SCR GENERATED WAVEFORM MODELING

Thomas Blair, P.E., Phasetronics/Motortronics, Clearwater, Florida

With the proliferation of SCR (silicon controlled rectifier) power controls in the power industry, waveform harmonic content has become an issue of extreme interest. This paper describes a method of mathematically modeling the SCR phase controlled waveform. Then this paper describes a method of calculating the harmonic coefficients of the waveform. Then this paper describes a method of calculating the RMS (root mean square) and average value of current for the various conduction angles, as well as the THD (total harmonic distortion). The example used is an SCR with a delay angle of 90 degrees. Lastly, this paper provides the values calculated for a conduction degrees from 1 to 180 degrees in increments of 1degree.

While this paper provides the reader with a method of estimating the value for THD, please realize that the value calculated here would be a "worst case" value. This is due to the fact that, in an industrial system, there a many factors that effect the value of THD. For example, this analysis assumes a purely resistive load. In reality, most power controls control power to highly inductive components such as transformers or motors. In these applications, the inductance of the load will tend to cause the value of dI/dt to increase. This will have the beneficial effect of decreasing the odd order harmonic coefficients thus causing the value of THD in the actual application to be less than mo deled here. Similarly, any inductance in the feeder circuit from either the conductors or the supplying distribution transformer will tend to cause the value of dI/dt to increase. This will also have the beneficial effect of decreasing the odd order harmonic coefficients thus causing the value of THD in the actual application. Another issue is where the harmonics are actually being metered. Normally, with harmonics, the concern is the heating of the transformer supplying an industrial facility. Because of this, the normal location for monitoring the value of THD is at the service entrance to an industrial facility. Normally, the SCR controlled load is not the only load in the system. There will normally be other linear loads in the facility. Because of this, the THD as measured at the line leads of a power control would commonly be much higher then the THD measured at the service entrance to the system. Because of these factors, the values determined in the following analysis can be considered worse case and actual application THD should be some value less.

I DESCRIPTION OF SCR CONTROLLED POWER CIRCUIT

In the SCR power control circuit, the SCR device is placed directly in the AC circuit in series with the load[1]. The firing of the SCR is delayed by some time period. While the SCR is not gated, the output voltage is zero. When the SCR is gated, the output voltage is the line voltage from the time of gating to the next zero crosses when the SCR commutates off. The voltage waveform on the line side of the SCR power control is a pure sine wave (assuming no saturation occurs of the system) but the current waveform is a "chopped" sine wave. See figure #2 for an example of an SCR circuit.

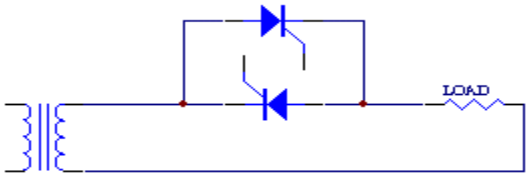

FIGURE #2: SCR CONTROLLED CIRCUIT

II MODELING OF SEMICONDUCTOR GENERATED WAVEFORM

In the SCR phase angle controlled circuit, the SCR is gated at some time delay (Td) after the zero cross of the applied voltage. The load voltage is that portion of the sine wave that is let through by the SCR device. The load RMS voltage is varied by varying the time delay before applying the gate signal to the SCR device. In discrete format, the SCR phase angle controlled waveform is evaluated as:

$$Fb(t) := Vp \cdot \sin\left\{\frac{2\cdot\pi}{Tb}\cdot t\right\}\cdot\left[\sum_{N=0}^{\infty}\left[\mu\left\{t - \frac{N\cdot Tb}{2} - Td\right\} - \mu\left[t - \frac{(N+1)\cdot Tb}{2}\right]\right]\right]$$

Once again, we will make the base frequency 60 Hz for this modeling example. If there is not inductance in the system, and we normalize the waveform to a load resistance of 1 ohm, then the current waveform on the line side exactly mirrors the voltage waveform across the load. An example waveform is shown below in figure #3 with a delay angle of 90 degrees and with a peak voltage of 1 and a frequency of 60 Hz.

DEFINITION OF CONSTANTS FOR PURPOSE OF CALCULATIONS:

$TIME := 2\cdot\pi$ $N := 180$ $J30 := 1..2\cdot N$ $K2 := 20$ $Fi := 60$

$Z := 100$ $M := 0..Z$ $M2 := 1..Z$ $Ti := \frac{1}{Fi}$ $TIME_{J30} := \frac{J30}{2\cdot Fi\cdot N}$

CALCULATION OF PHASE ANGLE CONTROLLED SINE WAVE:

$DEGREE := 90$ ANGLE OF DELAY OF SCR GATING (IN DEGREES)

$Ip := 1$ PEAK VALUE OF CURRENT FOR THE SINEWAVE

$Z1 := 1..DEGREE$ INDEX FOR FIRST HALF OF POSITIVE WAVEFORM

$Z2 := DEGREE + 1, DEGREE + 2..N$ INDEX FOR SECOND HALF OF POSITIVE WAVEFORM

$Z3 := N + 1, N + 2..N + DEGREE$ INDEX FOR FIRST HALF OF NEGATIVE WAVEFORM

$Z4 := N + DEGREE + 1, N + DEGREE + 2..2\cdot N$ INDEX FOR SECOND HALF OF NEGATIVE WAVEFORM

$ISIN_{Z1} := 0$ CURRENT VALUE FOR FIRST HALF OF POSITIVE WAVEFORM

$ISIN_{Z2} := Ip\cdot\sin\left(\pi\cdot\frac{Z2}{N}\right)$ CURRENT VALUE FOR SECOND HALF OF POSITIVE WAVEFORM

$ISIN_{Z3} := 0$ CURRENT VALUE FOR FIRST HALF OF NEGATIVE WAVEFORM

$ISIN_{Z4} := Ip\cdot\sin\left(\pi\cdot\frac{Z4}{N}\right)$ CURRENT VALUE FOR SECOND HALF OF NEGATIVE WAVEFORM

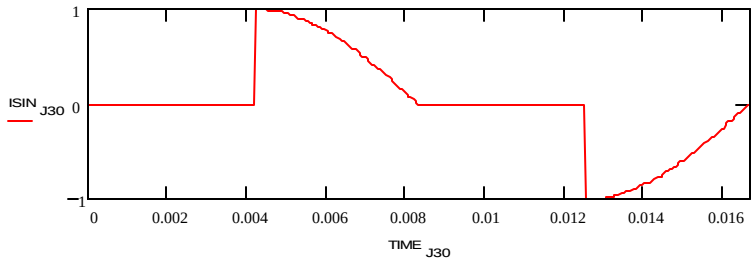

FIGURE #3: SCR GENERATED WAVEFORM

III HARMONIC ANALYSIS OF WAVEFORMS

Now that we have successfully defined our SCR device generated waveform, the next step in our analysis is to calculate the harmonic coefficients and then calculate the total harmonic distortion of this waveform. Any waveform can be defined as the summation of sinusoidal waveforms with varying coefficients of gain at increasing frequencies. This is the basis for harmonic analysis[3]. It is recommended that the harmonic coefficients be calculated from DC up to at least 10 times base carrier frequency to ensure accuracy for the PWM generated waveform. For clarity, the example below shows all harmonics from DC up to 100 times base frequency. For the SCR controlled waveform it will be seen that the majority of harmonics exist in the 3, 5, 7, 9, 11, and 13 harmonics and it is common practice to just calculate these harmonic coefficients.

DEFINITION OF CONSTANTS FOR PURPOSE OF CALCULATIONS:

$Ts := 2 \cdot N$ DEFINITION OF SAMPLE PERIOD FOR FORIER ANALYSIS

$THETA_{J30} := 2 \cdot \pi \cdot Fi \cdot TIME_{J30}$ CALCULATION OF HARMONIC FREQUENCIES

DEFINITION OF THE COEFFICIENT FOR THE AVERAGE COMPONENT OF THE WAVEFORM UNDER EVALUATION

$$A_0 := \frac{2}{Ts} \cdot \left(\sum_{J30=1}^{Ts} ISIN_{J30} \right) \qquad B_0 := 0$$

$A_0 = 0$

DEFINITION OF THE COEFFICIENT FOR THE FUNDAMENTAL COMPONENT OF THE WAVEFORM UNDER EVALUATION

$C1 := 1$

$G_{J30} := \cos(THETA_{J30} \cdot C1)$ $H_{J30} := \sin(THETA_{J30} \cdot C1)$

$$A_1 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_1 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_1 = -0.318$ $B_1 = 0.494$

DEFINITION OF THE COEFFICIENT FOR THE SECOND HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C2 := 2$

$G_{J30} := \cos(THETA_{J30} \cdot C2)$ $H_{J30} := \sin(THETA_{J30} \cdot C2)$

$$A_2 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_2 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_2 = 0$ $B_2 = 0$

DEFINITION OF THE COEFFICIENT FOR THE THIRD HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C3 := 3$

$G_{J30} := \cos(THETA_{J30} \cdot C3)$ $H_{J30} := \sin(THETA_{J30} \cdot C3)$

$$A_3 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_3 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_3 = 0.318$ $B_3 = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE FOURTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C4 := 4$

$G_{J30} := \cos(THETA_{J30} \cdot C4)$ $\qquad$ $H_{J30} := \sin(THETA_{J30} \cdot C4)$

$$A_4 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_4 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_4 = 0$ $\qquad$ $B_4 = 0$

DEFINITION OF THE COEFFICIENT FOR THE FIFTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C5 := 5$

$G_{J30} := \cos(THETA_{J30} \cdot C5)$ $\qquad$ $H_{J30} := \sin(THETA_{J30} \cdot C5)$

$$A_5 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_5 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_5 = -0.106$ $\qquad$ $B_5 = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE SIXTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C6 := 6$

$G_{J30} := \cos(THETA_{J30} \cdot C6)$ $\qquad$ $H_{J30} := \sin(THETA_{J30} \cdot C6)$

$$A_6 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_6 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_6 = 0$ $\qquad$ $B_6 = 0$

DEFINITION OF THE COEFFICIENT FOR THE SEVENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C7 := 7$

$G_{J30} := \cos(THETA_{J30} \cdot C7)$ $\qquad$ $H_{J30} := \sin(THETA_{J30} \cdot C7)$

$$A_7 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_7 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_7 = 0.106$ $\qquad$ $B_7 = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE EIGHTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C8 := 8$

$G_{J30} := \cos(THETA_{J30} \cdot C8)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C8)$

$$A_8 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_8 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_8 = 0$ $\quad$ $B_8 = 0$

DEFINITION OF THE COEFFICIENT FOR THE NINTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C9 := 9$

$G_{J30} := \cos(THETA_{J30} \cdot C9)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C9)$

$$A_9 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_9 := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_9 = -0.064$ $\quad$ $B_9 = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE TENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C10 := 10$

