ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

Islanded Microgrid -Hierarchical Droop Control in Reactive Power Management

B.M.Sadique [1], B.Manthru Naik [2]

M.Tech Student, Dept. of EEE, Dr. Samuel George Institute of Engineering &Technology, Markapur, JNTU Kakinada University, India[1]

Associate Professor, Dept. of EEE, Dr. Samuel George Institute of Engineering &Technology, Markapur, JNTU Kakinada University, India[2]

ABSTRACT: A microgrid (MG) is a local energy system consisting of a number of energy sources (e.g., wind turbine or solar pan-els among others), energy storage units, and loads that operate connected to the main electrical grid or autonomously. MGs pro-vide flexibility, reduce the main electricity grid dependence, and contribute to changing large centralized production paradigm to local and distributed generation. However, such energy systems require complex management, advanced control, and optimiza-tion. Moreover, the power electronics converters have to be used to correct energy conversion and be interconnected through common control structure is necessary. Classical droop control system is often implemented in MG. It allows correct opera-tion of parallel voltage source converters in grid connection, as well as islanded mode of operation. However, it requires com-plex power management algorithms, especially in islanded MGs, which balance the system and improves reliability. The novel reactive power sharing algorithm is developed, which takes into account the converters parameters as apparent power limit and maximum active power. The developed solution is verified in sim-ulation and compared with other known reactive power control methods.

KEYWORDS: Distributed generation, droop control, micro-grid (MG), power converters, reactive power sharing.

I. INTRODUCTION

MICROGRID (MG) is a separate system that produces and storages electrical energy, which consists of renew-able energy sources (RES), local loads, and energy storage based on batteries or supercapacitors. It is inherent part of modern and popular smartgrids [1], [2], which includes also intelligent buildings, electrical car stations, etc. All RES are using power electronics devices (e.g., converters), which num-ber significantly increasing and costs decreasing in range 1%–5% every year [3]–[7]. RES are usually connected to the grid and many installations cause the parallel operation of RES close to each other. This is one of reasons to future change of the classical structure of electrical power systems, toward new solution containing distributed generation, energy stor-age, protection and control technologies, and improving their performances [8].

MG is highly advanced system from control and communi-cation point of view. It has to manage power for local loads as well as control all converters with high efficiency and accuracy, especially when MG operates as islanded system. Islanding mode of operation provide the uninterruptible power supply for local loads during grid faults. The performances of islanded MG are specified according to IEEE Standard 1547.4 [9]. With increasing number of RES applications, operating paral-lel, close to each other (few km) and with developed islanded mode of operation, the MGs are become perfect solution for RES integration

Fundamental algorithms of ac MGs, described in [10]–[20], are based on master–slave control or hierarchical droop con-trol. The first solution includes only one converter with voltage control loop (VCL), operating as a master, and others oper-ating in current control loop (CCL)—slaves. The produced power is controlled by sources with CCL and the voltage amplitude and frequency is keeping in point of common cou-pling (PCC) by master unit. Disadvantage of this solution is no possibility to connect other VCL sources to MG, which are the most popular and used RES solutions. The second control solution, called droop control, includes many VCL sources and provides possibility to many different RES inter-connection. The idea of droop control is based on active and reactive power related to voltage

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

frequency and amplitude droop on coupled impedances. Unfortunately, classical droop control method with proportional droop coefficients does not provides proper reactive power sharing between converters connected to common ac bus. In classical approach, the equal reactive power sharing (ERPS) can be obtained only when active powers are equal and droop coefficients are well chosen. When active powers are changing, the reactive power sharing cannot be controlled causing overload or reactive power cir-culation between converters. Moreover, the important issue in droop control is static trade-off between voltage regulation and reactive power [21]. For increasing reactive power, the voltage droop on converter's output impedance also increase, what may cause overvoltage. In order to provide appropri-ate power sharing and minimize the risk of converter damage the many additional aspects (e.g., nominal apparent power,

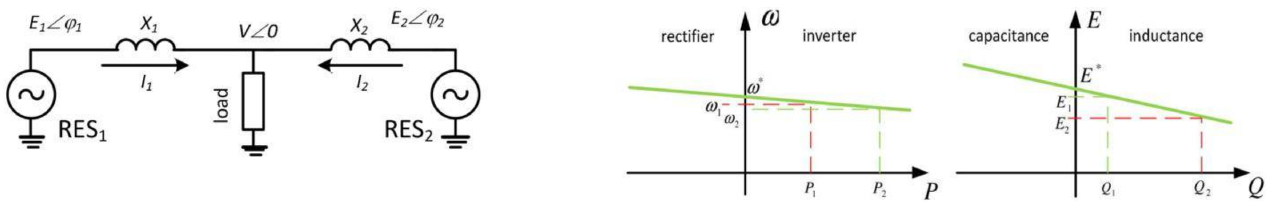


Fig. 1. Equivalent circuit of parallel connected VSIs.

instantaneous active power, nominal voltage of converter) have to be considered in control system.

