Multi-Chamber Arrester Field Test Experience on Medium Voltage Overhead Line in Asia

Matthieu Zinck, Jean-Baptiste Frain

***Abstract*—this paper discuss issues on medium voltage overhead lines related to lightning and consequences of lightning overvoltage. Few standard lightning protection solutions are discussed in terms of expected performances and limitations. Finally, implementation of Multi Chamber Arresters and results after 1 year of operation in high lightning density area, above 9.5 flashes per km^2 per year, are presented.**

Keywords-component; lightning, medium voltage, multi-chamber arrester, overvoltage.

I. Introduction

Long Flashover and Multi Chamber Arresters (LFA and MCA) [1, 2] have been now in use for over 15 years in the Commonwealth of Independent States (CIS); including Russia and Ukraine. Over a million of devices have been installed showing excellent durability and performances. Nevertheless several questions on performances in Asia and in particular South-East Asia environment have been raised including:

- Are Multi-Chamber Arrester really useful as Medium Voltage line in Asia are rather strongly insulated?
- Can this device actually withstand the level of lightning density and amplitude of the region?
- Can the device work in the various configuration of neutral earth arrangement, pole and cross-arm design of the different countries?
- What performance can we really expect?

Through field test, type test in laboratories and data collection of utilities throughout the Asian region, this paper discuss these questions.

II. Lightning Impulse Withstand of Medium Voltage Overhead Lines

From Fuzhou province in China (lat : 26.091325°) down to Bali in Indonesia (lat -8.497054°), a large part of Asian population and therefore medium voltage lines are located in latitudes where flash density shall range from 6 to 20 flashes cloud to ground per year.

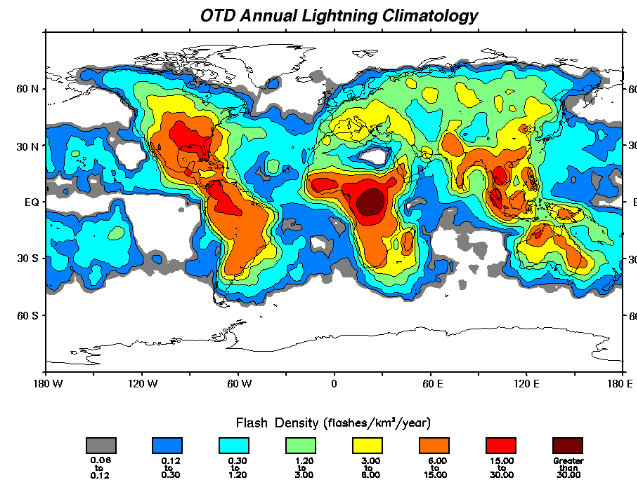

Fig. 1. The global distribution of total lightning flash density observed by the Optical Transient Detector (OTD) (September 1995-August 1996)

Throughout the years, due to the abundant vegetation, animals, winds, strong rains and pollutions, utilities have strongly raised the level of insulations of their Medium Voltage lines to solve most of the transient's effects. Table 1 summarizes the main parameters of insulation of some of the countries and shows that, in Thailand for example, total lightning positive flashover impulse withstand of insulator and insulated conductor is as high as 380kV.

TABLE 1
LINE LIGHTNING IMPULSE WITHSTAND

Country	Network Nominal P-P Voltage / kV	Type of Pole / Cross Arm	Insulator standard (+) Lightning Impulse Withstand in KV	Type of Conductor	Conductor standard (+) Lightning Impulse Withstand / KV
Malaysia (peninsular)	33	Steel / Steel	250	Bare	0
Thailand	24	CR / CR	180	Insulated	200
China (south)	10	CR / Steel	180	Bare	0
Vietnam	22	CR / CR	180	Insulated	200
Indonesia	24	CR / Steel	125	Insulated	125
Cambodia	22	CR / Steel	125	Insulated	125

Standard insulation parameters of some Countries in Asia located in high lightning density zone.

