AN_65XX_061 OCTOBER 2009

# Teridian 71M65XX Using DC-Tolerant CTs by J&D Electronics

## Introduction

DC-tolerant CTs are gaining importance in the metering marketplace. As compared to general-purpose CTs, DC-tolerant CTs have a much larger phase angle and can also be less linear than general-purpose CTs at low currents. J&D Electronics Co Ltd, Korea, has introduced a series of DC-tolerant CTs that can be successfully used in accurate electricity meters when combined with the excellent compensation features of the Teridian family of metering ICs. Regardless whether the 71M6511, 71M6513, 71M6521, 71M6523, 71M6531/32, 71M6533/34, or the latest 71M6541/42 or 71M6543 is used, linearization of the CT output over current and over temperature can be implemented easily and in a straight forward manner.

## The J&D Electronics CTs

J&D Electronics provided samples of several advanced CTs to Teridian for testing. The model JDTN100W was selected for testing in a poly-phase meter setup. The data sheet of the JDTN100W (see Figure 1) indicates that it is a CT that has a narrowly contained magnitude error and large phase shift, which itself has a strong temperature dependency. At 60° load angle, we would expect the phase error shift from 3.1° (-40°C) to 5.2° (+85°C) to cause an error component for the Wh measurement of 5.8%. Even at constant temperature, the phase angle varies by as much as 0.3% over current, resulting in a Wh error of 0.54%. This means that compensation has to be introduced for the phase error over temperature and over current at the least.

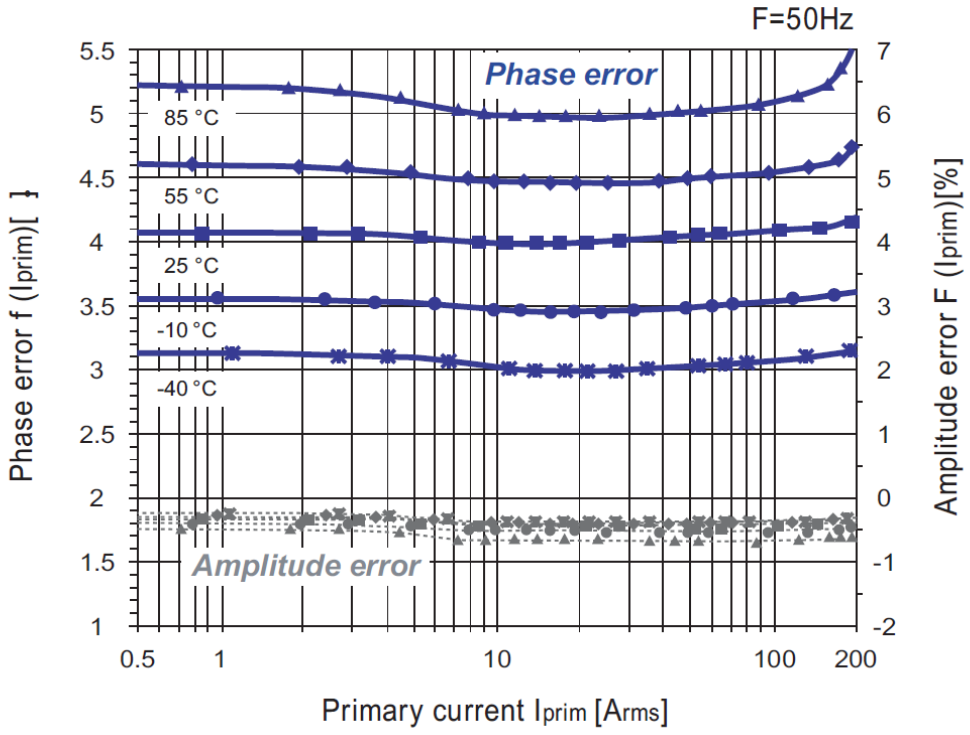


**Figure 1: JDTN100W Performance**

## Calibration

The JDTN100W were calibrated in a poly-phase meter using the Teridian 71M6534. As expected, the errors at 60° and 300° load angles were large due to the large phase angle presented by these CTs to the meter. The initial, un-calibrated measurements are shown in Figure 2 through Figure 4. All measurements were done at 50 Hz.