There are only few papers describing reactive power shar-ing between parallel operating converters in islanded ac MGs. The researchers focused on ERPS between all RES usually controlled by MG central control unit [22]–[27] or imple-mented as virtual impedances [15], [28]. From the other hand, researches consider reactive power sharing in order to optimize transmission power losses by appropriate optimization algo-rithm (e.g., particle swarm optimization) [29]–[31], which can be neglected in MGs, hence the short distances and the line impedances are low.However, algorithms described in literature are not consid-ering capabilities of single RES, which have limited apparent power. If active power, usually calculated from maximum peak power tracking (MPPT) algorithms [32]–[37], obtain almost nominal apparent converter limit the equal power sharing algo-rithms cannot be used, because the overload can occur, what leads to damage or exclusion from operation of RES unit. The new reactive power sharing algorithm is developed and presented in this paper. In Section I, the current solu-tions and problems of reactive power sharing are described. In Section II, the classical droop control is presented, which is used in converter's control system. A new algorithm is fea-tured in Section III and the simulation results are shown in Section IV in order to presenting the problem of reactive power sharing and proper operation of developed solution.

II. CLASSICAL DROOP CONTROL

When at least two RES are connected through energy converters to the MG, the droop control method is often applied [11], [14], [15], what provides the correct parallel operation of voltage source converters (VSI). The equivalent circuit of two converters connected to common ac MG bus can be presented by Fig. 1. Presented scheme is similar to the equivalent circuit of syn-chronous generator, hence the active and reactive power of *k*th

converter connected to ac MG can be described as

$$P_k = \frac{E_k V}{X_k} \sin \phi_k$$

$$Q_k = \frac{E_k V \cos \phi_k - V}{X_k}$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

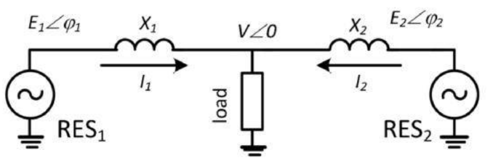
Vol. 5, Issue 12, December 2016

where P, active power; E, converter voltage amplitude
V, volt-age amplitude in PCC
; X, coupling impedance; and ϕ, angle of converter
voltage (see Fig. 1).

Based on above equations it can be assumed as below

1) Active power P mainly depends on ϕ, which is changing by ω.

2) Reactive power Q depends on voltage amplitude E.



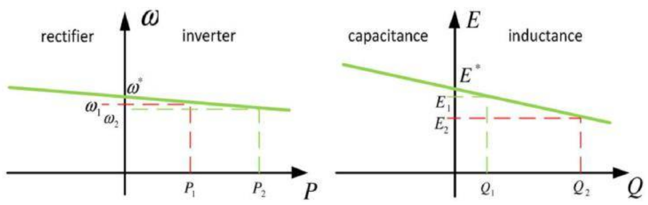


Fig. 2. *P–ω* and *Q–E* droop characteristics.

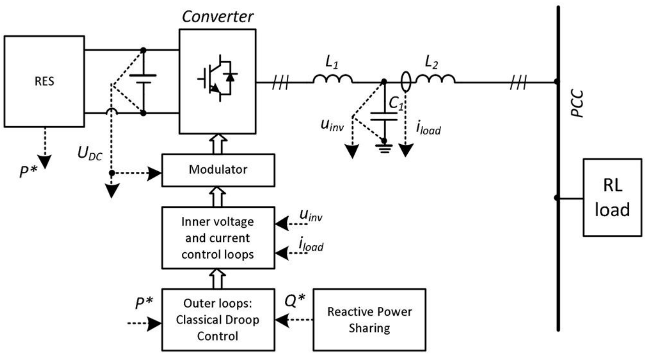


Fig. 3. Block scheme of control structure for one of the converters in islanded MG.

Hence, the P-ω and Q-E droop characteristics can be drawn (Fig. 2). In order to implement these characteristics in VSI control algorithm, the outer droop control loops are created (Fig. 3), which can be described by

$$\omega = \omega^* - G_p(s) \cdot (P - P^*) \qquad (3)$$

$$E = E^* - G_q(s) \cdot (Q - Q^*) \qquad (4)$$

where, E and ω are referenced voltage amplitude and fre-quency for inner control loops, E^* and ω^* are nominal voltage amplitude and frequency, P and Q are calculated active and reactive power, P^* and Q^* are the active and reactive power referenced values, and $G_p(s)$ and $G_q(s)$ are corresponding transfer functions.

