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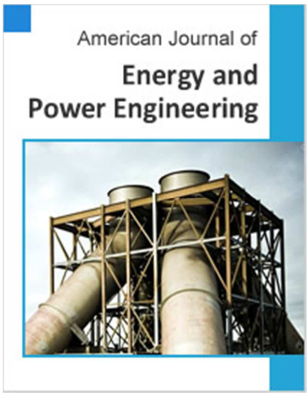

Virtual Instrument for Crimped Connections Temperature and Specific Losses Monitoring During Electrical Tests

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Abstract
This paper proposes a useful and modern solution for monitoring temperatures and specific losses of crimped connections using a virtual instrument developed in LabVIEW. It is a flexible instrument, which allows user to measure and record values during electrical tests and compare them with references, in order to decide if the tests should continue or not. The proposed solution is very useful not only for the steady state thermal regime but also for transient regime because it can be identified the improper connections before the final electrical machine or equipment assembly. The determination of specific losses implies calculating the initial rate of temperature raise starting from steady state thermal regime equation. A good crimped connection can withstand high levels of temperature and vibration, and it is of paramount importance to detect any failure before final assembly. Therefore, there are two main advantages of using this proposed solution. Firstly, it is a less time-consuming solution for electrical tests in order to detect any improper connections which could affect the electrical machine further operation. Secondly, it is very useful in order to identify those crimped connections that have not been executed correctly before final assembly. In the final part of the paper it was concluded that it will be of significant importance to develop further this virtual instrument in order to provide the user with the possibility of having a graphical representation of the acquired and stored data in real time. It is the case of temperature recorded during electrical tests.

1. Introduction

Due to technological simplicity and possible usage at temperatures above soldering, crimped connections are widely used in the manufacturing of electrical machines and various electrical equipments.

Developed to replace the need of soldered connections, crimping technology provides a high quality connection between a terminal and a wire at a relatively low applied cost [7]. The key elements in crimping process are:

-the ferrule/terminal;
-wire;
-tooling.

The quality of crimped connections is usually evaluated by using various non-destructive methods, such as contact resistance and temperature measurement, and destructive methods, namely pull test. Lately, a lot of electrical equipments and machines failures are due to the inefficient usage of crimped connections.

In [4], [6] and [7] several solutions for temperature measurement using data acquisition system and LabVIEW are presented. This paper proposes a solution for monitoring temperatures and specific losses of crimped connections using a virtual instrument developed in LabVIEW.

It is a flexible instrument, which allows user to measure and record values during electrical tests and compare them with references, in order to decide if the tests should continue or not.

The developed virtual instruments extremely useful to be used for both steady state thermal regime as well as transient regime because it is a way to identify improper connections before final assembly. The determination of specific losses involves calculating the initial rate of temperature raise starting from steady state thermal regime equation. Thus, there are two main advantages of using this proposed solution. Firstly, it is a less time-consuming solution for electrical tests in order to detect any improper connections which could affect the electrical machine further operation. Secondly, it is very useful in order to identify those crimped connections that have not been executed correctly before final assembly. More important, this VI does not limit the type of DAQ system that can be used in data acquisition process.

2. Method

In order to acquire and record temperature values from thermocouples type K a data acquisition system consisting in four parts (Figure 1) is used. The main part of DAQ system is NI PCI 6221 acquisition board. With the associated software (LabVIEW) and using a theoretical background to calculate specific losses, a virtual instrument is created, which facilitates the acquisition process.

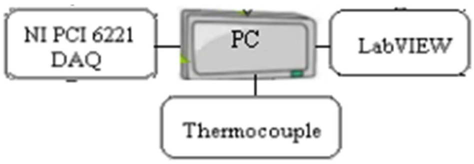

Figure 1. *Diagram of temperature measurement system.*

In order to obtain the relation which gives specific losses it was considered a homogeneous and isotropic area with density γ and specific heat c, situated in an environment with temperature θ_0. Due to specific losses uniformly distributed with density p(W/m^3), the temperature θ satisfies [3]:

$$\frac{\vartheta\theta}{\vartheta t} = \frac{1}{c\cdot\gamma}\cdot div\left(\lambda\cdot grad\theta\right) - \frac{\theta}{\tau} + \frac{p}{c\cdot\gamma} \quad (1)$$

where:

- $\gamma\left(Kg/m^3\right)$ - density;
- $c\left(J/Kg\cdot K\right)$ - specific heat;
- $\lambda\left(W/m\cdot K\right)$ - thermal conductivity;
- $\tau = \dfrac{\iiint_V c\cdot\gamma\cdot \mathrm{d}v}{\oint\!\!\oint_S \alpha\cdot \mathrm{d}S}$ - local thermal time constant.

