitive parameters that could have an important role in optimal management of such systems.

II. Modeling of 3 Phase Microgrids with Droop Buses

A. Line modeling

Line modeling [2] in this study is based on the dependency on frequency of line reactance. Carson's equations are used for a three phase grounded four wire system. With a grid that is well grounded, reactance between the neutral potentials and the ground is assumed to be zero. The impedance matrix required to model the electromagnetic couplings between conductors and the ground, assumes the following form:

$$[Z_{ij}^{abcn}(f)] = \begin{bmatrix} Z_{ij}^{aa} & Z_{ij}^{ab} & Z_{ij}^{ac} & Z_{ij}^{an} \\ Z_{ij}^{ba} & Z_{ij}^{bb} & Z_{ij}^{bc} & Z_{ij}^{bn} \\ Z_{ij}^{ca} & Z_{ij}^{cb} & Z_{ij}^{cc} & Z_{ij}^{cn} \\ Z_{ij}^{na} & Z_{ij}^{nb} & Z_{ij}^{nc} & Z_{ij}^{nn} \end{bmatrix} \tag{1}$$

Kron's reduction [4] is applied to (1), and the line model including the effects of the neutral or ground wire and the impacts of the frequency in unbalanced systems can be attained:

$$[Z_{ij}^{abc}] = \begin{bmatrix} Z_{ij}^{aa-n} & Z_{ij}^{ab-n} & Z_{ij}^{ac-n} \\ Z_{ij}^{ba-n} & Z_{ij}^{bb-n} & Z_{ij}^{bc-n} \\ Z_{ij}^{ca-n} & Z_{ij}^{cb-n} & Z_{ij}^{cc-n} \end{bmatrix} \tag{2}$$

B. Load modeling

The frequency and voltage dependency of the power supplied to the loads can be represented as follows:

$$P_{Li} = P_{0i}|V_i|^{\alpha}\left(1 + K_{pf}\Delta f\right) \tag{3}$$

$$Q_{Li} = Q_{0i}|V_i|^{\beta}(1 + K_{qf}\Delta f) \tag{4}$$

where P_{0i} and Q_{0i} are the rated real and reactive power operating points respectively; α and β are the real and reactive power exponents. The values of α and β for these kinds of loads are given in [7]. Δf is the frequency deviation (f-f_0); K_{pf}ranges from 0 to 3.0, and K_{qf} ranges from -2.0 to 0 [5].

C. Distributed Generators modeling

The three phase injected real and reactive power from a DG unit with droop inverter interfaced generation can be expressed in the follow equations:

$$P_{Gi} = -K_{Gi}(f - f_{0i}) \tag{5}$$

$$Q_{Gi} = -K_{di}(|V_i| - V_{0i}) \tag{6}$$

In these equations, the coefficients K_{Gi} and K_{di} as well as V_{0i} and f_{0i} characterize the droop regulators of distributed generators.

III. Formulation of the Unbalanced Three Phase Power Flow Solution

A. Formulation [2]

From Fig. 1, the relation between the branch voltages V_{ij} and branch currents I_{ij} between two nodes i and j can be attained as follow:

$$[V_{ij}^{a,b,c}] = [Z_{ij}^{a,b,c}][I_{ij}^{a,b,c}] \tag{7}$$

$$[V_{ij}^{a,b,c}] = \begin{bmatrix} V_i^a - V_j^a \\ V_i^b - V_j^b \\ V_i^c - V_j^c \end{bmatrix}, \quad [I_{ij}^{a,b,c}] = \begin{bmatrix} I_{ij}^a \\ I_{ij}^b \\ I_{ij}^c \end{bmatrix} \tag{8}$$