Typically in classical droop control $G_p(s)$ and $G_q(s)$ are proportional (constant) droop coefficients. It has hap-pened, when MG not includes any energy storage and total load cannot absorb total injected power. These pro-portional coefficients can be calculated by (5) and (6). Block schemes of P-ω and Q-E control loops is presented in Fig. 4

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

$$G_p(s) = m = \frac{\omega_{max}}{P_{max}} \quad (5)$$

$$G_q(s) = n = E_{max} \quad (6)$$

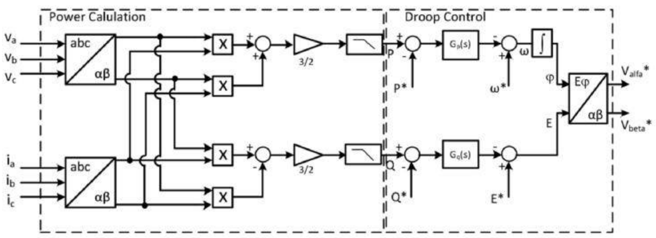
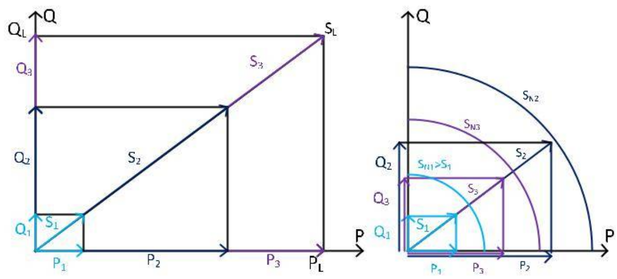


Fig. 4. Block scheme of classical droop control.

where, m, active power coefficient; n, reactive power coef-ficient; ω_{max}, maximum allowed voltage frequency droop; E_{max}, maximum allowed voltage amplitude droop; P_{max}, maximum allowed active power; and Q_{max}, maximum allowed reactive power.



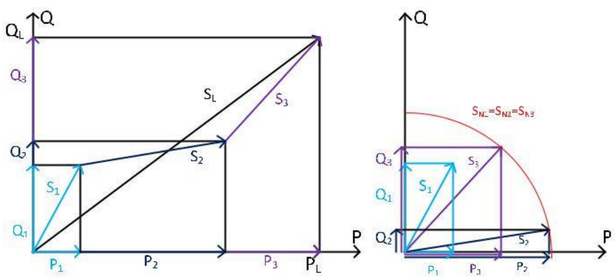


Fig. 6. *P-Q* characteristics for three parallel inverters with PRPS.

(a) Unlimited case. (b) Limited case—inverters 2 and 3 operate with maximum apparent power. $P_{1,2,3}$, active power for each inverter; $Q_{1,2,3}$, reactive power for each inverter; $S_{1,2,3}$, apparent power for each inverter; $S_{N\ 1,2,3}$, nominal apparent powers; P_L, load active power; Q_L, load reactive power; and S_L, load apparent power.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

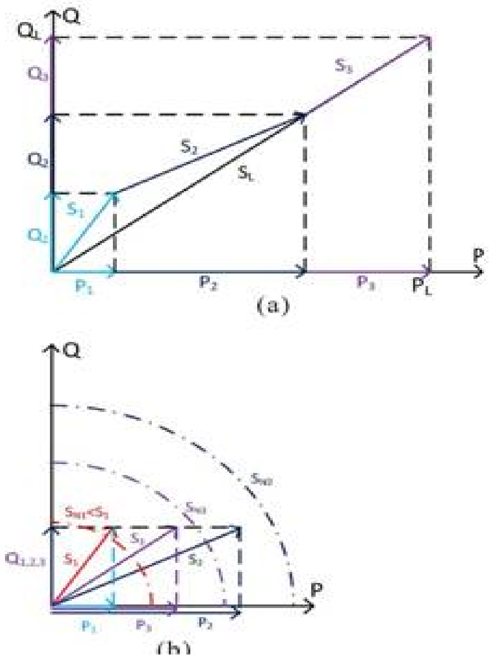


Fig. 5. P-Q characteristics for three parallel converters with significant dif-ferences between nominal apparent powers and ERPS. (a) Vector sum of converter's and load apparent power. (b) Converter's apparent powers and them nominal apparent powers—overload for inverter 1 (note: apparent power S_1 excite nominal apparent power $S_{N\ 1}$). $P_{1,2,3}$, active power for each inverter; $Q_{1,2,3}$, reactive power for each inverter; $S_{1,2,3}$, apparent power for each inverter; $S_{N\ 1,2,3}$, nominal apparent powers; P_L, load active power; Q_L, load reactive power; and S_L, load apparent power.

