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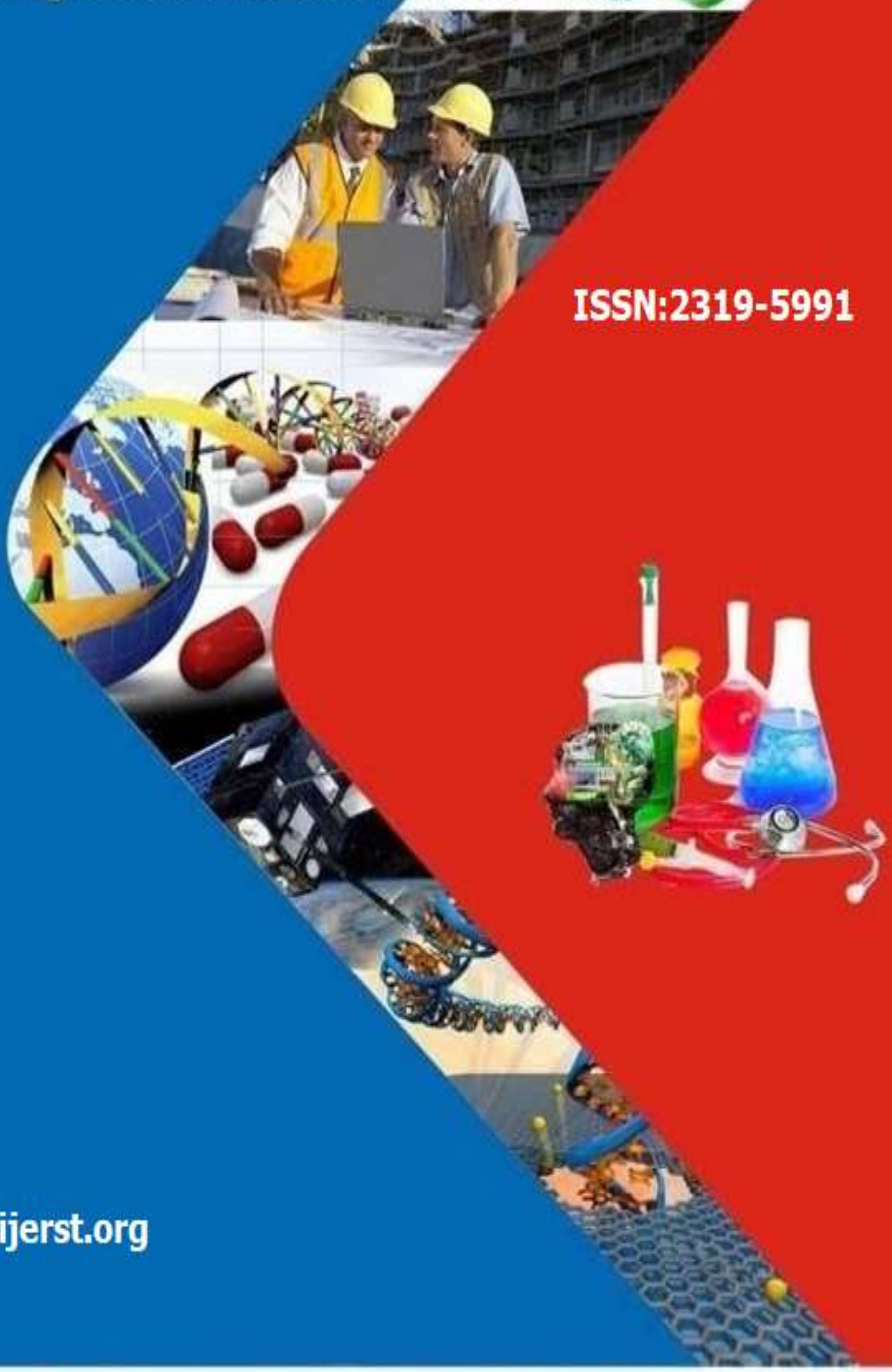

