New Dry Type Insulated Non-Conventional Instrument Transformers for Your IEC 61850 Digital Substation

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SUMMARY

Today dry type insulation technologies are available for conventional instrument transformers offering a safe, maintenance-free and eco-friendly alternative to the oil and gas insulation technologies that have been the industry standard. As the power industry prepares for a future digital era grid dry type insulated, non-conventional instrument transformers (NCITs) will continue to offer the same dry insulation benefits for the future digital substation. This paper will review the seamless evolution of dry insulation technology into the digital non-conventional instrument transformers that are starting to appear in the market. Developed to meet IEC 61850 protocols these new NCITs use the same dry type insulation technologies that have a proven service record for durability and reliability with an in-service population of tens of thousands of units installed worldwide.

Our power grids will be stressed harder and harder in the future due to changing consumption patterns. More infrastructure will need to be built. However, the impact of having to build more infrastructure can be mitigated by more use of smart technologies. It is important that utilities start the transition by using more intelligent technologies to manage the monitoring, analytics and information flow at its substations with a strong emphasis of utilizing these technologies down to the distribution levels.

KEYWORDS

Non-conventional instrument transformer, smart grid, dry type insulated, IEC 61850, integrated low power instrument transformer.

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THE GROWING TREND TO DIGITIZE SUBSTATION AUTOMATION SYSTEMS

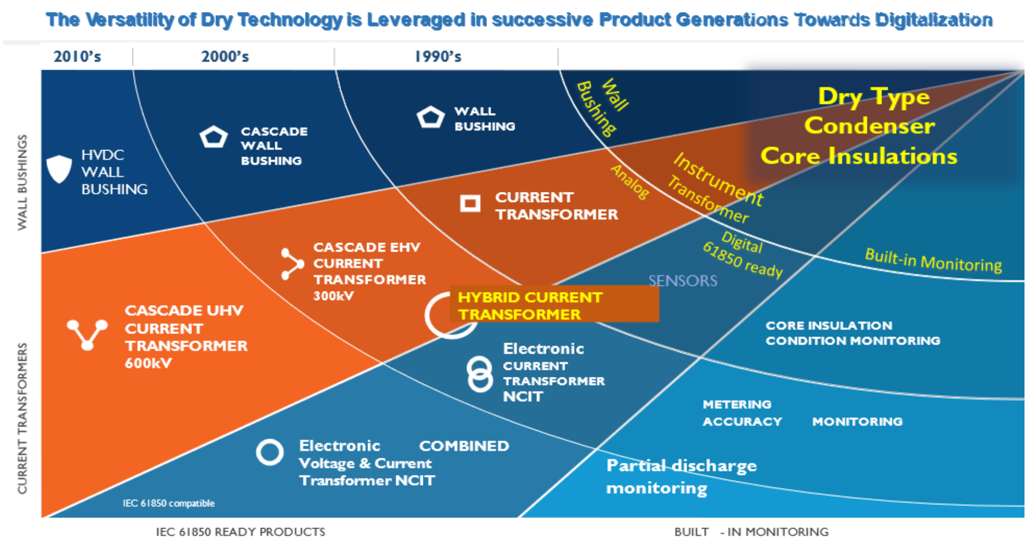
IEC 61850 defines the communication protocols for the next generation of digital substations. Features include data modelling for the protection and control functions, various reporting schemes, the fast transfer of event data and data storage. The Smart Grid will consist of controls, computers, automation, and new technologies and equipment working together, but in this case, these technologies will work with the electrical grid to respond digitally to our quickly changing electric demand [1]. As the power industry is preparing for a future digital era grid there is a growing trend seeing electronic and optical based digital sensors entering new and older substations. The power industry is going through a new learning curve from manufacturing to implementation into the power grid as new technologies and concepts are being introduced.

The smart grid concept will take time to implement fully as it involves millions of different components required to work in harmony. As a first step toward this goal utilities must look to using more intelligent technologies to manage the monitoring, analytics and information flow at its substations with a strong emphasis of utilizing these technologies down to the distribution levels. As it is a new field, many different technological approaches have been proposed. This paper is presenting the unique aspects offered by the leveraging of mature conventional dry insulated designs into digital equivalents.

