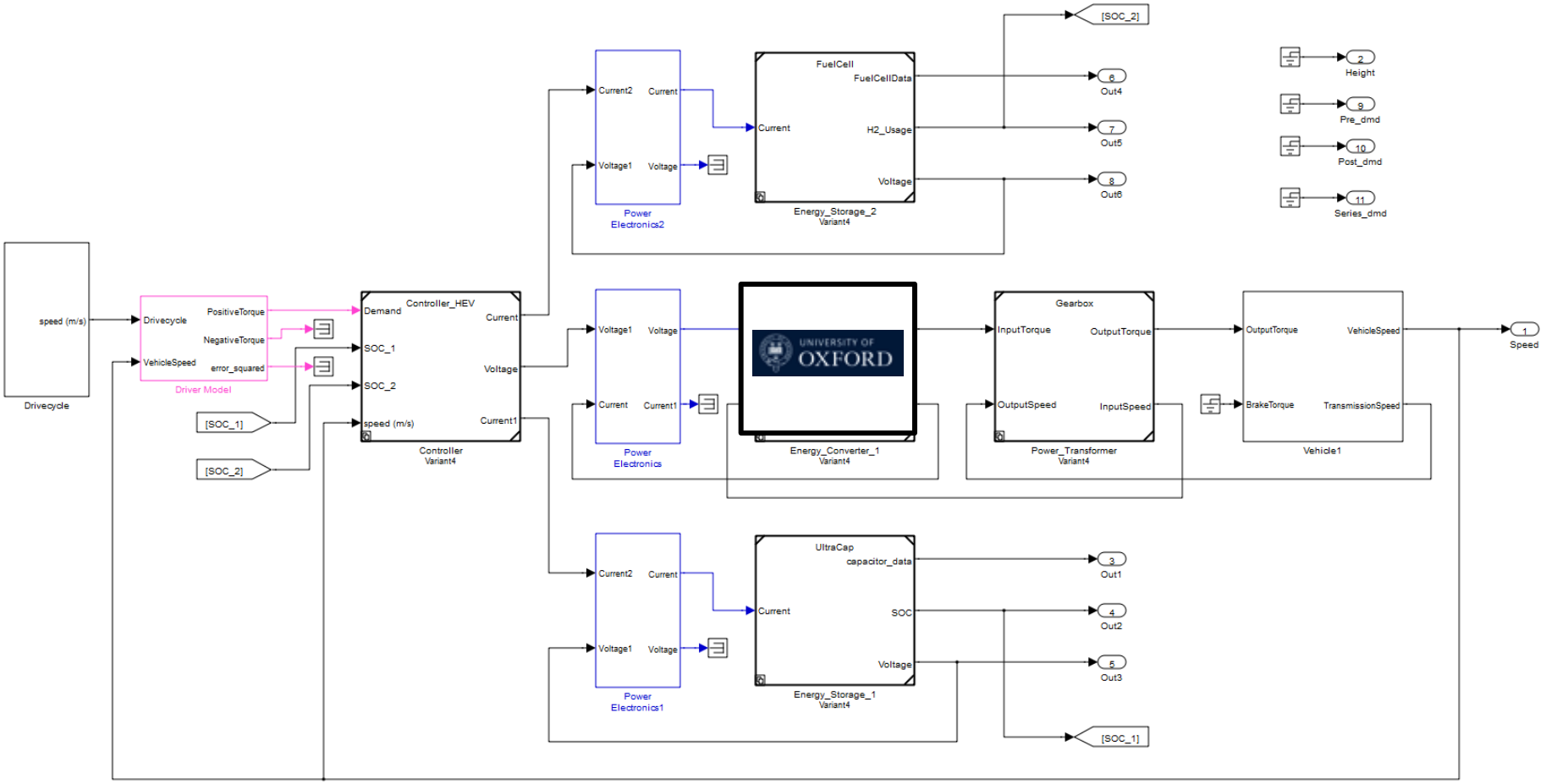
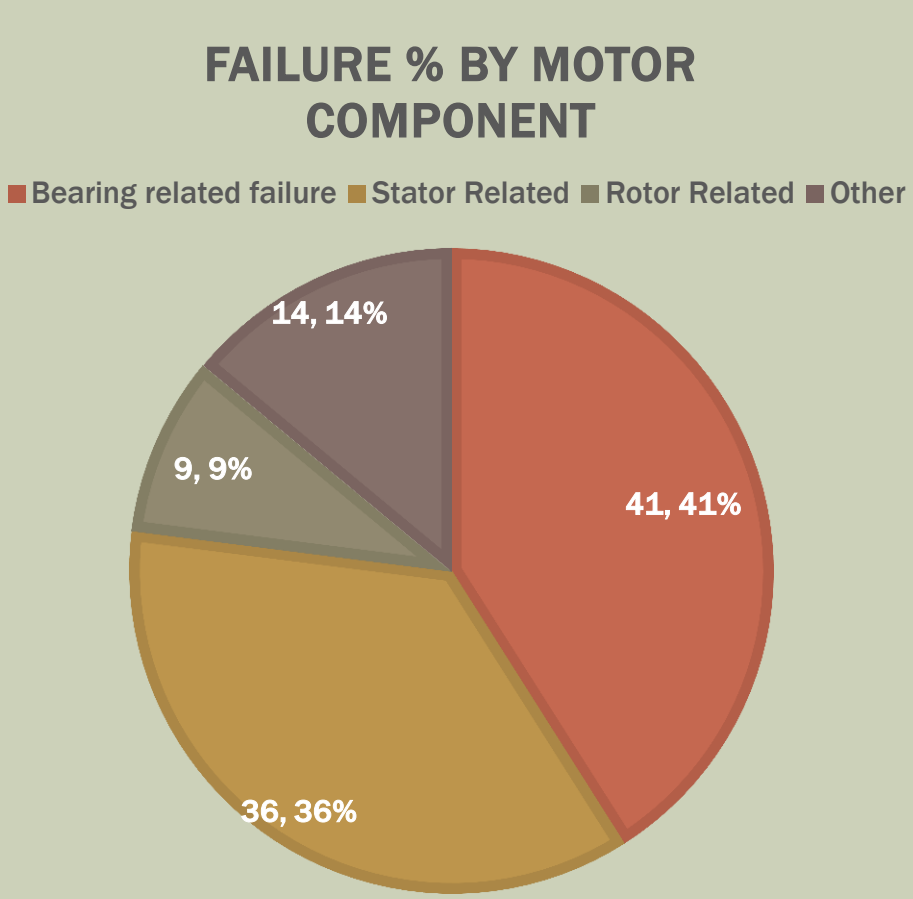
