Influence of Climatic Conditions in China on Reliability of Power Earthing System

Robert Marciniak[#1], Marek Loboda[#2], Radoslaw Nowak[#3]

[#1,3] *Galmar*

ul. Kobylinska, 61-424 Poznan, Poland

[1]robert@galmar.pl

[3]n.radoslaw@galmar.cn

[*2]*Warsaw University of Technology, Dept. of High Voltage Engineering and Electrical Apparatus*
ul. Koszykowa 75, 00-665 Warsaw, Poland

[2]marek.loboda@ee.pw.edu.pl

***Abstract*— The paper is addressed to studies of earth electrodes' corrosion occurring in different climatic conditions based on comparative results from Poland and Jiangxi province in south of China.**

The Polish company Galmar – manufacturer of copper coated earth electrodes and conductors started in Poland in 2003 the long-term project of field corrosion tests of earth rods made from different materials. The results of field corrosion tests of steel earth rods with zinc galvanized and copper protective coatings are analysed after exposure in two different sites in Poland after removal from soil in 2 years intervals (after 2,4 and 6 years). In year 2009 Galmar representatives visited few sites in Ghanzou (Jiangxi province) in China where was observed corrosion of earthing system 110 kV substation and 220 kV transmission line after relatively short time of service (app. 7 - 10 years). The examples of earth electrodes corrosion in China have been analysed and compared with the results from field test in Poland.

The prediction of service life time of any kind of earthing systems, which should be usually not shorter than 20-30 or more years is difficult and usually not taken into account as the design factor. The results of long term field corrosion tests of different types of earth rods in Poland and examples of unexpected fast corrosion damages in earthing system installed in Ghanzou in China show the increasing role of corrosion aspects when designing the earthing system especially for power system installation with the aim to assure their stable parameters in expected service time.

I. INTRODUCTION

Components of earthing system for different applications, including power installations and lightning protection, which are buried in soil (earth electrodes and conductors) are subject to much harsher conditions than the components installed above ground. The service lifetime of earthing system is determined primarily by their ability to resist corrosion.

Corrosion of earth electrodes is caused by electrochemical processes in soil or by stray currents in the earth and occurs at a rate depending on the type of soil and material of electrodes and the nature of the environment. Environmental factors such as moisture, dissolved salts forming an electrolyte, degree of aeration, but also seasonal temperature variations and extent of movement of electrolyte combine to make this condition a very complex one.

A special attention shall be also taken to influence of atmospheric and climatic conditions, which are varying in very big ranges worldwide. The characterization of global climatic conditions is illustrated in Fig.1, where the map of world climate classification is shown [1].

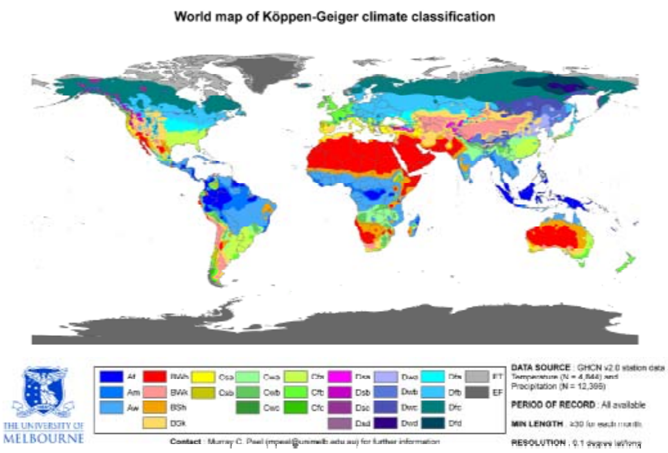


Fig.1. World map of climate classification according to Koppen-Geiger [1].

The climate in Jiangxi province in China is humid subtropical climate, characterized by hot, humid summers and cool winters. Significant amounts of precipitation occur in all seasons in most areas. Winter rainfall (and sometimes snowfall) is associated with large storms with winds prevailing from west to east. Most summer rainfall occurs during thunderstorms and an occasional tropical storm or hurricane.

