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Small Signal Model Averaging of Bi-directional Converter

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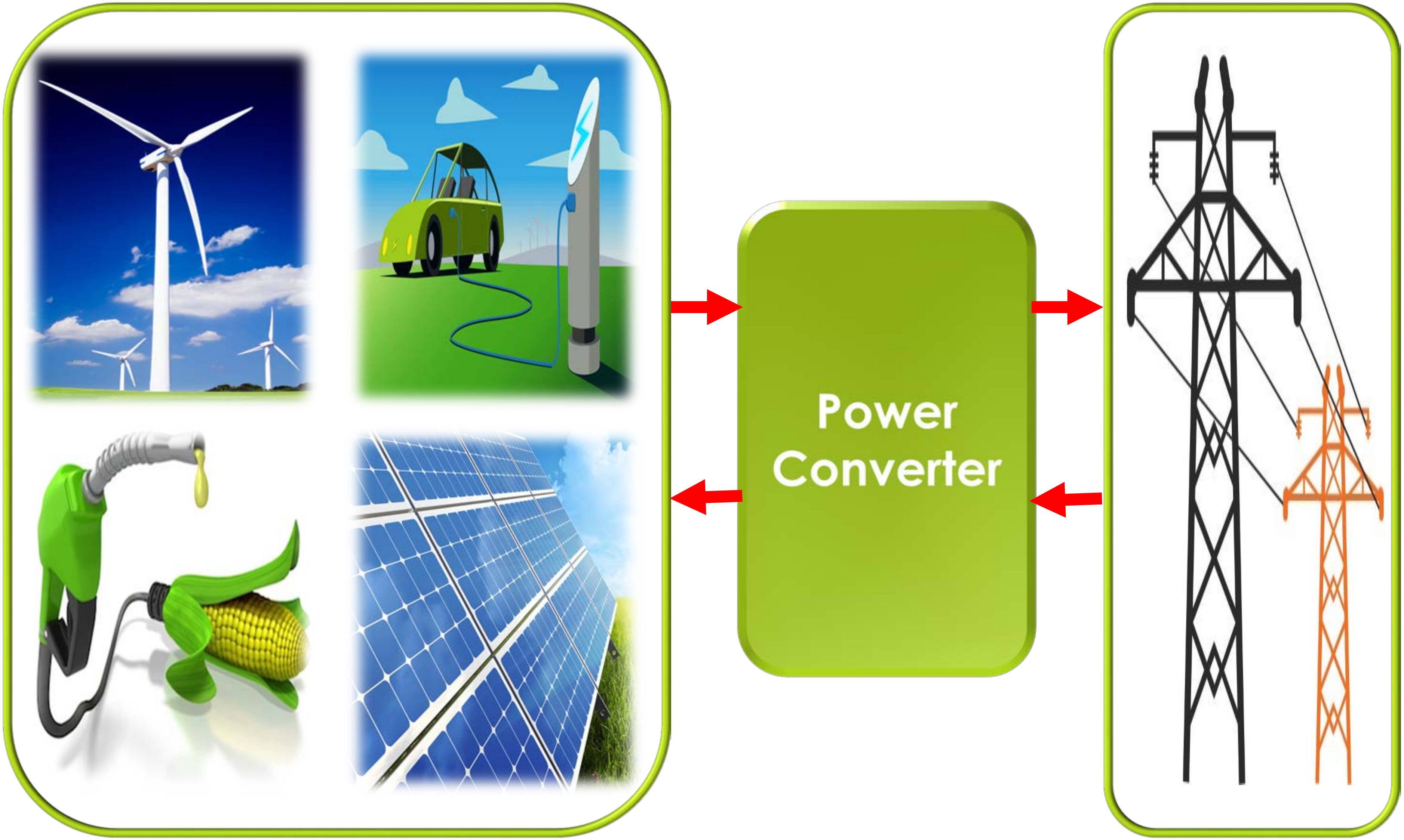
Background



