Partial Discharge Pulse Wave Shape Characteristics and On-site Measurements in HV Cable Systems

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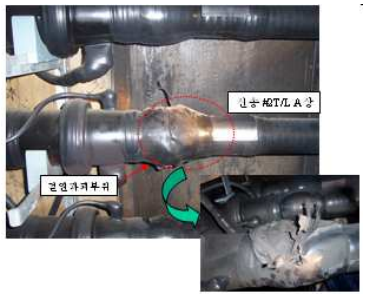
Failure in HV Cable System





Mainly occurs in the Joints

Diagnosis for Joints using PD measurement

Steps in On-site PD measurement

On-site PD measurement

- using PRPD pattern and Noise discrimination methods

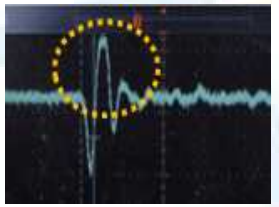
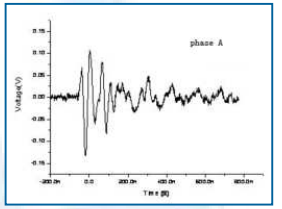
Location of measured Signals

- TOA method using 2 sensors
- **not easy in case of EBA**

Decision Making of Defect

- **Location is most important !!**

PD Pulse Wave shape Analysis

EBA Joint

Different !!!

Formation of PD Pulse Wave Shape

- Deformation of Wave Shape by Transmission & Reflection due to the Route Impedance

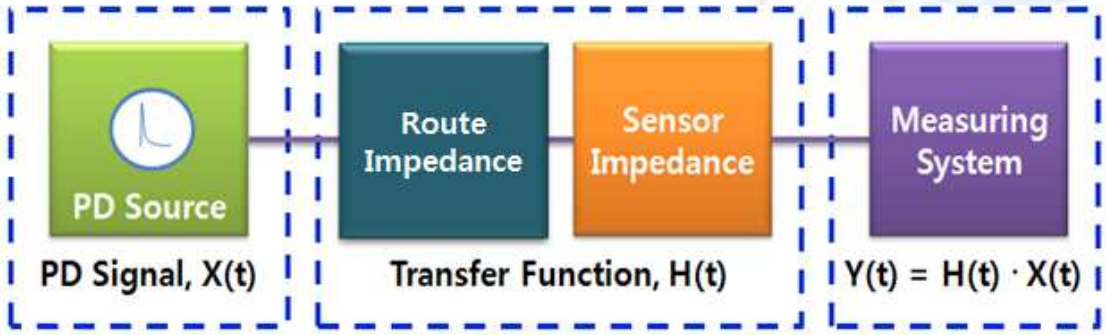
Wave Shapes for different Joint Structures

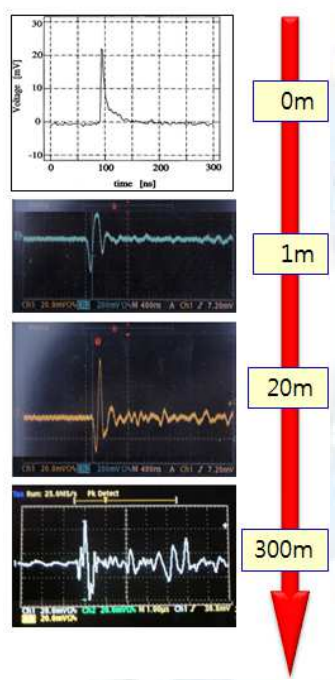
- **Simulation of PD Pulse Wave Shape**
- **On-site Experiences**

Part I

Considerations on Partial Discharge Pulse Wave Shape

Formation Process of PD Pulse Wave Shape





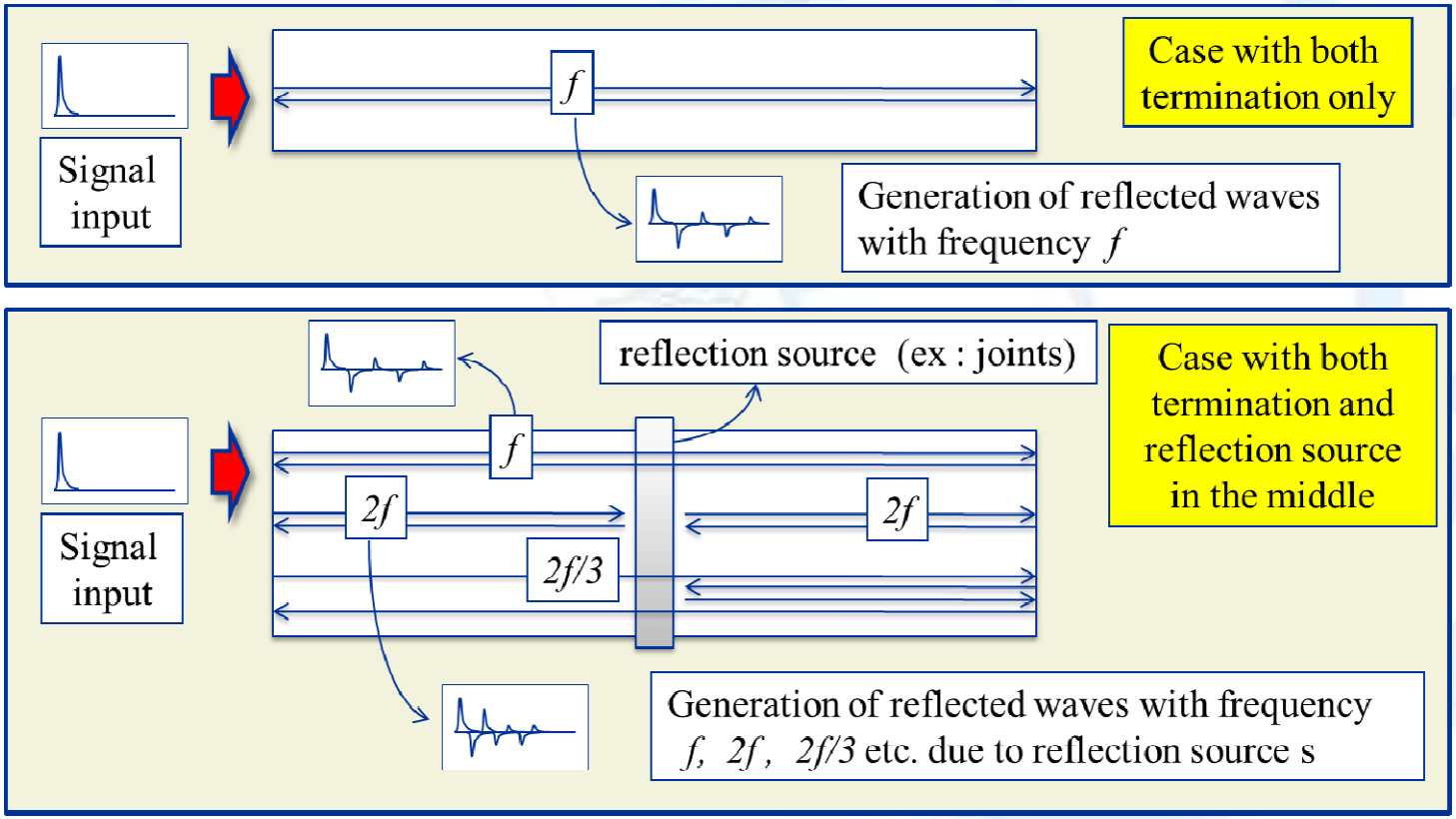
Impedance of the Route makes an effect mostly on the formation of the wave shape.

