# ACCURATE REACTIVE POWER SHARING IN AN ISLANDED MICROGRID USING ADAPTIVE VIRTUAL IMPEDANCES

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**ABSTRACT:** Owing to mismatched feeder impedances in an islanded microgrid, the conventional droop control method typically results in errors in reactive power sharing among distributed generation (DG) units. In this study, an improved droop control strategy based on secondary voltage control is proposed to enhance the reactive power sharing accuracy in an islanded microgrid. In a DG local controller, an integral term is introduced into the voltage droop function, in which the voltage compensation signal from the secondary voltage control is utilized as the common reactive power reference for each DG unit. Therefore, accurate reactive power sharing can be realized without any power information exchange among DG units or between DG units and the central controller. Meanwhile, the voltage deviation in the microgrid common bus is removed. Communication in the proposed strategy is simple to implement because the information of the voltage compensation signal is broadcasted from the central controller to each DG unit. The reactive power sharing accuracy is also not sensitive to time-delay mismatch in the communication channels. Simulation results are provided to validate the effectiveness of the proposed method..

**Key words**: Droop control, low-bandwidth synchronization signals, microgrid, reactive power sharing, and voltage recovery operation.

## 1. INTRODUCTION

THE application of distributed generation (DG) has been increasing rapidly in the past decades. Compared to the conventional centralized power generation, DG units have ad- vantages of less pollution, higher efficiency of energy utilization, more flexible installation location, and less power transmission losses. Most of the DG units are Connected to the grid via power electronic converters, which introduces system resonance, protection interference, etc. To overcome these problems, the microgrid concept was first proposed in the US by the Consortium for Electrical Reliability Technology Solutions [1]. Compared to use a single DG unit, microgrid could offer superior power management within the distribution networks. Moreover, the microgrid can operate in grid-connected mode or islanded mode and benefit both the utility and customers in economy [2]–[7].

In an islanded mode, the load power in the microgrid should be properly shared by multiple DG units. Usually, the droop control method which mimics the behavior of a synchronous generator in traditional power system is adopted, which does not need the use of critical communications [8]–[14], [21], [22]. The active power sharing is always achieved by the droop control method easily. However, due to effects of mismatched feeder impedance between the DGs and loads, the reactive power will not be shared accurately. In extreme situations, it can even result in severe circulating reactive power and stability problems [11]. To overcome the reactive power sharing issue, a few improved methods have been proposed. Specifically, there are mainly three approaches to address the effect of the interconnecting line impedance on droop-based control. The first approach is to introduce the virtual output impedance by modifying the output voltage reference based on output current feedback [11], [13], [14], [23]. This method can reduce the reactive power sharing error by reducing the relative error of the output impedances

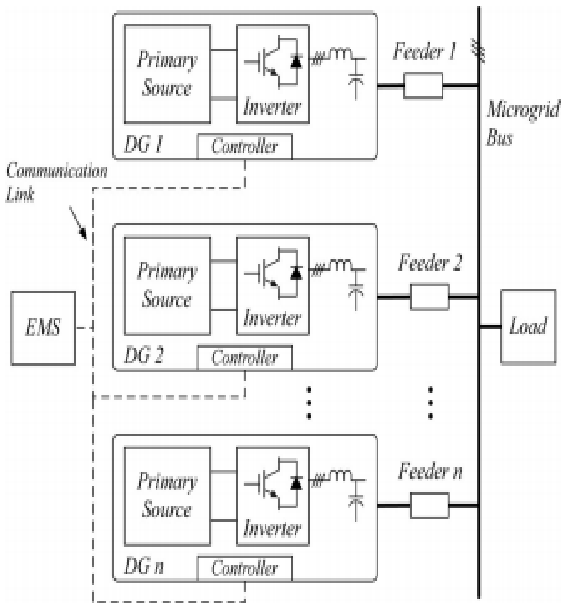


Fig. 1. Islanded microgrid with communication links to an energy management system (EMS).

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## .II. MICROGRID

The net micro grid could even provide ancillary services such as local voltage control. In case of disturbances on the main network, micro grids could potentially disconnect and continue to operate separately. This operation improves power quality to the customer. From the grid's perception, the benefit of a micro grid is that it can be considered as a controlled entity within the power system that can be functioned as a single aggregated load. Customers can get benefits from a micro grid because it is designed and operated to meet their local needs for heat and power as well as provide uninterruptible power, enhance local reliability, reduce feeder losses, and support local voltages. In addition to generating technologies, micro grid also includes storage, load control and heat recovery equipment. The ability of the micro grid to operate when connected to the grid as well as smooth transition to and from the island mode is another important function.

