Analyzing and Modeling the Separation Distance of Lightning Arresters for 400kv Transfer Substation's Protection against the Lightning Strokes

Imhimmad Abood[1], Ahmed altawwary[2] and Abdhakeem Alkwas[3]

1- University of Gharian, faculty of engineering , email: aboodali1966@gmail.com

2- High institute for sciences and technology Gharian, electric dept. email:as69287@gmail.com

3 - University of Sabratha, faculty of engineering, email: ash_hakem@yahoo.com

الملخص

تتعرض الشبكات القدرة الكهربائية|(ذات الجهد العالي) إلى ضربات الصواعق أحياننا (ناتجة عن البرق) ذات جهد عالي عابر عالي القيمة ونتيجة لذلك ترتفع جهود النظام العابرة إلى قيم عالية جدا قد تؤدي إلى دمار أحد مكونات الشبكة الكهربائية ، ولفهم هذه الظواهر و نتمكن من تفادي خطرها على أنظمة القدرة الكهربائية يجب استعمال برامج متطورة لمحاكاة الشبكات ودراسة تأثير هذه الجهود الزائدة العابرة وطرق الحماية منها لتحسين أداء الشبكة تحت هذه الظروف ، حيث تم اختيار برنامج الموجات الكهرومغناطيسية (ATP) لهذا الدراسة، وكان الهدف من هذا البحث هو تحليل و دراسة تأثير ضربات الصواعق وطرق الحماية منها باستخدام حاجزة الصواعق(Lightning Arrester) وكذلك دراسة تأثير بعد حاجزة الصواعق عن المحول لحماية محطة تحويل الجهد العالي (400KV) من ضربات الصواعق، وتم الاختبار على شبكة نقل ومحطة تحويل جهد 400KV مكونة من أربعة أبراج، تتعرض هذه الشبكة إلى ضربات صاعقة بتيارات مختلفة مع تغير بعد الحاجزة عن المحول، وكانت الدراسة مدعومة بنوعين من حاجزات الصواعق (**Zinc Oxide–porcelain EXLIM Q1**)و(**Zinc Oxide–silicone polymerPEXLIM Q2**)أظهرت نتائج الدراسة ان تحديد المسافة بين حاجزة الصواعق و الوحدة المراد حمايتها ونوعية حاجزة الصواعق تلعب دورا مهم في توفير الحماية وعدم خروج المحطة عن العمل.

Abstract

This paper presents a study modification of separation distance of lightning arrester protecting a 400KV sub-station from lightning strokes related to the distance between the transformer and lightning arrester (the installation place of the lightning arrester) a simple model was created in ATP and the distance between the arrester and transformer were varied.to ensure proper installation and to reduce the high lightning failure rate and to eliminate devastating impact, caused by lightning, the model e installation represents circuit composed of four towers . Program ATP-Draw (Alternative Transient Program) was used to simulate the problem. The simulation was done on three stages and the results were compared.

Key Words : lightning arrester, current, distance (the installation place of the lightning arrester related to protected unit), transformer

1.0 -Introduction

Sub-stations are the most sensitive part in power systems and are exposed to many stresses, like Transients over voltages which caused by lightning discharges or switching operations. So Lightning is the main reason for outages in transmission and distribution lines [1].

A surge lightning arrester is a protective device which is must be used in to substations to be protected. The highly non-linear characteristics of an arrester allow the arrester to limit the voltage across its terminal during conduction of surge current, arrester exhibits very low impedance. This study was executed using two kinds of lightning arresters Zinc Oxide PEXLIM –Q2) and (Zinc Oxide EXILIM –Q1). the 1980s polymeric ZnO surge arresters have been developed quickly and put into operation on transmission lines in parallel with the insulators to limit the over voltages based on their excellent performance [2], [3],[4]

2.0 - System under study:

This part introduces single line diagrams of the 400kv network. Which has triplet bundle conductors. Tower footing resistance of this system is 10 Ω and the range of lighting current is 300KA with negative peak and the following fig (2.1) shows model for a 400kV network. The Physical

specifications of conductors and geometrical parameters of the tower are given in table (2.1).