Overview

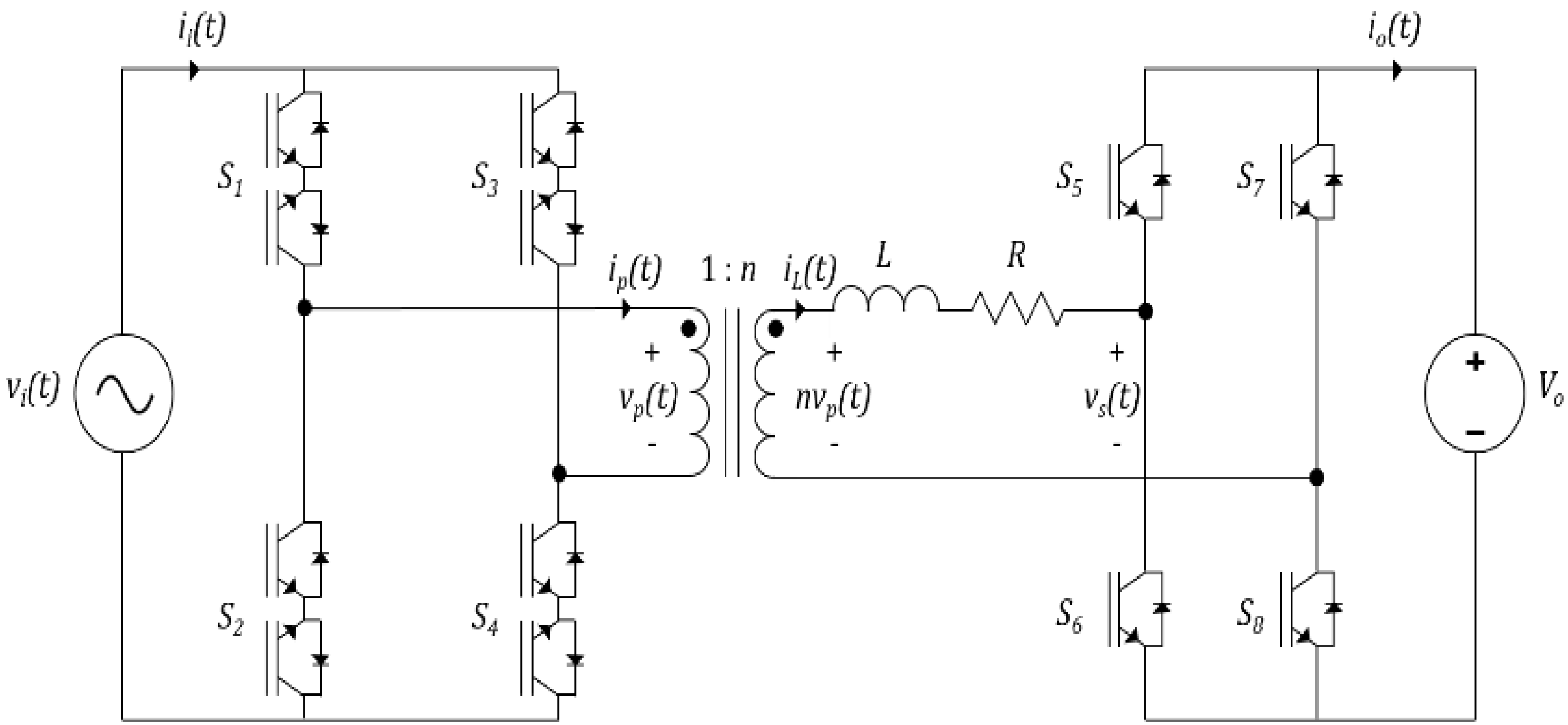
Dual-Active-Bridge AC/DC Converter

Small-signal Plant Model

by State-space Averaging Technique

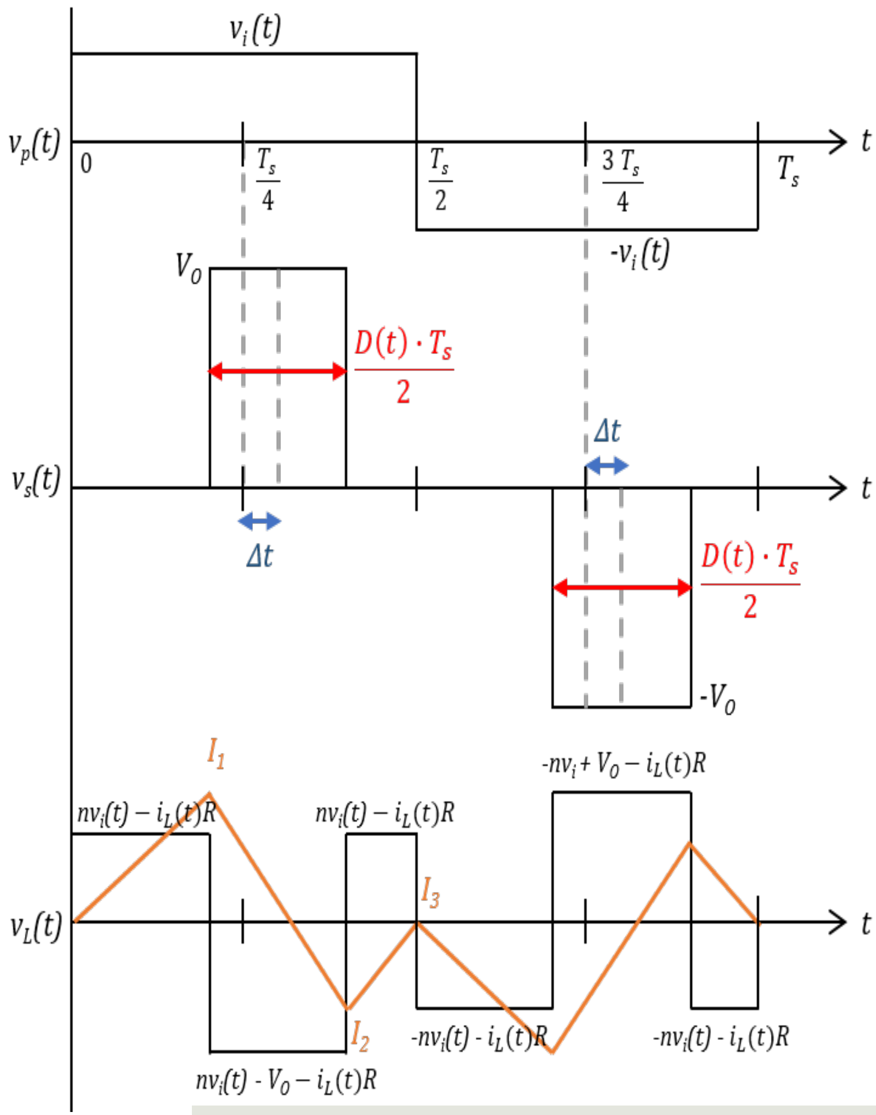
Advance Controller

Topology of the Proposed Converter



$$nv_p(t) = v_L(t) + i_L(t)R + v_s(t)$$

Modulation Cycle



$$\dot{X} = \begin{cases} -\frac{R}{L}X + \frac{1}{L}U, & 0 < t < \frac{T_s}{4}(1+\delta-D) \\ -\frac{R}{L}X + \left(\frac{1}{L} - \frac{1}{L\cdot D}\right)U, & \frac{T_s}{4}(1+\delta-D) < t < \frac{T_s}{4}(1+\delta+D) \\ -\frac{R}{L}X + \frac{1}{L}U, & \frac{T_s}{4}(1+\delta+D) < t < \frac{T_s}{2} \\ -\frac{R}{L}X - \frac{1}{L}U, & \frac{T_s}{2} < t < \frac{T_s}{2} + \frac{T_s}{4}(1+\delta-D) \\ -\frac{R}{L}X + \left(-\frac{1}{L} + \frac{1}{L\cdot D}\right)U, & \frac{T_s}{2} + \frac{T_s}{4}(1+\delta-D) < t < \frac{T_s}{2} + \frac{T_s}{4}(1+\delta+D) \\ -\frac{R}{L}X - \frac{1}{L}U, & \frac{T_s}{2} + \frac{T_s}{4}(1+\delta+D) < t < T_s \end{cases}$$