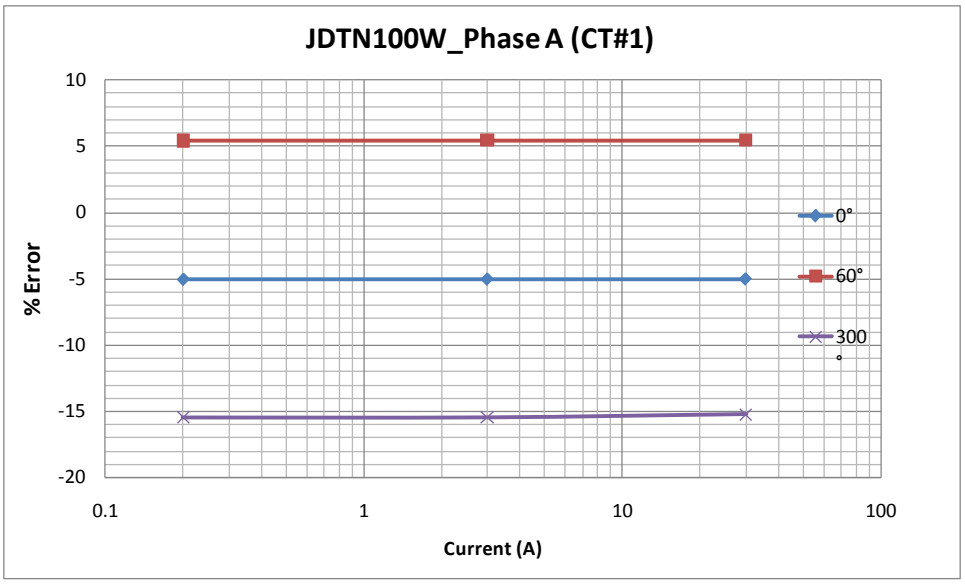


**Figure 2: JDTN100W, Phase A, before Calibration**

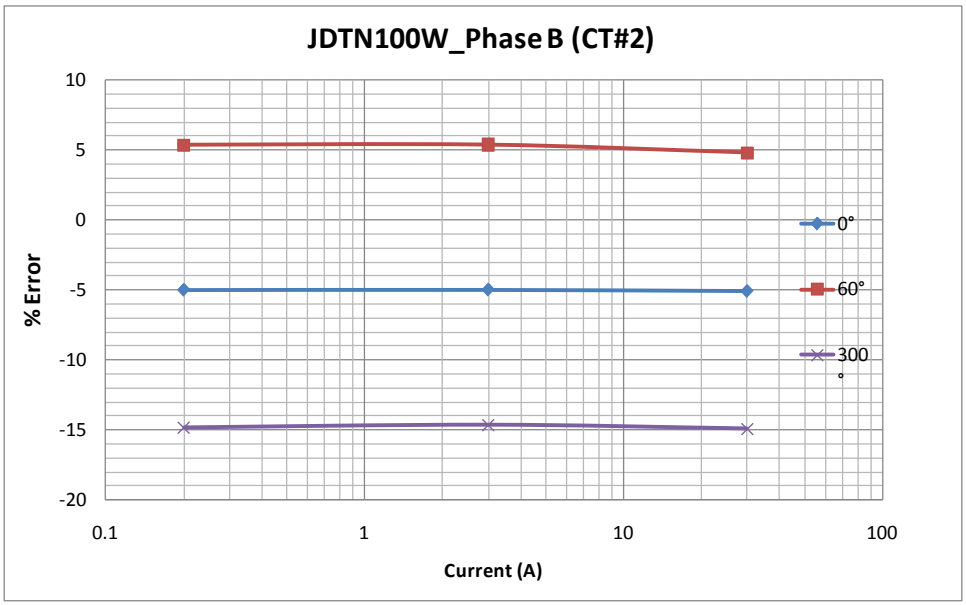


**Figure 3: JDTN100W, Phase B, before Calibration**

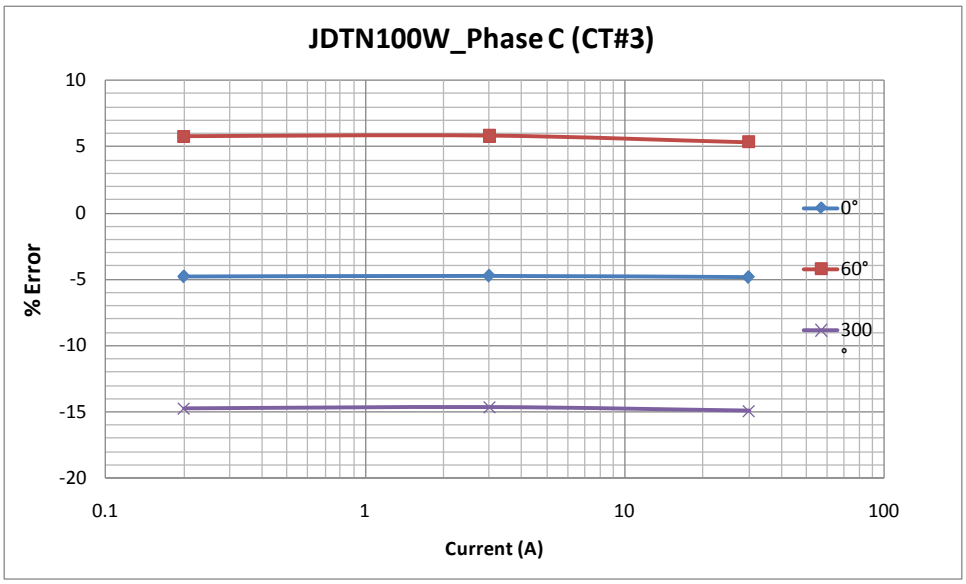


**Figure 4: JDTN100W, Phase C, before Calibration**

Teridian's standard 5-point calibration method was used to calibrate each phase at 30 A. This brought the Wh error for most test currents far below the 1% range, as shown in Figure 5 through Figure 7. Below 0.3 A however, the Wh error increases, which shows that the calibration coefficients for 30 A are not effective at low currents.

