Influencing Factors on the Lifetime of Turn-to-turn Insulation for Type II Inverter-fed Motors at Repetitive Square Voltages

1. Introduction

Because of many significant advantages such as improved control, energy efficiency and compactness with respect to DC voltage drives, power electronics drives has been widely used in the past decades of years. Shortly after this drive mode became popular for controlling induction motors, it became evident that the impulse surges, induced by interaction between converter and inverter-fed motor, would cause premature failures of stator insulation systems[1-4]. According to the research results in recent years, partial discharge is claimed to be the root cause of these premature failures[5, 6].

International Electrotechnical Commission (IEC) has released technical specifications (TS) (IEC TS 60034-18-41 for Type I motors and IEC TS 60034-18-42 for Type II motors)[7, 8] to reduce the impacts of above insulation reliability problems. For lower voltage (<700V) Type I inverter-fed motors, whose insulation systems are made up of organic materials, PD should not occur during the expected lifetimes. Therefore, according to IEC TS 60034-18-41, partial discharge inception voltage (PDIV) measurements should be performed to ensure that the PD will not occur during the whole life time of Type I inverter-fed motors. While for Type II motors, who work at higher voltages (>700V) and have far more complex insulation systems, life tests should be carried out to ensure the quality of insulation systems in accordance with the IEC TS 60034-18-42.

The TS specified that, life tests both at repetitive square and AC voltages, should be carried out on insulation models, which are made to replicate the insulation features of Type II motor insulation systems. To get reasonable life times results, suitable square voltage parameters should be selected, and there are following important points should be considered,

(1) Because of the larger capacitance of Type II motor insulation models, the rise time of the square voltage finally stressed on the samples is difficult to controlled at a required value. Therefore, the effect of the rise time on lifetime of insulation models should be investigated.

(2) Accelerated aging tests are generally performed at high frequency square voltages. Due to frequency can affect the space charge accumulation inner the PD points, probably, life test results at different frequencies would be not linear, which should be considered when insulation systems quality is evaluated based on the life test results at some specified frequency.

(3) Since the duty cycle of square voltage waveforms would change PD occurring probabilities, magnitude and thus, life time test results, this parameters should also be considered when performing life tests on insulation models.

2. Research target and experimental system setup

This research aims to investigate the influence of impulse voltage (rise time, frequency, duty cycle) on the lifetime of insulation system models used in Type II inverter-fed motor insulation systems. Since PD induced insulation aging is a leading factor of insulation life for form-wound insulation, the effect of impulse voltage parameters on PD characteristics will be studied, such as PD pulse time and frequency features, PD magnitude variation trends during whole life time and

insulation surface erosion conditions.

Endurance tests will be performed at square voltages and during the whole lifetime, PD events will be recorded resorting to ultra-high frequency (UHF) test method and computer controlled data acquisition system. The endurance test and PD measurement system is sketched in Figure 1.

The Tech-square is developed based on an Insulated Gate Bipolar Transistor (IGBT) switch and can provide square waveforms with controllable duty cycle and frequency (≤10kHz). By adjusting the connected resistance board, it can output repetitive square voltage waveforms with different rise times from 50ns to 1.0μs. Trek 20/30 is a high voltage power amplifier, able to generate square voltage waves with rise times longer than 16μs and frequency no higher than 5kHz. The duty cycle of two generators can be controlled in a large range. The insulation system models, one end is connected to high voltage and the other to ground, are fixed below an insulation board. An horn antenna, manufactured by Techimp, is placed at a distance of 20cm from and directed to the sample. A high voltage divider (bandwidth 50MHz, 1000:1) is used to get the low voltage signal used for phase synchronization. The sample, UHF sensor and divider are placed in a climate chamber in order to control the environment parameters (temperature and relative humidity) . A wide band/high speed digital oscilloscope (maximum 16Gs/s sample rate, 2GHz bandwidth) is used to record PD pulses cycle by cycle. The trigger voltage and PD pulse data is transferred to PC and, database is used to store the great mount data during life tests. In order to obtain phase resolved PD (PRPD) patterns automatically and comparison analysis with UHF data, Techimp PD-Check PD test system is also used to record PD patterns automatically.

In order to suppress the interference induced by impulse generator switch-on/off activities[9], both hardware and software high-pass will be used, depending on the signal-to-noise ratio requirements.