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ROLE BASED ACCESS CONTROL WITH BMS ADAPTABILITY FOR MICRO GRIDS ON INVERTERS

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ABSTRACT
This paper proposes a robust control strategy for power sharing among parallel inverters in a single-phase AC microgrid. It combines variable incline and discrete droop control with proportional-resonant loops to ensure both dynamic stability and harmonic suppression. A two-time-scale model is developed, separating slow frequency regulation from fast power-sharing and voltage control. The system remains input-to-state stable despite uncertainties, with tracking errors shown to be asymptotically bounded. Fuzzy logic enhances flexibility and adaptability, while optimal gain tuning ensures fast recovery from disturbances. Simulation results validate the method's effectiveness, demonstrating accurate, stable, and responsive power sharing under varying conditions within a hierarchical, real-time monitored microgrid environment.

Introduction

Microgrid systems (MGSs) are evolving to implement power-sharing control strategies that address unsupplied demand from individual distributed energy resources (DERs). A distribution system connected to a load can receive active power from DERs, which integrate various energy sources and storage systems. Rather than relying on costly new DER installations, multiple DER units within neighbouring subsystems can collaborate to utilize surplus electricity and meet overall power demands. Each subsystem typically comprises a DER, a power interface, and a regional electrical power system (EPS). In such configurations, operating multiple inverters concurrently is often essential to enhance system reliability—especially when load prioritization is necessary. The converted power signals must conform to established power quality standards, which regulate factors such as total harmonic distortion (THD), and voltage and frequency variations (adapter/load network voltage). In addition to adhering to national standards, several guidelines and standards for power quality—such as IEEE 1547 [1]—have been considered. One major challenge is maintaining power quality, as DER dynamics can impact system stability. While external communication systems can be leveraged for optimal controller performance [2]–[6], these solutions tend to be expensive and inflexible in terms of implementation and scalability. As a result, earlier studies [7] have explored communication-less approaches. These alternatives often assume highly inductive line impedances and focus on characteristics of traditional high-voltage distribution networks. In contrast, typical MGS distribution lines are shorter, more robust, and exhibit higher inductance than those found in conventional power distribution systems. Therefore, standard droop control strategies may not be directly applicable to modern microgrid architectures.

Literature Review

Distributed cooperative synchronization strategy for multi-bus microgrids

Microgrids can operate in both grid-connected mode and islanded mode. In order to smooth transfer from islanded mode to grid-connected mode, it is necessary to synchronize the point of common coupling (PCC) with main utility grid (UG) in voltage frequency, phase and amplitude. Conventional synchronization methods based on centralized communication are very costly and not suitable for multi-bus microgrids that have a large number of distributed generators (DGs). To address this concern, this study presents an active synchronization control strategy based on distributed cooperation technology for multi-bus microgrids. The proposed method can reconnect the microgrid in island to UG seamlessly with sparse communication channels. Synchronization correction signals are

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generated by a voltage controller, which are only transmitted to the leader DGs. Meanwhile, each DG exchanges information with its neighbours

An Enhanced Power Sharing Scheme for Voltage Unbalance and Harmonics Compensation in an Islanded AC Microgrid