Climate in Poland is the humid continental climate found over large areas of landmasses, where there is a zone of conflict between polar and tropical air masses. The humid continental climate is marked by variable weather patterns and a large seasonal temperature variance. Summers are often warm and humid with frequent thunderstorms and winters can be very cold with frequent snowfall and persistent snow cover.

These climatic conditions as well as the characteristic of local soil parameters have significant influence on corrosion processes and corrosion rates for steel earth electrodes with zinc galvanised protective coatings.

II. Examples of Earth Electrodes Corrosion in South of China

In autumn 2009 few sites of power system installations in Ghanzou (Jiangxi province) in China were visited by Galmar representatives with the aim of investigation of current state of earthing system constructed and in service in period of app. 10 years.

It was possible to perform visual inspection of earth electrodes present state. The earth electrodes have been uncovered by taking away the upper layer of soil and the corrosion effects on earth electrodes and conductors were carefully checked. The results of inspection are shown in Fig.2 and Fig.3.

The first analysed case is shown Fig.2 and concerns the earthing conductor made of zinc galvanized steel tape having initial cross section dimensions 30 x 4 mm.

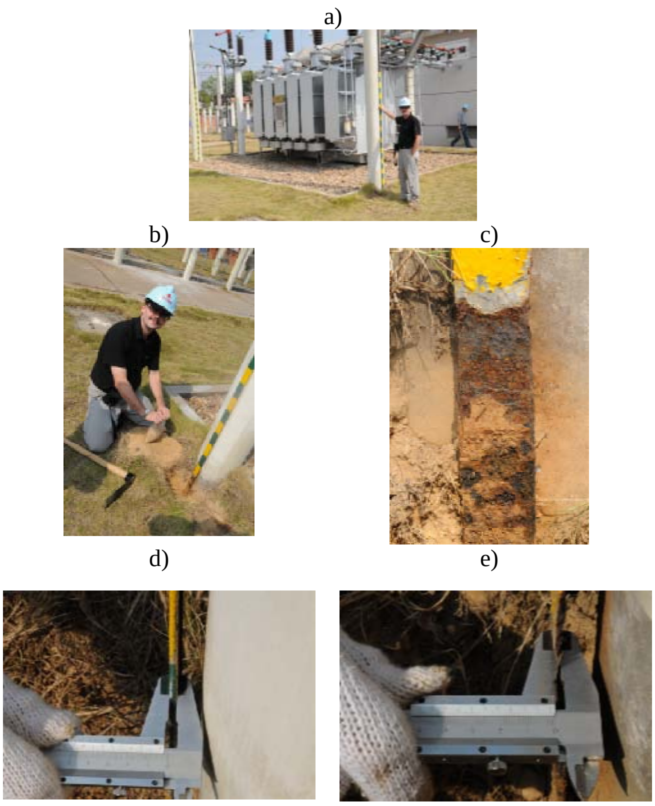


Fig.2. Pictures of 110 kV substation earth electrode inspection with significant corrosion damages after 10 years exposure in soil: a) general view of substation, b) uncovering of soil upper layer, c ÷ d) measurements of earthing tape thickness.

The part of the earthing conductor placed in soil below earth surface corroded uniformly. The comparison of the tape width above and below the soil surface, measured as shown in Fig.2d and 2e was reduced of app. 2,5 mm, which means by app. 60%. It can be assessed that in this specific case the corrosion rate is roughly of 0,25 mm/year.

The second investigated case illustrated in Fig.3 is related to earthing system of 220 kV overhead transmission line tower.