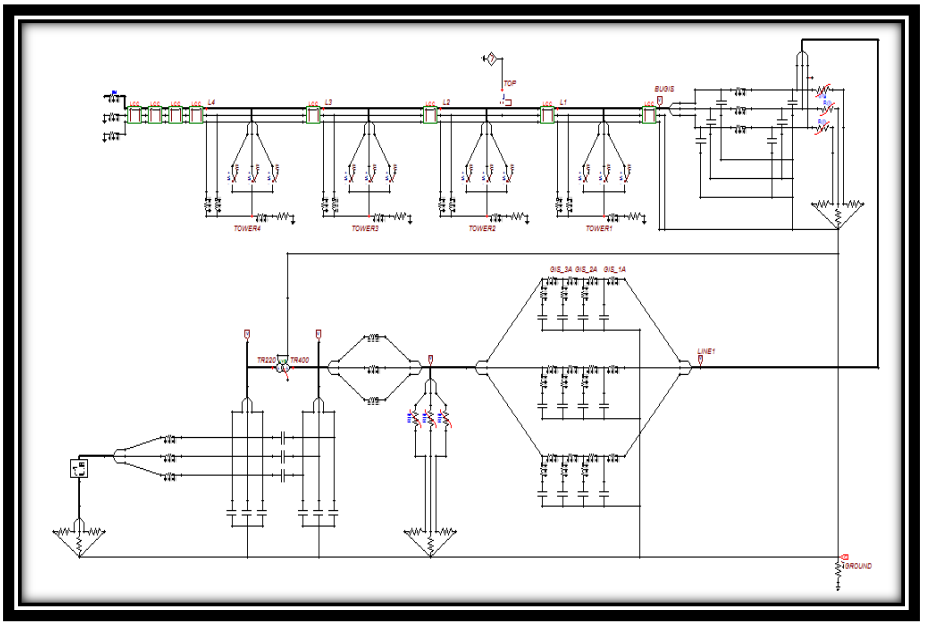

Fig (2.1): Shows the structure of 400kv studied system circuit modeled in ATP

2.1 -Conductor characteristics:

Table (2.1): Conductor characteristics:

Ph.no	R_{in}	R_{out}	R_{ho}	H_{oriz}	V_{tower}	V_{mid}	*Separ*	*Alpha*	*N.b*
	(cm)	(cm)	Ω/kmDC	M	M	m	Cm	Deg	
1	0	**1.3195**	**0.079**	**-11.38**	**41.7**	**27.4**	**40**	**30**	**3**
2	**0**	**1.3195**	**0.079**	**0**	**42.7**	**28.4**	**40**	**30**	**3**
3	**0**	**1.3195**	**0.079**	**11.38**	**41.7**	**27.4**	**40**	**30**	**3**

2.2-Ground wire characteristics:

Table (2.2) shows the vertical and horizontal distances of the conductor and the ground wire from the surface.

Table (2.2): Ground wire characteristics

Ph.no	R_{in}	R_{out}	R_{ho}	H_{oriz}	V_{tower}	V_{mid}	Separ	Alpha	N.b
	(cm)	(cm)	Ω/kmDC	M	M	M	Cm	Deg	
4	0.48	0.87	0.3	-6.28	51.27	39.07	0	0	0
5	0.48	0.87	0.3	6.28	51.27	39.07	0	0	0

Table (2.3): Conductor arrangement of overhead transmission line

Number.ph	Vertical	Horizontal
1	41.7 m	-11.38m
2	42.7 m	0
3	41.7 m	11.38m
Ground wire	Vertical	Horizontal
4	51.27 m	0 m
5	51.27 m	0 m

3.3 Surge arresters those were used in an electrical circuit

3.3.1-First arrester (Zinc Oxide EXILIM-Q1):

Table (3.1) shows brief performance data.

Table (3.1): Brief performance data

System voltage	170-420kv
Rated voltage	42 - 360kv
Nominal discharge current	20 KA
Line discharge class	Class 4
Short-circuit	65kA
Mechanical Strength	2500Nm
Design altitude	max 1800m

Ambient temperature	-50 Cº to +45 Cº
Frequency	15 – 62 Hz

3.3.2–Second arrester (Zinc Oxide PEXLIM –Q2)

Table (3.2) shows brief performance data.

Table (3.2): Brief performance data

System voltage	**52 - 420kv**
Rated voltage	42 - 420kv
Nominal discharge current	10 KA
Line discharge class	Class 3
Short-circuit	50kA
Mechanical Strength	2500Nm
Design altitude	max 1800m
Ambient temperature	-50 Cº to +45 Cº
Frequency	15 – 62 Hz

The surge arrester characteristic of the 400kv network is from General Electrical Company of Libya (GECOL).

4.0 - ATP Analysis of 400kv circuit diagram:

Three cases were done to test the system under study. In each case it will be calculated extent the basic insulation level (BIL) of the transformer and then shows the impact of the lightning on the transformer insulator.

4.1-First Case:

1- The ground wire (shielding line) of the overhead transmission lines exposed to lightning stroke. The lightning current of the stroke is fixed (260kA). With changing the separation distance between (the installation place of the lightning arrester) and the transformer from (5m to 30m), increasing 5m each step using the two types of lightning arresters and

measuring the resulting of the internal voltage on the primary winding of transformer and basic insulation level **(BIL)**of the transformer for both lightning arresters.