According to the level of Medium Voltage overhead line insulation, utilities shall expect over the years several tripping and conductor breakage occur due to lightning. These lightning issues create loss in exploitation as well as danger for people.

The Table 2 summarizes the expected rate of overvoltage on the line exceeding insulation level in standard conditions in some of the countries located in the high lightning density area. EGM model and induced overvoltage formula were used from [14], [15], and [16] to achieve the calculation. Standard parameters and hypothesis used for overhead line were: height

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Matthieu Zinck – Asia Pacific Manager (matthieu.zinck@streamer-electric.com)
Jean-Baptiste Frain – Business Development Manager (jb.frain@streamer-electric.com)

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was 7.5m, 1 circuits, pole footing resistance of 10Ω, no shielding wire installed, no shielding elements on the line. Other parameters taken for calculation are list in Table 1. Typical values for ground flash densities have been used for the various simulations.

TABLE 2
EXPECTED FLASHOVER RATES

Country	Cloud to Ground Flash Density / Flashes per km2 per year	Standard (+) Lightning Impulse Withstand (insulator / conductor) Total / kV	Expected Flashover Rate per 100km per year	
			Insulator & Conductor	Insulator only
Malaysia	20	(250 / 0) 250	107	107
Thailand	15	(180 / 200) 380	43	77
China	9	(180 / 0) 180	16	16
Vietnam	15	(180 / 200) 380	40	71
Indonesia	20	(125 / 125) 250	78	143
Cambodia	15	(125 / 125) 250	54	98

Expected flashover rate in standard conditions for various Asian countries.

From Table 2 it can be noticed, that at initial stage, when insulation of conductor are new, flashover rates are fairly moderate. But if insulation level decreases through destruction of insulation material of the conductor, flashover rate can double leading to sometimes over 1 flashover per kilometer per year.

Table 3 provides the breakdown of origin of flashover in Induced Overvoltage or Direct lightning. It is interesting to observe that flashover due to direct lightning almost does not vary, while almost all contribution to increase in flashover rate is due to induced overvoltage.

In fact, direct lightning strokes on the line, even for very limited current discharges, lead to overvoltage that are almost always exceeding the insulation withstand of lines. In Thailand a direct lightning stroke as low as 1kA on a conductor can lead to flashover of the 380kV insulation.

TABLE 3
FLASHOVER RATES IN FUNCTION OF LIGHTNING ORIGIN

Country	Insulator & conductor			Insulator only		
	Direct	Induced	Total	Direct	Induced	Total
Malaysia	58	49	107	58	49	107
Thailand	31	12	43	33	45	77
China	7	9	16	7	9	16
Vietnam	28	11	40	30	41	71
Indonesia	43	36	78	44	99	143
Cambodia	29	24	54	30	68	98

Breakdown of expected yearly flashover rate for 100km of medium voltage line in function of direct lightning stroke or induced overvoltage.

III. EVOLUTION OF LIGHTNING INSULATION WITHSTAND AND BREAKAGE OF COVERED CONDUCTORS

Conductors, when insulated, are mostly equipped with partial insulation made of XLPE coated with an extra HDPE layer, with total thickness of ranging from 2.5mm in China to 6.5mm in Thailand or Vietnam. This conductor insulation, as seen in Table 1 contributes sometimes to more than 50% to the lightning impulse withstand capability of the line.

This extra insulation shield, at initial stage, is deteriorated due various factors listed here under:

1. As analyzed in [4], starting 80kV lightning overvoltage convert water trees inside the XLPE into cavities prompt for partial discharges. As partial discharge do they work, in particular under preformed tie, XLPE insulating property gets lower.
2. Mechanical forces; weight of the line on the edge of insulator, wind and trees.
3. Pollution provides application of phase voltage to cover of conductor will lead to partial discharges, treeing and finally - puncture of the insulation.
4. As seen in Table 3, flashovers mostly due to direct lightning.

As lightning impulse insulation withstand of line decreases through the years, chances of follow current establishment strongly increase.