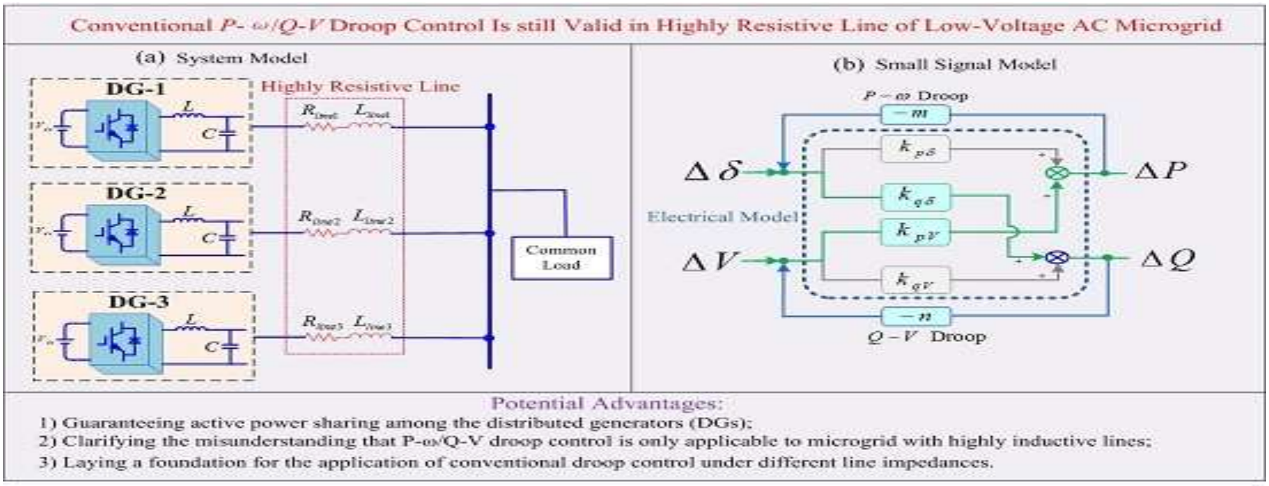
In this paper, an enhanced hierarchical control structure with multiple current loop damping schemes for voltage unbalance and harmonics compensation (UHC) in ac islanded microgrid is proposed to address unequal power sharing problems. The distributed generation (DG) is properly controlled to autonomously compensate voltage unbalance and harmonics while sharing the compensation effort for the real power, reactive power, and unbalance and harmonic powers. The proposed control system of the microgrid mainly consists of the positive sequence real and reactive power droop controllers, voltage and current controllers, the selective virtual impedance loop, the unbalance and harmonics compensators, the secondary control for voltage amplitude and frequency restoration, and the auxiliary control to achieve a high-voltage quality at the point of common coupling

Accurate Reactive Power Sharing in an Islanded Microgrid Using Adaptive Virtual Impedances

In this paper, a reactive power sharing strategy that employs communication and the virtual impedance concept is proposed to enhance the accuracy of reactive power sharing in an islanded microgrid. Communication is utilized to facilitate the tuning of adaptive virtual impedances in order to compensate for the mismatch in voltage drops across feeders. Once the virtual impedances are tuned for a given load operating point, the strategy will result in accurate reactive power sharing even if communication is disrupted. If the load changes while communication is unavailable, the sharing accuracy is reduced, but the proposed strategy will still outperform the conventional droop control method.

Experiment/survey/study

Initially, power-sharing in microgrids was managed using the conventional droop control method. This technique operates under the assumption that line impedance is predominantly inductive, implying a power factor close to 90 degrees between the source and the load. It was originally designed for grid-connected systems, where the regional electrical power system (EPS) connects to the primary distribution or transmission grid, typically through highly inductive distribution lines.However, with the increasing implementation of the EPS framework in microgrid systems—particularly as a foundation for smart grid development (as referenced in IEEE 1547 [1])—there is a growing need to extend and adapt the conventional droop control (CDC) methodology. Traditional droop control in independent microgrids is characterized by the droop relationship between active power (P) and angular frequency (ω), and between reactive power (Q) and voltage (V), as described in [7]. Nevertheless, many standalone microgrid systems exhibit more resistive line impedance rather than inductive, rendering the conventional droop approach less effective. This discrepancy has prompted the development of improved CDC methods tailored for resistive distribution networks. Several advancements in CDC have been proposed, utilizing both similar and alternative structural frameworks. To ensure effective power distribution, the control of inverters must be both accurate and adaptable.



