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Prognostic Indication of Power Cable Degradation

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Abstract

The reliability and the health performance of network assets are of a great interest to power network operators. This project investigates methods of developing a prognostic capability for evaluating the health and long term performance of ageing distribution cable circuits. From the instant of installation and operation, the insulating materials of a cable will begin to age as a result of a combination of mechanical, thermal and electrical factors. Development of simulation models can significantly improve the accuracy of prognostics, allowing the targeting of maintenance and reduction of in service failures [1]. Real-time measurements taken close to underground cables can update the simulation models giving a more accurate prognostic model.

Mechanisms of Cable Failure

Manufacturing Imperfections: Tend to increase the local stress leading to either initial failure or higher rates of aging.
Poor Workmanship: Damage caused during installation could increase the local stress leading to either early failure or higher rates of aging.
Overheating: Tends to accelerate thermal ageing of the dielectric. The impact can be restricted to short lengths (local) if the adverse thermal environment is localized.
Mechanical: Tends to lead to mechanical failure reducing the dielectric strength. The impact can be restricted to short lengths if the mechanical stress is localized.
Water Ingress: Tends to reduce the dielectric strength and increase the local stress. [2]

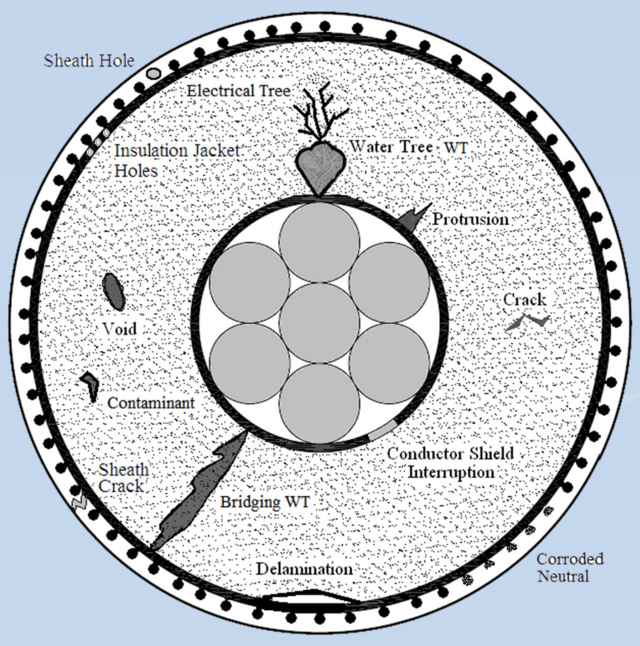

Figure 1 Cable cross-section [2]

Experimental Surface Trough for Cable Simulation

A model surface trough is used to develop a thermal prognostic simulation model which will predict the likely temperature impact on a cable at burial depth according to weather conditions and known loading. Trough consists of two 4 meter trenches one filled with small grain sharp sand and the second is unfilled.

Simulated cables are constructed by a heater tape wrapped around a length of aluminum pipe . The tape has a nominal power of 400 W ,thus for a pipe of 3.95 meters the maximum heat loss is approximately 100 W per meter.

The surface temperature of the cable is continuously monitored using 74 thermocouples placed inside the cables at various positions within the trench and surrounding soil as well as the weather conditions such as solar radiation, soil moisture content, wind speed, humidity, rainfall and air-temperature.

Figure 2 Cable duct test bed for prognostic indicator assessment

Computer program operates various pre set load/time profiles patterns to control the heat output to the simulated cables. The controller sets the voltage of supply to the heater tape whilst reading the current and voltage flowing through the tape . Six Variable Transformers (Variacs) are connected to each simulated cable and six stepper motors are connected with the Variacs in order to control the voltage output of the Variacs according with their movement (clockwise increasing voltage and anticlockwise decreasing voltage) .