THE DEVELOPMENT OF DRY TYPE NON-CONVENTIONAL STAND-ALONE INSTRUMENT TRANSFORMERS

Dry type current transformers ranging in voltages from 66 kV to 600 kV that use a PTFE (PolyTetraFluoroEthylene) tape as its primary conductor insulation have been in-service for over 25 years. This dry type insulation technology has a proven service record with over 25,000 units operating reliably in all types of extreme environments worldwide [2] [3].

Traditional instrument transformers are not able to meet many of today’s changing power grid performance needs which include an increasing demand for digitally integrated monitoring and control systems. This has led to the development of the new electronic instrument transformer technology with its better performance characteristics. This paper introduces some of the recently developed dry type insulated non-conventional instrument transformers that meet the IEC 61850 protocols and beyond. But a key distinction comes from the fact that these non-conventional instrument transformers have been designed around dry type insulation technologies that were initially introduced for the conventional instrument transformer market [4]. This provides a seamless transition from analog to digital with a proven record for performance and reliability. The digital function can be operated the same way as the conventional instrument transformer as the sensing and analog to digital conversion (ADC) has been kept at ground potential.



The Electronic Current Transformer with Rogowski Coil Current Sensing (eCT)

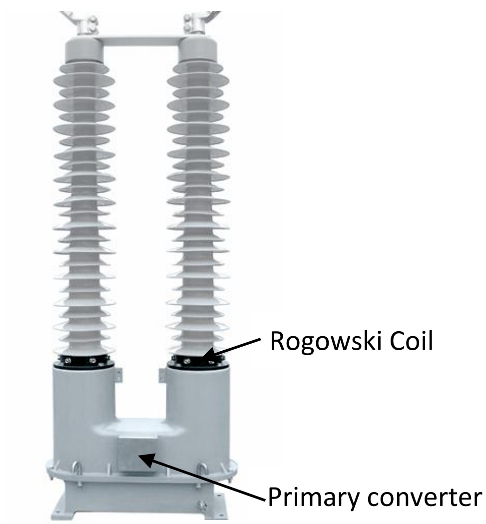
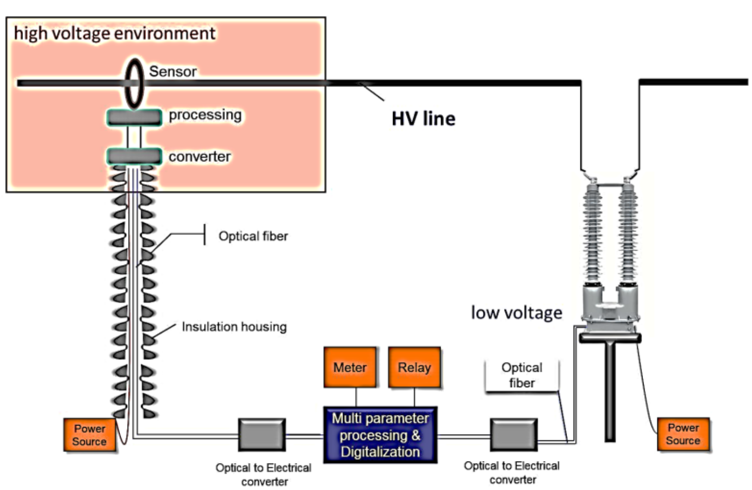


Figure 1 – the eCT

This electronic CT (eCT) uses a dead tank design that houses the sensor and primary converter in a grounded box which provides shielding from electromagnetic interference, temperature variations and vibration (see Figure 1). A dead tank design also allows for quick "plug and play" installation at substation locations typically used for older electromagnetic CT installations and easy replacement and electronics maintenance. Figure 2 below clearly shows the advantages of a dead tank sensing configuration over the conventional HV sensing configuration.