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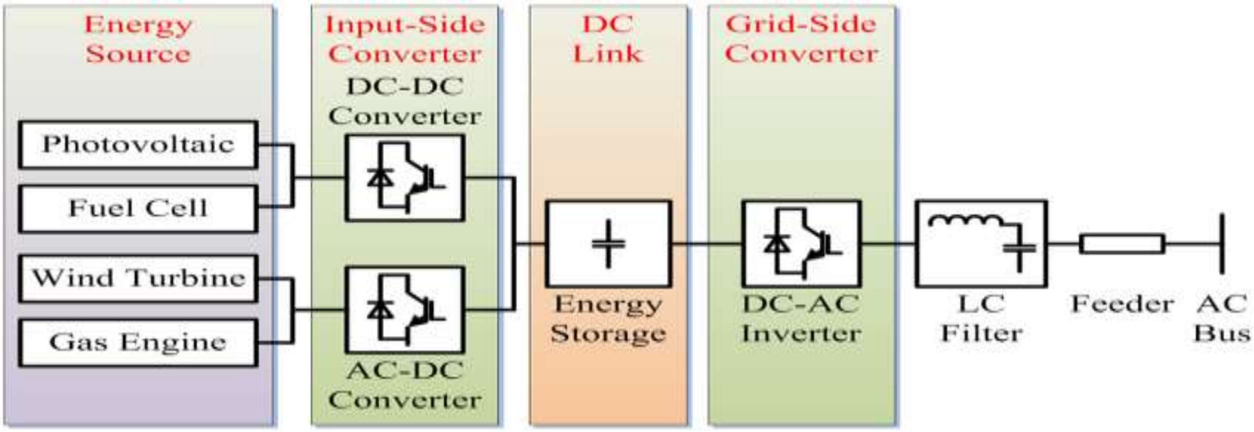

Figure 1. Microgrid systems are consisting of several sub-systems.

Figure 2 shows a non-compensated system composed of a reverse system (PWM and VSC), an LCL filter, and a distribution line connected to a PCC from the connection point (PoC). Line impedance can vary depending on the combination of R and L, the dominant inductive (L line) (long-distance line from PoC to PCC at high voltage), or the dominant resisitive (R line) (short-distance line from PoC to PCC at low/medium voltage).Our approach allows us to choose between using LCL and LC filters. In the case of LC filters, R2 and L2 can be removed.The output to be controlled is a sinusoidal waveform of the power interface output (VLC), which is directly connected to the PCC voltage. Then a sinusoidal waveform with a certain phase (u_{ref}) is the input to the PWM that is connected to the inverter and serves as a reference for the gate signal. The controller output provides this input value. In Grid mode, Uref and Vgrid are the system state inputs.

