An Inverter Control Technique for an RES-based Islanded Microgrid

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Abstract- An advanced modulation technique-based harmonic control approach, known as hysteresis inverter control, in an inverter-connected renewable energy source (RES)-based islanded microgrid system is proposed in this paper. An LC low-pass filter is also used with the feedback control scheme in order to ascertain the control of harmonics in a desired manner. With a view to understanding both the fundamental and harmonic components of the output wave-shapes, fast fourier transform (FFT) analysis is carried out in this paper. MATLAB software is used to simulate the inverter performance within a microgrid system with the proposed feedback control. It has been found that system wave-shapes are sinusoidal and the total harmonic distortion (THD) is less than 0.5%, meaning the proposed method is effective.

Keywords RES, Hysteresis modulation, Islanded microgrid, FFT, THD.

1. Introduction

The concept of microgrid (MG) has been come into existance in order to deal with the increased penetration of distributed generation [1]. Microgrids can be regarded as a collection of distributed generators and loads [2]. When they are operated in islanded mode, the renewable energy sources distribute power to the load with propoer voltage and frequency regulation [3-12]. However, the harmonics problem affects the operation of inverter-intefaced islanded microgrids; in which inverters are used to convert renewable dc generation into ac.

The waveforms of inverter-connected system are usually assumed as sinusoidal. However, in reality, some harmonic components are found in the waveforms [13,14]. Consequently, advanced pulse-width modultion (PWM) techniques are needed to apply to get a good result. Inverter current control approach is demonstrated in [13] with negligible THD. Phase displacement-based modulation method is given in [14]. Feedback delta modulation process is provided in [15].

However, all these aforementioned advanced modulation techniques lack accuray in RES-based islanded microgrid system. Therefore, a feedback PWM called hysteresis modulation is proposed in [16]. This paper utilizes this modulation to control haromonics in RES-based islanded microgrids.

This paper focuses on the the utility of hysteresis modulation technique in controlling harmonics in an RES-based islanded microgrids. FFT analysis is illustrated to realize the effect of harmonics under diverse load conditions.

2. Hysteresis Modulation for Inverter Control in a Microgrid System

A simple RES-based microgrid system is shown in “Fig.1”, where inverter is used to convert dc RES into ac so that power can be supplied to the load. The inverter uses hysteresis modulation and this modulation technique controls the inverter response by tracking sinusoidal references within specified error margins [17]. In this modulation, the inverter switching function is dependent on instantaneous microgrid line responses and switching function harmonics give the inverter harmonics [18]. This modulation also ensures excellent dynamic response, stability and wide tracking bandwidth [19].

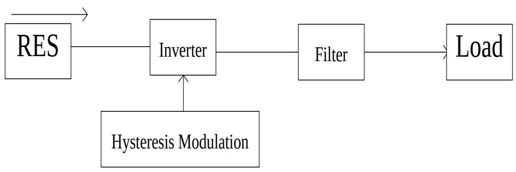

Fig. 1. RES-based microgrid structure.

A single-phase hysteresis half bridge RES converter is depicted in "Fig.2". For simplicity of understanding, the dc supply provided by the RES is divided into two constant dc sources. Two valves Q_1 and Q_2 are turned on and off for a particular time. If both are on or off the output responses are zero. When Q_1 is on but Q_2 is off, the inverter responses are positive. Again the inverter gives negative responses when the opposite is true. A time delay is maintained between two switches to avoid the shorting out of DG sources [20]. The switching state of the valves is described in "Fig.3". The inverter ouput responses are made to track sinusoidal references in order to get modulated outputs within a specified relay bands [21].

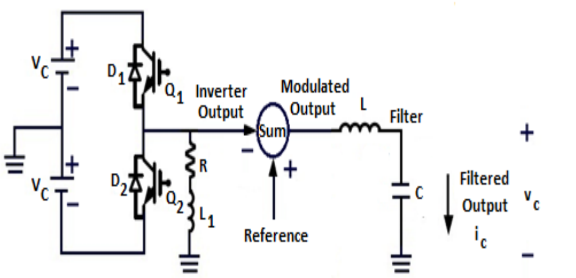

Fig. 2. Single-phase half bridge inverter with hysteresis modulation.

