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Analysis of Insulation Strength of Connection of High Voltage Transformer with FEMLAB

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Abstract: In this paper insulation strength of connection of high voltage transformer under various of voltages and stress was simulated and analyzed with FEMLAB. The purpose of this paper is to find and study of electrical field due to transient over voltage on connection of transformer and then examine its insulation strength

Key words: Power transformer, connection, Software FEMLAB, insulation breakdown.

INTRODUCTION

POWER transformers are of the most important components in a power system. These equipments are under various stresses due to over load and transient over voltages.

Ideal transformer is an onest that suffered above conditions for definite time according to definite standards therefore mentioned conditions should be considered in design of transformers and necessary anticipation should be done.

The more 70 percents of transformers' failure in power network is due to over voltages .of course with improvement of industry of surge arresters this value decreased to lower of 50 percents. However over voltages are main factors in transformers' failure.

According to performed tests on several kinds of transformers ,under various over voltages ,it have been seen that the most voltage stress was on the first layer of windings of transformer, therefore this layer of winding has special importance in most of transformers and in order to increase of insulation strength of these windings special maneuver was carried out .further was attempted with using of changed winding approaches for increasing the uniformity of voltage through the windings and therefore decrease the voltage on these windings.

Although these designs were successful somewhat, but the problem that occur in some transformers in recent year, leads to amendment of insulation system of winding close to coupling of transformer to network.

This problem was due to insulation breakdown in sectional of winding that named connection.

Indeed the connection is a piece of wire that its material and its cross section is the same of winding and it used to connect the transformer to network and outdoor connections, and because it is near to high voltage beside other winding then there is probability high electrical field on it and therefore there is its breakdown. and whereas this section of winding designated for connection therefore its geometry may not be as direct wire and has skew and sway that it increase the probability of breakdown in this location and in order to prevent it must be enough precision in design transformer.

Whatever in every design has special importance, is field study on that section .in recent year to receive this purpose various software were implemented that FEMLAB is one of them. The purpose of this paper is to find and study of electrical field due to transient over voltage on connection of transformer and then examine its insulation strength.

At first the construction of transformer for mentioned section is defined and then software FEMLAB and the method of design of connection in FEMLAB and its analysis brought. And finally the result of simulation and conclusion of paper is presented.

The Connection of Transformer and IT'S SPECIFICATION:

The material and cross section of connection usually are the same as winding that used in transformer, and from point of insulation is as same as other part of transformer, which its insulation is with paper

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impregnated with oil. Ordinary windings of transformer winded on core and hence they are rotary and because of high voltage winding winded on low voltage winding thus it may have more bend radius and it is obviously that the more bend radius the lower obtained electrical field at constant potential, thus attempted to winding of coil be monotonously.

And to prevent of generation points with small bend radius, but this case cant been used for connection because its duty is connecting and unfortunately the points that must be connected are not opposite therefore the connection may have sways and skews necessarily, and that said electrical field at these points will increase strongly and may be existed insulation breakdown under various stress such as switching voltages and lighting voltages. This is the because of problem that occur for transformer in recent year. Fig. 1 shows the scheme of various parts of studied transformer.

The connections also have been shown in Fig.1.

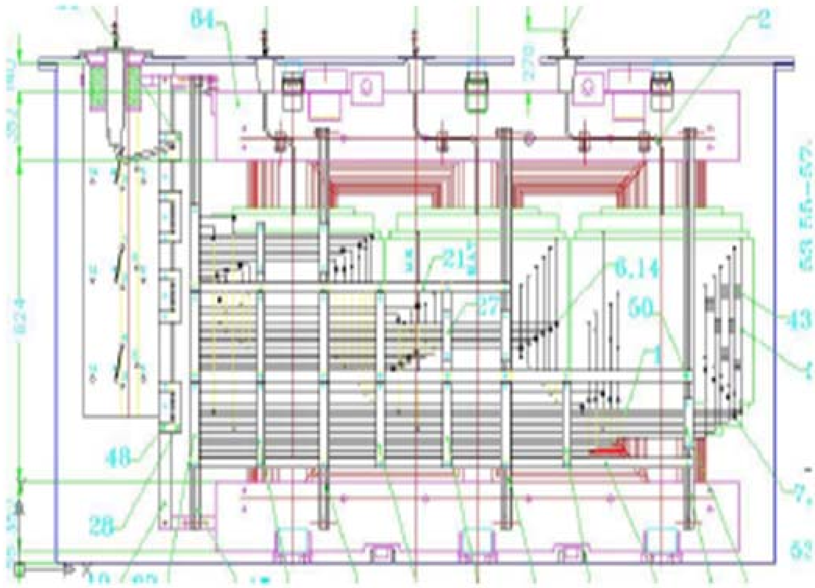

Fig. 1: Connection in studied transformer.