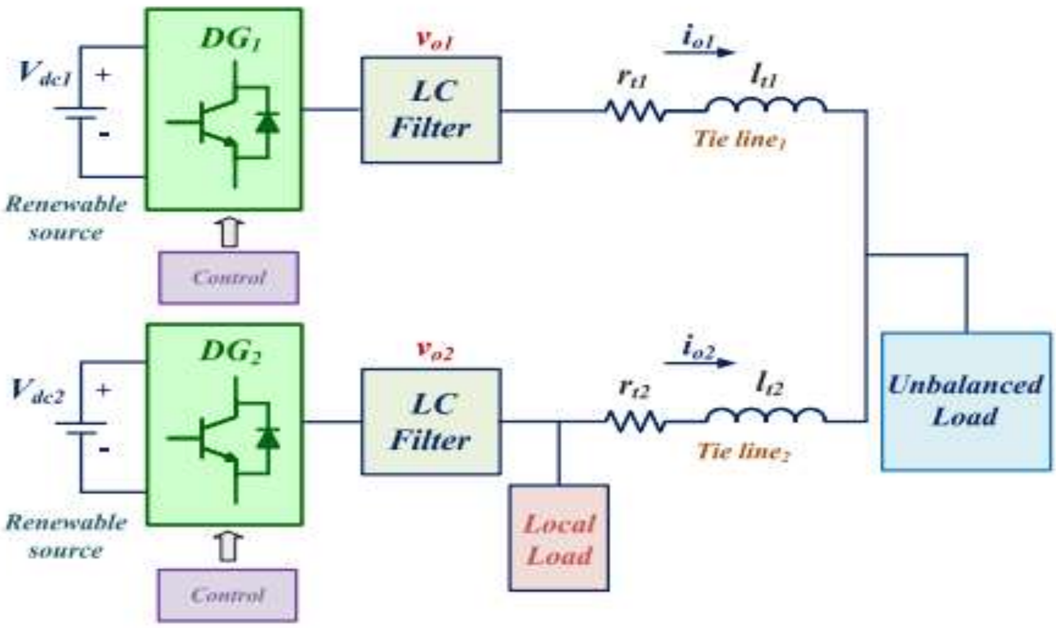

Fig. 2. Single line diagram of the system considered for off-line simulations.

CONTROL APPROACH FOR A SUB-SYSTEM

The subsystem shown in Figure 2 should have an independent control scenario, especially if it is isolated from the main network. The control of proportional inequality (PI) is primarily used for this purpose. The extended method used in micro grid DG single DG is taking into account the dynamics of load and DC source with the help of integral proportional derivatives (I-PD) and Fuzz-PI-based controllers. However, these methods have not yet considered the power-sharing mechanism.Therefore, the i_{th} parameter in the proposed method equation is related to the i_{th} controller.

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F_{w_i} and F_{v_i} represent the power values calculated based on the measured grid current in subsystem i (i_{grid_i}), the calculated RMS grid voltage and the impedance shown in equations (1) and (2)

$$F_{w-i} = \frac{X_{2-i}+X_{line_i}}{Z_{2_i}+Z_{line_i}} P_i - \frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}} Q_i \quad \text{----------------------(1)}$$

$$F_{v_i} = \frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}} P_i + \frac{X_{2_i}+X_{line_i}}{Z_{2_i}+Z_{line_i}} Q_i \quad \text{-----------------------(2)}$$

Calculation of voltage references ($U_{ref\ \_i}$) for the PWM, which subsequently determines the gate signal for inverter, The virtual or calculated angular frequency at the i-th terminal ($\omega*_{\ grid}$) of the grid connection to the load is called ω_{o_i}. Similarly, the voltage reference of the output terminal is represented as v_r and the i-th actual output voltage (v_{grid}) is calculated and expressed as $V *_{grid}$ or V_{o_i}, which is terminal output voltage. $s\omega_{in\_i} = \omega_r - m_i f_{\omega_i} + K_{ew}(\omega_r - \omega_{0_i})$, $sV_{in\_i} = V_r - n_i F_{v_i} + K_{ev}(V_r - V_{0_i})$, $m_i = \frac{\omega_r - e_w K_{ew}}{s}$,$n_i = \frac{v_r - e_v K_{ev}}{s}$

To obtain m_i and n_i values, you need to determine the necessary phase error (e_w) and the RMS voltage error (e_v) as part of the system requirements. We need to know the value of the line impedance to determine the maximum active and reactive power of the load network for the P_i and Q_i values. If two inverters have the same share ratio, m_1 (subsystem 1) is equal to m_2 (subsystem 2). If subsystem 1 requires to supply more power than subsystem 2 ($P_1 = 2P_2$ and $Q_1 = 2Q_2$), $m_2 = 2\ m_1$. It is similar to the n_i setting.

It highlights the importance of monitoring and collecting real-world data from PV systems, which is essential for validating and testing the proposed control mechanisms and power-sharing strategies. These results confirm the effectiveness of the proposed method in achieving accurate power-sharing and ensuring power quality and system stability in microgrid applications using LC filters. The performance of the system with LCL filters is similar.