- Different wave shapes are formed due to different impedances between the PD source and the sensor.

Possible to analyze PD characteristics using Pulse Wave Shape analysis

Concept of Reflection Wave

- Traveling wave reflects at the changing point of impedance such as joints, so various frequency components are generated.

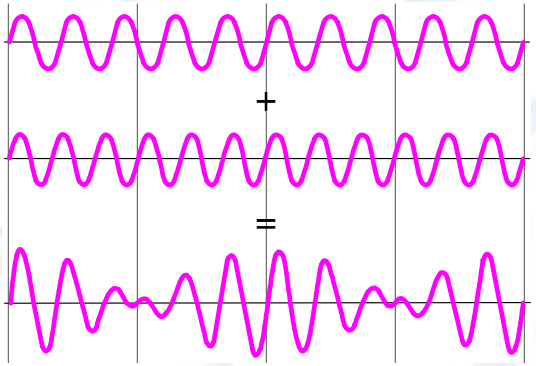


Concept of Wave Superposition

- If more than 2 waves with different frequency are piled up, superposition wave is generated and makes beats with enlarged magnitude.

$$y_1 = A\cos\omega_1 t \qquad y_2 = A\cos\omega_2 t$$

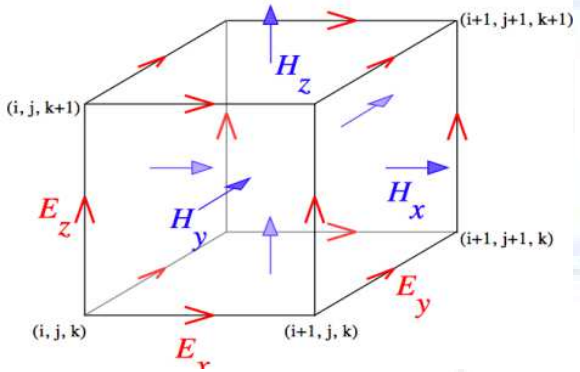
$$\begin{aligned} y &= y_1 + y_2 \\ &= A\cos\omega_1 t + A\cos\omega_2 t \\ &= 2A\cos\left(\frac{\omega_1+\omega_2}{2}\right)t\ \cos\left(\frac{\omega_1-\omega_2}{2}\right)t \end{aligned}$$



- The impulse-like shaped PD pulse at the starting point can be changed into complicated wave shape with various frequency components due to the different impedances through the route form the PD source to the sensor.
- Main frequencies of the measured PD pulses are formed with transmission and reflection of the traveling wave.

PD pulse wave shape Simulation

- FDTD : Finite Difference Time Domain (시간영역 유한차분법)



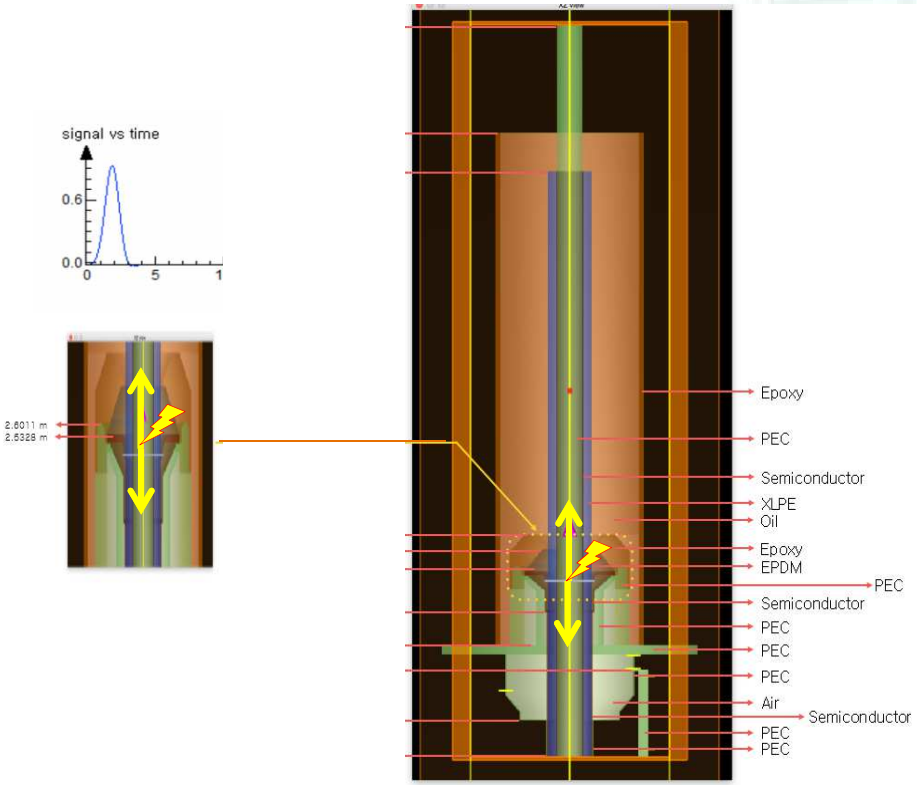
$$\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} + \sigma \vec{E}$$

$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} + \sigma_m \vec{H}$$

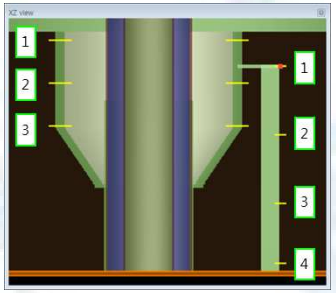
- Electro-magnetic fields for Yee cell units were analyzed with time on the basis of Maxwell Equations.

