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Performance Evaluation of Load Sharing Strategy in Micro-Grid by Distribution Generation (DG) Units

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Abstract:

The voltage droopcontrol and its different variations have been reported in the literature.However, in a low-voltage microgrid, due to the effects of nontrivialfeeder impedance, the conventional droop control is subjectto the real and reactive power coupling and steady-state reactivepower sharing errors.However, due to mismatched feeder impedance theconventional droop control is subject to steady-state realand reactive power coupling steady-state reactive powersharing errors in the low voltage microgrid. Hence, forthe composite (meshed or looped) microgrid the reactivepower sharing is more challenging to do.Theproposed compensation method will accomplishes precisereactive power sharing at the steady state as same as theperformance of real power sharing through frequencydroop control. Simulation results obtained usingMATLAB software will validate the feasibility of theproposed method.

Key words:

Distributed generation (DG), microgrid, improvedcompensation method, real and reactive power sharing.

I.INTRODUCTION:

The Distributed generation, also called on-site generation, dispersed generation, decentralized generation, distributed energy or district energy, generates electricity from many small energy sources. DG by delivering clean and renewable energy close to customers last can ease the strains of many conventional transmissions and distribution infrastructures [1].

On the other hand, high penetration of power electronicsbasedDG units also introduces a few issues, such as systemresonance, protection interference, etc. In order to overcomethese problems, the microgrid concept has been proposed, whichis realized through the control of multiple DG units. Comparedto a single DG unit, the microgrid can achieve superior powermanagement within its distribution networks. In addition, theislanding operation of microgrid offers high reliability powersupply to the critical loads [2]. Therefore, microgrid is consideredto pave the way to the future smart grid.

In an islanded microgrid, the loads must be properly sharedby multiple DG units. Conventionally, the frequency and voltagemagnitude droop control is adopted, which aims to achievemicrogrid power sharing in a decentralized manner [3]-[5]. However, the droop control governed microgridis prone to have some power control stability problemswhen the DG feeders are mainly resistive [2]. It can also beseen that the real power sharing at the steady state is alwaysaccurate while the reactive power sharing is sensitive to theimpacts of mismatched feeder impedance. Moreover,the existence of local loads and the networked microgridconfigurations often further aggravate reactive power sharing problems.

In response to the islanding microgrid control challenges, thispaper presents a simple reactive power sharing compensationscheme. The proposed method first identifies the reactive powersharing errors through injecting small real-reactive power couplingdisturbances, which are activated by the low-bandwidthsynchronization flag signals from the central controller.

Thenthe accurate reactive power sharing is realized by manipulatingthe injected transient real-reactive power coupling using an intermittentintegral control. With the proposed scheme, reactivepower sharing errors are significantly reduced. After the compensation,the proposed droop controller will be automaticallyswitched back to the conventional droop controller. Note thatthe proposed accurate power control method is effective for microgridswith all types of configurations and load locations, andit does not need the detailed microgrid structural information. Simulation results are provided to verify theproposed load demand sharing method.

II.CONVENTIONAL METHOD:

Microgridoperation:

Themicrogrid is composed of a number of DG units and loads.Each DG unit is interfaced to the microgrid with an inverter,and the inverters are connected to the common ac bus throughtheir respective feeders.

Considering that the focus of this paperis the fundamental real and reactive power control, nonlinearloads are not considered in the microgrid. The microgrid andmain grid status are monitored by the secondary central controller [6]. According to the operation requirements, themicrogridcan be connected (grid-connected mode) or disconnected(islanding mode) from the main grid by controlling the statictransfer switch (STS) at the point of common coupling (PCC).

During the grid-connected operation, real and reactive powerreferences are normally assigned by the central controller andthe conventional droop control method can be used for powertracking. However, to eliminate the steady-state reactive powertracking errors, the PI regulation for the voltage magnitude controlwas developed. Therefore, power sharing isnot a real concern during the grid-connected operation. Whenthe microgrid is switched to islanding operation, the total loaddemand of the microgrid must be properly shared by these DGunits.

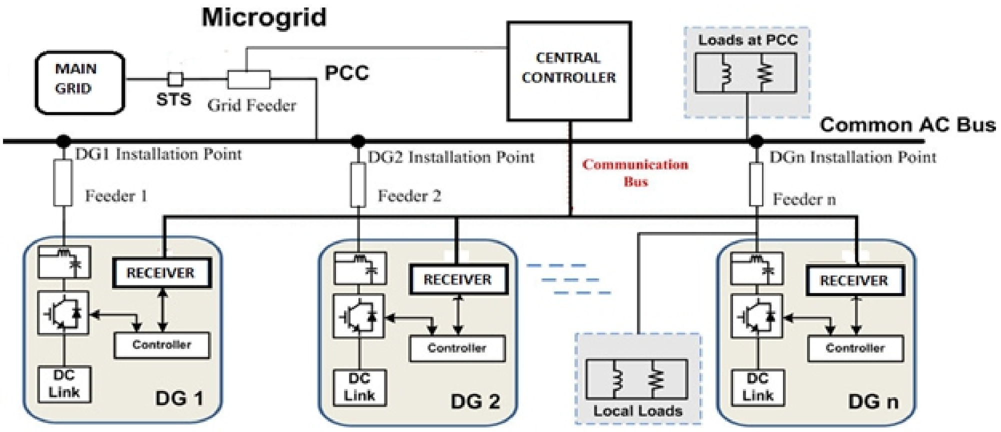

Fig 1: schematic diagram of microgrid structure.