$G_{J30} := \cos(THETA_{J30} \cdot C10)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C10)$

$$A_{10} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{10} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{10} = 0$ $\quad$ $B_{10} = 0$

DEFINITION OF THE COEFFICIENT FOR THE ELEVENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C11 := 11$

$G_{J30} := \cos(THETA_{J30} \cdot C11)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C11)$

$$A_{11} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{11} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{11} = 0.064$ $\quad$ $B_{11} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE TWELTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C12 := 12$

$G_{J30} := \cos(THETA_{J30} \cdot C12)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C12)$

$$A_{12} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{12} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{12} = 0$ $\quad$ $B_{12} = 0$

DEFINITION OF THE COEFFICIENT FOR THE THIRTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C13 := 13$

$G_{J30} := \cos(THETA_{J30} \cdot C13)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C13)$

$$A_{13} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{13} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{13} = -0.045$ $\quad$ $B_{13} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE FOURTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C14 := 14$

$G_{J30} := \cos(THETA_{J30} \cdot C14)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C14)$

$$A_{14} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{14} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{14} = 0$ $\quad$ $B_{14} = 0$

DEFINITION OF THE COEFFICIENT FOR THE FIFTHTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C15 := 15$

$G_{J30} := \cos(THETA_{J30} \cdot C15)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C15)$

$$A_{15} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{15} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{15} = 0.045$ $\quad$ $B_{15} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE SIXTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C16 := 16$

$G_{J30} := \cos(THETA_{J30} \cdot C16)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C16)$

$$A_{16} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{16} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{16} = 0$ $\quad$ $B_{16} = 0$

DEFINITION OF THE COEFFICIENT FOR THE SEVENTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C17 := 17$

$G_{J30} := \cos(THETA_{J30} \cdot C17)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C17)$

$$A_{17} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{17} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{17} = -0.035$ $\quad$ $B_{17} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE EIGHTEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C18 := 18$

$G_{J30} := \cos(THETA_{J30} \cdot C18)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C18)$

$$A_{18} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{18} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{18} = 0$ $\quad$ $B_{18} = 0$

DEFINITION OF THE COEFFICIENT FOR THE NINETEENTH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C19 := 19$

$G_{J30} := \cos(THETA_{J30} \cdot C19)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C19)$

$$A_{19} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{19} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{19} = 0.035$ $\quad$ $B_{19} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 20TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C20 := 20$

$G_{J30} := \cos(THETA_{J30} \cdot C20)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C20)$

$$A_{20} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{20} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{20} = 0$ $\quad$ $B_{20} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 21TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C21 := 21$

$G_{J30} := \cos(THETA_{J30} \cdot C21)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C21)$

$$A_{21} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{21} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{21} = -0.029$ $\quad$ $B_{21} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 22TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C22 := 22$

$G_{J30} := \cos(THETA_{J30} \cdot C22)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C22)$

$$A_{22} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{22} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{22} = 0$ $\quad$ $B_{22} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 23TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C23 := 23$

$G_{J30} := \cos(THETA_{J30} \cdot C23)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C23)$

$$A_{23} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{23} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{23} = 0.029$ $\quad$ $B_{23} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 24TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C24 := 24$

$G_{J30} := \cos(THETA_{J30} \cdot C24)$ $H_{J30} := \sin(THETA_{J30} \cdot C24)$

$$A_{24} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{24} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{24} = 0$ $B_{24} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 25TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C25 := 25$

$G_{J30} := \cos(THETA_{J30} \cdot C25)$ $H_{J30} := \sin(THETA_{J30} \cdot C25)$

$$A_{25} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{25} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{25} = -0.024$ $B_{25} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 26TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C26 := 26$

$G_{J30} := \cos(THETA_{J30} \cdot C26)$ $H_{J30} := \sin(THETA_{J30} \cdot C26)$

$$A_{26} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{26} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{26} = 0$ $B_{26} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 27TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C27 := 27$

$G_{J30} := \cos(THETA_{J30} \cdot C27)$ $H_{J30} := \sin(THETA_{J30} \cdot C27)$

$$A_{27} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{27} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{27} = 0.024$ $B_{27} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 28TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C28 := 28$

$G_{J30} := \cos(THETA_{J30} \cdot C28)$ $H_{J30} := \sin(THETA_{J30} \cdot C28)$

$$A_{28} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{28} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{28} = 0$ $B_{28} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 29TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C29 := 29$

$G_{J30} := \cos(THETA_{J30} \cdot C29)$ $H_{J30} := \sin(THETA_{J30} \cdot C29)$

$$A_{29} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{29} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{29} = -0.021$ $B_{29} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 30TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C30 := 30$

$G_{J30} := \cos(THETA_{J30} \cdot C30)$ $H_{J30} := \sin(THETA_{J30} \cdot C30)$

$$A_{30} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{30} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{30} = 0$ $B_{30} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 31TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C31 := 31$

$G_{J30} := \cos(THETA_{J30} \cdot C31)$ $H_{J30} := \sin(THETA_{J30} \cdot C31)$

$$A_{31} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{31} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{31} = 0.021$ $B_{31} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 32TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C32 := 32$

$G_{J30} := \cos(THETA_{J30} \cdot C32)$ $H_{J30} := \sin(THETA_{J30} \cdot C32)$

$$A_{32} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{32} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{32} = 0$ $B_{32} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 33TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C33 := 33$

$G_{J30} := \cos(THETA_{J30} \cdot C33)$ $H_{J30} := \sin(THETA_{J30} \cdot C33)$

$$A_{33} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{33} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{33} = -0.018$ $B_{33} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 34TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C34 := 34$

$G_{J30} := \cos(THETA_{J30} \cdot C34)$ $H_{J30} := \sin(THETA_{J30} \cdot C34)$

$$A_{34} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{34} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{34} = 0$ $B_{34} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 35TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C35 := 35$

$G_{J30} := \cos(THETA_{J30} \cdot C35)$ $H_{J30} := \sin(THETA_{J30} \cdot C35)$

$$A_{35} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{35} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{35} = 0.018$ $B_{35} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 36TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C36 := 36$

$G_{J30} := \cos(THETA_{J30} \cdot C36)$ $H_{J30} := \sin(THETA_{J30} \cdot C36)$

$$A_{36} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{36} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{36} = 0$ $B_{36} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 37TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C37 := 37$

$G_{J30} := \cos(THETA_{J30} \cdot C37)$ $H_{J30} := \sin(THETA_{J30} \cdot C37)$

$$A_{37} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{37} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{37} = -0.016$ $B_{37} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 38TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C38 := 38$

$G_{J30} := \cos(THETA_{J30} \cdot C38)$ $H_{J30} := \sin(THETA_{J30} \cdot C38)$

$$A_{38} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{38} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{38} = 0$ $B_{38} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 39TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C39 := 39$

$G_{J30} := \cos(THETA_{J30} \cdot C39)$ $H_{J30} := \sin(THETA_{J30} \cdot C39)$

$$A_{39} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{39} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{39} = 0.016$ $B_{39} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 40TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C40 := 40$

$G_{J30} := \cos(THETA_{J30} \cdot C40)$ $H_{J30} := \sin(THETA_{J30} \cdot C40)$

$$A_{40} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{40} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{40} = 0$ $B_{40} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 41TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C41 := 41$

$G_{J30} := \cos(THETA_{J30} \cdot C41)$ $H_{J30} := \sin(THETA_{J30} \cdot C41)$

$$A_{41} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{41} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{41} = -0.014$ $B_{41} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 42TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C42 := 42$

$G_{J30} := \cos(THETA_{J30} \cdot C42)$ $H_{J30} := \sin(THETA_{J30} \cdot C42)$

$$A_{42} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{42} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{42} = 0$ $B_{42} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 43TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C43 := 43$

$G_{J30} := \cos(THETA_{J30} \cdot C43)$ $H_{J30} := \sin(THETA_{J30} \cdot C43)$

$$A_{43} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{43} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{43} = 0.014$ $B_{43} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 44TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C44 := 44$

$G_{J30} := \cos(THETA_{J30} \cdot C44)$

$H_{J30} := \sin(THETA_{J30} \cdot C44)$

$A_{44} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right]$

$B_{44} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$

$A_{44} = 0$

$B_{44} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 45TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C45 := 45$

$G_{J30} := \cos(THETA_{J30} \cdot C45)$

$H_{J30} := \sin(THETA_{J30} \cdot C45)$

$A_{45} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right]$

$B_{45} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$

$A_{45} = -0.013$

$B_{45} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 46TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C46 := 46$

$G_{J30} := \cos(THETA_{J30} \cdot C46)$

$H_{J30} := \sin(THETA_{J30} \cdot C46)$

$A_{46} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right]$

$B_{46} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$

$A_{46} = 0$

$B_{46} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 47TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C47 := 47$

$G_{J30} := \cos(THETA_{J30} \cdot C47)$

$H_{J30} := \sin(THETA_{J30} \cdot C47)$

$A_{47} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right]$

$B_{47} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$

$A_{47} = 0.013$

$B_{47} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 48TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C48 := 48$

$G_{J30} := \cos(THETA_{J30} \cdot C48)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C48)$

$$A_{48} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{48} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{48} = 0$ $\quad$ $B_{48} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 49TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C49 := 49$

$G_{J30} := \cos(THETA_{J30} \cdot C49)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C49)$

$$A_{49} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{49} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{49} = -0.012$ $\quad$ $B_{49} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 50TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C50 := 50$

$G_{J30} := \cos(THETA_{J30} \cdot C50)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C50)$

$$A_{50} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{50} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{50} = 0$ $\quad$ $B_{50} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 51TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C51 := 51$

$G_{J30} := \cos(THETA_{J30} \cdot C51)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C51)$

$$A_{51} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{51} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{51} = 0.012$ $\quad$ $B_{51} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 52TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C52 := 52$

$G_{J30} := \cos(THETA_{J30} \cdot C52)$ $H_{J30} := \sin(THETA_{J30} \cdot C52)$

$$A_{52} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{52} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{52} = 0$ $B_{52} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 53TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C53 := 53$

$G_{J30} := \cos(THETA_{J30} \cdot C53)$ $H_{J30} := \sin(THETA_{J30} \cdot C53)$

$$A_{53} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{53} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{53} = -0.011$ $B_{53} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 54TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C54 := 54$

$G_{J30} := \cos(THETA_{J30} \cdot C54)$ $H_{J30} := \sin(THETA_{J30} \cdot C54)$

$$A_{54} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{54} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{54} = 1.253 \cdot 10^{-15}$ $B_{54} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 55TH HARMONIC OF THE WAVEFORM UI
EVALUATION

