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Investigation of nigerian 330 kv electrical network with distributed generation penetration – part II: optimization analyses

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Abstract: The objective of this paper is to present the tools implemented in PowerFactory for the optimization of the proposed network. It involves the calculate optimal power flow analysis (OPF); optimal placement, type and size of capacitors in the network; the optimal type of reinforcement cables and overhead lines and lastly, optimization of a certain objective function in a network, whilst fulfilling equality constraints (the load flow equations) and inequality constraints (that is, generator reactive power limits). The applications of the OPF include transmission line overload removal, transmission system control, available transfer capability calculation (ATC), real and reactive power pricing, transmission component valuation, and transmission system marginal pricing. Power capacitors are very useful for power factor correction, loss reduction, voltage profile improvement and distribution system-capacity release/increase. The conductor, which is determined by this optimization method, maintains acceptable voltage levels of the radial distribution system. Besides, it gives maximum saving in the capital cost of conducting material and cost of energy losses. The method also shows that only proper selection of optimum branch conductors reduces losses.

Keywords: Optimization, Optimal Placement, Reinforcement Cables, Overhead Lines, Load Flow, Inequality Constraints, Powerfactory, Digsilent

1. Introduction

PowerFactory's optimal power flow (OPF) module optimizes a certain objective function in a network whilst fulfilling equality constraints (the load flow equations) and inequality constraints (that is, generator reactive power limits) [1]. By means of simple command edit dialogues it is possible to calculate the optimal placement, type and size of capacitors in radial distribution networks; the optimal separation points of meshed networks and the optimal type of reinforcement cables and overhead lines. The cable-size optimization process minimizes the annual cost of the network. As constraints for the optimization it uses the admissible voltage band (in terms of maximum voltage drop along the feeder) and loading limits for the planned network.

2. Methodology

Figure 1 shows the proposed Nigerian 330 kV electrical network (37-bus system). The parameters used are depicted in Table 1. The conventional and distributed generation sources were modeled using a calculation program called PowerFactory, written by DIgSILENT version 14.1. The name DIgSILENT stands for "DIgital SImuLation and Electrical NeTwork calculation program". It is a computer aided engineering tool for the analysis of industrial, utility, and commercial electrical power systems.

It has been designed as an advanced integrated and interactive software package dedicated to electrical power system and control analysis in order to achieve the main objectives of planning and operation optimization [1].

3. Network Modeling in PowerFactory

The Network Model contains the electrical and graphical information for the grid. To further enhance manageability, this information is split into two subfolders: diagrams and network data. An additional subfolder, Variations, contains all expansion stages for planning purposes. The network model folder contains the all graphical and electrical data which defines the networks and the single line diagrams of the power system under study. This set of data is referred as the network data model. The proposed Nigerian 330 kV electrical network (37 buses), shown in Figure 1, was modeled using this software.