Solving (1) in permanent regime, with the body uniformly heated (gradθ=0) it results:

$$\theta(t) = \theta_\infty + \left(\theta_1 - \theta_\infty\right)\cdot e^{-\frac{t-t_1}{\tau}} \quad (2)$$

Specific losses will be:

$$p_{sp} = c\cdot\left.\frac{d\theta}{dt}\right|_0 \left(W/kg\right) \quad (3)$$

The initial rate of temperature rise can be determined by drawing the tangent at the origin at heating curve.

$$\left.\frac{d\theta}{dt}\right|_0 = \tan(\alpha)\left(K/s\right) \quad (4)$$

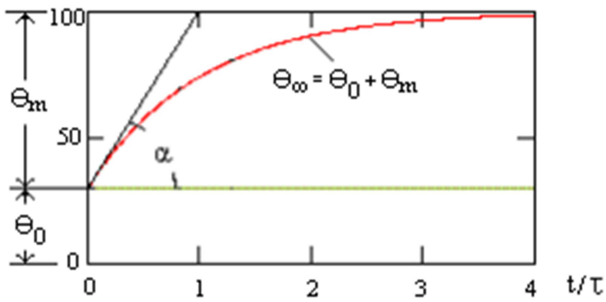

Figure 2. *Graphical method for determining specific losses.*

3. Results

Starting from LabVIEW and DAQ system, a virtual instrument (VI) for temperatures and specific losses monitoring was developed. The VI allows user to make measurements on five channels using five samples in the same time. The main element is DAQ Assistant, which is used to define the acquisition channels and measurement settings (Figure 3).

In order to measure the temperature of crimped connections, a thermocouple K type was used with a cold junction compensation.