State-space Averaging Technique

$$\dot{X} = \left[A_1\left(\frac{(1+\delta-D)}{4}\right) + A_2\left(\frac{D}{2}\right) + A_3\left(\frac{(1-\delta-D)}{4}\right) + A_4\left(\frac{(1+\delta-D)}{4}\right) + A_5\left(\frac{D}{2}\right) + A_6\left(\frac{(1-\delta-D)}{4}\right)\right]X$$
$$+\left[B_1\left(\frac{(1+\delta-D)}{4}\right) + B_2\left(\frac{D}{2}\right) + B_3\left(\frac{(1-\delta-D)}{4}\right) + B_4\left(\frac{(1+\delta-D)}{4}\right) + B_5\left(\frac{D}{2}\right) + B_6\left(\frac{(1-\delta-D)}{4}\right)\right]U$$

$$D = \overline{D} + d$$

$$X = \overline{X} + x$$

(d is a small signal variation of D and x is a small signal variation of X.)

Small-Signal Plant Model

$$\dot{x} = \left[A_1\left(\frac{-d}{4}\right) + A_2\left(\frac{d}{2}\right) + A_3\left(\frac{-d}{4}\right) + A_4\left(\frac{-d}{4}\right) + A_5\left(\frac{d}{2}\right) + A_6\left(\frac{-d}{4}\right)\right]\bar{X}$$

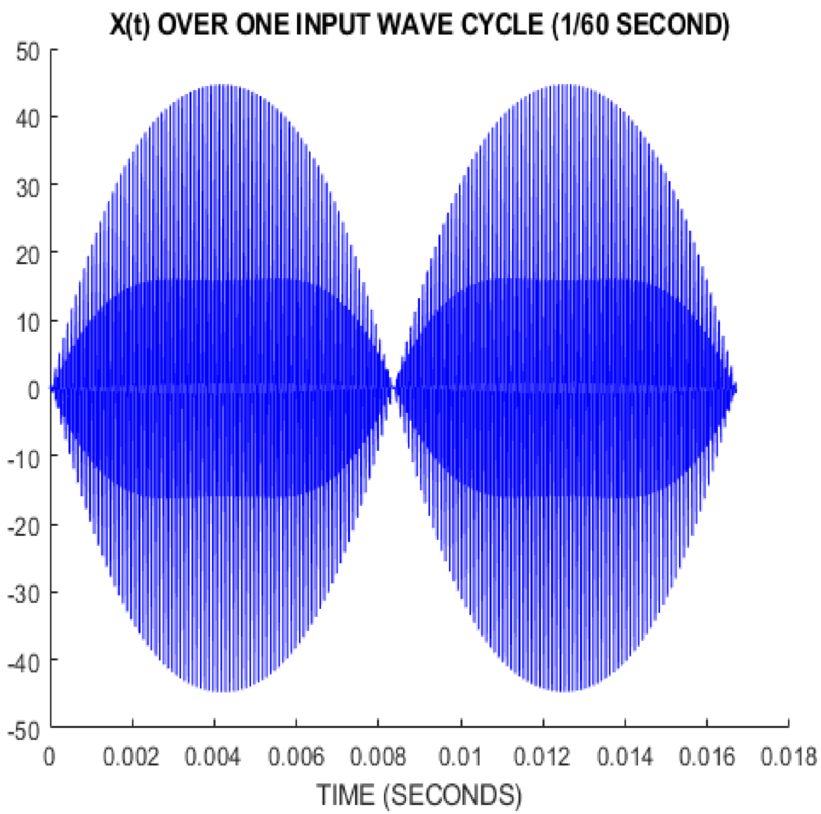
$$+\left[A_1\left(\frac{(1+\delta-\bar{D})}{4}\right) + A_2\left(\frac{\bar{D}}{2}\right) + A_3\left(\frac{(1-\delta-\bar{D})}{4}\right) + A_4\left(\frac{(1+\delta-\bar{D})}{4}\right) + A_5\left(\frac{\bar{D}}{2}\right) + A_6\left(\frac{(1-\delta-\bar{D})}{4}\right)\right]x$$