PD Simulation in EBA (1)

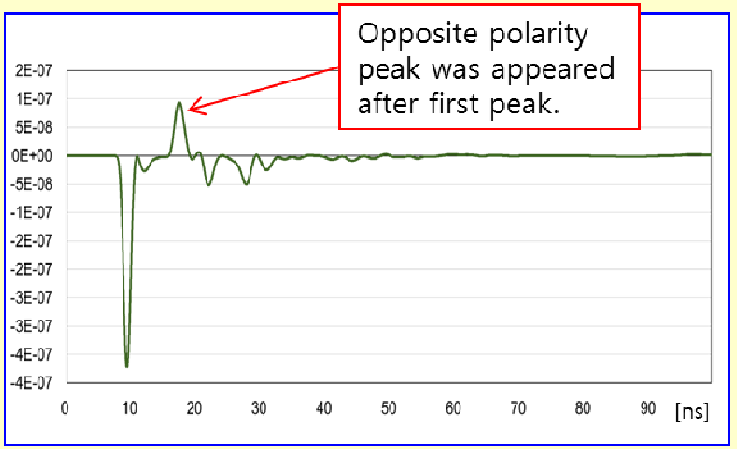
Simulation Model for EBA in HV cable (EBA : End Bushing in Air)



Sensor Positions

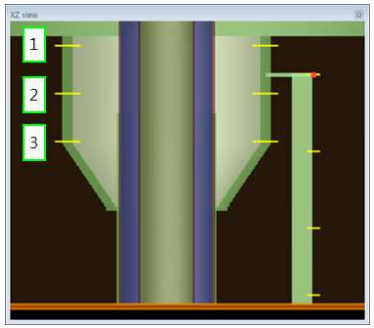


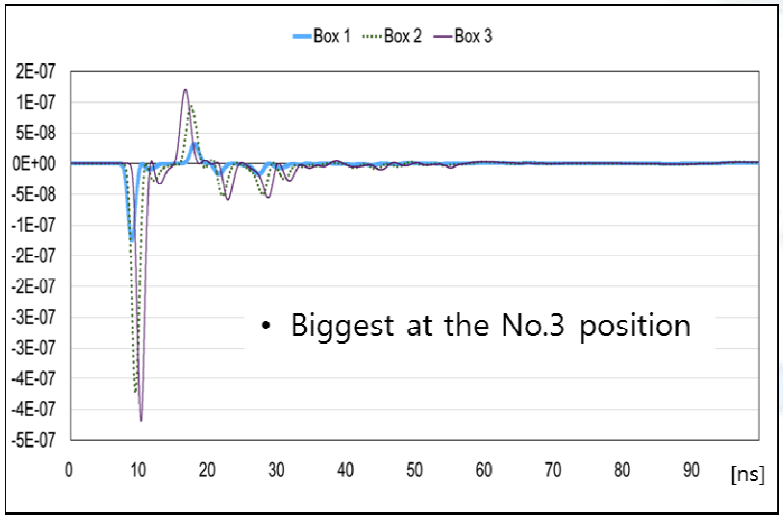
- Simulated Result at No. 2 position



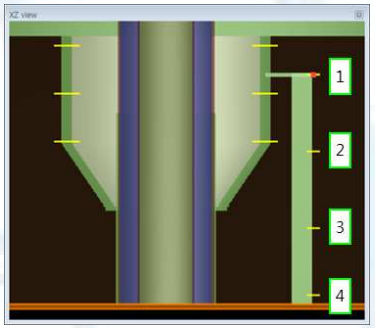
PD Simulation in EBA (2)