Conventional HV sensing configuration	Dead Tank Sensing Configuration (eCT)
• The sensing part is located at high voltage line level. • Insulation is needed from the HV line to ground to protect connecting fibers • Sensor needs power from ground to HV line • Requires a specific installation. • With sensing being at high voltage level it is exposed to climate rigors and complicates maintenance	• Sensing is at the low voltage insulated end of the eCT • Sensor & converter in grounded box, shielded from electromagnetic interference, temperature changes and vibration • Sensor powered by grid at ground level • The eCT can be installed at the same location and under the same configuration of older electromagnetic CTs • Easy replacement, maintenance and electronic upgrade

Figure 2 – Fiber-Optic Current Sensing vs Dead Tank Current Sensing

Hybrid Designs – A flexible option to transition to digital

Due to its complexity the IEC 61850 standard will take years if not decades to implement in most countries. In the meantime, CTs that are failing or approaching their end of life will still need to be replaced. The choice of using the same dry type insulation invented for conventional CTs allowed for a unique hybrid option; combining both analog and digital sensing in the same unit. For utilities with a focus on a future digital upgrade of their grid a hybrid eCT that is equipped with both traditional secondary iron cores and a Rogowski sensor and converter has been developed (see Figure 3). When the time comes for a substation to be digitally operated a simple switch-over connection in the secondary box is all that is needed to make it a fully operational electronic CT.

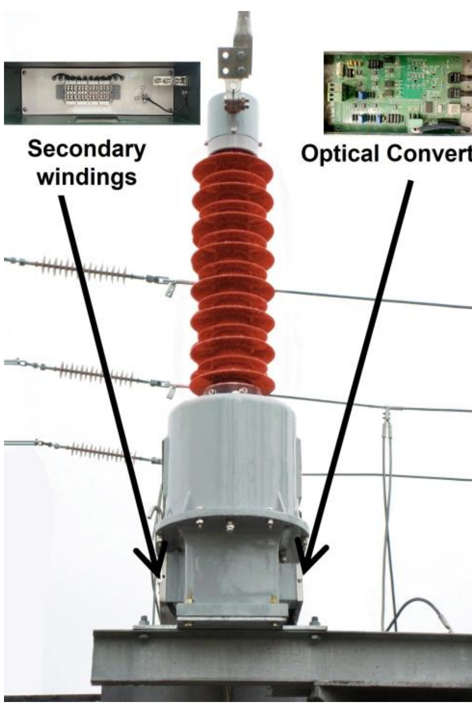


Figure 3 - the Hybrid eCT

The Electronic Dry Type Insulated Combined Electronic Voltage and Current Transformer (eVCT)

Figure 4 - the eVCT

This device provides a seamless transition to IEC 61850 operations. The measurement functions are based on measurement of the voltage using a capacitor voltage divider and current using a Rogowski Coil. As shown in Figures 5 and 6 the eVCT uses a dry type high-voltage Resin Impregnated Fiberglass bushing insulation structure [5] with three sets of capacitive screens as a primary winding: C1 is a voltage-grading capacitor group for high-voltage insulation, Cs is a voltage-dividing capacitor group made according to the design requirements, and C3 is a shielded capacitor group designed for interference immunity. Using this capacitive design, a voltage signal source with a simple structure, strong stability and a high precision level can be obtained. An acquisition unit converts the recorded data into a digital serial protocol which is transmitted via optical fibre to the Merging Unit (MU) located in the control room. The fundamental difference from other electronic instrument transformers in the market is that the collector (Rogowski Coil/capacitor voltage divider) and the acquisition unit are at earth potential. By installing these devices at earth potential the problems of electromagnetic interference, instability and power supply are easily solved and maintenance is more convenient.

