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RESEARCH ARTICLE OPEN ACCESS

Control Technique for Inverter Based Micro Grid

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Abstract:

A Microgrid (MG) is essentially a low-voltage network comprising local distributed energy sources and local loads. Typically, MGs are small-scale power supply systems with total installed capacities ranging from a few hundred kilowatts to a few megawatts. The primary objective of microgrids is to supply power to remote areas or villages utilizing locally available resources where no grid connection exists. Additionally, microgrids can be designed to provide uninterrupted, high-quality power to sensitive loads within a specific area.

Microgrids can operate in two modes: **grid-connected mode** and **islanded mode**, each requiring distinct control strategies. This project focuses primarily on the islanded mode operation.

In the existing method, the virtual output impedance technique is employed. However, this approach can amplify the magnitude of harmonic currents due to the derivative of the output current, leading to power supply interruptions and unsatisfactory power sharing among inverters.

To address these issues, a new control technique is proposed, integrating the **Second Order Generalized Integrator (SOGI)** with virtual output impedance. This method effectively enhances the impedance and limits circulating (harmonic) currents in the inverter.

The primary objective of this project is to minimize harmonic currents in the inverter and ensure proper power sharing among inverters during islanded mode operation using the proposed control technique.

The proposed method is implemented and validated through simulation in the MATLAB/SIMULINK environment.

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INTRODUCTION

Nowadays, the interconnection of Distributed Generations (DG) operating in parallel with electrical power networks is significantly transforming the conventional standards of energy distribution. Distributed generation has garnered global attention due to ecological concerns, rising energy costs, and the high construction expenses associated with traditional power plants. DG systems are relatively small and often utilize renewable energy sources such as fuel cells, gas turbines, micro-hydro systems, wind turbines, and photovoltaic panels. Unlike traditional rotating generators, many DG systems employ power electronic inverters. These inverters typically include fast current-limiting features for self-protection and are less likely to sustain damage from out-of-phase reclosing.

The integration of distributed generation can enhance power quality within the power system. However, this interconnection, particularly when involving reverse power flow, can introduce challenges such as voltage and frequency deviations, harmonics, reliability issues, and the phenomenon of islanding.

Islanding is one of the primary technical concerns related to distributed generation connected to utility networks. It occurs when a portion of the utility system, containing both load and distributed generation, remains energized while being disconnected from the main grid. Islanding detection is a mandatory feature for grid-connected inverters as outlined in international standards and guidelines.

Inverters typically operate with current control at unity power factor and utilize passive monitoring methods for islanding detection, which rely on locally measured parameters. During islanding, the voltage magnitude and frequency at the point of common coupling (PCC) tend to deviate from the grid's rated values due to power imbalances. Traditionally, distribution systems have been assumed to lack active power generation and rely entirely on transmission networks. However, with the integration of DG, this assumption is no longer valid. Modern practices mandate that DG systems disconnect from the grid during islanding scenarios.

The primary issues associated with islanding include:

1. **Protection challenges:** A portion of the system remains energized unpredictably.
2. **Insufficient grounding:** The islanded system may not be adequately grounded through the DG interconnection.
3. **Out-of-phase reclosing:** Immediate reclosing could result in phase mismatches.
4. **Voltage and frequency instability:** Loss of control over these parameters within the system.
5. **Transient stresses:** Excessive transient stresses may occur upon grid reconnection.
6. **Uncoordinated protection schemes:** Mismatched protection systems can lead to operational failures.

Islanding detection techniques aim to monitor DG output parameters and determine whether islanding has occurred based on these measurements. These techniques are broadly categorized into **remote methods** and **local methods**, with each approach offering specific advantages in addressing this critical concern.

PROPOSED CONCEPT

This section introduces the proposed concept, including the operation of a Microgrid (MG) in different modes, such as grid-connected and islanded modes, along with their respective control strategies, such as **p-q control techniques** and **constant current control techniques**. It also reviews various droop control methods and the proposed control approach, followed by a summary.

A Microgrid (MG) is considered a low-voltage network that integrates local **Distributed Energy Resources (DERs)** and local loads. The power output of the DERs is managed by either a central controller or individual controllers. Typically, MGs are small-scale power networks with total installed capacities ranging from a few hundred kilowatts to a few megawatts. The primary purpose of MGs is to supply power to remote areas or villages using locally available resources, especially in regions without grid connectivity. Additionally, MGs can be designed to provide uninterrupted, high-quality power to sensitive loads within specific areas.

