AN UNBALANCED LOAD CONTROL FOR THREE PHASE POWER CONVERTER IN DISTRIBUTION SYSTEM

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ABSTRACT

Here in this paper presents the operation of a distributed generation (DG) system controlled by a dc-dc step-up converter and a dc-ac voltage source inverter (VSI) interfaced using the power grid. To create a stable mode when different types of loads are connected locally or when working under incident, the step-up converter must control the dc link voltage, designate the VSI to regulate its terminal voltage. The power flow between the grid and the DG is stabilized by utilize a power or voltage process that regulates the amplitude and the displacement of the grid voltage synthesized by the DG, while a phase-locked loop algorithm is execute to synchronize the grid and DG. Additionally, a set of simulations are done independent of the load type or its work regime (whether it is connected to the grid). The efficient of the proposed method is evaluated by experimental results.

***Keywords*: *Distributed Generation (DG), Islanding Modes, Power Converters*.**

I. INTRODUCTION

The application of distributed generation (DG) supply is currently being examine as a solution to the arise problems of energy need. Apart from the resultant decrease in the size of the generating plants and the probability of modular implementation, DG systems locate on non-conventional energy sources (fuel cells, photovoltaic and depositor techniques like as ultra-capacitors and batteries) are of more interest due to their low environmental result and technical advantages such as improvements in voltage levels and minimize power-losses when a DG system is placed in radial lines. DG systems also apply cogeneration and better overall system efficiency.

A DG system control at high performance involve a detailed consideration of the feeder where the DG will be placed, plus an assessment of the load type the DG should supply locally and its operating regime. Without these requirements, the cause of DG may be more destructive than beneficial: the addition of new generation sources in the distribution system may affect transient effects due to switching operating, changing short-circuit estimation, lower limit of stability, and reverse of the power flow through the distribution system ,build make erroneous methods of the protection devices and islanding in part of the process. In addition, the DG method should not more the limits developed by international standards for the following variables: harmonic distortion, voltage imbalance, voltage variations and fast transients, whether the local load is unstable, nonlinear, or an irregular load, like a motor. As like, the useful of power or current in the d-q synchronous reference frame as control variables to instruct the voltage source inverter (VSI) connected to the grid has generated appreciable interest from the scientific association. With either plan, before or after the probability takes place, the command variable balance the same, using the DG employ with slight capability to supply the load. On the other more, two command algorithms are proposed to increase the grid-connected and intentional-islanding going running methods in, in this the DG system must find the situation and switch from power or current to voltage as a control variable to give constant rms voltage to the local loads.

The power flow is observed by controlling the amplitude and angle of displacement between the voltage generated by the DG and the grid voltage, i.e., the command variable is the same before and after the islanding methods obtained. The voltage control provide the capability to supply different types of loads to the DG system, such as linear, nonlinear, machine, constant, or unbalance, As like, if the DG working in the islanding performance. These kinds of controls are useful for D Separating in parallel as each of the DGs are joined to the grid through a distribution transformer (DT).As like this, the other process introduced in are more effective.

This paper analyses the results caused by 50 to 5000-kVADG sources placed into the distribution network, whether the local load is linear or nonlinear, or if the grid is working under abnormal states. Section II considers the process used to drive both converters. Section III considers the technique to control the power flow through the grid. Sections IV and V display the simulations and experimental setup to support the previous analysis, while the main points extend in this paper appearing the conclusion.

II. CHARACTERISTICS OF THE DG SYSTEM

Fig.1 shows a diagram of the network used to study typical connection of a DG network to a specific feeder, while studies to examine the best site for DG placing should be operated before the working inspection. A power plan tallow a secondary reference (DG network),while in this study the better grid is a basic arrangement system found in 1547 standard (simulated network) or a California measurement 4500 source (innovative process). Furthermore, the primary energy worn in the proposed DG network is the same as the old reveal renewable energy sources.