III. PROPOTIONAL REACTIVE

A. DEVELOPMENT OF PRPS ALGORITHM

In order to manage reactive power in islanded ac MG the instantaneous active power and nominal apparent power of each converter have to be taking into consideration. Based on Fryze power theory, that power can be represented by orthog-onal vectors, which lengths are active and reactive power and their vector sum is equal to the apparent power. The reactive power limit for each converter can be calculated.harmonic (distortion) power is neglecting since only resistive-inductive load is considered.This relation for several converters with different possible nominal apparent powers and equal reactive powers (three converters in this example) can be interpreted graphically in Fig. 5(a). In power balanced system the vector sum of converter's apparent powers is equal to load apparent power regardless of the power management method, however, the algebraic sum of apparent powers is different for each control strategy. As a result, there is possible situation, that sum of converter's apparent powers are higher than the demand, which may lead to converters operating with maximum apparent power. Furthermore, if control priority is keeping maximum active power, the overload of converter can occur, as it is shown in POWER SHARING Fig. 5(b) for converter 1, what is not acceptable, because itcause disable or damage of this device.In order to improves the reactive power management and keeping total generated apparent power below maximum level as long as possible, the proposed reactive control algorithm.

The relation S_L/ S_k in limited cases is lower than one, but it is keeping on highest possible level [Fig. 6(b)] providing the best exploitation of RES with maximum active power

$$Q_{uk} = \frac{Q_L}{P_L} P_k \qquad (8)$$

$$P_k^2 + Q_k^2 = S_k^2 \leq S_{Nk}^2 \quad \forall k \qquad (9)$$

$$Q_k = Q_L \quad \forall k \qquad (10)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

where, Q_{uk}, calculated reactive power value for unlimited case; Q_L, total reactive power demand; P_L, total active power; P_k, active power of "*k*" converter; Q_k, reactive power of *k* converter; S_k, apparent power of *k* converter; and S_{Nk}, nominal apparent power of *k* converter.

Based on (8)–(10) and described analysis of reactive power sharing novel control algorithm was developed. The flowchart of the algorithm is shown in Fig. 7. In first stage system param-eters are saved in *K*-elements tables, where *K*—number of converters, *P[K]*—measured active powers, S_N *[K]*—nominal apparent powers. Furthermore, limits of reactive powers for each converter $Q_{\mathrm{max}k}$, as well as total active power P_L are calculated

$$P_L = P_k. \qquad (11)$$

In the next stage, the auxiliary parameter *Qsum*, defined as a sum of reference reactive powers of all limited and unlimited converters, is compared with load reactive power. This parame-ter allows checking if reactive power balance is retained. When *Qsum*, as a result of stages 3–5 described below is differ-ent than total reactive power Q_L, then algorithm is going to stage 3, otherwise the stage 6 fallowed and final referenced values of reactive power Q_k* are defined for each converter.

In stages 3–5 the main calculation process of the refer-ence values is executed. Firstly, the reactive power values proportional to active powers are calculated (stage 3). The pro-portionality factor is composed of parameters *Prest* and *Qrest*, which are total active and reactive power PL and QL in unlim-ited case, otherwise they are smaller by excluding all active and reactive powers of limited converters (stage 5). Next, the limitation is checked (stage 4) and the reference value is set to maximum or to proportional. Depending on the result, auxil-iary parameters *Qlim*, *Plim* or *Qunl*, *Punl* are calculated, which are sums of active and reactive power of converters operating with maximum apparent power or below it correspondingly (stage 4). Then after all *K* iterations, the parameters *Prest*, *Qrest*, *Qsum* are calculated and the algorithm is going back to stage 2, where the condition (10) is checked, as mentioned above.

B. IMPLEMENTATION OF DEVELOPED ALGORITHM

For more extensive MG (e.g., number of sources *K* > 10), the calculation of final reference values in one common control

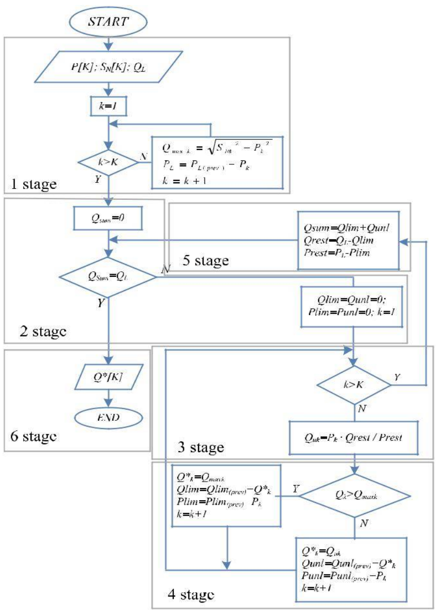


Fig. 7. Block diagram of developed reactive power sharing algorithm.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

unit [e.g., secondary control unit (SCU)] may be long and not be possible, especially if calculations in SCU have to be done in one converter switching period (usually 100–500 μs). Hence, based on Fig. 7 the algorithm can be splitted between all primary control units (PCU) containing inner control loops and SCU, which is mainly responsible for compensating the voltage amplitude and frequency deviation caused by droop control in PCU.