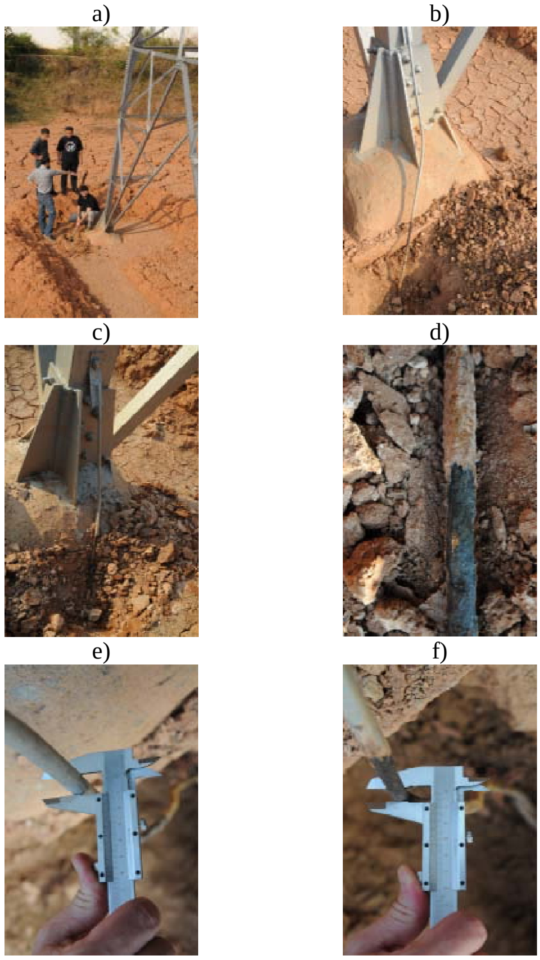


Fig.3. Pictures of 220 kV transmission line tower earth electrode inspection with significant corrosion damages after 10 years exposure in soil:
a) general view of tower leg, b), c) earthing conductors of tower earthing system, d) details of corroded earthing solid round conductor, e) measurements of earthing conductor diameter.

In this case also the part of the steel zinc galvanized round earth conductor corroded uniformly in soil below the earth surface. The comparison of the conductor diameter above and below the soil surface, measured as shown in Fig.3e and 3f, shows reduction of this diameter of app. 3 mm comparing initial value 12 mm above the ground. It can be assumed that in this specific case the corrosion rate is roughly of 0,15 mm/year radial.

This unexpected fast degradation of earthing zinc-galvanised tape in soil is caused by electrochemical corrosion process, accelerated by local climatologic influence and soil characteristics – mainly moisture content in soil and wide variation of temperature. In case of earthing round wire the subsurface corrosion is also observed.

The climatologic statistical information for Ghanzou region based on long-term observations is shown in Table 1. This region is characterised by wide variations of mean temperature - always is above zero in °C, by very high amount of rainfall within whole year (up to over 200 mm in spring time) and relatively short sunshine duration, even in the summertime (app. 2,5 – 8,8 hours per day).

TABLE I
CLIMATOLOGIC INFORMATION FOR GANZHOU, CHINA FROM WEATHER STATION LOCATED AT 25.9 N, 115.0 E, ALTITUDE: 124 M

	Years/ Month	Jan	Feb	Mar	Apr	May	Jun
A	1961 - 1990	8.1	9.4	13.8	19.4	24.0	26.8
		Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
		29.5	29.0	26.1	21.2	15.4	10.0
B	1961 - 1990	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
		61.2	95.5	160.7	200.5	214.6	209.1
		Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
		96.7	122.7	93.3	76.1	53.8	38.3
C	1961 - 1990	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
		7.2	10.6	13.6	14.4	14.3	12.3
		Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
		8.0	8.7	7.1	5.7	5.3	5.1
D	1961 - 1990	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
		3.3	2.7	2.6	3.5	4.8	5.7
		Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
		8.8	8.2	6.4	5.5	4.8	4.6
A - Mean Temperature (deg. C), **B - Rainfall Amount** (mm), **C - Days with Rain** (No. of days with at least 1.0 mm of rainfall) **D - Mean Daily Sunshine Duration** (hours)							

It means that practically whole year there is a high or very high moisture volume in the soil. High yearly amount of rainfall (app. 1420 mm) and relatively short sunshine duration cause that upper layers of local soil are rarely dried during the whole year.

