NOTE: These instructions only apply to designs using shunts or current transformer (CT) current sensors.

1. Gain calibration process ($\theta Applied_{degrees} = 0°$)

$$voltageSF(new)_{ph} = voltageSF(initial)_{ph} \times \left(\frac{vrmsApplied_{ph}}{vrmsAverage_{ph}}\right)$$

$$currentSF(new)_{ph} = currentSF(initial)_{ph} \times \left(\frac{irmsApplied_{ph}}{irmsAverage_{ph}}\right)$$

$$actApplied_{ph} = vrmsApplied_{ph} \times irmsApplied_{ph} \times \cos(\theta Applied_{radians})$$

$$activePowerSF(new)_{ph} = activePowerSF(initial)_{ph} \times \left(\frac{actApplied_{ph}}{actAverage_{ph}}\right)$$

$$reactivePowerSF(new)_{ph} = activePowerSF(new)_{ph}$$

2. Phase calibration process ($\theta Applied_{degrees} = 60°$)

Determine the initial total preload unit (TPU) from the whole sample delay (WSD) and fractional sample delay (FSD) from the EMDC-programmed MCU. FSD has units of preload bits. OSR is the ADC oversampling rate and equals the maximum number of preload bits that can be used for fractional sample delays.

$$FSD(initial)_{ph} = phaseCorrection(initial)_{ph} \,\&\, (OSR - 1)$$

$$WSD(initial)_{ph} = phaseCorrection(initial)_{ph} \gg 10$$

$$TPU(initial)_{ph} = \left(WSD(initial)_{ph} \times OSR\right) + FSD(initial)_{ph}$$

Recalculate $actApplied_{ph}$ since $\theta Applied_{degrees}$ was changed from 0 to 60 degrees.

$$actApplied_{ph} = vrmsApplied_{ph} \times irmsApplied_{ph} \times \cos(\theta Applied_{radians})$$

Calculate the active power error based on the applied active power.

$$actError_{ph} = 100 \times \left(\frac{actAverage_{ph}}{actApplied_{ph}} - 1\right)$$

Calculate the whole sample resolution (WSR) based on the ADC sampling frequency (4kHz) and AC signal frequency (e.g. 60 Hz). One AC cycle is 360 degrees, so WSR indicates how many degrees can be delayed per whole sample. Normally, whole sample delays are done in software by shifting one array index with respect to another array index. The WSR units are degrees.

$$WSR = 360° \times \left(\frac{f_{AC\,signal}}{f_{ADC\,sampling}}\right)$$

Calculate the fractional sample resolution (FSR) based on the WSR and ADC oversampling rate (OSR). The FSR indicates how many degrees an ADC sample can be delayed per preload bit. The maximum number of preload bits supported is equal to the OSR. The FSR units are degrees.

$$FSR = \frac{WSR}{OSR}$$

Calculate the minimum error delta for each FSR unit. This value will be used later to correlate the number of FSR units required to address the total active power error and update the new TPD.

$$errorDelta_{ph} = 100 \times \left(\frac{\cos(\theta Applied_{degrees}) - \cos(\theta Applied_{degrees} + FSR)}{\cos(\theta Applied_{degrees})} \right)$$

Calculate the total preload delta based on the calculated active power error.

$$preloadDelta_{ph} = -(int)round\left(\frac{actError_{ph}}{errorDelta_{ph}} \right)$$

Calculate the new TPU.

$$TPU(new)_{ph} = TPU(initial)_{ph} + preloadDelta_{ph}$$

Make sure the new TPU does not exceed the limits in either direction. HAL_ADC_V_ARRAY_LENGTH and HAL_ADC_I_ARRAY_LENGTH are the sizes of the voltage and current arrays and are defined in the 'hal_adc.h' file.

$$preloadMin = -OSR \times HAL\_ADC\_V\_ARRAY\_LENGTH$$

$$preloadMax = OSR \times HAL\_ADC\_I\_ARRAY\_LENGTH$$

$$preloadMin \leq TPU(new)_{ph} \leq preloadMax$$

Extract the new WSD and FSD values from the new TPU.

For TPU values greater than or equal to zero:

$$FSD(new)_{ph} = TPU(new)_{ph} \% OSR$$

$$WSD(new)_{ph} = (int)floor\left(\frac{TPU(new)_{ph}}{OSR} \right)$$

$$TPU(initial)_{ph} = (WSD(initial)_{ph} \times OSR) + FSD(initial)_{ph}$$

For negative TPU values:

$$FSD(new)_{ph} = (TPU(new)_{ph} \% OSR) + OSR$$

$$WSD(new)_{ph} = (int)floor\left(\frac{TPU(new)_{ph}}{OSR} \right)$$

$$TPU(initial)_{ph} = (WSD(initial)_{ph} \times OSR) + FSD(initial)_{ph}$$

Set the new WSD value equal to the upper 6 bits in $phaseCorrection(new)_{ph}$.

$$phaseCorrection(new)_{ph} = WSD(new)_{ph} \ll 10 \, \& \, 0xFC00$$

Set the new FSD value in $phaseCorrection(new)_{ph}$.

$$phaseCorrection(new)_{ph} = phaseCorrection(new)_{ph} \mid FSD(new)_{ph}$$

Update the $phaseCorrection_{ph}$ value on the EMDC-programmed MCU.