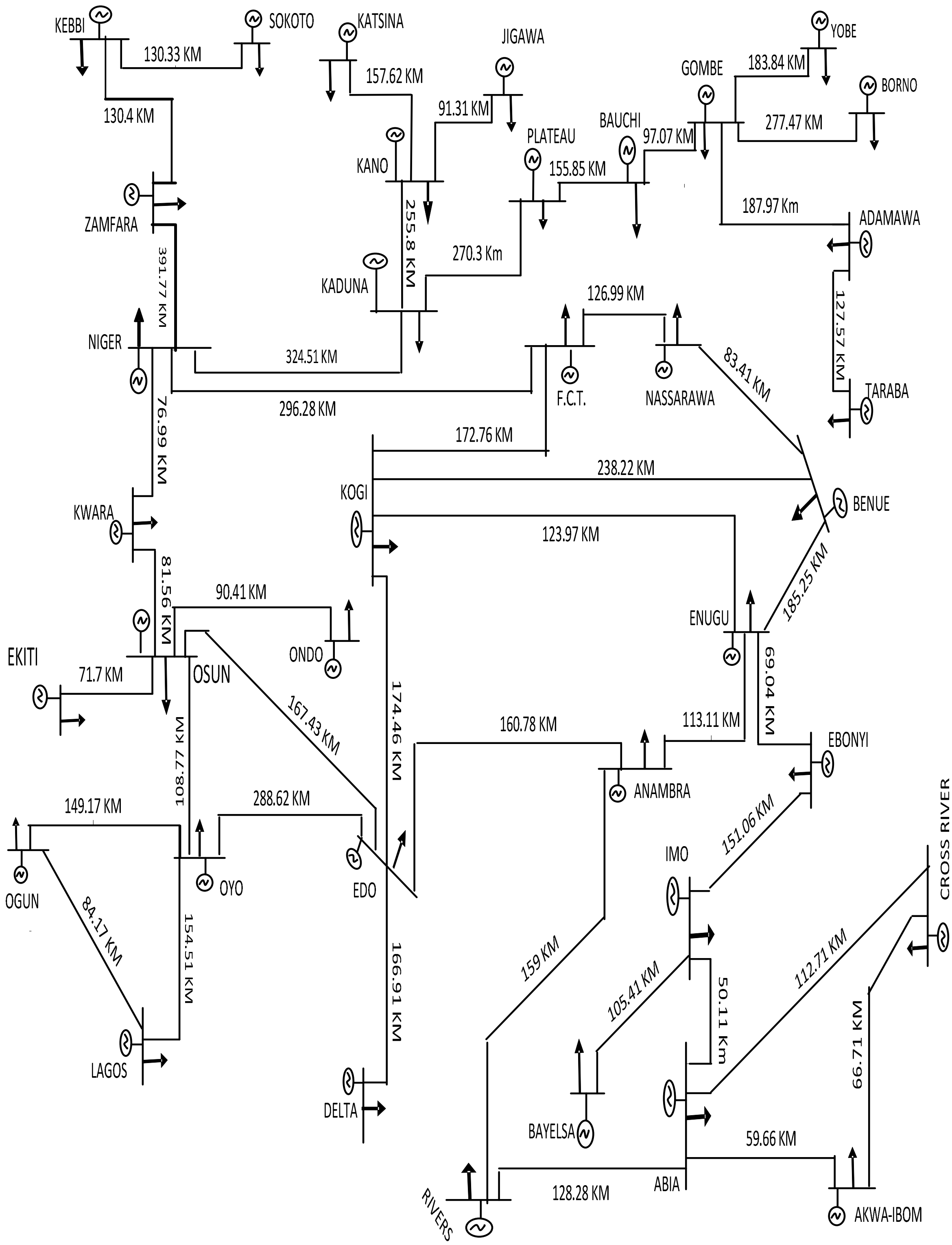


Figure 1. Proposed Nigerian 330 kV electrical network (37-bus system).

Table 1. *Proposed Power generation and Allocation per State.*

S/N	State	Total Capacity Per State (Mw)	Population Size	Real Power Allocation (P)	Reactive Power Allocatn (Q)
1	F.C.T.	535	1,405,201	906.79	363
2	Abia	2,404	2,833,999	820.42	328
3	Adamawa	100	3,168,101	917.14	367
4	Akwa-Ibom	1,790	3,920,208	1,134.87	454
5	Anambra	1,705	4,182,032	1,210.67	484
6	Bauchi	742.6	4,676,465	1,353.80	542
7	Bayelsa	350	1,703,358	493.11	197
8	Benue	2,130	4,219,244	1,221.44	489
9	Borno	120.8	4,151,193	1,201.74	481
10	Cross River	705	2,888,966	836.33	335
11	Delta	5,900	4,098,391	1,186.45	475
12	Ebonyi	230	2,173,501	629.21	252
13	Edo	1,000	3,218,332	931.68	373
14	Ekiti	70	2,384,212	690.21	276
15	Enugu	1,050	3,257,298	942.96	377
16	Gombe	400	2,353,879	681.43	273
17	Imo	425	3,934,899	1,139.12	456
18	Jigawa	146.2	4,348,649	1,258.90	504
19	Kaduna	379.2	6,066,562	1,756.22	702
20	Kano	246	9,383,682	3,216.50	1,287
21	Katsina	111	5,792,578	1,676.91	671
22	Kebbi	240	3,238,628	937.56	375
23	Kogi	1,804	3,278,487	949.10	380
24	Kwara	90	2,371,089	686.41	275
25	Lagos	1,616	9,013,534	3,609.35	1,444
26	Nassarawa	196	1,863,275	539.40	216
27	Niger	2,710	3,950,249	1,143.57	457
28	Ogun	2,125	3,728,098	1,079.26	432
29	Ondo	920	3,441,024	996.15	398
30	Osun	65	3,423,535	991.09	396
31	Oyo	3,800	5,591,589	1,618.72	647
32	Plateau	245.4	3,178,712	920.21	368
33	Rivers	3,924	5,185,400	1,501.13	600
34	Sokoto	133.6	3,696,999	1,070.25	428
35	Taraba	3,735	2,300,736	666.05	266
36	Yobe	140	2,321,591	672.08	269
37	Zamfara	246	3,259,846	943.70	377
	Total	**42,529.95**	**140,003,542**	**42,529.95**	**17,012**

4. Optimal Capacitor Placement

Optimal capacitor placement (OCP) is an automatic algorithm that minimizes the cost of losses and voltage constraints in a radial distribution network by proposing the installation of new capacitors at nodes (busbars used in this research) within the network. The size and type of capacitor is selected from a list entered by the user. The algorithm also considers the annual cost of such capacitors and only proposes new capacitors for installation when the reduction of energy loss and voltage constraint costs exceeds the annual cost of the capacitor (investment, maintenance, insurance among others), that is, the economic benefits due to energy loss reduction are weighted against the cost of installation of such capacitors while keeping the voltage profile of the system within defined limits [2-6].

The optimization algorithm minimizes the annual total network cost which is a sum of three parts [1]:

$$\text{Total costs} = C_{losses} + \sum_{i=1}^{m}\left(C_{capi}\right) + \sum_{i=1}^{n}\left(C_{VoltVioli}\right) \quad (1)$$

where

• C_{losses} corresponds to the annual cost of grid losses. This is the I^2R loss of all elements in the network;

• C_{capi} corresponds to the annual cost of capacitors (investment, maintenance, insurance), as indicated on the description page of the capacitor type, m is the number of installed capacitors;

• $C_{VoltVioli}$ corresponds to a fictitious cost used to penalize the bus voltage violation, n is the number of feeder buses.