Elements	Notations	Details
DER 1	ESO 1	PV array (4*10 Series and Parallel Modules), Each module has Pmax 125W, Vmp 17.8 V, Imp 7.023 A, Voc 21.36 V, Isc 7.444A,maximum system voltage 1.000 v.
	EST 1	Lithium Ion, Nominal Voltage 48 V, Rated capacity 140Ah, Initial stage of charge 90%
DER 2	ESO 2	PV array (4*15 Series and Parallel Modules), Each module has Pmax 125W, Vmp 17.8 V,Imp 7.023 A,Voc 21.36 V,Isc 7.444A,maximum system voltage 1.000 v.
	EST 2	Lithium Ion, Nominal Voltage 48 V, Rated capacity 150Ah, Initial stage of charge 85%
Interface 1	INV 1	IGBT 2 arms
	PWM 1	Single-Phase full -bridge (4 pulses)
	Filter 1	R1=0.001Ω, L1=20mH, Cf=22µF, Rf=48.2288Ω, R2=0.0001, L2=5mH.
Interface 2	INV 2	IGBT 2 arms
	PWM 2	Single-Phase full -bridge (4 pulses)
	Filter 2	R1=0.001Ω, L1=20mH, Cf=22µF, Rf=48.2288Ω, R2=0.0001, L2=5mH.
CB	CB Swiching Times	Switching times:CB 1(2s ON, 10s OFF), CB1.1 (4s ON,10s OFF),CB 1.2(8s ON, 10s OFF), CB 2.1(6s ON, 10s OFF),CB 2.2(8s ON, 10s OFF).
Impedance	Line 1	Rg1≈0Ω, Lg1=0.01mH

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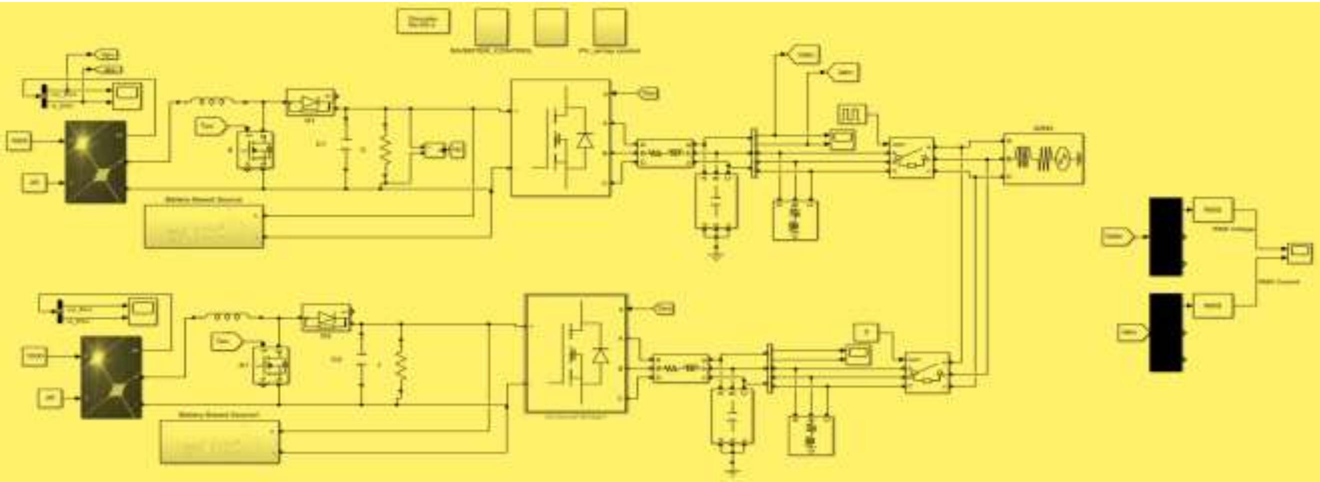
Line Load	Line 2	Rg2≈0Ω, Lg2=0.01mH
	Load 1.1	2.5 kW,200 VAR(QL),50 VAR(QC)
	Load 1.2	750 W,75 VAR(QL), 25 VAR (QC)
	Load 1.3	1.3kW,50 VAR (QL), 25 VAR(QC)
	Load 2.1	2.5 kW,150 VAR(QL), 50 VAR(QC)
	Load 2.2	750 W,75 VAR(QL), 25 VAR (QC)
	Load 2.3	600W,50 VAR (QL), 25 VAR(QC)