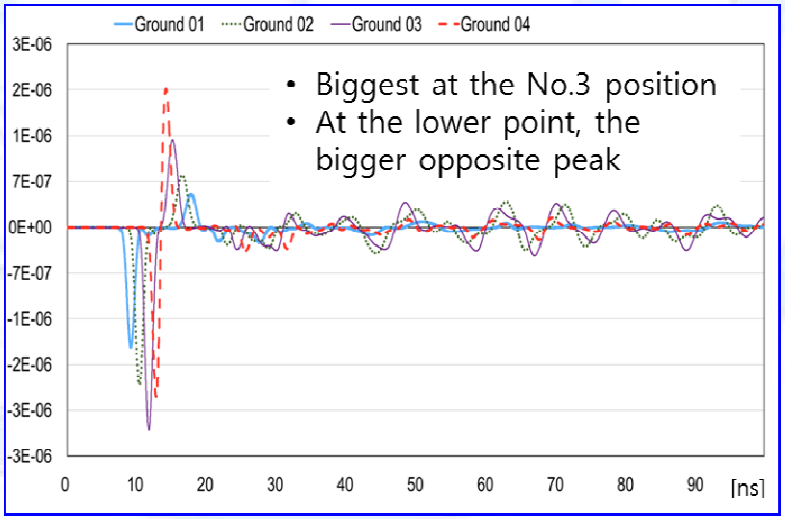
At the position inside Cupper Box





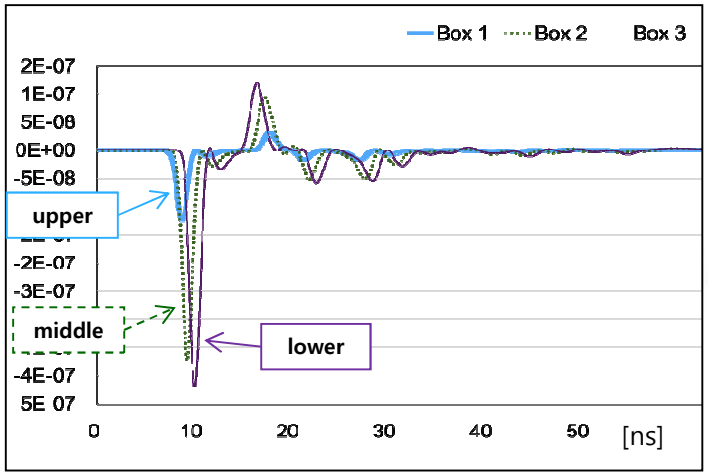
At the Ground Wire



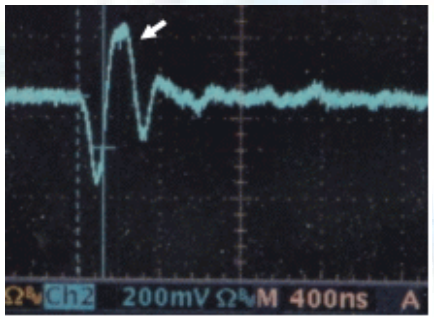


PD Simulation in EBA (3)

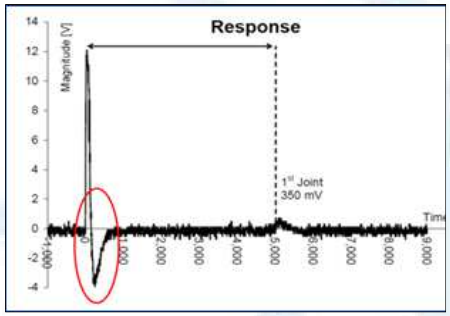
Simulation Results



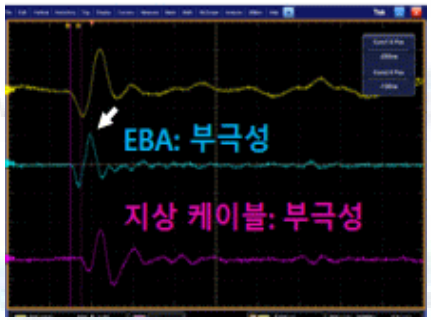
On-site Measurements



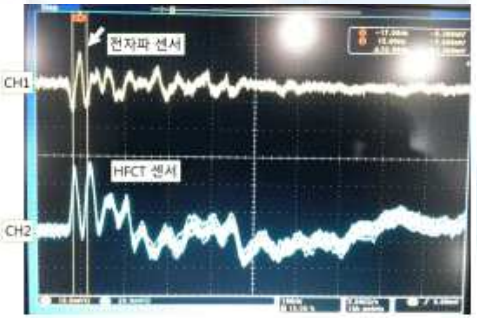
PD pulse in EBA (XLPE cable)



Injected pulse
during After Laying Test



PD pulse in EBA
(345kV XLPE cable)



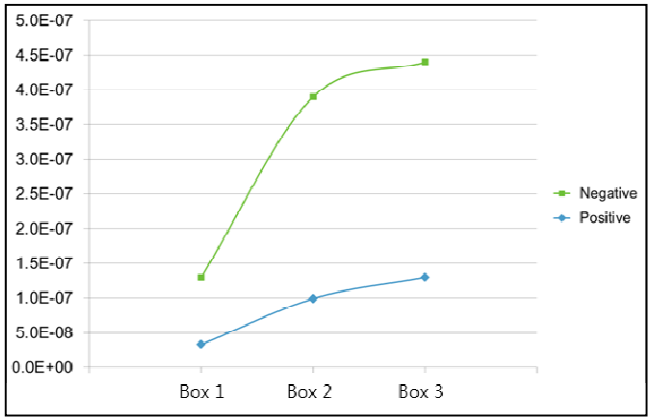
Injected pulse
During Type Test

PD characteristics in EBA

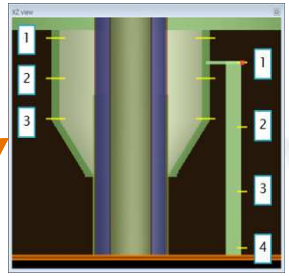
- Big opposite peak after first peak, then decreased.
- Simulated result is very similar to On-site measured ones.

PD Simulation in EBA (4)

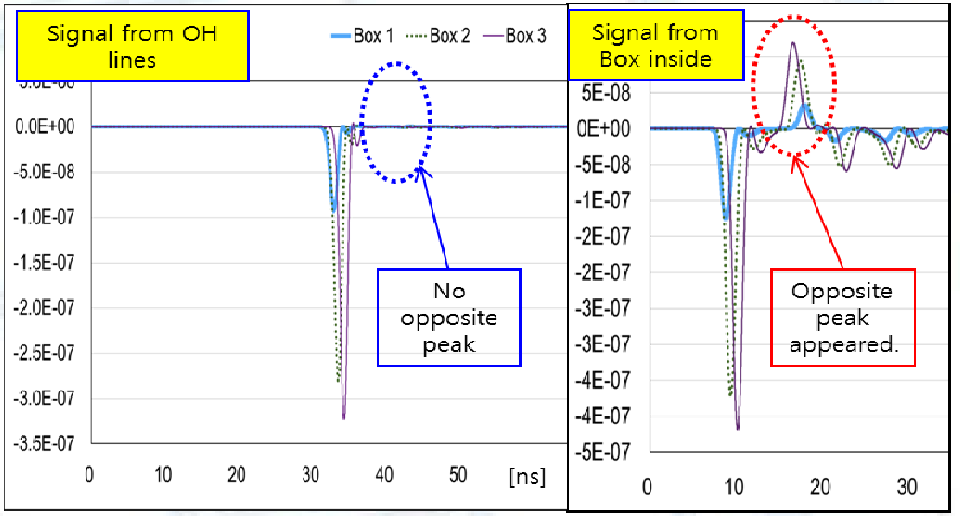
Optimal location of sensors



- Optimal point is the lowest end of Cupper box.

