



Top of sine injection into the grid

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Introduction

Distributed generation:

Negative resistance generator?

- Has to be avoided.

Sine wave?

- Is it minimal circuit?
- Is it robust in humid environment?

Non sine wave?

- Could be tolerated if harmonics are limited?
- Could have a third harmonic in opposite phase with peak rectifiers?
- Could be accepted?

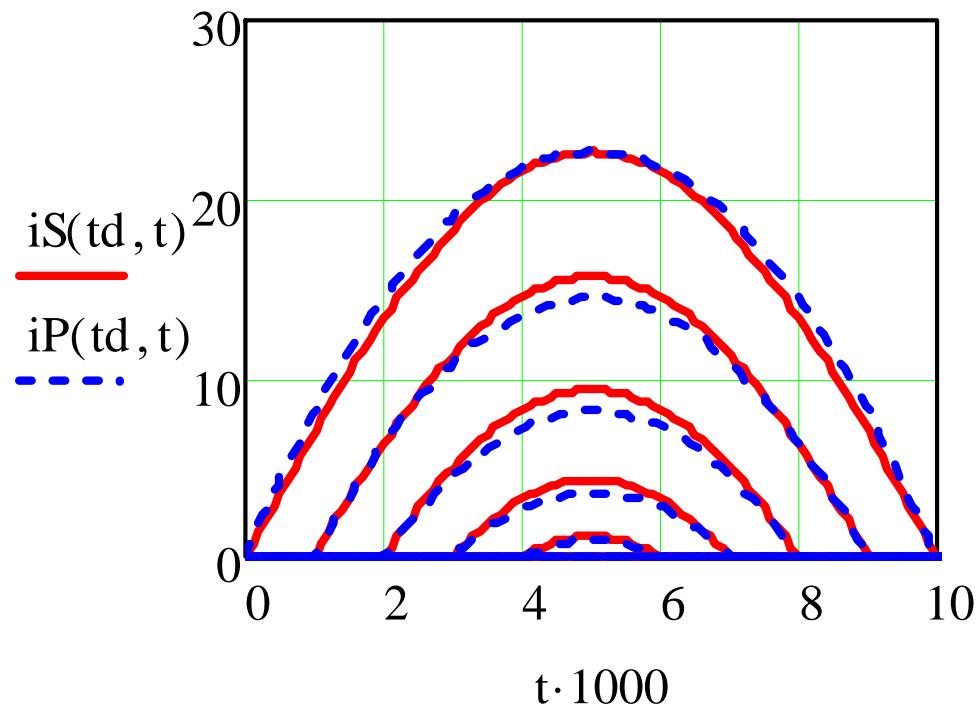
2. Design philosophy

Top of sine:

$$iS(td, t) := \max[0, I_{pk} \cdot (\sin(\omega \cdot t) - \sin(\omega \cdot td))]$$

Top of parabola:

$$iP(td, t) := \max\left[0, I_{pk} \cdot \left[\left(1 - \frac{td}{0.005}\right)^2 - \left(1 - \frac{t}{0.005}\right)^2 \right]\right]$$



2. Design philosophy

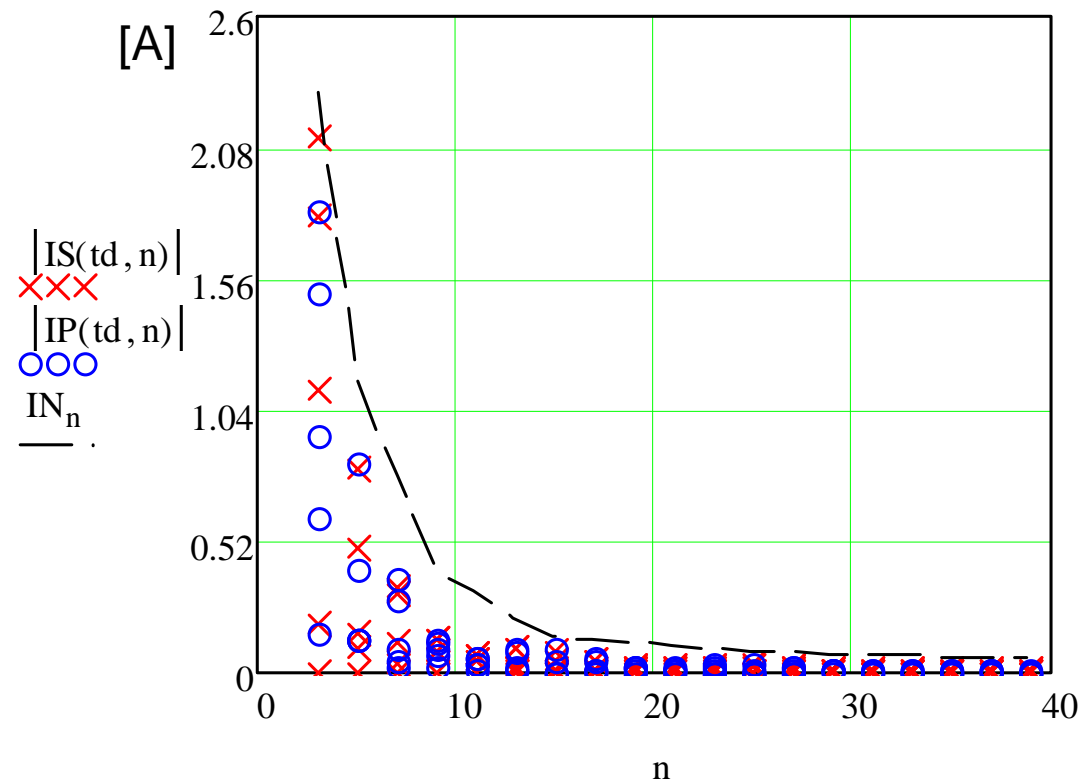
Harmonics of
top of sine:

$$IS(n, I_{off}) := \frac{\sqrt{2}}{0.01} \cdot \int_0^{0.01} iS(t, I_{off}) \cdot \sin(n \cdot \omega \cdot t) dt$$

Harmonics of
top of parabola:

$$IP(n, I_{off}) := \frac{\sqrt{2}}{0.01} \cdot \int_0^{0.01} iP(t, I_{off}) \cdot \sin(n \cdot \omega \cdot t) dt$$

Fig. 2. Current harmonics dependent on the delay time, for $t_d=0,1,2,3,4$ ms.
Dashed line: limit of EN 61000-3-2 For 16A

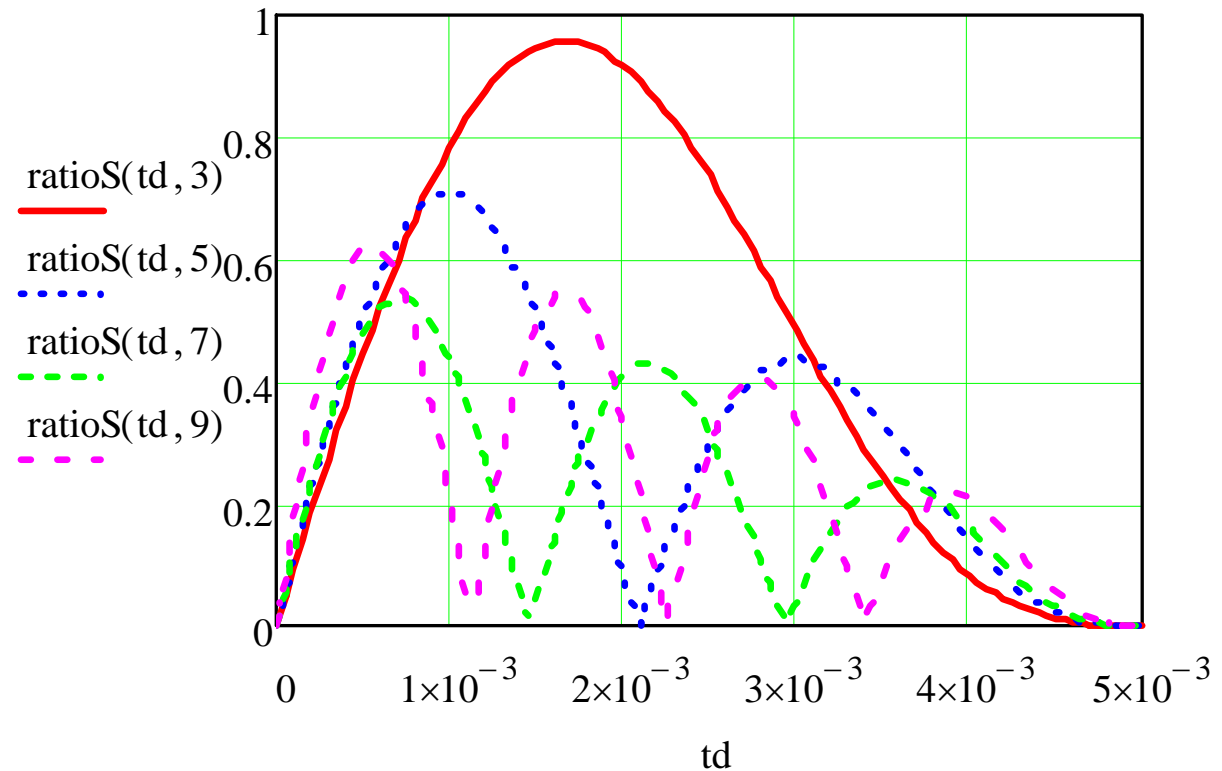


2. Design philosophy

Ratio
top of sine/standard

