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# Compatible Control of Power Sharing for Microgrid Systems Based on Inverters

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## Abstract

This abstract presents a comprehensive strategy for controlling power sharing in parallel inverters within a single-phase AC microgrid. The strategy integrates continuous variable incline and discrete droop control with different gains to ensure stability. Additionally, proportional-resonant loops are incorporated to suppress harmonic components without impacting the dynamics of droop control. The microgrid system is modeled in a two-time-scale form, with droop control tracking real frequency variations in the slower time scale and power sharing dynamics, voltage regulation, and harmonic compensation operating in the faster one. Despite the presence of mismatches and uncertainties, the tracking error is shown to be asymptotically bounded, and the system remains input-to-state stable around the desired operation point. The relationship between control gain and power sharing performance index is analyzed throughout the experimental work, and a set of optimal gains is determined to ensure the fastest recovery of the power sharing error. It discusses a novel approach to flexible power-sharing control for inverter-based microgrid systems with fuzzification. Key features of the control strategy include advanced forecasting techniques for predicting generation and load patterns, real-time monitoring of system parameters, and the incorporation of a hierarchical control structure. To demonstrate the effectiveness of the proposed control approach, simulation studies were conducted on a representative inverter-based microgrid model with fuzzy logics demonstrating excellent dynamic performance in providing stable, fast, and accurate power sharing control.

## Keywords
Microgrid, smart grid, power-sharing control, PV systems, power electronics.

## 1. Introduction

Microgrid systems (MGSs) are currently developing power-sharing control solutions to handle the unsupplied demand from a single distributed energy resource (DER). A distribution system that is connected to a load can receive active energy from DER, a power source that combines energy sources and storage. Instead of installing costly new DERs, numerous DER units situated in nearby subsystems must work together to use excess electricity to meet the requirements. DER, the power interface, and the regional power system (regional EPS) make up a subsystem. In this situation, using several inverters at once is frequently required to increase system reliability, particularly when loading priority is involved. Converted signals must meet the standard's power quality standards, which include maximum total harmonic distortion (THD) and voltage and frequency variation (adapter/load network voltage). In addition to national norms, a number of suggestions or standards for energy quality criteria have been taken into consideration, including IEEE 1547 (revision of IEEE Standard 2003), 2018. The dynamics of DER may affect electricity quality hence the primary challenge is how to govern systems to satisfy these criteria. For optimal performance, the controller can use external communication (Y. Sun, C. Zhong, X. Hou, J. Yang, H. Han, and J. M. Guerrero, Mar. 2017.) (T. Caldognetto and P. Tenti, Dec. 2014.) But in terms of investment and growth, its technology is costly and rigid. The usage of external communication was not included in other earlier papers (M. C. Chandorkar, D. M. Divan, and R. Adapa, Jan. 1993.) through (X. Hou, Y. Sun, W. Yuan, H. Han, C. Zhong, and J. M. Guerrero,Nov. 2016) This approach uses highly inductive line impedances and concentrates on the features of traditional distribution lines, or high-voltage networks. Compared to traditional electrical distribution networks, the common MGS distribution lines become more inductive and robust. Compared to conventional methods, the voltage network is lower and the distribution line's distance is shorter. Therefore, a typical MG is not immediately subjected to the first droop control approach.

### 1.1 Objectives

First Droop Control Technique for Grid-Connected Systems: The first droop control technique was created for grid-connected systems with a trailing power factor of about 90 degrees between the power source and the load due to a mostly inductive line impedance. A high inductive distribution line, which is typical in grid-connected configurations, was anticipated to be present in this design.

Microgrid Systems (MGS) Extension: The line impedance is more resistive than inductive due to the rise of microgrid systems (MGS), which frequently use distributed energy resources (DERs) and storage with shorter distribution lines. Due to their power restrictions, inverters—which are frequently used in MGS for AC loads—may need to operate in parallel to meet demand.

classic Droop Control in MGS: In stand-alone MGS, the classic droop control approach entails a relationship between reactive power (Q) and voltage (V) droop, as well as active power (P) and angular frequency (ω). This method is insufficient for systems with resistive line characteristics, though, because it implies inductive line impedance.

Droop Control Adaptation for Resistive Line Impedance: The development and adaptation of the Conventional Droop Control (CDC) concept for use in microgrids with resistive distribution networks is discussed in the article. It is stated that several CDC innovations with varied structures have been investigated, and that accurate power-sharing across inverters requires precise and adaptable control systems.

Improving Flexibility and Accuracy of Power-Sharing: The goal of the study is to expand the previous CDC approach in order to increase the flexibility of its structure and get more accuracy in power-sharing and the intended power quality. More adaptable control techniques are needed for the smooth integration of subsystems in microgrids in order to maximize power-sharing.

## 2. 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 generated by a voltage controller, which are only transmitted to the leader DGs. Meanwhile, each DG exchanges information with its neighbours. Finally, the voltage of PCC will synchronize with the main grid and all DGs will achieve the consensus behaviours. Compared with traditional synchronization methods, the proposed method does not need complex communication networks and improves flexibility and redundancy. Even if the distributed communication breaks down, the primary droop control can still operate robustly. Small signal model of entire system is developed to adjust the parameters of distributed active synchronization controller. Simulation results are presented to verify the effectiveness of the proposed method.

### 2.2 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. By using the proposed unbalance and harmonics compensation, the auxiliary control, and the virtual positive/negative-sequence impedance loops at fundamental frequency, and the virtual variable harmonic impedance loop at harmonic frequencies, an accurate power sharing is achieved. Moreover, the low bandwidth communication (LBC) technique is adopted to send the compensation command of the secondary control and auxiliary control from the microgrid control centre to the local controllers of DG unit. Finally, the hardware-in-the-loop results using dSPACE 1006 platform are presented to demonstrate the effectiveness of the proposed approach.