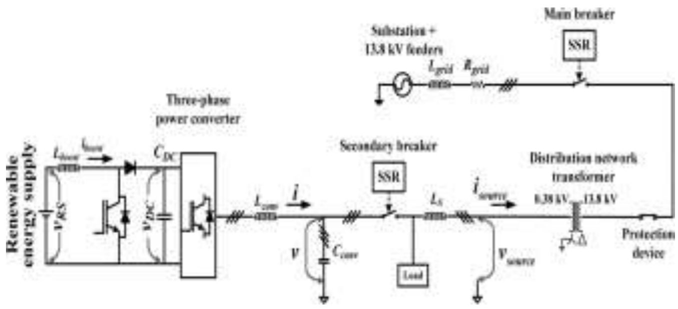


Fig. 1 Basic Diagram of the Distributed Generation System

A dc-dc converter is mission to equalize the dc link voltage and supply energy for quick transients when used by the local load period of a dc-ac converter is used to assurance the power quality convey to customers (regional load) and the particular feeder. To evade disturbances between the dc-ac conversion and the feeders, a phase-locked loop (PLL) algorithm related with the zero voltage crossing detectors was worn.

2.1 DC-DC Converter

A dc-dc step-up converter was worn as an interface linking the dc source and dc link of the three-phase dc-ac converter. The step-up converter increases the dc voltage and provide the quick transients of energy needed for the local load, thereby decreases disturbances in the feeder current.

The operation of the step-up converter is as like to a voltage source, and the power it convey to the grid based on the point of maximum power (PMP) explain by the dc source. The PMP is procure using a tracking algorithm, based on the primary energy reference.

2.2 DC-AC Converter

Closed-loop supervises of the output current and voltage were execute to assurance inverter voltage standard. PIs controllers are also worn as the control methods, while the design process of these PIs is the like as that worn in the dc-dc step-up converter.

While the closed-loop cut-off frequency of the PI current controller was taken one decade given the switching frequency, the PI of the current continues a good compensation quality in the frequency scope of interest. To increase this capability, a feed forward of the reference voltage should be worn to compensate the remaining error in the closed-loop gain at less frequency. Due to its good power and the used for a decrease switching frequency, the voltage controller performs a less regulation bandwidth (a small hundred Hertz).

2.3 Grid Characteristics

In the simulations, the total distribution network found in 1547 standard is composed of 13.8-kV feeders connected to a 69-kV radial line along 69/13.8-kV substation transformers, as shown in Fig. 1. To place the DG at the distribution network, a 13.8/0.38 kV distribution systems transformer is used to equalize the voltage levels. The line imitation employed in the simulations took into version the Bergeron'straveling wave process worn by the Electromagnetic Transients ways, which employ wave propagation phenomena and line end variations. Additionally, a set of switches was added between the DGs and distribution network, isolating them from each other to evade the DG network supplies loads (loads placed in near feeders where the DG was placed) connected to the high voltage side of the distribution transform. Due to the high level of power and voltage, 12 kHz was worn as the PWM switching frequency for both converters.

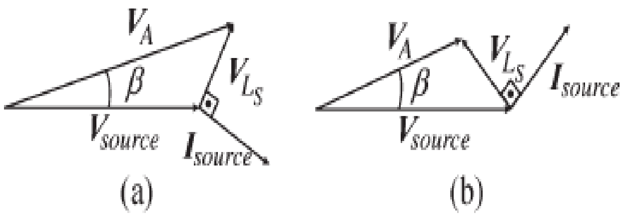
2.4 Synchronization Algorithm

To connect the DG to the grid, it is important to synchronize both networks, which is done by mode of a PLL algorithm that computes the average of the internal product between $vsource$ and the synchronous voltage ($v\_\perp$). If this equals zeroin steady-state regime, $v\_\perp$ and $vsource$are perpendicular and synchronized.

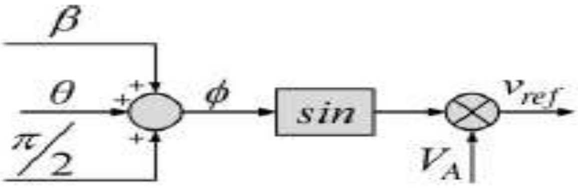
To differentiate the characteristic equation of the prototype transfer function with the PLL closed-loop transfer function, PI constants can be modify by choosing the most selected values for the natural undamped frequency (ωn)and damping ratio (ξ). To avoid stability problems, ωn should ideally be greater than one or two periods of the fundamental frequency, and the maximum overshoot lower than 30%.

III. POWER CONTROL THROUGH THE FEEDER

Energy generated by the renewable energy sources can be transferred to the grid by controlling the amplitude of the voltage created by the DG, and the angle between the grid voltage and the DG voltage (β angle) through a coupling inductor (LS). This provide as an additional inductance used to connect the DG to the grid, or the leakage inductance of the DT. If LS is a DT parameter, $vsource$ must be fined on the high voltage side of the distribution network transformer.