$C55 := 55$

$G_{J30} := \cos(THETA_{J30} \cdot C55)$ $H_{J30} := \sin(THETA_{J30} \cdot C55)$

$$A_{55} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{55} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{55} = 0.011$ $B_{55} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 56TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C56 := 56$

$G_{J30} := \cos(THETA_{J30} \cdot C56)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C56)$

$$A_{56} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{56} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{56} = 0$ $\quad$ $B_{56} = -1.066 \cdot 10^{-15}$

DEFINITION OF THE COEFFICIENT FOR THE 57TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C57 := 57$

$G_{J30} := \cos(THETA_{J30} \cdot C57)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C57)$

$$A_{57} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{57} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{57} = -0.01$ $\quad$ $B_{57} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 58TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C58 := 58$

$G_{J30} := \cos(THETA_{J30} \cdot C58)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C58)$

$$A_{58} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{58} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{58} = -1.158 \cdot 10^{-15}$ $\quad$ $B_{58} = 1.081 \cdot 10^{-15}$

DEFINITION OF THE COEFFICIENT FOR THE 59TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C59 := 59$

$G_{J30} := \cos(THETA_{J30} \cdot C59)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C59)$

$$A_{59} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{59} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{59} = 0.01$ $\quad$ $B_{59} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 60TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C60 := 60$

$G_{J30} := \cos(THETA_{J30} \cdot C60)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C60)$

$$A_{60} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{60} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{60} = 0$ $\quad$ $B_{60} = 1.188 \cdot 10^{-15}$

DEFINITION OF THE COEFFICIENT FOR THE 61ST HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C61 := 61$

$G_{J30} := \cos(THETA_{J30} \cdot C61)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C61)$

$$A_{61} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{61} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{61} = -0.009$ $\quad$ $B_{61} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 62ND HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C62 := 62$

$G_{J30} := \cos(THETA_{J30} \cdot C62)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C62)$

$$A_{62} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{62} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{62} = -1.173 \cdot 10^{-15}$ $\quad$ $B_{62} = -1.871 \cdot 10^{-15}$

DEFINITION OF THE COEFFICIENT FOR THE 63RD HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C63 := 63$

$G_{J30} := \cos(THETA_{J30} \cdot C63)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C63)$

$$A_{63} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{63} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{63} = 0.009$ $\quad$ $B_{63} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 64TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C64 := 64$

$G_{J30} := \cos(THETA_{J30} \cdot C64)$ $H_{J30} := \sin(THETA_{J30} \cdot C64)$

$$A_{64} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{64} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{64} = 0$ $B_{64} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 65TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C65 := 65$

$G_{J30} := \cos(THETA_{J30} \cdot C65)$ $H_{J30} := \sin(THETA_{J30} \cdot C65)$

$$A_{65} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{65} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{65} = -0.009$ $B_{65} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 66TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C66 := 66$

$G_{J30} := \cos(THETA_{J30} \cdot C66)$ $H_{J30} := \sin(THETA_{J30} \cdot C66)$

$$A_{66} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{66} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{66} = 0$ $B_{66} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 67TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C67 := 67$

$G_{J30} := \cos(THETA_{J30} \cdot C67)$ $H_{J30} := \sin(THETA_{J30} \cdot C67)$

$$A_{67} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{67} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{67} = 0.009$ $B_{67} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 68TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C68 := 68$

$G_{J30} := \cos(THETA_{J30} \cdot C68)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C68)$

$$A_{68} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{68} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{68} = 0$ $\quad$ $B_{68} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 69TH HARMONIC OF THE WAVEFORM UNDEF EVALUATION

$C69 := 69$

$G_{J30} := \cos(THETA_{J30} \cdot C69)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C69)$

$$A_{69} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{69} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{69} = -0.008$ $\quad$ $B_{69} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 70TH HARMONIC OF THE WAVEFORM UNDEF EVALUATION

$C70 := 70$

$G_{J30} := \cos(THETA_{J30} \cdot C70)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C70)$

$$A_{70} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{70} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{70} = 0$ $\quad$ $B_{70} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 71TH HARMONIC OF THE WAVEFORM UNDEF EVALUATION

$C71 := 71$

$G_{J30} := \cos(THETA_{J30} \cdot C71)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C71)$

$$A_{71} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{71} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{71} = 0.008$ $\quad$ $B_{71} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 72TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C72 := 72$

$G_{J30} := \cos(THETA_{J30} \cdot C72)$ $H_{J30} := \sin(THETA_{J30} \cdot C72)$

$$A_{72} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{72} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{72} = 0$ $B_{72} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 73TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C73 := 73$

$G_{J30} := \cos(THETA_{J30} \cdot C73)$ $H_{J30} := \sin(THETA_{J30} \cdot C73)$

$$A_{73} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{73} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{73} = -0.007$ $B_{73} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 74TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C74 := 74$

$G_{J30} := \cos(THETA_{J30} \cdot C74)$ $H_{J30} := \sin(THETA_{J30} \cdot C74)$

$$A_{74} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{74} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{74} = 0$ $B_{74} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 75TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C75 := 75$

$G_{J30} := \cos(THETA_{J30} \cdot C75)$ $H_{J30} := \sin(THETA_{J30} \cdot C75)$

$$A_{75} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{75} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{75} = 0.007$ $B_{75} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 76TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C76 := 76$

$G_{J30} := \cos(THETA_{J30} \cdot C76)$ $H_{J30} := \sin(THETA_{J30} \cdot C76)$

$$A_{76} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{76} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{76} = 0$ $B_{76} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 77TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C77 := 77$

$G_{J30} := \cos(THETA_{J30} \cdot C77)$ $H_{J30} := \sin(THETA_{J30} \cdot C77)$

$$A_{77} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{77} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{77} = -0.007$ $B_{77} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 78TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C78 := 78$

$G_{J30} := \cos(THETA_{J30} \cdot C78)$ $H_{J30} := \sin(THETA_{J30} \cdot C78)$

$$A_{78} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{78} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{78} = 0$ $B_{78} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 79TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C79 := 79$

$G_{J30} := \cos(THETA_{J30} \cdot C79)$ $H_{J30} := \sin(THETA_{J30} \cdot C79)$

$$A_{79} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{79} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{79} = 0.007$ $B_{79} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 80TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C80 := 80$

$G_{J30} := \cos(THETA_{J30} \cdot C80)$ $H_{J30} := \sin(THETA_{J30} \cdot C80)$

$$A_{80} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{80} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{80} = 0$ $B_{80} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 81TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C81 := 81$

$G_{J30} := \cos(THETA_{J30} \cdot C81)$ $H_{J30} := \sin(THETA_{J30} \cdot C81)$

$$A_{81} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{81} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{81} = -0.006$ $B_{81} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 82TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C82 := 82$

$G_{J30} := \cos(THETA_{J30} \cdot C82)$ $H_{J30} := \sin(THETA_{J30} \cdot C82)$

$$A_{82} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{82} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{82} = -1.114 \cdot 10^{-15}$ $B_{82} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 83TH HARMONIC OF THE WAVEFORM UNDEF
EVALUATION

$C83 := 83$

$G_{J30} := \cos(THETA_{J30} \cdot C83)$ $H_{J30} := \sin(THETA_{J30} \cdot C83)$

$$A_{83} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{83} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{83} = 0.006$ $B_{83} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 84TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C84 := 84$

$G_{J30} := \cos(THETA_{J30} \cdot C84)$ $H_{J30} := \sin(THETA_{J30} \cdot C84)$

$$A_{84} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{84} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{84} = 0$ $B_{84} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 85TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C85 := 85$

$G_{J30} := \cos(THETA_{J30} \cdot C85)$ $H_{J30} := \sin(THETA_{J30} \cdot C85)$

$$A_{85} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{85} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{85} = -0.006$ $B_{85} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 86TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C86 := 86$

$G_{J30} := \cos(THETA_{J30} \cdot C86)$ $H_{J30} := \sin(THETA_{J30} \cdot C86)$

$$A_{86} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{86} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{86} = 0$ $B_{86} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 87TH HARMONIC OF THE WAVEFORM UNDE EVALUATION

$C87 := 87$

$G_{J30} := \cos(THETA_{J30} \cdot C87)$ $H_{J30} := \sin(THETA_{J30} \cdot C87)$

$$A_{87} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{87} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{87} = 0.006$ $B_{87} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 88TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C88 := 88$

$G_{J30} := \cos(THETA_{J30} \cdot C88)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C88)$

$$A_{88} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{88} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{88} = 0$ $\quad$ $B_{88} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 89TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C89 := 89$

$G_{J30} := \cos(THETA_{J30} \cdot C89)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C89)$

$$A_{89} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{89} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{89} = -0.006$ $\quad$ $B_{89} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 90TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C90 := 90$

$G_{J30} := \cos(THETA_{J30} \cdot C90)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C90)$

$$A_{90} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{90} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{90} = 0$ $\quad$ $B_{90} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 91TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C91 := 91$

$G_{J30} := \cos(THETA_{J30} \cdot C91)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C91)$

$$A_{91} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right] \qquad B_{91} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{91} = 0.006$ $\quad$ $B_{91} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 92TH HARMONIC OF THE WAVEFORM U
EVALUATION

$C92 := 92$

$G_{J30} := \cos(THETA_{J30} \cdot C92)$ $H_{J30} := \sin(THETA_{J30} \cdot C92)$

$$A_{92} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{92} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{92} = 0$ $B_{92} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 93TH HARMONIC OF THE WAVEFORM U
EVALUATION

$C93 := 93$

$G_{J30} := \cos(THETA_{J30} \cdot C93)$ $H_{J30} := \sin(THETA_{J30} \cdot C93)$

$$A_{93} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{93} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{93} = -0.005$ $B_{93} = -0.006$

DEFINITION OF THE COEFFICIENT FOR THE 94TH HARMONIC OF THE WAVEFORM U
EVALUATION

$C94 := 94$

$G_{J30} := \cos(THETA_{J30} \cdot C94)$ $H_{J30} := \sin(THETA_{J30} \cdot C94)$

$$A_{94} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{94} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{94} = 0$ $B_{94} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 95TH HARMONIC OF THE WAVEFORM U
EVALUATION

$C95 := 95$

$G_{J30} := \cos(THETA_{J30} \cdot C95)$ $H_{J30} := \sin(THETA_{J30} \cdot C95)$

$$A_{95} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{95} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{95} = 0.005$ $B_{95} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 96TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C96 := 96$

$G_{J30} := \cos(THETA_{J30} \cdot C96)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C96)$

$$A_{96} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{96} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{96} = 0$ $\quad$ $B_{96} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 97TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C97 := 97$