There are two possible situations for a terminal voltage and the calculation for the fictitious voltage violation cost is slightly different for each situation. The two situations are explained as follows: firstly, the voltage U of a terminal is within the allowed voltage band (between $v_{\max}$ and $v_{\min}$), but deviates from the nominal voltage of 1 p.u.. The penalty cost is calculated as:

$$C_{VoltVioli} = w_1 \Delta U \quad (2)$$

where:

ΔU is the absolute deviation from the nominal voltage in p.u. $\left(\Delta U = \left|U - U_n\right|\right)$. w_1 is the penalty factor (parameter 'weight') inside the admissible voltage band in \$/%. for situation two, the voltage U is outside the allowed band (greater than $v_{\max}$ and less than $v_{\min}$), its penalty cost corresponds to:

$$U \rangle\ U_n + \Delta U_{\max} \quad (3)$$

$$C_{VoltVioli} = w_2\left(\Delta U - \Delta U_{\max}\right) + w_1 \Delta U$$

or

$$U \langle\ U_n - \Delta U_{\max} \quad (4)$$

if voltage is lower than minimum limit

$$C_{VoltVioli} = w_2\left(\Delta U - \Delta U_{\min}\right) + w_1 \Delta U \quad (5)$$

where: ΔU is the absolute deviation from the nominal voltage U_n in p.u.; $U_n + \Delta U_{\max}$ is the higher voltage limit in p.u.; $U_n - \Delta U_{\max}$ is the lower voltage limit in p.u.; w_2 is the penalty factor (parameter 'weight') for voltage outside the admissible voltage band in \$/% Energy cost (\$/kWh) was entered manually. The calculation of the cost of the network losses is as follows:

$$TC = MC \cdot 8760 L \quad (6)$$

where:
TC is the total cost per annum in \$;
MC is the energy cost of losses in \$/kWh; and
L is the total losses in kW.

5. Cable-Size Optimization

The objective function for the optimization is the annual cost for the reinforced lines. This includes investment, operational cost and insurance fees. The following constraints were considered in the optimization process, where the implementation is based on fictitious penalty cost: maximum admissible line loading: an admissible overloading percentage may be defined by the user to avoid overrating of the lines. Typically any overloading can be avoided by selecting the appropriate type of conductor for cables and overhead lines. The penalty factor for these lines therefore is fixed and cannot be defined by the user. maximum voltage drop: depending on the system topology, on the loads and on the length of the feeder, it may not be possible to avoid voltage band violations of some nodes due to voltage drop. This may be mitigated by the installation of a capacitor during a post processing optimization. The specific penalty cost of the optimization therefore is a parameter that can be defined by the user to weight the voltage loss against the line investments.

This optimization process minimizes the annual cost of the network. As constraints for the optimization it uses the admissible voltage band (in terms of maximum voltage drop along the feeder) and loading limits for the planned network. The optimization does not need a load curve or a load forecast, as the impact of the conductor type on the cost of losses is not considered within the function. Input data for the reinforcement optimization is a network model that is complete for load-flow calculation [1, 7-9].

6. Optimal Power Flow

PowerFactory's optimal power flow (OPF) module optimizes a certain objective function in a network whilst fulfilling equality constraints (the load flow equations) and inequality constraints (that is, generator reactive power limits). The user can choose between non-linear and linear optimization methods [1].

If AC optimization method is selected, the OPF performs a non-linear optimization based on a state-of-the-art interior-point algorithm. The following sections explain the selection of objective function to be optimized, the selection of control variables, and the definition of inequality constraints.

The objective functions are: minimization of losses: the goal of the optimization is to find a power dispatch which minimizes the overall active power loss; minimization of costs: the goal of the optimization is to supply the system under optimal operating cost. More specifically, the aim is to minimize the cost of power dispatch based on non-linear fuel cost functions for each generator and on tariff systems for each external grid. For this purpose, for each generator, a cost function for its power dispatch and a tariff system as shown in Figure 2.