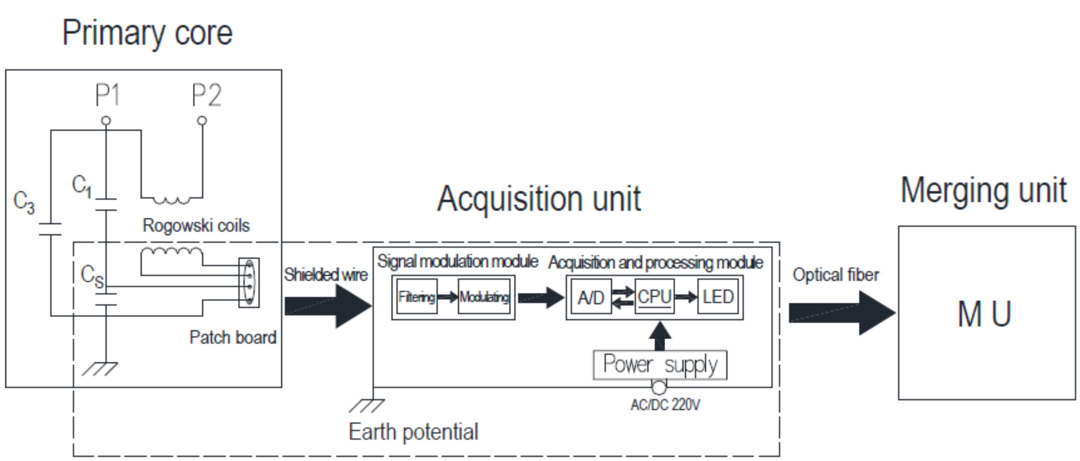
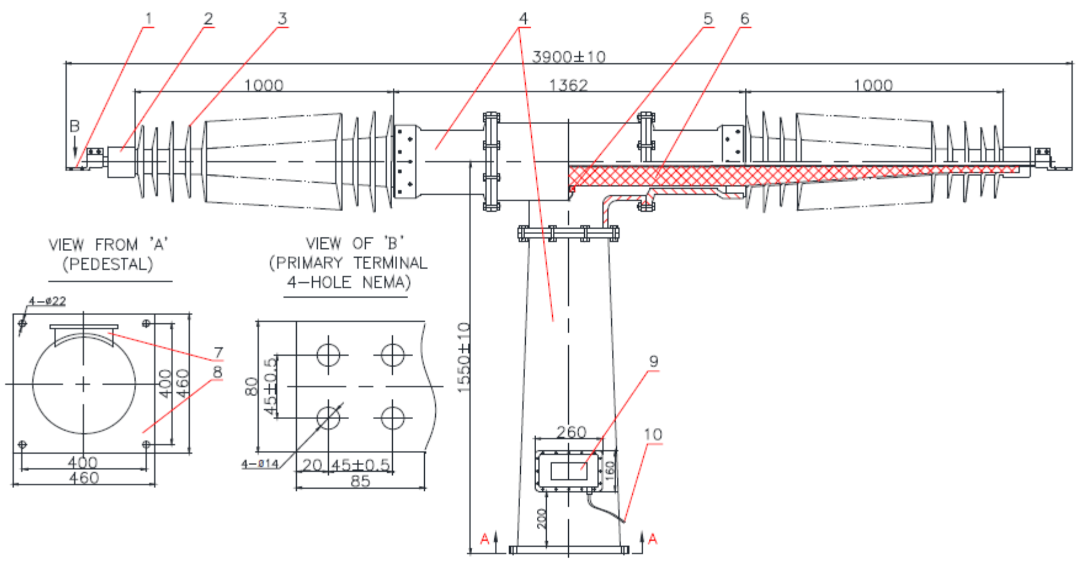


Figure 5 – eVCT Schematic Representation

eVCT Specifications	
Rated voltage:	35~ 1000 kV
Rated frequency:	50 Hz, 60Hz
Rated primary current:	100~4000A
Accuracy level current: Accuracy level voltage:	0.5S/5P 0.5/3P
Accuracy limit factor:	20, 25, 30, 35, 40
Sampling frequency:	80~256 points/week
Rated secondary output: (measuring) voltage: Rated secondary output: (measuring / protection) current:	2D41H 2D41H/01CFH
Rated short-time thermal current:	50kA, 3 sec
Rated dynamic current:	125kA
Electromagnetic compatibility immunity	Assessment Criteria A
Communication Protocol	IEC61850-9-2LE
Power supply:	DC 220V/0.1A
Ambient temperature:	-40 °C to +70 °C