Phasor Diagrams (A) Delivering Active and Reactive Power (B) Delivering active and Absorbing Reactive Power



The β angle is determined by the average power flowing to the grid (*Psource*), the connection reactance (*XLS*), the rms phase voltage (*VA source*) synthesized by the grid, and the rms voltage produced (*VA*) by the DG according to. After defining the β angle, the DG voltage amplitude of ***V** A* must be adjusted according to, where *VA source* and *XLS* are the same parameters described in . If *Q source*= 0 the unity power factor (PF) to the feeder is obtained. Additionally, *LS* is designed for a small voltage variation on the ac local voltage produced by the dc-ac inverter The β angle is determined by the average power flowing to the grid (*P source*), the connection reactance (*XLS*), the rms phase voltage (*VA source*) synthesized by the grid, and the rms voltage produced (*VA*) by the DG according to After defining the β angle, the DG voltage amplitude of ***V** A* must be adjusted according to , where *VA source* and *XLS* are the same parameters described in . If *Q source*= 0 the unity power factor (PF) to the feeder is obtained. Additionally, *LS* is designed for a small voltage variation on the ac local voltage produced by the dc-ac inverter the voltage reference (*vref*) of the dc-ac power converter is determined by displacing θ by $\pi/2$ and adding the β angle to the result. The φ angle is then used as the argument of a sinusoidal function and multiplied by *VA* to obtain the voltage reference that must be synthesized at the VSI terminals

$$\beta = sin^{-1}\left(\frac{P_{source}\,|X_{L_S}|}{V_{A_{source}}V_A}\right)$$

$$V_A = \sqrt{2}\left(\frac{V_{A_{source}}^2 - Q_{source}\,|X_{L_S}|}{V_{A_{source}}\cos\beta}\right)$$

IV. SIMULATION ANALYSIS

Simulations were performed using MatLab/Simulink software,
as shown in Fig. 1.

4.1 Connection and Power Transfer

Two procedures are required to connect the DG system to the feeder. First, an algorithm must be used to synchronize *vsource* with the voltage produced by the converter *v*. After synchronization; the algorithm to detect zero crossing of *vsource* must be initiated. When this is done, the switch connecting both systems is closed, minimizing the transient effects to the feeder(which occur up to 0.2 s).Subsequently, a soft transfer (40 kVA/s) of power starts at 0.25 s of the simulation range, followed by a base load operation. Due to the method used—synchronization and soft transfer of power—minimal disturbances are observed in the grid.

Due to load capability, the current flowing through the grid inverts its direction, making additional power come from the grid. At the moment of the load connection, most of the electric variables are submitted to fast transients.

However, this is not observed in the grid voltages because the short-circuit power of the grid is higher than the short-circuit power of the DG network. To verify the power quality deliver to customers, total harmonic distortion (THD) of the DG voltage is well below 5%, whereas the PF is close to unity.

4.2 Nonlinear Load

Another issue to be analysed is the influence of a non linear load connected to the DG terminals. In this case, the control technique used to synthesize the ac voltage by the inverter plays an important role. In fact, it reduces the impedance of the inverted, making the DG network compensate the local load harmonics. In this process, the load is placed at 0.4 s and the DG network is connected to the grid at 2 s, abide so for 6 s.

To observe the system's capability, the minimal value of active and reactive power flows through the grid, with the nonlinear load represented by a non-controlled three-phase power rectifier plus *RC* load that demands around 50 kVA from the DG. In this operation mode, the THD of the voltage imposed by the VSI rises to 3%, even with the resonant controller minimizing the 1st, 3rd, and 5th to 15th harmonics contents, however, the THD of the load current achieves more than 115%. To observe what happens with the DG network, a small time interval (1.96 to 2.04 s) before and after the connection with the grid is present while demonstrates the DG capability to supply nonlinear loads in the connected or isolated modes.

4.3 Islanding Mode Consideration

When a short-circuit occurs on the high voltage side of the DT system, the protection devices closest to the event disconnect the grid from the distribution system in order to avoid stability issues. However, the DG remainder connect, forming a local area whose mode of operations may be dangerous if the local load demand is greater than the power produced by the DG. To avoid this, the DG must identify the contingency as soon as possible and disconnect it from the local area.