From (7) the branch currents can be attained:

$$[I_{ij}^{a,b,c}] = [Y_{ij}^{a,b,c}][V_{ij}^{a,b,c}] \tag{9}$$

where $[Y_{ij}^{a,b,c}]$ is the branch admittance matrix:

$$[Y_{ij}^{a,b,c}] = [Z_{ij}^{a,b,c}]^{-1} = \begin{bmatrix} Y_{ij}^{aa-n} & Y_{ij}^{ab-n} & Y_{ij}^{ac-n} \\ Y_{ij}^{ba-n} & Y_{ij}^{bb-n} & Y_{ij}^{bc-n} \\ Y_{ij}^{ca-n} & Y_{ij}^{cb-n} & Y_{ij}^{cc-n} \end{bmatrix} \tag{10}$$

For each bus i, the injected power in each of the three phases can be calculated as follows:

$$[S_i^{a,b,c}] = [V_i^{a,b,c}][I_{i,inj}^{a,b,c}]^{conj} \tag{11}$$

where $[I_{i,inj}^{a,b,c}]^{conj}$ is the vector of the complex conjugate of the injected currents in each of the three phases at bus i. This injected current can be calculated by the sum of all the branch currents conneted with bus i:

$$I_{i,inj}^{a,b,c} = \sum_{\substack{j=1 \\ j\neq i}}^{n_{br}} I_{ij}^{a,b,c} \tag{12}$$

Let $P_i^{a,b,c}$ and $Q_i^{a,b,c}$ denote the calculated real and reactive power injected to the microgrid at each of the three phases at bus i. Substituting eqns. (9) and (12) in (11), the real and reactive powers for phase a, P_i^a and Q_i^a can be attained, as follows. Similar equations can be extracted for the calculated active and reactive power for phase b and c:

$$P_i^a = \sum_{\substack{j=1 \\ j\neq i}}^{n_{br}} \sum_{ph=a,b,c} \begin{bmatrix} |V_i^a|\left|Y_{ij}^{a(ph)-n}\right|\left|V_i^{(ph)}\right|\cos(\theta_{ij}^{a(ph)} + \delta_i^{(ph)} - \delta_i^a) \\ -|V_i^a|\left|Y_{ij}^{a(ph-n)}\right|\left|V_j^{(ph)}\right|\cos(\theta_{ij}^{a(ph)} + \delta_j^{(ph)} - \delta_i^a) \end{bmatrix}$$

$$Q_i^a = \sum_{\substack{j=1 \\ j\neq i}}^{n_{br}} \sum_{ph=a,b,c} \begin{bmatrix} |V_i^a|\left|Y_{ij}^{a(ph)-n}\right|\left|V_j^{(ph)}\right|\sin(\theta_{ij}^{a(ph)} + \delta_i^{(ph)} - \delta_i^a) \\ -|V_i^a|\left|Y_{ij}^{a(ph-n)}\right|\left|V_i^{(ph)}\right|\sin(\theta_{ij}^{a(ph)} + \delta_i^{(ph)} - \delta_i^a) \end{bmatrix}$$

The system mismatch equations describing the power flow in islanded microgrids is thus made up of n-equations comprising the n-unknown variables to be calculated. The voltage angle at bus 1 is taken as the system reference by setting $\delta_i^a = 0$. The number of mismatch equations describing each bus in the system depends on the type of bus (such as PQ bus, PV bus or Droop-bus). In this work, we assume that all buses are droop-buses. It means that all Distributed Generation, DG, units at each bus use droop inverter interfaced generators.

For each of the Droop-bus i, the mismatch equations are given as follow:

$$\begin{cases} 0 = P_{Li}^{a,b,c}\left(f,\left|V_i^{a,b,c}\right|\right) - P_{Gi}^{a,b,c} \\ \qquad + P_i^{a,b,c}\left(f,\left|V_i^{a,b,c}\right|,\left|V_j^{a,b,c}\right|,\delta_i^{a,b,c},\delta_j^{a,b,c}\right) & (13) \\ 0 = Q_{Li}^{a,b,c}\left(f,\left|V_i^{a,b,c}\right|\right) - Q_{Gi}^{a,b,c} \\ \qquad + Q_i^{a,b,c}\left(f,\left|V_i^{a,b,c}\right|,\left|V_j^{a,b,c}\right|,\delta_i^{a,b,c},\delta_j^{a,b,c}\right) & (14) \\ 0 = \left|V_i^a\right| - \left|V_i^b\right| & (15) \\ 0 = \left|V_i^a\right| - \left|V_i^c\right| & (16) \\ 0 = \delta_i^a - \delta_i^b - \left(\frac{2\pi}{3}\right) & (17) \\ 0 = \delta_i^a - \delta_i^c + \left(\frac{2\pi}{3}\right) & (18) \\ 0 = P_{Gi}^a + P_{Gi}^b + P_{Gi}^c - P_{Gi}\,(f) & (19) \\ 0 = Q_{Gi}^a + Q_{Gi}^b + Q_{Gi}^c - Q_{Gi}\left(\left|V_i^{a,b,c}\right|\right) & (20) \end{cases}$$

The corresponding unknown variables for Droop-bus i are given as:

$$x_{Di} = \left[\delta_i^{a,b,c}\left|V_i^{a,b,c}\right|P_{Gi}^{a,b,c}Q_{Gi}^{a,b,c}\right]^T \quad (21)$$

The corresponding unknown variables for all Droop-buses can be given as:

$$x_D = \left[x_{D1} \dots x_{Dn_d}\right]^T \quad (22)$$

where n_d is the number of Droop-buses.

So the total number of mismatch equations, n, and their corresponding unknown variables X, in the three phase islanded micrograms can be given as:

$$n = 12 \times n_d \quad (23)$$

$$X = [x_D f] \quad (24)$$

B. Solution method

The mismatch equations are nonlinear algebraic equations. The Trust region method is a robust method to solve such problems. Using function "fsolve" of Matlab which uses the Trust region method, we can obtain the unbalanced three phase power flow solution.

IV. Application

The load flow problem for an islanded system has been followed using the methodology proposed above. The test system is the 25 bus system in [6], the bus-data are shown in the Appendix A, and we assume that all of Generators are droof-buses. Many sets of parameters have been tried and a variation in power losses as well as in frequency has been observed. The following underlying hypotheses have been made: the base power and base voltage for per unit calculations have been set to S_B = 30MVA and V_B = 4.16 kV, and bus#1 is taken as reference for displacements ($\delta_i^a = 0$).

Using the function "fsolve" in Matlab to solve equations (13)-(20) we get the power flow results (voltage profile and loads in each phase and the total system loses) shown in table II of appendix A.

Table I shows the real and reactive power in each phase and the total injected power from all the DG units in p.u.

TABLE I. DG Units Real and Reactive power Generation in 25-Bus Unbalanced Test System

Bus ID of Gen	P_{Ga}	P_{Gb}	P_{Gc}	Q_{Ga}	Q_{Gb}	Q_{Gc}	P_G total	Q_G total
13	0.0092	0.0094	0.0099	0.0066	0.0072	0.0078	0.0285	0.0217
19	0.0096	0.0091	0.0098	0.0104	0.0107	0.0108	0.0285	0.0320
25	0.0188	0.0182	0.0200	0.0056	0.0057	0.0060	0.0570	0.0173

Taking the values reported in Table II for parameters K_{Gi}, K_{di}, V_{0i}, f_{0i} for the inverter interfaced generators, the following results for frequency and power losses are obtained. In all the results reported voltage drops in all buses are below the admissible values (5%).

TABLE II. General result

Bus ID of Gen	K_{di}	V_{0i} /pu	K_{Gi}	f_{0i}/pu	f /pu	Ploss /pu	Vmin /pu	Vmax /pu
13	5.00	1.0400	10.00	1.0020	0.9992	0.0060	0.9519	1.0468
19	10.00	1.0500	10.00	1.0020				
25	5.00	1.0400	20.00	1.0020				

Changing the value of K_G, K_d, V_0 and f_0 of generators and calculating the power flows, we get the first results that are shown in Tables III to VII. In all the trials, the parameters that stay unchanged (K_{Gi}, K_{di}, V_{0i}, f_{0i}) assume the values in Table II. In table III, only parameter KG_{13} has been changed.