Current transducers are used to convert the real time current in the cable (0-2 A) into a voltage output (0-10 V) and Voltage transducers to convert the output voltage from the Variacs (0- 240 V) into a lower voltage (0-10 V) . The output signals from both transducers are read real-time by a Data Acquisition device which collaborates with a Control Algorithm written in LabVIEW to sent the appropriate digital signals to the stepper motors and adjust the corresponding power profile demands.

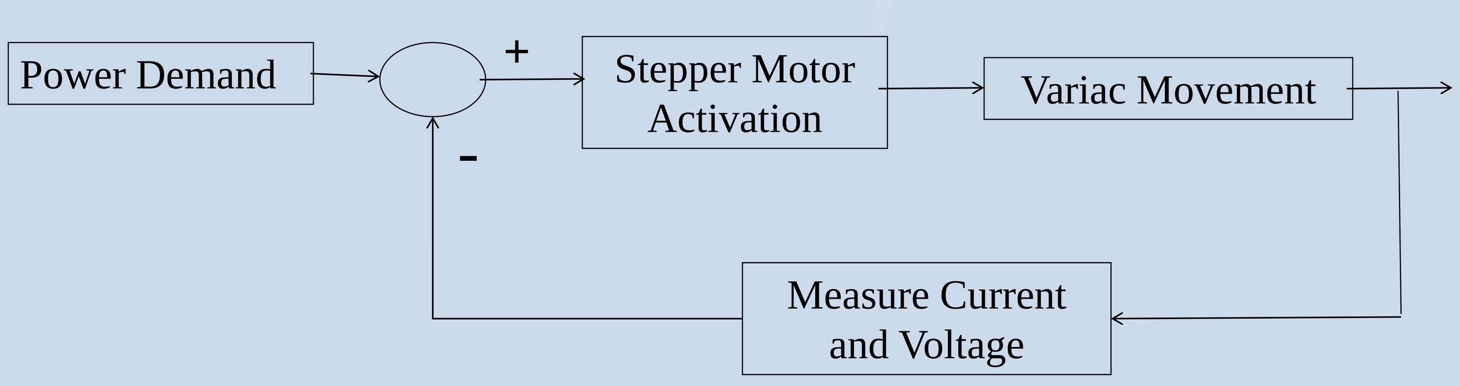

Figure 3 Simulated Cable power output control system

Experimental Setup and Results

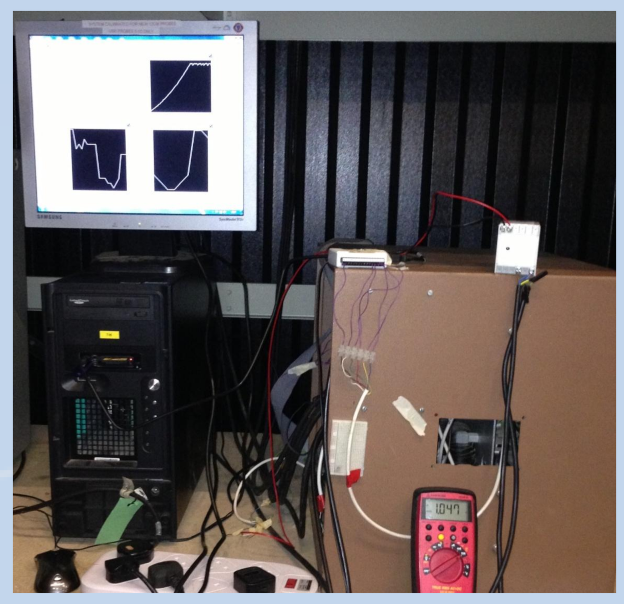