To understand the effects on the grid and power converters, the following series of events was performed. First, a balanced three-phase linear load demanding almost 25 kW was connected to the DG terminals at the beginning of the simulation. At 1.8 s, the power produced by the DG system was reduced (*pDC* drops from 125 kW to 100 kW) and a 75-kW three phase linear load was connected to the DG terminals to obtaina minimal power level exchanged with the grid, which, as reported in literature, is the most difficult situation to identify the islanding mode.

4.4 Islanding and Reconnection to the Feeder

Another important aspect of the DG operation is the is landing mode followed by a reconnection. As above, the test performed here considers a limited power level exchanged with the grid.

At the beginning of the simulations, a balanced three-phase linear load demanding 30 kW was connected to the DG terminals.

The power produced by the DG system was reduced from125 kW to 90 kW, and a 25-kW three-phase linear load was connected 1.25 s after the simulate range started.

The DG voltage amplitude was subsequently adjusted to exchange −10 kVAr with the grid. This was undertaken to obtain a minimal level of active (35 kW) and reactive (−10 kVAr) power through the grid, Unlike what occurred in Section IV-C, the effects of islanding (at 3.0 s) approved by a reconnecting (at 5.0 s) are evident on the dc link voltage and power, or on the power passing through the grid, with the most drastic type being the dc link power, while dropped to zero when the grid was reconstructed.

V. EXPERIMENTAL RESULTS

A 3-kVA experimental setup was find to verify the given control method. The tests were implemented assume linear load, nonlinear load, and motors start-up, or while a disturbance happened on the grid voltage. When a negative signal was created with *isource*, the given signal have to be displaced by 180◦. The first test was controlled while the DG was applying a balanced linear load that demand 2 kW (0.655 kW per phase) of more active power from the grid. By examined the power quality indicated, a unity PF was also procure (where zero reactive power is change with the grid), and the THD of the DG system voltage did not more than 1%. In the second test, the added power (2.7 kW) that was not being utilize by the linear load was inject into the grid, and the same steps to find power quality was operated. The THD of the DG system voltage is lesser than1%, when the PF measure close to one. Based on the nonlinear load problems, in the third test, a three phase No controlled rectifier was placed with a resistive load to its dc link connection. This load type customers 0.35 kVA, like as1.7 kW is dispatch to the grid. At a set time, the nonlinear load was doubled increases and the power now that was injected into the grid was decreased to 1.35 kW. While the nonlinear load was attached, the compensation ability dropped, make the THD of the DG network voltage and the PF method the power quality limits developed by international standards. This position may effects a nonlinear current flow through the grid if a resonant controlling is not apply. While a resonant controller balance the first and fifth harmonic component was placed in parallel with the PI voltage controller, the converter impedance decrease and the DG ac voltage became distortion less. According to the PF and DG system voltage THD following stabilization were approximately 0.99 and 2%, respectively, when the THD of the load current was above 50%.

In the fourth test, the DG network is supplying 0.5 kW to the resistive load and 1.7 kWto the grid. While the system was caused to a frequency step variation (0.5 Hz), a power fluctuation happens from the DG to the grid and vice-versa, which should be seen in the *isource*. Like as, the power control changed the β angle, like as the voltage amplitude generated by the dc-ac converter in order to decreased the transients as suddenly as possible. However, these transients were slow damped because the amplitude of the DG network is narrow, the extra switched resistance used in parallel with *CDC* to increase the system damping was not worn, and the additional inductance *LS* was design to obtain its less value.

VI. CONCLUSION

This paper presents an alternative method to connect a DG network to the grid, thereby the amplitude and displacement of the voltage more synthesized by the DG is controlled with respect to the grid voltage and the control variable ahead and after the possibility is always the same. Further, a dc-dc step-up converter and a dc-ac VSI are worn in a DG network as an interring with the power grid. The simulation and experimental results explains that the connection of DG system sources can have bad effects, depending on the relation procedures. To increase the DG network operation, the dc connection voltage must be regulated, in this step by a dc-dcstep-up converter. PI controllers related with resonant controllers are used as a solution to similar distortion-free DG voltage, even though when the local load is nonlinear or when distortion happened in the grid voltage. While the PLL algorithm route as suddenly as possible, the frequency oscillations are less damped due to the termination of amplitude.

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