Specific characteristics of soil sample taken from investigated sites in Ghanzou and found of on chemical analysis of their water extract (ratio soil/distilled water = 1:1 by weight) are shown in Table II. The results do not indicate a very corrosive components and characteristics of soil, which could indicate that the observed very fast developing corrosion process was due to very unfavourable for earth electrodes chemical characteristics of investigated sites (see Table II).

TABLE II
CHARACTERISTIC OF SOIL SAMPLE FROM GHANZOU SITE

Components	pH of water extract	Electrolytic conductivity (resistivity)	Presence of ions in water extract
Mixture of sand and gravel with organic components	6,5	250 microS/cm (40 Ω·m)	Tracks of Na^+ and SO_4^{2-}

III. RESULTS OF FIELD CORROSION TESTS OF EARTH ELECTRODES IN CLIMATIC CONDITIONS OF NORTH AND CENTRAL POLAND

In year 2003 few tens of steel earth rods with different protective coating materials, namely galvanized zinc, electrodeposited zinc and copper coating were embedded in two different sites in Poland with the aim to compare the influence of environmental conditions on corrosion of steel earth rods with copper and zinc coatings.

It was selected two sites A – Mielno, which is located in northern part of Poland on the Baltic coast area and B – Inowroclaw in central part of Poland.

The characteristic of climatic conditions in both sites in Poland is shown in Table III [2].

TABLE III
CLIMATOLOGIC NFORMATION FOR MIELNO AND INOWROCLAW IN POLAND

Site	Climatic factor	Years/ Month	January	July
A - Mielno	Av. Temperature [deg. C]	1971-2000	0	17
	Rainfall Amount [mm]	1971-2000	Mean yearly 650 mm	
	Av. Yearly Sunshine Duration [hours]	1971-2000	Mean yearly 1650	
B - Inowroclaw	Av. Temperature [deg. C]	1971-2000	-2	18
	Av. Rainfall Amount [mm]	1971-2000	Mean yearly 550 mm	
	Av. Yearly Sunshine Duration [hours]	1971-2000	Mean yearly 1600	

The temperature variation in both sites in Poland is much smaller than in Ghanzou region, but in wintertime several days with negative temperatures are observed. The amount of yearly rainfall in sites in Poland is app. 2-3 times lower than in Jiangxi province as well as average daily mean sunshine duration by app. 1 hour. It means that the climatic dependent corrosive factors of soils in Poland are for earth electrodes much more benign.

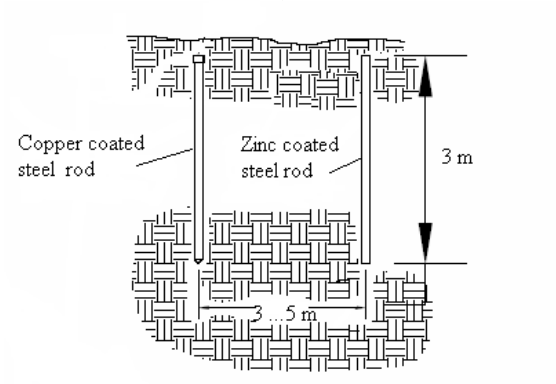
In both sites where field tests of earth electrodes are under continuation the soil is sandy having resistivity varying in ranges shown in Table IV. However, in coast area (site A) one should take into account the influence on corrosion rate of salt mist from the see, deposited in soil due to wind aeration.

The tested steel rods with zinc coating were made using two different technologies:

a) galvanised coating (hot dip galvanized),
b) using electrodepositing technique.