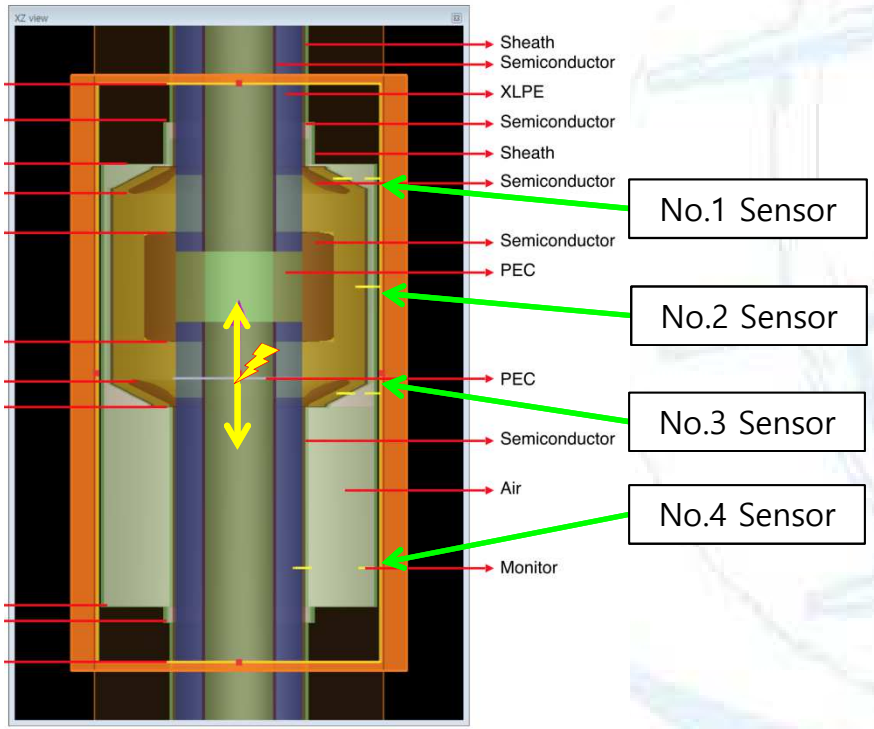


Comparison of Pulse inside EBA and Pulse from Overhead Lines

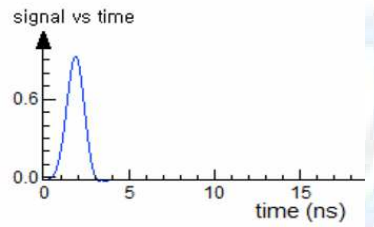


- Opposite peak appears, when the pulse generating inside of the box of EBA.
- No opposite peak shows when the pulse comes from OH lines.
- However, further study is needed including other facilities. (ex, surge arrestor)

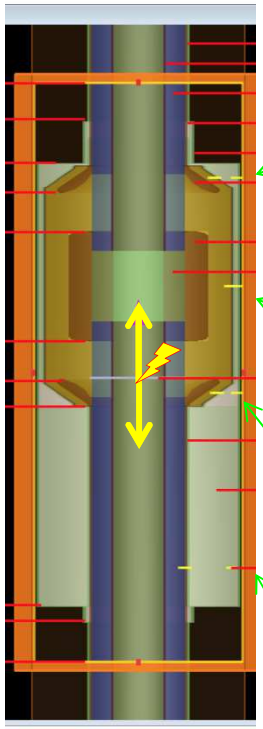
PD Simulation in PMJ (1)
(PMJ : Pre-Molded Joint)



Material	radius	Conductivity	Permittivity
Conductor	4.37 mm	-	-
Semiconductor	1 mm	1	2.3
LSR	-	1E-14	3.0
XLPE	11 mm	1E-14	2.3
Air	-	0	1



PD Simulation in PMJ (2)

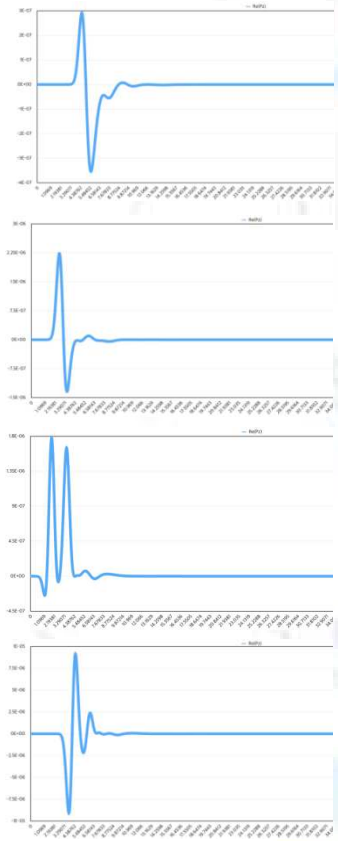


No.1 Sensor

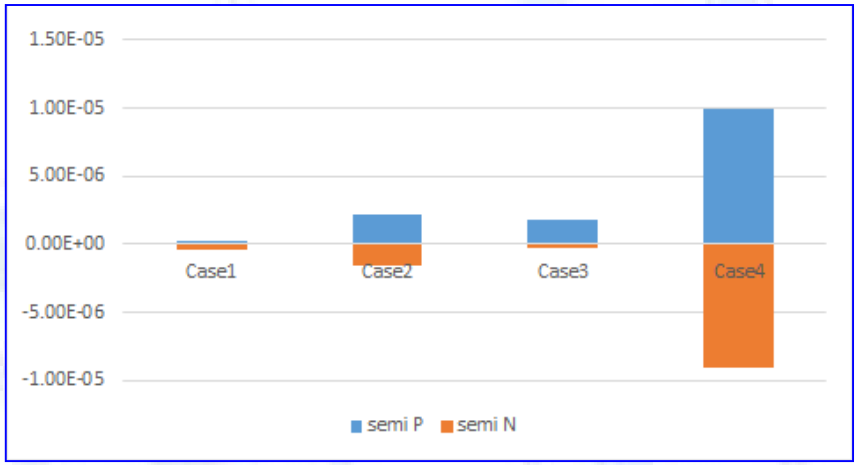
No.2 Sensor

No.3 Sensor

No.4 Sensor



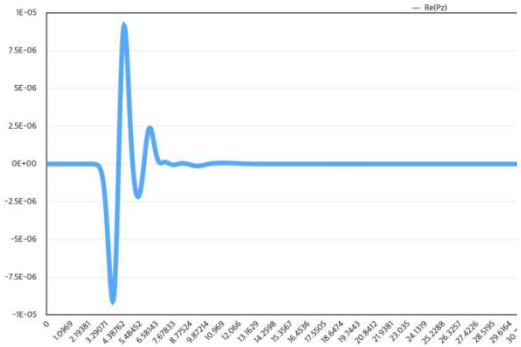
Magnitude of positive & negative peak at each position