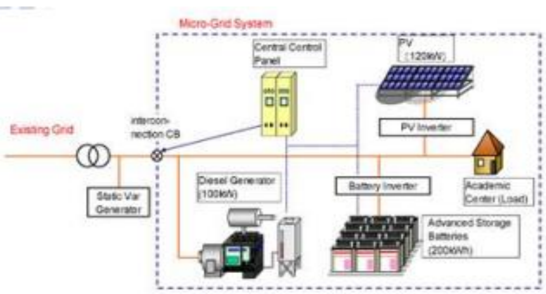


Fig-2: Microgrid system

### A. Supply to Grid

The Power Stream Microgrid is connected to the distribution system and is supplying energy to the grid using renewable solar or wind power. Stored electricity from the Sodium Nickel Chloride, Lithium Ion Battery and Lead Acid Battery Systems can also be used to supply energy to the grid. During the Supply to Grid operating mode, the natural gas generator will not be operated

### B. Supply from Grid

The Power Stream Microgrid is connected to the distribution system and is taking energy from the grid to power its load. Electricity can also be stored in the Sodium Nickel Chloride, Lithium Ion Battery and Lead Acid Battery Systems for future consumption. During the Supply from Grid operating mode, the solar photovoltaic system and wind turbine system may also be powering the load and charging the batteries, but the natural gas generator will not be operated.

### C. Island (Generator)

The Power Stream Microgrid is designed to operate in isolation from the distribution grid with the Island (Generator) operating mode. During this mode, the natural gas generator will be the primary source of electricity with the renewable solar and wind generators providing supplementary power. Electricity stored in the Lead Acid, Sodium Nickel Chloride and Lithium Ion Battery Systems can also be used at this time.

### D. Island (No Generator)

The Power Stream Microgrid is designed to operate in isolation from the distribution grid with the Island (No Generator) operating mode. During this mode renewable solar and wind generators will be primary source of power. Electricity stored in the Lead Acid, Sodium Nickel Chloride and Lithium Ion Battery Systems can also be used at this time. Since all generation sources are intermittent with this operating mode, low priority Microgrid loads may be disconnected depending on the amount of generation available.

## III. PROPOSED CONTROL STRATEGY

Proposed Controller The feasibility of the condition in (12) can be further investigated by using the principle of virtual impedance and the approximation in (3). Considering the use of a virtual impedance to generate the voltage δV∗1 , from Fig. 3

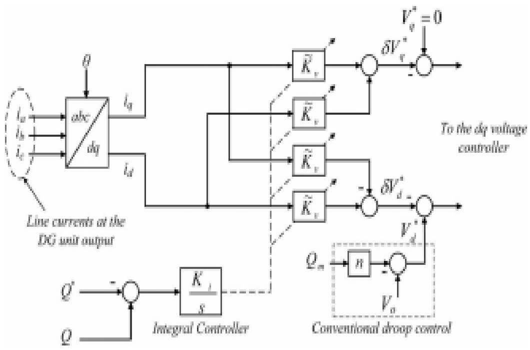


Fig.3. Proposed adaptive virtual impedance controller.

unit shares its actual reactive power load with the microgrid EMS over the communication link. The EMS calculates the proper share for each unit based on its rating and the total load and sends it back to each unit, along with a controller enable signal (EN). Note that the communication link is not used here within the closed loop of the tuning control, but instead it is used to set the reactive power reference that will be used in the tuning process.

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Therefore, the sharing accuracy at steady state is unaffected by time delays in the communication channels. Consequently, each unit will utilize the received reactive power share reference Q∗ to adaptively tune K˜v . The received Q∗ value will not vary with transients in the reactive power of each unit caused by the tuning process, since it is calculated based on the total reactive power load. Therefore, Q∗ will be a fixed reference until the total reactive power load changes. Once K˜v is tuned for a given load condition, accurate reactive power sharing will continue even if the communication channel becomes unavailable, as long as the load does not change.. The proposed controller to tune the virtual impedance variable K˜v is shown in Fig. 4. A simple integral control loop can be used to tune K˜v by regulating Q indirectly to match Q∗. The virtual impedance is implemented in the dq-frame where θ represents the phase angle of the unit output voltage. Note that the objective of the controller is not to regulate the reactive power directly but to tune the virtual impedance to a value that compensates for the effect of the feeder mismatch on the reactive power sharing. Therefore, once the virtual impedance is tuned for the current load conditions it will result in accurate sharing, and in reasonable sharing if the load changes and communication is disrupted.