During the islanding operation, DG units as illustrated inFig. 1 can operate using the conventional real power–frequencydroop control and reactive power–voltage magnitude droopcontrol as

$\omega = \omega_0 - D_P \bullet P$

$E = E_0 - D_Q \bullet Q$

Where ω_0 and E_0 are the nominal values of DG angular frequencyand DG voltage magnitude, P and Q are the measuredreal and reactive powers after the first-order low-pass filtering(LPF), DP and DQ are the real and reactive power droop slopes. With the derived angular frequency and voltage magnitude are as in equations, the instantaneous voltage reference can be obtainedaccordingly.

Reactive power sharing:

It is not straightforward to evaluate the reactive power sharingaccuracy in a complex networked microgrid. For the sake ofsimplicity, this section first considers a simplified microgridwith two DG units at the same power rating.The magnitudes of thevoltage sources are obtained as

$E_1 = E_0 - D_Q \bullet Q_1$

$E_2 = E_0 - D_Q \bullet Q_2$

Where E1 and E2 are the DG voltage magnitudes regulated bythe droop control, and Q1 and Q2 are the output reactive powersof DG1 and DG2, respectively.

For the power flowing through either physical or virtualimpedance, its associated voltage drop on the impedance yieldsthe following approximation as
$\Delta V = (X \bullet Q + R \bullet P)/E_0$
Where P and Q are the real and reactive powers at the powersending end of the impedance, R and X are the correspondingresistive and inductive components of the impedance, E_0 is thenominal voltage magnitude, and ΔV is the voltage magnitudedrop on the impedance.
The output real powers of DG1and DG2 are obtained as
$P_1 = P_2 = 0.5 \bullet P_{Total} = 0.5 \bullet (P_{pcc} + P_{Local1}+P_{Local2}+P_{Feeder1}+P_{Feeder2})$
WhereP_{Total} means the real power demand within the islandedmicrogrid, and $P_{Feeder1}$ and $P_{Feeder2}$ are the real power loss onthe feeders. Similarly, the reactive power demand (Q_{Total}) isdefined as
$Q_{Total}=Q_{pcc}+Q_{Local1}+Local2+Q_{Feeder1}+Q_{Feeder2}$

III.PROPOSED METHOD (REACTIVE POWER SHARING ERRORCOMPENSATION):

The objective ofthis section is to develop an enhanced compensation methodthat can eliminate the reactive power sharing errors withoutknowing the detailed microgrid configuration.Since the reactive power sharing errors are caused by a numberof factors and microgrids often have complex configurations,developing the circuit model-based reactive power sharing errorcompensation strategy is difficult.

Proposed controller:

To initialize the compensation, the proposed method adoptsa low-bandwidth communication link to connect the secondarycentral controller with DG local controllers [7].The commutationlink sends out the synchronized compensation flag signalsfrom the central controller to each DG unit, so that all the DGunits can start the compensation at the same time. This communicationlink is also responsible for sending the power referencefor dispatchable DG units during the microgrid grid-tied operation.Therefore, the proposed compensation scheme does notneed any additional hardware cost. The communication mechanismcan be realized using power line signaling or smart meteringtechnologies, or other commercial infrastructures, suchas digital subscriber lines, or wireless communications.

The enhanced power control strategy is realized through thefollowing two stages.

Initial Power Sharing Using Conventional Droop:

Before receiving the compensation flag signal, the conventional droop controllers are adopted for initialload power sharing. Meanwhile, the DG local controller monitorsthe status of the compensation flag dispatched from themicrogrid central controller. During this stage, the steady-stateaveraged real power (P_{AVE}) shall also be measured for use inStage 2. Note that although the first-order LPFs have alreadybeen used in measuring the real and reactive powers (P and Q)for the conventional droop controller, the cut-offfrequency of LPFs cannot be made very low to get the ripple-freeaveraged real power (P_{AVE}) due to the consideration of system stability [8], [9]. Therefore, a moving average filter isused here to further filter out the power ripples. Themeasured average real power (P_{AVE}) is also saved in this stage,so that when the synchronization signal flag changes, the lastsaved value can be used for a reactive power sharing accuracyimprovement control in Stage 2.