What makes MGs unique is their dual-mode capability. They can operate in parallel with the main grid or seamlessly switch to islanded mode whenever their control system detects grid faults or disturbances in power quality. Once the fault is resolved or the disturbance disappears, the MG can resynchronize with the main network. The proliferation of MGs not only reduces the load on traditional power generation plants but also contributes to lowering the carbon footprint, benefiting the environment.

Inverter-based MGs play a crucial role in enhancing system reliability and integration with various DERs. With a robust control strategy, MGs enable **plug-and-play** access for Micro Sources (MS). Critical parameters that must be controlled in an MG include the active power dispatch of micro sources, power sharing among inverters, and maintaining system voltage and frequency stability.

A well-structured control strategy ensures that MGs function efficiently, adapt to dynamic conditions, and meet their operational objectives.

MG has to operating modes, grid connected mode and the other, islanded mode. When it is connected to grid, control strategy should be able to make inverters to pump the set value of active and reactive powers and here constant current control or PQ control can be implemented. During islanded mode, control strategy should control the voltage and frequency of the MG in addition to the active and reactive powers and here p-f and Q-V droop methods find their application. This droop method is more suitable for high and medium voltage grids because of their inductive nature.

For low voltage grids, especially MGs, where the sources are resistively coupled, control method opposite to conventional droop methods work more accurately but there are problems related to stability, and only, voltage control is achieved but no power dispatch and proper control over power sharing among the inverters is complex. In order to address these issue, indirect operations of conventional droop or virtual impedance loop methods may be used.

In this project a novel control strategy which uses virtual impedance loop method and Second Order General Integrator (SOGI) in conjunction with indirect operation of conventional droop method is proposed.

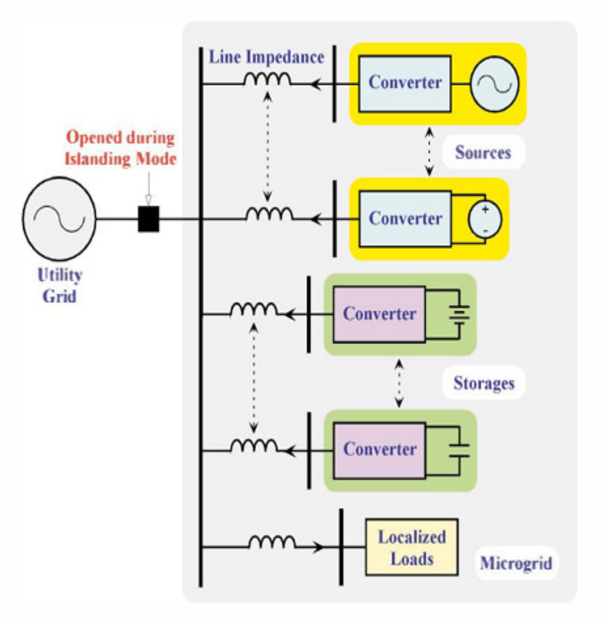


Fig Structure of Micro grid

PROPOSED CONTROL TECHNIQUE

In virtual output impedance loop method, the derivative of output current may amplify the magnitude of harmonic currents. So this cannot be implemented if the harmonic content in the output current is high. This problem can be addressed by using SOGI. SOGI is basically a frequency adjustable resonant circuit and it is implemented by connecting two integrators in a cascaded manner to form a closed loop. The block diagram of SOGI is shown in Fig 4.8.

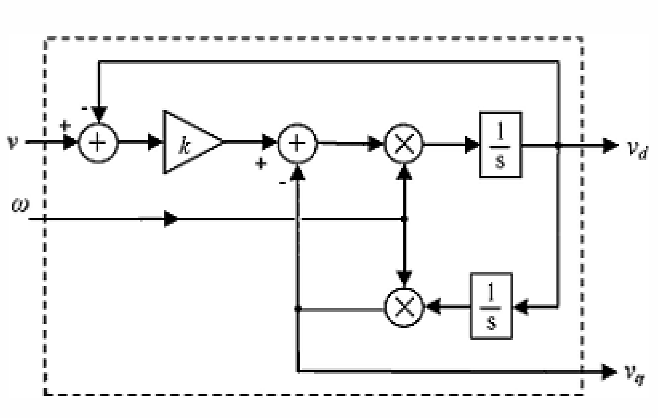


Fig 4.8 Block diagram of SOGI

SOGI has two inputs; one is actuating quantity, v, and the other, ω frequency and produces two output signals V_d and V_q which will have a phase shift of 90^0. Here in this control, inverter output current is given as actuating input and system frequency, the other input. So if the input to SOGI is I_0=I sin (ωt), then the two outputs are given by the equations,

$$V_d = I_o \sin(\omega t)$$

$$V_q = -I_o \cos(\omega t)$$

Now the virtual impedance loop can be implemented by using these two outputs.
The time derivative of output current is given by,

$$\frac{dI_o}{dt} = \frac{d(I\sin(\omega t))}{dt} = I\omega\cos(\omega t) = \omega V_q \qquad (4.16)$$

