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ANFIS CONTROLLER BASED REACTIVE POWER MANAGEMENT IN AUTONOMOUS MICROGRID

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Abstract: *This paper proposes different power management techniques such as equal power sharing, proportional power sharing in droop control for reactive power management in islanded microgrids. The droop control first implemented to the synchronous generators. And this project translates the droop control to the voltage source converter. Wind power generation and fuel cell power generating systems are used as distributed generation systems. In this paper the fuel cell may be considered with rated active power only.*

This paper proposes ANFIS controller and effectiveness of this controller is compared with PI controller.

Keywords: *Adaptive Neuro Fuzzy System (ANFIS), Proportional Integral controller (PI Controller), Voltage Source Converter (VSC).*

I.INTRODUCTION

Microgrid (MG) is a separate system that produces and storages electrical energy, which consists of renewable energy sources (RES), local loads, and energy storage based on batteries or super capacitors. 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 number 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 storage, protection and control technologies, and improving their performances [8]. MG is highly advanced system from control and communication 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 parallel, 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 control. The first solution includes only one converter with voltage control loop (VCL), operating as a master, and others operating 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 coupling (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 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 circulation 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 appropriate power sharing and minimize the risk of converter damage the many additional aspects (e.g., nominal apparent power instantaneous active power, nominal voltage of converter) have to be considered in control system. There are only few papers describing reactive power

sharing between parallel operating converters in islanded ac MGs. The researchers focused on ERPS between all RES usually controlled by MG central control unit [20]–[22] or imple- mented as virtual impedances [15]. From the other hand, researches consider reactive power sharing in order to optimize
transmission power losses by appropriate optimization algorithm (e.g., particle swarm optimization), which can be neglected in MGs, hence the short distances and the line impedances are low.

The new reactive power sharing algorithm is developed and presented in this paper.

II. POWER MANAGEMENT TECHNIQUES

EQUAL POWER SHARING:

The adoption of droop controls not enough to complete the performance of reactive power sharing among the inverters. The performance of reactive power sharing can be improved with (secondary control) power management techniques such as equal power sharing (EPS) and proportional power sharing (PPS). The EPS algorithm can produce a reactive power reference and it is described in (1).

$$Q_{ref} = \frac{1}{k}\sum_{k-1}^{k} q_k \frac{Q_{total}}{k} \qquad (1)$$

The block scheme of hierarchical control structure with droop method and equal reactive power sharing algorithm is shown in figure 1.It must be noticed, that additional communication links between the secondary controller and control units of each inverter must be applied in this approach, what is a drawback of this solution. However, accurate power sharing may be obtained, providing better exploitation of DG units in microgrid system.

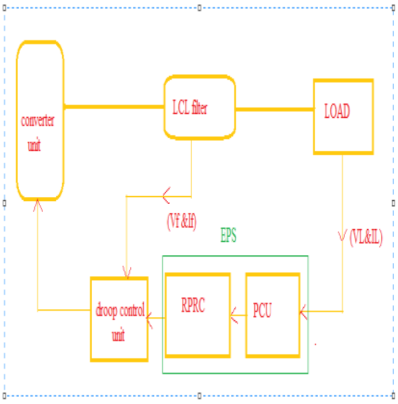

Fig 1 Block scheme of equal reactive power sharing.

PROPORTIONAL POWER SHARING:

The vector sum of converters apparent power is equal to the load apparent power in power balanced network irrespective of power management techniques. But algebraic sum of apparent powers are different for power management techniques. The damage of converter may occurs when the sum of apparent power greater than load apparent power. The improvement in reactive power sharing can be achieved by the relation $S_{demand} / \sum S_{converters}$ at maximum level.

The situation that when apparent power of converters is lower than the nominal values the above relation is equal and the reactive power sharing of converters is proportional to the active power of the respective converter and it is described in (2).

$$Q_i = \frac{Q_L}{P_L} P_i (2)$$

The over loading of converter can be prevented with the condition (3) and reactive power balance of MG can fulfilled with (4).

$$P_i^2 + Q_i^2 = S_i^2 \le S_{Ni}^2 \qquad (3)$$

$$\text{sum } Q_i = Q_L \ (4)$$

The proportional power sharing algorithm entirely depends on (2) and (4). The flow chart of control algorithm is illustrated in fig 2.

