# FOPI based H6 converter for improve the performance of PV integrated medium voltage grid applications

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**ABSTRACT:** In this paper proposes a Fractional order PI (FOPI) control scheme-based hybrid pulse width modulation (PWM) method to improve the performance of the PV fed medium voltage grid. Integrated solar-PV with medium voltage grid by utilized superconducting magnetic energy storage (SMES)-based H6 inverter instead of traditional transformer approach. The SMES circuit topology serves as a secondary power source used in PV power outage or transient conditions. Due to absence of galvanic isolation, a leakage current establishes while operating the H6 inverter circuit. To overcome this problem an advanced FOPI based hybrid PWM control technique presented in this current work. The proposed PWM approach can reduces total harmonic distortion (THD) in the H6 inverter's output voltage. It employs a novel carrier waveform alongside a modulating signal derived from fundamental sine and triangular waves. Compared to conventional PWM control approaches, the proposed PWM method delivers superior efficiency and reduced leakage current throughout the power conversion process. For validation of the effectiveness of proposed approach simulations carried out in MATLAB/Simulink platform..

**KEYWORDS: PWM, SMES, SOLAR, THD, H6 INVERTER.**

**I.INTRODUCTION:** One of the most promising renewable energy sources at the moment is solar photovoltaic (PV) energy [1], [2]. There are two kinds of situations in which PV power [3] can interface with a low- to medium-voltage grid. There are two types of inverter systems: transformer-based and transformerless [4]. Traditional transformer-based PV systems have a number of issues, such as higher transformer loss and a big, cumbersome system structure that lowers power quality and efficiency. On the other hand, a transformerless photovoltaic system has advantages such as high power density, reactive power transfer capabilities, and small size [5]. Additionally, the transformerless inverter has a drawback of not having adequate galvanic isolation. As a result, it creates a leakage current issue, which is concerning for the interface of PV with a medium-voltage grid [6]. However, in a superconducting magnetic energy storage (SMES) integrated transformerless system, power, and voltage stability issues can be resolved by using the SMES system as a temporary transient power source. Leakage current, high total distortion (THD), and power loss are still regarded as serious problems for SMES-integrated transformerless systems, as they heavily depend on the inverter architecture and pulse width modulation (PWM) technique [7], [8].

To solve the leakage current issue, a novel circuit structure is proposed in [9]. The circuit topology is based on the H6 architecture and performs quite well in terms of leakage current mitigation. However, the circuit topology requires two additional diodes, which not only increases the semiconductor loss but also reduces the overall efficiency of the inverter system. Another topology based on the H6 architecture is proposed in [10], which aims to reduce the leakage current completely. However, during leakage current reduction, it requires an extra complex control scheme to generate proper gate pulses for the power semiconductor switches. A similar type of approach is observed in the literature [11]. To lower the THD of the output voltage, the literature utilizes a new type of PWM technique. The inverter output voltage THD reduces to a critical level compared to conventional unipolar pulse width modulation (UPPWM) and bipolar pulse width modulation (BPPWM) with the proposed PWM technique. However, the lower-order harmonic is not reduced to an accepted level.

Moreover, conventional UPPWM and BPPWM are used by most of theH6 architecture-based transformerless inverters [12], [13]. Which not only injects a massive amount of THD into the inverter output voltage but also makes the system inefficient. Therefore, it is preferable to come up with a new PWM technique to solve the aforementioned issues. As a result, a hybrid PWM strategy is proposed in this paper to suppress the THD of the inverter output voltage. Again, the proposed technique is suitable to reduce the leakage current of the H6 inverter by ensuring a stable common mode voltage.

**II.SYSTEM CINFIGARATION:** The entire system is based on H6 transformerless architecture which is illustrated in Fig.1. The input side consists of a PV array and DC-DC boost converter. SMES chopper is also implemented on the input side to ensure the effectiveness of the power flow during power conversion. Six power semiconductor switches (S1-S6) are the core ofH6 architecture and the grid side inductor, Lg1, and Lg2 along with filter capacitor Co are also illustrated in Fig.1. (S1-S6) are the core ofH6 architecture and the grid side inductor, Lg1, and Lg2 along with filter capacitor Co are also illustrated in Fig.1.

