INVESTIGATING THE IMPACT OF REPRESENTATION OF MV POWER LINES IN THE DISTRIBUTION SYSTEM FOR THE STUDIES OF POWER FLOW CONSIDERING DG

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ABSTRACT

In this work, we present a case study that examines the impact of improper representation of lines in a primary distribution network. In this context, this work evaluates how a variation in the model can influence the results obtained with the power flow, for real networks of the Brazilian electrical system. For the results of the power flow to be reliable, given the most diverse operating conditions, it is necessary that the components of the distribution system be modeled appropriately. In this context, this paper analyzes in a case study, the impact of the main mathematical models that can be used to represent lines of distribution systems and evaluates how they influence the results obtained with the load flow. They are considered overhead power lines, considering the topological provisions and load conditions of the feeder. We are dealing with a real problem, and as we conduct the studies in a real network, network information and power measurements are provided by the corresponding power utility. Based on the assessments made at work, it is concluded that, due to the topology of the distribution systems, it will be possible to demonstrate that, the effect of line modeling for some large networks with relatively low charge density present in the Brazilian electrical system causes a significant impact on the calculated power flow results.

INTRODUCTION

This paper presents a case study that examines the impact of improper representation of lines in a primary distribution network through the short line model, which considers the effect of the shunt branch to be negligible. The primary distribution network that was studied is present in the Brazilian electric system, located in the State of Tocantins.

Through the calculation of the power flow, it is possible to carry out studies of the electrical systems in permanent regime. This type of study requires extensive numerical analysis, which should consider simplification techniques given the large size of some systems. The solution of this mathematical problem allows to determine, for example, voltage and power at each point of the system being studied.

For the results to be reliable, distribution systems must be modelled correctly. In this context, this work evaluates how a variation in the model can influence the results obtained with the power flow, for real networks of the Brazilian electrical system.

They are considered overhead powerlines, considering the topological provisions and load conditions of the feeder. We are dealing with a real problem, and as we conduct the studies in a real network, network information and power measurements are provided by the corresponding power utility. The networks covered in this case study have some characteristics of their own.

Some Brazilian regions have primary distribution networks with great extension, mainly due to the distribution of small consumption centres in large territorial areas - feeder with total length of more than ~300 [km] of the main feeder, operating mainly in 34.5 [kV] and with relatively low load, presenting as extremely capacitive feeders and with distributed generation.

The network is formed by multiphase feeders, without transposition between phases, to which must be added the load unbalance, distributed generation insertion, feeders with high extension, which results in a high level of imbalance between phases.

Added to this is the tendency to have to operate distribution systems more and more efficiently, considering the greater penetration of distributed generation, storage systems and demand response, resulting in the need to have reliable means for their operation and planning. The method used to calculate the power flow is the backward forward sweep [4], [7] and the time calculation is given by the peak hours of the network load.

In order to highlight the impact of the modelling on the analysed network, the power flow calculation is performed twice, a first, considering evaluations due to the topology of the distribution systems, with the lines represented by the short line model with own and mutual impedances calculated by modified Carson equations, and a second analysis, considering the medium line equations model.

Motivation

Some Brazilian regions possess primary distribution networks with large extension, primarily due to the distribution of small centers of consumption in large territorial areas. The network addressed in this case study consists of a feeder with main feeder’s total length of 300 kilometers

[km], operating mostly in 34.5 [kV] and with relatively low load. The network is present in the state of Tocantins, which is one of Brazilian's states with lowest population density.
The low population density is somehow related to the presence of extensive lines, which even in medium voltages considerably increase the reactive power absorption due to the shunt branch capacitive current. In these cases, the short line model may be inappropriate and provide inconsistent power flow results.
So, the main objective is to show the impact of the choice of the representation of a distribution line in the calculation of power flow considering the characteristics of some distribution networks.

DEVELOPMENT

This section will present: the basic methodology, mathematical formulation and the proposed methodology.
The network analyzed "Dianópolis-Almas (04028074)" suggested by the power utility for its peculiarity to contain child substations - modeling that allows segregation of important electrical regions in order to identify possible actions of planning and combating losses, used in extensive circuits with elevating transformers and / or voltage relievers - and for being a network extensive assisted in operating voltage of 34,5KV.
When using to represent this type of network the modeling of short lines, it despises the reactive values relative to the capacitive effect of the distribution lines and in this case can obtain calculated values of power flow very distant from the reality.