$G_{J30} := \cos(THETA_{J30} \cdot C97)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C97)$

$$A_{97} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{97} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{97} = -0.005$ $\quad$ $B_{47} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 98TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C98 := 98$

$G_{J30} := \cos(THETA_{J30} \cdot C98)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C98)$

$$A_{98} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{98} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{98} = 0$ $\quad$ $B_{98} = 0$

DEFINITION OF THE COEFFICIENT FOR THE 99TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C99 := 99$

$G_{J30} := \cos(THETA_{J30} \cdot C99)$ $\quad$ $H_{J30} := \sin(THETA_{J30} \cdot C99)$

$$A_{99} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot G_{J30}) \right] \right] \qquad B_{99} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} (ISIN_{J30} \cdot H_{J30}) \right] \right]$$

$A_{99} = 0.005$ $\quad$ $B_{99} = 0.006$

DEFINITION OF THE COEFFICIENT FOR THE 100TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

DEFINITION OF THE COEFFICIENT FOR THE 100TH HARMONIC OF THE WAVEFORM UNDER EVALUATION

$C100 := 100$

$G_{J30} := \cos(THETA_{J30} \cdot C100)$

$H_{J30} := \sin(THETA_{J30} \cdot C100)$

$$A_{100} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot G_{J30} \right) \right] \right]$$

$$B_{100} := \frac{2}{Ts} \cdot \left[\left[\sum_{J30=1}^{Ts} \left(ISIN_{J30} \cdot H_{J30} \right) \right] \right]$$

$A_{100} = 0$

$B_{100} = 1.006 \cdot 10^{-15}$

IV REGENERATION OF WAVEFORM FROM HARMONIC COEFFICIENTS

In order to verify that the majority of harmonic coefficients have been found, it is highly recommended that the waveform be regenerated from the coefficients and compared with the original waveform. If the majority of coefficients have been found, the regenerated waveform should closely approximate the original waveform. In this analysis, the harmonics from DC to the 100^{TH} harmonic were evaluated and are reconstructed below.) Then the reconstructed waveform is graphed over the original waveform to verify accuracy. This waveforms are shown in figure #4.

$$IFB0 := \frac{A_0}{2}$$

$IFB1_{J30} := A_1 \cdot \cos(THETA_{J30} \cdot C1) + B_1 \cdot \sin(THETA_{J30} \cdot C1)$

$IFB2_{J30} := A_2 \cdot \cos(THETA_{J30} \cdot C2) + B_2 \cdot \sin(THETA_{J30} \cdot C2)$

$IFB3_{J30} := A_3 \cdot \cos(THETA_{J30} \cdot C3) + B_3 \cdot \sin(THETA_{J30} \cdot C3)$

$IFB4_{J30} := A_4 \cdot \cos(THETA_{J30} \cdot C4) + B_4 \cdot \sin(THETA_{J30} \cdot C4)$

$IFB5_{J30} := A_5 \cdot \cos(THETA_{J30} \cdot C5) + B_5 \cdot \sin(THETA_{J30} \cdot C5)$

$IFB6_{J30} := A_6 \cdot \cos(THETA_{J30} \cdot C6) + B_6 \cdot \sin(THETA_{J30} \cdot C6)$

$IFB7_{J30} := A_7 \cdot \cos(THETA_{J30} \cdot C7) + B_7 \cdot \sin(THETA_{J30} \cdot C7)$

$IFB8_{J30} := A_8 \cdot \cos(THETA_{J30} \cdot C8) + B_8 \cdot \sin(THETA_{J30} \cdot C8)$

$IFB9_{J30} := A_9 \cdot \cos(THETA_{J30} \cdot C9) + B_9 \cdot \sin(THETA_{J30} \cdot C9)$

$IFB10_{J30} := A_{10} \cdot \cos(THETA_{J30} \cdot C10) + B_{10} \cdot \sin(THETA_{J30} \cdot C10)$

$$IFB11_{J3O} := A_{11} \cdot \cos\left(THETA_{J3O} \cdot C11\right) + B_{11} \cdot \sin\left(THETA_{J3O} \cdot C11\right)$$

$$IFB12_{J3O} := A_{12} \cdot \cos\left(THETA_{J3O} \cdot C12\right) + B_{12} \cdot \sin\left(THETA_{J3O} \cdot C12\right)$$

$$IFB13_{J3O} := A_{13} \cdot \cos\left(THETA_{J3O} \cdot C13\right) + B_{13} \cdot \sin\left(THETA_{J3O} \cdot C13\right)$$

$$IFB14_{J3O} := A_{14} \cdot \cos\left(THETA_{J3O} \cdot C14\right) + B_{14} \cdot \sin\left(THETA_{J3O} \cdot C14\right)$$

$$IFB15_{J3O} := A_{15} \cdot \cos\left(THETA_{J3O} \cdot C15\right) + B_{15} \cdot \sin\left(THETA_{J3O} \cdot C15\right)$$

$$IFB16_{J3O} := A_{16} \cdot \cos\left(THETA_{J3O} \cdot C16\right) + B_{16} \cdot \sin\left(THETA_{J3O} \cdot C16\right)$$

$$IFB17_{J3O} := A_{17} \cdot \cos\left(THETA_{J3O} \cdot C17\right) + B_{17} \cdot \sin\left(THETA_{J3O} \cdot C17\right)$$

$$IFB18_{J3O} := A_{18} \cdot \cos\left(THETA_{J3O} \cdot C18\right) + B_{18} \cdot \sin\left(THETA_{J3O} \cdot C18\right)$$

$$IFB19_{J3O} := A_{19} \cdot \cos\left(THETA_{J3O} \cdot C19\right) + B_{19} \cdot \sin\left(THETA_{J3O} \cdot C19\right)$$

$$IFB20_{J3O} := A_{20} \cdot \cos\left(THETA_{J3O} \cdot C20\right) + B_{20} \cdot \sin\left(THETA_{J3O} \cdot C20\right)$$

$$IFB21_{J3O} := A_{21} \cdot \cos\left(THETA_{J3O} \cdot C21\right) + B_{21} \cdot \sin\left(THETA_{J3O} \cdot C21\right)$$

$$IFB22_{J3O} := A_{22} \cdot \cos\left(THETA_{J3O} \cdot C22\right) + B_{22} \cdot \sin\left(THETA_{J3O} \cdot C22\right)$$

$$IFB23_{J3O} := A_{23} \cdot \cos\left(THETA_{J3O} \cdot C23\right) + B_{23} \cdot \sin\left(THETA_{J3O} \cdot C23\right)$$

$$IFB24_{J3O} := A_{24} \cdot \cos\left(THETA_{J3O} \cdot C24\right) + B_{24} \cdot \sin\left(THETA_{J3O} \cdot C24\right)$$

$$IFB25_{J3O} := A_{25} \cdot \cos\left(THETA_{J3O} \cdot C25\right) + B_{25} \cdot \sin\left(THETA_{J3O} \cdot C25\right)$$

$$IFB26_{J3O} := A_{26} \cdot \cos\left(THETA_{J3O} \cdot C26\right) + B_{26} \cdot \sin\left(THETA_{J3O} \cdot C26\right)$$

$$IFB27_{J3O} := A_{27} \cdot \cos\left(THETA_{J3O} \cdot C27\right) + B_{27} \cdot \sin\left(THETA_{J3O} \cdot C27\right)$$

$$IFB28_{J3O} := A_{28} \cdot \cos\left(THETA_{J3O} \cdot C28\right) + B_{28} \cdot \sin\left(THETA_{J3O} \cdot C28\right)$$

$$IFB29_{J3O} := A_{29} \cdot \cos\left(THETA_{J3O} \cdot C29\right) + B_{29} \cdot \sin\left(THETA_{J3O} \cdot C29\right)$$

$$IFB30_{J3O} := A_{30} \cdot \cos\left(THETA_{J3O} \cdot C30\right) + B_{30} \cdot \sin\left(THETA_{J3O} \cdot C30\right)$$

$$IFB31_{J3O} := A_{31} \cdot \cos\left(THETA_{J3O} \cdot C31\right) + B_{31} \cdot \sin\left(THETA_{J3O} \cdot C31\right)$$

$$IFB32_{J3O} := A_{32} \cdot \cos\left(THETA_{J3O} \cdot C32\right) + B_{32} \cdot \sin\left(THETA_{J3O} \cdot C32\right)$$

$$IFB33_{J3O} := A_{33} \cdot \cos\left(THETA_{J3O} \cdot C33\right) + B_{33} \cdot \sin\left(THETA_{J3O} \cdot C33\right)$$

$$IFB34_{J3O} := A_{34} \cdot \cos\left(THETA_{J3O} \cdot C34\right) + B_{34} \cdot \sin\left(THETA_{J3O} \cdot C34\right)$$

$$IFB35_{J3O} := A_{35} \cdot \cos\left(THETA_{J3O} \cdot C35\right) + B_{35} \cdot \sin\left(THETA_{J3O} \cdot C35\right)$$

$$IFB36_{J3O} := A_{36} \cdot \cos\left(THETA_{J3O} + C36\right) + B_{36} \cdot \sin\left(THETA_{J3O} + C36\right)$$

$$IFB37_{J3O} := A_{37} \cdot \cos\left(THETA_{J3O} + C37\right) + B_{37} \cdot \sin\left(THETA_{J3O} + C37\right)$$

$$IFB38_{J3O} := A_{38} \cdot \cos\left(THETA_{J3O} + C38\right) + B_{38} \cdot \sin\left(THETA_{J3O} + C38\right)$$

$$IFB39_{J3O} := A_{39} \cdot \cos\left(THETA_{J3O} + C39\right) + B_{39} \cdot \sin\left(THETA_{J3O} + C39\right)$$

$$IFB40_{J3O} := A_{40} \cdot \cos\left(THETA_{J3O} + C40\right) + B_{40} \cdot \sin\left(THETA_{J3O} + C40\right)$$

$$IFB41_{J3O} := A_{41} \cdot \cos\left(THETA_{J3O} + C41\right) + B_{41} \cdot \sin\left(THETA_{J3O} + C41\right)$$

$$IFB42_{J3O} := A_{42} \cdot \cos\left(THETA_{J3O} + C42\right) + B_{42} \cdot \sin\left(THETA_{J3O} + C42\right)$$

$$IFB43_{J3O} := A_{43} \cdot \cos\left(THETA_{J3O} + C43\right) + B_{43} \cdot \sin\left(THETA_{J3O} + C43\right)$$

$$IFB44_{J3O} := A_{44} \cdot \cos\left(THETA_{J3O} + C44\right) + B_{44} \cdot \sin\left(THETA_{J3O} + C44\right)$$

$$IFB45_{J3O} := A_{45} \cdot \cos\left(THETA_{J3O} + C45\right) + B_{45} \cdot \sin\left(THETA_{J3O} + C45\right)$$

