The Development of Grid-Tie Inverter as Bidirectional DC/AC Converter in the DC Microgrid Network

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Abstract. In the dc microgrid, the backup battery has a function as a backup of electric energy source. However, if energy of the backup battery has been full, while renewable energy generator keeps supplying the dc microgrid, then excess energy stored in the dc microgrid can be supplied to grid utility. While, if the dc microgrid suffers deficiency of supply energy, then the grid utility can supply back to the dc microgrid. This system will run if it uses bidirectional DC/AC converter. This research will be developing bi-directional inverter scheme using the GTI, so it will be obtained bi-directional converter with a low cost and reliable. This experiment is started by determining voltage and current needed by GTI in order to run in the grid utility. The output voltage of DC-DC converter used by the dc microgrid is 254 V connected to the bidirectional converter with maximum current from the source is 20A. The power contribution supplyed from the dc microgrid to the grid utility is 90–124.3 VA.

Introduction

Inverter is a power electronic device that converts direct current (DC) voltage to alternating current (AC). The inverter can be categorized into two types i.e. *inverter off grid* and *inverter on grid.* Inverter off grid is inverter that operates independently without connecting to the grid utility (PLN), while inverter on grid is inverter that connected to the grid utility. *Inverter grid-tie* (GTI) is included in the category of inverter on grid. GTI is an inverter that functions for converting direct current voltage to alternating current voltage connected directly to grid source without synchronization. GTI is used in a renewable energy generator like photo cell or wind power [1, 2]. GTI can only operate if it is connected to the grid, if it is not connected to the grid it can notoperate.GTI has ability to synchronize voltage and frequency from the grid [3]. In general, basic topology of GTI circuit consists of three types of circuit [4], i.e. *inverter LF-transformator, inverter HF-transformator and transformer-less inverter.* Conventional GTI usually only uses *LF-transformator* for raising input voltage. *LF-transformator* provides galvanic isolation between network and photo voltaic array. The type of *LF-tranformator inverter* has heavy weight and large size.

The inverter efficiency can be increased by changing *LF-transformator with HF-transformator*. DC-DC phase shift converter can perform MPPT (*Maximum Power Poin Tracking*) function and at the same time can provide galvanic isolation. *Transformer-less inverter*uses boost converter for controlling voltage from PV to match with input voltage needed. Diagram block of a GTI is shown in Figs. 1a and 1b.

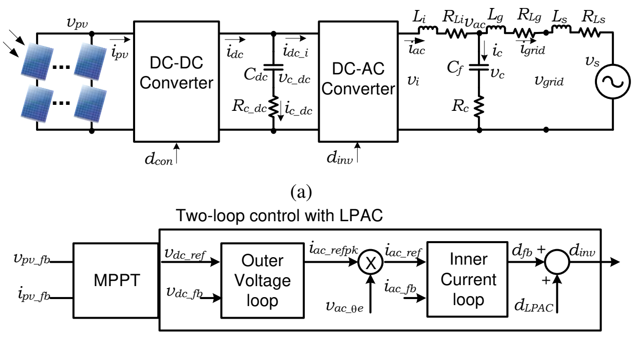

Fig. 1. (a) GTI configuration; and (b) Diagram Block of GTI model [4]

In 2009 Yaow-Ming, et.al,.perform the research about b*iderectional grid –tied inverter* (BGI), using power control on DC load form grid utility (*grid connection mode/GCM*), using power factor correction (PFCM) that suplied dc loads, however, it does not supply dc source or the dc microgrid [5]. This background makes GTI can be developed into *Biderectional DC/AC converter* in the dc microgrid. This research is development of research about GTI performance in photo voltaic [2,5] , Fig. 2. Reading of the power flow from dc microgrid network to utility grid and vice versa use the real power does not distinguish active and reactive power capability as that of B. Crowhurst, EF [7].

GTI has the ability to connect directly to the grid utility, so GTI is classified to *inverter on grid*. Power that produced by photovoltaic or wind power is used partly for local load demand and partly transmitted to grid utility. The problem appear when GTI connected to the grid, it will supplying power on GTI input to the grid, until limit of power input or power capacity of inverter. So that if the battery is connected directly to GTI, the battery power that should be used for backup power, will supplied to grid too, so it is necessary to develop power control that will regulate the mechanism of charging and supplying power from dc microgrid to grid. This research will be developing bi-directional inverter scheme using the GTI, so it will be obtained bi-directional converter with a low cost and reliable.