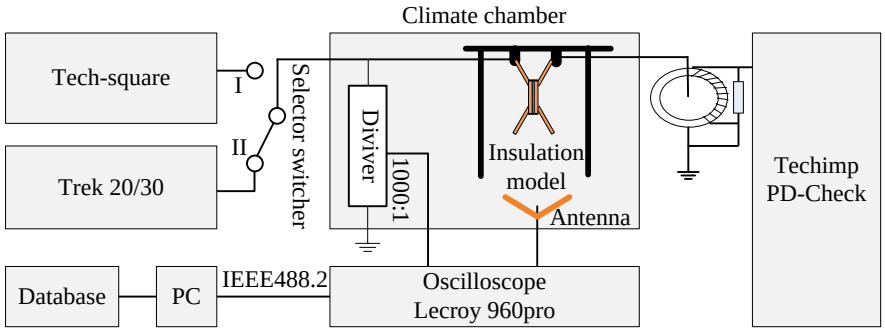
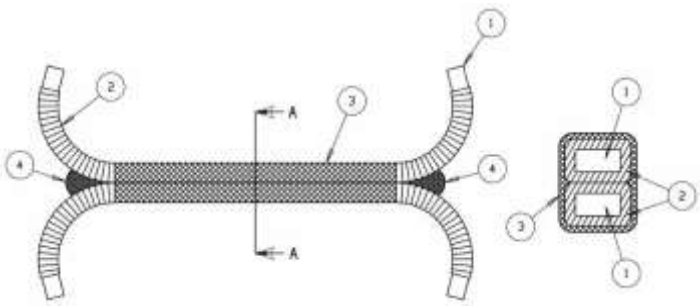


Figure 1. The endurance test and PD measurement systems



1. Copper conductor 2.Turn insulation 3.Mainwall insulation 4.sillicon filler

Figure 2. Turn-to-turn insulation samples[8]

The insulation model used in this study is shown Figure 2. To get statistical life time results, at each square voltage with specified parameters, at last 5 samples will be tested. The statistical results, including, for example, average lifetime, Weibull parameter values, will be calculated based on the experimental results.

3. Resources needed for the study

Table 1 reports all resources will be needed for this study, including equipments, specimens and software. It can be seen that most resources have been available. The software for data acquisition should be improved in order to (1) save data storage space for a great mount PD data recording during the life tests; (2) increase the data transferring and processing speed at high speed data acquisition condition. Moreover, in order to get lifetime statistical results, many insulation system models are needed, this work should be finished before the study.

Table 1. All the resources needed in this study

No.	Resource Name	Available
1	Tech-square impulse voltage generator	Yes
2	Trek 20/30 power amplifier	Yes
3	High voltage probe (1000:1, bandwidth 50MHz)	Yes
4	Digital Oscilloscope (Lecroy 9600, maximum sample rate 16Gs/s, bandwidth 2GHz)	Yes
5	Data acquisition software and hardware based on virtual instrument technologies	No
6	PD monitoring systems (Techimp PD-Check) and PD current transformer sensor	Yes
7	PD UHF sensor (a horn antenna) and 500MHz high-pass filter	Yes
8	Type II insulation system model specimens	No
9	Climate chamber	Yes
10	Database system (SQL Server 2008 development version)	Yes
11	Optical microscope	Yes
12	scanning electron microscope	Yes

4. Experimental results and data processing

The experimental results obtained in this study and related data processing methods will be used are reported as follows,

(1) Life time data of all insulation system models. At least 5 life time data at each square voltage condition will be obtained, on which statistical calculation, including averaging, Weibull analysis, will be performed.

(2) PD magnitude, occurring phase and firing voltages. After PD pulse extracting based on the original data, the processed PD data will be save into database, which makes it easier to carry out afterward statistical calculation. Based on the data, the results such as PRPD patterns, PD magnitude vs. life time, PD magnitude variation trends during the whole life times of the tested samples, lifetime vs. square voltage parameters (rise time, duty cycle and frequency), will be obtained.

(3) Breakdown erosion photos taken by optical microscope and scanning electron microscope, will be used to study the possible different erosion status caused by PD events at different square

voltage parameters.

5. Conclusions expected

According to life time test results and PD statistical values obtained in this study, following conclusions could be expected,

(1) The effect of square voltage parameters to the lifetime of insulation models used in Type II inverter-fed motors. The mechanism interpretation would be given based on a great mount of PD data monitoring during the endurance tests;

(2) Provided that the effect caused by impulse voltage waveform parameters on Type II insulation models should not ignored, some suggestion for parameter selection, when performing qualification and type tests required in IEC TS-60034-14-42, would be given ;

(3) The PD data and PD erosion photos, would provide insight into the PD physics of PD at repetitive square voltages and based on which, some suggestions for corona resistance material development and improvement would be given.

References

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