**2.3 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. In addition, the reactive power sharing accuracy based on the proposed strategy is immune to the time delay in the communication channel. The sensitivity of the tuned controller parameters to changes in the system operating point is also explored. The control strategy is straightforward to implement and does not require knowledge of the feeder impedances. The feasibility and effectiveness of the proposed strategy are validated using simulation and experimental results from a 2-kVA microgrid.

## 3. Methods

**3.1 The Evolution of Power-Sharing Control Mechanisms in CDC Systems**

Power sharing was initially accomplished using the first droop control technique. According to this method, the power factor between the source and the load is around 90 since the line impedance is assumed to be virtually inductive. It is intended for a network-connected system with a high inductive distribution line that connects to the major distribution/transmission grid via the EPS area. At the moment, MGS tends to use the EPS framework from (IEEE 1547(revision of IEEE Standard 2003), 2018.) more to prepare the way for a smart grid system. Thus, the idea of droop control ought to be expanded. According to (M. C. Chandorkar, D. M. Divan, and R. Adapa, Jan. 1993.) the droop relationship between active power (P) and angular frequency (w) and reactive power (Q) and voltage (V) is the classic droop control method of a typical independent MGS.

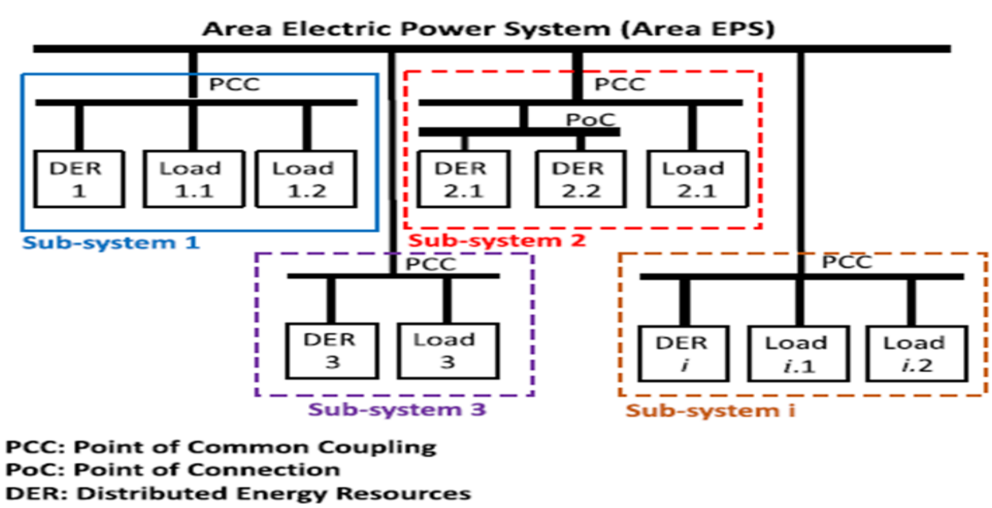


Figure 1. Microgrid systems are consisting of several sub-systems.

However, the first droop control method is not applicable to independent conventional MGSs since they appear to have a resistance line impedance. The development of the CDC concept can therefore make it feasible in a resistive distribution network. The same or different structures can be used to illustrate a number of CDC advances. To attain the proper flexibility in power distribution, inverter control needs to be accurate and adaptable. More control mechanism flexibility is necessary for the smooth integration of subsystems in power-sharing. In order to offer structure flexibility, high-quality power sharing accuracy, and energy quality, the article expanded on earlier approaches.

**3.2 Model of a Plant in a Subsystem**

An EPS that incorporates multiple subsystems, each with its own DER and controller, is depicted in Fig. 1. Subsystems can be used in microgrids. IEEE 1547 is the source of the word "EPS" (revision of IEEE Standard 2003, 2018.) Connecting DER to the subsystem's local load or loads during an independent mode, as well as to other subsystems connected to the grid (connected from the utility to the main network) or to the subsystem/microgrid, is known as the point of common coupling, or PCC. In order to facilitate control design and minimize implementation faults, controllers should have comparable mechanisms for similar types of microgrids or subsystems (such as AC or DCC networks), given that the controller is dispersed throughout each DER or subsystem.

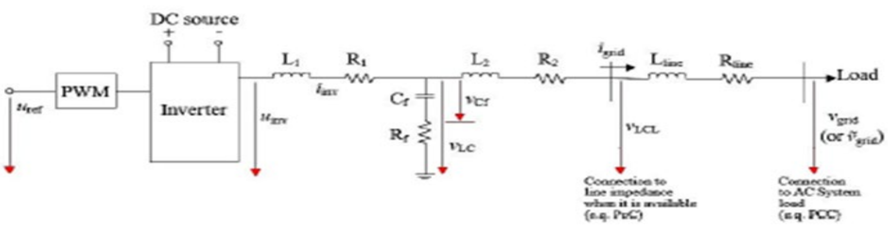


Figure 2. Single-phase representation of inverter, filter and line connection in a sub-system.

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 resistive (R line) (short-distance line from PoC to PCC at low/medium voltage).