An LC low-pass filter is also appended at the inverter output terminals so that sinusoidal harmonic free responses can be got [22]. The required inverter equations are given from "Eq. (1-4)".

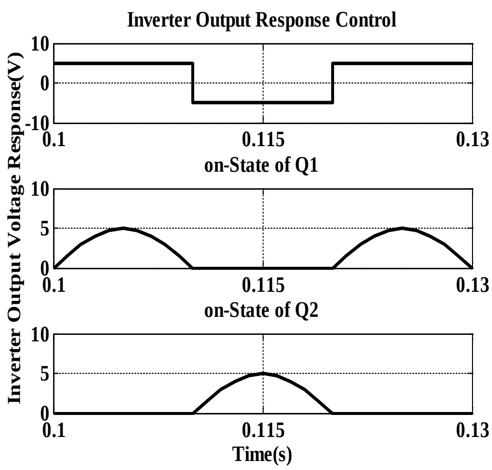

Fig. 3. Inverter voltage control by changing the switching state of the valves.

Instantaneous inverter output voltage,

$$v = \sum_{n=1}^{\infty} 2\frac{2v_C}{n\pi}\sin(nwt) \quad (1)$$

Instantaneous inverter output current,

$$i = \sum_{n=1}^{\infty} 2\frac{2v_C}{n\pi\sqrt{R^2+(nwL)^2}}\sin(nwt-\theta n) \quad (2)$$

where, θn is the lagging or leading angle depending upon the connected load.

Instantaneous inverter output current with filter,

$$i_C = \sum_{n=1}^{\infty} 2\frac{2v_C}{n\pi\sqrt{\left(-1/nwc\right)^2}}\sin(nwt-\theta c). \quad (3)$$

where, θc is the current leading angle of the capacitor.

Instantaneous inverter output voltage with filter,

$$v_C = \frac{1}{C}\int i_c\, dt \quad (4)$$

3. Performance Analysis of the Proposed Inverter Control Approach

This section evaluates the performance of the hysteresis-based inverter control method by means of MATLAB simulation.

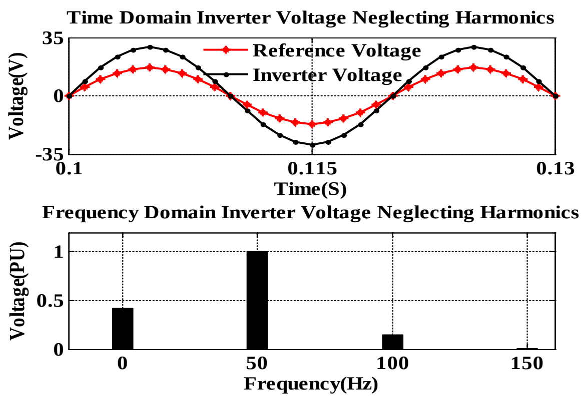

Fig. 4. Ideal response of inverter output voltage (R-load).

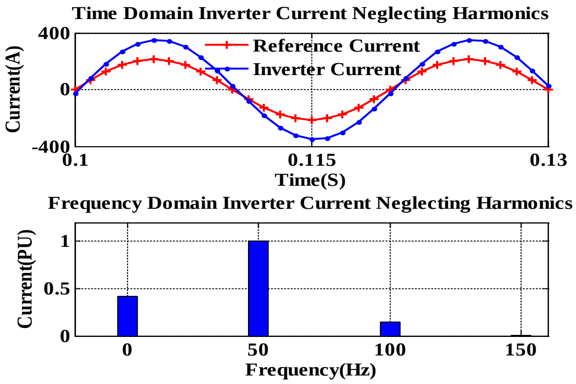

Fig. 5. Ideal response of inverter output current (R-load).

