# Voltage and Pulse Endurance Test of New Generation wire CORONA-R™ developed by P. Leo - BCwire®

*Mr. Wai Fung Choi, Prof. Eric Cheng and Mr. Peter Wong*

***Abstract*— Inverters are commonly used in varies motor application. This greatly increases the pulse endurance stress of the wire due to switching transience. A new type of wire with three layers of insulation material has been developed by BCwire® to overcome aforementioned problem. Which this paper will give brief introduction of the wire, details test procedure, preliminary results with compared with traditional insulation wires which where commonly used nowadays. The aim of this paper is to let user have better understanding of this new type of wire and give enough information for wire selection.**

## I. Nomenclature

Wire of different insulation materials will be introduced here:

The wire with name PE(I)/PAI- is with two insulation layer that Polyamideimide in the outer layer and with a Polyterster in the inner layer coat on the conductor. NEMA MW35.

While the new wire developed by BCwire® with name MPE/CR/PAI is with three insulation layer. The outer layer is Polyamideide. The middle is a Corona Resistant Enamel. The inner layer of Modify Polyesster coated on the inductor.

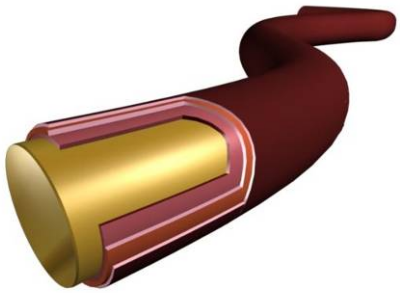

Fig 1: Configuration of the BCwire with 3 insulation layers MPE/CR/PAI

This work was supported in part by The Hong Kong Polytechnic University and P. Leo & Co., (B.C.) Ltd. BCWIRE®

Mr. Wai Fung Choi is with Power Electronics Research Laboratory, the Department of Electrical Engineering,, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong(eewfchoi@polyu.edu.hk)

Mr. Peter Wong is with P. Leo & Co. Ltd. , P.O. Box 94250, 'Richmond,B.C.V62A6, Canada Email: peter@pleo.com)

Prof. Eric Cheng is with the Department of Electrical Engineering,, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong(eewfchoi@polyu.edu.hk)

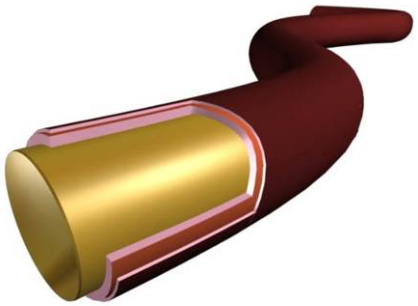

Fig 2: Configuration of the BCwire with 2 insulation layer MPE/PAI-CR

Another new wire also developed by BCwire® with name MPE/PAI-CR is with two insulation layers that Polyamideimide in the outer layer and with a Corona Resistant Enamel in the inner layer of Modify Polyester coat on the conductor. With new nanotechnology the MPE/PAI-CR, the outerlayer with corona resistant enamel with partied size distribution D[v,0.10] (microns)=0.09, the wire flex properties (20% snap) 3x compare the old design 20% 5X has been much improved.

The aforementioned two wires by BCwire® is feathered by the Nanotechnology in the Basecoat or Topcoat can substitutable for MW35 or MW37 & most MEMA standard.

## II. Introduction

Insultaion of copper wire is an important process in transformer, inductor and motor design [1-2]. In the past, there are a number of studies in the work including using enamel, corona-resistance enamels, mica tapes, and fuses glass and PET fibers over enamels has been used [3]. The insulation tapes for layer insulation includes corona-resistant enamel, corona resistance enamel, polyester and epoxy-bonded mica, silicone tapes and film-backed mica tapes are used. Corona is an ionization of gas that occurs in between spaces of the insulation material (or namely 'voids') when the stress of high voltage gradient exists, that also cause electron discharge. The insulation material will eventually breakdown by the bombardment of ions and case electrical failure.

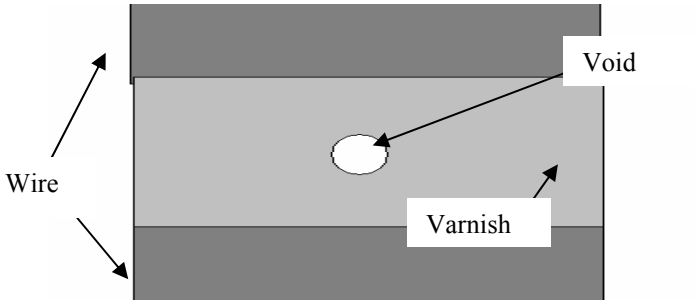


Fig 3: Void in Magnet wires

Usually using layers of tapes or even gas [4] is very inconvenient and increase the overall size, and cost. Using internal insulation of the wire will reduce the external insulation and cost.