$$IFB46_{J3O} := A_{46} \cdot \cos\left(THETA_{J3O} + C46\right) + B_{46} \cdot \sin\left(THETA_{J3O} + C46\right)$$

$$IFB47_{J3O} := A_{47} \cdot \cos\left(THETA_{J3O} + C47\right) + B_{47} \cdot \sin\left(THETA_{J3O} + C47\right)$$

$$IFB48_{J3O} := A_{48} \cdot \cos\left(THETA_{J3O} + C48\right) + B_{48} \cdot \sin\left(THETA_{J3O} + C48\right)$$

$$IFB49_{J3O} := A_{49} \cdot \cos\left(THETA_{J3O} + C49\right) + B_{49} \cdot \sin\left(THETA_{J3O} + C49\right)$$

$$IFB50_{J3O} := A_{50} \cdot \cos\left(THETA_{J3O} + C50\right) + B_{50} \cdot \sin\left(THETA_{J3O} + C50\right)$$

$$IFB51_{J3O} := A_{51} \cdot \cos\left(THETA_{J3O} + C51\right) + B_{51} \cdot \sin\left(THETA_{J3O} + C51\right)$$

$$IFB52_{J3O} := A_{52} \cdot \cos\left(THETA_{J3O} + C52\right) + B_{52} \cdot \sin\left(THETA_{J3O} + C52\right)$$

$$IFB53_{J3O} := A_{53} \cdot \cos\left(THETA_{J3O} + C53\right) + B_{53} \cdot \sin\left(THETA_{J3O} + C53\right)$$

$$IFB54_{J3O} := A_{54} \cdot \cos\left(THETA_{J3O} + C54\right) + B_{54} \cdot \sin\left(THETA_{J3O} + C54\right)$$

$$IFB55_{J3O} := A_{55} \cdot \cos\left(THETA_{J3O} + C55\right) + B_{55} \cdot \sin\left(THETA_{J3O} + C55\right)$$

$$IFB56_{J3O} := A_{56} \cdot \cos\left(THETA_{J3O} + C56\right) + B_{56} \cdot \sin\left(THETA_{J3O} + C56\right)$$

$$IFB57_{J3O} := A_{57} \cdot \cos\left(THETA_{J3O} + C57\right) + B_{57} \cdot \sin\left(THETA_{J3O} + C57\right)$$

$$IFB58_{J3O} := A_{58} \cdot \cos\left(THETA_{J3O} + C58\right) + B_{58} \cdot \sin\left(THETA_{J3O} + C58\right)$$

$$IFB59_{J3O} := A_{59} \cdot \cos\left(THETA_{J3O} + C59\right) + B_{59} \cdot \sin\left(THETA_{J3O} + C59\right)$$

$$IFB60_{J3O} := A_{60} \cdot \cos\left(THETA_{J3O} + C60\right) + B_{60} \cdot \sin\left(THETA_{J3O} + C60\right)$$

$$IFB61_{J3O} := A_{61} \cdot \cos\left(THETA_{J3O} \cdot C61\right) + B_{61} \cdot \sin\left(THETA_{J3O} \cdot C61\right)$$

$$IFB62_{J3O} := A_{62} \cdot \cos\left(THETA_{J3O} \cdot C62\right) + B_{62} \cdot \sin\left(THETA_{J3O} \cdot C62\right)$$

$$IFB63_{J3O} := A_{63} \cdot \cos\left(THETA_{J3O} \cdot C63\right) + B_{63} \cdot \sin\left(THETA_{J3O} \cdot C63\right)$$

$$IFB64_{J3O} := A_{64} \cdot \cos\left(THETA_{J3O} \cdot C64\right) + B_{64} \cdot \sin\left(THETA_{J3O} \cdot C64\right)$$

$$IFB65_{J3O} := A_{65} \cdot \cos\left(THETA_{J3O} \cdot C65\right) + B_{65} \cdot \sin\left(THETA_{J3O} \cdot C65\right)$$

$$IFB66_{J3O} := A_{66} \cdot \cos\left(THETA_{J3O} \cdot C66\right) + B_{66} \cdot \sin\left(THETA_{J3O} \cdot C66\right)$$

$$IFB67_{J3O} := A_{67} \cdot \cos\left(THETA_{J3O} \cdot C67\right) + B_{67} \cdot \sin\left(THETA_{J3O} \cdot C67\right)$$

$$IFB68_{J3O} := A_{68} \cdot \cos\left(THETA_{J3O} \cdot C68\right) + B_{68} \cdot \sin\left(THETA_{J3O} \cdot C68\right)$$

$$IFB69_{J3O} := A_{69} \cdot \cos\left(THETA_{J3O} \cdot C69\right) + B_{69} \cdot \sin\left(THETA_{J3O} \cdot C69\right)$$

$$IFB70_{J3O} := A_{70} \cdot \cos\left(THETA_{J3O} \cdot C70\right) + B_{70} \cdot \sin\left(THETA_{J3O} \cdot C70\right)$$

$$IFB71_{J3O} := A_{71} \cdot \cos\left(THETA_{J3O} \cdot C71\right) + B_{71} \cdot \sin\left(THETA_{J3O} \cdot C71\right)$$

$$IFB72_{J3O} := A_{72} \cdot \cos\left(THETA_{J3O} \cdot C72\right) + B_{72} \cdot \sin\left(THETA_{J3O} \cdot C72\right)$$

$$IFB73_{J3O} := A_{73} \cdot \cos\left(THETA_{J3O} \cdot C73\right) + B_{73} \cdot \sin\left(THETA_{J3O} \cdot C73\right)$$

$$IFB74_{J3O} := A_{74} \cdot \cos\left(THETA_{J3O} \cdot C74\right) + B_{74} \cdot \sin\left(THETA_{J3O} \cdot C74\right)$$

$$IFB75_{J3O} := A_{75} \cdot \cos\left(THETA_{J3O} \cdot C75\right) + B_{75} \cdot \sin\left(THETA_{J3O} \cdot C75\right)$$

$$IFB76_{J3O} := A_{76} \cdot \cos\left(THETA_{J3O} \cdot C76\right) + B_{76} \cdot \sin\left(THETA_{J3O} \cdot C76\right)$$

$$IFB77_{J3O} := A_{77} \cdot \cos\left(THETA_{J3O} \cdot C77\right) + B_{77} \cdot \sin\left(THETA_{J3O} \cdot C77\right)$$

$$IFB78_{J3O} := A_{78} \cdot \cos\left(THETA_{J3O} \cdot C78\right) + B_{78} \cdot \sin\left(THETA_{J3O} \cdot C78\right)$$

$$IFB79_{J3O} := A_{79} \cdot \cos\left(THETA_{J3O} \cdot C79\right) + B_{79} \cdot \sin\left(THETA_{J3O} \cdot C79\right)$$

$$IFB80_{J3O} := A_{80} \cdot \cos\left(THETA_{J3O} \cdot C80\right) + B_{80} \cdot \sin\left(THETA_{J3O} \cdot C80\right)$$

$$IFB81_{J3O} := A_{81} \cdot \cos\left(THETA_{J3O} \cdot C81\right) + B_{81} \cdot \sin\left(THETA_{J3O} \cdot C81\right)$$

$$IFB82_{J3O} := A_{82} \cdot \cos\left(THETA_{J3O} \cdot C82\right) + B_{82} \cdot \sin\left(THETA_{J3O} \cdot C82\right)$$

$$IFB83_{J3O} := A_{83} \cdot \cos\left(THETA_{J3O} \cdot C83\right) + B_{83} \cdot \sin\left(THETA_{J3O} \cdot C83\right)$$

$$IFB84_{J3O} := A_{84} \cdot \cos\left(THETA_{J3O} \cdot C84\right) + B_{84} \cdot \sin\left(THETA_{J3O} \cdot C84\right)$$

$$IFB85_{J3O} := A_{85} \cdot \cos\left(THETA_{J3O} \cdot C85\right) + B_{85} \cdot \sin\left(THETA_{J3O} \cdot C85\right)$$

$$IFB86_{J3O} := A_{86} \cdot \cos\left(THETA_{J3O} + C86\right) + B_{86} \cdot \sin\left(THETA_{J3O} + C86\right)$$

$$IFB87_{J3O} := A_{87} \cdot \cos\left(THETA_{J3O} + C87\right) + B_{87} \cdot \sin\left(THETA_{J3O} + C87\right)$$

$$IFB88_{J3O} := A_{88} \cdot \cos\left(THETA_{J3O} + C88\right) + B_{88} \cdot \sin\left(THETA_{J3O} + C88\right)$$

$$IFB89_{J3O} := A_{89} \cdot \cos\left(THETA_{J3O} + C89\right) + B_{89} \cdot \sin\left(THETA_{J3O} + C89\right)$$

$$IFB90_{J3O} := A_{90} \cdot \cos\left(THETA_{J3O} + C90\right) + B_{90} \cdot \sin\left(THETA_{J3O} + C90\right)$$

$$IFB91_{J3O} := A_{91} \cdot \cos\left(THETA_{J3O} + C91\right) + B_{91} \cdot \sin\left(THETA_{J3O} + C91\right)$$

$$IFB92_{J3O} := A_{92} \cdot \cos\left(THETA_{J3O} + C92\right) + B_{92} \cdot \sin\left(THETA_{J3O} + C92\right)$$

$$IFB93_{J3O} := A_{93} \cdot \cos\left(THETA_{J3O} + C93\right) + B_{93} \cdot \sin\left(THETA_{J3O} + C93\right)$$

$$IFB94_{J3O} := A_{94} \cdot \cos\left(THETA_{J3O} + C94\right) + B_{94} \cdot \sin\left(THETA_{J3O} + C94\right)$$

$$IFB95_{J3O} := A_{95} \cdot \cos\left(THETA_{J3O} + C95\right) + B_{95} \cdot \sin\left(THETA_{J3O} + C95\right)$$

$$IFB96_{J3O} := A_{96} \cdot \cos\left(THETA_{J3O} + C96\right) + B_{96} \cdot \sin\left(THETA_{J3O} + C96\right)$$

$$IFB97_{J3O} := A_{97} \cdot \cos\left(THETA_{J3O} + C97\right) + B_{97} \cdot \sin\left(THETA_{J3O} + C97\right)$$

$$IFB98_{J3O} := A_{98} \cdot \cos\left(THETA_{J3O} + C98\right) + B_{98} \cdot \sin\left(THETA_{J3O} + C98\right)$$

$$IFB99_{J3O} := A_{99} \cdot \cos\left(THETA_{J3O} + C99\right) + B_{99} \cdot \sin\left(THETA_{J3O} + C99\right)$$