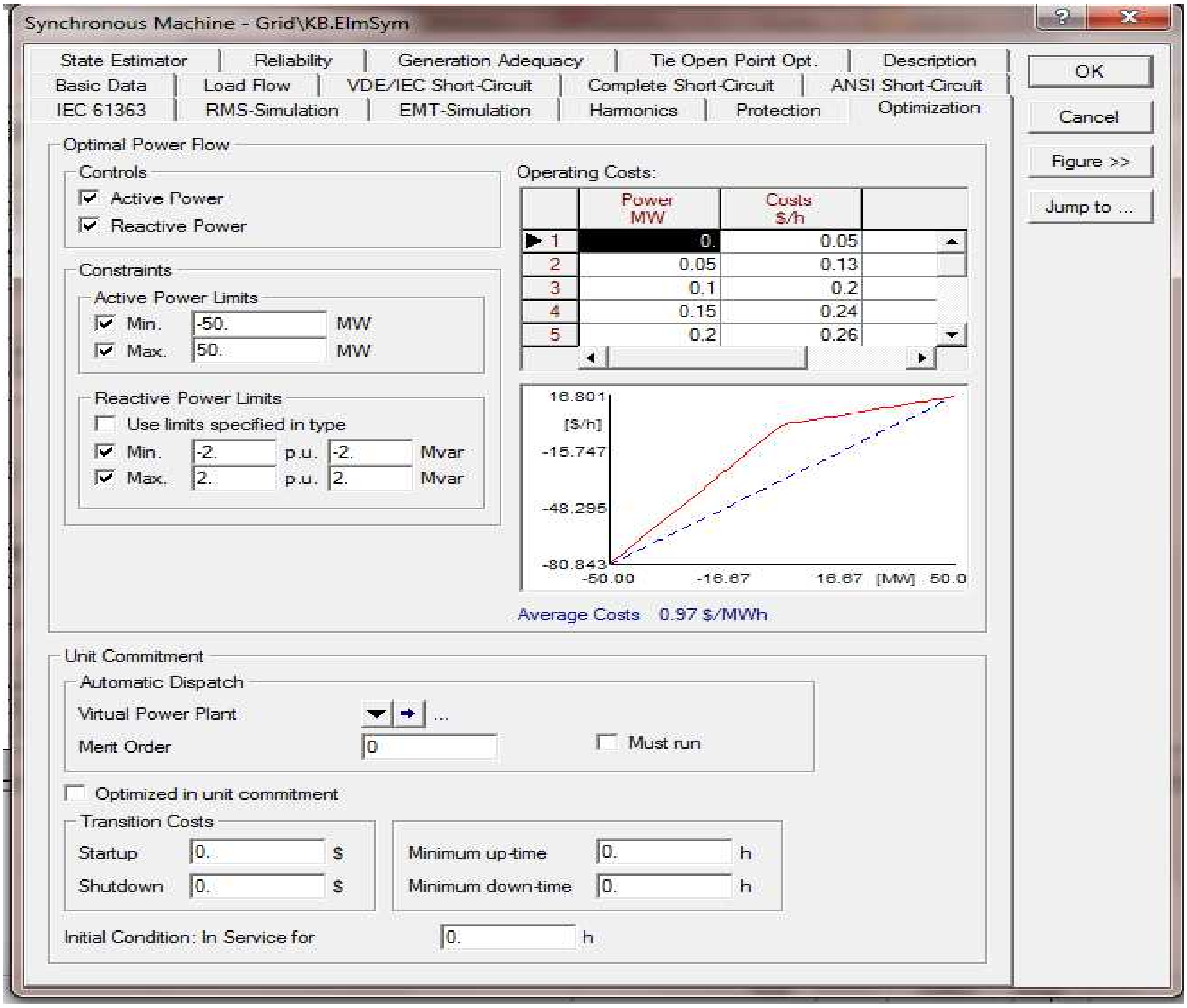


Figure 2. *Optimization tab of synchronous machine.*

Cost functions for generators: imposing a fuel cost function on a generator element is done as follows: on the 'Optimization tab' of each synchronous machine (ElmSym) element's dialogue (Figure 2), it is possible to specify the operating costs of the unit with the aid of the Operating Costs table (which relates active power produced (in MW) to the corresponding cost (in $/h)). This data is then represented graphically for verification purposes as seen in the figure, beneath the Operating Costs table. The number of rows that can be entered in to the table is unlimited.

Minimization of load shedding: the goal of this objective function is to minimize the overall cost of load shedding, such that all constraints can be fulfilled. In order to minimize the overall load shedding, for each individual load, the cost of shedding was specified (in $ per shed MW).

The non-linear optimization is implemented using an iterative interior-point algorithm based on the Newton-Lagrange method. This is summarised mathematically as follows:

$$\min = f(\vec{x}) \tag{7}$$

subject to:

$$g(\vec{x}) = 0; \quad h(\vec{x}) \le 0 \tag{8}$$

where g represents the load flow equations and h is the set of inequality constraints.

Introducing a slack variable for each inequality constraint, this can be reformulated as:

$$g(\vec{x}) = 0; \quad h(\vec{x}) + \vec{s} = 0; \quad \vec{s} \ge 0 \tag{9}$$

Incorporating logarithmic penalties and minimize the function:

$$\min = f(\vec{x}) - \mu \sum_i \log(s_i) \tag{10}$$

where μ is the penalty weighting factor.

In order to change the contribution of the penalty function:

$$f_{pen} = \sum_i \log(s_i) \tag{11}$$

to the overall minimization, the penalty weighting factor μ will be decreased from a user defined initial value $(\mu_{\max})$ to a user-defined target value $(\mu_{\min})$.

Furthermore, the following describes the configuration of a DC optimization formulation of OPF in PowerFactory. Internally, from the settings provided, a linear programming (LP) formulation of the problem is derived. The load flow is calculated using the linear DC load flow method. PowerFactory uses a standard LP-solver (based on the simplex method and a branch-and-bound algorithm) which ascertains whether the solution is feasible. The result of the linear optimization tool includes calculated results for control variables, such that all imposed constraints are fulfilled and the objective function is optimized. Provided that a feasible solution exists, the optimal solution will be available as a calculation result. That is, the algorithm will provide a DC load flow solution, where all generator injections are set to optimal values.