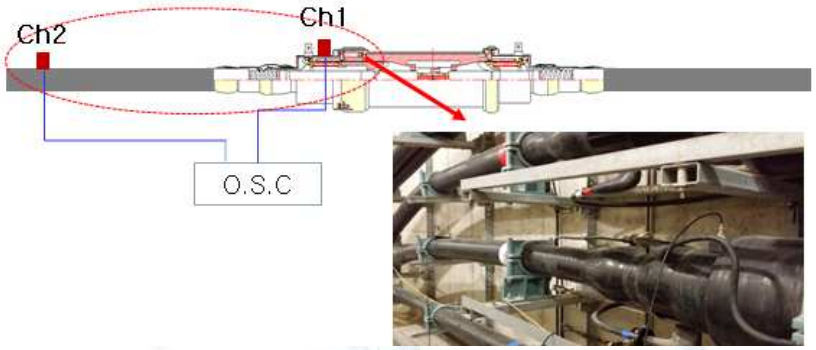
- Pulse wave shape is oscillating in PMJ.
- No. 4 is the optimal position to measure PD in PMJ.

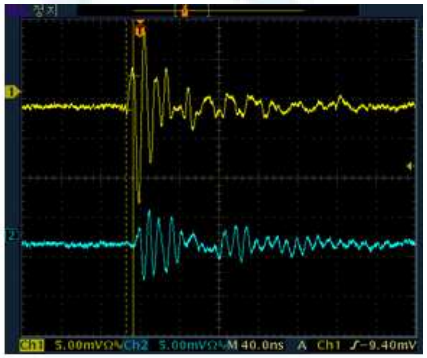
PD Simulation in PMJ (3)

Simulation Result



On-site Measurements

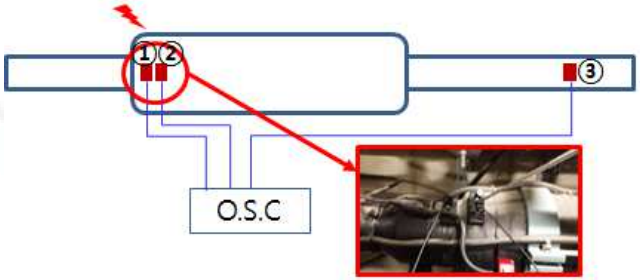


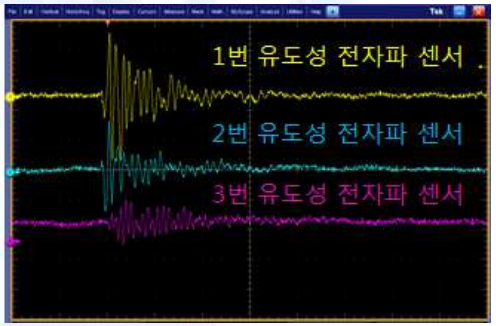


PD pulse in PMJ (345kV XLPE) (1)

PD characteristics in PMJ

- Oscillating several times
- Biggest magnitude at the end of PMJ
- Similar result between simulation and on-site measurement





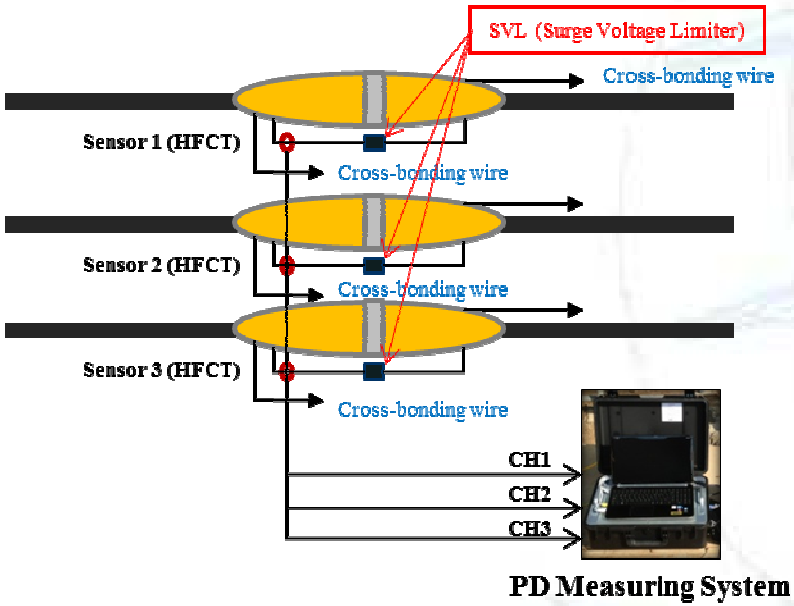
PD pulse in PMJ (345kV XLPE) (1)

Part II

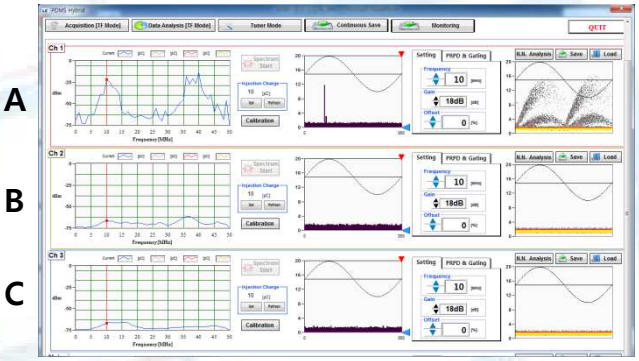
Experience of On-site PD Measurement

PD Measurement in PMJ – 345kV XLPE Cable (1)