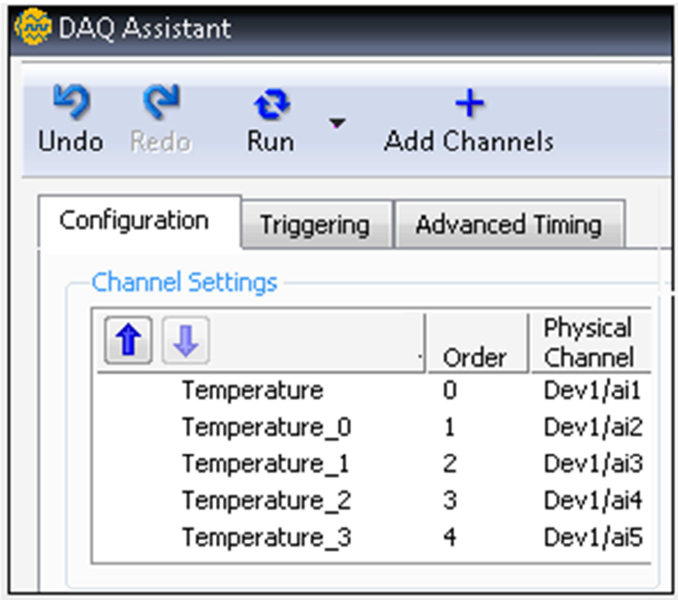

Figure 3. *DAQ Assistant in LabVIEW.*

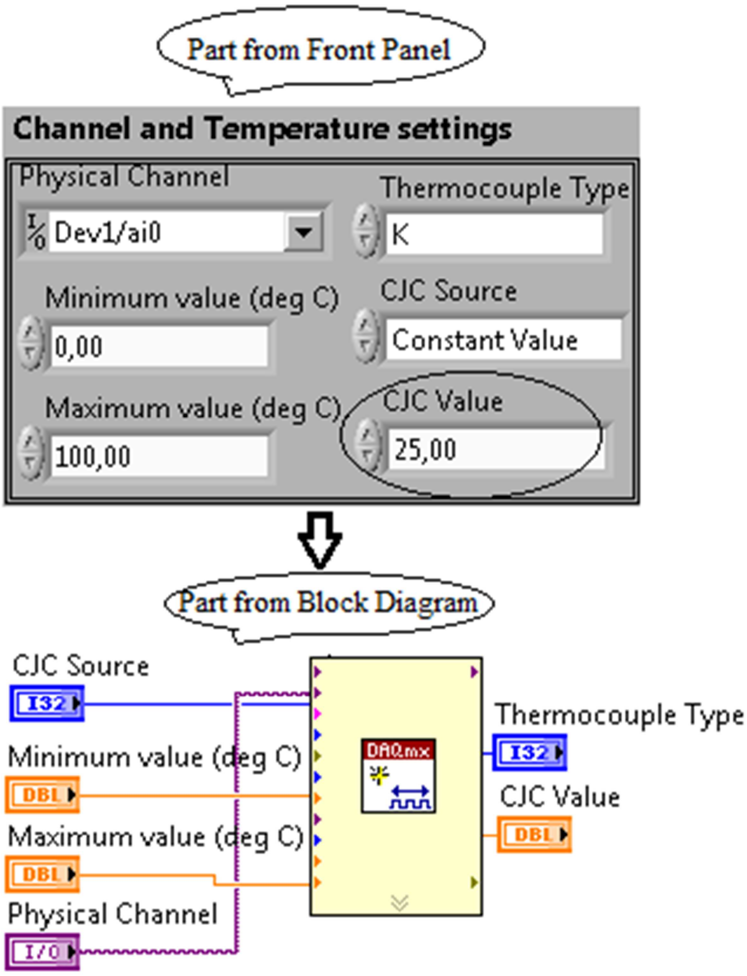

Figure 4. *Parts from Front Panel and Block Diagram related to CJC.*

Due to the fact that thermocouples sensitivity is high, a CJC software compensation was used (Figure 4.). Front Panel of virtual instrument developed in LabVIEW is presented in Figure 5.