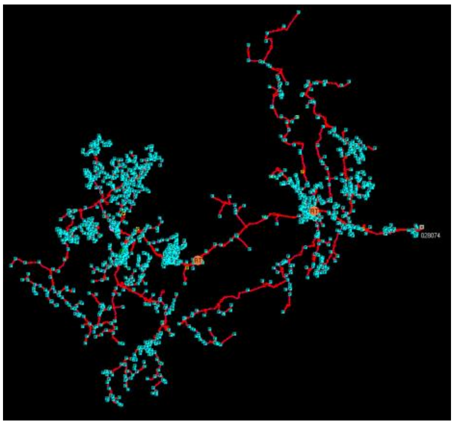

Figure 1 - Real network used for testing

Mathematical Formulation

The use of short-line modeling is enough for calculating power flow in most medium voltage networks in Brazil. However, this model is not enough for long feeders with a voltage level of 34.5 kV, where the capacitive effect is more perceptible.
Considering the model π for distribution lines, the absorption of reactive power by the capacitive effect of the three-phase lines can be calculated generically as:

$$Q = 3 \times C \times 377 \times \frac{l}{2} \times \frac{V^2}{\sqrt{3}} \qquad (1)$$

wherein:

Q = reactive power absorbed (VAr)
C = line capacitance (F/m)
l = length of lines (m)
V = rated voltage (V)

It is observed that for a high voltage and length we have a more significant effect of the reactive power absorbed by the capacitive effect of the distribution lines.

Short lines model

Generally, the short lines are those with extension of up to 80 km or 50 miles. The capacitance of lines up to 80 km is discarded, as it is small, as well as the conductance (dispersion) in derivation.
Thus, the line is represented by its serial parameters and their respective effects, that is, resistance and inductance short line model their respective effects, i.e., resistance and inductance (inductive reactance) [1],[2],[3].

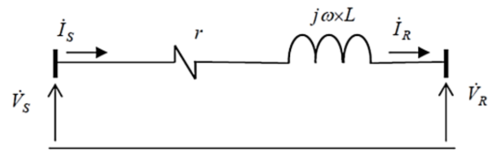

Figure 2 - Short line model for one of the phases

where: I_S is a current that comes from the transmitter bus; I_R is the current that arrives in the receiving bus; V_S is the phase-neutral voltage of the transmitter bus; V_R is the phase-neutral voltage of the receiver bus.

Medium lines model

The middle lines are those extending from 80 km (or 50 miles) to 240 km (or 150 miles). In this case, we consider the capacitive effect of the lines, including the shunt-inductive capacitance (imaginary part of the shunt admittance), and the shunt conductance is also neglected. Representing the network through the π - nominal model, the line capacitance is concentrated at both ends and divided by 2.

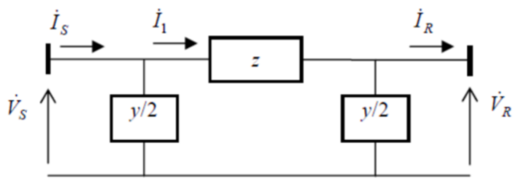

Figure 3 – The π-nominal midline model for one of the phases

Demand correction

A good network management system is based on power flow calculations. However, for the power flow [5], [6], [7] result to represent well the network reality, the load must be very well characterized from the demand calculation performed based on billing data and typical curves.
This calculation, however, has inaccuracies, since the typical curves have a certain statistical validity and, frequently, it is not known how the load of the consumer is divided between the phases that in the feeder. In addition, there is the question of the quality of the registry of the electric utility that can affect the quality of the calculation result.
There may be several causes of discrepancies between demands measured at the output of the substation and the demands estimated by the power flow calculation.
In this context, there are difficult aspects to deal with, such as: (i) eventual registration errors, (ii) possible errors in meters, (iii) existence of clandestine consumers, (iv) the implementation of permanent switching operations in the distribution network and the corresponding updating in the register databases; (v) difficulty in characterizing the demand of the loading points.
The method for the correction of demand used by electric power company in Brazil currently considered the measurement data at the beginning of the feeder. These data are used to calculate a correction factor in the phase that presents the highest measured current.
This factor is then applied equally across all feeds and demands of the three feeder phases, so that the imbalances estimated by the load flow calculation along the feeder remain unchanged after the application of the method, even if this results in values discrepancies from those previously measured.
It should be noted that the habit of using a consumer's electric energy is not the same every day. Thus, the two-day load curves are not necessarily the same.
When the questionnaire response is obtained with information on consumer habits, it is possible to estimate the shape of the load curve of that consumer.
But this curve is an average value, not meaning that it will be repeated every day.
When several of these average curves are added to determine, for example, the load curve of a city, it is likely that the result obtained will be valid, since although there is randomness in the individual consumption, the global randomness ends up compensating and the result of the sum average is the load of the city.
When the objective is to determine the current at the beginning of the feeder, different values will certainly be verified between the current measured by the utility and that calculated by means of the estimated demands of the distribution transformers and part of the primary transformer. The calculation is carried out by a radial power flow responsible for determining the currents in all sections of the network and the voltages in all the bus.