"Fig.4" and "Fig.5" describe the time domain and frequency domain responses of the inverter voltage and current in ideal case,; in which no harmincs exist. On the other hand, "Fig.6" and "Fig.7" represent the modulated voltage and current both in time domain and frequency domain under the same condition. Here, the obtained THD is 0%, which is impractical. THD is calculated by using "Eq. 5".

$$THD = \sqrt{\frac{Im^2 - Im_1^2}{Im^2_1}} \qquad (5)$$

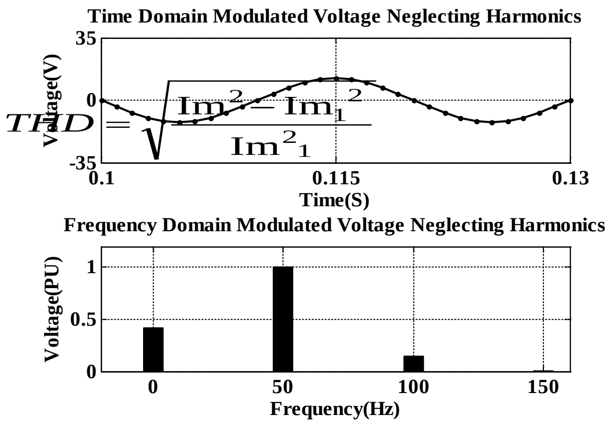

Fig. 6. Modulated voltage without harmonics (R-load).

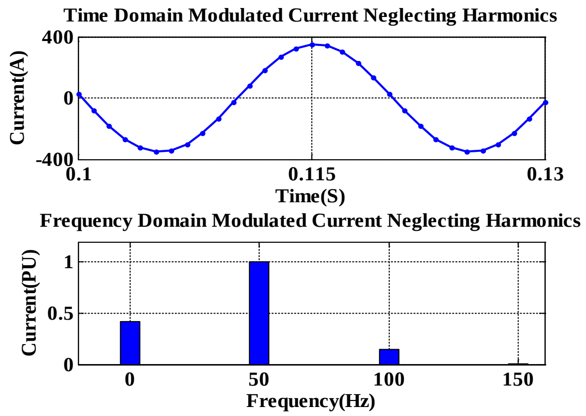

Fig. 7. Modulated current without adding harmonics (R-load).

In order to find out the performance of the inverter control method with RL load, harmonics components are taken into consideration.

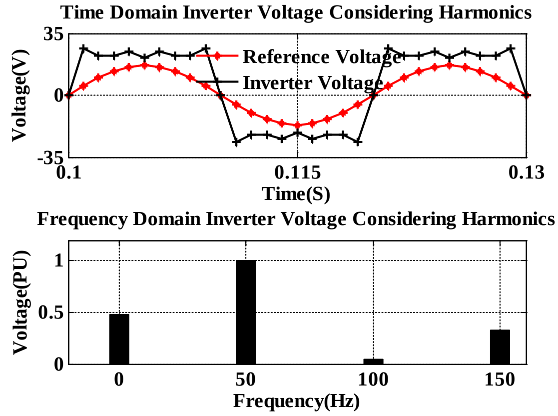

Fig. 8. Inverter ouput voltage with harmonics (RL-load).

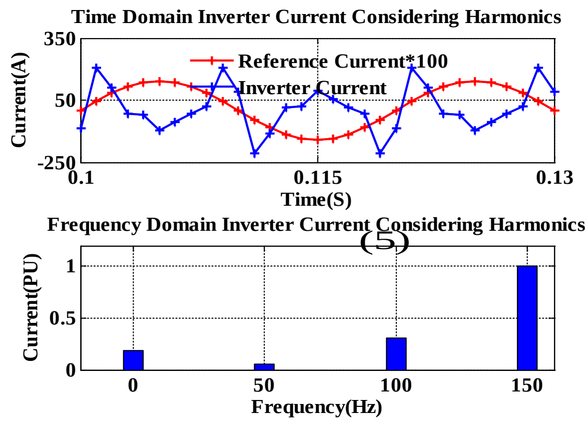

Fig. 9. Inverter Ouput Current with Harmonics (RL-load).

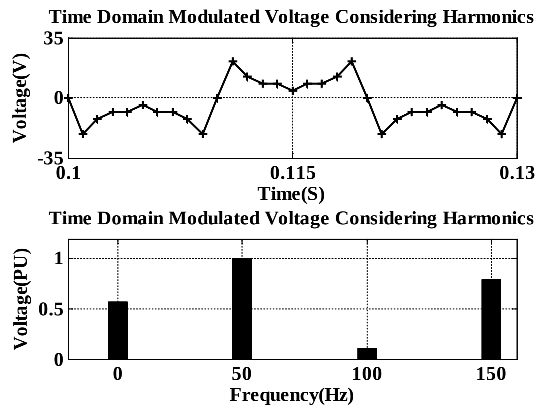

Fig. 10. Modulated ouput voltage with harmonics (RL-load).