Power Sharing Improvement through Synchronized Compensation:

The reactive power sharingerror is compensated by introducing a real-reactive power couplingtransient and using an integral voltage magnitude controlterm. As this compensation is based on the transient couplingpower control, it shall be carried out in all DG units in a synchronizedmanner. Once a compensation starting signal (sentfrom the central controller) is received by the DG unit localcontroller, the averaged real power calculation stops updating,and the last calculated P_{AVE} is saved and used as an input of thecompensation scheme. The proposed method is developed based on the assumptionthat the real power load demand is constant during the compensationtransient in Stage 2. For a real power load variation duringthe compensation stage, the proposed controller may leave somereactive power sharing errors after the compensation. There aretwo types of real power variations: steady-state real power variations/ripples and microgrid load switching. To limit the impactsof small real power demand variations during the compensationtransient a dead band is placed before the integral control ofthe real power difference (P–PAVE). To avoid the impacts oflarge load demand variations or load switching in a microgrid,the compensation period should be properly designed by tuningthe integral gain (KC) in (10). A long compensation period willsubject to possible microgrid load demand changes, while a toofast compensation will lead to excess transient and affect theaccuracy as well.

IV.SIMULATION RESULTS:

A networked microgrid model has been established usingMATLAB/Simulink.

As shown in Fig. 8, the simulated microgridis composed of three identical DG units and two linearloads. With the same power rating, three DG units shall sharethe load equally. The detailed configuration of the DG unit ispresented in Fig. 9, where an LC filter is placed between theIGBT bridge outputs and the DG feeders.

The DG line currentand filter capacitor voltage are measured to calculate the real andreactive powers. In addition, the well-known multiloop voltagecontroller is employed to track the reference voltage.

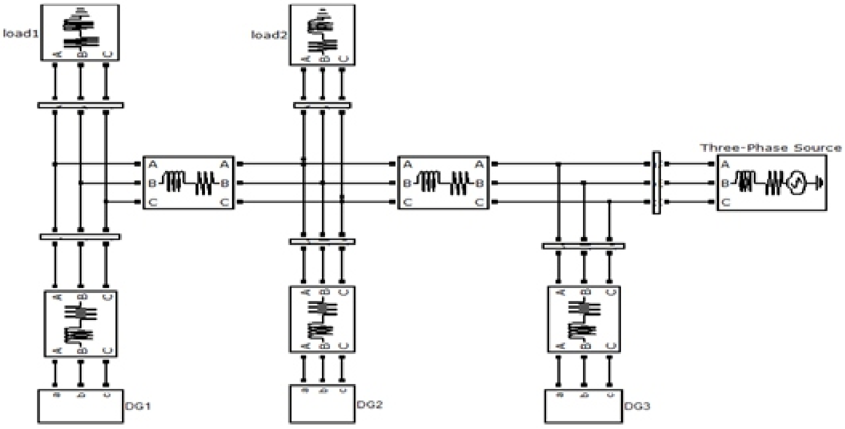

Figure 2: simulation design of distribution generation (DG) units integrated to grid

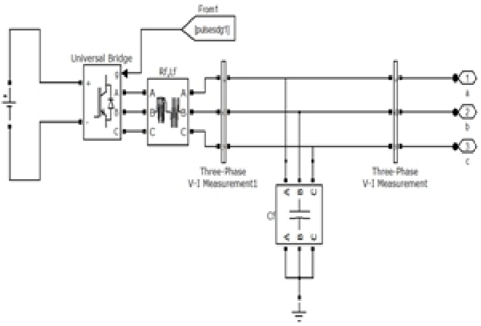

Figure 3: Distribution Generation (DG) unit

Fig. 6 demonstrates the reactive power flow of the DG units.Due to the unequal voltage drops on networked microgrid feeders,there are significant reactive power errors with the conventionaldroop control method. On the other hand, the proposedcompensation method starting at 1.0 s can effectively adjust thereactive power sharing error to almost zero.

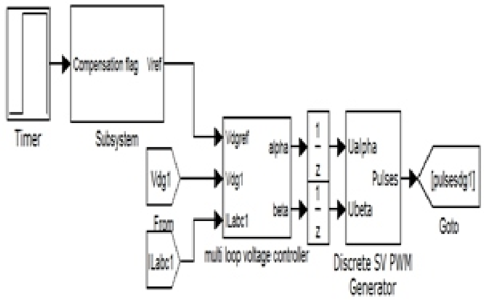

Figure: overall control strategy

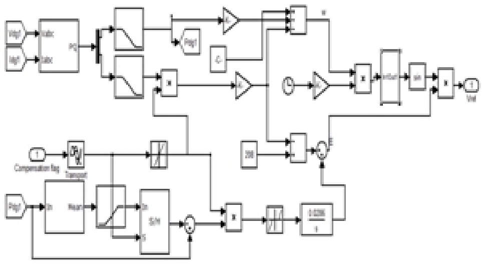

Figure 4: Synchronized reactive power compensation scheme.