PRPD Analysis



PD Measuring System



< 10MHz >

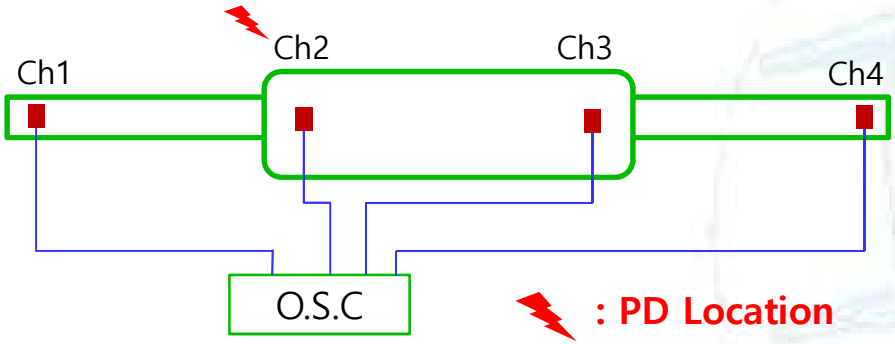
< 45MHz >

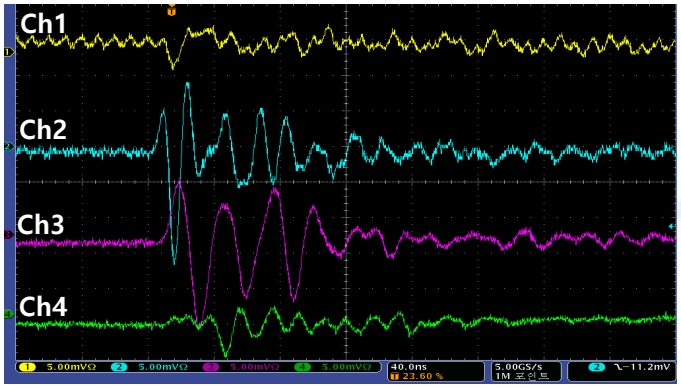
- Void patterns were appeared.
- Phase A would be a source.
- High frequency component exist.

PD Possible !

PD Measurement in PMJ – 345kV XLPE Cable (2)

Estimation of PD Location : TOA method





Δ_{1-2} =9ns

Δ_{3-2} =7ns

Δ_{4-2} =22ns

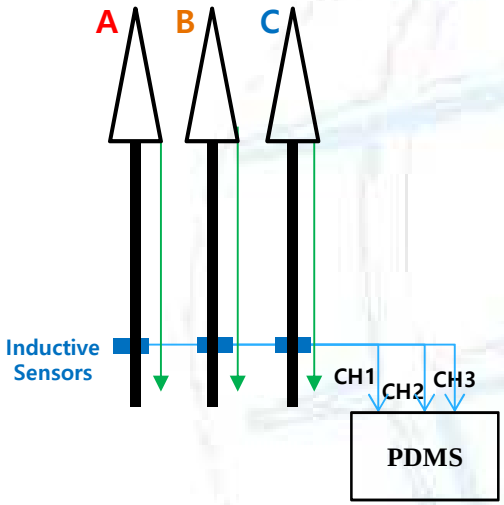
- CH2 is the fastest.
- Polarities of CH1 and CH2 are opposite.

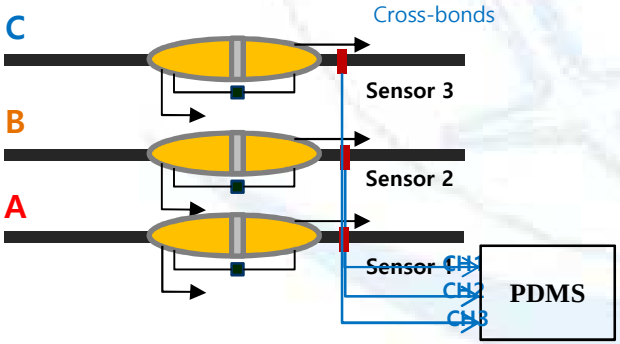
- CH2 must be the location.

PD Measurement in EBA – 345kV XLPE Cable (1)

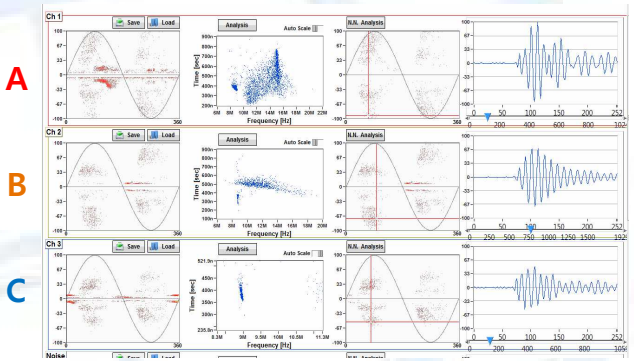
PRPD Analysis

- Similar void patterns in EBA and J/B1.
- Frequency in EBA is higher than in J/B1.
- Magnitude in EBA is bigger than in J/B1.
- Phase B seems to be the source.