Fig (4.1) shows the values of the internal voltages of the primary side of transformer the distance 5m lightning current 260kAusing(**Zinc Oxide EXILIM – Q1**).

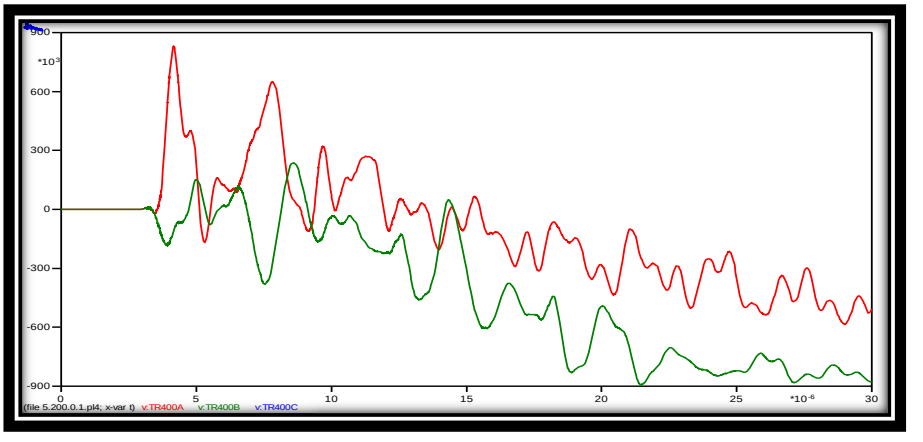

Fig (4.1): the transient over voltage on the primary winding of the transformer when distance (5m) and the lightning current (260 KA)

Fig (4.2) shows the values of the internal voltages of the transformer the distance 10m and the lightning current is fixed (**Zinc Oxide EXILIM – Q1**).

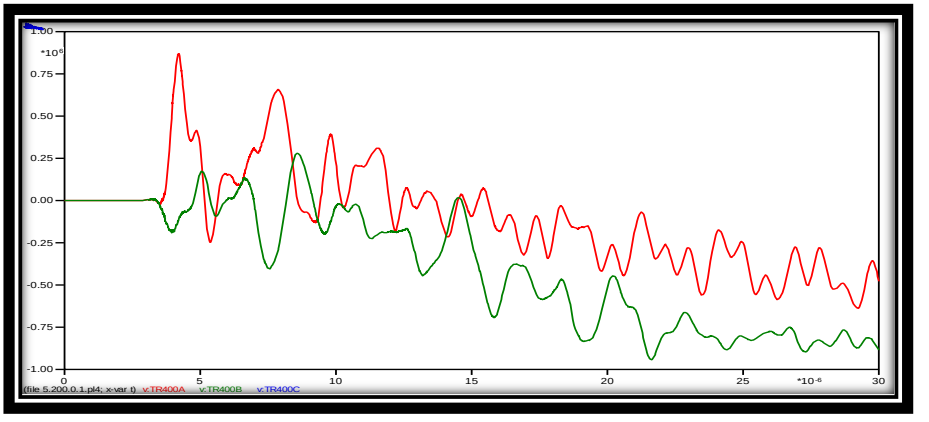

Fig (4.2): the transient over voltage on the primary winding of the transformer when distance(10m) and the lightning current(260 KA)

Fig (4.3) shows the values of the internal voltages of the transformer the distance 5m keeping the current fixed (**Zinc Oxide PEXLIM –Q2**)..

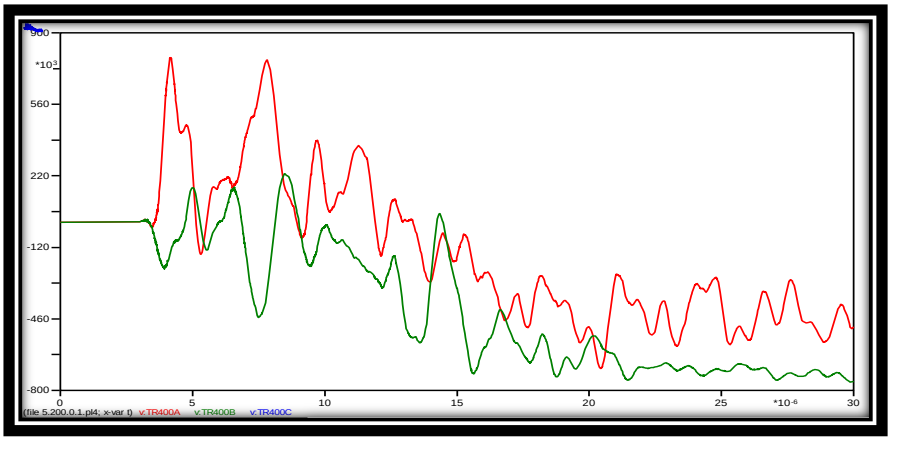

Fig (4.3): the transient over voltage on the primary winding of the transformer when distance(5m) and the lightning current(260 KA)

Fig (4.4) Shows the values of the internal voltages of the transformer the distance 10m the current is fixed using (**Zinc Oxide PEXLIM –Q2**).