As shown each connection needs two bends with angle 90 degree almost for connecting the windings of transformer to power network.

Purpose is the study of field on these connections .we decide to simulate this part in FEMLAB and find electrical field due to various stress (such as lighting voltage, maximum work voltage, …) and then with attention to this electrical field and insulation strength of paper, examine probable problems (such as insulation breakdown ,arc , …)due to it.

The specification of transformer and its connections that are studied brings in follow.

Nominal voltage: 230 kV/63 kV
Nominal power: 245 MVA
Nominal current of primary winding: 0.7 kA
Nominal current of secondary winding: 2.28KA
Tap percent: 19%
Cooling system: ONAF
Used insulation: paper class A with oil based
Primary and secondary connection: Yn, Δ
Vector group: $YnD11$
Date of design: 1387
Manufacturer: Irantransfo
And the specification of connection is:
The length of connection for each winding: 2 m
Material: copper wire according to TUN902096 standard.
Diameter: 14 mm

Geometry of Model and Boundary Conditions:
A: Geometry of Model:

Mentioned model has geometry similar to Fig.2

Fig. 2: Geometry of model.

Fig.2. depicts the connection of transformer with circular cross section with specifications of part II. With specific command in FEMLAB we can arrive to Fig .3.

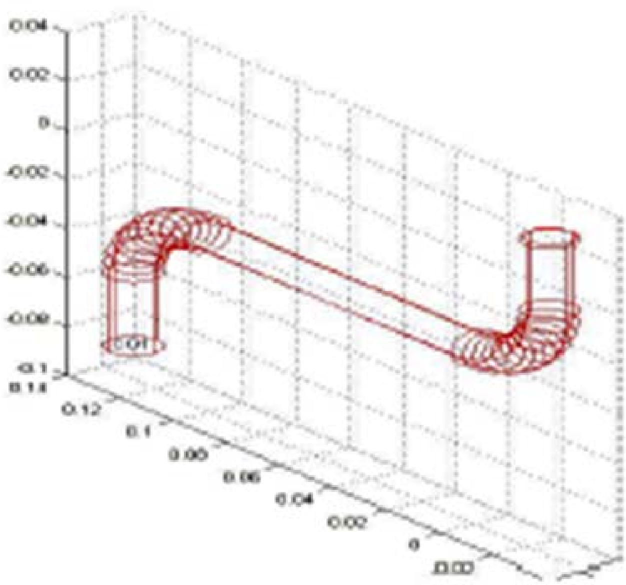

Fig. 3: The connection in FEMLAB.

B: Boundary Conditions:

In determination of boundary conditions would be noted that our purpose is find field at connection .in transformer the insulator paper is turned around connection and then transformer is full of oil. Hence there is insulator around connection and this insulator isolates the connection from grounded frame of transformer. Whereas any insulator isn't ideal therefore there is some leakage current between high voltage level and ground. Our purpose isn't determination this current .our purpose is find electrical field around connection and examines that is this field over than limit breakdown stamina field of oil or no? Hence it reasonable that suppose that around connection is isolated and use isolated boundary for all state.

According to what voltage is applied to connection (nominal, maximum work or lighting…), the problem was analyzed in several sate. In follow we study these states and define boundary condition for voltages applied to two ends of connections and not be forgotten that in all states, periphery part of connection is isolated from ground.

B.1) Boundary Condition in Nominal Voltage:

Whereas these studies is done in high voltage part, and because the voltage of this part is 132kV (phase to ground), so this voltage is nominal voltage of transformer and according to IEC76 standard, transformer must be experienced for all times. And whereas insulation studies are according to peak voltage of transformer, then boundary condition should be defined based this voltage. Since peak voltage is 186 kV, then constant voltage equal 186 kV must be applied to even top part of connection.