Our method gives us the option to use LC or LCL filters. R2 and L2 can be eliminated in the case of LC filters. The state-space models of the inverter, LCL filter, and line connection to the network are depicted in equations (1) through (2) as separate subsystems or microgrids, and equations (3) through (4) as on-grids. The power interface output (VLC), which is directly coupled to the PCC voltage, has a sinusoidal waveform that needs to be adjusted. The PWM that is connected to the inverter then receives a sinusoidal waveform with a specific phase ($u_{ref}$) as input, which acts as a reference for the gate signal. This input value is provided via the controller output. The system state inputs in Grid mode are $V_{grid}$ and $U_{ref}$.

$$s\begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} = \begin{bmatrix} \frac{-(R1+Rf)}{L1} & \frac{-1}{L1} & \frac{Rf}{L1} \\ \frac{1}{Cf} & 0 & \frac{-1}{Cf} \\ \frac{Rf}{(L2+Lline)} & \frac{1}{L2+Lline} & \frac{-(Rf+R2+Rline)}{(L2+Lline)} \end{bmatrix} * \begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} + \begin{bmatrix} \frac{1}{L1} \\ 0 \\ 0 \end{bmatrix} (u_{ref}) \text{----------}(1)$$

$$\begin{bmatrix} v_{lc} \\ i_{grid} \end{bmatrix} = \begin{bmatrix} R_f & 1 & -R_f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} [u_{ref}] \text{---------}(2)$$

$$s\begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} = \begin{bmatrix} \frac{-(R1+Rf)}{L1} & \frac{-1}{L1} & \frac{Rf}{L1} \\ \frac{1}{Cf} & 0 & \frac{-1}{Cf} \\ \frac{Rf}{(L2+Lline)} & \frac{1}{L2+Lline} & \frac{-(Rf+R2+Rline)}{(L2+Lline)} \end{bmatrix} * \begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} + \begin{bmatrix} \frac{1}{L1} & 0 \\ 0 & 0 \\ 0 & \frac{-1}{(L2+Lline)} \end{bmatrix} \begin{bmatrix} u_{ref} \\ v_{grid} \end{bmatrix} \text{----------}(3)$$

$$\begin{bmatrix} v_{lc} \\ i_{grid} \end{bmatrix} = \begin{bmatrix} R_f & 1 & -R_f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{inv} \\ v_{cf} \\ i_{grid} \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} u_{ref} \\ v_{grid} \end{bmatrix} \text{---------(4)}$$

**3.3 Sub-System Control Approach**

If the subsystem in Figure 2 is isolated from the main network, it should have an autonomous control scenario. The main tool for this is the regulation of proportional inequality (PI). In micro grid DG single DG, the enhanced technique uses Fuzz-PI-based controllers and integral proportional derivatives (I-PD) to account for the dynamics of the load and DC supply. Nevertheless, the power-sharing mechanism has not yet been taken into account by these approaches.

**3.4 The suggested method for power-sharing control among subsystems**

The suggested study offers a flexible approach for allocating power proportionately among subsystems while considering the utilization of actual PV data and battery simulations. Every subsystem, whether shared or independent, has a formal and adaptable control mechanism that can be used to link or disconnect from other subsystems. Furthermore, it has the ability to function both independently and in network mode.

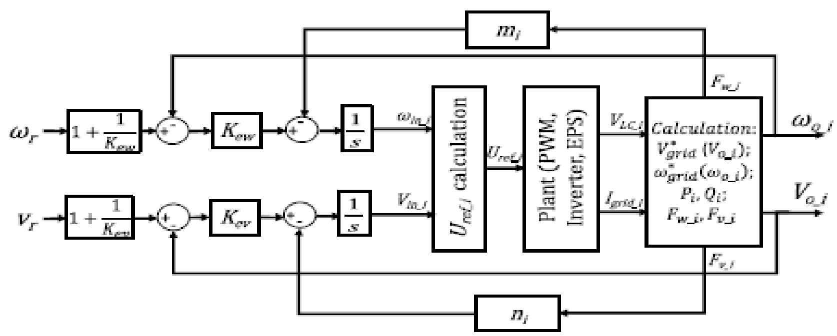


Figure 3. Block Diagram with subsystems.

The suggested control method block diagram is displayed in Figure 3, with each controller situated in the DER of each subsystem. As a result, the $i_{th}$ controller and the $i_{th}$ parameter in the suggested method equation are connected. The power values denoted by $F_{w\_i}$ and $F_{v\_i}$ are computed using the measured grid current in subsystem I ($i_{grid\_i}$), the computed RMS grid voltage, and the impedance shown in equations 5 and 6.

$$F_{w-i} = \frac{X_{2-i}+X_{line_i}}{Z_{2_i}+Z_{line_i}} P_i - \frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}} Q_i \text{----------(5)}$$

$$F_{v_i} = \frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}} P_i + \frac{X_{2_i}+X_{line_i}}{Z_{2_i}+Z_{line_i}} Q_i \text{------------(6)}$$

Equations (7) and (8) are used to calculate the voltage references (Uref _i) for the PWM, which in turn determines the gate signal for the inverter. $t_{\omega o\_i}$ is the virtual or computed angular frequency at the grid connection to the load's i-th terminal (ω∗ grid).

$$s\omega_{in\_i} = \omega_r - m_i f_{\omega_i} + K_{ew}(\omega_r - \omega_{0_i}) \text{ --------(7)}$$

$$sV_{in\_i} = V_r - n_i F_{v_i} + K_{ev}(V_r - V_{0_i}) \text{ ------------(8)}$$

$$m_i = \frac{\omega_r - e_w K_{ew}}{s} \text{ ------------(9)}$$

$$n_i = \frac{v_r - e_v K_{ev}}{s} \text{ ---------------(10)}$$

Similarly, the output terminal's voltage reference is denoted by $v_r$, and the terminal output voltage, or $V_{grid}$, is computed and written as the i-th actual output voltage ($v_{grid}$). As part of the system requirements, you must ascertain the required phase error (ew) and the RMS voltage error (ev) in order to acquire mi and ni values. To calculate the load network's maximum active and reactive power for the Pi and Qi values, we must know the line impedance value. m1 (subsystem 1) equals m2 (subsystem 2) if the share ratios of the two inverters are the same. m2 = 2 m1 if subsystem 1 needs to provide more power than subsystem 2 (P1 = 2P2 and Q1 = 2Q2). It is comparable to the $n_i$ environment.