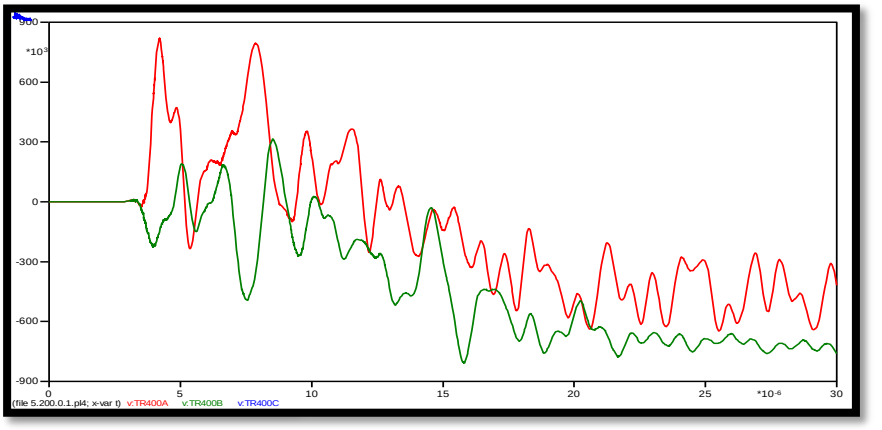

Fig (4.4): the transient over voltage on the primary winding of the transformer when distance(10m) and the lightning current(260 KA)

Calculating the Basic Insulation level of the transformer (BIL):

$$\%BIL = \frac{BIL - \max overvoltage}{\max overvoltage} \times 100$$

Where: (***BIL***) equal 1300kV**[5]**.

(**max *overvoltage***) Is the maximum voltage on the transformer on the primary side 400kV.To avoid destructive damage of the entire transformer the ratio of (BIL) must be more than 20%.

4.1.1-Calculating (BIL) of the transformer when using both types table(4.5).

Table (4.5) Calculating (BIL) according to Effect of increasing the distance (the installation place of lightning arrester related to primary winding of the transformer) when the lightning current is fixed 260KA.

Distance (m)	Zinc Oxide EXLIM – Q1		Zinc Oxide PEXLIM – Q2	
	Overvoltage (kV)	BIL%	Overvoltage (kV)	BIL%
5	894.17	45.23%	824.66	57.64%
10	994.88	30.66%	874.29	48.69%
15	1054.8	23.24%	904.08	43.79%
20	1097.9	18.42%	927.47	40.16%
25	1112.2	16.88%	940.02	38.29%
30	1134.7	14.56%	955.08	36.11%

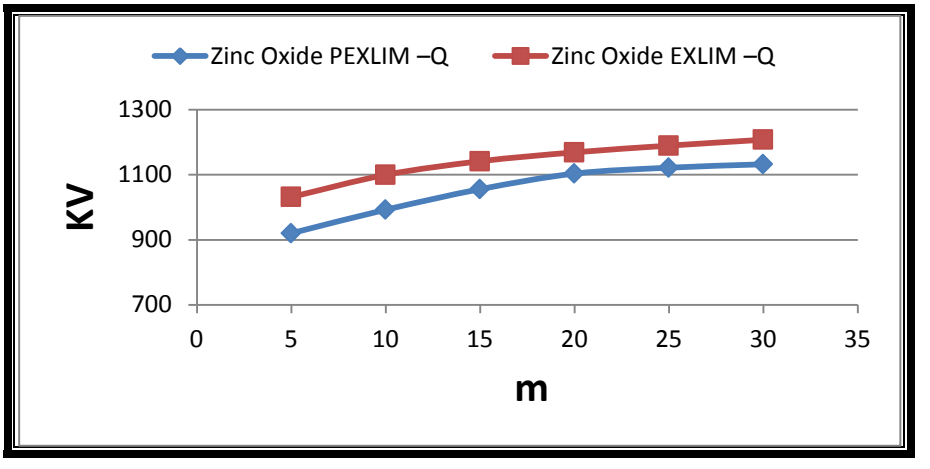

Fig (4.6)-The effect of distance (the installation place of lightning arrester related to the transient over voltage on the primary winding) when the current is fixed 260KA. For both arresters

From the previous results it is clear that.

