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A SIMPLE METHOD IN SINGLE PHASE GRID TIE INVERTER TO IMPROVE POWER SHARING AND QUALITY

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ABSTRACT

The utilization of renewable energy is currently growing very rapidly and one of its applications is in the grid system. Therefore, this research was conducted to investigate the use of parallel inverter in the grid to improve power sharing and quality. The parallel inverter consists of a current source-controlled inverter and signal processing filter. Concerning power-sharing, the reference current is expected to be equal to the actual in order to select the power requirement for the load and subsequently improve quality. This makes current a fundamental and harmonic component used as a reference to improve the sharing and quality of power in the system. However, the use of parallel inverter in the grid has been verified by power simulator software and the computational simulation results showed the simple proposed system to be effective.

Keywords: single phase, current control, power sharing, power quality.

INTRODUCTION

The demand for electrical energy continues to increase with the development of residential, office and industrial sectors. This has led to the need for alternative energy sources such as solar, wind, and others. Moreover, there is a very rapid utilization of an electrical power converter system for a parallel grid inverter in recent times [1-6]. In other words, the issue of parallel grid ties inverter was an interesting subject to be studied by many researchers.

A parallel inverter is commonly used in the grid for system power-sharing [7-9]. It is based on a voltage source observed through several parameters such as amplitude, frequency, and phase synchronization inverter [10-14]. The system requires a complex control structure such as the common use of isolation transformer and passive voltage control to avoid current circulation. Moreover, it is also based on power-sharing by controlling current with reference to any load [15-16]. The moderation has been reported to be very simple but the load is sometimes not only linear causing the distortion of current on the grid source [17-20]. Therefore, there is a need to improve the grid source current to be linear with the voltage source.

This research investigated the parallel grid-tie current-controlled inverter and its ability to operate as a sharing device to improve the quality of power. This makes it possible to select the power requirement on the load carried by the inverter. Due to the fact that a current-controlled inverter operates to improve power quality, the grid current source is expected to be linear to those associated with voltage and, in other conditions, operated at both. However, since the proposed system is based on the current-controlled inverter, it did not require synchronization voltage and also expected to work automatically in accordance with the desired reference.

RESEARCH METHOD

A parallel grid-tie inverter system is shown in Figure-1 with the source used as a reference power at the load and the current-controlled inverter was used as the selector. The condition to propose a power-sharing system was suggested. Moreover, Figure-1 shows that when the source of the grid is not linked in parallel with the current-controlled inverter. The amount of power needed is calculated using the following equation:

$$p_{\_Inv1}(t) = v_{\_Inv1}(t) \cdot \left(i_{\_Beban1} + i_{\_Beban2}\right)(t). \quad (1)$$

Circuiting the parallel current-controlled inverter shows the load 1 ($I_{\_Load1}$) was supplied by the current-controlled inverter ($I_{\_Inv}$) while load 2 ($I_{\_Load2}$) was by the grid source, therefore, the correlation power is as follows:

1. Load 1 requires the current $I_{\_Load1}$ absorbs the power of $V_{\_Grid} \times I_{\_Load1}$,
2. Load 2 requires the current $I_{\_Beban2}$ absorbs the power of $V_{\_Grid} \times I_{\_Load2}$.

The correlation of the power in Figure-1 is represented by

$$p_{\_Grid}(t) = v_{\_Grid1}(t) \cdot i_{\_Load2}(t). \quad (2)$$

and,

$$p_{\_Inv}(t) = v_{\_Inv}(t) \cdot i_{\_Load1}(t). \quad (3)$$

The current at load 1 was a reference for the current-controlled inverter and this was also reflected in the output. Meanwhile, load 2 was not controlled but rather supplied by the grid source. This, therefore, means

load 1 was selected to be supplied by the current-controlled inverter.