Objective functions are [1, 10-13]:

Feasibility check: performs a check of the network considering the specific controls and constraints;

Minimization of Generation Fuel Costs: the objective is to minimize generation costs. In the case that a cost minimization is calculated for each generator, a cost factor needs to be entered: cost curve $/MWh per generator (ElmSym). The (linear) algorithm uses a fixed cost-factor [$/MWh] per generator. This cost factor is the mid-cost between the costs at the generator's active power limits.

Min. Generator Dispatch Change: minimizes the change in generator dispatch from the generators' initial values.

The third method in OPL is contingency constrained DC optimization (LP method). It performs an OPL using DC optimization subject to various user-defined constraints and also to the constraints imposed by a set of selected contingencies. This method also considers user-defined post-fault actions. These actions include switch events, generator redispatch events, load shedding events and tap change events.

7. Results and Discussion

The global control parameters were selected on the Basic Options tab of the OPF (ComOpf) dialogue. The user can specify which parameters might serve as potential degrees of freedom for the OPF algorithm; that is, which parameters will contribute as controls. The smaller the minimum penalty weighting factor, the less the applied penalty will be for a solution which is close to the constraint limits. This may result in a solution that is close to the limiting constraint bounds.

Table 2. *A. C. losses minimization - summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	461.66	87.51	469.88
External infeed	0	0	0
Load P(U)	430.95	117.8	446.76
Load P(Un)	425.41	116.47	441.07
Load P(Un-U)	-5.54	1.33	0
Motor Load	0	0	0
Grid Losses	30.71	-30.28	0
Line Charging	0	-72.23	0
Compensation ind.	0	0	0
Compensation cap.	0	0	0
Installed Capacity	533.44	0	0
Spinning Reserve	71.78	0	0
Total power factor:	[-]		
Generation	0.98		
Load	0.96		
Motor	0		

On the other hand, a smaller minimum penalty weighting factor will result in a higher number of iterations required.

In order for the contingency constrained DC optimization (LP method) OPL to consider post-fault actions, the contingency analysis command assigned to the OPL must be 'Multiple Time Phases'. The contingency cases was defined to contain post-fault actions (transmission line linking F.C.T. and Niger generating stations). The report of the minimization (A.C. and D.C.) carried out are given in Tables 2 – 7.

Table 3. *A. C. costs minimization - summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	536.41	204.45	574.05
External infeed	0	0	0
Load P(U)	424.64	116.29	440.28
Load P(Un)	425.41	116.47	441.07
Load P(Un-U)	0.77	0.18	0
Motor Load	0	0	0
Grid Losses	111.77	88.16	0
Line Charging	0	-64.54	0
Compensation ind.	0	0	0
Compensation cap.	0	0	0
Installed Capacity	533.44	0	0
Spinning Reserve	-2.97	0	0
Total power factor:	[-]		
Generation	0.93		
Load	0.96		
Motor	0		

Table 4. *A. C. load shedding minimization – summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	431.72	59.05	435.74
Load P(U)	423.68	116.05	439.28
Load P(Un)	425.41	116.47	441.07
Load P(Un-U)	1.73	0.42	0
Grid Losses	8.05	-56.99	0
Line Charging	0	-67.99	0
Installed Capacity	533.44	0	0
Spinning Reserve	101.72	0	0
Total power factor:	[-]		
Generation	0.99		
Load	0.96		

Table 5. *D. C. cost minimization - summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	425.41	0	0
Load P(U)	425.41	0	0
Load P(Un)	425.41	0	0
Grid Losses	0	0	0
Installed Capacity	533.44	0	0
Spinning Reserve	108.03	0	0
Total power factor:	[-]		
Generation	0		
Load	0		
Motor	0		

Table 6. *D. C. generators dispatch - summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	425.41	0	0
Load P(U)	425.41	0	0
Load P(Un)	425.41	0	0
Load P(Un-U)	0	0	0
Grid Losses	0	0	0
Line Charging	0	0	0
Installed Capacity	533.44	0	0
Spinning Reserve	108.03	0	0
Total power factor:	[-]		
Generation	0		
Load	0		
Motor	0		

Table 7. *D. C. feasibility check – summary report.*

Parameters			
No. of Substations	37		
No. of Loads	37		
No. of Terminals	663		
No. of syn. Machines	36		
No. of Lines	43		
Parameters	MW	Mvar	MVA
Generation	425.41	0	0
Load P(U)	425.41	0	0
Load P(Un)	425.41	0	0
Installed Capacity	533.44	0	0
Spinning Reserve	108.03	0	0

To find the optimal configuration of capacitors, PowerFactory applies 2 different steps: sensitivity analysis to select the candidate buses for capacitor installation and optimization step to determine the actual locations and sizes of the shunt capacitors. After defining a busbar (at Kebbi) feeder using the software, the program automatically select other locations for capacitor placement. In this paper, install similar capacitor option was selected. The results are shown in Figure 3 - 5.

