ANALYSIS OF THE EXISTING EMPIRICAL RADIO NOISE PREDICTION MODELS PRECISION AND THE PERFORMANCE OF THESE MODELS APPLIED FOR OVERHEAD COMPACT TRANSMISSION LINES OPERATING ON 230 KV AND BELOW

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Abstract: This work presents the studies results with radio noise prediction empirical existing models applied for no compact overhead transmission lines and the performance of these prediction models when applied for compact configurations lines operating on 230 kV and below. One of objectives this work is to compare these radio noise prediction empirical existing models with recent measurements carried out on compacts lines on operation of Cemig system and to get more information for more consistent and security definitions for the right of way. Preliminary results, comparing calculated and measured values show that the radio noise empirical existent prediction models are not adequate for some overhead compact lines configurations.

1 INTRODUCTION

In the Overhead Transmission Line (OTL) projects, the radio noise prediction values for right of way are obtained by empiric or analytical formulations. The geometric and particular characteristics of the Overhead Compact Lines (OCL) presents reduced electric distances and operate in voltages of 230 kV and below. The radio noise prediction existing models not present a good performance like will be shown.

The increasing of ampacity in the electric system, associate to the necessity of optimized exploration of the right of way, have motivated this work based on the studies [1,2,3,4].

Several radio noise prediction empiric methods were developed [5,6], nevertheless, if not were considered some data and important points of project of difficult balance all these methods become not efficient.

In this process is necessary to determine more accurately the levels of potential gradient in the conductors surface, main variable for the empiric prediction methods, defined by the influence of the hardware, geometries and arrangements as the ambient conditions [7,8].

2 DEVELOPMENT

Based on the study [5,6] is presented a complementary study about the performance of radio noise empiric models applied for analyze of OTL groups.

2.1 Complementary Statistical study with the Radio Noise Prediction Empirical Existing Models

Figure 1 show the analysis of the radio noise prediction existing models precision using the Minimums Squared methodology (R^2), applied for the different OTL groups [5,6]. Can be observed , in general way a regular performance for the majority of models.

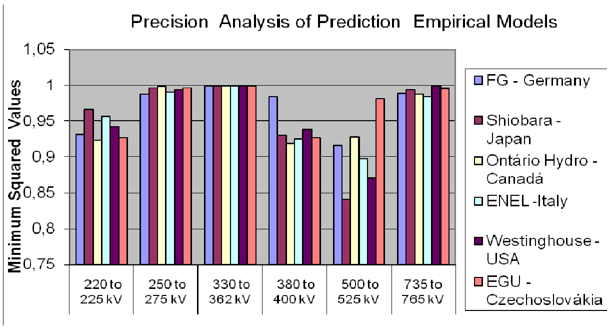


Figure 1 – Study with the Radio Noise Prediction Empirical Existing Models [5,6]

Figure 2 show the potential gradient conductors surface behavior on the in agreement with the characteristics of the studied OTL groups.

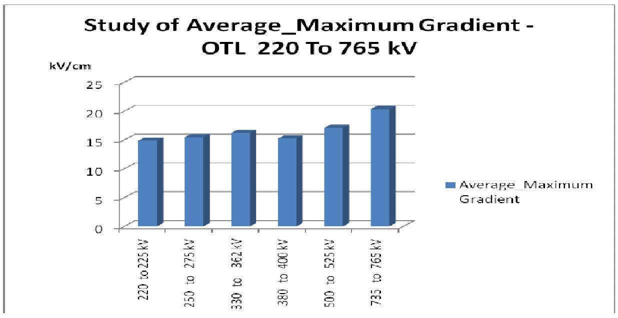


Figure 2 - Maximum Potential Gradient (kV/cm) analysis for the OTL groups [5,6]

Can be observed that the average maximum potential gradients behavior have levels around 15 to 20 kV/cm, factor that have a significant influence on the reference standard definition for each empirical prediction model.

The Figure 3, a study is presented, based on methodology 6 Sigma where an analysis of the empirical existing models prediction precision is tested with the ample study of measurement carried out by Cìgre and IEEE [5,6].

For the construction of the graph, Figure 3 were been used indices that inform the capacity of each model in processing all the information and is possible to evaluate if a model is capable to generate or to produce satisfactory resulted and if the models can reproduce the prediction model expectation.