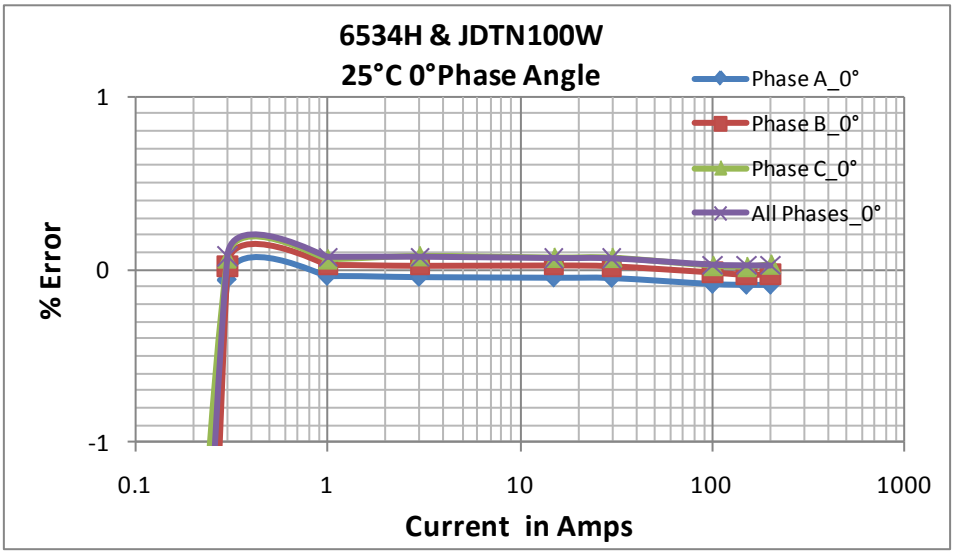


**Figure 5: JDTN100W, All Phases at 0° Load Angle, after Calibration**

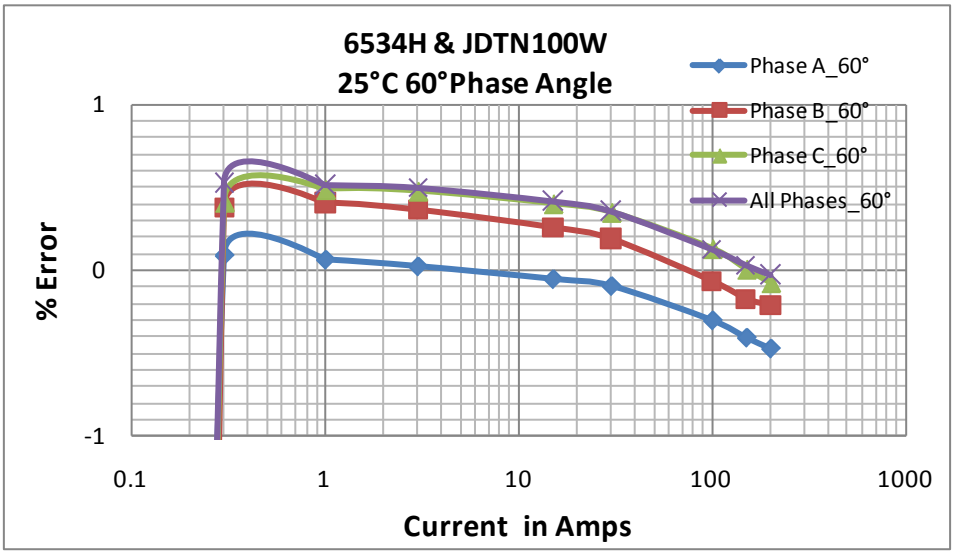


**Figure 6: JDTN100W, All Phases at 60° Load Angle, after Calibration**

In order to improve accuracy, a three-point calibration method was applied. Separate calibrations were made at 0.2 A, 3 A and 30 A, and the calibration coefficients for each current were obtained by linear interpolation from the calibration coefficients at 0.2 A, 3 A and 30 A. The result is shown in Figure 7. At room temperature, the meter is clearly within the ±0.2% error range.

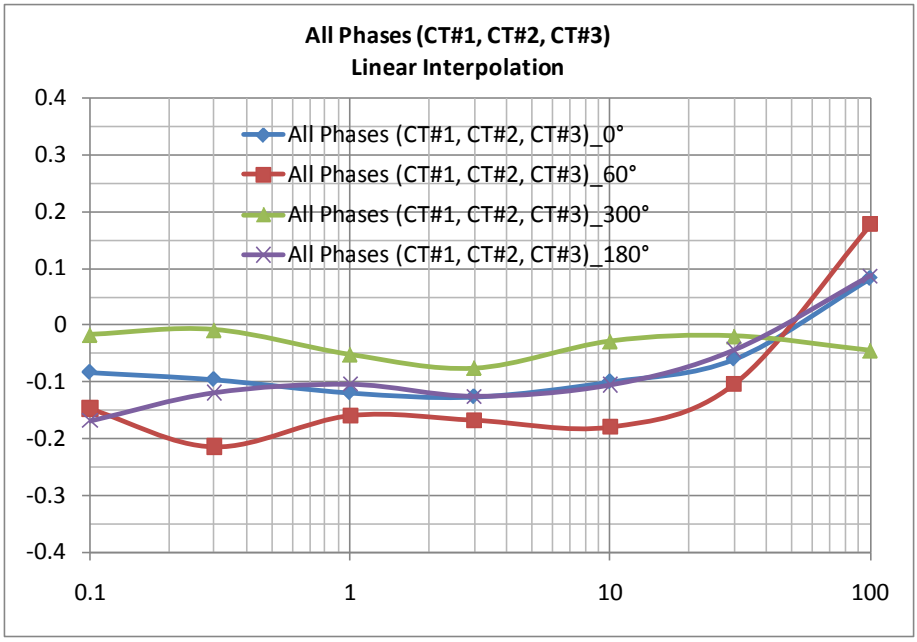


**Figure 7: JDTN100W, All Phases, with Three-Point Calibration**

Further efforts concentrated on achieving higher accuracy at various temperatures. As mentioned above, the phase error shift from 3.1° (-40°C) to 5.2° (+85°C) will cause an error component for the Wh measurement of 3.8% at 60° load angle. However, the phase angle of the CT can be compensated quite easily by the 71M6534 (and, of course, all other Teridian meter ICs) by changing the *PHADJ_n* coefficient in the CE. At 25°C, the phase angle introduced by the JDTN100W is 4°, resulting in a *PHADJ_n* coefficient of 9203. This coefficient will have to change by -2315 to 6888 at -40°C and by +2561 to 11764 at +85°C, as shown in Table 1, in order to compensate for the phase angle change in the JDTN100W.

**Table 1: *PHADJ_n* Correction over Temperature**

| T [°C] | Phase Error [°] | Error w/ respect to 25°C | PHADJ for Error | PHADJ Delta |
|---|---|---|---|---|
| | | | | |
| -40 | 3 | -1 | 6888 | -2315 |
| -10 | 3.5 | -0.5 | 8044 | -1159 |
| 25 | 4 | 0 | 9203 | 0 |
| 55 | 4.55 | 0.55 | 10481 | 1278 |
| 85 | 5.1 | 1.1 | 11764 | 2561 |

The numbers for *PHADJ_n* shown in Table 1 were obtained from the formulae given in Figure 8. Figure 8 is part of the set of calibration spread sheets provided to customers as part of the Teridian Demo Kit packages. Note that the calculation is done for 50 Hz, and that the numbers will change significantly for 60 Hz.