When follow current establishes, it rarely breaks the conductor in “one-shot”. In fact, as can be seen in [7], for an insulated copper conductor with core diameter of 13mm it takes 16 cycles (around 250ms) at 5000A short circuit current to break down. Circuit breaker and recloser would clear the fault in much shorter time. Therefore, loss of insulation is a slow evolution most the time hidden by reclosing operations. Figure 2 gives an example of evolution of lightning impulse withstand and ampacity through a few years. Figure 3 gives some pictures of intermediate stages seen in Indonesia and Vietnam.

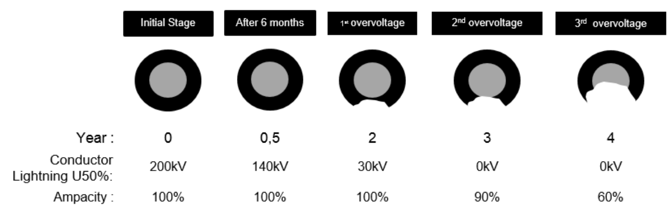

Fig 2. Example of process of degradation of XLPE insulation and breakage of conductors through several years and lightning overvoltages.

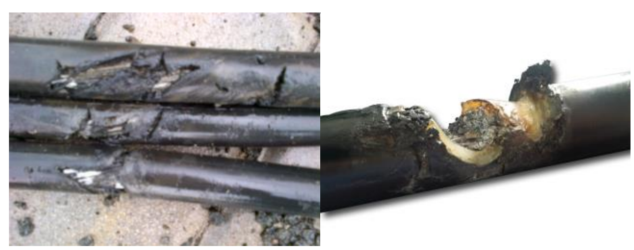

Fig 3. Lightning damage on XLPE insulated conductors. Left: superficial damage of conductor observed in Indonesia. Right: deep damage of conductor observed in Vietnam.

IV. PROTECTION OF OVERHEAD LINE

As seen from the previous paragraph on insulated lines direct lightning is by far the most damaging elements at early stage. Therefore it is necessary to have lightning protection solution which can actually withstand direct lightning on long terms.

As express in [8], average first return stroke shall be at least comprise between 1 and 2C.

Various lightning solutions can be used to protect overhead lines as can be seen in [10]. The following paragraph gives a short description of the solution and main issues.

A. Overhead Ground Wire

As shown in [3, 5] installing overhead ground wire grounded every 200m with grounding resistance bellow 5Ω on medium voltage lines can reduce up to 30% the number of outages. Limitation in performance is mostly due to the fact that overhead ground wire have a limited influence on induced overvoltage phenomenon due to the nature inductive currents. Besides, in case of direct lightning strokes, according to footing resistance and due to low level of insulation of medium voltage lines, back-flashover occurs.

If its cost is rather reasonable in regards with its lifespan, shielding wire performance also mainly depends on quality of grounding, which, without maintenance altered through the years. Durability of Shielding Wire towards direct lightning is rather not an issue.

B. Gapless Metal Oxide Arrester

As shown by [6] to prevent 80% of the outages on medium voltage lines due to lightning, 3 pcs (1 for each phase) of metal oxide arrester shall be installed every 200m.

Nevertheless, failure rate of metal oxide arresters used to protect line is rather high. In fact, distribution class metal oxide arrester with energy capability of 1.5 to 3kJ/KV shows lightning discharge capabilities of respectively 0.5 to 0.9C. Therefore failure rate can be as high as 5% per year when used for line protection.

For station class metal oxide arresters, their cost make them an un-economical solution to be installed throughout the line at pace required for adequate protection.

Beside performance highly depends of quality of grounding as for the shielding wire.

C. Gapped Metal Oxide Arrester

Their functioning and defaults are rather the same as metal oxide arrester to the following differences:

- Since not connected on the line, they prevent power losses,
- The “pickup” voltage depends on the air gap adjustment,
- Manufacturer often recommend to use them without conductor horn, which can lead to serious damage to the conductor in case of failure of zinc oxide blocks and follow current will only be stopped after several cycles through the switchgear trip.