Several types of wire in size AWG18 with the same thickness of insulation have been tested. They are namely:

*A. PE(I)/PAI (MW35) Magnet wire in Single coat*

*B. PE(I)/PAI (MW35) Magnet wire in Heavy coat*

*C. MPE/CR/PAI CORONA-R™ Magnet Wire*

*D. MPE/PAI-CR—CORONA-R™ Magnet Wire*

Voltage and Pulse Endurance tests were performed on above wires. Details description will be explained in the coming sections.

## III. WIRE TEST

The Voltage and Pulse Endurance tests are aimed to simulate the situation in realistic application in order to study the wire performance. In this case the voltage test is used to simulate the wire used in traditional line frequency application, while the pulse endurance test is to give better simulation of inverter feeding motor application. The test temperature was also set to a defined possible rise region to make the test closer to the actual environment.

### *A. Comparison of Electrical Stress Region*

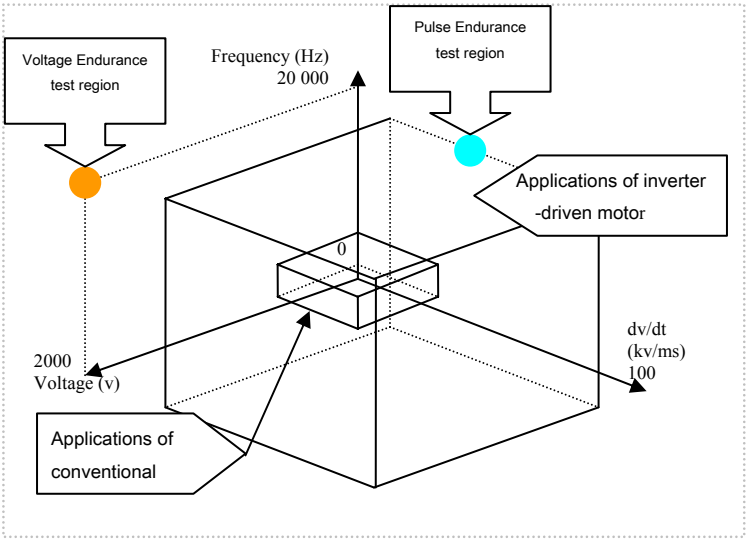


Fig 4: The test condition with respect to the 3-D coordination of voltage, dv/dt and frequency

The above diagram demonstrate the electrical stress region on varies application. The test we conducted is by the suggestion of the existing standards with selection of the extreme point of this diagram.

### *B. Pulse Endurance Tester Schematic*

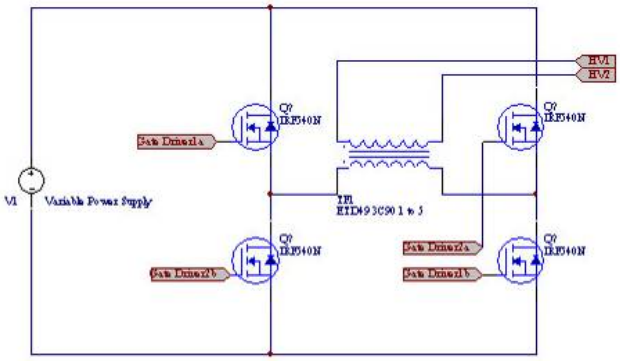


Fig 5: H-bridge circuit generating the pulse endurance test waveform

In order to generate a 2000Vpk-pk waveform required for the pulse enduance test, the circuit as shown in Fig 3 has been built to make high speed switching waveform. Fast gate driver was used and the full bridge transformer has been specially built with alternative layer of winding in order to decrease the leakage induction thus enhance the switching dV/dt rate.