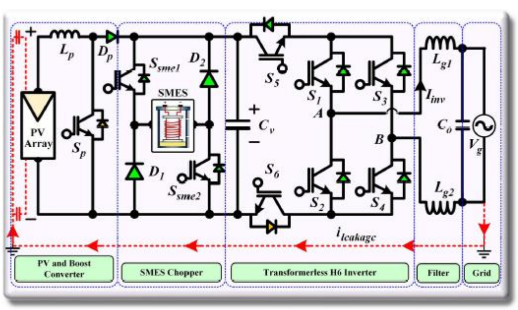



Fig. 1. H6 transformerless inverter architecture with SMES integration for grid-tied PV interfacing.

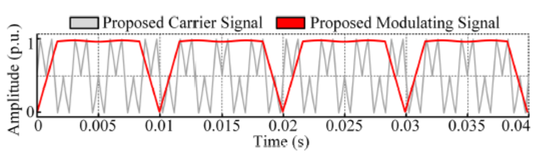



Fig. 2. Proposed hybrid PWM technique for H6 inverter.

Fig.2 illustrates the hybrid PWM technique consisting of a new carrier signal and a new modulating signal. The new modulating signal is compared to the high-frequency proposed carrier signal and generates the gate pulses for the H6 transformerless inverter.

**A. Proposed Carrier Signal Generation**

The generation procedure of the carrier signal along with the modulating signal is depicted in Fig.3. To generate the carrier signal, it requires a sine wave Q1 and a triangle wave Q2. Mathematically it can be represented as,

$$Q_1 = \beta \sin\left(\frac{2\pi}{3T} \times t\right) \quad (1)$$

$$Q_2 = \beta * (2\,/\,T) * (T/2 - |(t \bmod T) - T/2|) \quad (2)$$

Where, α, T, and t represent the amplitude, period, and instantaneous time, respectively. Finally, (1) and (2) are added together and saturated to form the final proposed carrier signal which can be represented as,

$$Q_3 = Q_1 + Q_2 \quad (3)$$

Here, the frequency of the triangle wave is three times greater than the frequency of the sine wave. Thus, the high-frequency carrier wave is generated and finally compared with the proposed modulating signal.

**B. Proposed Modulating Signal Generation** To generate the modulating signal of a sinusoidal wave, P1 is considered with an amplitude of δ and it can be represented as,

$$P_1 = \delta \sin(\omega t + \theta)$$

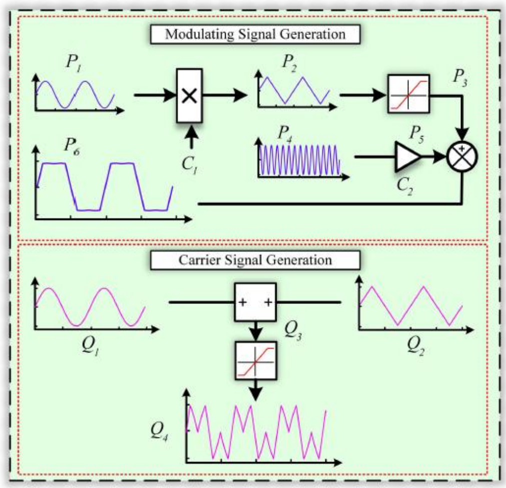



Fig. 3. Generation procedure of the proposed hybrid PWM technique for grid-tied H6 transformerless inverter.

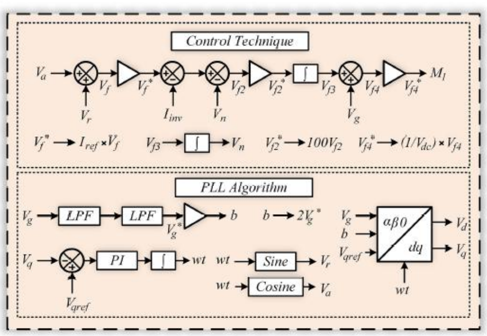



Fig. 4. Control technique of the grid-tied H6 transformerless inverter with proposed hybrid PWM technique.