V. Field test of Multi Chamber Arresters in Asia

The table 4 summarizes the some of the MCA field tests monitored in Asia, including information on numbers and status of field test at time of writing of article.

TABLE 4
ASIA MCA FIELD TEST

Country	Network Nominal P-P Voltage / kV	Numbers Arresters Installed	Location of installation	MCA installed	Status on 11 Dec 2014
Malaysia (Peninsular)	33	120	In vulnerable section	SAd35z	on-going, less than 1y
Thailand	24	104	Throughout the line backbone	SAi20z	on-going, less than 1y
China (south)	10	67	In vulnerable section	SAi10z	over 1 year
Vietnam (center)	22	60	In vulnerable section	SAi20z	on-going, less than 1y
Indonesia (West Java)	24	44	In first 3km from substation	SAi20z	over 1 year
Cambodia	22	60	Throughout the line backbone	SAi20z	on-going, less than 1y

Summary of MCA field test monitored in Asia region.

3 types of installation strategy can be distinguished:

In vulnerable sections: arresters are installed in selected section of lines where occurrence of flashover is higher than in the rest of the line. This can be due to:

- Higher exposure to lightning due to high lightning density in the area or higher altitude or absence of shielding elements.
- High footing resistance due to high soil resistivity. In fact, this circumstance has the effect to increase the flashover occurrence and trip significantly as well as deteriorating distribution class arrester and MV/LV substation located along the line.

In first 3 km from substation: arresters are installed in first few kilometers from HV/MV substation for 2 main purpose:

- As described in [7], within 3 first km form substation the fault current values are the highest, this is where chances for power arc self-extinguishing is the least and chance for durable damage to conductor the highest.
- By limiting chances of high faults, mechanical and thermal stress on HV/MV transformer are reduced, increasing potential lifespan of transformers.

Throughout the line backbone: arresters are installed throughout the line backbone in order to ensure a maximum availability of line. This can be the case, for example, of high values industrial lines.

VI. Multi Chamber Lightning Discharge Capability & Life Span of SAi02z

Multi Chamber systems arrester [9] are build a on a simple design which allows them to have lighting discharge capability of 2.4C for a rather limited material usage.

In fact, a 24kV multi chamber arrester (SAi020z) weighting 0.9kg has been successfully tested at CESI laboratory in April 2014 for 18 lightning discharge of 2,4C. Following discharges, successful 1.5kA rms follow current quenching tests were performed. Another lightning discharge capability test was performed at China EPRI in Beijing for discharges of 0.8C showing absolutely no deterioration of housing of MCA.

Average life span for SAi020z is given at 20years, due to its high lightning discharge capability.

Among 111 arresters installed in lightning density area of over 9.5 flashes per km2 over the past year none presented any defects. As can be seen in Table 5, 19 arresters have operated over 1 year. No damages of the MCA nor failures were reported.

TABLE 5
MCA DAMAGE REPORT

Country	Network Nominal P-P Voltage / kV	Numbers Arresters Installed	Operations over 1 year	Lightning Density in Flashes per km2 during the year	Crack(s) & damage(s) on arresters reported
China (south)	10	67	8	9.67	0
Indonesia (West Java)	24	44	11	17,07	0

Number of arresters presenting damage or cracks avec 1 year

Looking at the number of arresters installed and the respective lightning density, on the Chinese test line, only 0.24 direct lightning stroke over the year might have hit line close to MCA and in Indonesia only 1.16. Therefore further sampling needs to be waiting to conclude.

VII. DOUBLE EARTH-FAULT AND SHORT-CIRCUIT CURRENTS THROUGH EARTH

Multi Chamber arrester as described in [9] mostly work in 2 steps operation. Step 1, they discharge lightning through their body. Step 2, they stop the follow current establishment at network overcurrent first zero crossing, before end of 1st half-cycle.