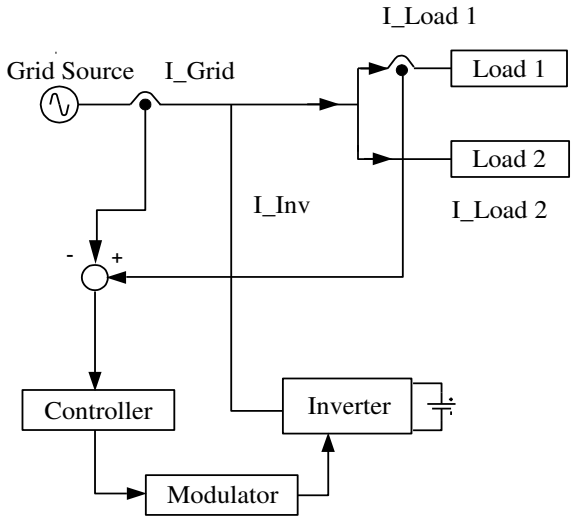

Figure-1. The proposed power sharing system.

The working principle involved keeping the inverter output current in accordance with the desired reference current by installing a proportional and integral control (PI controller) as shown in Figure-2.

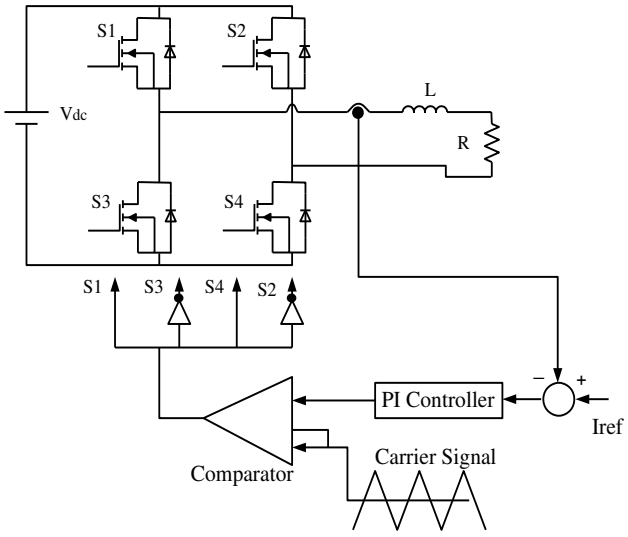

Figure-2. The inverter current controlled scheme.

This study considered loading a single-phase rectifier diode by using an inductive load to generate a current harmonic represented by load 2. The current-controlled inverter was used as an interface to inject current into the system as indicated in Figure-3.

The control circuit used was able to perform the extraction process by removing the harmonic and fundamental components to separate load 2 using the following relationship.

$$I_{-Load\,2} = I_{-Load\,2\,f} + I_{-Load\,2\,h} \quad (4)$$

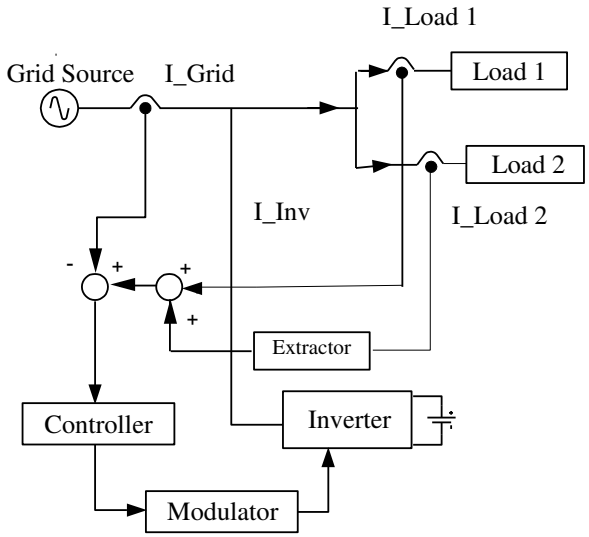

Figure-3. The proposed power sharing and or power quality improvement system.