So the virtual impedance can be implemented simply by multiplying impedance values Z(s) with $-V_q$

$$Z_V(S) = -\omega L_V V_q \qquad (4.17)$$

Similarly virtual resistor can be implemented by multiplying virtual resistor value with the output of SOGI V_d.

$$Z_V(S) = R_V V_d \qquad (4.18)$$

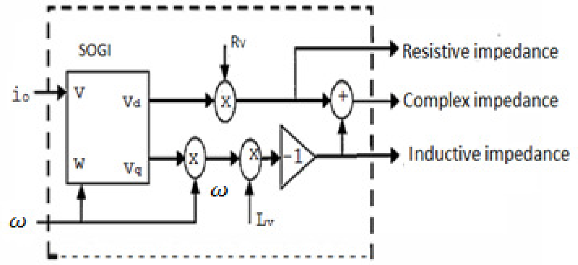


Fig Implementation of virtual impedance using SOGI

Hence it can be observed that the derivative of output current is avoided and thus power sharing and stability in the MG are not affected by the nonlinear loads to a good extent.

So if SOGI is used in conjunction with indirect operation of droop control method further more accuracy in power sharing and stability of the MG can be enhanced.

The voltage reference obtained by indirect operation of droop control is modified to achieve accurate power sharing and stability by introducing virtual impedance drop through SOGI, as shown in Fig 4.9 This modified voltage reference is used for pulse generation to trigger the inverters.

Indirect operation can be explained as follows. Here real power depends on the voltage profile and so reactive power is tuned in such a way that the resulting voltage profile satisfies the real power. In the low voltage grid the reactive power is a function of phase angle and this is adjusted with the active power frequency droop. The block diagram of the proposed control is shown in Fig 4.9.

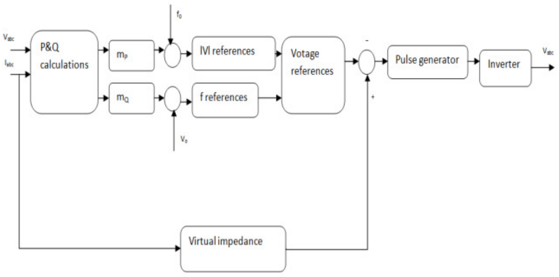


Fig 4.10 Block diagram of proposed control method using SOGI

4.6 SUMMARY

In this session, Introduction of proposed concept where MG different modes of operation like in grid connected mode and islanded operation have explained. And also review of various droop control techniques like conventional method and opposite conventional droop methods are explained. Proposed control technique have explained.

RESULTS & ANALYSIS

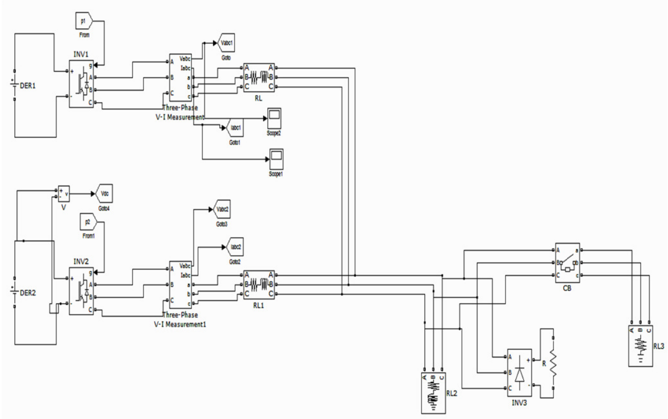


Fig Block diagram of tested micro grid structure in simulink

Fig 5.1 shows that it has two DER units interfaced by two inverters, inverter-1 and inverter-2 respectively and are connected through distribution system. In this system there are two critical loads, in which one is nonlinear load and another one is RL load and there it is a noncritical load, which is on/off with help of through a circuit breaker, which operates based on the situation of micro grid.