$$s\begin{bmatrix}\omega_{in_i}\\ v_{in_i}\end{bmatrix}=\begin{bmatrix}-m_i\left(\frac{\left(L_{2_i}+X_{line_i}\right)}{\left(Z_{2_i}+Z_{line_i}\right)}\right) & m_i\left(\frac{\left(R_{2_i}+R_{line_i}\right)}{\left(Z_{2_i}+Z_{line_i}\right)}\right)\\ -n_i\left(\frac{\left(R_{2_i}+R_{line_i}\right)}{\left(Z_{2_i}+Z_{line_i}\right)}\right) & -n_i\left(\frac{\left(L_{2_i}+X_{line_i}\right)}{Z_{2_i-}+Z_{line_i}}\right)\end{bmatrix}*\begin{bmatrix}P_i\\ Q_i\end{bmatrix}+\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}w_r\\ v_r\end{bmatrix}+\begin{bmatrix}d_{1i}\\ d_{2i}\end{bmatrix}\text{----------(11)}$$

$$\begin{bmatrix}\omega_{o\_i}\\ v_{o\_i}\end{bmatrix}=\begin{bmatrix}\frac{-m_i}{K_{ew}}\left(\frac{L_{2_i}+X_{line_i}}{Z_{2_i}+Z_{line_i}}\right) & \frac{-m_i}{K_{ew}}\left(\frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}}\right)\\ \frac{-n_i}{K_{ew}}\left(\frac{R_{2_i}+R_{line_i}}{Z_{2_i}+Z_{line_i}}\right) & \frac{-n_i}{K_{ew}}\left(\frac{L_{2_i}+X_{line_i}}{Z_{2_i}+Z_{line_i}}\right)\end{bmatrix}*\begin{bmatrix}P_i\\ Q_i\end{bmatrix}+\begin{bmatrix}\frac{1+K_{ew}}{K_{ew}} & 0\\ 0 & \frac{1+K_{ew}}{K_{ew}}\end{bmatrix}\begin{bmatrix}w_r\\ v_r\end{bmatrix}\text{----------(12)}$$

## 4. Data Collection

It emphasizes how crucial it is to keep an eye on and get actual data from PV systems in order to verify and evaluate the suggested control mechanisms and power-sharing plans. These outcomes demonstrate how well the suggested approach works in microgrid applications utilizing LC filters to provide precise power-sharing, guarantee power quality, and maintain system stability. The performance of the system with LCL filters is similar.

Table 1. List of parameters.

| 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 Load | Line 1 | Rg1≈0Ω, Lg1=0.01mH |
| | 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) |

## 5. Results and Discussion

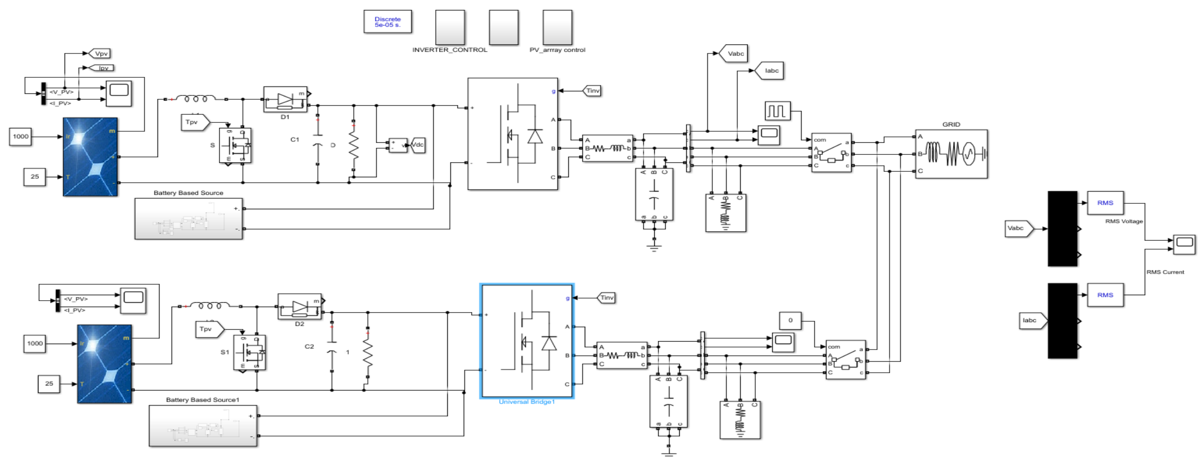


Figure 4. Simulation Model of Proposed System

### 5.1 Numerical Results

1. At 0 - 2s, Sub-system 1 and Sub-system 2 had their local load, 2.5 kW/150 VAR (Load 1.1. in TABLE 1) and 2 kW/100 VAR (Load 2.1) respectively without power-sharing,
2. At 2 - 4s, both sub-systems were connected with 2:1 power-sharing proportion, where Sub-system 1 supplied double power than Sub-system 2,
3. At 4 - 6s, more load (Load 1.2) was connected to be 5.25 kW/300 VAR in total with the same sharing proportion,
4. At 6 - 8s, Load 2.2. was connected and the total load increased to 6 kW/350 VAR,
5. At 8 - 10s, Load 1.3 and Load 2.3 were connected which increase the total sharing load to 7.8 kW/400 VAR in total,
6. At 10 - 12s, the power-sharing switch was disconnected where each Sub-system 1 and Sub-system 2 were connected to load with the same scenario at 0 _ 2s.

Based on recommendations in IEEE Standards Coordinating Committee 21, (IEEE Standard 1547 (revision of IEEE Standard 2003), 2018.) when DER is connecting to EPS, then the following recommendation must be fulfilled for voltage rating 0 - 500 kVA: frequency difference <0.3 Hz, RMS voltage difference <10% from the nominal rate, and Phase angle difference $<20^0$. Short-term flicker (<600 s) emission should be less than 0.35 and long-term (<2 h) emission <0.25. The individual odd harmonic order (h) <11 is less than 4.0 %. Furthermore, transient overvoltage limits (maximum overshoot) at 0-1.6 ms is <2 pu, at 1.6 - 3 ms is <1.7 pu, at 3-16 ms is <1.4 pu, and at 16-166 ms is <1.3 pu. The power quality analysis in the presented case is based on some requirements in these recommendations.