The control circuit schematic in Figure-3 led to the derivation of the following equation:

Without the connection, the current source inverter is equal to the load current as follows.

$$I_{Grid} + I_{Inv} = I_{-Load\,1} + I_{-Load\,2} \quad (5)$$

With the current-controlled inverter connected, the grid current is the same as the fundamental component of load current as shown in the following relationship.

$$I_{Grid} = I_{-Load\,2\,f} \quad (6)$$

This condition occurs because the inverter injected a current to compensate the grid source current:

$$I_{Inv} = I_{-Load\,1} + I_{-Load\,2\,h} \quad (7)$$

RESULT AND DISCUSSIONS

The analysis was verified through simulation based on power simulator software by using the scheme depicted in Figures 1 and 3 with the parameters used presented in Table-1. Moreover, the parallel inverter-grid system had both the linear and non-linear loads.

When parallel inverter connected to single phase grid source with linear load 1 and linear load 2, the linear load power 1 would be supplied by the power inverter, I_inv and I_load 1 had the same waveform, Figure-4. Figure 5 shown the linear load power 2 would be supplied by the single phase grid source, Igrid and I_load 2 had the same waveform.

Table-1. The simulation parameters.

Parameters	Value
Vinv	400 Volt
Vgrid	220 Volt
Linear Load 1	L: 10mH R : 20 Ohm
Linear Load 2	L: 10mH R : 50 Ohm
Non-linear Load 1	Diode rectifier L: 10mH R : 20 Ohm
Non-linear Load 2	Diode rectifier L: 60mH R : 50 Ohm
Inductor	5mH
Switching Frequency	10KHz

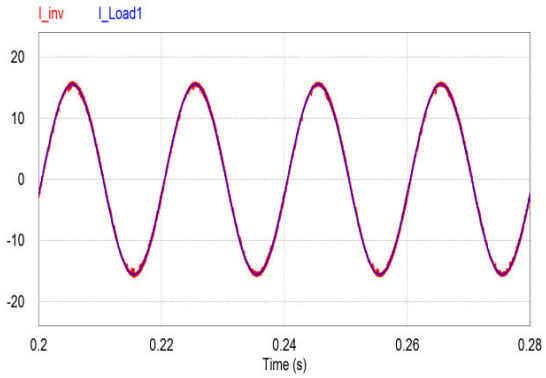

Figure-4. The load current 1 supplied by power inverter.

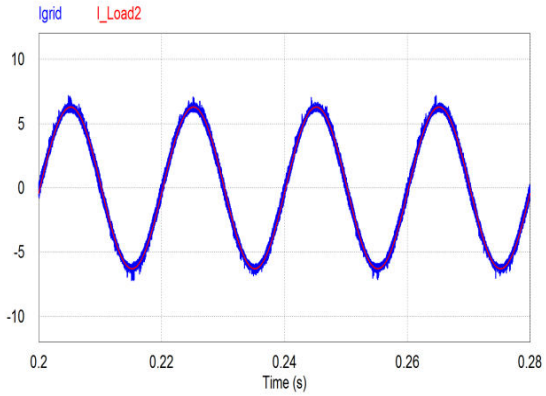

Figure-5. The load current 2 supplied by single phase grid source.

The connection of the parallel inverter to the single-phase grid source with non-linear load 1 and linear load 2 showed the non-linear load power 1 was supplied by the power inverter while I_inv and I_load 1 were observed to have the same waveform as shown in Figure-6. Meanwhile, Figure-7 shows the linear load power 2 was supplied by the single-phase grid source with Igrid and I_load 2 also found to have the same waveform.

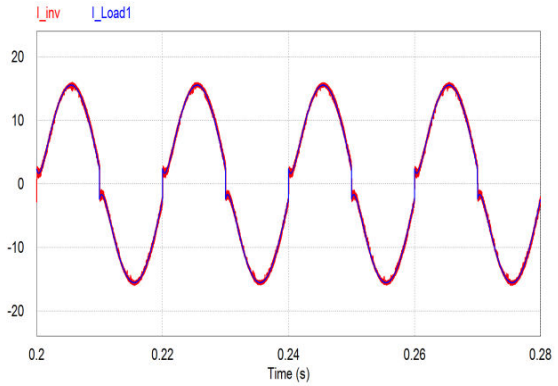

Figure-6. The load current 1 supplied by power inverter.