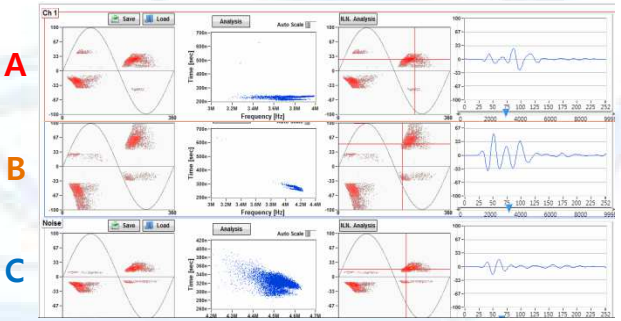




EBA : 9MHz



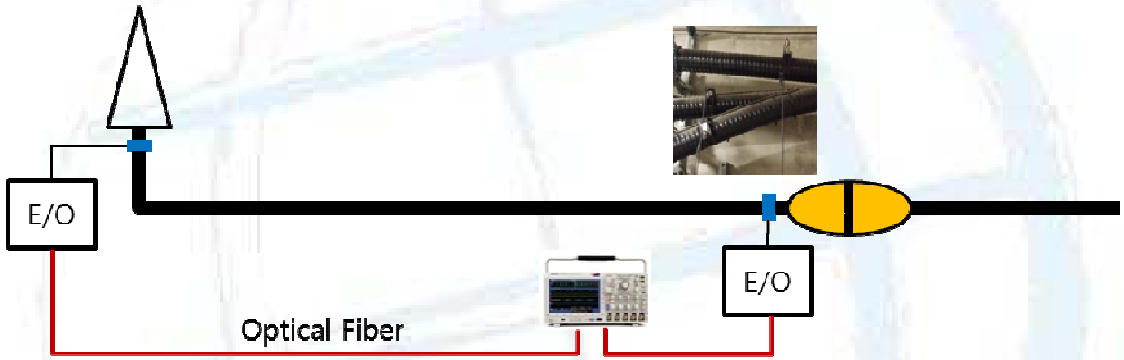
J/B1 : 3.2~4MHz

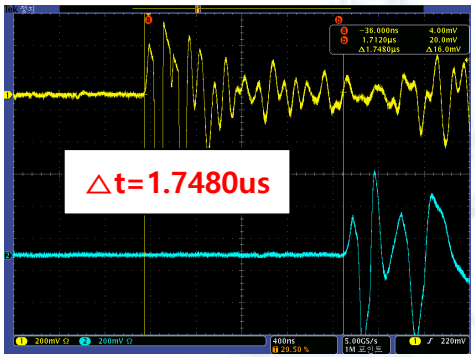


PD Measurement in EBA – 345kV XLPE Cable (2)

TOA using Optical Fiber

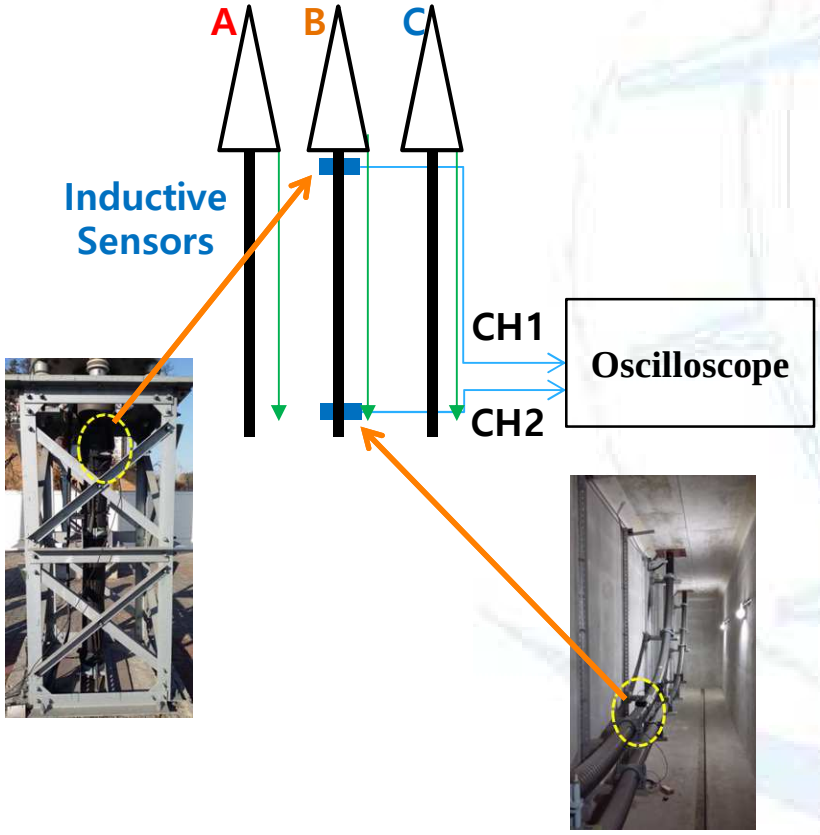
- Time difference is 1,748ns. → 292m
- EBA seems to be the source.

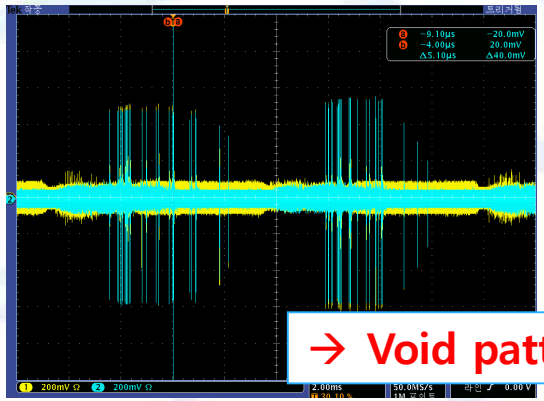




PD Measurement in EBA – 345kV XLPE Cable (2)

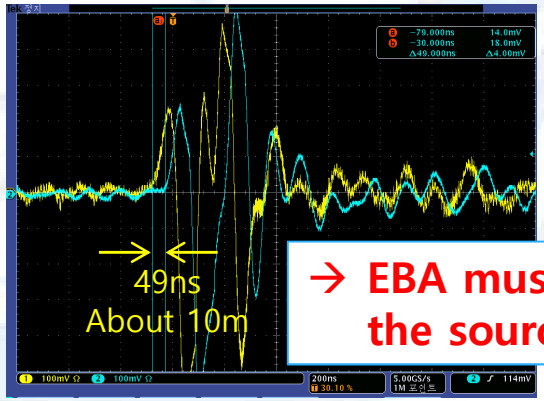
TOA using two inductive sensors





→ Void pattern

< 2ms/div >



→ EBA must be the source.

< 200ns/div >

PD Measurement in EBA – 345kV XLPE Cable (3)

After Dissection

- Yellowish solidified lubricant was found in the EBA.

Conclusions

- Finding PD location is the most important process during the PD measurement.
- TOA(Time of Arrival) and the Comparison of Polarity changes of the First Peak can be the powerful methods for the Finding PD Location.
- PD pulse wave shape itself can give a very important information to separate real PD, but further studies would be needed.

THANK YOU

fisuel