In China and Indonesia, arrester installed were "induced overvoltage" arresters. Their installation is meant to be one per pole, on alternate phases, as show in fig 4. Through this configuration arrester are primarily meant to work in pair or triplets with follow current establishing as double earth-fault or short circuit current through the earth. Thanks to this configuration, faults level are greatly reduced, allowing smaller devices to be used.

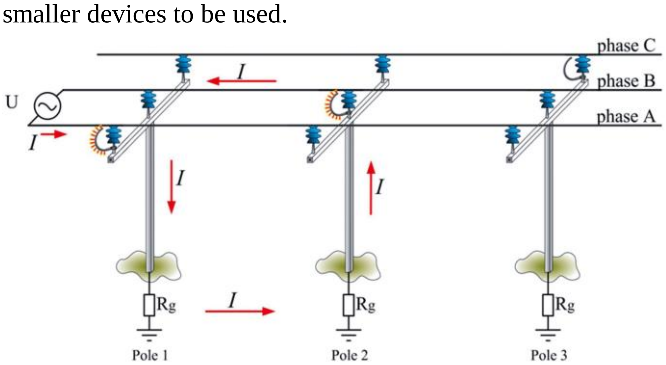

Fig 4. Double earth fault current loop, with arresters working in pairs

From 19 arresters that operated during the year of the field test, around 60%, 12 of them, worked in pair in configuration described in Fig 4. At least 1 operation occurred involving 3 arresters, while in at least 3 operations involved only 1 arrester.

TABLE 6
MCA TYPE OF OPERATIONS

Country	Numbers Arresters Installed	Aresters that operated over 1year	Single arrester operation	Pair arrester operation	Triplet arrester operation
China (south)	67	8	2	6	0
Indonesia (West Java)	44	11	2	6	3
TOTAL	111	19	4 (21%)	12 (63%)	3 (15%)

Number of operations of arresters alone, by pair or in triplets

VIII. INFLUENCE OF NETWORK SYSTEMS ON MULTI CHAMBER ARRESTER CHOICE

As seen in previous paragraph, arrester operation includes quenching of follow current. According to lightning event and network type the operation of "induced overvoltage" MCA can occur for a single device, or in pairs or triplets simultaneously. When a single MCA operates, follow current occur in form of single phase earth faults. But when MCA operates in triplet or in pairs, follow current values and path(s) will highly depend on line parameters.

It is necessary to ensure that follow current does not exceed breaking capacity of Multi Chamber Arrester and therefore to evaluate maximum prospective follow current in each case.

Follow currents value and path have to be evaluated as function of:

- Nominal voltage
- Neutral earthing arrangement
- Type of pole and cross arm
- Footing resistance
- Single or double line feeding
- Distance of fault location
- Impedance of system feeder
- Impedance of the arrester
- Presence of Shielding wire / overhead ground wire

Standard calculation methods of single or multiple phase short circuits and single or multiple earth faults can be found in [11].

On a 3 wire network, in absence of ground wire, due to their installation method, one per pole on alternate phases, faults for double or triple operations are respectively double or triple earth fault. In this case formula needs to take into account the impedance of the arrester and the impedance of the pole.

In most of the countries in Asia poles made of concrete reinforced are being used. These poles have a non-negligible impedance which reduces significantly the value of follow current. In [12] and [13] impedance of poles have been studied through various frequencies. A 22m height pole in concrete reinforced shows a power frequency impedance of 35Ω. It can be estimated that an average 7.5m concrete reinforce pole shall present an impedance of 5Ω minimum.

The table 7 provides the values of prospective single or double phase(s) follow current for field test lines.