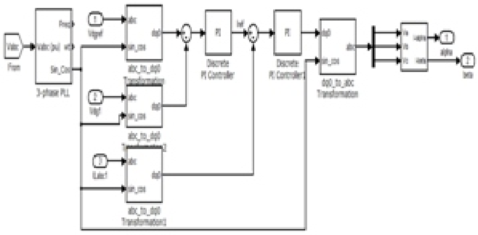

Figure 5: multi-loop voltage controller

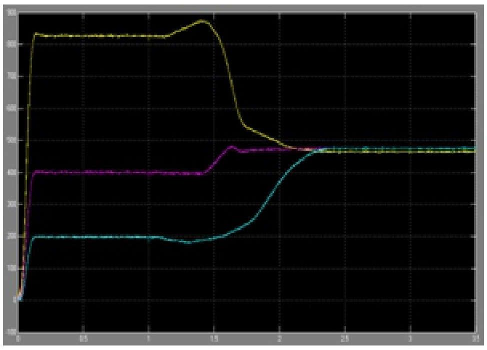

Figure 6: Simulated reactive power sharing performance in a network microgrid

Fig. 7 shows the real power flow of these DG units. Before the compensation, the real power is evenly shared with the conventional droop method. When the compensation is enabled at1.0 s, due to the transient real and reactive power coupling introduced, there are some disturbances in the realpower. However, the output real power goes back to the originalvalue at around 2.3 s.

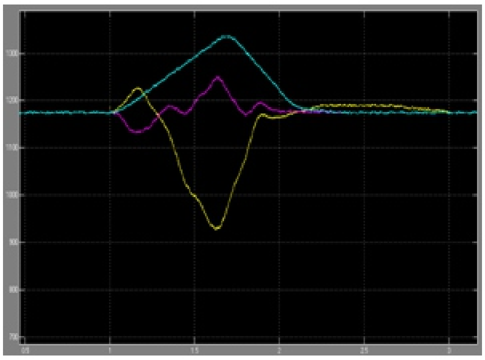

Figure 7: Simulated real power sharing performance in a network microgrid(compensated is activated at 1 s).

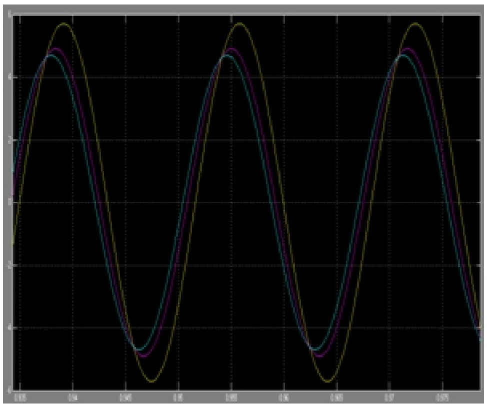

Figure 8: Simulated DG currents before compensation.

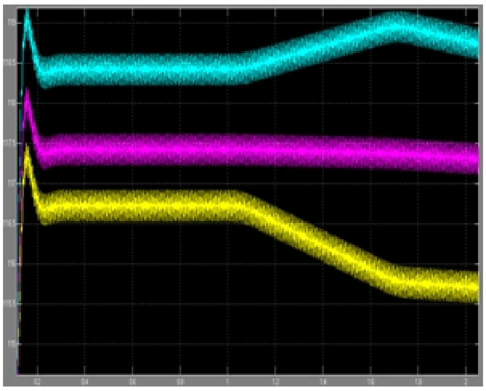

Figure 9: Simulated installation points voltage magnitudes.

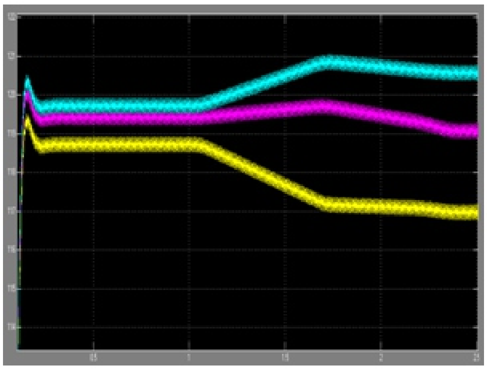

Figure 10: Simulated DG voltage magnitudes.

V.CONCLUSION:

The compensationstrategy also uses a low-bandwidth flag signal from the microgridcentral controller to activate the compensation of all DGunits in a synchronized manner. An improved microgrid reactive power sharingstrategy was proposed. Themethod injects a real-reactive powertransient coupling term to identify the errors of reactive powersharing and then compensates the errors using a slow integral term for the DG voltage magnitude control.

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