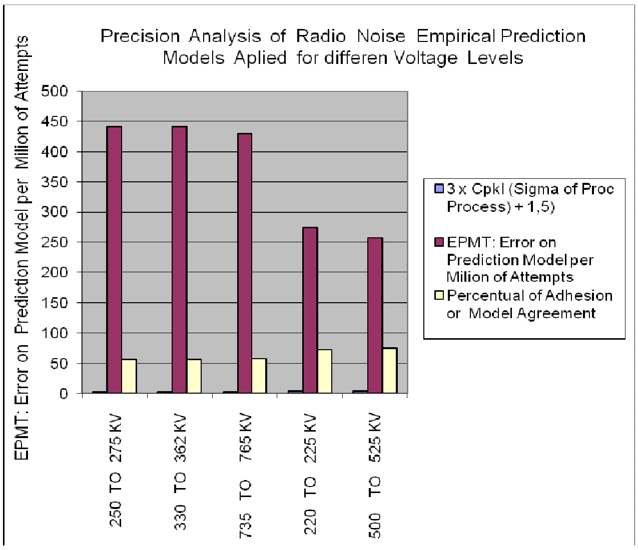


Figure 3 – Precision Analysis of Radio Noise Noise Empirical Prediction Models using the 6 Sigma Methology

In these analyses were given emphasis for the OTL of 220 to 225 kV, due to the fact of these voltage levels to approach more of the interest of this work. In this aspect it is possible to verify that the average diameter of the used conductors and its respective maximum gradients. These values are in average 2.85 cm for the diameter with average maximum gradients around 14.84 kV/cm.

The Figure 4, shows the performance of the prediction models applied for the OTL group of 220 to 225 kV, comparing with measurements carried out for a fixed point defined to 15m of the right of way, showing the variance of prediction models.

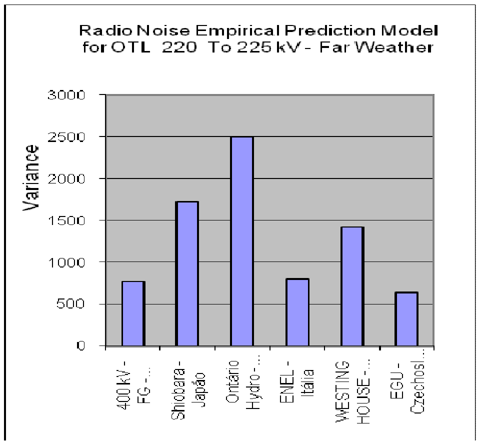
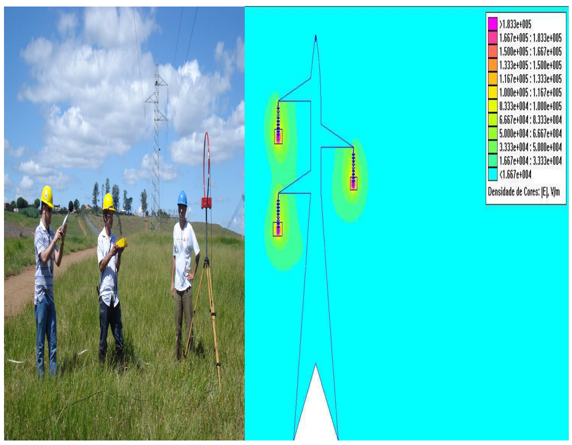


Figure 4 – Variance of the radio noise empiric prediction models

3 TESTS WITH THE RADIO NOISE PREDICTION EMPIRICAL EXISTING MODELS USING SIMULATIONS AND MEASUREMENTS OF NO COMPACT AND COMPACT OVERHEAD TRANSMISSION LINES

3.1 Potential Gradient Study Involving Compact and not Compact Configurations and Hardwares

The measurements data compilation of the on several types of compact and no compact OTL arrangements were carried out in laboratory and on OTL in operation of Cemig system. Associate to an ample study of potential gradients in several types of arrangements and conductors, Figures 5 to 7, show that is possible to mount a database for a statistical study, using the results and the behavior observed for each different OTL configuration.