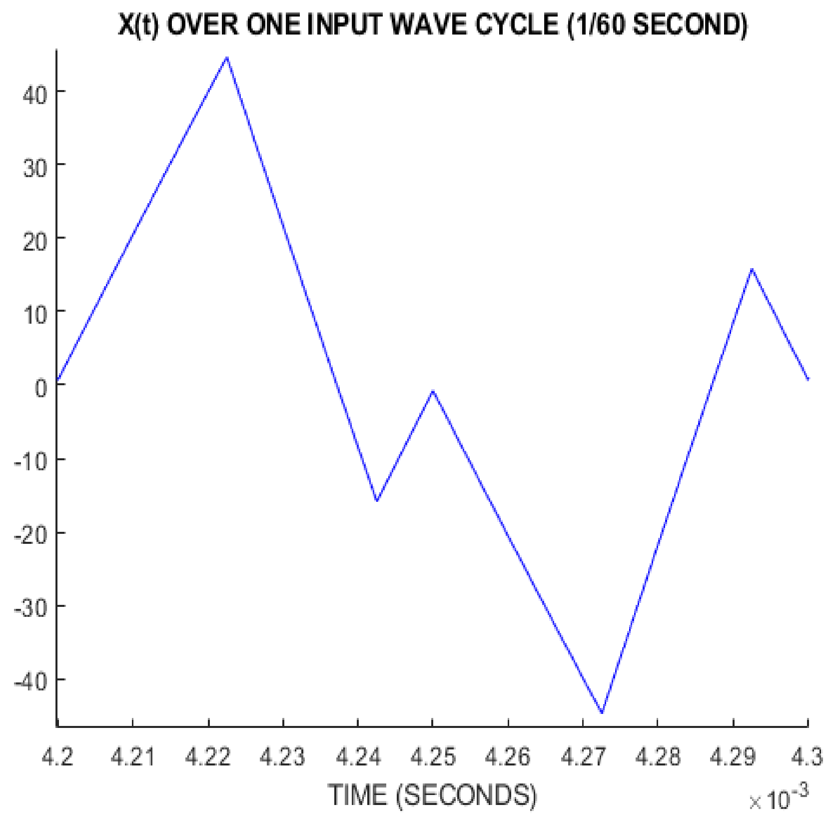
$$+\left[B_1\left(\frac{-d}{4}\right) + B_2\left(\frac{d}{2}\right) + B_3\left(\frac{-d}{4}\right) + B_4\left(\frac{-d}{4}\right) + B_5\left(\frac{d}{2}\right) + B_6\left(\frac{-d}{4}\right)\right]U$$