As a result, the time calculation in SCU may be reduced improving control dynamic and transient time. Proposed implementation of presented algorithm allows executing many processes parallel in PCUs. The block scheme of proposed control algorithm implemented in PC5Us and SCU is shown in Fig. 8.

The algorithm calculates the reactive power limit (7) and proportional reactive power value for unlimited cases (8) in each PCU independently. Furthermore, the auxiliary parame-ters Ps_k, Qs_k are defined (11), (12), based on actual reactive power reference value Q^*. In order to fulfill condition (10) the additional value of reactive power Q_k has to be added to value of unlimited case Q_{uk} for each unlimited converter. It is defined by (13) and depends on sum of active power of limited converters Ps_L, sum of reactive power of limited converters Qs_L, total active and reactive powers P_L and Q_L, reactive power value of unlimited case Qu_k and auxiliary parameter Qs_k. The parameter Q_k can be different for each k, proportionally to P_k, hence the PRPS for unlimited converters

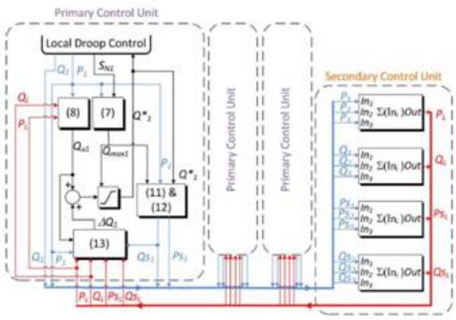


Fig. 8. Block diagram of developed reactive power sharing algorithm in real-time implementation.

is still satisfied. The final reference values of reactive powers are calculated, when the all conditions (9), (10) are fulfilled and the transferred data between PCUs and SCU do not change in next converter switching period. Furthermore, the steady-state of reactive power sharing in MG is obtained when the signals from controllers in inner control loops are established. This process may take a few hundred milliseconds, depending on the number of RES

$$Ps_k = \begin{cases} P_k \text{ if } Q^*_k = Q_{\max\, k} \\ 0 \text{ otherwise} \end{cases} \quad (12)$$

$$Qs_k = \begin{cases} Q^*_k \text{ if } Q^*_k = Q_{\max\, k} \\ 0 \text{ otherwise} \end{cases} \quad (13)$$

$$Q_k = \begin{cases} \frac{P_L - Ps_L}{P_k} \cdot (Q_L - Qs_L) - Q_{uk} & \text{if } Q_{uk} = Qs_k \\ Q_k \text{ otherwise} \end{cases} \quad (14)$$

$$Q_k^* = Q_{uk} + Q_k. \quad (15)$$

C. PRPS ALGORITHM IN REAL DISTRIBUTED CONTROL SYSTEM

In real distributed control system, several different pro-cessors in PCUs and remote SCU need to share their com-putational results. Any synchronization between PCUs and SCU are not required in presented solution. The delay can be neglected for modern communication infrastructure with transmission speed in range of megabit per second (Mb/s)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

and only few km distances between control units in all MG ele-ments. Therefore, application of distributed control system for developed algorithm was proposed (Fig. 8) what can allow for higher computational speed.

One of the possible communication problems is loss data in some periods. However, in presented solution, where the trans-ferred data are used only to calculations of referenced reactive powers for the lowest control loops in PCUs, it may cause the longer transient time (worse dynamic of control signals).

Another problem in distributed control system is different sampling time for PCUs (usually 5–10 kHz) and SCU [it can work with high sampling frequency (e.g., 40 kHz)]. These differences will not affect the proper operation of converters in MG.

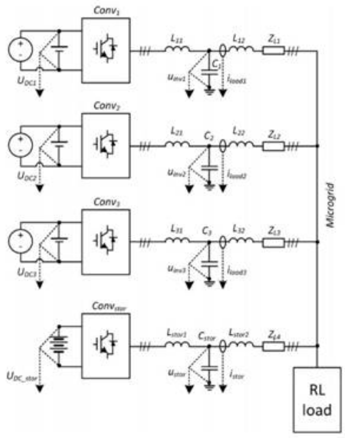


Fig. 9. Block scheme of simulation model.