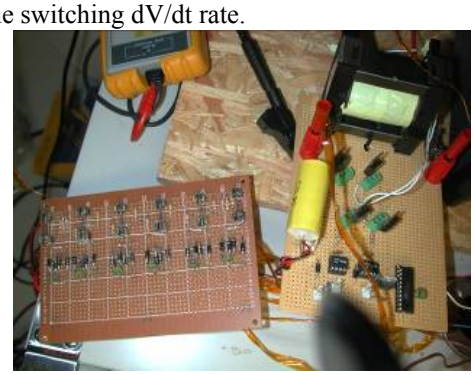

Fig 6: Prototype circuit for the endurance test

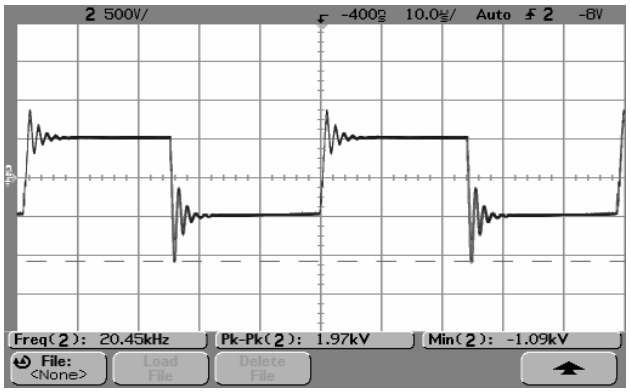


Fig 8: Voltage waveform of the pulse endurance test

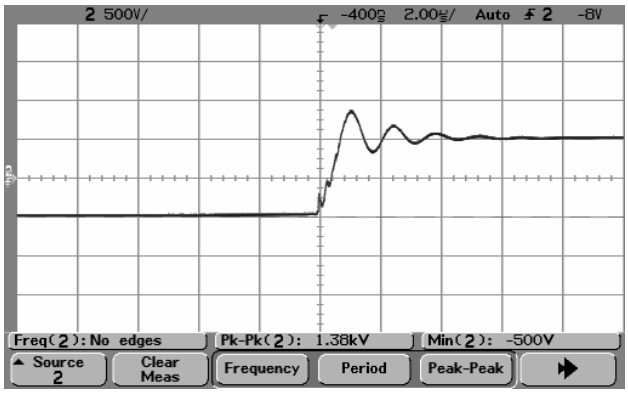


Fig 9: Rising edge of the voltage

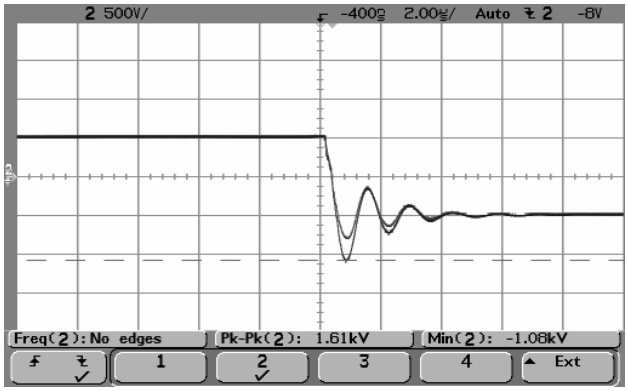


Fig 8: Falling edge of the voltage waveform. The dual voltage level in this waveform is caused by the occasional occur of the corona partial discharge

This test volatge is used to put in twisted pair of wire with a 50mA fuse in series. The breakdown of fuse indicate the insulation breakdown of wire and spark occurred..

### *C. Pulse Endurance Test Conditions*

Fig 10: Thermal chamber used for the endurance test

The pulse endurance test specifications as follow:

- The test temperature is 150±5°C, test voltage will be applied when oven reaching target temperature
- test voltage: 2000Vpk-pk
- fall time and rise time: 635ns and 425ns respectively
- trip current: 50mA by fuse
- The wire samples are prepared according to standard IEC-851-5

### *D. Pulse Endurance Test Results*

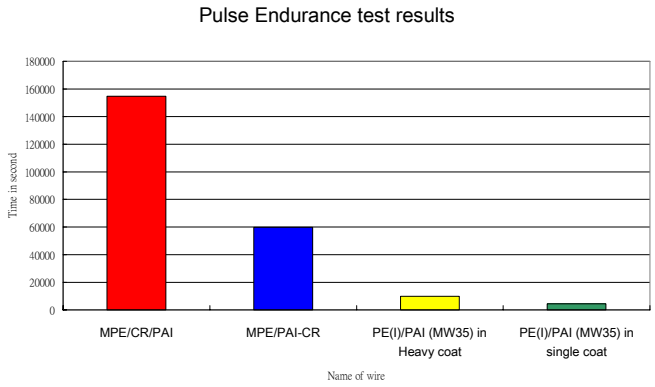


Fig 11: The results of the pulse endurance test. The MPE/PAI-CR wire are still going on testing and better performance were expected

*E. Voltage Endurance Results*

2000V r.m.s at 50Hz is applied to twisted wire specified by IEC-851-5. This voltage is generated by step up transformer.

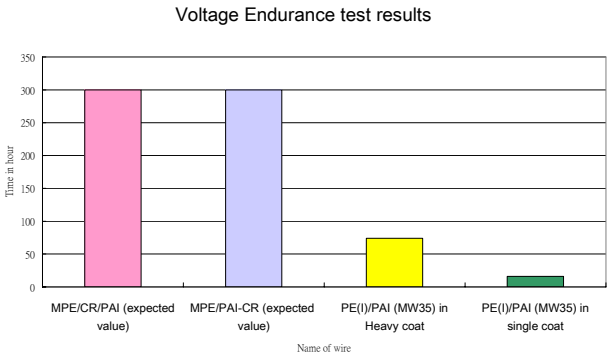


Fig 12: Results of the voltage endurance test, two CORONA-R™ wires are still on test on 2006-10-31