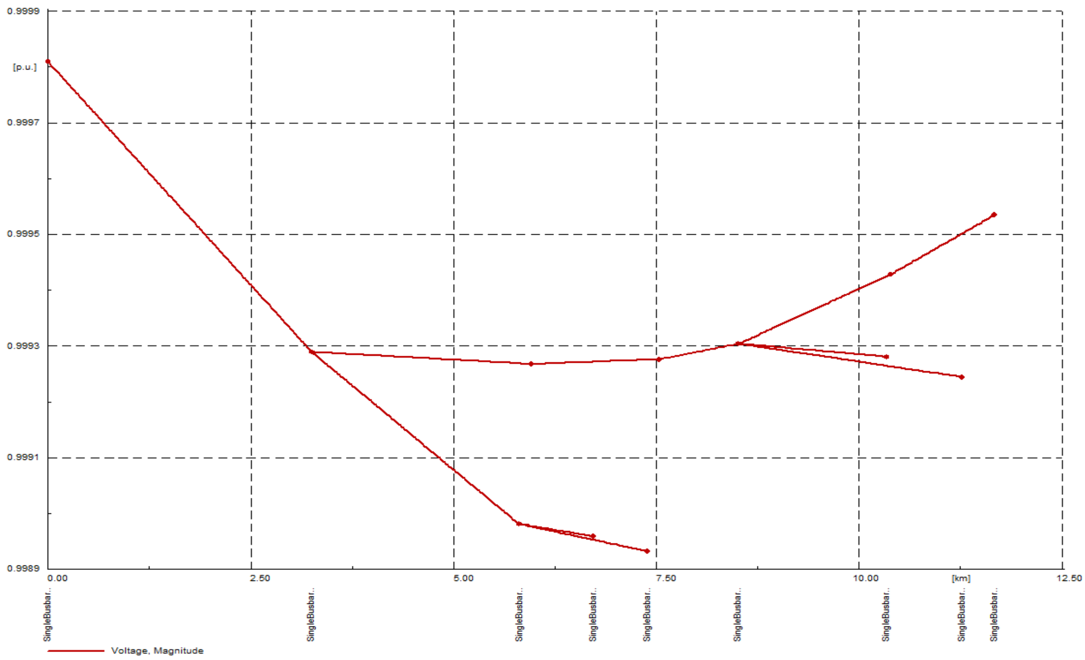
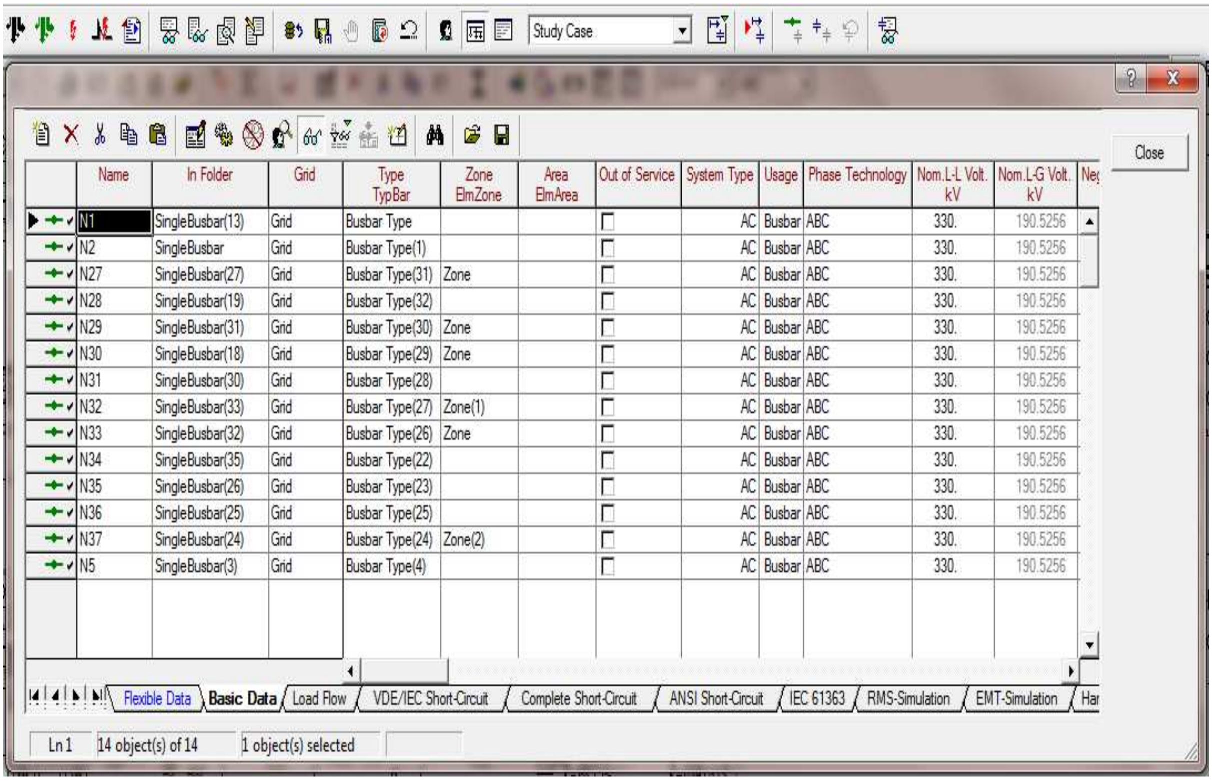
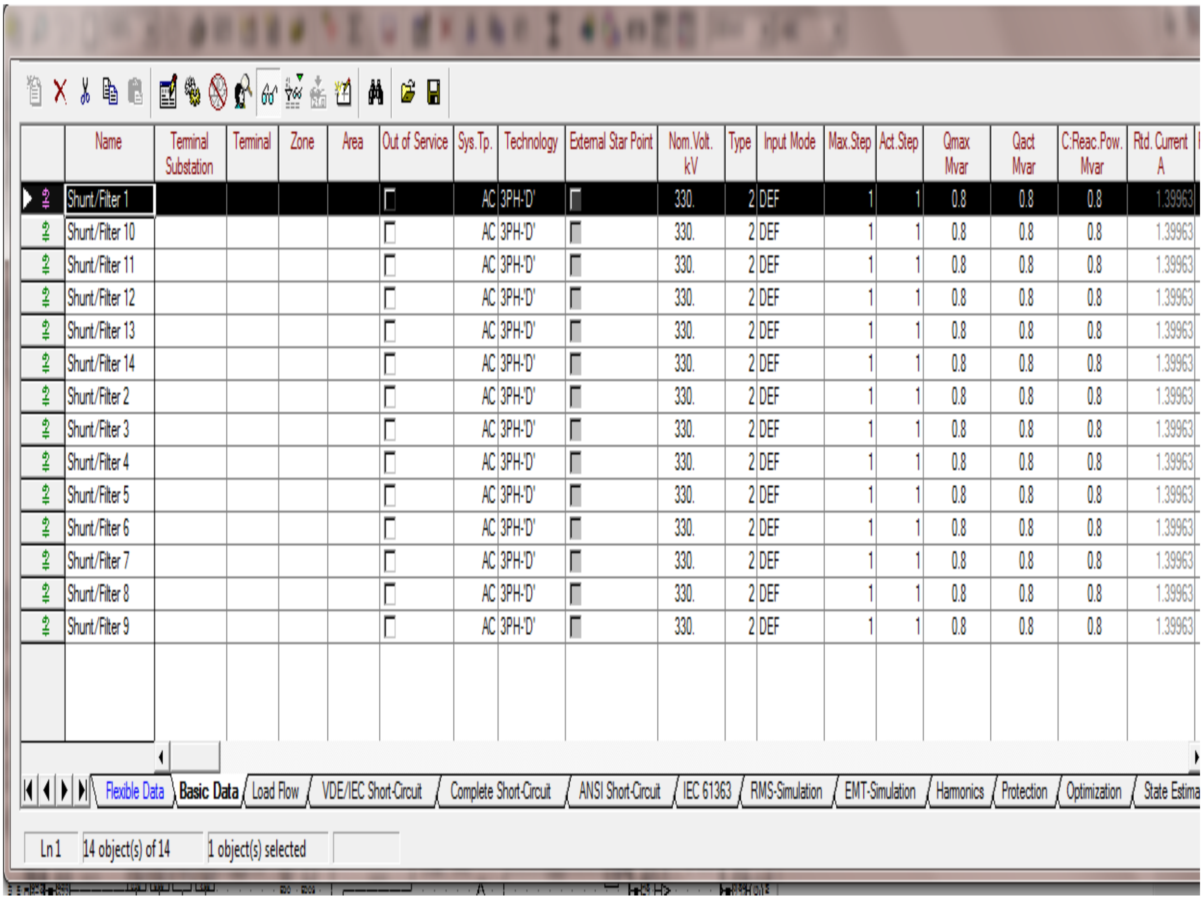