B.2) Boundary Condition in Maximum Work Voltage:

According to IEC76 standard power equipments shall be designed so that suffered maximum work voltage, which is defined, for all times. This value for 230 kV is equal to 245Kv (r.m.s), so the maximum value of it is 346 kV (phase to phase).so 200kV (phase to ground) is considered as boundary condition of top surface of connection.

B.3) Boundary Condition in Impulse Voltage:

The main part of insulation design is studying impulse voltage and its stress due to applying this voltage to insulator. Impulse voltage generated with various factors such as lighting or switching that occasionally arrive to several thousand kilo volt. According to standards for voltages over than 230 kV, this value for 230 kV is equal to 1100kV that must be applied to connection. as we know the impulse voltage hasn't defined sinusoidal form ,and we should necessarily do our analysis with standard form of impulse wave ,that is apply real form of switching voltage that is sum of two exponential function as under equation to connection and considered as boundary condition.

C)- Specific of Materials of Connections:

In this state the material of connection that is copper must be gave to FEMLAB that there is a ready program for it.

RESULTS AND DISCUSSION

A) Result Analysis of Field in State Nominal Network Voltage:

In this section the voltage equal to 186 kV apply to connection. This voltage must be applied to two parts of connections, upper surface and underneath surface. But values of these voltages aren't equal in practice. So must be a difference between the voltage levels of these points. But what difference?

For find the difference first we apply equal voltages to both end of connection and obtain the voltage at midpoint of connection. This value must multiply at 2 and this is the same voltage that must be applied to other end of connection. This is shown in Fig.4.in this Fig a constant voltage is applied to two ends of connection and voltage drop in midpoint will be equal to 7.5105 V.

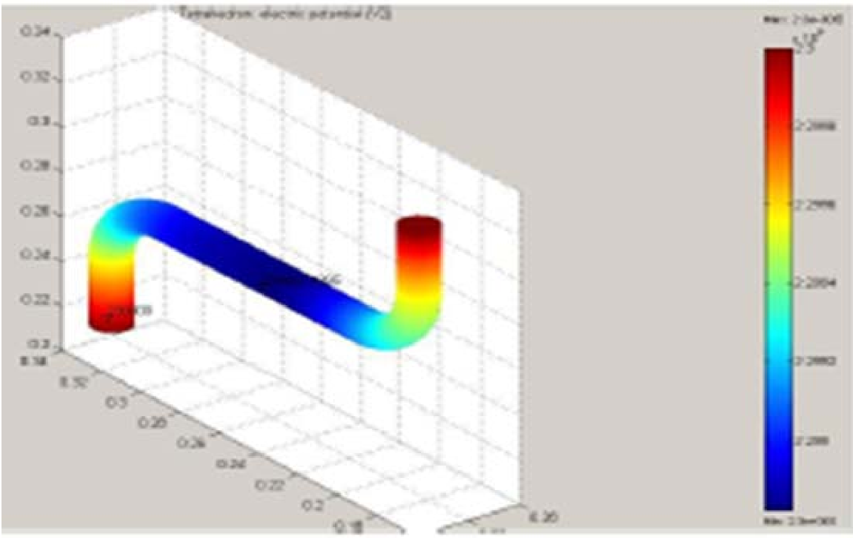

Fig. 4: Voltage distribution at connection for applying equal voltages to two ends of it.

If 186 kV apply to one end and 185.992 kV apply to other end, then the distribution of voltage through connection is similar to fig.5.