The copper coatings were made using original Galmar technology, which assures the thickness of copper coating of steel rod not less than 250 micrometers in any point of the rod surface. The rods were installed using pneumatic hammer. Exhumations were done with a pulling out machine as shown in Fig.4. Care was taken in each case to exhume a sample without destroying the earth electrode.

a)



b)

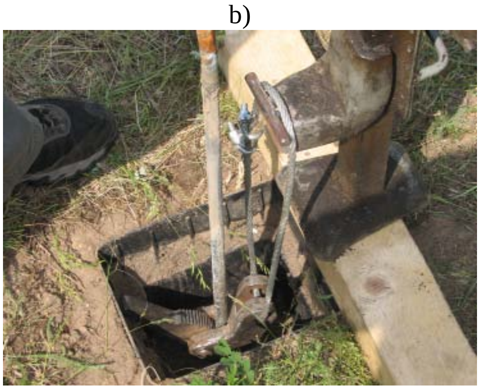


Fig.4. Representation of installed conditions (a) and exhumation of zinc galvanised steel rod (b).

The aim of the long term field corrosion tests is to study the corrosion effects in different soils of different kind commonly used steel earth rod coatings in the same environmental and climatic conditions. This observation is based on comparison of state of coating and coating thickness changes of individual rods after removal from soil every two years, with initial one.

In Table IV are given characteristics of earth rods removed after two, four and six years exposure in natural soil in sites A and B. and comparison of their physical condition. The pictures of fragments of earth rod removed from the soil in both sites after six years exposure are shown in Fig.5 and 6.

The measured average thickness of copper coatings of steel rods made by Galmar was after two, four and six years exposure in soil was similar to the initial one (see Table IV).

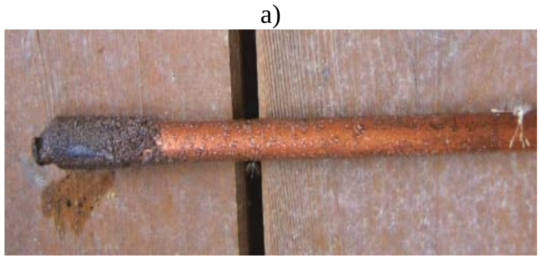
Copper coated earth rods embedded in both sites in the upper part (0,5 to 1,5 m from the erth surface) were covered with corrosion deposits joined with original soil, which were well adherent to the rod surface embedded. The lower part of rod had no visible corrosion centres neither after two nor after four years of exposure in soil (see Fig.5 and 6).

The earth rods with zinc galvanized coating installed in both sites were covered with corrosion products along their whole lengths. The thickness of coatings was much less than the initial one (see Table IV). When removing the steel with electrodeposited zinc coatings rods after 6 years it was seen that zinc coating was completely damaged by corrosion.

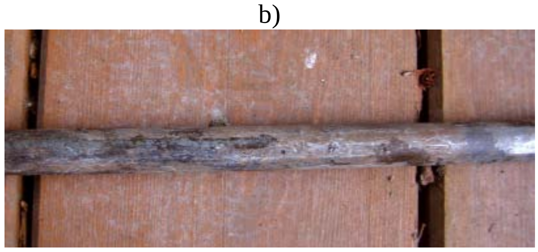
TABLE IV
RESULTS OF EARTH RODS FIELD CORROSION TESTS IN POLAND

Soil parameters			**Parameters of earth rods**				
Site	Kind and resi-stivity [Ω·m]	pH	Material	Coating thickness [micrometers]			
				Initial	After		
					2 years	4 years	6 years
A –Mielno	Sand 300 – 400	6,5	Copper (Galmar)	260 - 360	260-360	260-350	260-250
			Zinc galvanised	50-60	40-50	30-40	30-50
			Zinc electro-deposited	25 -30	0-15	0-10	0 locally up to 20
B - Inowroclaw	Sand 80 – 120	7,0	Copper (Galmar)	260 - 360	260-360	260-350	260-350
			Zinc galvanised	50-60	40-50	30-40	40-50
			Zinc electro-deposited	25-30	0-15	0-10	0 locally up to 20

a)



b)



c)