### 5.2 Graphical Results

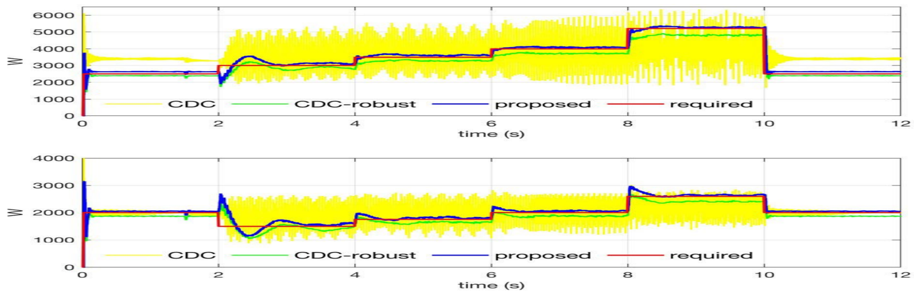


Figure.5 Comparison of active power ($P$) at the output terminal of sub-system 1 (top) and sub-system 2 (bottom).

### 5.3 Proposed Improvements

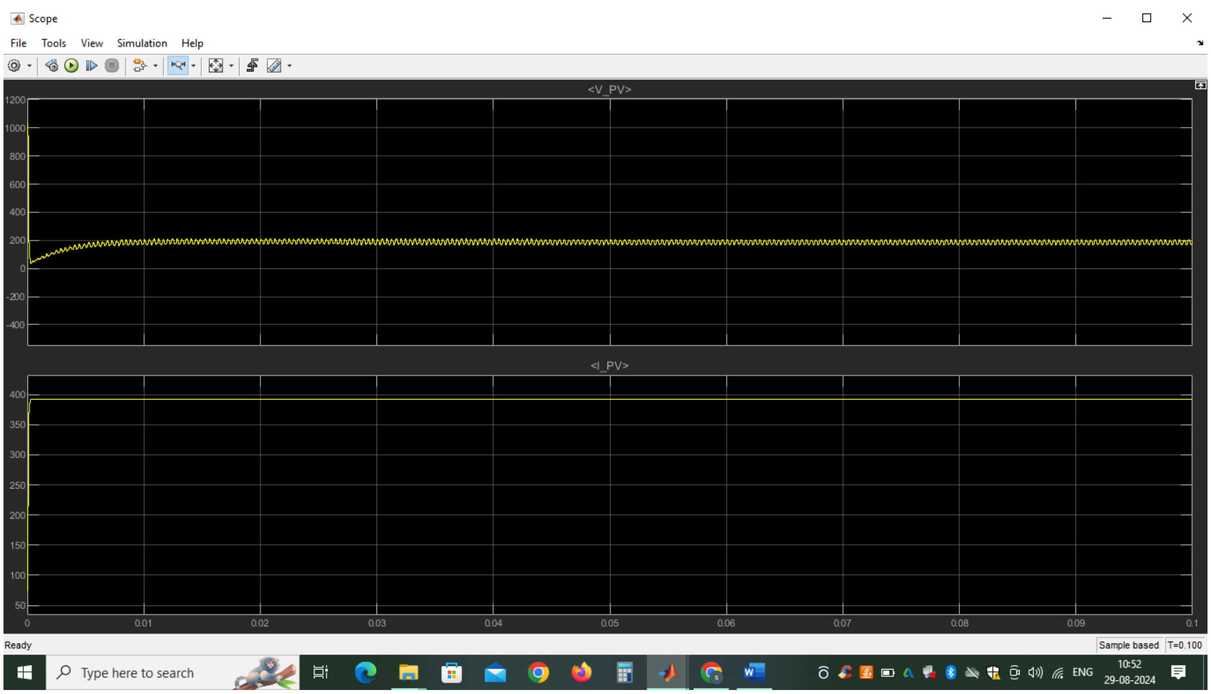


Figure.6 Comparison of active power ($P$) at the output terminal of sub-system 1,Without Fuzzification.