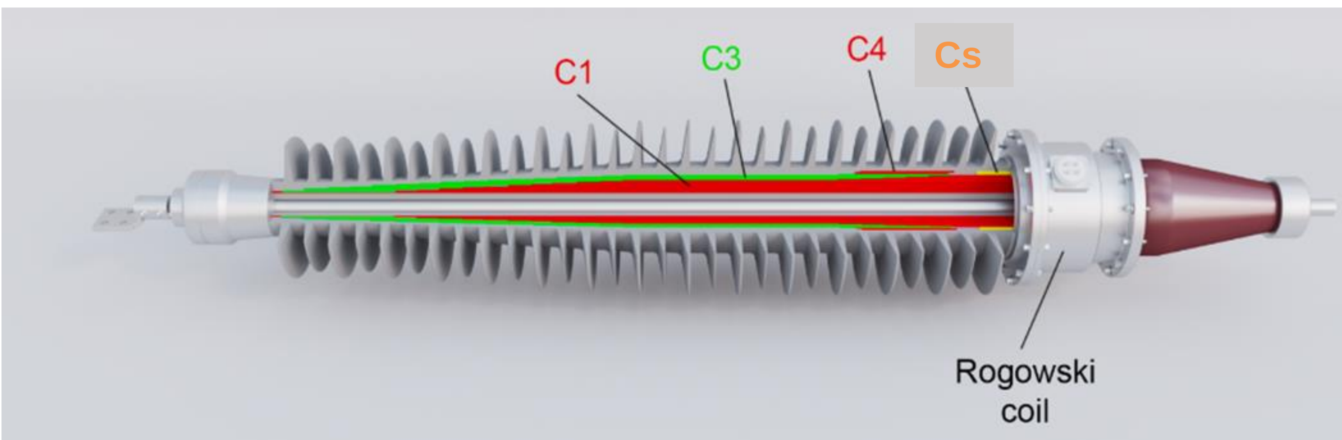
10	COMBINED CABLE AND OPTICAL FIBER	COPPER AND FIBER
9	NAMEPLATE	STAINLESS STEEL
8	PEDESTAL	ALUMINIUM
7	CASING FOR TERMINAL BOX	ALUMINIUM
6	PRIMARY WINDING	DRY TYPE BUSHING
5	ROGOWSKI COIL	COPPER
4	GROUND FLANGE	ALUMINIUM
3	SHEDS(Light Gray)	SILICONE RUBBER
2	EQUALIZER	ALUMINIUM
1	PRIMARY TERMINAL	COPPER
NO.	DESCRIPTION	MATERIAL

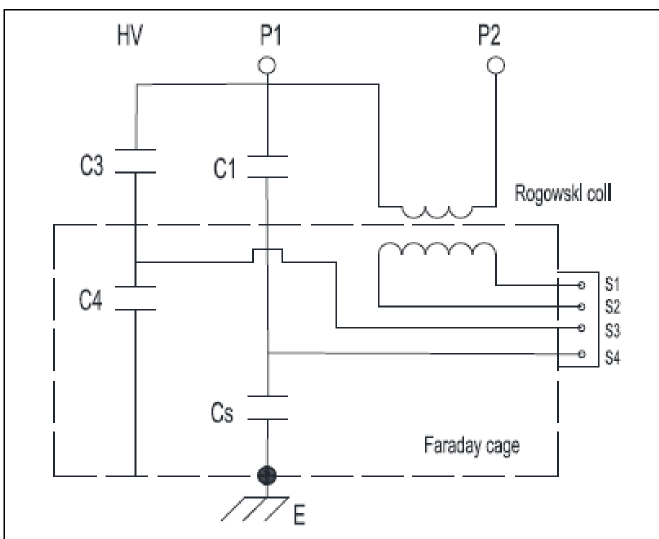
Figure 6 – eVCT Physical Layout and Specifications