$$IFB100_{J3O} := A_{100} \cdot \cos\left(THETA_{J3O} + C100\right) + B_{100} \cdot \sin\left(THETA_{J3O} + C100\right)$$

$$IFBT1_{J3O} := IFB0 + IFB1_{J3O} + IFB2_{J3O} + IFB3_{J3O} + IFB4_{J3O} + IFB5_{J3O} + IFB6_{J3O} + IFB7_{J3O} + IFB8_{J3O} + IFB9_{J3O}$$

$$IFBT2_{J3O} := IFB10_{J3O} + IFB11_{J3O} + IFB12_{J3O} + IFB13_{J3O} + IFB14_{J3O} + IFB15_{J3O} + IFB16_{J3O} + IFB17_{J3O} + IFB18_{J3O} + IFB19_{J3O}$$

$$IFBT3_{J3O} := IFB20_{J3O} + IFB21_{J3O} + IFB22_{J3O} + IFB23_{J3O} + IFB24_{J3O} + IFB25_{J3O} + IFB26_{J3O} + IFB27_{J3O} + IFB28_{J3O} + IFB29_{J3O}$$

$$IFBT4_{J3O} := IFB30_{J3O} + IFB31_{J3O} + IFB32_{J3O} + IFB33_{J3O} + IFB34_{J3O} + IFB35_{J3O} + IFB36_{J3O} + IFB37_{J3O} + IFB38_{J3O} + IFB39_{J3O}$$

$$IFBT5_{J3O} := IFB40_{J3O} + IFB41_{J3O} + IFB42_{J3O} + IFB43_{J3O} + IFB44_{J3O} + IFB45_{J3O} + IFB46_{J3O} + IFB47_{J3O} + IFB48_{J3O} + IFB49_{J3O}$$

$$IFBT6_{J3O} := IFB50_{J3O} + IFB51_{J3O} + IFB52_{J3O} + IFB53_{J3O} + IFB54_{J3O} + IFB55_{J3O} + IFB56_{J3O} + IFB57_{J3O} + IFB58_{J3O} + IFB59_{J3O}$$

$$IFBT7_{J3O} := IFB60_{J3O} + IFB61_{J3O} + IFB62_{J3O} + IFB63_{J3O} + IFB64_{J3O} + IFB65_{J3O} + IFB66_{J3O} + IFB67_{J3O} + IFB68_{J3O} + IFB69_{J3O}$$

$$IFBT8_{J3O} := IFB70_{J3O} + IFB71_{J3O} + IFB72_{J3O} + IFB73_{J3O} + IFB74_{J3O} + IFB75_{J3O} + IFB76_{J3O} + IFB77_{J3O} + IFB78_{J3O} + IFB79_{J3O}$$

$$IFBT9_{J3O} := IFB80_{J3O} + IFB81_{J3O} + IFB82_{J3O} + IFB83_{J3O} + IFB84_{J3O} + IFB85_{J3O} + IFB86_{J3O} + IFB87_{J3O} + IFB88_{J3O} + IFB89_{J3O}$$

$$IFBT10_{J3O} := IFB90_{J3O} + IFB91_{J3O} + IFB92_{J3O} + IFB93_{J3O} + IFB94_{J3O} + IFB95_{J3O} + IFB96_{J3O} + IFB97_{J3O} + IFB98_{J3O} + IFB99_{J3O}$$

$$IFBT11_{J3O} := IFB100_{J3O}$$

$IFBTT1_{J30} := IFBT1_{J30} + IFBT2_{J30} + IFBT3_{J30} + IFBT4_{J30} + IFBT5_{J30} + IFBT6_{J30}$

$IFBTT2_{J30} := IFBT7_{J30} + IFBT8_{J30} + IFBT9_{J30} + IFBT10_{J30} + IFBT11_{J30}$

$IFBTT_{J30} := IFBTT1_{J30} + IFBTT2_{J30}$

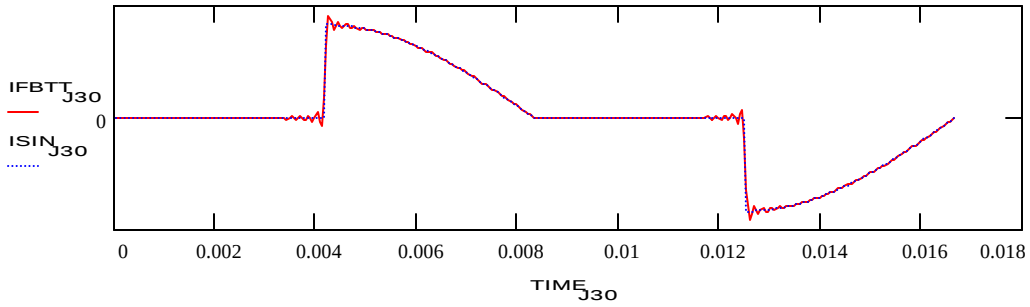

FIGURE #4: COMPARISON OF WAVEFORM REGENERATED FROM HARMONIC COEFFICIENTS (IFBTT) TO THE INITIAL SCR GENERATED WAVEFORM (ISIN)

Since the waveform formed by the summation of the harmonic coefficients very closely approximates the original waveform, we can conclude that most of the harmonic coefficients have been found.

V CALCULATION OF THE CURRENT AND POWER HARMONIC SPECTRUM VALUES AND THE AVERAGE AND RMS VALUES OF CURRENT FOR THE WAVEFORM.

As shown in figure #4, the regenerated waveform closely approximates the initial waveform. This indicates that the majority of significant harmonic coefficients have been calculated. The calculation of the current and power spectrum values are shown below. Then the calculation for the average and RMS values of current for the waveform (in percent of peak of the sine wave) are shown below. Then, the harmonic spectrums of this waveforms from DC to the 100th harmonic frequency are shown in figure #5 and figure #6 below.

CALCULATION OF HARMONIC AVG, RMS AND SPECTRAL LEVELS FOR CURRENT AND POWER (AGAIN ASSUMING A PURE RESISTANCE) FOR THE WAVEFORM UNDER EVALUATION

$$P_M := .5 \cdot \left[(A_M)^2 + (B_M)^2 \right]$$

CALCULATION OF POWER SPECTRUM

$$I_M := \sqrt{P_M}$$

CALCULATION OF CURRENT SPECTRUM

$$IAVGSCR := \frac{1}{Ts} \cdot \left[\sum_{J30=1}^{Ts} \left(\left| ISIN_{J30} \right| \right) \right] \cdot 100$$

CALCULATION OF AVG. VALUE OF MAGNITUDE OF WAVEFORM

$$IRMSSCR := \sqrt{\left[\frac{1}{Ts} \cdot \sum_{J30=1}^{Ts} \left(ISIN_{J30} \right)^2 \right]} \cdot 100$$

CALCULATION OF RMS. VALUE OF WAVEFORM

$IAVGSCR = 31.552$

AVERAGE VALUE OF MAGNITUDE OF WAVEFORM IN PERCENT OF PEAK VALUE OF FULL SINE WAVEFORM

$IRMSSCR = 49.721$

RMS VALUE OF WAVEFORM IN PERCENT OF PEAK VALUE OF FULL SINE WAVEFORM

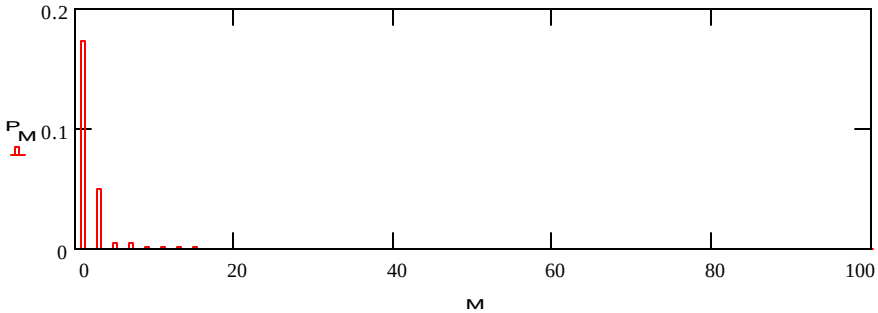

FIGURE # 5: GRAPHICAL REPRESENTATION OF POWER SPECTRUM FOR THE SCR GENERATED WAVEFORM..

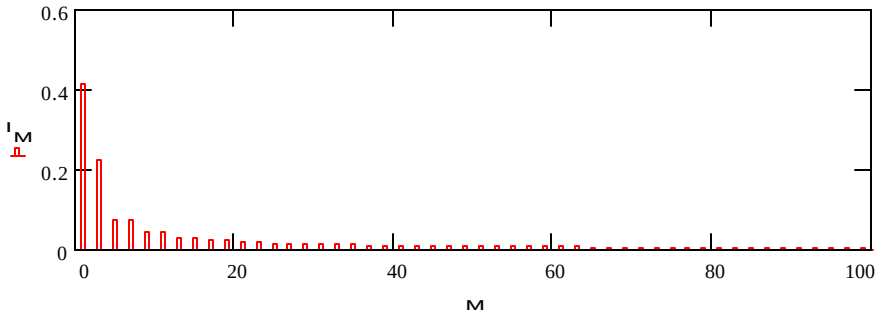

FIGURE # 6: GRAPHICAL REPRESENTATION OF CURRENT SPECTRUM FOR THE SCR GENERATED WAVEFORM.

For clarification, the values of the harmonic coefficients are shown below. As you can see, only the odd harmonics contribute to the THD of this waveform. Because of this, it is common to only calculate the odd harmonic coefficients in practice.

TABULATED DATA OF POWER AND CURRENT SPECTRUM AT VARIOUS HARMONICS

$z_3 := 25$ $m_3 := 0..z_3$

m_3	P_{m_3}	I_{m_3}	A_{m_3}	B_{m_3}
0	0	0	0	0
1	0.173	0.416	- 0.318	0.494
2	0	0	0	0
3	0.051	0.225	0.318	0.006
4	0	0	0	0
5	0.006	0.075	- 0.106	- 0.006
6	0	0	0	0
7	0.006	0.075	0.106	0.006
8	0	0	0	0
9	0.002	0.045	- 0.064	- 0.006
10	0	0	0	0
11	0.002	0.045	0.064	0.006
12	0	0	0	0
13	0.001	0.032	- 0.045	- 0.006
14	0	0	0	0
15	0.001	0.032	0.045	0.006
16	0	0	0	0
17	0.001	0.025	- 0.035	- 0.006
18	0	0	0	0
19	0.001	0.025	0.035	0.006
20	0	0	0	0
21	0	0.021	- 0.029	- 0.006
22	0	0	0	0
23	0	0.021	0.029	0.006
24	0	0	0	0
25	0	0.017	- 0.024	- 0.006

VI CALCULATION OF THE CURRENT AND POWER THD (TOTAL HARMONIC DISTORTION) VALUES FOR THIS WAVEFORM.