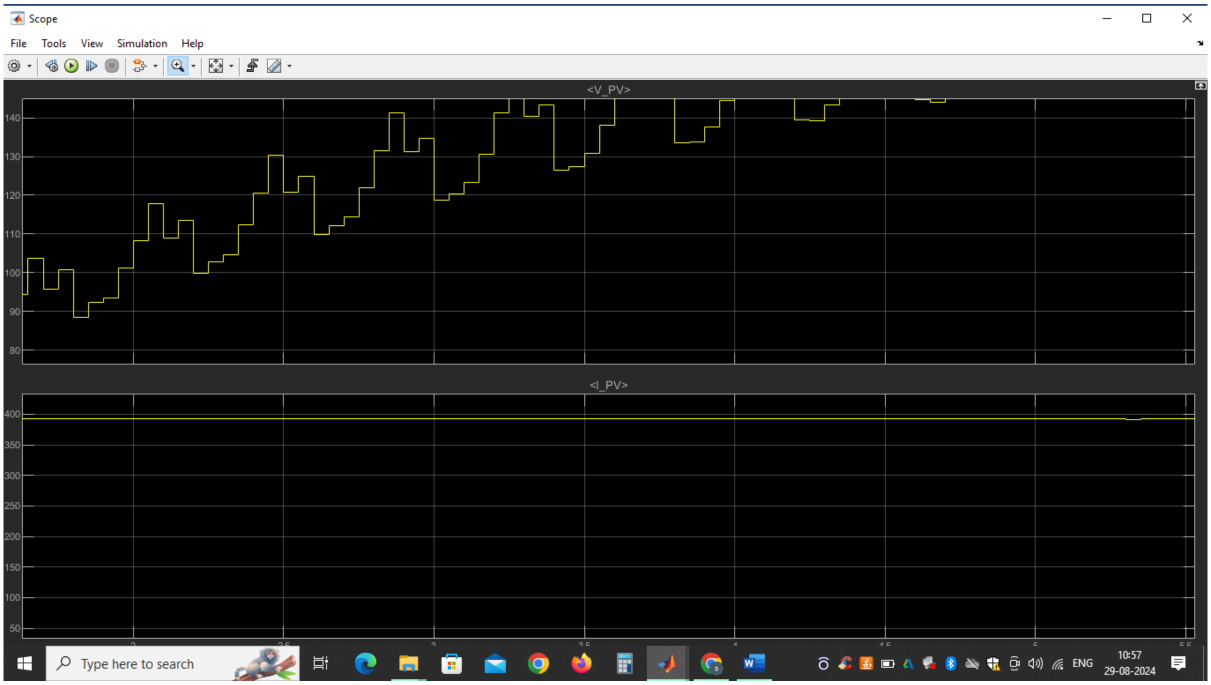


Figure.7 Comparison of active power (*P*) at the output terminal of  sub-system 2 , Without Fuzzification.

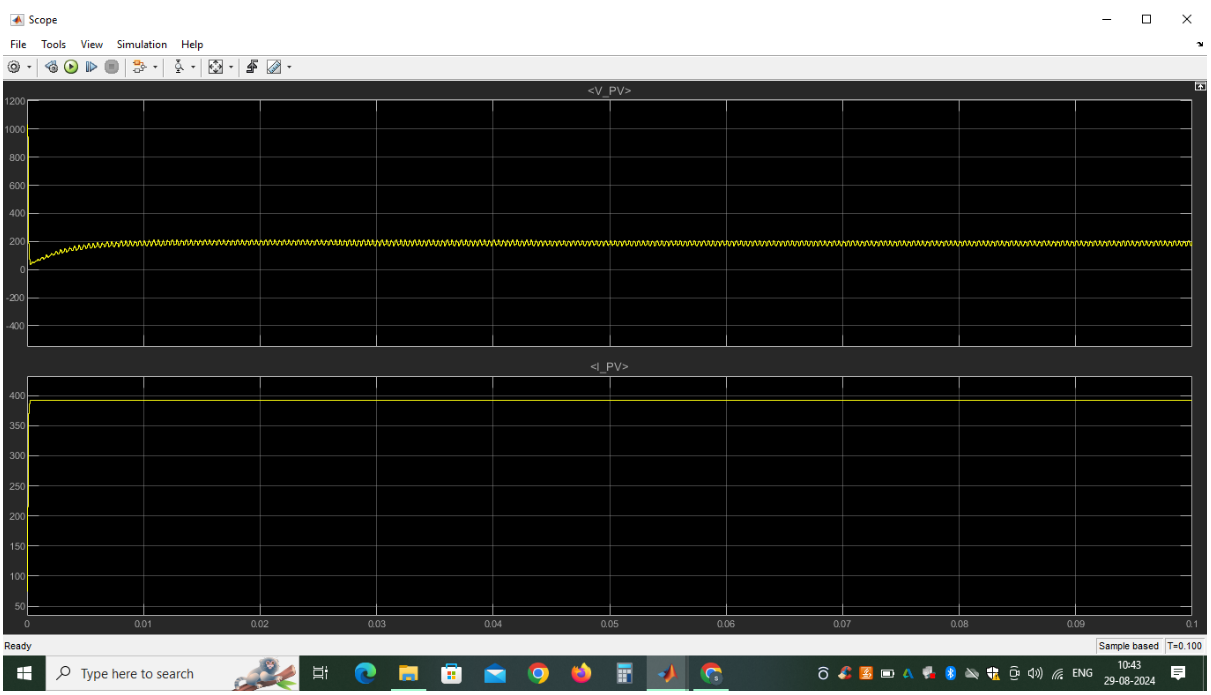


Figure 8. Comparison of reactive power (*Q*) at the output terminal of sub-system 1 , With Fuzzification.