THE DEVELOPMENT OF A DRY TYPE RESIN IMPREGNATED FIBERGLASS BUSHING WITH INTEGRATED LOW-POWER INSTRUMENT TRANSFORMERS

As shown in Figure 7 a dry type Resin Impregnated Fiberglass bushing [5] has been developed with integrated low power voltage and current transformers (capacitive divider (C1/Cs) and Rogowski coil for voltage and current measurement, respectively). The integrated capacitance scheme for this bushing also includes a C3 anti-interference capacitance to improve the accuracy of the voltage signal and an information collection capacitance (C4) for capturing high frequency partial discharge pulse current signals. Special processing devices can be provided for online monitoring of the bushing's primary insulation condition and partial discharge activity.

By integrating these low power voltage and current transformer functions into a dry type bushing technology that is known for its anti-seismic, explosion-resistant and intelligent monitoring characteristics the utility now has another tool for its digital substation to reliably replace a number of stand-alone instrument transformers with a single insulating component. Figure 8 shows an application example for this type of bushing in a substation.





C1 – main capacitor rated for the system voltage
Cs – low-voltage capacitor that extracts the voltage signal
C3 – anti-interference capacitor
C4 – information collection capacitor

The electronic voltage transformer function is realized by measuring the terminal voltage on Cs.

The electronic current transformer function is realized by using the principle of Faraday electromagnetic induction with several large air-core coils installed inside the grounded flange and outside the grounding screen.

Figure 7 – Dry Type RIF Bushing w/ Integrated LPITs

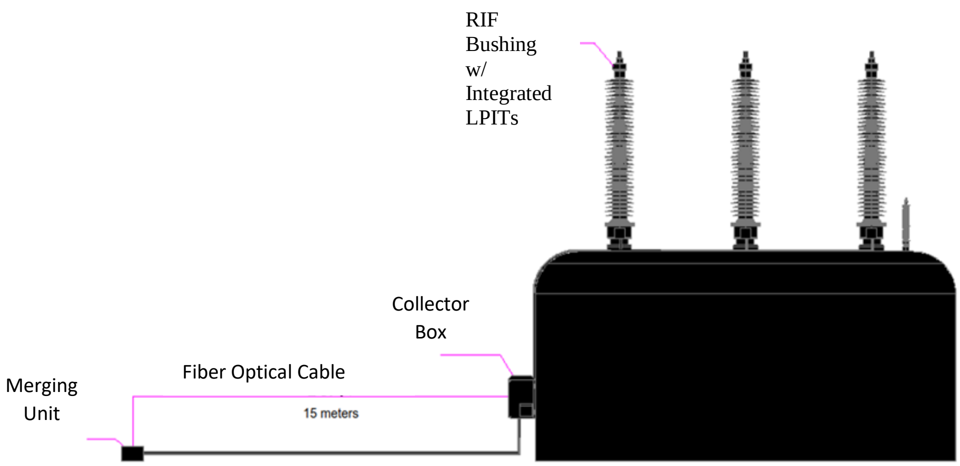


Figure 8 – An Application Example for the Dry Type RIF Bushing w/ Integrated LPITs

CONCLUSION

Our power grids will be stressed harder and harder in the future due to changing consumption patterns. More infrastructure will need to be built. However, the impact of having to build more infrastructure can be mitigated by more use of smart technologies. One area where these technologies can make a big impact is the digital substation. The digital substation is not only cheaper to build than conventional substations, but its two-way information flow between the utility and customer will allow the utility to better manage a changing load demand.

The power industry is moving quickly in the development of key digital substation assets such as high voltage circuit breakers, power transformers and current sensors. The digital approach for instrument transformers presented in this paper provides utilities with seamless options for implementing dry type digital technology into their substations, with the distinct benefit of previous field experience with dry type conventional (analog) instrument transformers, which have already validated the anti-seismic, explosion-resistant and environmentally friendly benefits of the dry insulation technology.

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