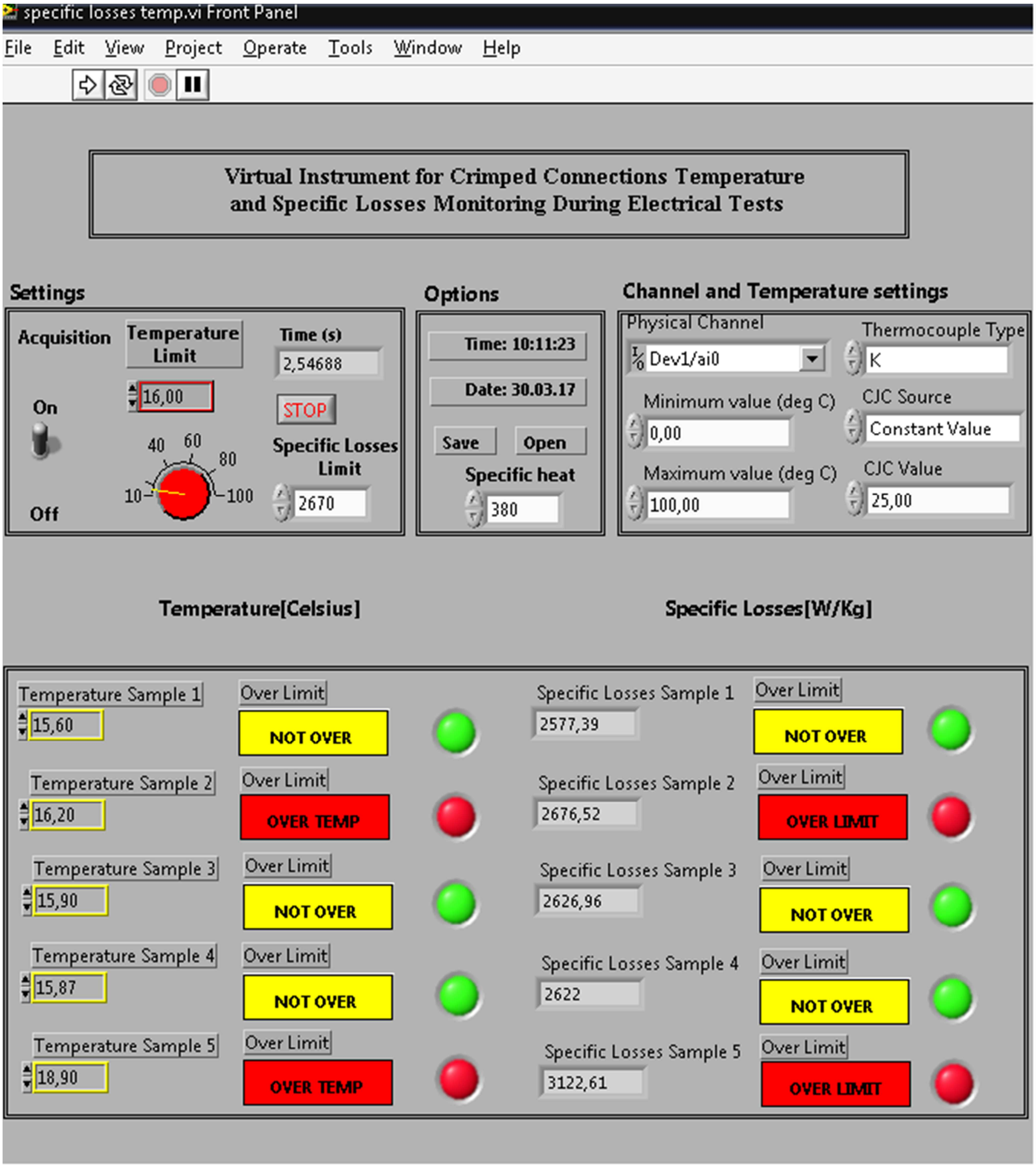

Figure 5. *Front Panel developed in LabVIEW.*

The associated Block Diagram of Front Panel in LabVIEW is presented in Figure 6.