TABLE 7
PROSPECTIVE FOLLOW CURRENTS

Country	Network Nominal P-P Voltage / kV	Standard Neutral Earthing Arrangement	# Wire	Shielding Wire	Double Phase (Earth) follow current /A	Single Phase (Earth) follow current / A
Malaysia	33	Neutral Earth Resistor	3W	YES	≈6000	≈1000
Thailand	24	Solidly Grounded	3W	NO	≈1200	≈1400
China	10	Insulated Neutral	3W	NO	≈500	≈100
Vietnam	22	Solidly Grounded	3W	NO	≈1200	≈1400
Indonesia	24	Neutral Earth Resistor	3W	NO	≈1200	≈800
Cambodia	22	Neutral Earth Resistor	3W	NO	≈1100	≈600

MCA has been developed in various version in order to match each case with an appropriate ratio performance-cost as higher fault breaking capacity also means more material and chambers to prevent its establishments.

In order to qualify operability of installed MCA, it has been verified in China and Indonesia that no trips in protected sections where related to lightning. To do so, lightning detection systems were used in order to geo-localize lightning stroke impacts, dates and time of impact. For China, lightning detection system of the national utility was used, for Indonesia, data were collected at BMKG, Badan Meteorologi Klimatologi Dan Geofisika, the national agency for climatology and geophysics, www.bmkg.go.id.
Considering number of operations, distance of HV/MV substations, it is reasonable to think that successful quenching of follow current has been taking place for high current value, in particular in Indonesian case.

TABLE 8
SUMMARY OF MCA OPERATIONS

Country	Network Nominal P-P Voltage / kV	Numbers Arresters Installed	Operations over 1 year	Distance of 1st operated arrester from HV/MV substation / km	Trips due to lightning in protection sections
China	10	67	8	≈5	0
Indonesia	24	44	11	≈0.2	0

Summary of operations of MCA in field test

IX. INSTALLATION OF MCA ON A 10KV LINE IN SOUTH OF CHINA

A 10kV feeder, called “Hang Luo Guo Chang including Caishichang & Renwu 2 taps” under White Rabbit F11 in Aotou sector has been chosen to be equipped with the SAi10z. Choice was made on the ground that heave problems occurred repeatedly every year on this zone.

White Rabbit F11 total length is 30.9km (fig 6) and composed of 17 branches. Line has an average of 30 outages per year.

One of the major criteria in order to qualify the efficiency of arrester is to measure the outages at MV substation.

Due to the high lightning outage occurrence, it is possible to equip only a section of the line rather than all the line in order to draw a conclusion.

As any part of the line can lead to switchgear tripping at MV substation it has been decided “to isolate” the location protected by SAi10z by choosing one branch and equip totally the branch with Multi Chamber Arrester.

The section chosen is ≈4km long (surrounded in red in Fig 6), which allow, over a year to draw a conclusion on the effectiveness of the arrester.

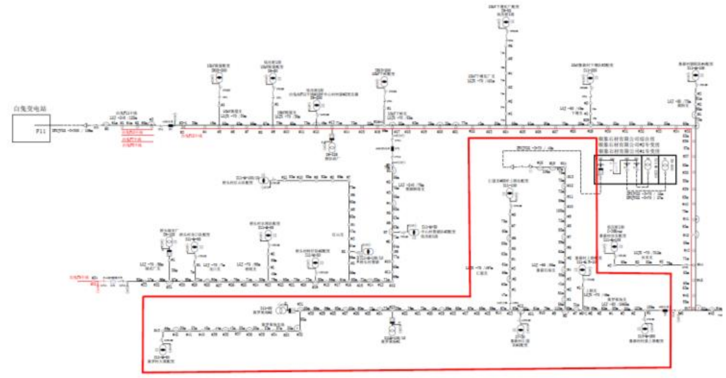

Fig 6: White Rabbit 11, “Hang Luo Guo Chang Branch line”. Surrounded by a red line, section chosen for the installation of the SAi10z Multi Chamber Arrester.