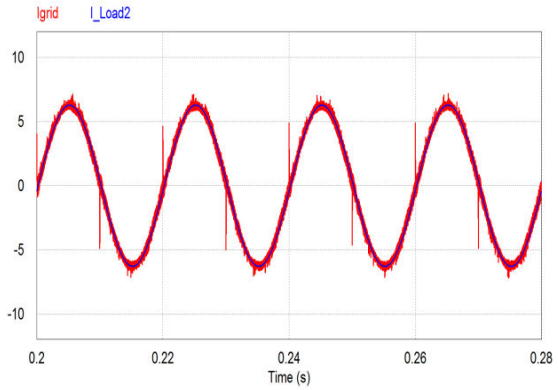

Figure-7. The load current 2 supplied by single phase grid source.

The connection of parallel inverter to single-phase grid source with linear load 1 and non-linear load 2 showed the linear load power 1 was supplied by the power inverter and harmonics load 2 was absorbed by the power inverter as shown in Figure-8. Meanwhile, Figure-9 shows the non-linear load power 2 was supplied by the single-phase grid source (the grid source current always supplies a fundamental load current 2), in other hand; Vgrid and Igrid input current would be in phase, Figure-10.

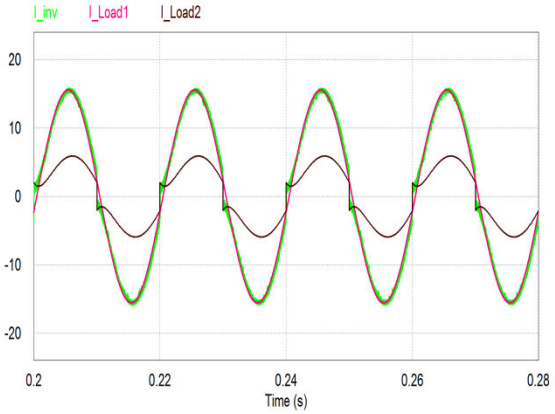

Figure-8. The load current 2 supplied by single phase grid source.

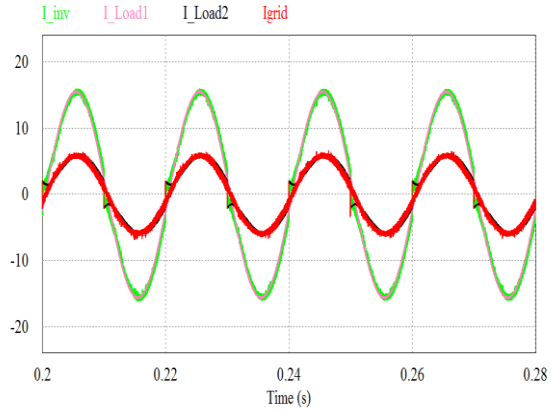

Figure-9. The load current 2 supplied by single phase grid source

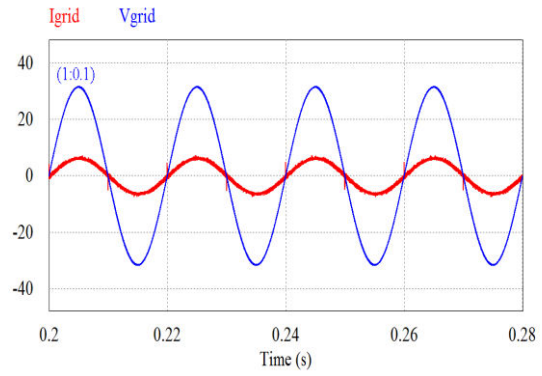

Figure-10. Vgrid Vs Igrid.

The connection of the parallel inverter connected to single-phase grid source with non-linear load 1 and non-linear load 2 indicated the non-linear load power 1 was supplied by the power inverter and harmonics while load 2 was absorbed by the power inverter as shown in Figure-11. Meanwhile, Figure-11 shows the non-linear load power 2 was supplied by the single-phase grid source (the grid source current always supplies a fundamental load current 2), in other hand; Vgrid and Igrid input current would be in phase, Figure-13.