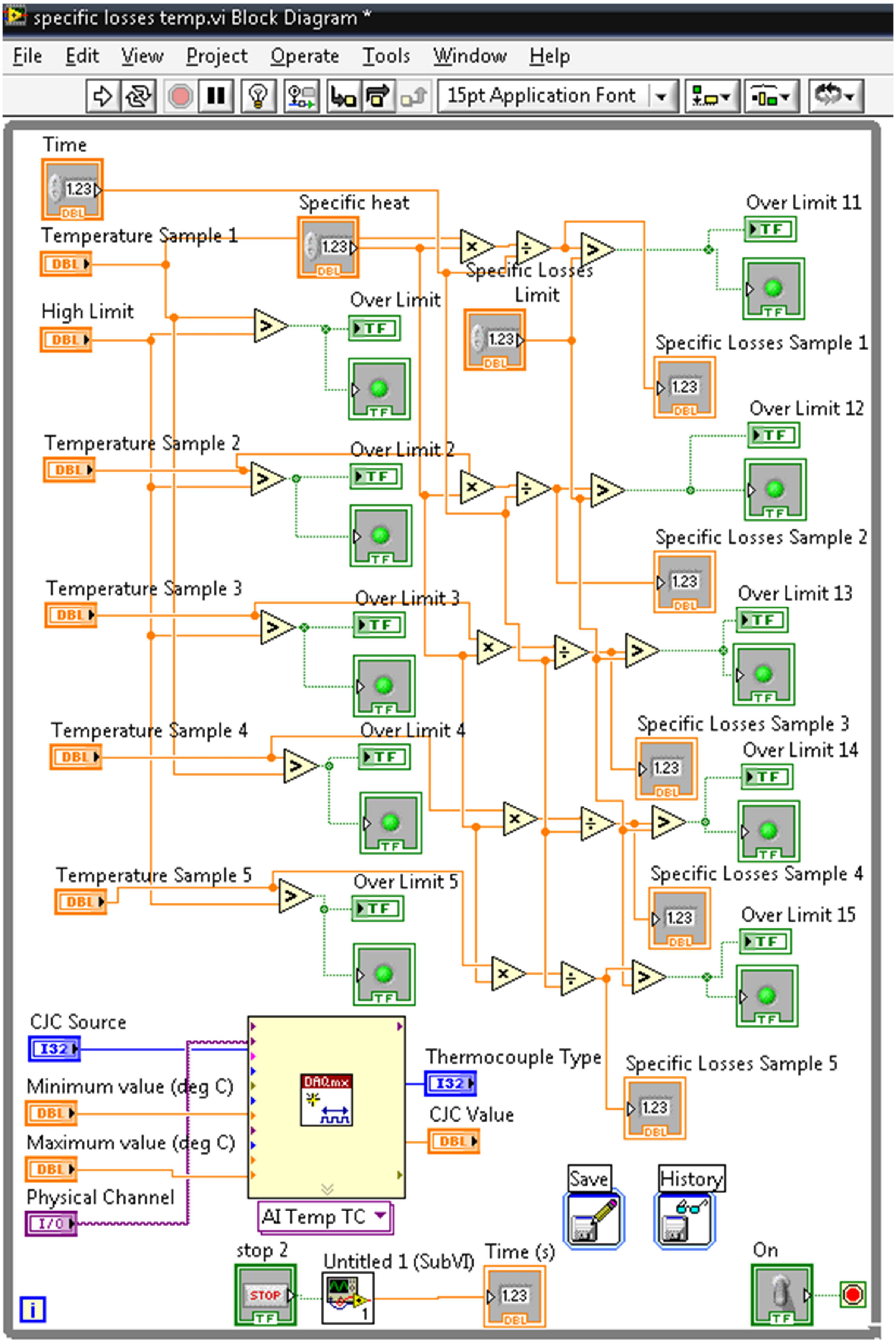

Figure 6. *Block Diagram corresponding to Front Panel in LabVIEW.*

4. Discussion

The resulted VI contains several important blocks:

- *settings* block: this part of the VI allows user to set the temperature and specific losses limits which will be compared with the measured and calculated values.

- *channel and temperature settings* block: here the user can choose physical channels, thermocouple type, minimum and maximum values for temperature and can also specify the value for cold junction compensation. It must be specified that the user can choose whatever type of thermocouple he need for his specific application. Also, this VI does not limit the type of DAQ system that can be used.

- *temperature* block: this block displays temperature values acquired from 5 samples in the same time and if they are exceeded or not the imposed limits;

- *specific losses* block: it displays specific losses values and if they are exceeded or not the imposed limits.

- *options* block: is used for displaying time and date and offers user the option to save the measurement values or to open an old file.

Specific losses are calculating using (3) during a short period of time, more precisely on the first part of the heating curve presented in Figure 2. The values recorded during monitoring process are displayed in real time, but also stored in a LabVIEW file for further analysis.

An experimental determination was carried out in order to verify the functionality of the developed virtual instrument. Using 5 samples having crimped connection the temperature at the surface was measured and then specific losses were calculated. As it can be shown in Figure 5 some samples that are tested have greater values of temperature and specific losses than the limits. As a result, this exceedance of limit value is signaled through a text message (Over limit) as well as visually by lighting a led.

Some standards impose limits for temperature and specific losses which can be introduced in a database. Having a database with the types of crimped connections and their associate temperature and specific losses values, it will help the test taker to decide if he should continue the tests or which one of the tested samples is properly executed or not. Consequently, it will reduce the time during the electrical tests because based on specific losses values it can be assumed if a connection is proper or improper executed.

5. Conclusion

Time is essential in our modern world, so every technical solution that can provide help in reducing time during manufacturing is welcome. This paper proposes a useful and modern solution for monitoring temperatures and specific losses of crimped connections using a virtual instrument developed in LabVIEW. It is a flexible instrument, which enables the measurement and recording of temperature and specific losses values during electrical tests and compare them with references, in order to decide if the tests should continue or not. The determination of specific losses involves calculating the initial rate of temperature raise. Thus, in order to achieve this, a subVI was created starting from steady state thermal regime equation.

Therefore, there are two main advantages of using this proposed solution. Firstly, it is a less time-consuming solution for electrical tests in order to detect any improper connections which could affect the electrical machine further operation. Secondly, it is very useful not only for the steady state thermal regime but also for transient regime because it can help to identify those crimped connections that have not been executed correctly before final assembly of electrical machines or equipment. More important, this VI does not limit the type of DAQ system that can be used in data acquisition process.

Going further, this virtual instrument can be developed in order to provide the user with the possibility of having a graphical representation of the acquired and stored data in real time. It is the case of temperature recorded during electrical tests.

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