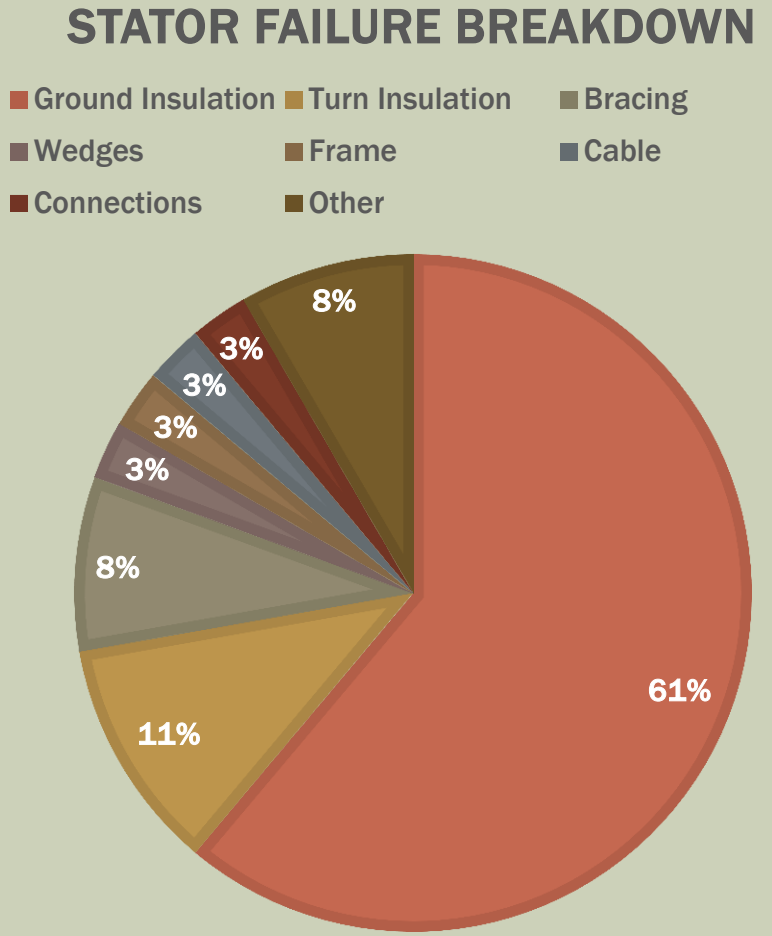
ELECTRICAL MACHINES