TABLE I
SIMULATION MODEL PARAMETERS

Converter 1	
Nominal apparent power	6000 VA
Inductance L_{11}	2 mH
Capacitance C_1	10 µF
Inductance L_{12}	3 mH
Converter 2	
Nominal apparent power	11000 VA
Inductance L_{21}	3 mH
Capacitance C_2	10 µF
Inductance L_{22}	2 mH
Converter 3	
Nominal apparent power	3200 VA
Inductance L_{31}	4 mH
Capacitance C_3	10 µF
Inductance L_{32}	5 mH
Storage Converter	
Nominal apparent power	50000 VA
Inductance L_{stor1}	4 mH
Capacitance C_{stor}	10 µF
Inductance L_{stor2}	4 mH
Load power	
Active power	21500 W
Reactive power	6000 Var

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

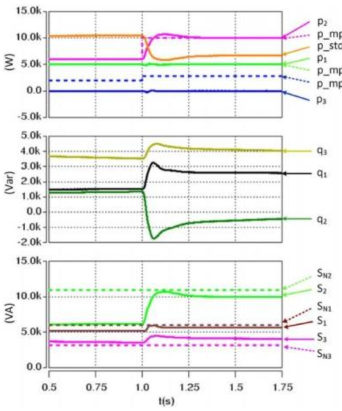
Vol. 5, Issue 12, December 2016

IV. SIMULATION RESULTS

The simulation model was built in Saber Synopsys to ver-ify described solution. The block scheme of simulation model is shown in Fig. 9. The three power converters connected to dc voltage sources (operating as a RES) and converter with storage was included in research. In order to meet the demand of active power the energy storage is unlimited in analysis, what provides the correct balance of active power in islanded MG. Furthermore, the line impedances (Z_{L1}, Z_{L2}, Z_{L3}, Z_{L4}) included in Fig. 9 can be neglected in low-voltage MG with LCL filters, where the impedances are much lower than filter impedances. In Table I, the parameters of simulation model are presented.

The simulation was performed and compared for three different control methods: 1) classical droop control; 2) ERPS [22]; and 3) proposed proportional power sharing. Firstly, the islanded MG presented by Fig. 9 was managed by basic droop control, without power management. For reac-tive power load connected to the MG, the uncontrolled reactive power sharing may result the overload of converter, even if the active power will be reduced to minimum.. It causes undesirable reactive power sharing in MG (the reactive power q_2 start to have capacitive character, what has to be compensated by other converters to keep the balance). Notice, that the reactive powers are equal when the active powers are equal as well (Fig. 11), which result from the proper selection of droop characteristics, but classical droop control cannot avoid the reactive power circulation. In Fig. 12, there are presented powers of converters in MG with ERPS algorithm [22]. In this solution in steady-state operation of converters the reactive powers q_1, q_2, and q_3 are equal independently on active powers. It prevents the reac-tive power circulation, but as it is shown in Fig. 12 after step change of active power, the equal reactive power of converters causes limitation of active power p_3, in order to not exciting the nominal level of apparent power. Hence, the RES cannot operate with maximum active power, calculated from MPPT algorithm [38].

Problems described above can be eliminated by using pro-portional power sharing algorithm, proposed in this paper. The solution prevents converters to be as reactive power load and provides maximum active powers from RES, keeping apparent power below nominal level as long as possible (Fig. 13).



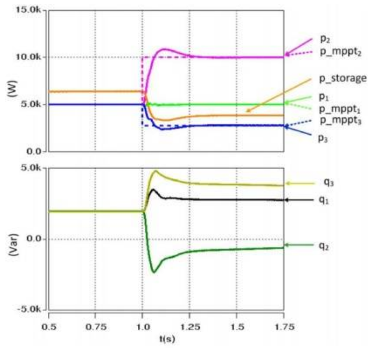


Fig. 10. Powers of converters in islanded MG without reactive power man-agement with step change of maximum active power from RESs: p_1, p_2, p_3,

$p_{storage}$, converters active powers; p_mppt$_1$, p_mppt$_2$, p_mppt$_3$, maximum active powers calculated from MPPT; q_1, q_2, q_3, converters reactive powers;
S_1, S_2, S_3, converters apparent powers; and $S_{N\,1}$, $S_{N\,2}$, $S_{N\,3}$, converters nominal apparent powers.