- The results in table (4.5) showed that as we increase the distance the internal transient over voltage increase and (BIL) is decreasing. and the decreasing is clear when the location of the arrester at 20 m (BIL) for(**Zinc Oxide EXLIM- Q1**) becomes less than the standard value (**18.42%**) compared with type (**Zinc Oxide PEXLIM Q2**)(**40.16%**) .According to the value of (BIL) for both types the second one can stands the lightning stroke tell 30 m.
- Figure (4.6) shows the effect of increasing the distance in steps (the installation place of lightning arrester) related to the transient over voltage on the primary winding of the transformer when the lightning current is fixed 260KA. For both arresters of the arrester .according to table (4.5) as we increase the distance the voltage on the primary side of the transformer increasing. although both are increasing with the same range the transient over voltage on the (**Zinc Oxide EXILIM – Q1**) is higher compared with the voltages value of arrester **(Zinc Oxide PEXLIM –Q2)** and this makes the (BIL)decreases .quality 1=2

4.2 - Second case:

study the resulting the transient over voltage when the overhead ground wire exposed to lightning stroke the separation distance fixed to (5m) the lightning current strokes ranging from(260 to 300kA) increasing 10KA in each step using both arresters **(Zinc Oxide PEXLIM –Q2)** and **(Zinc Oxide EXILIM –Q1)**.

Fig (4.7) shows the values of the internal transient over voltages of the transformer on the primary side 400kV changing the lightning current from (260 to 300kA) and distance is fixed 5m by using**(Zinc Oxide EXILIM – Q1)**..

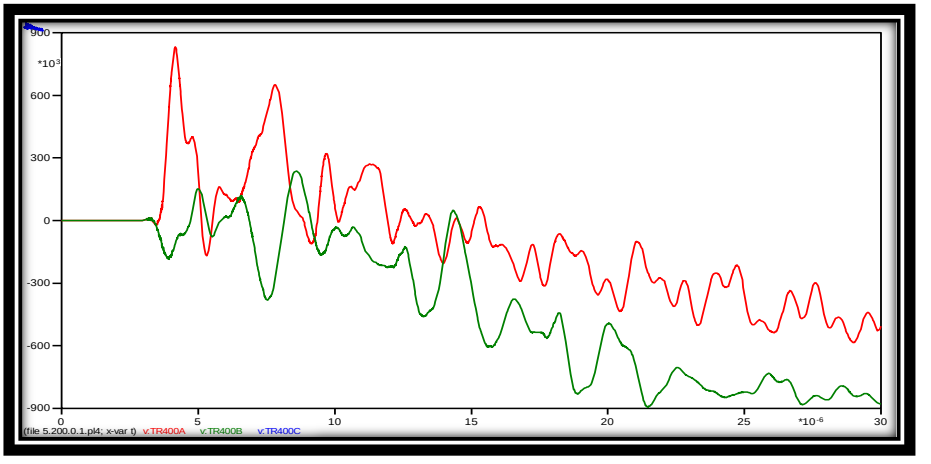

Fig (4.7): the transient over voltage on the primary winding of the transformer when distance (5m) and the lightning current (260 KA)

Figure (4.8) shows the values of the internal voltages of the transformer when the lightning current is 260kA the distance is fixed 5m using (**Zinc Oxide EXILIM–Q1).**

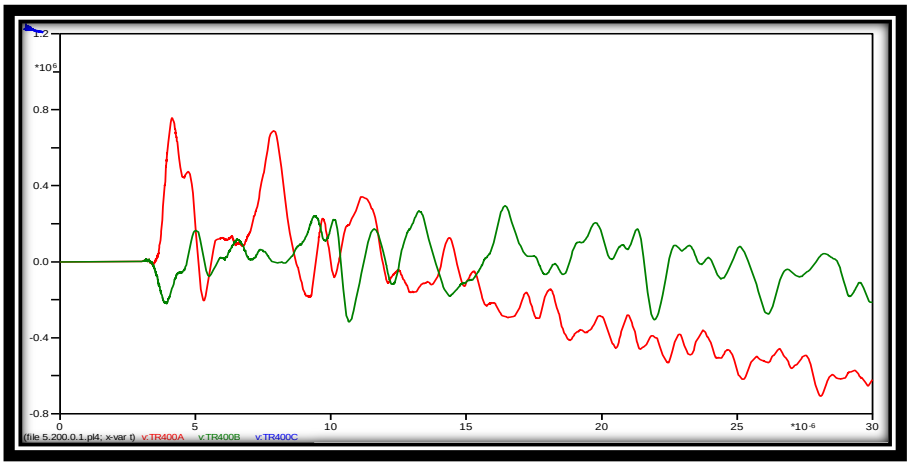

Fig (4.8): the transient over voltage on the primary winding of the transformer when distance (5m) and the lightning current (290 KA)

Figure (4.9) Shows the values of the internal voltages of the transformer when the lightning current is 270kA the distance is fixed 5m using (**Zinc Oxide PEXLIM–Q2**).