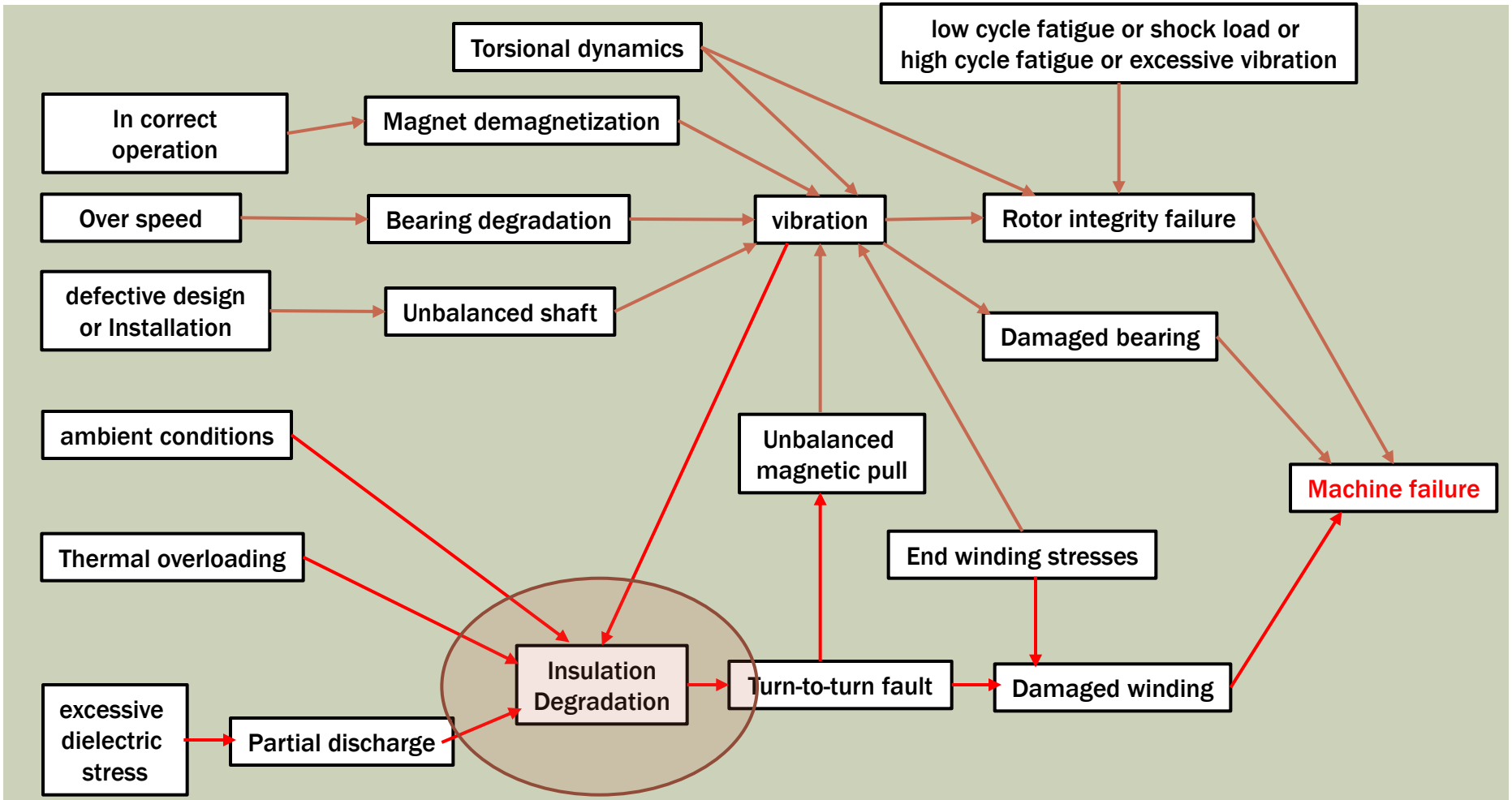
FAULTS IN MEDIUM VOLTAGE ELECTRICAL MACHINES