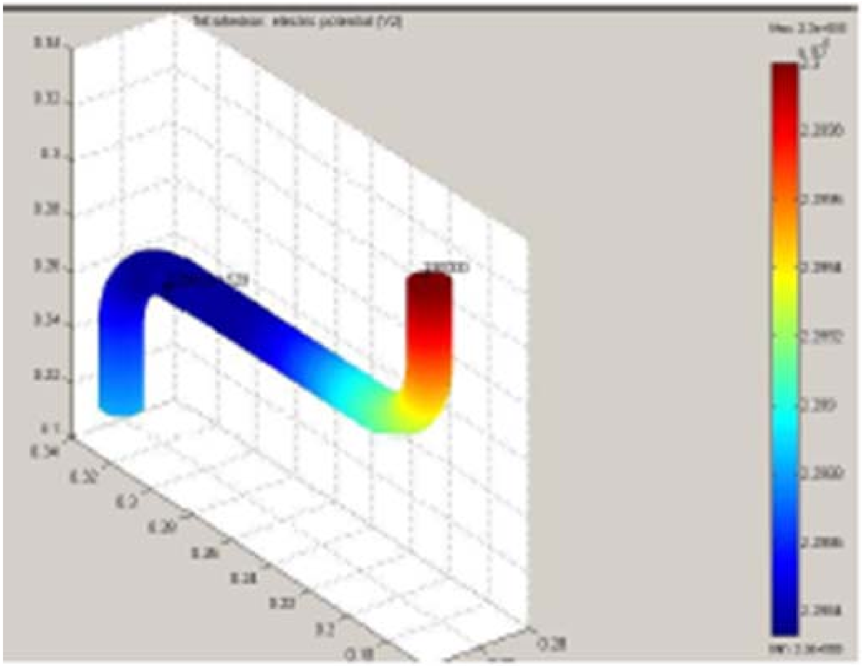

Fig. 5: Voltage distribution at connection for applying voltages according proposed method.

With this method we can analyses the electrical field at connection.Fig.6.shows this field.

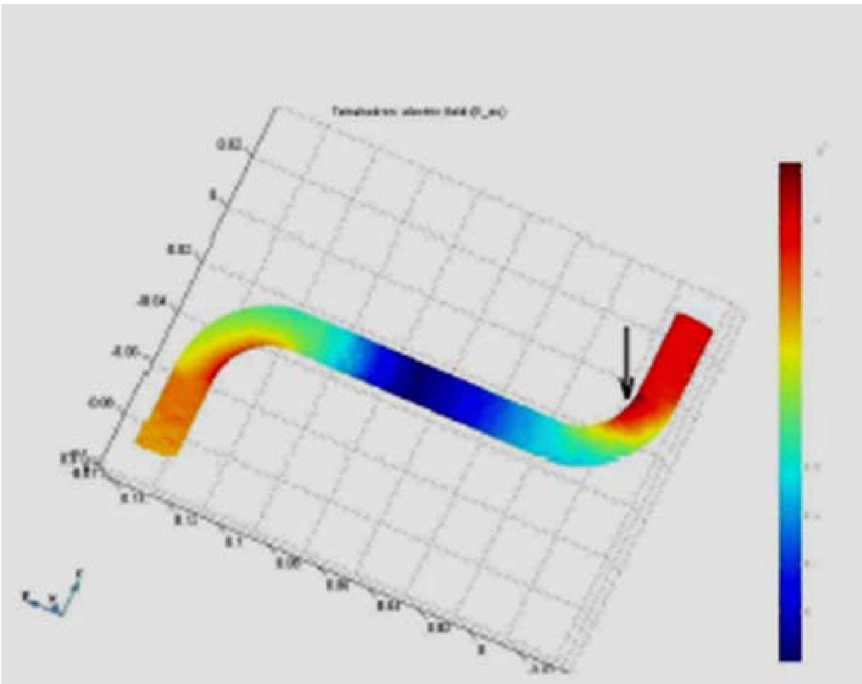

Fig. 6: Field distribution at state nominal voltage network.

It have been seen that field is more intensity in points with bend. The points with more color represent points with more intensity field. This strong field must be limited by insulator used in transformer else insulation breakdown occur in transformer.

The maximum value of field in this state is equal to 1.198*10^7 v/m that is shown in point marked with arrow.

B) Result Analysis of Field in State Maximum Work Voltage:

This state is similar to previous state but in this case the applied voltage to connection is equal to peak of maximum work voltage of network and is equal to 200kV.it is reasonable that in this state we obtain a picture similar to previous pictures but in this case field is more intensity. This is shown in Fig.7.