$$\text{ratioP}(\text{td}, n) := \frac{|\text{IP}(\text{td}, n)|}{\text{IN}_n} \cdot \frac{16}{|\text{IP}(0, 1)|}$$

Fig. 3. Detail of harmonic 3,5,7,9, compared to standard for top-of-sine, for changing delay time td

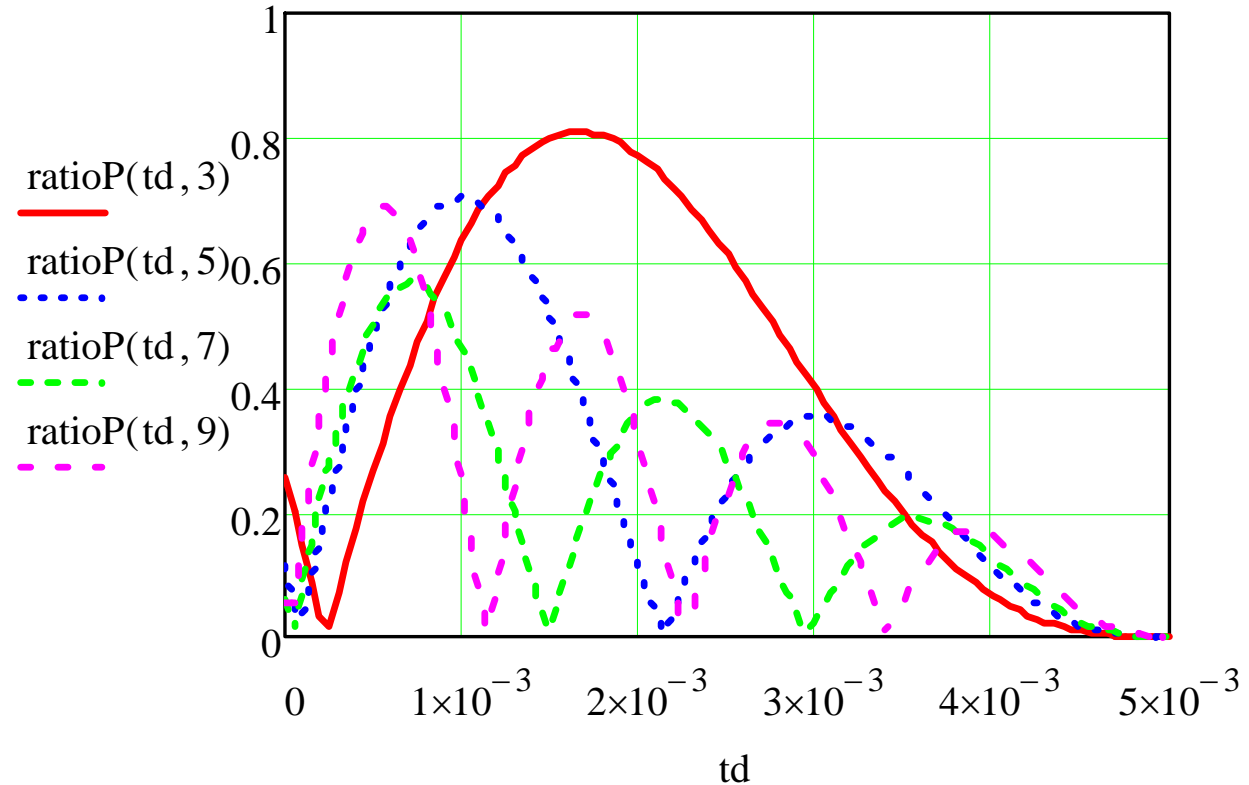


2. Design philosophy

Ratio
top of parabola/standard

$$\text{ratioS}(\text{td}, n) := \frac{|\text{IS}(\text{td}, n)|}{\text{IN}_n}$$

Fig.4. Detail of harmonic 3,5,7,9, compared to standard for top-of-parabola, for changing delay time td



3. Top-of-parabola modulation

Top of parabola:

- At $t_d = 0$ still 3rd harmonic present
- Max 3rd harmonic = 0.8; (this is lower than top-of-sine)

4. Application in a control method

Top of parabola:

- Synchronisation: Two times integrating the sign of the grid voltage
- Only shifting the reference: no multiplications necessary.
- Possible in analog or digital signal processing

5. Control Block diagram

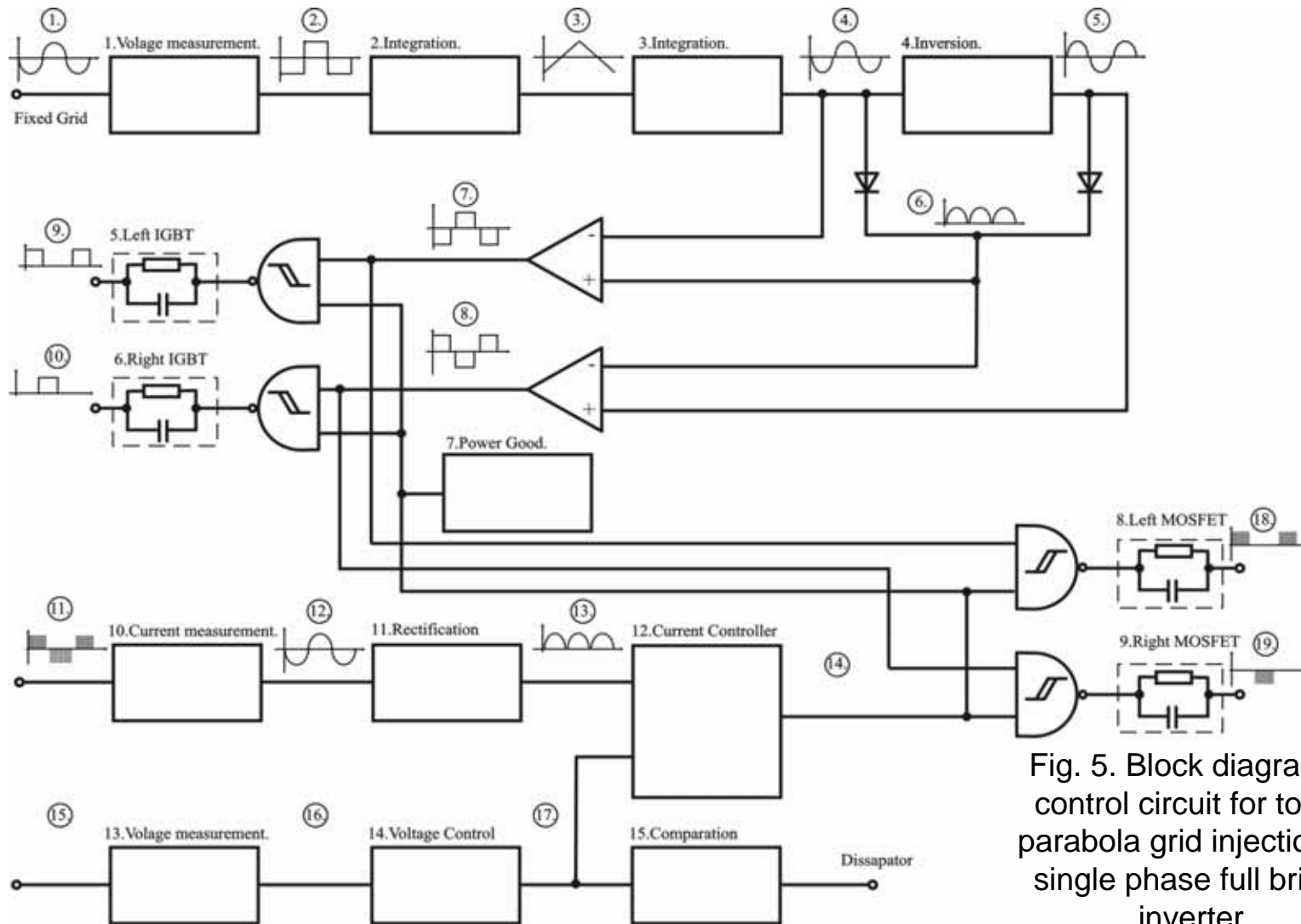


Fig. 5. Block diagram of control circuit for top-of-parabola grid injection for single phase full bridge inverter.

Conclusion

This paper proposes a control method uses

- **a top-of-sine or top-of-parabola current injection.**
- **easier generation**
- **no multiplication is needed.**
- **It satisfies to the harmonic standards for domestic use.**

Thank You for your attention!