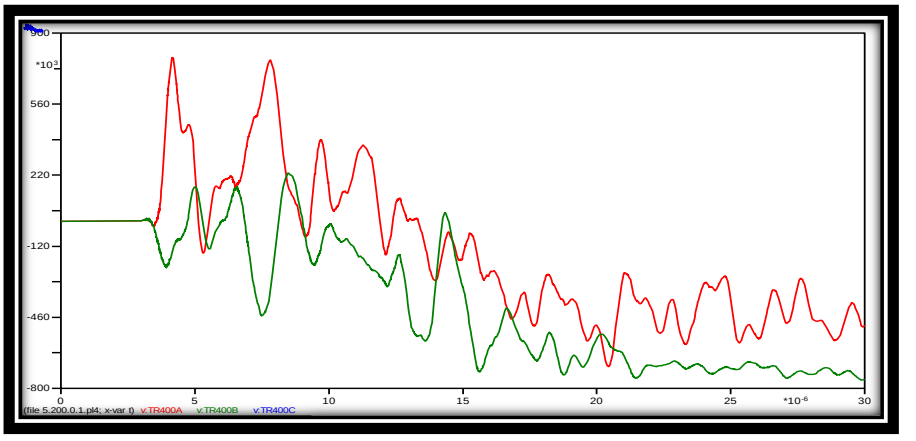

Fig (4.9): the transient over voltage on the primary winding of the transformer when distance (5m) and the lightning current (260 KA)

Fig (4.10) shows the values of the internal voltages of the transformer on the primary side 400kV result of lightning current 290kA by using (**Zinc Oxide PEXLIM –Q2**).

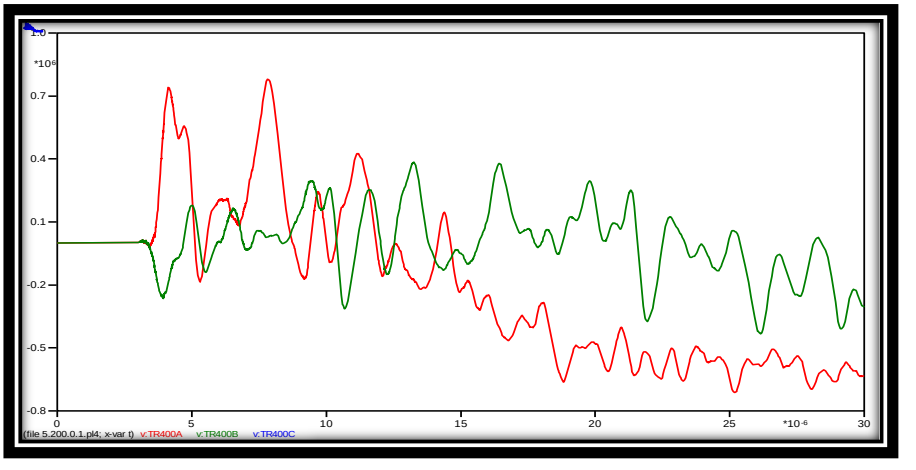

Fig (4.10): the transient over voltage on the primary winding of the transformer when distance (5m) and the lightning current (290 KA)

4.2.1- Calculating the (BIL) of the transformer when using both types when the separation distance is fixed (5m) and lightning current strikes ranging from(260 to 300kA)

The following table (4.6) shows the change of insulation level (BIL).

Table (4.6) Calculating (BIL) according to Effect of increasing of lightning current and the distance (the installation place of lightning arrester related to primary winding of the transformer) is fixed to 5m

Lightning current (kA)	Zinc Oxide EXILIM – Q1		Zinc Oxide PEXLIM – Q2	
	Overvoltage (kV)	BIL%	Overvoltage (kV)	BIL%
260	894.17	45.38%	824.66	57.46%
270	968.04	34.29%	877.48	48.15%
280	1017.2	27.80%	921.48	41.07%
290	1032.1	25.95%	933.32	39.28%
300	1036.6	22.22%	953.84	36.29%