[1] F. Albrecht, J. C. Appiarius, R. M. McCoy, E. L. Owen and D. K. Sharma, "Assessment of the Reliability of Motors in Utility Applications - Updated," in IEEE Transactions on Energy Conversion, vol. EC-1, no. 1, pp. 39-46, March 1986.

SUMMARY OF COUPLED EFFECTS OF FAILURES



[2] P. J. Tavner, "Review of condition monitoring of rotating electrical machines," in *IET Electric Power Applications*, vol. 2, no. 4, pp. 215-247, July 2008.

WORK UNDERTAKEN ON WINDING DEGRADATION

Aims :

- Investigate potential parameters that may be used for characterisation of winding insulation health
  e.g. : insulation resistance and capacitance

- Establish the relationship between winding insulation health and remaining life.

Further work:

- Investigate strategies to use this information for on-line prediction of the lifetime of an EV traction machine.

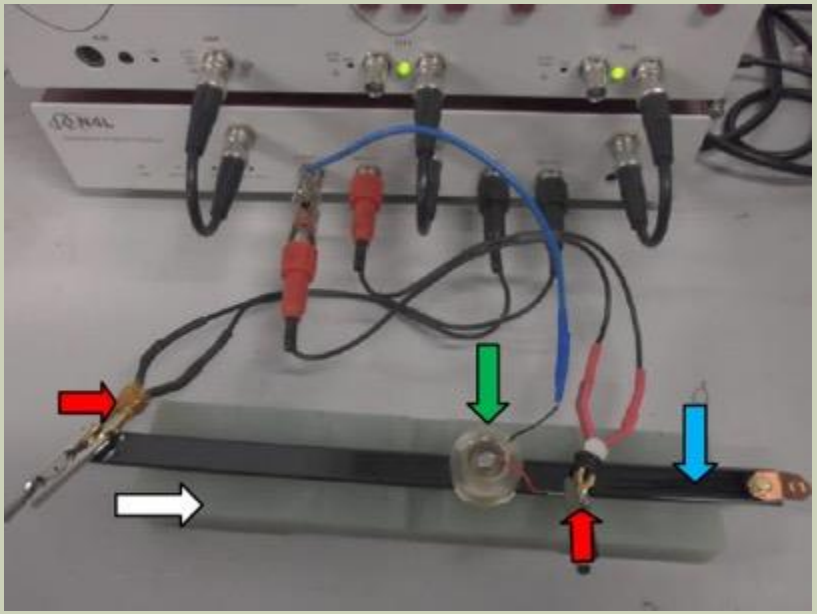
- Develop methods to incorporate this information at the machine design stage to develop machines with enhanced lifetime / high reliability.

WORK UNDERTAKEN ON WINDING DEGRADATION

Investigation of thermal degradation of Polyamide-Imide (PAI) insulation material

One of the six identical ovens with samples inside

Heated to 200 C, 215 C, 230 C, 245 C, 260 C and 275 C
Time: 100 hrs, 200 hrs, 400 hrs, 800 hrs and 1600 hrs



The measuring bench: white arrow shows the plastic case, blue shows he tested sample, red arrows shows the electrodes (applied voltage) and green shows the prototype moveable electrode

WORK UNDERTAKEN ON WINDING DEGRADATION

Investigation of thermal degradation of Polyamide-Imide (PAI) insulation material