RESULTS



Simulation Model of Proposed System

OUTPUT WAVEFORMS :

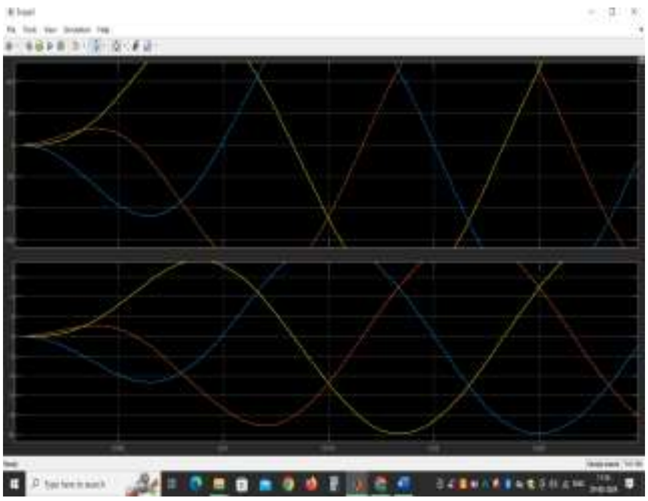


Fig 4 : Scope3 without fuzzy Vabc and Iabc

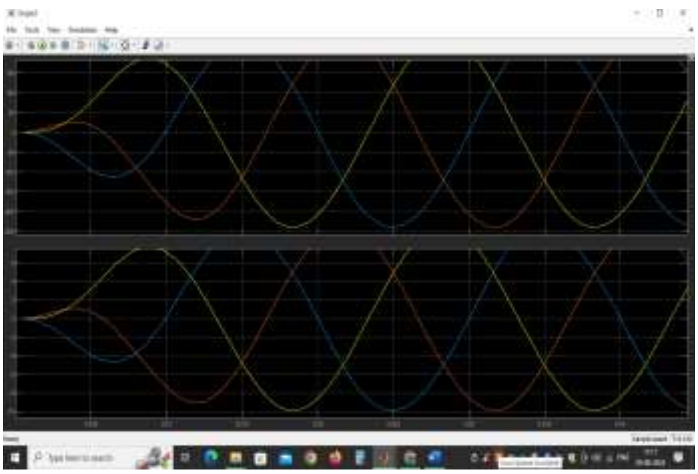


Fig 5: Scope3 with fuzzy Vabc & Iabc

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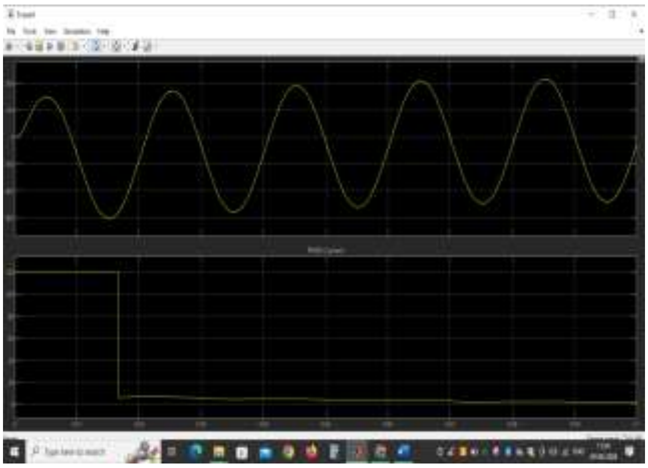