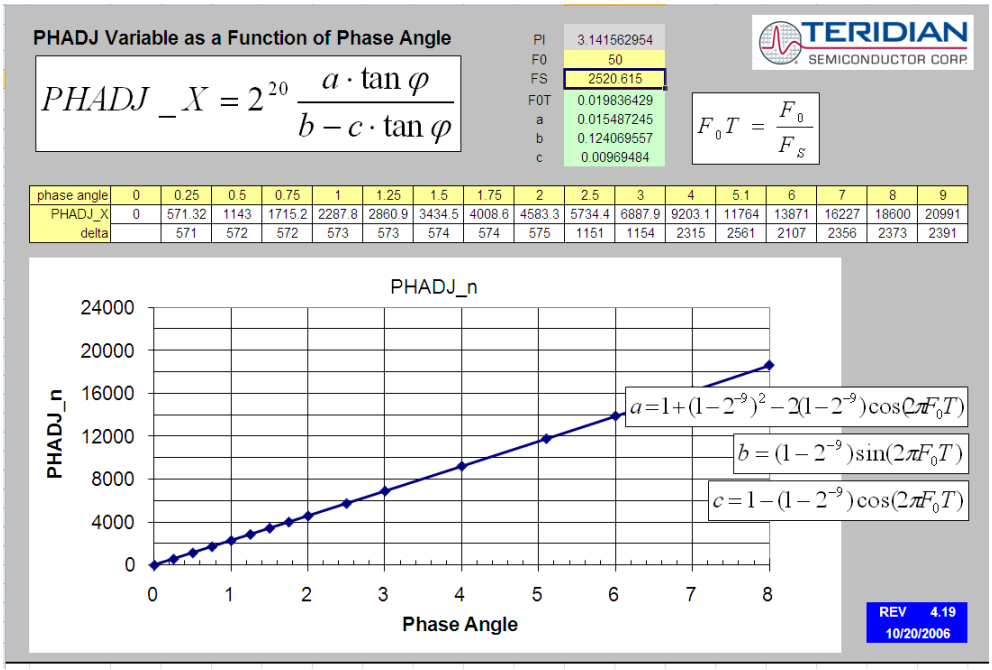


**Figure 8: *PHADJ_n* as a Function of Phase Angle**

A new set of measurements was done with the interpolated calibration coefficients as before, but with the *PHADJ_n* coefficients corrected by the *PHADJ* Delta values shown in Table 1. From the phase errors shown in Figure 1, we would expect the Wh errors at 60° load angle and +85°C temperature to increase by 3.3% (corresponding to the phase angle increase of 1.1°).

As seen in Figure 9 and Figure 10, the actual error is decreased to the range of -1.7% to +1.8%, which shows that the correction of the phase angle compensation works as expected. More important, the error curves for 0°, 60°, 300° and 180° are now much closer together, which proves that the temperature-dependent phase error has been successfully eliminated. The remaining error most likely comes from the temperature characteristics of the burden resistors. Fortunately, Teridian meter ICs and the code developed for them have powerful tools for temperature compensation which can be used to eliminate the remaining error.

In order to tackle the remaining error, a few simplified assumptions were made:

1) The function of Wh error over temperature is linear, which manifests itself in the equidistant phase error lines in Figure 1.
2) All CTs have the same phase error development over temperature. This assumption is probably a simplification, but in lack of individualized CT data, all we can do is assume that all CTs of the same batch resemble each other closely.