Fig. 11. Powers of converters in islanded MG without reactive power man-agement with step change of maximum active power from RESs and unlimited

nominal power: p_1, p_2, p_3, $p_{storage}$, converters active powers; p_mppt$_1$, p_mppt$_2$, p_mppt$_3$, maximum active powers calculated from MPPT; and
q_1, q_2, q_3, converters reactive power

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

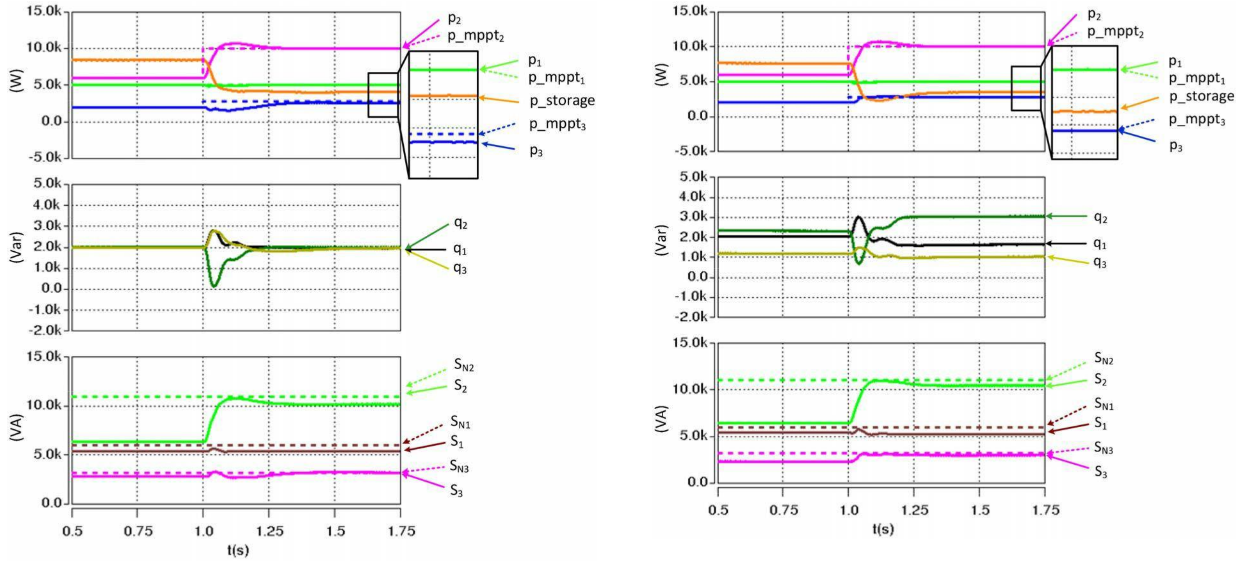


Fig. 13. Powers of converters in islanded MG without reactive power man-agement with step change of maximum active power from RESs: p_1, p_2, p_3,

$p_{storage}$, converters active powers; p_mppt_1, p_mppt_2, p_mppt_3, maximum active powers calculated from MPPT; q_1, q_2, q_3, converters reactive powers;
S_1, S_2, S_3, converters apparent powers; and $S_{N\,1}$, $S_{N\,2}$, $S_{N\,3}$, converters nominal apparent powers.

V. CONCLUSION

MG is the advance system for RES integration with own control structure. Usually the hierarchical control is imple-mented with droop control in primary level. In islanded mode of operation there is the need to manage reactive power shar-ing and allow RESs work with maximum active power. Hence, the new reactive power sharing algorithm was proposed in this paper, based on the analysis of power sharing between con-verters in MG. The novel solution prevents the reactive power circulation and disconnection or damage of any converter in MG. Moreover, it allows to converters operation with MPPT, causing better exploitation of each RES and keeping apparent power of each unit below nominal level as long as possi-ble. Because of short switching period of power electronics converters in RES, the algorithm was developed for imple-mentation in hierarchical control structure, providing parallel calculations in each PCU. Simulation analysis was performed, where the three solutions of power control in islanded MG were compared what confirms the correct operation of devel-oped algorithm and shows the advantage of proportional power sharing over others solution presented in literature.

REFERENCES

[1] Y. Xinghuo, C. Cecati, T. Dillon, and M. G. Simões, “The new frontier of smart grids,” *IEEE Ind. Electron. Mag.*, vol. 5, no. 3, pp. 49–63, Sep.
[2] F. Blaabjerg and J. M. Guerrero, “Smart grid and renewable energy systems,” in *Proc. Int. Conf. Elect. Mach. Syst. (ICEMS)*, Beijing, China, 2011, pp. 1–10.
[3] wp-content/uploads/2012/06/Annual_report_2011_lowres.pdf
[4] J. Kim, J. M. Guerrero, P. Rodriguez, R. Teodorescu, and K. Nam, “Mode adaptive droop control with virtual output impedances for an inverter-based flexible AC microgrid,” *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 689–700, Mar. 2011.
[5] J. Yaoqin, L. Dingkun, and P. Shengkui, “Improved droop control of parallel inverter system in standalone microgrid,” in *Proc. 8th Int. Conf. Power Electron. ECCE Asia*, Jeju, Korea, 2011, pp. 1506–1513.
[6] J. Seo, H. Lee, W. Jung, and D. Won, “Voltage control method using modified voltage droop control in LV distribution system,” in *Proc. Transmiss. Distrib. Conf. Expo. Asia Pac.*, Seoul, Korea, 2009, pp. 1–4.
[7] The European wind energy association. (Feb. 2013). *Wind in Power, 2012 European Statistics*. [Online]. Available: http://www.ewea.org/ fileadmin/files/library/publications/statistics/Wind_in_power_annual_ statistics_2012.pdf