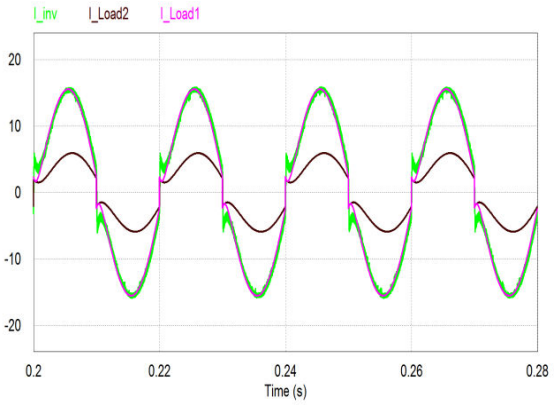

Figure-11. The load current 2 supplied by single phase grid source.

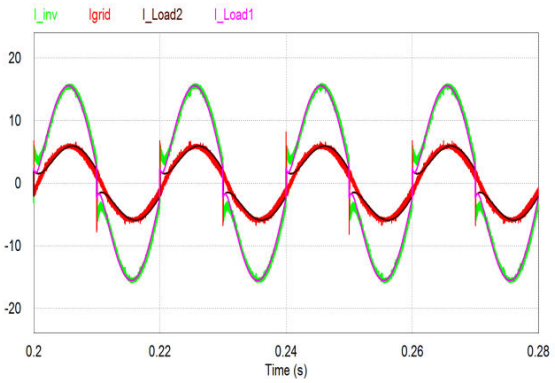

Figure-12. The load current 2 supplied by single phase grid source.

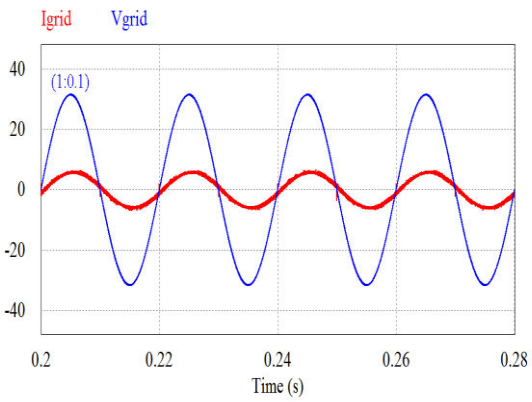

Figure-13. Vgrid Vs Igrid.

Figure-14 shows the current grid (Igrid) THD values analysis based on Figure-13. The Total Harmonic Distortion (THD) current grid (Igrid) analysis read values approximately 1.05% for Igrid at frequency of 50Hz.

THDi record function which is below 5% for 2.3 - 69kV usage IEEE 519-2014 harmonic limits standard [21].

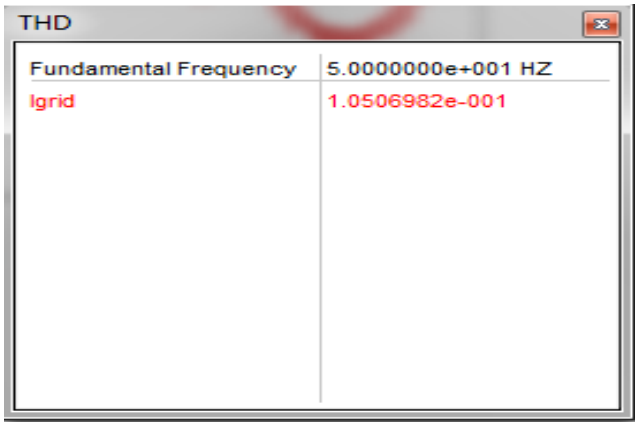

Figure-14. THD Igrid.

It is possible to adjust parallel inverters to the load and select either linear or non-linear load with the quantity adjusted to the capabilities of the inverter itself. Moreover, the computational simulations showed a load is linear irrespective of the source.

CONCLUSIONS

The parallel inverter proposed to improve power sharing and quality in the single-phase grid system was found to be effective. The method based on voltage source current-controlled was discovered to be very simple. Moreover, the power to linear or non-linear load 1 was supplied by the inverter while load 2 was supplied by the single-phase grid source and the harmonics load 2 was absorbed by the power inverter. However, the system was built to always look like a linear load.

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