TABLE III. Losses and frequency in the test system, changing KG13

K_{G13}	f/pu	Ploss/pu	Vmin/pu	Vmax/pu
30.00	**1.0000**	**0.0101**	**0.9502**	**1.0454**
20.00	0.9997	0.0075	0.9513	1.0460
10.00	*0.9992*	*0.0060*	*0.9519*	*1.0468*

TABLE IV. Losses and frequency in the test system, changing K_{G25}

K_{G25}	f/pu	Ploss/pu	Vmin/pu	Vmax/pu
40.00	**1.0000**	**0.0090**	**0.9518**	**1.0455**
30.00	0.9997	0.0074	0.9520	1.0460
20.00	*0.9992*	*0.0060*	*0.9519*	*1.0468*

TABLE V. Losses and frequency in the test system, changing K_{G13} and K_{G19}

K_{G13}	K_{G19}	f/pu	Ploss/pu	Vmin/pu	Vmax/pu
10.00	*10.00*	*0.9992*	*0.0060*	*0.9519*	*1.0468*
15.00	15.00	0.9997	0.0055	0.9516	1.0475
15.00	20.00	0.9999	0.0058	0.9509	1.0484
17.00	**20.00**	**1.0000**	**0.0057**	**0.9510**	**1.0482**

TABLE VI. LOSSES AND FREQUENCY IN THE TEST SYSTEM, CHANGING K_{G13} AND F_{025}

K_{G13}	f_{025}	f/pu	Ploss/pu	Vmin/pu	Vmax/pu
10.00	*1.0020*	*0.9992*	*0.0060*	*0.9519*	*1.0468*
10.00	1.0030	0.9996	0.0072	0.952	1.0462
18.00	**1.0030**	**1.0000**	**0.0079**	**0.9516**	**1.0455**
10.00	1.0035	0.9998	0.0080	0.9519	1.0458
13.00	**1.0035**	**1.0000**	**0.0082**	**0.9518**	**1.0456**

TABLE VII. LOSSES AND FREQUENCY IN THE TEST SYSTEM, CHANGING K_{G19} AND F_{025}

K_{G19}	f_{025}	f/pu	Ploss/pu	Vmin/pu	Vmax/pu
10.00	*1.0020*	*0.9992*	*0.0060*	*0.9519*	*1.0468*
15.00	1.0030	0.9999	0.0061	0.9518	1.0472
17.00	**1.0030**	**1.0000**	**0.0060**	**0.9517**	**1.0476**
15.00	1.0031	0.9999	0.0062	0.9519	1.0471
15.00	**1.0032**	**1.0000**	**0.0063**	**0.9519**	**1.0471**

In the tables, in italic, the parameters of basic case taking value from table II, while in bold are evidenced the sets of parameters showing the rated frequency value. As it can be observed, there are many different sets of parameters (marked in bold in each table) satisfying the condition f = 50Hz, in all cases, however, the frequency does not vary for more than 0.2 Hz as prescribed by the IEEE standard while power losses change. So it means that changing system parameters will produce a change of the power loss in the system. **With f within the admissible range, the set of parameters satisfying the condition of minimum power losses can thus be chosen for optimal system operation.**

V. CONCLUSION

The paper proposes the use of the Trust Region Method to solve the power flow problem in 3 phase unbalanced microgrid system. Authors have solved the 25 test bus system showing how the power losses term varies as the regulators parameters vary as well, thus showing that these are sensitive parameters that could have an important role in optimal management of such systems. These results suggest an idea for further work on optimal system operation considering also stability issues.