The signal, P1 is multiplied with constant C1. Mathematically it can be represented as,

$$P_2 = P_1\, C_1 \tag{5}$$

After that a saturated signal, P3 is considered utilizing saturating procedure with the value of P2 in a region of −φ to φ, where φ = 0.85δ. Thus,

$$P_3 = \begin{cases} P_2 & when,\ |P_2| < \phi \\ -\phi & when,\ P_2 \le -\phi \\ \phi & when,\ P_2 \ge \phi \end{cases} \tag{6}$$

Another sinusoidal, $P_4$ is generated with the following equation:

$$P_4 = \eta \sin(\omega t + \theta) \tag{7}$$

where, $\eta = 5\delta$. $P_5$ signal is generated as follows:

$$P_5 = C_2 P_4 \tag{8}$$

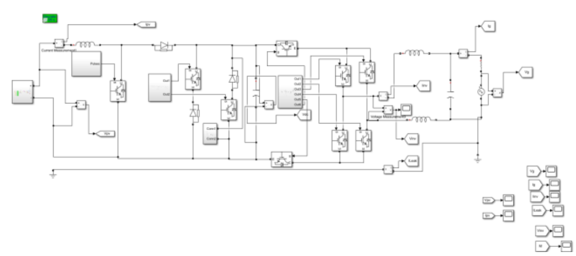
where, $C_2 = -0.5\,\eta$

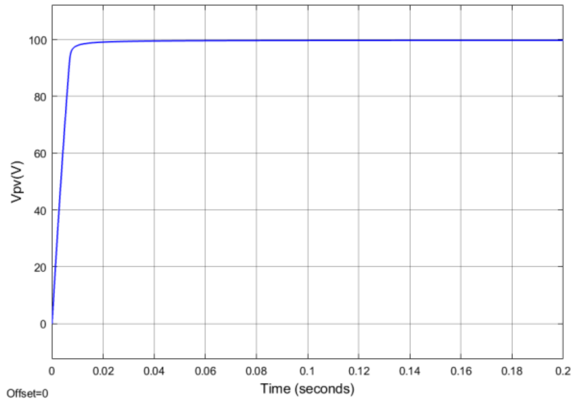
Finally, the proposed modulating signal is generated utilizing the following equation,

$$P_6 = P_5 + P_3 \tag{9}$$

**C. Control Technique** The control technique of the H6 transformerless inverter is based on a simple PI controller that can switch the output current from active to reactive while maintaining the grid voltage constant. The representation of the control parameter is depicted in Fig. 4.