Once the difference between the current values has been verified, the calculated value can be corrected through the following iterative process:

1) Calculate the ratio between the measured value and the calculated value, thus obtaining a multiplicative index (K).
2) This multiplicative index is applied to the distribution transformers in order to provide an increase (if K> 1) or decrease (if K <1) in the calculated current value.
3) The iterative process ends when the value of K becomes equal to 1, that is, when the calculated value of the current becomes equal to the measured value of the same.

The correction process, until then made for current values, can be performed for values of active power and reactive power, treating these quantities together and independently.
The difference between the two corrections is that when the correction is made by the value of the current, the power factor is kept constant. This is not the case for the second case, where the power factor is susceptible to changes, since the active and reactive powers are directly influenced by the phases involved.
It should be noted that demand correction can be done from any other part of the network under analysis, provided there is a measuring point.
A correction from a second measuring point upstream of a first is only responsible for an adjustment of the uncorrected loads, that is, the loads affected by the first correction will not be influenced by the second one.

RESULTS

The measurements used in this analysis are taken from a measurement file, "LD Dianápolis - Almas.xls", available from the electricity utility, and contain measurements every 15 minutes of the month of august of a recent year. The mean and maximum monthly values of the active and reactive power measurements are calculated and are shown in Table 1e and Table 2.

Table 1 - Measurements for "lightweight" load level

Light Load		
	P(kW)	Q(kVAr) capacitive
Average	4075,795	-1623,455
Max	6436,8	-3067,2

Table 2 - Measurements for "heavy" load level

Heavy Load		
	P(kW)	Q(kVAr) - capacitive
Average	4390,098	-1471,123
Max	7430,4	-2656,8

Results without capacitance of the cables considered (short lines model)

The maximum measurement value of the levels is used to represent the worst case occurring during the analyzed period.
For short-line modeling, the calculated reactivity is inductive at both levels, neglecting the effect of line capacitances.

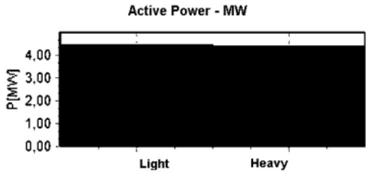

Figure 4 - ACTIVE power calculated without considering the effect of the capacitive reactive of the cables

Comparing the calculated values of the Figure 4 and Figure 5 with the measured values of the Table 1 and Table 2, we have the following results.

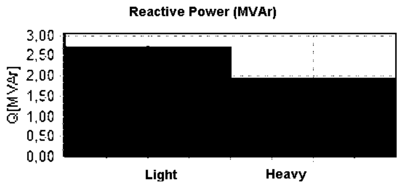

Figure 5 - REACTIVE power calculated without considering the effect of the capacitive reactive of the cables

Table 3 -Power output Active/reactive calculated without considering the effect of the capacitive reactive of the cables to the 04028074 feeder

P(MW)	Q(MVAr)
4,43	2,72
4,37	1,93

For the low level we have the measured value of P (MW) equal to approximately 4.43MW and Q (MVAr) of approximately 2.72MVAr inductive.

Table 4 - Comparison of calculated and measured values in the "lightweight" level without capacitance

Light Load				
	Measured		Percent error (%)	
	P(kW)	Q(kVAr) capacitive	P(kW)	Q(kVAr)
Average	4075,795	-1623,455	8%	160%
Max	6436,8	-1987,2	45,3%	173%

For the heavy load level we have the calculated value of P (MW) equal to approximately 4, 37MW and Q (MVAr) of approximately 1, 93MVAr inductive.