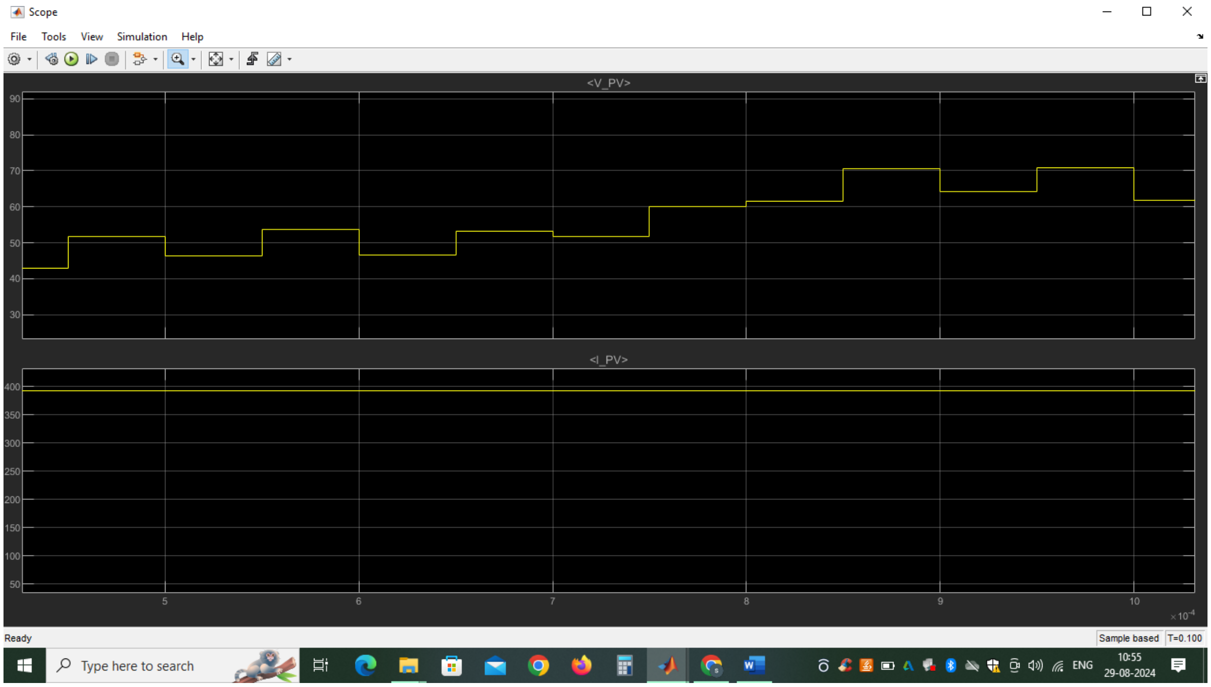


Figure 9. Comparison of reactive power ($Q$) at the output terminal of sub-system 2 , With Fuzzification.

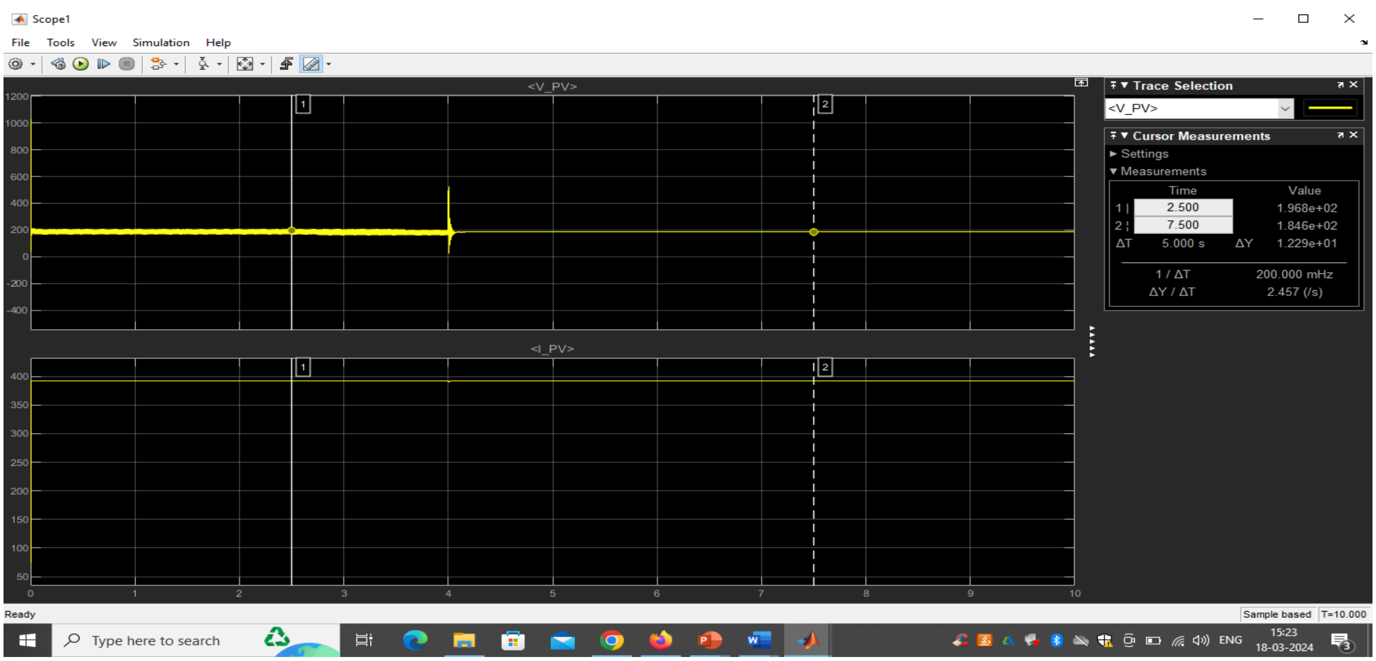


Figure 10. Comparison of reactive power ($Q$) at the output terminal ofsub-system 1 (top) and sub-system 2 (bottom).

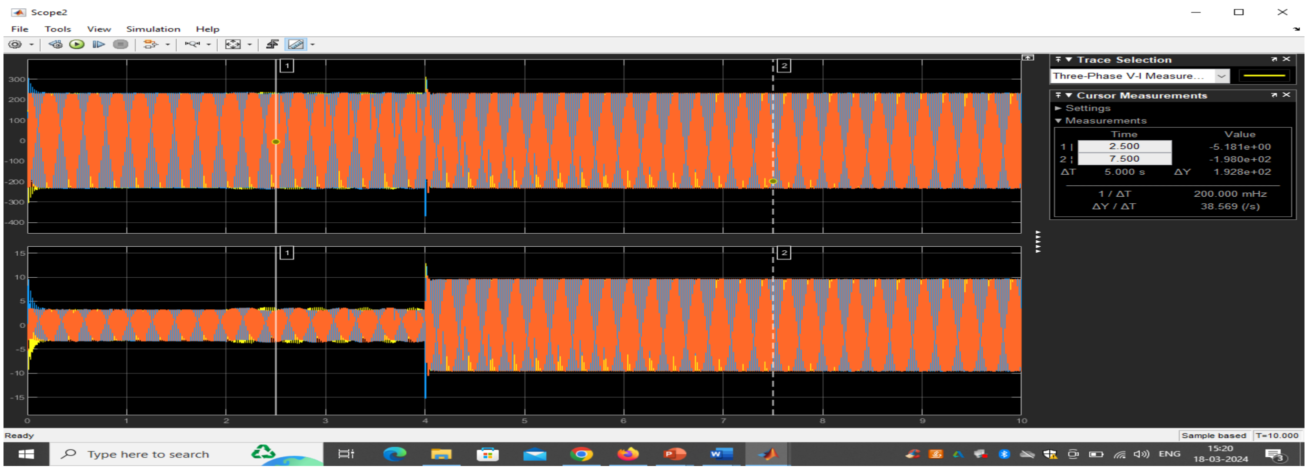


Figure 11. Comparison of grid RMS voltage ($v_{grid}$) of sub-system 1 (top)and sub-system 2 (bottom).