260°C after 400hrs

245°C after 800hrs

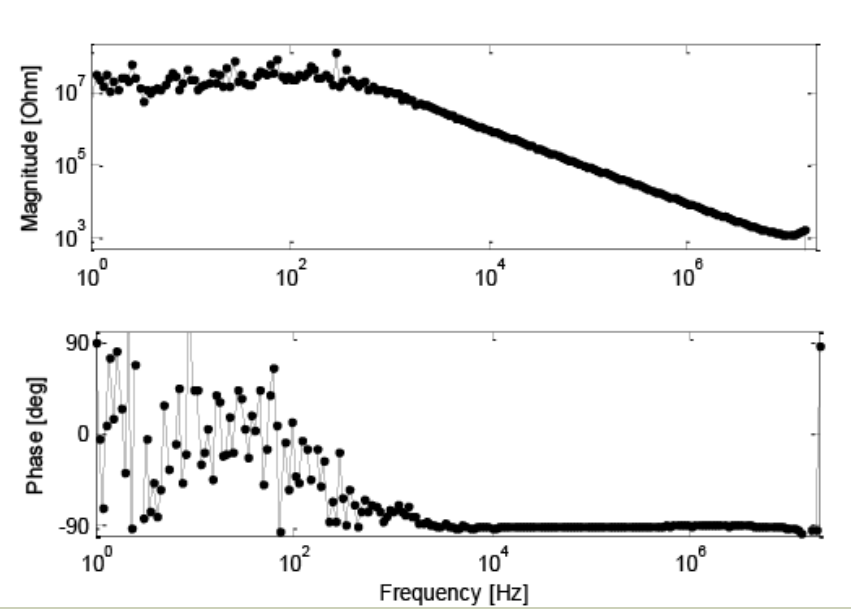
Catastrophic insulation failure of samples at 260°C after 1600 hours

260°C after 800hrs

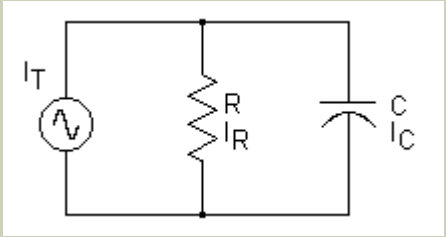
275°C after 400hrs

WORK UNDERTAKEN ON WINDING DEGRADATION

Resistance / capacitance equivalent circuit model of Polyamide-Imide (PAI) insulation



Example Impedance spectroscopy measurement result of an insulation sample



Equivalent circuit of the measurement setup

$$Z(j\omega) = \frac{R}{1 + j\omega RC}$$

Equivalent complex impedance model

WORK UNDERTAKEN ON WINDING DEGRADATION

Interpretation of Resistance / Capacitance measurement with thermal aging

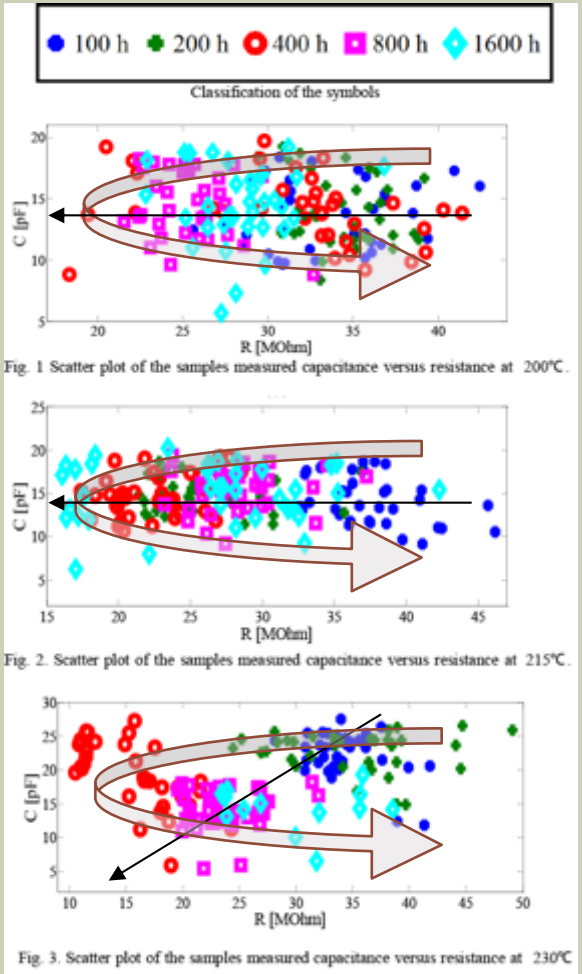


Fig. 1 Scatter plot of the samples measured capacitance versus resistance at 200°C.