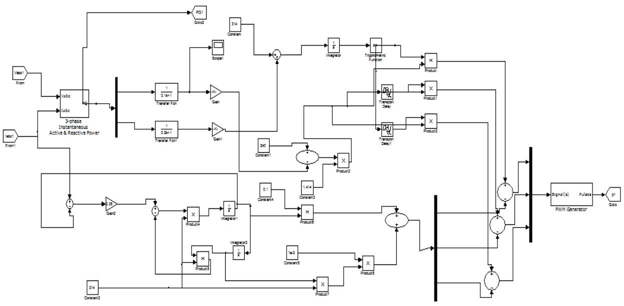


Fig Simulink circuit of the proposed control strategy

Fig 5.2 shows the simulink circuit of the proposed control strategy, in this circuit the voltages are given to three phase instantaneous active and reactive power block. This gives the real and reactive power, these real and reactive powers are converting to voltage and frequency through transformation circuit, the voltage is connected to PI controller circuit. This PI controller corrects the error signals and will give voltage signals. The voltage signals will be phase shift to 0^0, 120^0, 240^0 and these are connected summing circuit and another circuit, voltage is given to second order general integrator. This output is connected to virtual impedance. This will give the output result as three phase voltage signals. These voltage signals are used for pulse generation to trigger the inverter.

Output results:

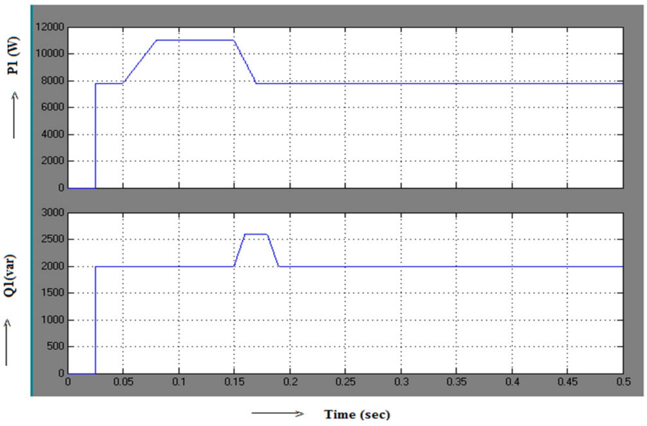


Fig Real & reactive power of the inverter-1

Fig 5.3 shows the real and reactive power of inverters. When the load is connected between the time 0.5sec to 0.15sec, real power demand is increasing and reactive power is decreasing. When the load is removed the real power is decreasing and reactive power is increasing in the inverter 1.

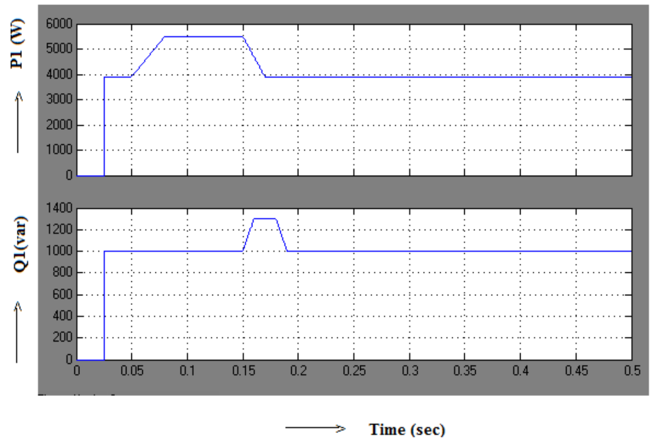


Fig Real & reactive powers of inverter-2

Fig 5.3 shows the real and reactive power of inverters. When the load is connected between the time 0.5sec to 0.15sec, real power demand is increasing and reactive power is decreasing. When the load is removed, the real power is decreasing and reactive power is increasing in the inverter 2. This means proper power sharing between inverter 1 and inverter 2 has done.

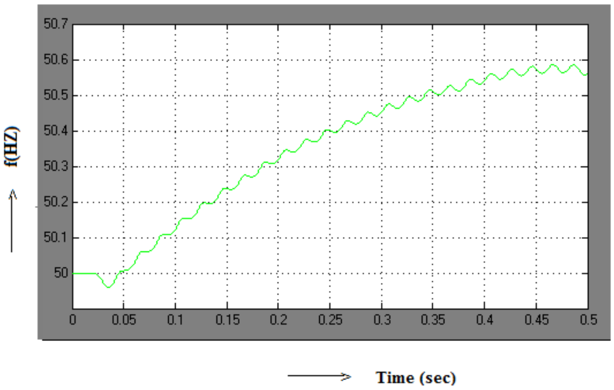


Fig Frequency of the inverters

Fig 5.5 shows the frequency of the inverters; here the inverter frequency is stable in 50.55 Hz.