(a) (b)

Figure 5 - a) Study with the Radio Noise Measurements on the special OTL with compact conductors (b) Simulation studying the superficial potential gradient for the special OTL measured

The Figures 5 to 7, allowed us to establish a relation between the maximum gradients and the critic gradient of each model

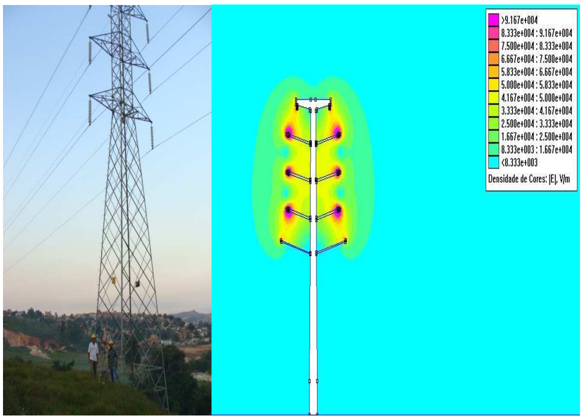


Figure 6 - (a) Study with the Radio Noise Measurements on the OTL double circuit (b) Simulation studying the superficial potential gradient for the OTL measured

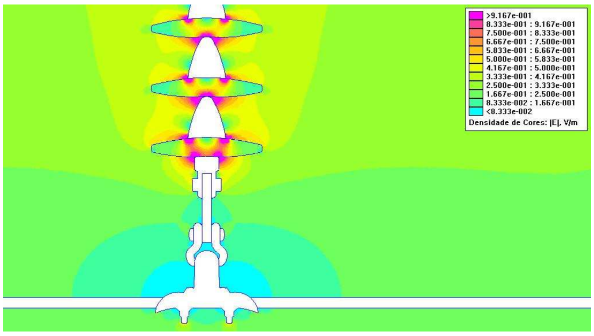


Figure 7 – Detailing of the superficial potential gradient in hardware and insulators of the OTL.

The Table 1 presents the results of some OCL gradients calculated where is possible to observe that relations between the maximum and the critical gradient are above of 80%. For these cases, all empirical predictions models not showed good correlations between radio noise measurements and calculations.

Table 1 – Overhead Compact Lines Gradients

Overhead Compact Lines (OCL)			**Gradient (kV/cm)**		**%***
Utilite	**Tensão (kV)**	**Conductor**	**Maximum**	**Critical**	
Puget Power	230	Narcisios	18,9	22,7	83
CEMIG¹	161	Linnet	19,9	23,9	83
CEMIG²	138	Tulip	19,7	24,2	81
CEMIG	138	Linnet	19,4	23,9	81
CEMIG³	138	Sparrow	22,3	24,81	80
CEMIG	138	Penguin	22,79	24,52	93

* Percentual relations between the maximum and the critical gradient.

1 - In Figure 13 is presented the radio noise measurements profile of this line.

2 - In Figure 15 is presented the radio noise measurements profile of this line,

3 - In Figure 14 is presented the radio noise measurements profile of this line.

3.2 Radio Noise Measurements on Overhead Transmission Lines of Cemig System

The measurements program was applied for no compact OTL of 69, 138, 230, 345 and 500 kV. The graphs, Figures 8 to 11, show the measurements carried out and its respective comparisons with simulations, using the main existing empirical prediction models. Observe that there is a good correlation between all prediction curves and the measurements carried out.