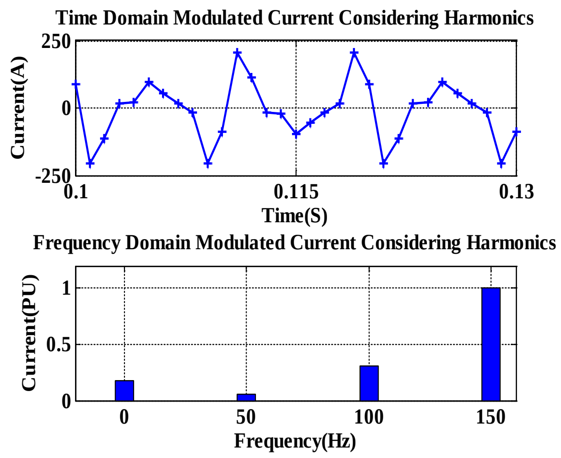

Fig. 11. Modulated output current with harmonics (RL-load).

"Figs. 8-11", indicate the responses of hysteresis controlled inverter when harmonics are present at the output terminal; in which output voltage and current are shown in the first two figures. Whereas, later two figure out the modulated outputs. However, unwanted harmonic components are found and THD is 41.415% which is far beyond satisfactory range.

To eradiate the effects of harmonics, a low-pass filter is used and output is taken across the filter. Now, the filttered responses are simulated in "Figs. 12-13". It is noticed that the fundamental frequency component has the highest amplitude. Using 'Eq. 5', THD is calculated and its only 0.1% that can be considered as a negligible amount. As a result, it can be said that the proposed inverter control methodology can ascertain harmonics free responses within an RES-based islanded microgrid.

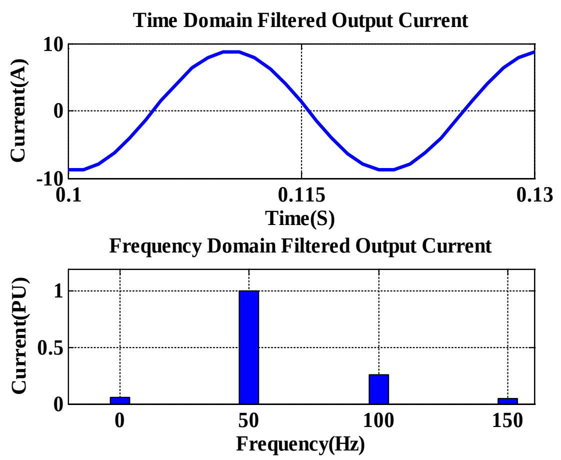

Fig. 12. Output current after filtering (RLC-load).

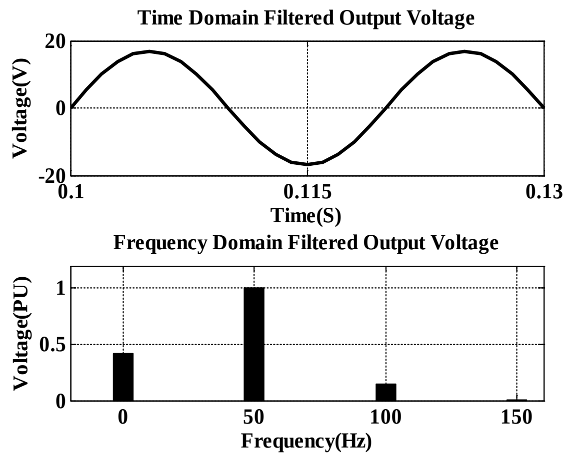

Fig. 13. Output voltage after filtering (RLC-load).

2. Conclusion

Hysteresis modulation-based harmonics control for inverter-connected RES-based islanded microgrid is given in this paper so that the connected load can be fed with sinusoidal waveform-based inputs. From simulated figures, it is seen that the waveforms of both inverter responses are sinusoidal and the evaluated THD results validate the effectiveness of the proposed strategy in RES-based microgrid system. In future, this concept can be implemented on a large test system with multiple sources and loads.

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