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I. APPENDIX A

TABLE I. BUS DATAS

Bus number	Bus code	Load phase A, kW		Load phase B, kW		Load phase C, kW		Generator				Exponent of Loads	
		P	Q	P	Q	P	Q	K_{di}	V_{0i}, pu	K_{Gi}	f0i, pu	α	β
1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000	0.00	0.00
2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000	0.00	0.00
3	0	35.00	25.00	40.00	30.00	45.00	32.00	0.00	0.00	0.00	1.000	0.18	6.00
4	0	50.00	40.00	60.00	45.00	70.00	35.00	0.00	0.00	0.00	1.000	1.51	3.40
5	0	40.00	30.00	37.00	28.00	50.00	32.00	0.00	0.00	0.00	1.000	0.92	4.04
6	0	40.00	20.00	45.00	32.00	35.00	25.00	0.00	0.00	0.00	1.000	0.18	6.00
7	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000	1.51	3.40
8	0	35.00	10.00	45.00	32.00	40.00	28.00	0.00	0.00	0.00	1.000	1.51	3.40
9	0	60.00	45.00	50.00	40.00	50.00	35.00	0.00	0.00	0.00	1.000	0.18	6.00
10	0	35.00	25.00	40.00	30.00	45.00	32.00	0.00	0.00	0.00	1.000	1.51	3.40
11	0	45.00	25.00	35.00	20.00	40.00	26.00	0.00	0.00	0.00	1.000	1.51	3.40
12	0	50.00	35.00	60.00	45.00	70.00	40.00	0.00	0.00	0.00	1.000	0.92	4.04
13	**2**	**35.00**	**25.00**	**45.00**	**32.00**	**40.00**	**30.00**	**-**	**-**	**-**	**-**	**1.51**	**3.40**
14	0	50.00	20.00	60.00	25.00	70.00	35.00	0.00	0.00	0.00	1.000	0.92	4.04
15	0	133.30	50.00	100.00	25.00	75.00	30.00	0.00	0.00	0.00	1.000	1.51	3.40
16	0	45.00	15.00	35.00	20.00	50.00	26.00	0.00	0.00	0.00	1.000	0.18	6.00
17	0	40.00	10.00	35.00	8.00	50.00	15.00	0.00	0.00	0.00	1.000	1.51	3.40
18	0	35.00	25.00	40.00	30.00	45.00	32.00	0.00	0.00	0.00	1.000	0.18	6.00
19	**1**	**60.00**	**45.00**	**50.00**	**35.00**	**50.00**	**40.00**	**10.00**	**1.05**	**10.00**	**1.002**	**0.92**	**4.04**
20	0	40.00	30.00	35.00	25.00	45.00	32.00	0.00	0.00	0.00	1.000	1.51	3.40
21	0	50.00	35.00	40.00	33.00	45.00	36.00	0.00	0.00	0.00	1.000	0.18	6.00
22	0	50.00	35.00	60.00	45.00	70.00	40.00	0.00	0.00	0.00	1.000	0.92	4.04
23	0	60.00	45.00	50.00	40.00	70.00	35.00	0.00	0.00	0.00	1.000	1.51	3.40
24	0	35.00	25.00	40.00	30.00	50.00	32.00	0.00	0.00	0.00	1.000	1.51	3.40
25	**1**	**60.00**	**45.00**	**50.00**	**30.00**	**40.00**	**35.00**	**5.00**	**1.04**	**20.00**	**1.002**	**1.51**	**3.40**