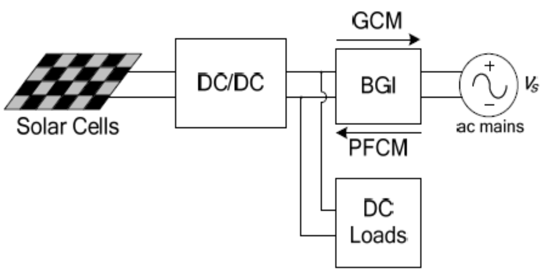

Fig. 2. Diagram block of BGI supplying dc load [5]

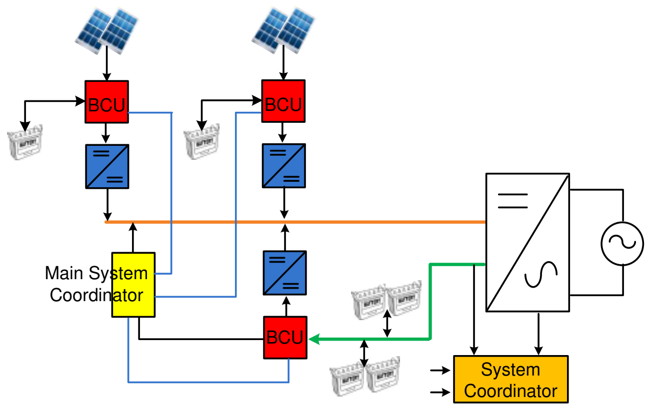

Fig. 3. DC microgrid is connected to utility grid through *bi-directional DC/AC Converter*

This research will analyzes too, power transfer from dc microgrid to utility grid and vice versa. DC microgrid system that is connected to the utility grid through bi-directional DC/AC Converter as shown in Fig. 3.

Propose Design of Bidirectional DC/AC Converter in DC Microgrid

DC Microgrid can be analogized as a renewable energy source because the produced voltage is DC Voltage. Design of Bidirectional DC/AC converter consists of four circuit types i.e.:

a. Buck converter
b. Grid-tie inverter
c. Rectifier
d. Boost converter

GTI design as Bidirectional DC/AC converter in dc microgrid network shown in Fig. 4. Application of GTI in the dc microgrid will provide power contribution to utility grid as much as power capability of dc micro network, in order to the capability of dc microgrid can supply the existing local loads, then controlling voltage in the input side GTI is necessary performed i.e. performing the output voltage of the DC-DC converter (Boost converter). Real Power and reactive power of the GTI is supplied to utility grid shown in equations 1 and 2 [6].

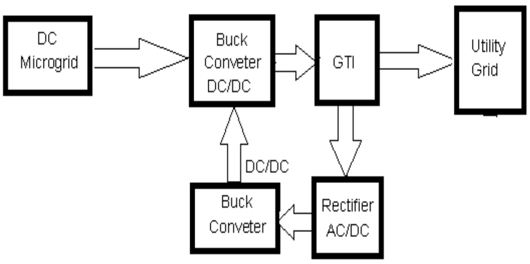

Fig. 4. Design scheme of bidirectional DC/AC converter

$$Real\ Power, P = \frac{|V_{inv}||V_{grid}|}{Z_t} \sin\sigma \qquad \ldots(1)$$

$$Reactive\ Power, Q = \frac{|V_{inv}|^2}{Z_t} - \frac{|V_{inv}||V_{grid}|}{Z_t} \cos\sigma \qquad \ldots(2)$$

Where, V_{inv} = Inverter Output Voltage
V_{grid} = Power grid voltage
Z_t = Impedance of the linking line
σ = Angle different between V_{inv} and V_{grid}

Determining the percentage of decreasing voltage is shown in Eq. 3

$$\%\ decreasing\ voltage = \frac{Vnl - VFL}{VFL} \qquad \ldots\ldots\ (3)$$

where :

- *Vnl = no load voltage*
- *VFL = full load voltage*

Experiment

The development of GTI as *Bidirectional DC/AC Converter* is performed with testing step from GTI by determining:

a. Limit of the lowest voltage requirement of GTI
b. The requirement of current and voltage capacity in the battery of the dc micro grid
c. Loading ofthe dc micro grid
d. Capacity of current and voltage in the input side of GTI

e. The ability of supply power of GTI to thegrid utility (*power serring*).
f. The ability of grid utility supply to the dc micro grid.