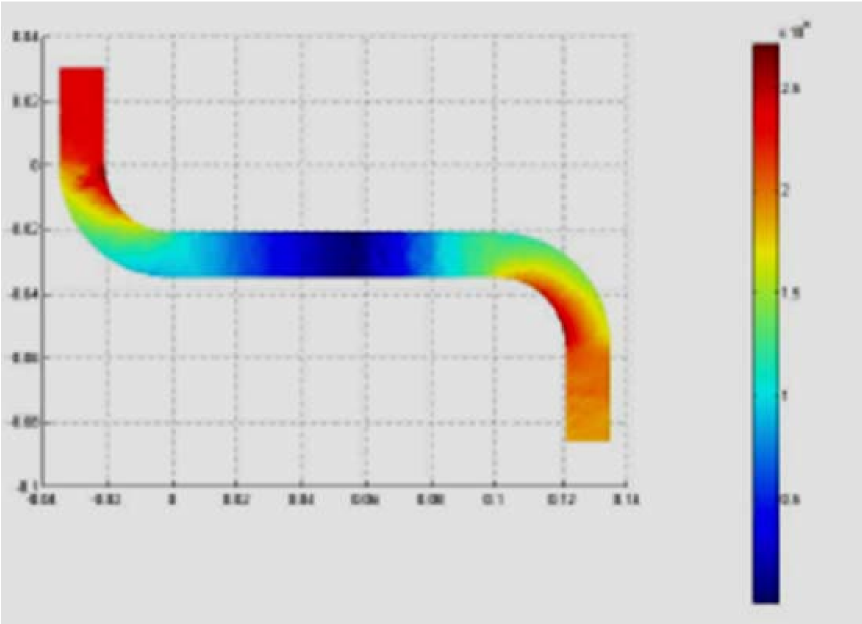

Fig. 7: Field distribution at state maximum work voltage.

In this state maximum field is more than previous state and is equal to 1.568*10^7 .and anticipated that in points with lower bend radius field is lower than points with more bend radius.

C) Result Analysis of Field in State Switching Voltage:

In this case the equation of applied voltage to connection is equation (1).

It is clear that when problem is solved we can plot answer in desirable time but we obtain it when wave form arrives to its peak. All time of simulation is 500 µs and time that wave arrives to its peak is 150µs. Fig.8. Shows the analysis of field.

As shown field are more than other points in points with more bend radius.

In this case maximum value field is 5.9928*10^8 v/m.

Insulation Analysis:

Main insulation materials with optimal breakdown strength spcefic that used in large power transformer are impregnated paper to oil, cellulose materials such as paper and compressed wood.

The main specific of oil for design insulation of transformer is its good dielectric strength. That for very pure oil in laboratory conditions is 40 kV/mm. but in practice engineering condition this value decrease to 33kV/mm in maximum degree of its purity .but in standards this value is defined equal 20 kV/mm.

The insulator around winding transformer is paper that impregnated to oil when transformer was filled of oil. Dielectric strength of paper impregnated to oil is more than either oil or paper alone. in fact the duty of paper is penetrating oil to detail parts.

Dielectric strength paper impregnated to oil is defined according to dielectric strength of these oil insulation distances.

Insulation strength of paper impregnated to oil in new transformer is about 20-40 kV/mm and its permabability factor is 3.6.

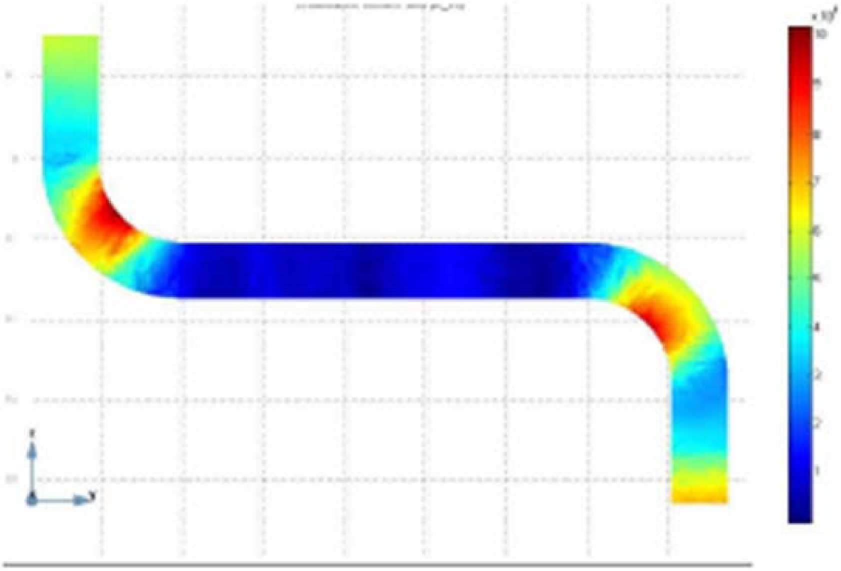

Fig. 8: Field distribution at switching voltage.