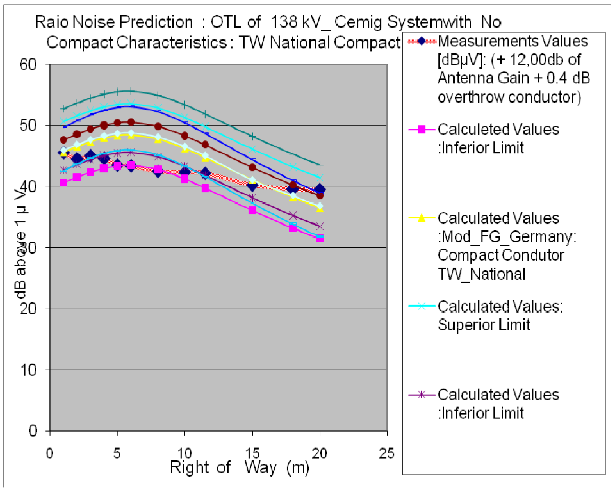


Figure 8 – OTL of 138 kV: Nova Granja – Vespasiano1

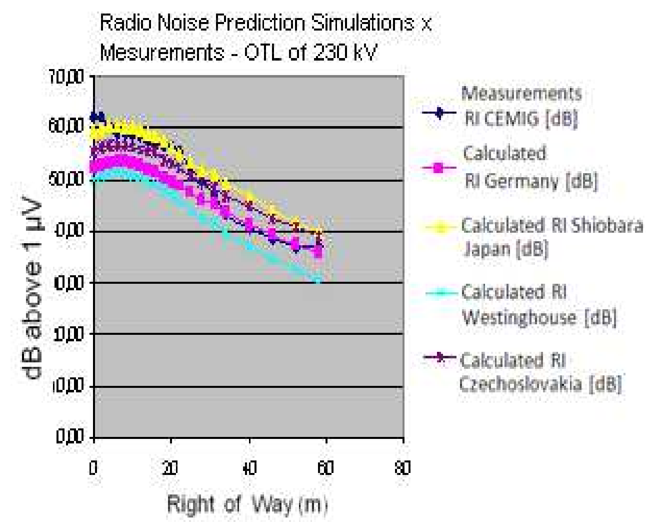


Figure 9 - OTL of 230 kV Sabará - Mesquita

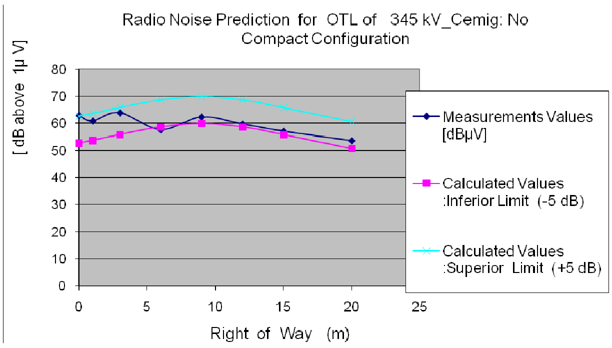


Figure 10 - OTL of 345 kV – Neves 1 - Mesquita

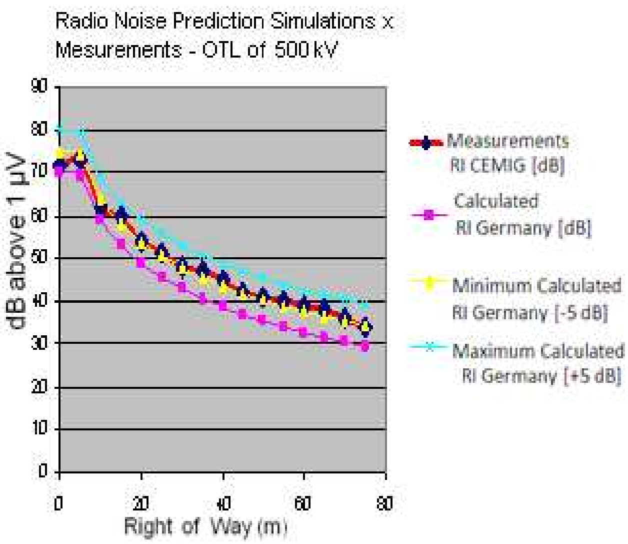


Figure 11 - OTL of 500 kV Neves 1–Bom Despacho3

The Figures 8 to 11, show the difference between the measured and calculated values, where is possible to observe that prediction curves, considering a minimum and maximum values (± 5 dB) keeping the measurement values inside these limits, indicating a good prediction.

An exception appears for the OLT of 69 kV, Figure 12, where the prediction values are extremely inferior in relation to the measured values, showing the prediction curves bellow in relation to measurement values.

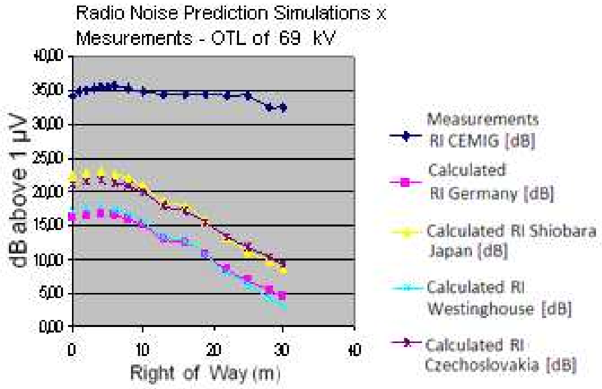


Figure 12 – OTL of 69 kV: Caeté – Sabará (special case)

3.3 Radio Noise Measurements on Overhead Compact Lines of Cemig System

A verification of radio noise prediction empirical existing models performance, were carried out a series of measurements on OCL Cemig system, involving the voltages of 138, 161 kV.