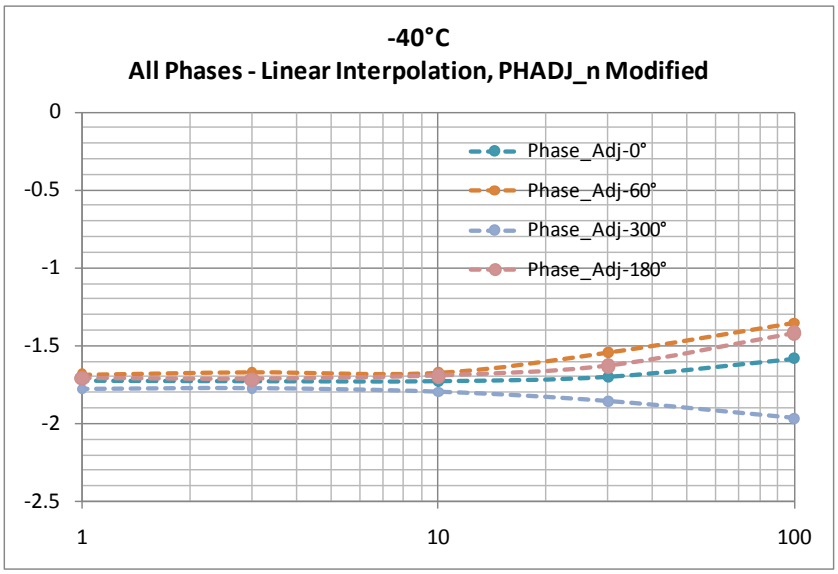


**Figure 9: Wh Error at -40°C with *PHADJ_n* Corrected per Table 1**

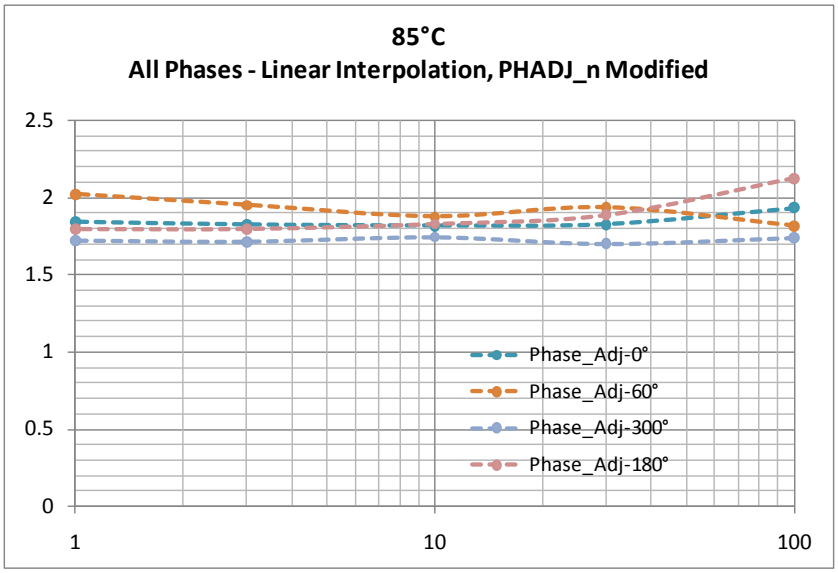


**Figure 10: Wh Error at +85°C with *PHADJ_n* Corrected per Table 1**

Assuming -1.7% error at all phase angles and -40°C, and +1.8% error at +85°C, we can utilize the internal temperature compensation of the CE code in the 71M6534. This mechanism implements compensation as follows:

$$GAIN\_ADJ = 16385 + \frac{DELTA\_T \cdot PPMC}{2^{14}} + \frac{DELTA\_T^2 \cdot PPMC2}{2^{23}}$$

In the above formula, *GAIN_ADJ* is a gain control value that is applied to all voltage and current channels of the 71M6534. A value of 16385 represents unity gain. *DELTA_T* is the deviation from calibration temperature in multiples of 0.1°C, *PPMC* and *PPMC2* are the linear and quadratic coefficients. To compensate for +1.8% Wh error at +85°C, *GAIN_ADJ* needs to be 1.8%/2 lower than 16385. Similarly, to compensate for -1.7% Wh error at -40°C,

  

*GAIN_ADJ* needs to be 1.7%/2 higher than 16385. We can then calculate values for *PPMC* and *PPMC2* that satisfy the desired target values for *GAIN_ADJ*. In this case, where there is a linear relationship between temperature and phase error, *PPMC* is -3800, and *PPMC2* is 0.

The load lines shown in Figure 11 and Figure 12 show how all compensation mechanisms combined are able to bring the Wh error well within the 0.2% range. These graphs were obtained by combining the following compensation mechanisms:

1) Linear interpolation of calibration coefficients over the current range (manual).
2) Adjustment of the phase angle correction dependent on the temperature (manual).
3) Automatic magnitude adjustment using the internal temperature compensation mechanism of the CE code.