[8] The European wind energy association. (Feb. 2012). *Wind in Power, 2011 European Statistics*. [Online]. Available: http://www.ewea.org/ fileadmin/files/library/publications/statistics/Wind_in_power_2011_ European_statistics.pdf

[9] ZPRYME and IEEE smart grid. (Nov. 2012). *Power Systems of the Future: The Case for Energy Storage, Distributed Generation and Microgrids*. [Online]. Available: http://www.admu.edu.ph/sites/default/ files/zprymepowersystems.pdf

[10] *Guide for Design, Operation, and Integration of Distributed Resource Island Systems With Electric Power Systems*, IEEE Standard 1547.4, 2011.

[11] A. Engler and N. Soultanis, "Droop control in LV-grids," in *Proc. Int. Conf. Future Power Syst.*, Amsterdam, The Netherlands, 2005, pp. 1–6.

[12] J. Kim, J. M. Guerrero, P. Rodriguez, R. Teodorescu, and K. Nam, "Mode adaptive droop control with virtual output impedances for an inverter-based flexible AC microgrid," *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 689–700, Mar. 2011.

[13] J. Yaoqin, L. Dingkun, and P. Shengkui, "Improved droop control of parallel inverter system in standalone microgrid," in *Proc. 8th Int. Conf. Power Electron. ECCE Asia*, Jeju, Korea, 2011, pp. 1506–1513.

[14] J. Seo, H. Lee, W. Jung, and D. Won, "Voltage control method using modified voltage droop control in LV distribution system," in *Proc. Transmiss. Distrib. Conf. Expo. Asia Pac.*, Seoul, Korea, 2009, pp. 1–4.

[15] C. Lee, C. Chu, and P. Cheng, "A new droop control method for the autonomous operation of distributed energy resource interface converters," in *Proc. Energy Convers. Congr. Expo. (ECCE)*, Atlanta, GA, USA, 2010, pp. 702–709.

[16] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuna, and M. Castilla,

[17] "Hierarchical control of droop-controlled AC and DC microgrids— A general approach toward standardization," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.

[18] W. C. Shan, L. X. Lin, G. Li, and L. Y. Wei, "A seamless operation mode transition control strategy for a microgrid based on master–slave control," in *Proc. Chin. Control Conf. (CCC)*, Hefei, China, 2012, pp. 6768–6775.

[19] V. Verma and G. G. Talpur, "Decentralized master–slave operation of microgrid using current controlled distributed generation sources," in

[20] Proc. IEEE Int. Conf. Power Electron. Drives Energy Syst. (PEDES), Bangalore, India, 2012, pp. 1–6.

[21] J. C. Vasquez, "Reactive power sharing and voltage harmonic distortion compensation of droop controlled single phase islanded microgrids," IEEE Trans. Smart Grid, vol. 5, no. 3, pp. 1149–1158, May 2014.

[22] J. Kim, J. M. Guerrero, P. Rodriguez, R. Teodorescu, and K. Nam, "Mode adaptive droop control with virtual output impedances for an inverter-based flexible AC microgrid," *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 689–700, Mar. 2011.

[23] J. Yaoqin, L. Dingkun, and P. Shengkui, "Improved droop control of parallel inverter system in standalone microgrid," in *Proc. 8th Int. Conf. Power Electron. ECCE Asia*, Jeju, Korea, 2011, pp. 1506–1513.

[24] N. Eghtedarpour and E. Farjah, "Power control and management in
a. hybrid AC/DC microgrid," *IEEE Trans. Smart Grid*, vol. 5, no. 3,
b. 1494–1505, May 2014.

[25] Q. C. Zhong, "Robust droop controller for accurate proportional load sharing among inverters operated in parallel," *IEEE Trans. Ind. Electron.*, vol. 60, no. 4, pp. 1281–1290, Apr. 2013.

BIOGRAPHY

Mr. B.M.SADIQUE he is pursuing M.Tech at Dr.samuel George institute of engineering &technology.Markapur,Jntu Kakinada University.

Mr. B.MANTHRU NAIK,M.Tech. Associate Professor Dr.samuel George institute of engineering &technology. Markapur,Jntu Kakinada University