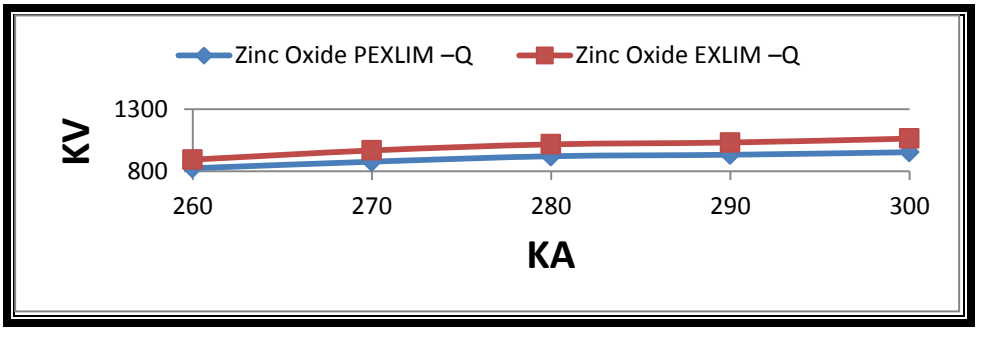

Fig (4.11)-The effect of lightning current to the transient over voltage on the primary winding of transformer when the distance is fixed 5 m. For both arresters

From previous results we can conclude the following:

- The results in table (4.6) show that as we increase the lightening current the internal transient over voltage increase and the (BIL) is decreasing it is clear when the lighting current is 300kA (BIL) for (**Zinc Oxide EXLIM- Q1**) is about to becomes less than the standard value (**22.22%**) compared with type (**Zinc Oxide PEXLIM Q2**)(**36.29%**) .according to the value of (BIL) for both types the second one can stands the lightening stroke better than the first one.
- Results in table (4.6) show that (BIL) decreasing as we increasing the current especially when the lightning current at 300KA and type (**Zinc Oxide PEXLIM Q2**). Stands much better than type (**Zinc Oxide EXLIM- Q1**) and the transformer will subjected to high voltage wave is about to break down and (BIL) stayed more than 20% even the lightning current at 300kA.
- Figure (4.11), as the arrester (the protection device) is close to transformer as the (BIL) is high even the current is high so by any way this means that distance factor is represented important role in protection المقاومة,while it finds that the value of the current in the arresters (**Zinc Oxide PEXLIM – Q2**) and (**Zinc Oxide EXILIM – Q1**) equally happen significant difference in voltage between retardants.

4.3 -Third case:

3- Studying the voltage behavior when the lightning stroke falls direct to transmission line .When the lightning current ranging from (260kA to 300kA) And the separation distance fixed (5m) using both arresters.

Fig(4.12) shows the values of the internal transient over voltages of the transformer when the lightning strike transmission line directly the lightning current (300KA)and separation distance fixed (5m) by using (**Zinc Oxide EXILIM –Q1**).

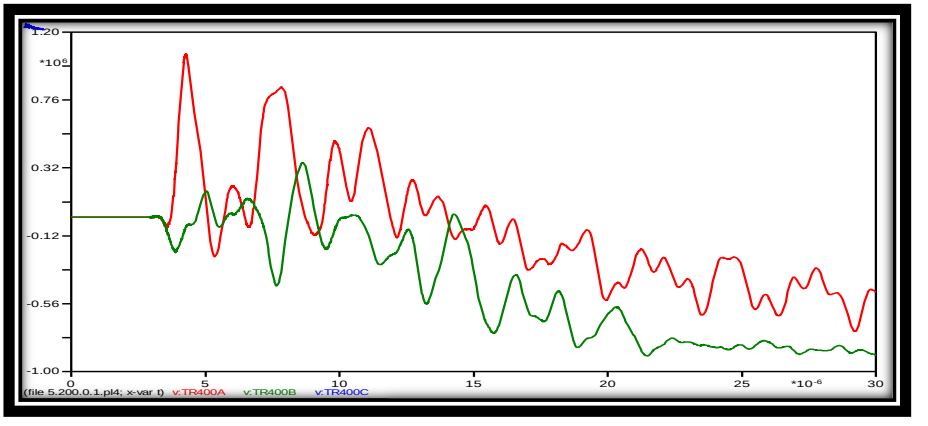

Fig (4.12): the transient over voltage on the primary winding of the transformer when the lightning current (300kA) distance (5m)

Fig (4.13) shows the values of the internal transient over voltages of the transformer when the lightning strike directly transmission line with lightning current (300KA) using (**Zinc Oxide PEXLIM –Q2**).