A similar measurements study was carried out by Puget Power [12], where a ample measurements program on a OCL of 230 kV where were evidenced significant differences comparing the measured values and d radio noise prediction using empirical models.

The Figures, 13 to 15, show the measurements carried out on OCL of Cemig operating system and a respective comparisons with simulations using the main radio noise existing empirical prediction models. Is possible to see that the measurements values are keeping inferior that the prediction values.

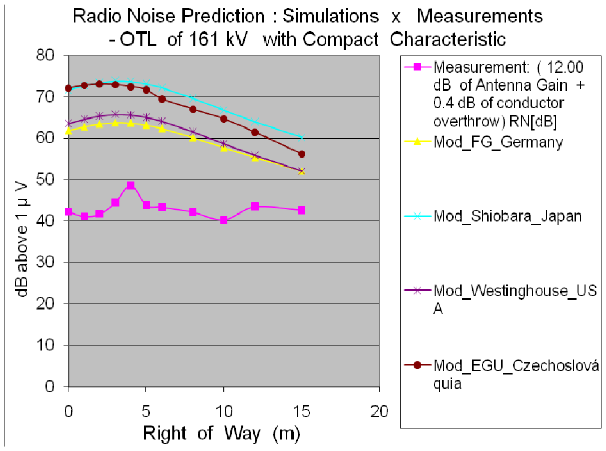


Figure 13 - OCL of 161 kV: Salto Grande-Ipatinga

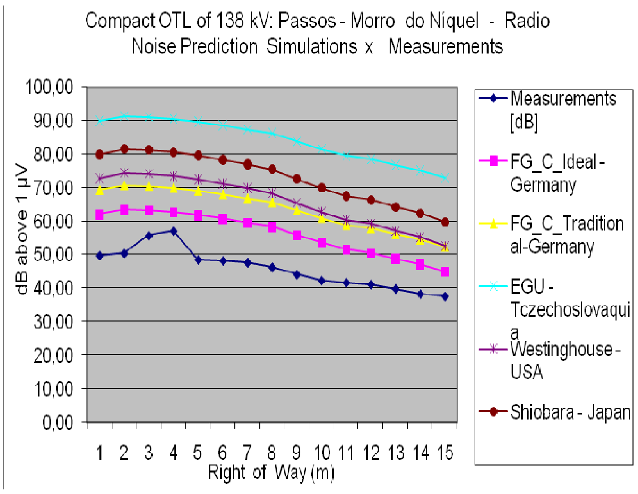


Figure 14 – OCL of 138 kV Passos-Morro do Níquel

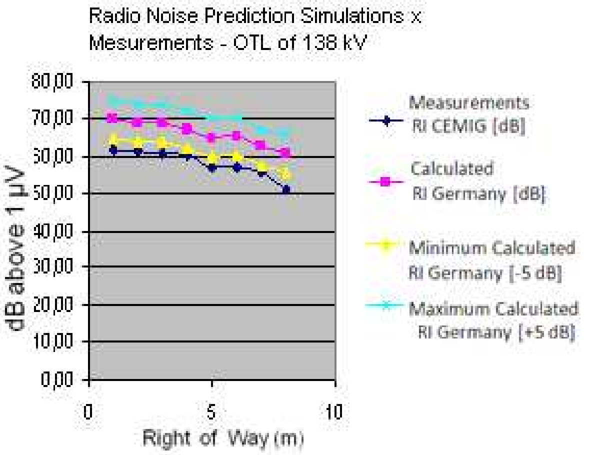


Figure 15 – OCL of 138 kV BH Bonsucesso – Demetrô C

4 STATISTICAL STUDY FOR RADIO NOISE PREDICTION EMPIRICAL EXISTING MODELS PERFORMANCE ANALYSIS

The statistical behavior of a great part of the natural phenomena can be described by probability curves as the corona effect. In the case of the OCL models operating for 230 KV and below, we need a application of not traditional statistical studies [9,10,11], capable to compensate the lack of a enough samples amount for a consistent statistical work.