TABLE II. LOAD FLOW RESULTS OF THE PROPOSED POWER FLOW IN 25 BUS TEST SYSTEM,

Bus no	Phase A				Phase B				Phase C			
	Van (pu,rad)		Load (pu)		Vbn (pu,rad)		Load (pu)		Vcn (pu,rad)		Load (pu)	
	Mag	Agl	P	Q	Mag	Agl	P	Q	Mag	Agl	P	Q
1	0.9775	0.0000	0.0000	0.0000	0.9750	-2.0877	0.0000	0.0000	0.9749	2.0931	0.0000	0.0000
2	0.9775	0.0000	0.0000	0.0000	0.9750	-2.0877	0.0000	0.0000	0.9749	2.0931	0.0000	0.0000
3	0.9780	0.0004	0.0012	0.0007	0.9755	-2.0876	0.0013	0.0009	0.9753	2.0933	0.0015	0.0009
4	0.9782	0.0009	0.0016	0.0012	0.9757	-2.0872	0.0019	0.0014	0.9755	2.0936	0.0022	0.0011
5	0.9745	-0.0007	0.0013	0.0009	0.9717	-2.0885	0.0012	0.0008	0.9709	2.0913	0.0016	0.0009
6	0.9659	-0.0030	0.0013	0.0005	0.9639	-2.0879	0.0015	0.0009	0.9649	2.0928	0.0012	0.0007
7	0.9654	-0.0027	0.0000	0.0000	0.9643	-2.0869	0.0000	0.0000	0.9645	2.0939	0.0000	0.0000
8	0.9578	-0.0058	0.0011	0.0003	0.9561	-2.0888	0.0014	0.0009	0.9578	2.0919	0.0012	0.0008
9	0.9776	0.0026	0.0020	0.0013	0.9773	-2.0840	0.0017	0.0012	0.9776	2.0982	0.0017	0.0010
10	0.9952	0.0079	0.0012	0.0008	0.9947	-2.0813	0.0013	0.0010	0.9946	2.1028	0.0015	0.0010
11	1.0157	0.0131	0.0015	0.0009	1.0156	-2.0790	0.0012	0.0007	1.0151	2.1075	0.0014	0.0009
12	1.0200	0.0184	0.0017	0.0013	1.0193	-2.0746	0.0020	0.0016	1.0183	2.1121	0.0024	0.0014
13	**1.0357**	**0.0133**	**0.0012**	**0.0009**	**1.0357**	**-2.0811**	**0.0016**	**0.0012**	**1.0357**	**2.1077**	**0.0014**	**0.0011**
14	0.9557	-0.0063	0.0016	0.0006	0.9545	-2.0886	0.0019	0.0007	0.9547	2.0916	0.0022	0.0010
15	0.9519	-0.0078	0.0041	0.0014	0.9521	-2.0898	0.0031	0.0010	0.9537	2.0915	0.0023	0.0011
16	0.9623	-0.0040	0.0015	0.0004	0.9615	-2.0871	0.0012	0.0005	0.9608	2.0928	0.0017	0.0007
17	0.9533	-0.0075	0.0012	0.0003	0.9515	-2.0883	0.0011	0.0007	0.9509	2.0909	0.0015	0.0009
18	0.9859	-0.0046	0.0012	0.0008	0.9836	-2.0938	0.0013	0.0009	0.9825	2.0888	0.0015	0.0010
19	**1.0468**	**-0.0213**	**0.0021**	**0.0018**	**1.0468**	**-2.1157**	**0.0017**	**0.0014**	**1.0468**	**2.0730**	**0.0017**	**0.0016**
20	1.0047	-0.0102	0.0013	0.0010	1.0033	-2.1019	0.0012	0.0008	1.0012	2.0845	0.0015	0.0011
21	0.9779	-0.0036	0.0017	0.0010	0.9755	-2.0918	0.0013	0.0009	0.9745	2.0891	0.0015	0.0010
22	0.9741	-0.0022	0.0016	0.0011	0.9709	-2.0901	0.0019	0.0013	0.9702	2.0896	0.0023	0.0012
23	0.9931	0.0101	0.0020	0.0015	0.9916	-2.0797	0.0016	0.0013	0.9911	2.1024	0.0023	0.0011
24	1.0133	0.0189	0.0012	0.0009	1.0122	-2.0731	0.0014	0.0010	1.0118	2.1121	0.0017	0.0011
25	**1.0365**	**0.0273**	**0.0021**	**0.0017**	**1.0365**	**-2.0671**	**0.0018**	**0.0011**	**1.0365**	**2.1217**	**0.0014**	**0.0013**
Total	**PLa**	**QLa**	**PLb**	**QLb**	**PLc**	**QLc**	**PLtotal**	**QLtotal**	**f/pu**	**Ploss**	**Vmin /pu**	**Vmax /pu**
	0.0357	0.0213	0.0346	0.0223	0.0377	0.0377	0.1080	0.0813	0.9992	0.0060	0.9519	1.0468