Conclusion:

With increasing volume oil, its insulation strength decreases,so for study of field must consider limit of breakdown insulation of paper and attempt to don't overrun obtained field from possible voltages against limit of endurable field for paper impregnated to oil.

Therefore in this paper in order to analyze electrical field, limit of breakdown field for paper impregnated to oil is calculated.

As respects said in previous section endurable field for paper impregnated to oil is defined as 20-40kV/mm if suppose that thickness paper around connection is 3.5 mm then strength of this insulation is nearly 120 kV/mm that if field overrun this value then it is dangerous for transformer and its insulator and so increase possible of breakdown insulation.

In state of apply a maximum work voltage, value field in this case is 1.568*10^7 V/m that has appreciable difference with stamina insulation of paper (0.1*10^9), so we aren't worry of breakdown.

In state of apply switching voltage value of field is 0.59928*10^9, that is over than limit stamina paper. this state is same state that if surge arrester doesn't act right, and doesn't decrease voltage, transformer will damage.

In power system network almost devoted surge arrester to protect transformers and their duty are conduction over voltages due to lighting or switching to ground, but often have been seen that they don't act and over voltages entered to equipments and caused serious damages to them. hence insulation design of equipment must be such as that makes necessary security.

Transformer, as main equipment in power system isn't exempt and must be done its insulation design accurately.

Up studies shows that a power transformer is how vulnerable against over voltages and possibility of damaging in it isn't low .so must be attended to design of transformer.

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REFERENCES

Aboelsaad, M.M., L. Shafai, M. Rashwan, "Numerical assessment of unipolar corona ionised field quantities using the finite-element method (HVDC transmission lines) ", Science, Measurement and Technology, IEE Proceedings.

Abdel-Salam, M. and Z. Al-Hamouz, 1994. Novel finite-element analysis of space-charge modified fields“, IEEE Transactions on Magnetics, 41(5).

App. Syst., 1969, 88: 713-731.

Aboelsaad, M.M., L. Shfai and M.M. Rashwan, 1989. "Improved analytical method for computing unipolar Dc coroa losses,"IEEE Proc, 136(1).

Afjayi, S., 2000. Eb.'NumericalMethopd',ShahidBeheshti,Tehran, pp: 144.

Abdel-Salam, M., M. Faghally, S. Abdel-Sattar, D. Shamloul, 1984. ”Analysis of ac Corona Power Loss for Single Phase Transmission Lines”,Intern.Symposium on Gaseous Dielectrics,Knoxville, pp: 492-497.

High voltage Engineering Fundamentals E. Kuffel, W.S. Zanegal, J. Kuffel, Second Edition.

Horestine, M., 1984. “Computation of corona space charge, electric field, and V–I characteristics using equipotential charge shells,” IEEE Trans. Ind. Applicat., 20: 1607-1612.

Hassan, M.Y., M.A. Almaktar, M.P. Abdullah, F. Hussin, M.S. Majid, H.A. Rahman, 2010. ” The Impact of Transmission Loss Component on Transmission Cost Recovery in Pool Electricity Markets”, Praise Worthy Prize S.r.l(IREE), 5(4): 1736-1746.

Lloyd, W.L. Jr. and E.C. Satarr, 1927. ”Methods Used in Investigating Corona Loss by Means of cathode Ray Oscillogrsph”, AIEE Trans, 26: 997-1008.

Morrow, R. and J.J. Lowke, 1984. “Streamer propagation in air” Journal of Physics D: Applied Physics, 30: 614-627.

Sarma, M.P. and W. Janischewsky,”Analyis of corona losses on dc transmission lines. Pt. I-Unipolar lines”,IEEETrans.Power.

Sarma, M.P. and W. Janischewsky, 1969. ”Analyis of corona losses on dc transmission lines. Pt.II-Bipolar lines”,IEEETrans.Power App.Syst., 88: 1491.