The total harmonic distortion is defined as the ratio of the RMS value of the harmonic coefficients to the magnitude of the fundamental component[3]. The current and power total harmonic distortion levels are calculated below. Note that the power total harmonic distortion assumes that the load is purely resistive. If the load is purely resistive, then the current waveform mirrors the voltage waveform exactly. This allows us to easily calculate the power total harmonic distortion knowing that power = voltage * current. If there are reactive components in the load, then the current waveform does not mirror exactly the voltage waveform. In this case, both voltage and current waveforms would have to be modeled and then power calculated from that result.

$$PTHD := \frac{\sqrt{\sum_{M=2}^{Z} (P_M)^2}}{P_1} \cdot 100$$

CALCULATION OF POWER THD

$$ITHD := \frac{\sqrt{\sum_{M=2}^{Z} (I_M)^2}}{I_1} \cdot 100$$

CALCULATION OF CURRENT THD

$PTHD = 29.734$

POWER THD VALUE IN PERCENT IN PERCENT OF FUNDAMENTAL

$ITHD = 65.243$

CURRENT THD VALUE IN PERCENT OF FUNDAMENTAL

VII SUMMATION OF RESULTS FOR VARIOUS CONDUCTION ANGLES FROM 1 TO 180 DEGREES:

The table below uses the above procedure to calculate the values of Irms, Iavg, THD current, and THD power with respect to the angle of delay. The “delay angle” is the angle of the sine wave where the SCR is not gated. The “conduction angle” is the angle of the sine wave where the SCR is gated. Therefore, to find the value of a certain conduction angle, subtract that conduction angle from 180 degrees. Then look up this “delay angle” below. The values of Irms and Iavg are normalized to the peak current value of the full conduction sine wave. The values of THD current and THD power are normalized to the fundamental component at that particular conduction angle. Then Irms, Iavg, THD current and THD power are all plotted with respect to delay angle in figures 7, 8, 9, and 10 below for a graphical representation of the effect of delay angle on these values.

Delay Angle	Irms	Iavg	THD current	THD power
(Degrees)	(%peak I)	(%peak I)	(% fund.)	(% fund.)
0	70.71	63.66	0.00	0.00
1	70.71	63.65	0.14	0.00
2	70.71	63.63	0.36	0.00
3	70.71	63.60	0.64	0.00
4	70.71	63.56	0.94	0.00
5	70.70	63.52	1.28	0.00
6	70.70	63.46	1.65	0.01
7	70.69	63.39	2.05	0.01
8	70.69	63.31	2.46	0.01
9	70.68	63.23	2.91	0.02
10	70.66	63.13	3.37	0.03
11	70.65	63.02	3.85	0.04
12	70.63	62.91	4.35	0.05
13	70.61	62.78	4.86	0.07
14	70.59	62.65	5.39	0.08
15	70.56	62.50	5.94	0.11
16	70.53	62.35	6.49	0.13
17	70.50	62.19	7.06	0.16
18	70.46	62.02	7.64	0.19
19	70.42	61.84	8.23	0.23
20	70.28	61.65	8.84	0.27
21	70.21	61.45	9.45	0.32
22	70.27	61.24	10.07	0.37
23	70.21	61.02	10.70	0.43
24	70.14	60.80	11.34	0.49
25	70.07	60.56	11.98	0.56
26	70.00	60.32	12.64	0.63
27	69.91	60.06	13.30	0.72
28	69.83	59.80	13.96	0.80
29	69.73	59.53	14.64	0.90
30	69.63	59.26	15.32	1.00
31	69.53	58.97	16.00	1.11
32	69.42	58.68	16.69	1.23
33	69.30	58.37	17.39	1.36
34	69.17	58.06	18.09	1.49
35	69.04	57.74	18.80	1.64
36	68.90	57.42	19.51	1.79
37	68.75	57.08	20.23	1.95
38	68.60	56.74	20.95	2.12
39	68.44	56.39	21.68	2.30
40	68.27	56.03	22.41	2.50

Delay Angle	Irms	Iavg	THD current	THD power
(Degrees)	(%peak I)	(%peak I)	(% fund.)	(% fund.)
41	68.10	55.67	23.15	2.70
42	67.91	55.30	23.89	2.91
43	67.72	54.92	24.63	3.13
44	67.52	54.53	25.38	3.37
45	67.32	54.14	26.13	3.61
46	67.10	53.74	26.89	3.87
47	66.88	53.34	27.65	4.14
48	66.65	52.92	28.42	4.42
49	66.42	52.50	29.19	4.71
50	66.17	52.08	29.96	5.02
51	65.92	51.65	30.74	5.34
52	65.65	51.21	31.52	5.67
53	65.38	50.76	32.31	6.01
54	65.10	50.31	33.10	6.37
55	64.82	49.86	33.89	6.74
56	64.52	49.40	34.69	7.13
57	64.22	48.93	35.50	7.53
58	63.91	48.46	36.31	7.95
59	63.59	47.99	37.12	8.38
60	63.26	47.50	37.94	8.82
61	62.92	47.02	38.76	9.29
62	62.58	46.53	39.59	9.76
63	62.22	46.03	40.42	10.25
64	61.86	45.53	41.25	10.76
65	61.49	45.03	42.10	11.28
66	61.11	44.52	42.94	11.82
67	60.73	44.01	43.80	12.38
68	60.33	43.50	44.65	12.95
69	59.93	42.98	45.52	13.54
70	59.52	42.46	46.39	14.15
71	59.10	41.93	47.26	14.77
72	58.67	41.40	48.14	15.41
73	58.24	40.87	49.03	16.07
74	57.80	40.34	49.92	16.74
75	57.35	39.80	50.82	17.43
76	56.89	39.26	51.73	18.14
77	56.42	38.72	52.64	18.86
78	55.95	38.18	53.56	19.60
79	55.47	37.63	54.49	20.36
80	54.98	37.08	55.43	21.13

Delay Angle	Irms	Iavg	THD current	THD power
(Degrees)	(%peak I)	(%peak I)	(% fund.)	(% fund.)
81	54.49	36.54	56.37	21.92
82	53.98	35.99	57.32	22.73
83	53.49	35.43	58.28	23.55
84	52.96	34.88	59.25	24.39
85	52.44	34.33	60.22	25.25
86	51.91	33.77	61.21	26.11
87	51.37	33.22	62.20	27.00
88	50.83	32.66	63.21	27.90
89	50.27	32.11	64.22	28.81
90	49.72	31.55	65.24	29.73
91	49.16	31.00	66.28	30.67
92	48.59	30.44	67.32	31.63
93	48.02	27.89	68.38	32.59
94	47.44	27.33	69.44	33.57
95	46.85	28.78	70.52	34.56
96	46.26	28.23	71.62	35.57
97	45.67	27.68	72.72	36.59
98	45.07	27.13	73.84	37.62
99	44.46	26.58	74.97	38.66
100	43.85	26.03	73.44	39.72
101	43.24	25.48	77.27	40.79
102	42.62	24.94	78.44	41.88
103	42.00	24.40	79.63	42.98
104	41.37	23.86	80.84	44.10
105	40.74	23.32	82.06	45.23
106	40.10	22.79	83.30	46.37
107	39.46	22.26	84.55	47.53
108	38.82	21.73	85.83	48.71
109	38.18	21.20	87.12	49.91
110	37.53	20.68	88.44	51.12
111	36.88	20.16	89.77	52.35
112	36.23	19.65	91.13	53.59
113	35.57	19.14	92.50	54.86
114	34.91	18.63	93.90	56.15
115	34.25	18.13	95.33	57.45
116	33.59	17.63	96.78	58.78
117	32.93	17.13	98.25	60.13
118	32.26	16.64	99.76	61.50
119	31.60	16.16	101.29	62.90
120	30.93	15.67	102.85	64.32

Delay Angle	Irms	Iavg	THD current	THD power
(Degrees)	(%peak I)	(%peak I)	(% fund.)	(% fund.)
121	30.26	15.20	104.44	65.77
122	29.60	14.73	106.06	67.24
123	28.93	14.26	107.72	68.74
124	28.26	13.80	109.41	70.27
125	27.59	13.35	111.14	71.83
126	26.93	12.90	112.90	73.43
127	26.26	12.45	114.70	75.05
128	25.60	12.01	116.55	76.71
129	24.93	11.58	118.45	78.41
130	24.27	11.16	120.38	80.15
131	23.61	10.71	122.37	81.92
132	22.95	10.33	124.41	83.74
133	22.29	9.92	126.50	85.61
134	21.64	9.52	128.64	87.52
135	20.99	9.13	130.85	89.48
136	20.31	8.74	133.12	91.50
137	19.69	8.35	135.46	93.57
138	19.05	7.99	137.87	95.70
139	18.41	7.63	140.35	97.89
140	17.78	7.27	142.92	100.15
141	17.15	6.92	145.57	102.48
142	16.52	6.58	148.31	104.88
143	15.90	6.24	151.14	107.37
144	15.29	5.92	154.08	109.94
145	14.68	5.60	157.13	112.60
146	14.07	5.29	160.30	115.37
147	13.47	4.98	163.60	118.24
148	12.88	4.69	167.06	121.22
149	12.30	4.40	170.60	124.37
150	11.72	4.13	174.35	127.57
151	11.15	3.86	178.27	130.97
152	10.58	3.60	182.36	134.52
153	10.03	3.34	186.67	138.25
154	9.48	3.10	191.22	142.16
155	8.94	2.86	196.00	146.29
156	8.41	2.64	201.05	150.65
157	7.89	2.42	206.42	155.27
158	7.38	2.21	212.13	160.17
159	6.88	2.01	218.19	165.39
160	6.39	1.82	224.68	170.98

Delay Angle	Irms	Iavg	THD current	THD power
(Degrees)	(%peak I)	(%peak I)	(% fund.)	(% fund.)
161	5.91	1.61	231.68	176.98
162	5.45	1.47	239.20	183.45
163	4.99	1.31	247.32	190.45
164	4.55	1.16	256.18	198.08
165	4.12	1.01	265.91	206.44
166	3.70	0.88	276.56	215.67
167	3.30	0.75	288.36	225.93
168	2.91	0.64	301.68	237.46
169	2.54	0.53	316.69	250.56
170	2.19	0.44	333.65	265.63
171	1.85	0.35	353.48	283.28
172	1.54	0.27	377.22	304.39
173	1.24	0.20	405.27	330.29
174	0.96	0.15	439.37	363.18
175	0.71	0.10	485.29	407.67
176	0.49	0.06	549.28	473.03
177	0.29	0.03	627.05	572.92
178	0.13	0.01	700.00	700.00
179	0.00	0.00	738.62	704.40