Figure 3. *Voltage profile plot showing the new capacitors after optimization starting from Niger busbar.*



Name	In Folder	Grid	Type TypBar	Zone ElmZone	Area ElmArea	Out of Service	System Type	Usage	Phase Technology	Nom.L-L Volt. kV	Nom.L-G Volt. kV
N1	SingleBusbar(13)	Grid	Busbar Type				AC	Busbar	ABC	330.	190.5256
N2	SingleBusbar	Grid	Busbar Type(1)				AC	Busbar	ABC	330.	190.5256
N27	SingleBusbar(27)	Grid	Busbar Type(31)	Zone			AC	Busbar	ABC	330.	190.5256
N28	SingleBusbar(19)	Grid	Busbar Type(32)				AC	Busbar	ABC	330.	190.5256
N29	SingleBusbar(31)	Grid	Busbar Type(30)	Zone			AC	Busbar	ABC	330.	190.5256
N30	SingleBusbar(18)	Grid	Busbar Type(29)	Zone			AC	Busbar	ABC	330.	190.5256
N31	SingleBusbar(30)	Grid	Busbar Type(28)				AC	Busbar	ABC	330.	190.5256
N32	SingleBusbar(33)	Grid	Busbar Type(27)	Zone(1)			AC	Busbar	ABC	330.	190.5256
N33	SingleBusbar(32)	Grid	Busbar Type(26)	Zone			AC	Busbar	ABC	330.	190.5256
N34	SingleBusbar(35)	Grid	Busbar Type(22)				AC	Busbar	ABC	330.	190.5256
N35	SingleBusbar(26)	Grid	Busbar Type(23)				AC	Busbar	ABC	330.	190.5256
N36	SingleBusbar(25)	Grid	Busbar Type(25)				AC	Busbar	ABC	330.	190.5256
N37	SingleBusbar(24)	Grid	Busbar Type(24)	Zone(2)			AC	Busbar	ABC	330.	190.5256
N5	SingleBusbar(3)	Grid	Busbar Type(4)				AC	Busbar	ABC	330.	190.5256