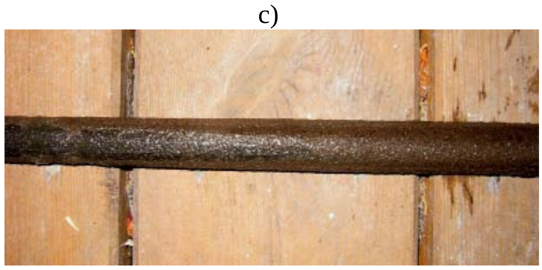


Fig.5. The exemplary pictures of rod fragments directly after removal from the soil in site A – Mielno, after six years exposure: (a) – copper coating, (b) zinc galvanized coating, (c) – zinc electrodeposited coating.

a)

b)

c)

Fig.6. The exemplary pictures of rod fragments directly after removal from the soil in site B – Inowroclaw, after six years exposure: (a) – copper coating, (b) zinc galvanized coating, (c) – zinc electrodeposited coating.

III. SUMMARY AND CONCLUSIONS

Comparison of field corrosion tests of steel earth electrodes in Poland and inspection results of power earthing system in Ghanzou, China shown evidence of fast development of steel zinc galvanized earth electrodes corrosion buried in soil.

The rate of corrosion of earth electrodes is much faster in Jiangxi province than in Poland due to corrosion favourable climatic condition in south of China – mainly high moisture of soil resulting from high amount of yearly rainfall rate and temperature variations in range 8 - 30 °C (mean monthly values).

Corrosion rate of steel galvanized earth rods in Polish climatic conditions is much more smaller than in south of China. This rate in Poland is app. 5 - 10 micrometers/year for round rods, while in China for round conductors is app. 10 times faster.

Field corrosion test results in Poland show evidence of better corrosion protection by copper coated steel earth electrodes compared with zinc coatings made using different technologies.

The results of comparative field corrosion tests results of earth rods performed in Poland are in good agreement with similar test results for earth rods with different type of protective coatings and different metals performed in USA in frames of long term study realized by NBS, NCEL and National Electrical Grounding Research Project [3,4].

Based on observations and inspections of real earthing installations in Ghanzou, we suggest not to install the zinc coated steel earthing system components – mainly earth electrodes and conductors for power system in those regions of China, where the climatic conditions are similar to typical for Jiangxi province.

Dimensioning of earth electrodes and selection of protective coatings for steel rods and conductors shall base on practical test results performed by independent institutions and manufacturers of this kind of products worldwide, mainly in field conditions which are usually characterized by different environmental parameters.

In current proposals of IEC and EN standards related to earthing system component for lightning protection systems (LPS) [5] the most important requirements are concentrated on quality and long term performance in different environments, namely to mechanical strength and corrosion resistance [6]. But up to now no requirements on corrosion tests for buried in soil components related to influence of environmental and climatic factors in soil are introduced, which as known from worldwide carried out field tests have essential influence for their long service time and reliable performance.

REFERENCES

[1] Wikipedia.Available: http://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification h

[2] Available: http://www.imgw.pl/wl/internet/zz/klimat/0502_polska.html

[3] R.W. Drisko, “Field Testing of Electrical Grounding Rods”, Naval Civil Engineering Laboratory, Port Hueneme, California. Published by United States Department of Commerce, National Technical Information Service, February 1970.

[4] Ch. Rempe: “A Technical Report on The Service Life of Ground Rod Electrodes”, *Erico Publ*. 2003.

[5] EN 50164-2 (IEC 62561 – 2) : Lightning protection components (LPC). Part 2: Requirements for conductors and earth electrodes. Draft of new version 2009.

[6] M. Loboda, R. Marciniak: “Essential Requirements for Earthing System Determining the Efficiency of Lightning Protection”. *In Proc. 2010 Asia-Pacific Symposium on EMC, Topical Meeting on Lightning Protection*, Beijing, China, April 2010.