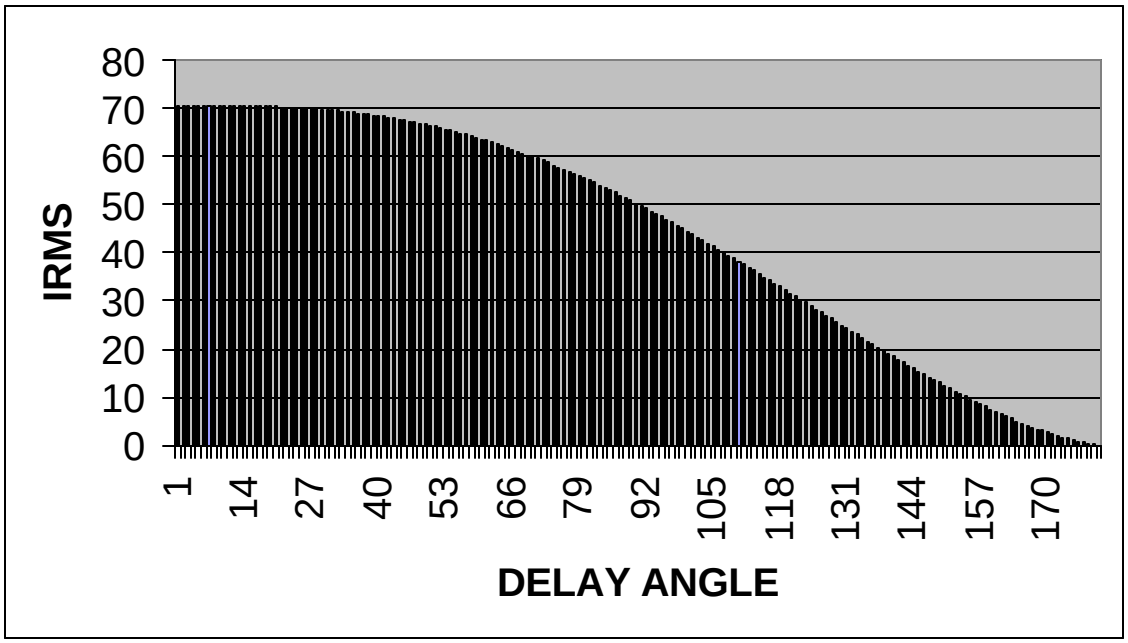

FIGURE # 7: GRAPHICAL REPRESENTATION OF THE VALUE OF Irms WITH RESPECT TO DELAY ANGLE.

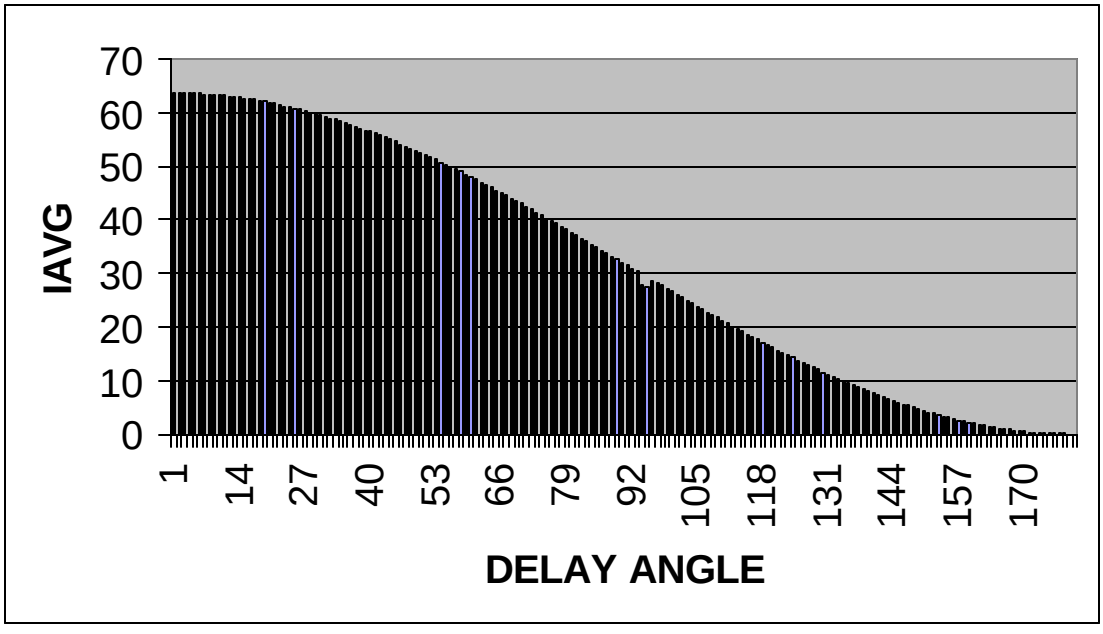

FIGURE # 8: GRAPHICAL REPRESENTATION OF THE VALUE OF Iavg WITH RESPECT TO DELAY ANGLE.

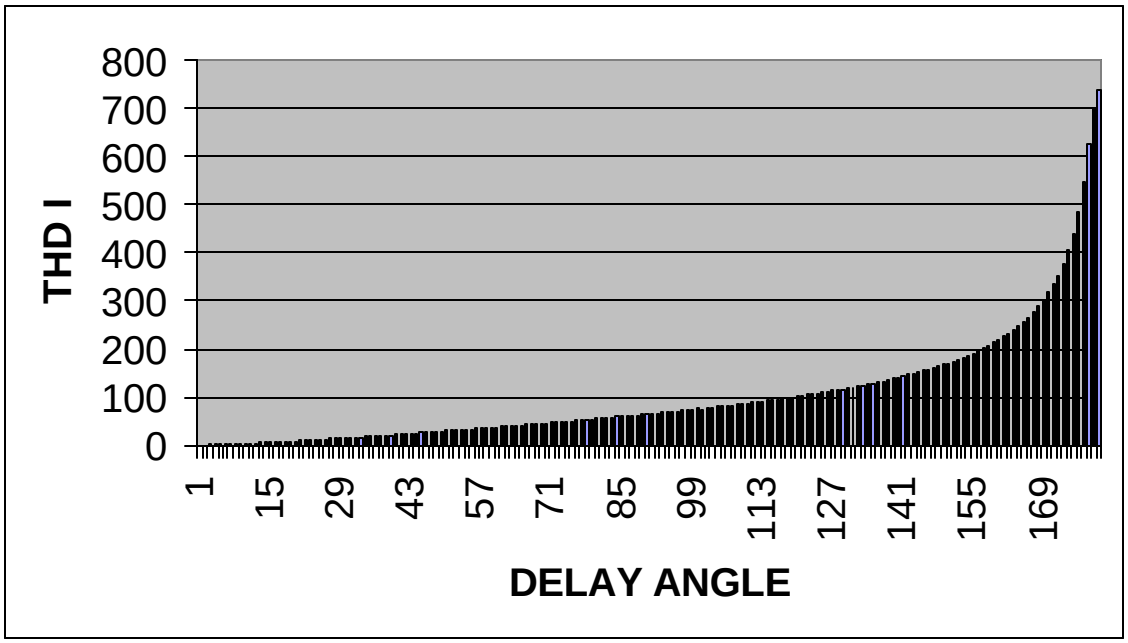

FIGURE # 9: GRAPHICAL REPRESENTATION OF THE VALUE OF THD current WITH RESPECT TO DELAY ANGLE.

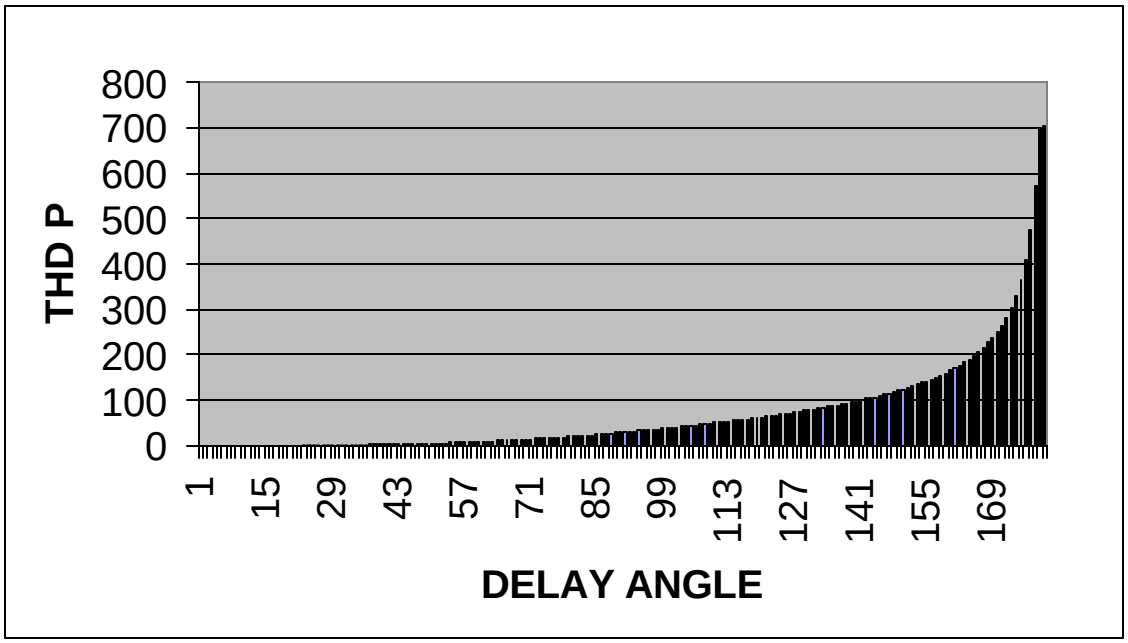

FIGURE # 10: GRAPHICAL REPRESENTATION OF THE VALUE OF THD power WITH RESPECT TO DELAY ANGLE.

VIII CONCLUSION

In this paper, we have demonstrated a method of mathematically modeling an SCR semiconductor generated waveforms. Then we have analyzed these waveforms for harmonic content, rms and average values of current at any given angle of conduction. Finally, we have evaluated the rms and average value of current for all conduction angles from 1 to 180 degrees as well as the values of THD current and THD power for all conduction angles from 1 to 180 degrees.

IX REFERENCES

[1] Bose, B. K.., "MODERN POWER ELECTRONICS Evolution, Technology, and Applications", IEEE Press, 1992.

[2] Stevenson, William D. Jr., "Elements of Power System Analysis", McGraw Hill, 1982.

[3] Jordan, Edward C., "Reference Data for Engineers: Radio, Electronics, Computer, and Communications", Howard W. Sams & Company, 1985