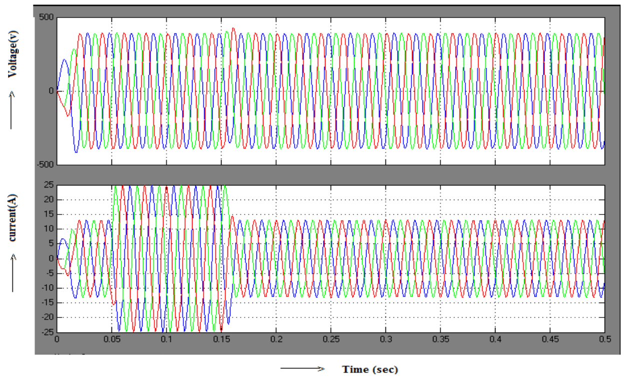


Fig Output voltage & current of inverter-1

Fig 5.6 shows the output result of voltage and current of inverter, where the circuit breaker is closed at the duration of 0.05 sec to 0.15 sec when the load is connected. The inverter current raises to 25 A in inverter 1 and voltage is constant.

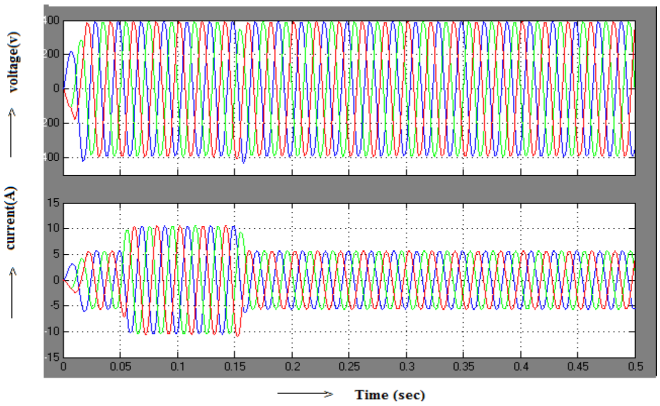


Fig Output voltage & current of inverter-2

Fig 5.7 shows the output result of voltage and current of inverter, where the circuit breaker is closed at the duration of 0.05 sec to 0.15 sec when the load is connected. The inverter current raises to 10 A in inverter 1 and voltage is constant.

By seeing these results when critical or non critical loads are connected, the inverters share the current properly so that there is no effect on the inverters operation by using the second order general integrator with virtual impedance method. The circulating currents in the inverter 1 and inverter 2 share accordingly. So that the inverters are not affected by the circulating currents and inverters work effectively.

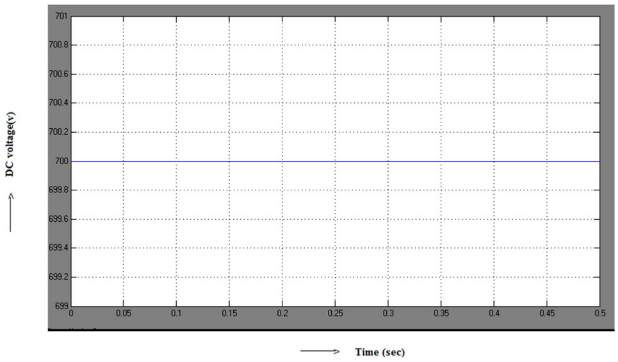
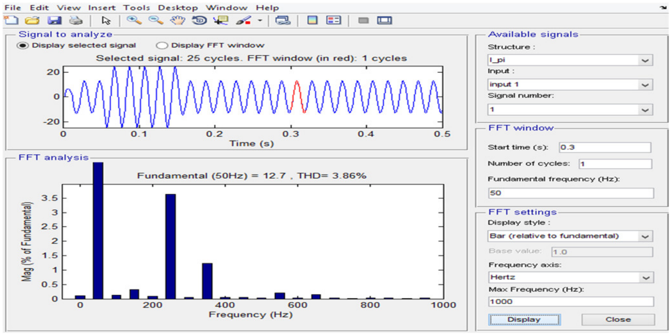


Fig DC bus voltage of the inverters

Fig 5.8 shows dc supply voltage of inverter 1 and inverter 2. The dc input voltage is given to inverters in simulink circuit.



● Display selected signal ○ Display FFT window

Structure : I_pi
Input : input 1
Signal number: 1
Start time (s): 0.3
Number of cycles: 1
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 1000

Fig THD analysis results of circulating current

Fig 5.9 shows the total harmonic distortion results of the circulating current. Using the controlling techniques we can limit the circulating currents within the acceptable value.

CONCLUSION

The virtual impedance loop with SOGI control method can effectively enhance the power sharing ability of inverters and this technique limits the circulating currents in the inverters effectively. This type of control method can be used for the MGs which are located at rural or remote place.

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