Hang Luo Guo Chang Brunch line” is equipped with:

- 67 poles among which
  - 7 section poles
  - 16 tension poles
  - 44 intermediate poles
- 7 transformers 10/0.4kV
- Total length around 4km
- 3 Wires system
- Average pole footing resistance above 30Ω

In order to monitor the installation several criteria will be used:

- Event recorder at substation to monitor the number of outages.
- Outages due to lightning will be distinguished from other causes outages through lightning monitoring system.
- Outages on protected branch will be differentiated from other part of “Hang Luo Guo Chang Branch line” feeder through 2 elements:
  - Thanks to the lightning detection system it is possible to locate the area where lightning flash occurred,
  - As per procedure linemen will locate the location of the faults on the line.

SAi10z operations under lightning impulse will be monitored thanks to one-time-operation indicators.
Periodic visit on the line were schedules to monitor evolution of arrester installation as well as one-time-operation indicators

Fig 7: one-time-indicator. Left: initial state. Middle: during lightning impulse. Right: broken bulb, after lightning.

Several visits have been scheduled from 22nd August 2013 to the 10 August 2014.

TABLE 9

INSPECTION VISITS SUMMARY

Date of visit	Notes
24th September 2013	Arrester on pole #6 of sub-branch (see Fig 14 operated). After verification on lightning monitoring system, lightning has been indeed present in this area during period
5th December 2013	Routine visit, no particular evolution noted
9th April 2014	Arrester on pole #25 of main branch operated
20th June 2014	Arrester which operated : -main branch on pole #2, -main branch on pole #6-1 and #7 - sub-branch on pole #1 and #2 - main-branch on pole #24

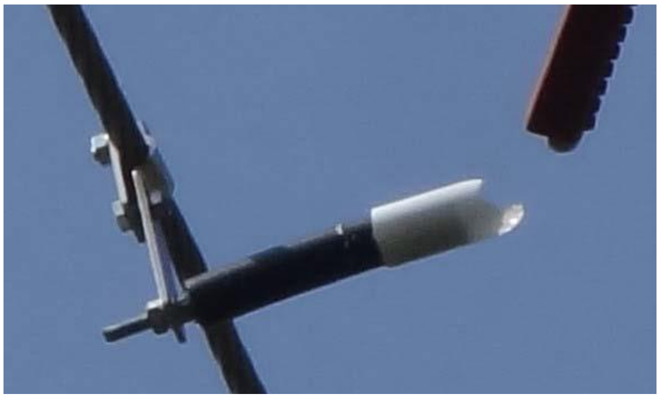

Fig 8: Broken indicator of Arrester on pole #6 of sub-branch

From August 2013 to August 2014, several majors lightning events occurred on the line:

- 20 September 2013
- 30-31 March 2014
- 11 May 2014
- 17 May 2014
- 23 May 2014

During the same period 12 trips occurred due to lighting on “un-protected” section of the line.

SAi010z operated at least 8 successful times (Indicators were not changed). Total potential outages of the line could have been 20, which show by indicator’s broken numbers that SAi010z prevented 40% of the outages. No SAi10z showed any sign of damage.

X. Installation including Gapless Metal Oxide Arresters and MCA

In field in China, line equipped with MCA had no standard gapless arrester installed except on MV/LV transformer. But on test line in Indonesia, several gapless metal oxide arrester were installed.

As can be seen in figure 9, several MCA operations have been observed on poles adjacent with standard metal oxide arresters.

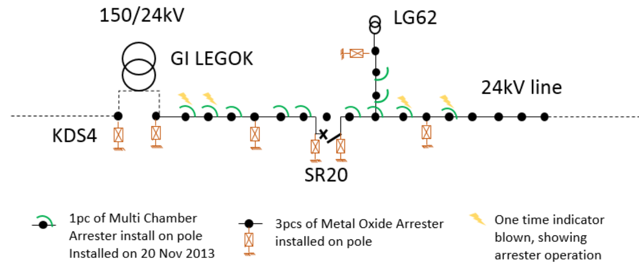

Fig 9. Extract of Serpong, Indonesia, field test report reporting operations of MCA on adjacent poles installed with gapless metal oxide arresters.

Analysis of operations and conjectures on operation circumstances has been described in the following paragraphs.