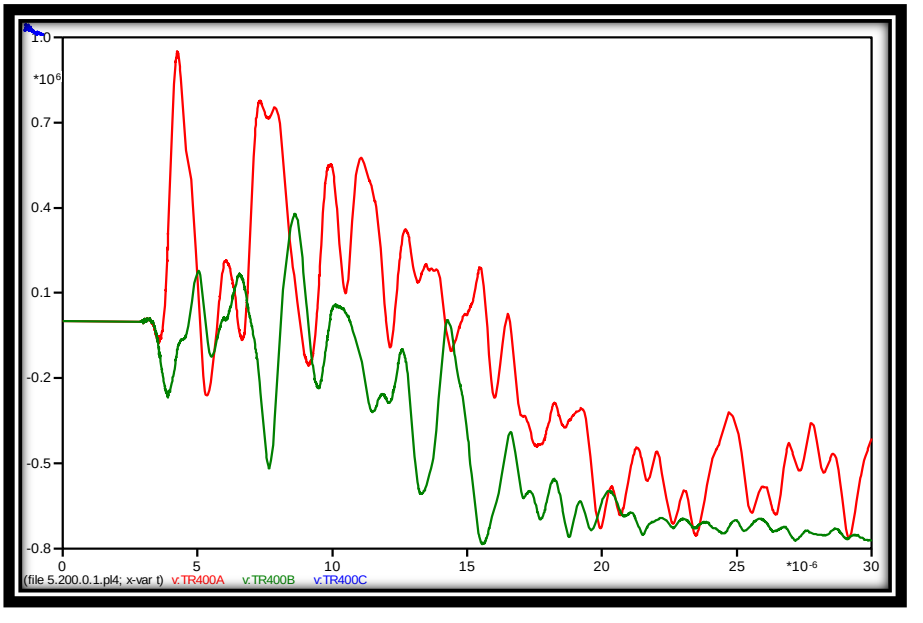

Fig (4.13): the transient over voltage on the primary winding of the transformer when the lightning current (300kA) distance (5m)

4.3.1- Calculating the (BIL) of the transformer when using both types when the separation distance is fixed (5m) and lightning current strikes ranging from(260 to
300kA)
The following table (4.7) shows the change of Basic insulation level (BIL).

Table (4.7) Calculating (BIL) according to Effect of increasing the lightning current and the distance(the installation place of lightning arrester related to primary winding of the transformer) is fixed to 5 m. for both lightning arresters

Lightning current (kA)	Zinc Oxide EXILIM – Q1		Zinc Oxide PEXLIM – Q2	
	Overvoltage (kV)	BIL%	Overvoltage (kV)	BIL%
260	1038.4	25.19%	943.67	%37.76
270	1039.2	25.09%	950.07	36.83%
280	1041.9	24.77%	5950.1	36.82%
290	1050.1	23.79%	950.20	36.81%
300	1057.9	22.88%	950.25	36.80%

Note: as we increase the lightning current by 10kA tell 300kA as the basic insulation level (BIL) is decreasing for both arresters. according to the table (4.7) type (**Zinc Oxide PEXLIM – Q2**) can stands the lightning much better than type (**Zinc Oxide EXILIM – Q1**) which is about to Breakdown when the lightning current (300kA).

4. Conclusions:

In this paper, a simple substation model and the effect of lightning strokes and a multiple strokes of lightning flash were all successfully simulated and analyzed using program ATP, and the effect of distance factor related to protection device was approved (place of lightning arrester).The study was supported with Different types of arresters which were identified and tested to choose the best one for power protection systems. More than this the results established the need for

lightning protection using lightning arresters .and results obtained by this study can summaries in these points:

1- As the separation distance between protection device (the installation place of the lightning arrester) and transformer increasing as the transient over voltage at the primary winding of the transformer increasing and (BIL) of the transformer decreasing compared to the standard level of (BIL) and the transformer will be more subjected to insulation failure .
2- As the current of lightning stroke increase as the transient over voltage on the primary winding of the transformer increasing. and the (BIL) will decrease then the transformer will be more subjected to damage
3- The separation distance and the lightning current are the main factors in our study the distance (the installation place of arrester related to the protected unit) is adjustable compared with lightning current is naturally uncontrollable and because Most of the transformers failures seem to be due to the excessive separation lengths between the transformer and the lightning arresters which will expose the transformer to excessive transient over voltage so it should always be evaluated to ensure adequate protection.
4- Point (1) and (2) according to the results for (BIL) transient overvoltage approving that the priority is for the distance (location of the lightning arrester related to transformer) then the value of the current of lightning stroke comparing two different tests. Distance factor is playing the important role in protection even the lightning current is very high.
5- Two types of lightning arresters were tested(**Zinc Oxide PEXLIM Q2**) and(**Zinc Oxide EXLIM- Q1**) and results approved that (**Zinc Oxide PEXLIM Q2**) is much better than the first one for withstanding traveling waves due to lightning which causing insulation failure in power systems.

5. References

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