## IV SIMULATION RESULTS

CIRCUIT DIAGRAM:

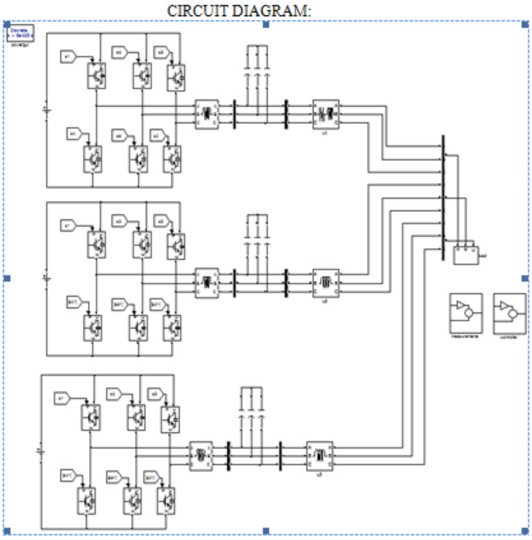
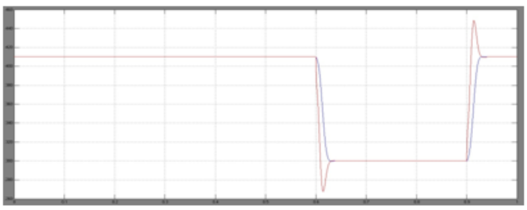


**Fig4: Proposed Simulation Circuit**



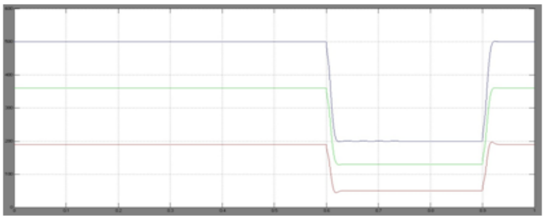


**Fig5: Real and Reactive powers of conventional Droop control**

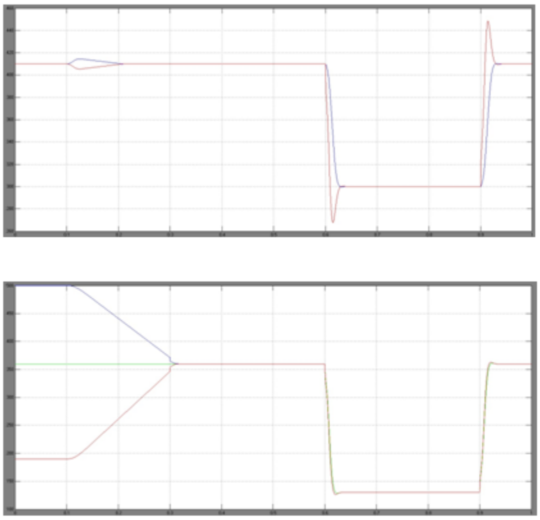


**Fig6: Real and Reactive powers of Proposed control**

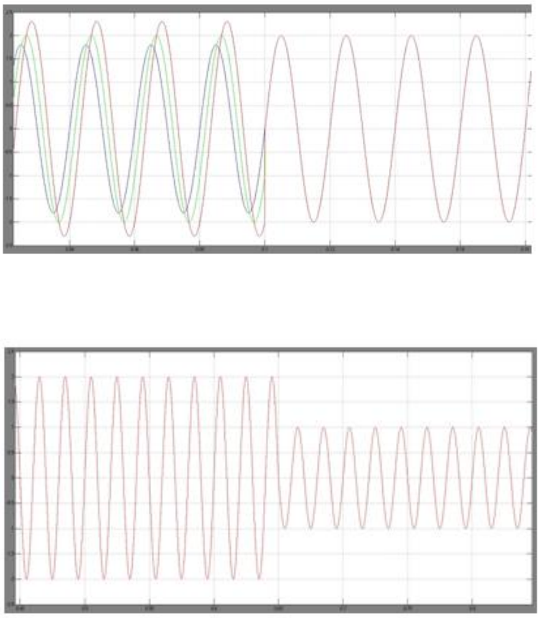


**Fig7: Simulated feeder currents. (a) Under conventional control (before enabling the controller). (b) Under the proposed control strategy.**

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## V CONCLUSION

A control strategy to improve reactive power sharing in an islanded microgrid has been proposed and validated in this paper. The strategy employs communication to exchange the information needed to tune adaptive virtual impedances in order to compensate for the mismatch in feeder impedances. The control strategy does not require knowledge of the feeder impedances, and is straightforward to implement in practice. It is also insensitive to time delays in the communication channels. It has been shown that the proposed technique is tolerant of disruptions in the communication links while still outperforming the conventional droop control method. The sensitivity of the tuned controller parameters to changes in the system operating point has also been investigated. It has been shown that the system operating point is mainly determined by the power factor, and the higher the load power factor, the less sensitive the parameters are to the operating point.

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