Figure 4 Control Unit of Simulated Cables

Figure 5 Variac Unit

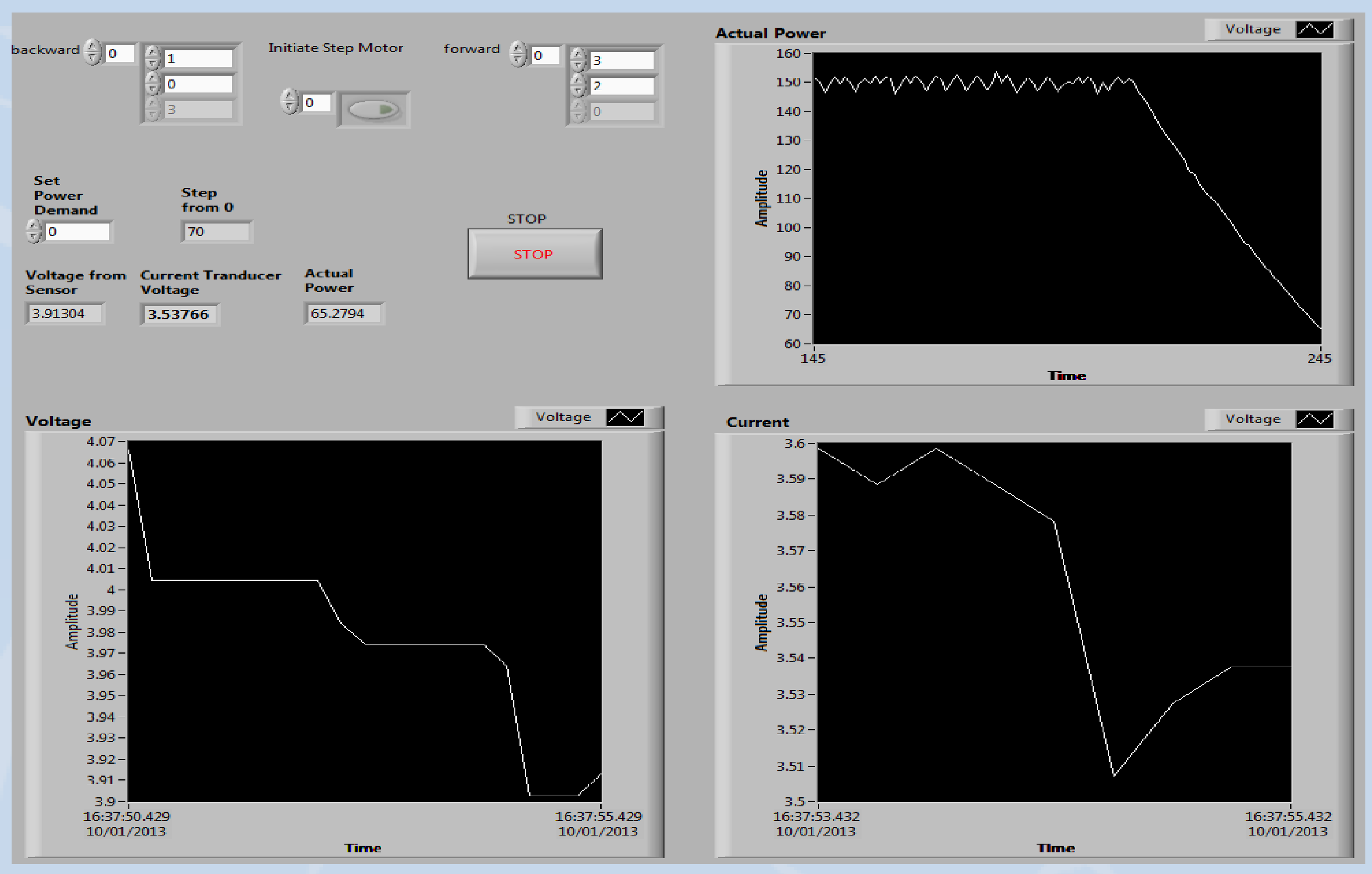

Figure 6 Experimental Framework for load/time power demand profiles

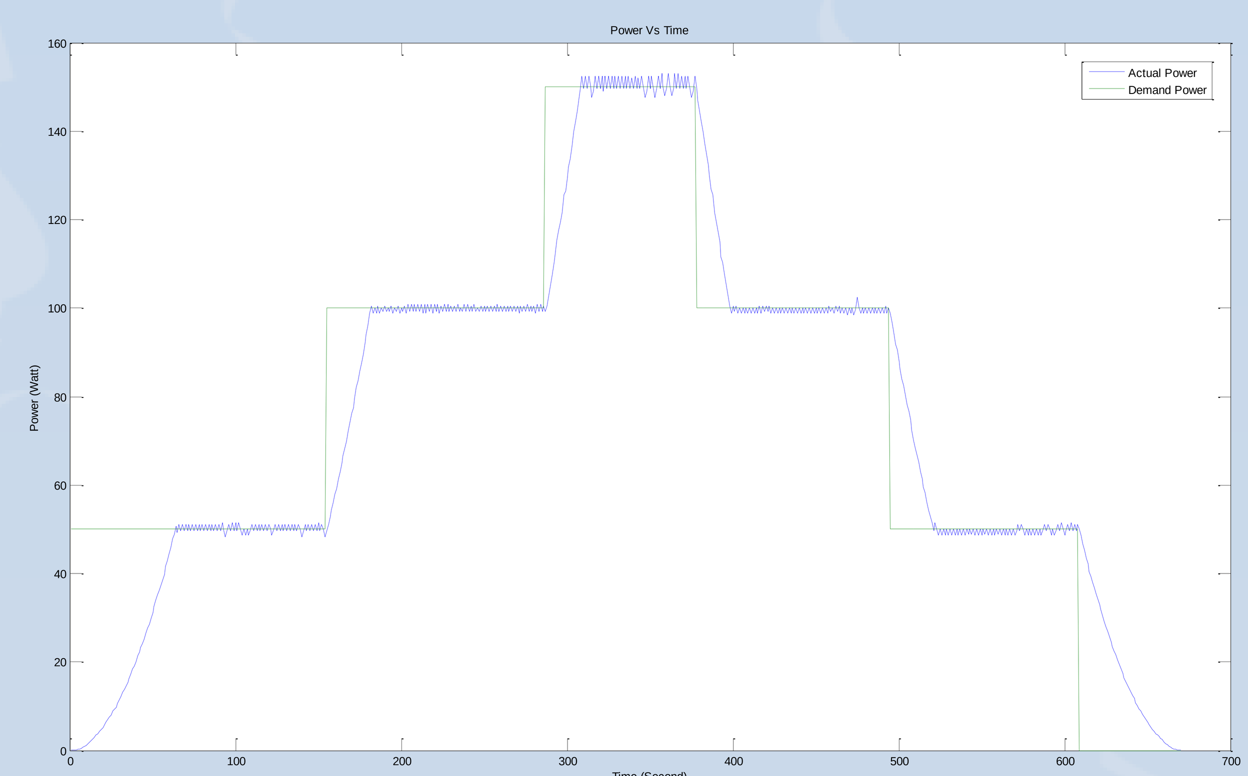

Figure 7 Experimental Result for load/time power demand profile

Conclusions and Future Work

Having commissioned the experiment setup the first step to produce a thermal prognostic simulation model has been successfully attempted .

Further work includes:

- Finalise testing the thermal prognostic simulation model which will be able to predict anomalies of temperature measurements along the cable and indicate a possible degradation activity in a cable.
- Investigate further factors affecting the health of the cable such as mechanical and electrical factors.

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References

[1] S Christou, J Steele-Davies, , P L Lewin and S G Swingler, ," Condition monitoring and prognostic indicators for network reliability" *HubNet Smart Grids Symposium, Bristol, GB, 11 - 12 Sep 2012.* 1pp.

[2] Hartlein R., et al., NEETRAC Miroslav Begovic, School of ECE, Georgia Institute of Techology J. C. Hernández Mejia, Universidad de Los Andes, Merida, Venezuela , *DOE Award No. DE-FC02-04CH11237 , (NEETRAC Project Numbers: 04-211 / 04-212 / 09-166) ,pp. 41-42, Publ. 2011*