## III.SIMULATION RESULTS:

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Time (seconds)
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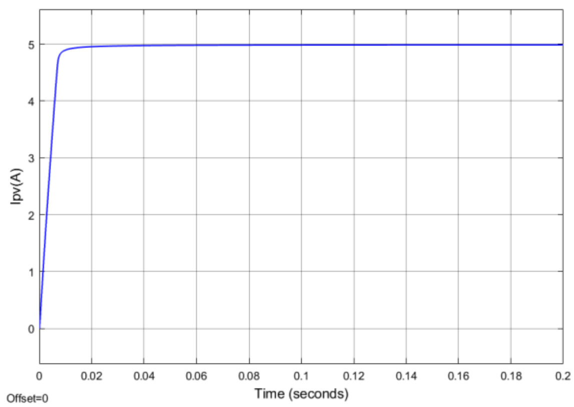
Ipv(A)
Time (seconds)
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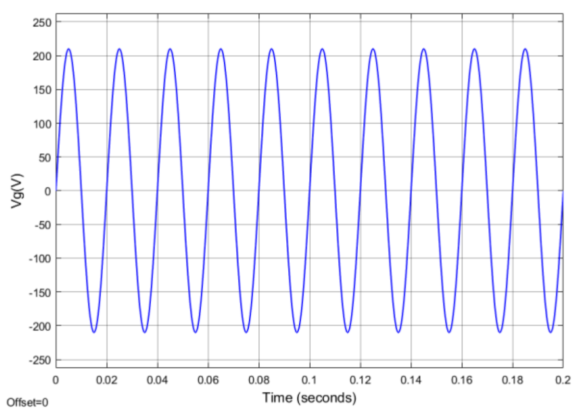
Vg(V)
Time (seconds)
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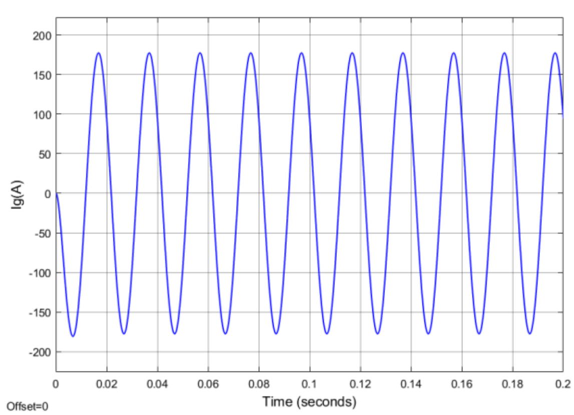
Ig(A)
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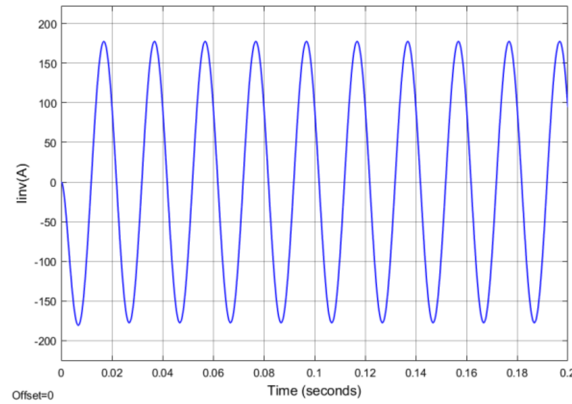
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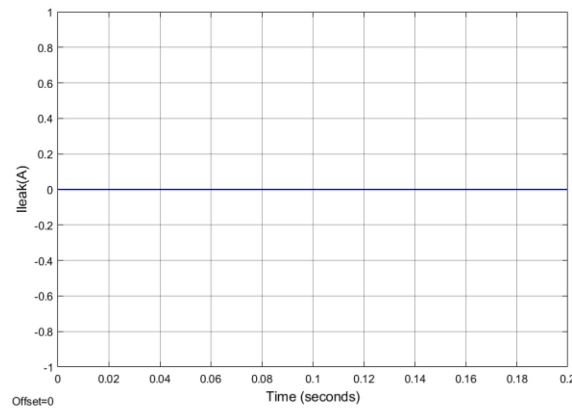
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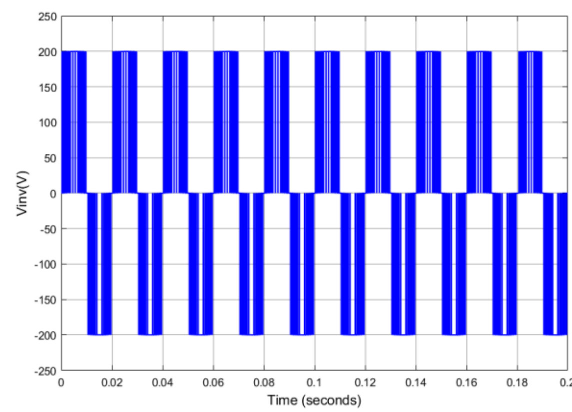
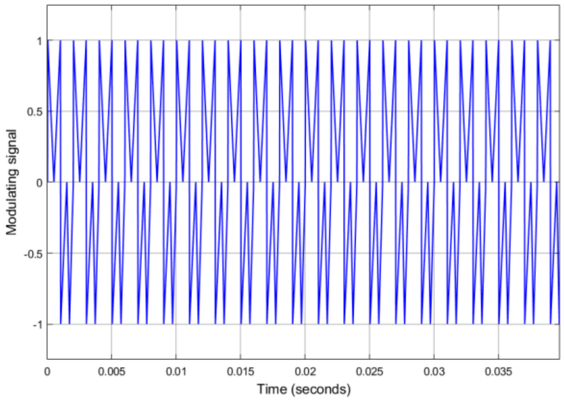

Vinv(V)
Time (seconds)




## IV.CONCLUSION

In this paper presented the operation of FOPI control scheme-based hybrid PWM method for H6 converter circuit. Through this method, the H6 converter operated effectively and mitigates the leakage current. Hence, enhanced the overall performance of the system. Compared to traditional transformer-based control methods PV-fed medium-voltage grids, the proposed control framework simple to design and more economical. The improve the power quality, stability and reliability of the network the SMES system is utilized. From the simulation outcomes it is emphasized that the proposed hybrid PWM provides superior performance and minimized leakage current throughout the power conversion process.

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