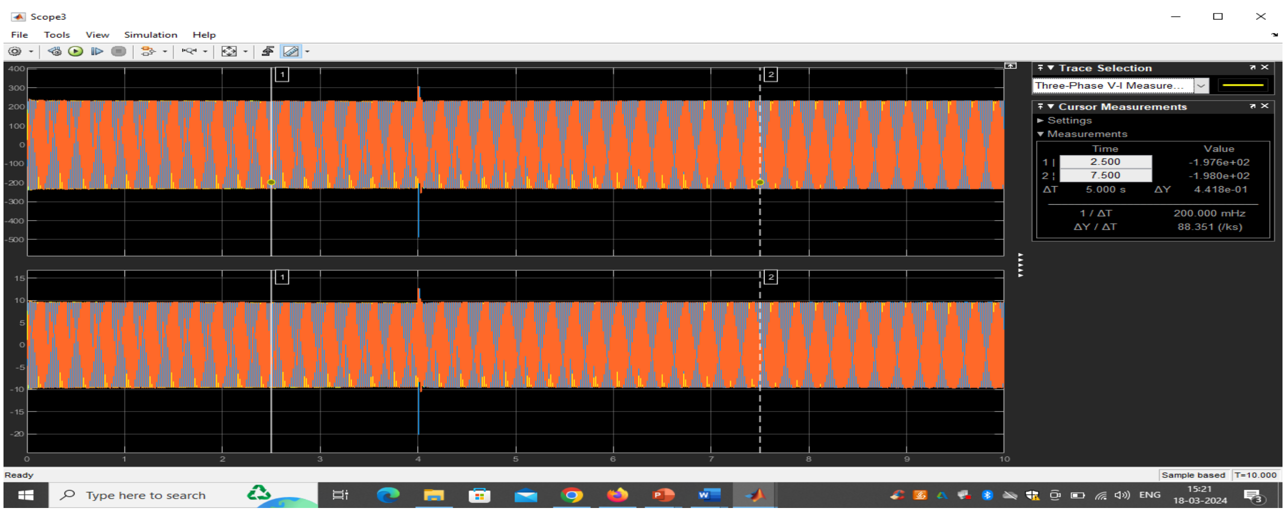


Figure 12. Comparison of Frequency at the output terminal ($f_{grid}$) of sub-system1 (top) and sub-system 2 (bottom).

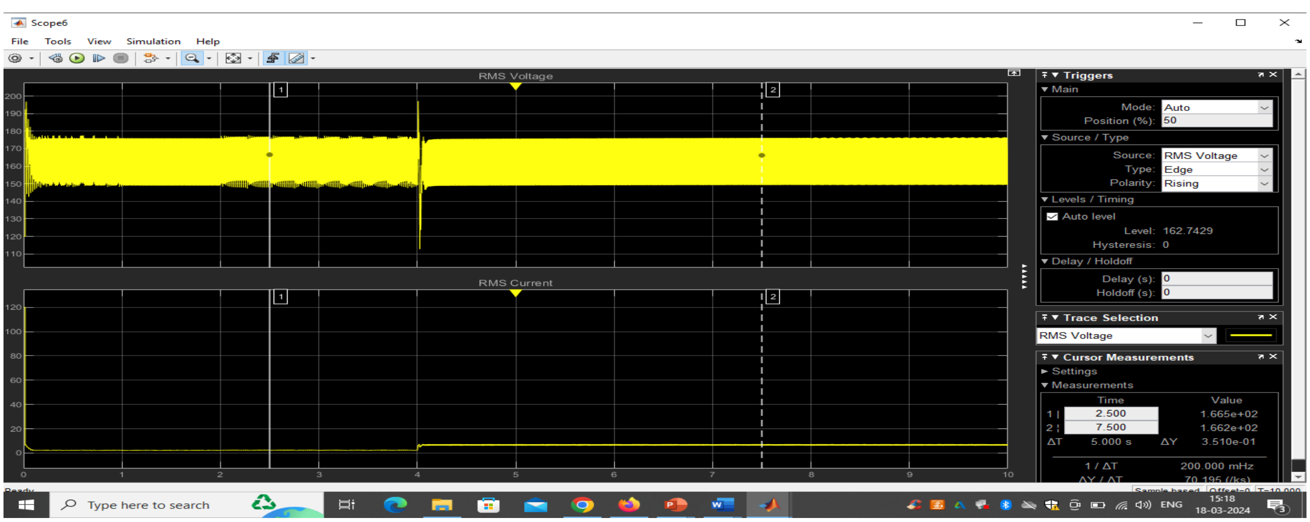


Figure 13. Comparison of grid current ($I_{grid}$) of sub-system 1 (top) andsub-system 2 (bottom).

### 5.4 Validation

To demonstrate the effectiveness of the proposed control approach, simulation studies were conducted on a representative inverter-based microgrid model with fuzzy logics. Results indicate improved power quality, enhanced stability during transient events, and efficient utilization of distributed energy resources. The control strategy effectively minimizes grid disturbances while promoting increased integration of renewable energy sources.

## Conclusion

This research describes a new control strategy for accurate power sharing and high-power quality in microgrid systems using parallel-operated inverters. The comparative simulation results, which comprise conventional droop control (CDC), CDC with robustness, and the suggested method, demonstrate the superior performance of the proposed method in a variety of ways. These elements include power-sharing and non-sharing modes, as well as transient behaviour during connection and disconnection events.

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