Table 5 - Comparison of calculated and measured values in the load level "heavy" without capacitance

Heavy Load				
	Measured		Percent error (%)	
	P(kW)	Q(kVAr) capacitive	P(kW)	Q(kVAr)
Average	4390,098	-1471,123	0,5%	176%
Max	7430,4	-2656,8	70%	172,6%

Results with cable capacitance considered (mid-line model)

For the midline modeling there was a large difference in the reactive power of the measured feeder, becoming the active power capacitive.
This demonstrates the great influence that the inclusion of the capacitive effect of the lines in the modeling of extensive networks of 34,5kV can cause in the results.

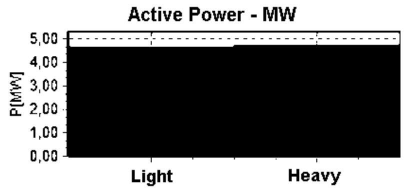

Figure 6 - Active Power calculada considerando o efeito do reativo capacitivo dos cabos

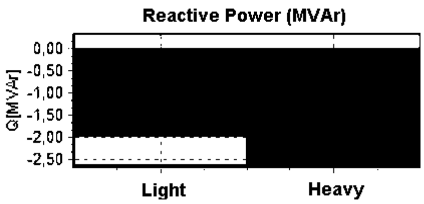

Figure 7 - Reactive Power Potência Reativa calculada considerando o efeito do reativo capacitivo dos cabos

Comparing with the measured values of the Table 1 and Table 2, we have the following results: For the light load level, we have the calculated value of P (MW) equal to approximately 4, 64MW and Q (MVAr) of approximately -2,0 MVAr capacitive.

Table 6 - Comparison of calculated and measured values in the "lightweight" level of load with capacitance

Light Load				
	Measured		Percent error(%)	
	P(kW)	Q(kVAr)	P(kW)	Q(kVAr)

		capacitive		
Average	4075,795	-1623,455	12,1	18,8
Max	6436,8	-3067,2	38,7	53,36

For the heavy load level we have the calculated value of P (MW) equal to approximately 4, 71MW and Q (MVAr) of approximately -2, 65 MVAr capacitive.

Table 7 - Comparison of calculated and measured values in the "heavy" load level with capacitance

Heavy Load				
	Measured		Percent error (%)	
	P(kW)	Q(kVAr) capacitive	P(kW)	Q(kVAr)
Average	4390,098	-1471,123	6,8%	44,5%
Max	7430,4	-2656,8	57,7%	0,2%

The results presented in Table 6 and Table 7 correspond to the difference between the measured values and the calculated values without considering the capacitances of the lines (short line model).
It is noted that the values of reactive power calculated and measured are distant, and the calculated value presents inductive reactive and the measured value, presents capacitive reactive.
The percentage errors presented are in the order of 170% when compared with mean and maximum values of measurement. The results presented in Table 4 and Table 5 correspond to the difference between the measured values and the calculated values considering the capacitances of the lines (mean lines model).
It is possible to observe that the calculated and measured reactive power values are considerably closer, and both, calculated value and measured value have a capacitive characteristic.
The percentage errors presented when compared with mean values of measurement are of 10% and when compared with maximum values are of 50%.
By analyzing the results presented, it is evidenced the approximation of the values of reactive power measured and calculated when the capacitances of the lines are considered.
The modeling of Midlines for the "Dianópolis-Almas" Network (04028074) showed more coherent results in relation to short line modeling.
To use medium line modeling, it is necessary to enter the capacitance information of the cables, C (KVAr/km), which are used in the network under analysis.
In possession of this information, the calculations should be performed using the modeling of medium lines for the distribution lines that have cable with informed capacitance.
It can be concluded that the difficulties encountered for the correction of demand in the network of long lines of 34, 5KV are due to the large difference presented between measured values and calculated when short line modeling is used.
By using the midline modeling we consider the capacitances of the lines and we will have calculated values closer to the measurements, therefore we must find minor difficulties in the process of correction of demand using the measurements in these cases Specific.

CONCLUSION

In this case study, it is shown that the effect of the shunt lines current, for some extensive networks with relatively low load density present in the Brazilian electrical system, causes expressive impact on the calculated power flow results.
Based on the evaluations, it will be possible to demonstrate that due to the topology and modeling of the distribution system, the effect of line modeling for some large networks with relatively low charge density present in the Brazilian electrical system causes a significant impact on the flow results of calculated power. The comparison between the measured values and the calculated power flow results, using short and medium line models, will be presented in this article.

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