Fig 6: Scope4 without fuzzy Vrms & Irms of subsystem1

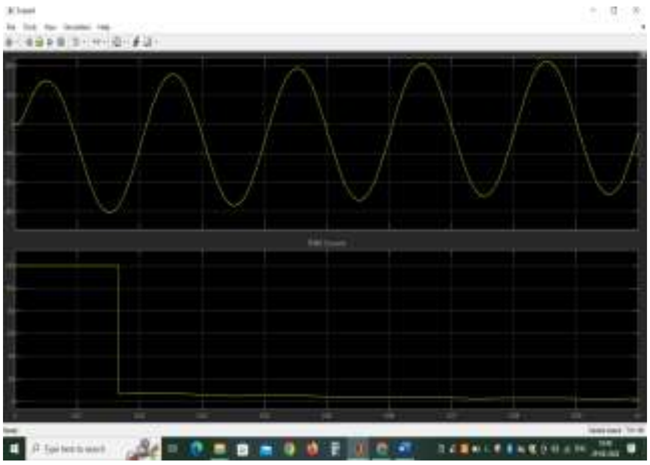

Fig 7: Scope4 with fuzzy Vrms & Irms of subsystem1

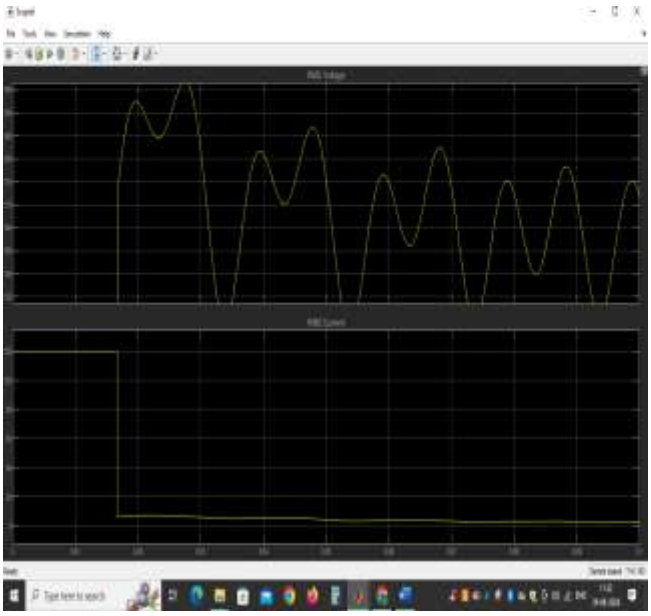

Fig 8:Scope5 without fuzzy Vrms & Irms of subsystem2

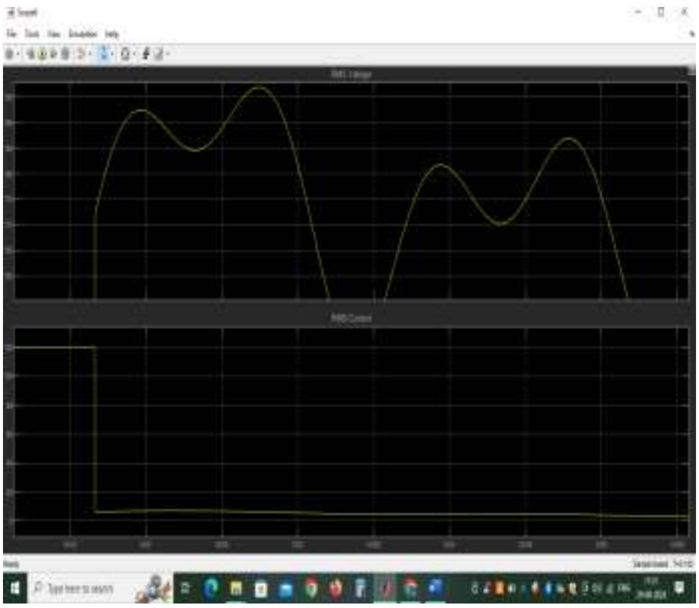

Fig 9:Scope5 with fuzzy Vrms & Irms of subsystem2

CONCLUSION

This paper introduces a novel control method designed for accurate power-sharing and high-power quality in microgrid systems with parallel-operated inverters. The comparative simulation results, which include conventional droop control (CDC), CDC with robustness, and the proposed method, highlight the superior performance of the proposed method across various aspects. These aspects include power-sharing and non-sharing modes, as well as transient behaviours during connection and disconnection events.

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