The Bayes model was constructed and incorporates all the sensibility of the measurements and simulations results acquired and achievement. The Bayes model to be considered for this work defines some actions, being "[action/been]", that it is written in function of probability "p" that defining the condition of the maximum gradient for OCL configurations to be bigger than 80% of the critical gradient, verified through the Peek formulation [7]. The conditions for the maximum gradient for OCL configurations, to be less then or equal to the 80% of the critical gradient is defined by "(1-p)". For the case of OCL analyzed the gradient level é very close to the critical and this condition is not favorable for application of radio noise existent empiric prediction models.

Based on a detailed superficial gradient behavior study for the OCL and comparing with the radio noise measurements field results, is possible to define a "posteriori" probability for the condition that the maximum gradient to be bigger than 80% of critical gradient for all measured OCL in this work.

For construction of a statistic Bayes model capable to evaluate the agreement probability for the use of the radio noise prediction empirical existing models when applied for OCL were used the equations (1) and (2)

$$p(Grad_{máx} > 80\%Grad_{crítici} \,|\, Grad_{máx} > 80\%Grad_{crítici}) = \frac{0.05p}{0.05p + 0.01(1-p)} \quad (1)$$

$$p(Grad_{máx} \le 80\%Grad_{crítici} \,|\, Grad_{máx} > 80\%Grad_{crítici}) = \frac{0.6p}{0.6p + 0.7(1-p)} \quad (2)$$

The weight of the decision, final function strategical decision "m", can be visualized through the graph of Figure 16.

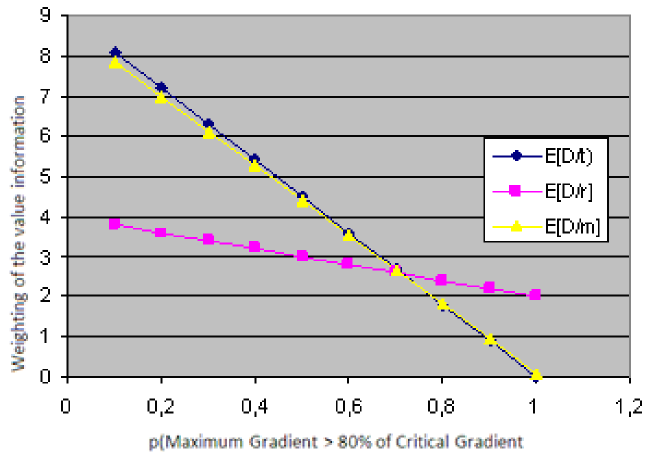


Figure 16. Evolution of the functions and [D/t], and [D/r] and and [D/m]

Applying the Bayes rule is possible to obtain a priori information (using the data of simulation and measurements data) and this way to get the "posteriori "information that we search or need.

The Figure 16, by the equations that represent the strategic functions, where " t " represents to option of developing a new prediction model for radio noise prediction on OCL or the option " r " that represents to continue using the existing empirical prediction models.

The Figure 16, shows the construction of a new strategy system function, "m", showing that the optimal decision, characterized by meeting point of 3 straight lines.

The Figure 16, show a probability " p " for the maximum gradient to be bigger than 80% of critical gradient, for all cases studied in this work.

The meeting point of 3 lines (equations), Figure 16, indicates which is the probability of maximum gradient is bigger than 80% of critical gradient. This condition inform us that the existing empirical prediction models will have a great possibility of fail , with 71% of probability, if applied for OCL. This condition can be verified by the all measurements results observed for OCL, Figures 13 to 15, were all predictions, carried out, by the empirical model, were not good.

5 CONCLUSION

The condition of the radio noise prediction empirical existing models was developed by an ample and hard work, where weren't involved the OCL models.

The superficial gradients on OCL conductors approach or exceed 90% of the critical gradient and for these cases is possible than the radio noise prediction empirical existing models failing. The same occurs for the geometries of OTL have a maximum gradient less than 12 kV/cm as those occur for OTL of 69 kV.

The studies show that the applications of the radio noise existing prediction models have a large possibility of fail when applied for the configurations of OCL of 230 kV and below.

Is necessary an ample measurement work and data collecting of the OCL models in operating in order to improve these empirical models for more accuracy and efficient prediction.

6 ACKNOWLEDGMENTS

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