Fig. 2. Scatter plot of the samples measured capacitance versus resistance at 215°C.

Fig. 3. Scatter plot of the samples measured capacitance versus resistance at 230°C

Key observations for temperature below 230 ^{0}C:

- Capacitance does not have an observable trend effected by aging during 200 ^{0}C & 215 ^{0}C tests
- Insulation resistance drops first and then increases:
  200 ^{0}C – drops for 800 hrs followed by an increase
  215 ^{0}C – drops for 400 hrs followed by an increase
  230 ^{0}C – drops by 50% for 400 hrs followed by an increase
- Capacitance drops by 38% from 200 hrs to 800 hrs

WORK UNDERTAKEN ON WINDING DEGRADATION

Interpretation of Resistance / Capacitance measurement with thermal aging

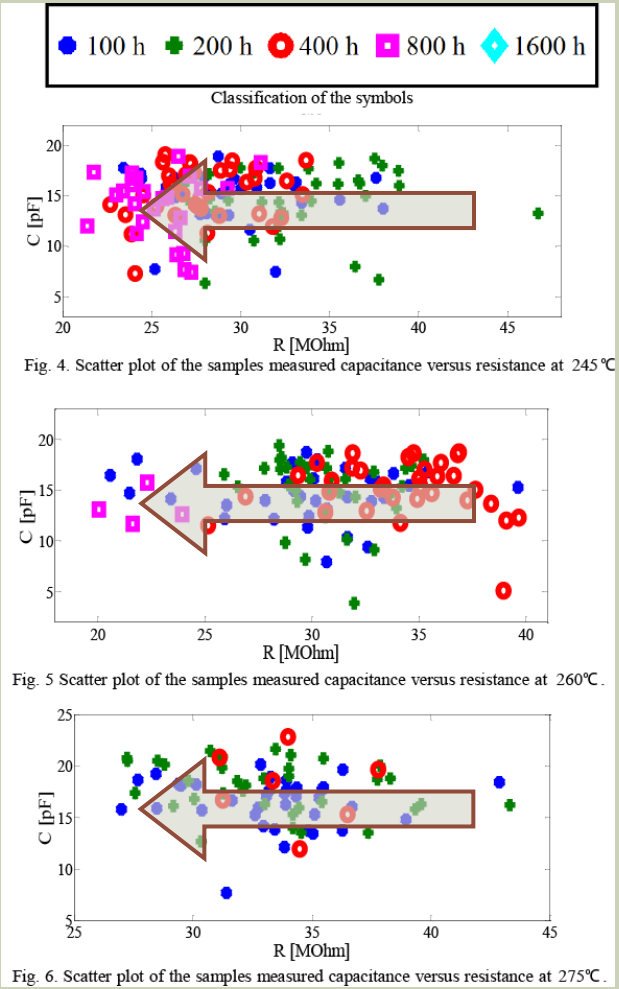


Fig. 4. Scatter plot of the samples measured capacitance versus resistance at 245℃

Fig. 5 Scatter plot of the samples measured capacitance versus resistance at 260℃.

Fig. 6. Scatter plot of the samples measured capacitance versus resistance at 275℃.

Key observations for temperature above 230 ^{0}C:

- Capacitance does not have an observable trend effected by aging during 245 ^{0}C, 260 ^{0}C & 275 ^{0}C tests
- Resistance decreases with aging
- Potential change of phase in PAI due to glass transition

Catastrophic insulation degradation of samples at 260°C after 1600 hours

WORK UNDERTAKEN ON WINDING DEGRADATION

Key conclusions:

- A sudden drop in insulation capacitance is an indication of the onset of winding degradation
- The resistance of the winding insulation decreases with thermal aging below 230 ^{0}C. However, the resistance increases with the onset of winding degradation
- For temperatures above 230 ^{0}C, the PAI may transfer phase and as a result, the trend in resistance decreases with thermal aging

ONGOING WORK

- Investigation on the relationship of insulation breakdown voltage and partial discharge with thermal aging
- Investigation of the effects of the presence of manufacturing solvents in insulation breakdown
- Generalisation of the results to be applicable in machine insulation system with PAI