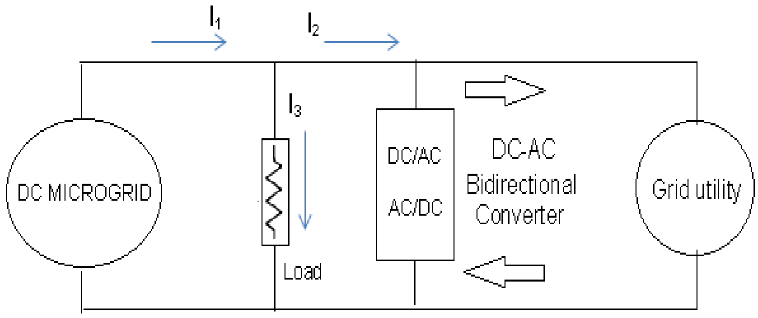

Fig. 5. DC Microgrid supply current load and power supply to the grid utility

Scheme of development GTI testing as *Bidirectional DC/AC Converter* with grid utility is shown in Fig. 5. Current I_1 is the current flows from the DC microgrid. Current I_2 is the current flows from DC microgrid to distribute over power from the DC microgrid to the utility grid. Current I_3 is the current flows from the DC microgrid to distribute the load

In order to know the ability of GTI supply power to the grid utility, then simulated with a power supply that can be controlled in order to determine the lowest limit of the working voltage of the GTI. The Operating voltage of GTI 10,5V - 28 V. GTI has 2 indicator lamps red and green [8]. The red indicator lamp indicates power flowing to GTI, while the green lamp indicates power supplied by GTI to the grid. These two indicator lamps are parameters of operating GTI. In order to know the minimum and maximum current ability of operating GTI, then the current parameter is installed so that the supply ability of GTI to the grid can be limited. While, for testing the operating voltage is performed in voltage 10 V-24 V.

The lowest voltage limit is needed to know supply characteristics of GTI. The input voltage is fed from 1Vdc - 10 Vdc [8].

Table 1. The loading of the DC micro network

I_1 (A)	I_2 (A)	I_3 (A)	V_{DC}
0.57	0.57	0	253
0.6	0.57	0.03	250
0.63	0.57	0.06	248
0.66	0.57	0.09	246
0.66	0.54	0.12	245
0.68	0.54	0.14	243
0.7	0.52	0.18	241
0.7	0.49	0.21	240
0.7	0.46	0.24	239
0.7	0.43	0.27	238

Result and Discussion

The load in the dc micro network is increased from 0.03A to 0.27A. It is shown in I_1. The load is deliberately limited relating to the capacity of conductor and protection that limited at 20 A, so that the dc micro network can still transmit power to the grid. The testing results of increasing load in the dc micro network can be seen in Table 1.

The ability of the DC microgrid to supply power to the grid utility. The magnitude of power contribution of the dc microgrid to the grid utility at the moment without the load is 146.3 VA, while in maximum current, the GTI loading can contribute 90.4 VA. The power contribution in the grid is shown in Graph Fig. 6.

Implementation from diagram block of *Bidirectional DC/AC Converter* as shown in Fig. 7, then the implementation of *Bidirectional DC/AC Converter* is connected into the dc microgrid system shown Fig. 8.

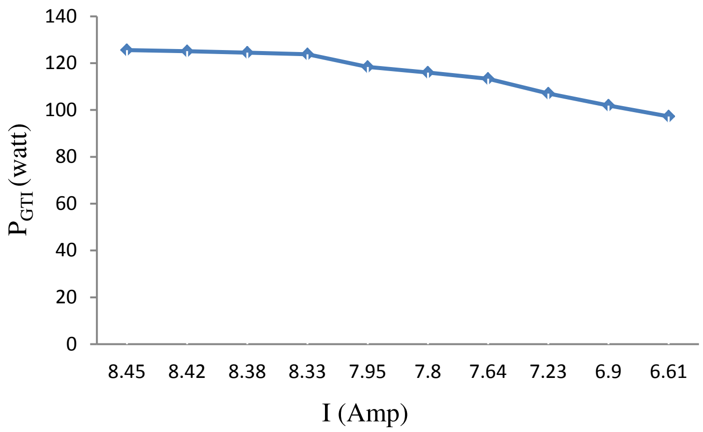

Fig. 6. Power contribution of the dc micro network to the grid

Fig. 7. Implementation of (*Bidirectional DC/AC Converter*)

Fig. 8. Implementation of *Bidirectional DC/AC Converter* with the dc micro network

Conclusion

From the research results of inverter grid-tie development to become *Bidirectional DC/AC Converter, the conclusion* can be drawn, each component can work well. Grid-tie component has the highest efficiency compared to the other component. There are three sections of existing power loss is in the Back converter,| Boos conveter and AC-DC converter. The power transmitted to the grid through the dc microgrid at the moment without load is 124.3 VA, but when loaded is 0.27 A, it is still able to contribute 90.4 VA. When the dc micro grid has the deficiency of supply or fault in system, then the grid will supply power in accordance with power attached to the dc microgrid.

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