Figure 4. *List of busbars automatically selected for capacitor placement.*



Name	Terminal Substation	Terminal	Zone	Area	Out of Service	Sys.Tp.	Technology	External Star Point	Nom.Volt. kV	Type	Input Mode	Max.Step	Act.Step	Qmax Mvar	Qact Mvar	C:Reac.Pow. Mvar	Rtd. Current A
Shunt/Filter 1						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 10						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 11						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 12						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 13						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 14						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 2						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 3						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 4						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 5						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 6						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 7						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 8						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963
Shunt/Filter 9						AC	3PH-'D'		330.	2	DEF	1	1	0.8	0.8	0.8	1.39963

Figure 5. *List of capacitors selected for the busbars.*

The objective function for cable-size optimization is the annual cost for the reinforced lines by defining an admissible overloading percentage to avoid overrating of the lines, the maximum voltage drop allowed for the new network topology and standard overhead line types for the new assignment. In the proposed network, cubicle linking transmission line (between Taraba and Adamawa generating stations) and Adamawa busbar was defined for the optimization. The penalty factor (2) was defined on the basic parameter page. This allows choosing adequate cable despite the cost.

IEC standard and Zebra cable types used based on cross sectional area (CSA) and rated current. The base apparent power (S_{base}) used was 100 MVA, while the transmission line lengths (in Kilometers, Km) were per-unitized on the base value of 100 Kilometres. Tables 8-11 show the simulation results using PowerFactory.

Table 8. *IEC standard cable – feeder report based on CSA.*

Name	First Branch	Input Current [kA]	Total Load (MW)
N28_Line(40)	Line(40)	0.057	6.664
N29_Line(42)	Line(42)	0.019	0
N30_Line(39)	Line(39)	0.01	0
N3_Line(2)	Line(2)	0.018	395.853
Generation [MW]	Losses [MW]	Max. Loading [%]	Min. Voltage [kV]
37.25	0.002	70.58	1
0	0	0	0
0	0	0	0
421.496	0.225	79.31	0.999

Table 9. *IEC standard cable – feeder report based on rated current.*

Name	First Branch	Input Current [kA]	Total Load (MW)
N28_Line(40)	Line(40)	0.057	6.664
N29_Line(42)	Line(42)	0.019	0
N30_Line(39)	Line(39)	0.01	0
N3_Line(2)	Line(2)	0.018	395.853
Generation [MW]	Losses [MW]	Max. Loading [%]	Min. Voltage [kV]
37.25	0.002	70.58	1
0	0	0	0
0	0	0	0
421.496	0.225	79.31	0.999

Table 10. *Zebra cable – feeder report based on CSA.*

Name	First Branch	Input Current [kA]	Total Load (MW)
N28_Line(40)	Line(40)	0.057	6.664
N29_Line(42)	Line(42)	0.019	0
N30_Line(39)	Line(39)	0.01	0
N3_Line(2)	Line(2)	0.018	395.853
Generation [MW]	Losses [MW]	Max. Loading [%]	Min. Voltage [kV]
37.25	0.002	70.58	1
0	0	0	0
0	0	0	0
421.496	0.225	79.31	0.999

Table 11. *Zebra cable – feeder report based on rated current.*

Name	First Branch	Input Current [kA]	Total Load (MW)
N28_Line(40)	Line(40)	0.057	6.664
N29_Line(42)	Line(42)	0.019	0
N30_Line(39)	Line(39)	0.01	0
N3_Line(2)	Line(2)	0.018	395.853
Generation [MW]	Losses [MW]	Max. Loading [%]	Min. Voltage [kV]
37.25	0.002	70.58	1
0	0	0	0
0	0	0	0
421.496	0.225	79.31	0.999

8. Conclusion

The main goal of optimal power flow analysis is to acquire the complete voltage angle and the magnitude information for each bus found in a power system that is required to accommodate specific load and produce voltage and real-power conditions. The applications of the OPF include transmission line overload removal, transmission system control, available transfer capability calculation (ATC), real and reactive power pricing, transmission component valuation, and transmission system marginal pricing.

Power capacitors are very useful for power factor correction, loss reduction, voltage profile improvement and distribution system-capacity release/increase. The conductor, which is determined by this optimization method will maintain acceptable voltage levels of the radial distribution sys-

tem. Besides, it gives maximum saving in the capital cost of conducting material and cost of energy losses.
The method also shows that only proper selection of optimum branch conductors reduces losses.

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