$$\equiv \boldsymbol{E}\cdot\boldsymbol{x} + \boldsymbol{F}\cdot\boldsymbol{d}$$

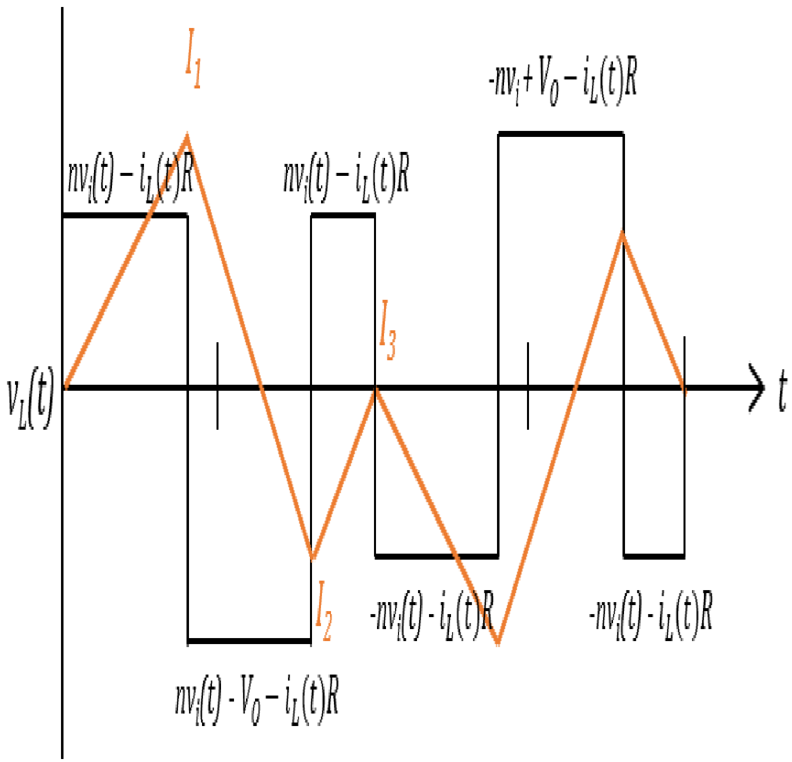
$$\frac{x}{d} = [sI-E]^{-1}F = \frac{adj[sI-E]}{\det[sI-E]}F$$