While metal oxide arresters protect insulators and conductor by enforcing a specific voltage, called residual voltage, MCA ensure protection through sparkover voltage. Sparkover voltage being the voltage at which air gap of arrester with line is being “bridge” by lightning discharge.

As per IEC standard sparkover voltage is determined through up and down method using 1.2/50us waveform. But sparkover voltage is actually greatly influenced by front time of lightning overvoltage. Tests on MCA, SAi020z, 24kV, installed on the Indonesian field test line, see figure 10, show that sparkover voltage can increase up to 120kV for front time of 0.43µs down to 66.6kV for front time of 5.12µs.

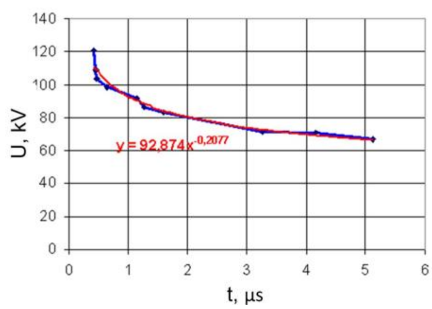

Fig 10. Flashover voltage in function of front time for SAi20z

On Indonesian field test line, heavy duty polymer metal oxide arresters (MOA) from a high end make were used. The MOA presented following characteristics:

- 10kA nominal discharge,
- rated voltage 24kV,
- MCOV 19.5kV,
- Residual voltage of 70.7kV at 3kA discharge.

First conjecture that can be imagined is that, in case of similar footing resistance, residual voltage of MOA was above spark over voltage of SAi020z. In fact residual voltage of gapless metal oxide arresters increases with discharge current. SAi020z spark-over voltage remains below 66.6kV for lightning waveform front time of 5µs and more. For strong lightning discharge, usually with average front time of 5 µs, SAi020z is therefore likely to operate “before” gapless metal oxide arresters.

Second conjecture, overvoltage “imposed” on the line by metal oxide arresters depends their footing resistance. If footing resistance was high, level of overvoltage at adjacent poles might have exceeded MCA sparkover voltage. In this case, both device have operated and contributed to discharge the overvoltage.

XI. Comparison Before and After Installation

As mentioned in an earlier paragraph, local lightning data have been used to correlate trips at recloser or substation switchgears with lightning occurrences on the line.

It can be noted that due to the level of accuracy of lightning localization system, distance of influence of lightning discharge on lines, as well as uncertainty on timestamp synchronization, it was considered that lightning occurring in range of 500m and within +/- 5mins where at the origin of the trip.

Table 10 summarizes trips due to lightning before installation and after installations of MCA. It can be noticed that no trip in the area protected by MCA were due to lightning during the period where MCAs were installed. It shall be reminded that MCAs operated 8 times in case of Chinese line and 11 times in case of Indonesia lines.

Table 10
Lightning Occurrences vs Date and Time of Trips

Country	Before MCA Installation			After MCA Installation		
	Observation duration	Nb of Trips dues to lightning	Tripping rate over 100km	Observation duration	Nb of Trips dues to lightning	Tripping rate over 100km
Indonesia	601 days	9	≈55	354 days	0	≈0
China	365 days	4	≈100	365 days	0	≈0

XII. Conclusion

Lightning strongly affects short terms and long terms operation of Medium Voltage lines, leading in best case in lowering lightning insulation withstand and outages, and, in worst cases, in breakage of covered conductor.

Due to frequency of direct lightning in high lightning density zone, in order to protect durably and efficiently medium overhead lines it is important to equip lines with high lightning discharge capability equipment.

Laboratory and field test has been conducted on Multi Chamber Arrester over a year in China and Indonesia and are still on-going in Thailand, Vietnam, Malaysia and Cambodia. Preliminary analysis on protections sections of lines located in high lightning density areas show promising results in terms of MCA lightning withstand, protection by MCA of covered conductor, and reduction of outages due to lightning.

XIII. Acknowledgment

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