*F. Electrical Properties Comparison*

Table 1: Result of the voltage endurance test

| Wire Type | MPE/CR /PAI | MPE/PAI -CR | 18 H MW35 | 18 S MW35 |
|---|---|---|---|---|
| 2000 V rms, @ 150 C | * | * | 74.1 hrs | 16.2 hrs |
| Pulse Endurance Index | 34.4 | #13.3 | 2.2 | 1.0 |

*** The voltage endurance test are still undergoing at 2006-10-31, the figure above only give a estimated value**
**# The MPE/PAI-CR wire are still going on testing and better performance were expected**

*G. MPE/CR/PAI wire applications:*

The pulse and voltage endurance test results enable us the measures on now to replace the existing design with the new generation wire. Below are some working examples:

*VDT -Open Ventilated Dry Type Transformers*

Fig 13: A typical high voltage transformer using open ventilation

VDT – Open Ventilated Dry Type transformer wound with **CORONA-R™** wire. The use of **CORONA-R™** magnet wire gives higher resistant to these Electrical Stresses and permits design changes that result in improved winding efficiencies. For example, the strand insulation will be designed for the system, including the resin/varnish used for the coil consolidation. Ionization damage can occur in voids, surface, corners, and areas where the field is divergent.

*HVT – High Voltage Transformer*

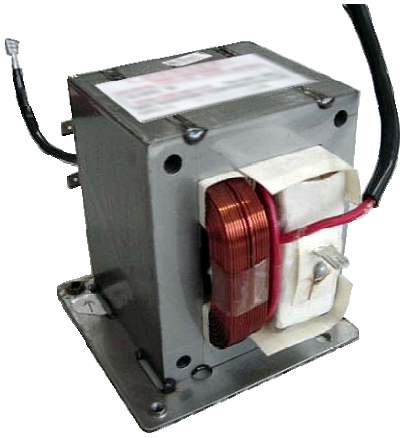

Fig 14: HV transformer using Silicone rubber wire

This type of transformer design need to have a filament wire in between the Primary and Secondary coil, This wire need to have high dielectric breakdown (over 12kV) and with good corona resistance. Right now, HVT manufacturer uses Silicone Rubber Wire and with Mica Sheet to protect for the Corona with very high material cost. With new developed **CORONA-R™** wire, they can use our **CORONA-R™** wire to replace the silicone rubber wire and reduce the Mica sheet thickness.

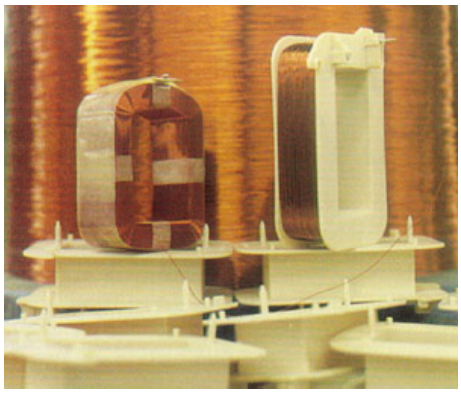

Fig 15: Use as secondary wire

## IV. Conclusion

The endurance test for the copper wire has been examined. The new copper wire is insulated by 3 layers of MPE/CR/PAI that is namely **BCwire®**. Experimental test has confirmed that the endurance is superior as compared to the conventional single and double insulation wire. The new wire can be sued for high voltage transformer and the insulation material or tape can be reduced. IT will also improved the overall coupling of the transformer and improve the efficiency.

## V. REFERENCES

[1] Nikolajevic, S.V.; Pekaric-Nad, N.M.; Dimitrijevic, R.M.;, "A new concept in construction of cable terminations for medium voltages", IEEE Transactions on Power Delivery, Volume 13, Issue 3, July 1998, pp. 712 - 717

[2] Erdman, J., Pankau, J., Campbell, J., Skibiniski, G. "Assessing AC Motor Dielectric Withstand Capability to Reflected Voltage Stress Using Corona Testing" IEEE 1996 IAS.

[3] Rehder, R.H.; Draper, R.E.; Moore, B.J.; "How good is your motor insulation systems", IEEE Electrical Insulation Magazine, Volume 12, Issue 4, July-Aug. 1996, pp. 8 – 14.

[4] Cooke, C.M.; Velazquez, R.; "The insulation of ultra-high-voltage in coaxial systems using compressed SF6gas", IEEE Transactions on Power Apparatus and Systems, Volume 96, Issue 5, Part 1, Sept. 1977, pp. 1491 - 1497

## VI. ACKNOWLEDGEMENT

The author gratefully acknowledge the financial support of the Hong Kong Polytechnic University and P Leo & Co. Ltd.

## VII. BIOGRAPHIES