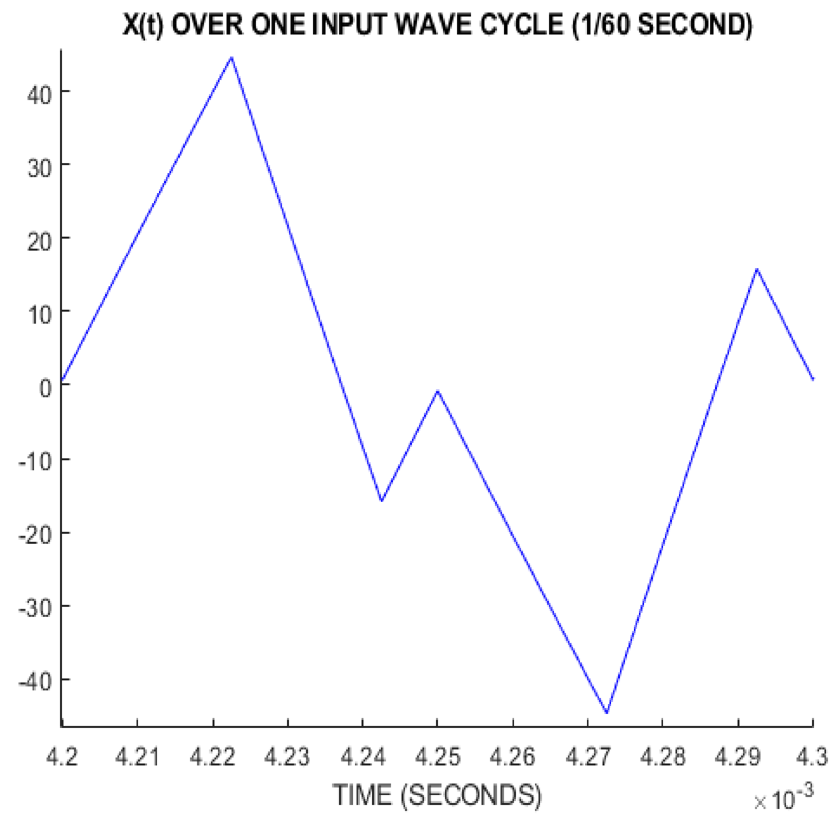
Simulation Results



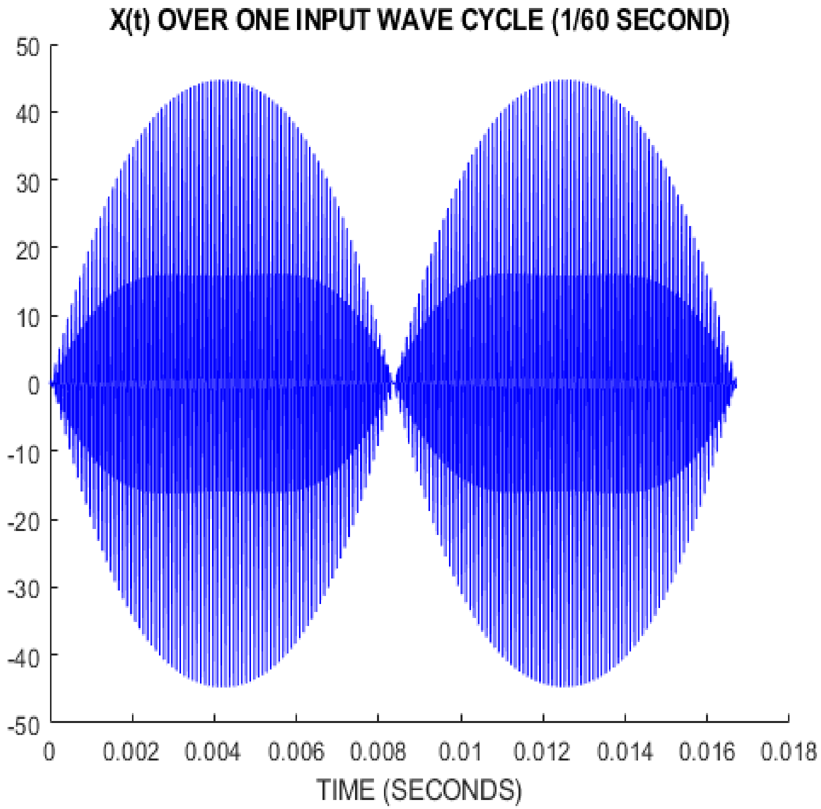


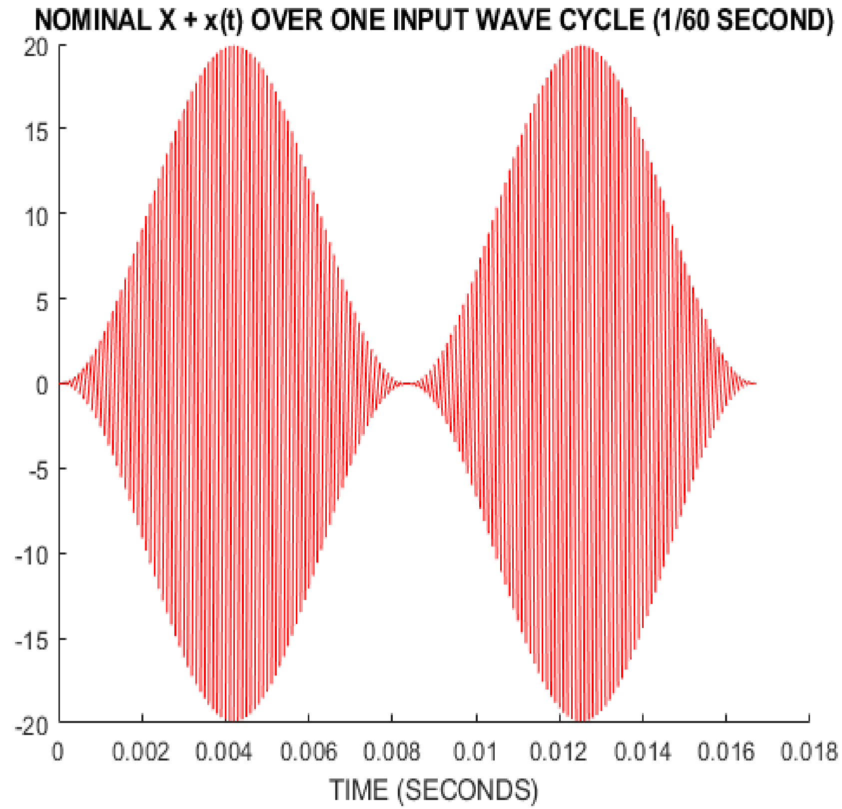
Simulation Results





Simulation Results





Conclusions

Computationally **easier**

But still **captures the relevant dynamics**