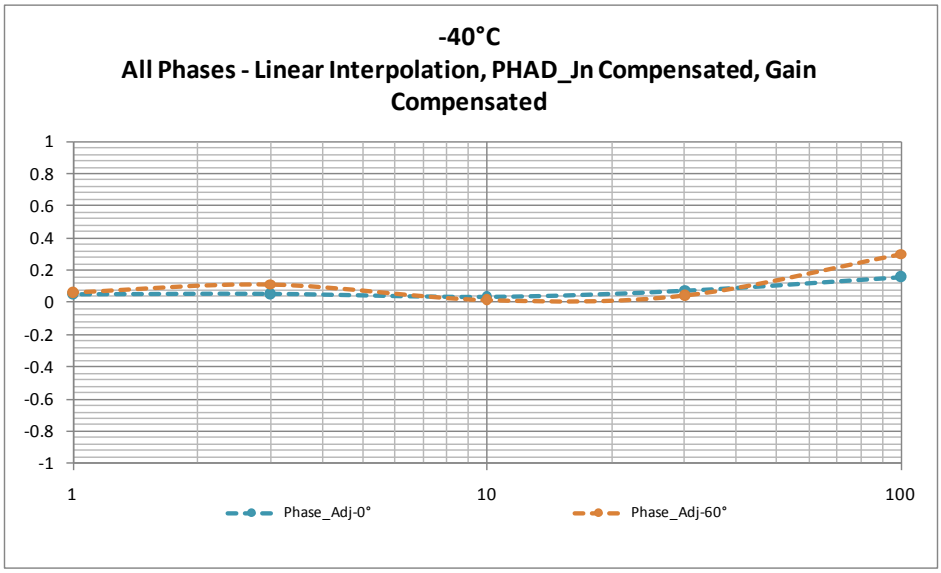


**Figure 11: Wh Error at -40°C with *PHADJ_n* Corrected, Linear Interpolation and *GAIN_ADJ* Control**

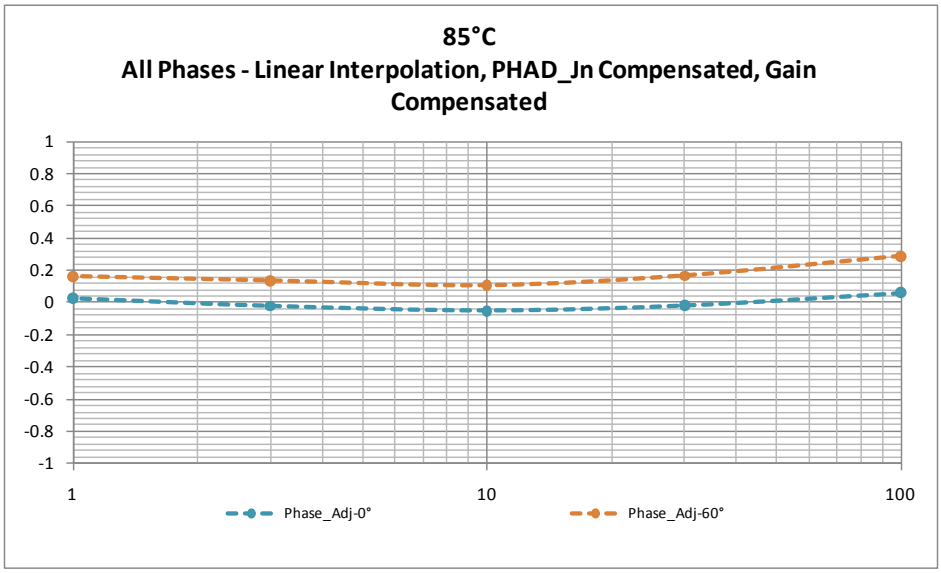


**Figure 12: Wh Error at +85°C with *PHADJ_n* Corrected, Linear Interpolation and *GAIN_ADJ* Control**

## Conclusion

J&D Electronics CTs of the type JDTN100W were successfully tested with Teridian metering ICs providing compensation for magnitude and phase characteristics. The achieved accuracy was better than 0.5% over the industrial temperature range and over the current range used for residential meters.

An automated compensation mechanism for Wh magnitude errors exists in the CE code of the 71M6534. Other compensation mechanisms may be implemented in MPU code.

## Revision History

| Revision | Date | Description |
|---|---|---|
| Rev. 1.0 | 10/6/2009 | First release. |



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