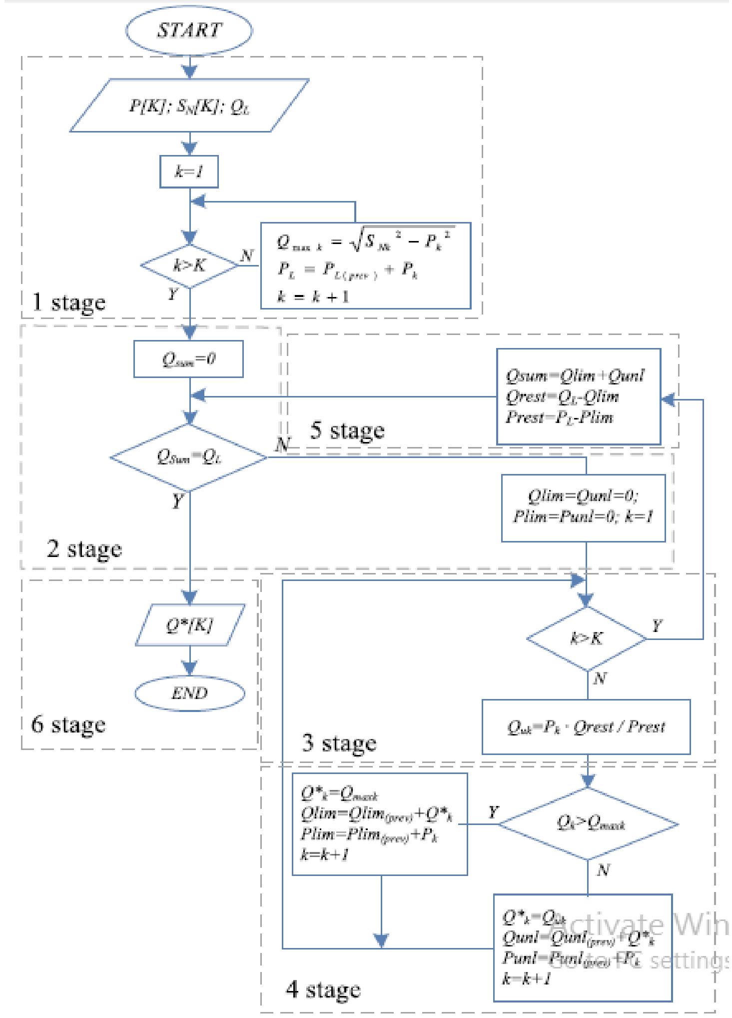

Fig.2 Flow chart

III. ANFIS CONTROLLER

ANN has strong learning capabilities at the numerical level. Fuzzy logic has a good capability of interpretability and can also integrate expert's knowledge. The hybridization of both paradigms yields the capabilities of learning, good interpretation and incorporating prior knowledge. ANN can be used to learn the membership values for fuzzy systems, to construct IF-THEN rules, or to construct decision logic. The true scheme of the two paradigms is a hybrid neural/fuzzy system, which captures the merits of both the systems. This concept is made use of in developing the ANFIS controller in this chapter. A neuro-fuzzy system has a neural-network architecture constructed from fuzzy reasoning. Structured knowledge is codified as fuzzy rules, while the adapting and learning capabilities of neural networks are retained. Expert knowledge can increase learning speed and estimation accuracy.

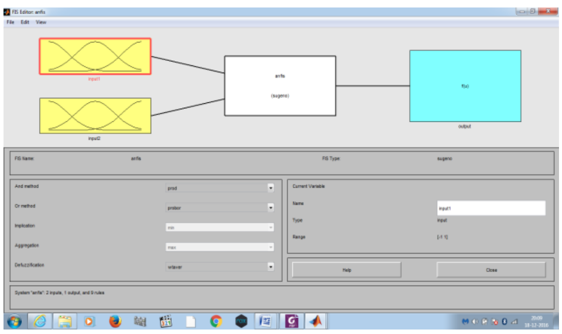

Fig.3 ANFIS Controller structure

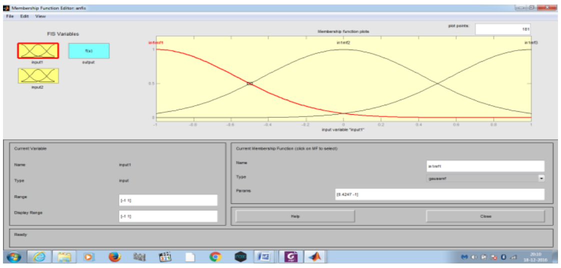

Fig.4 input1 membership function

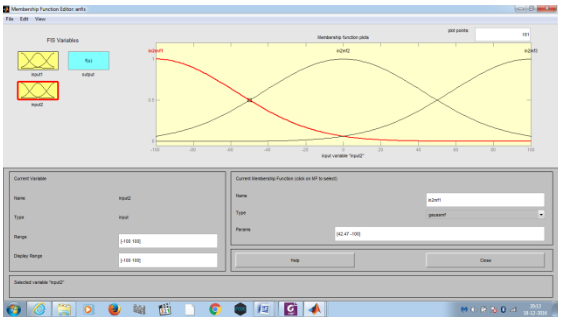

Fig.5 input2 membership function

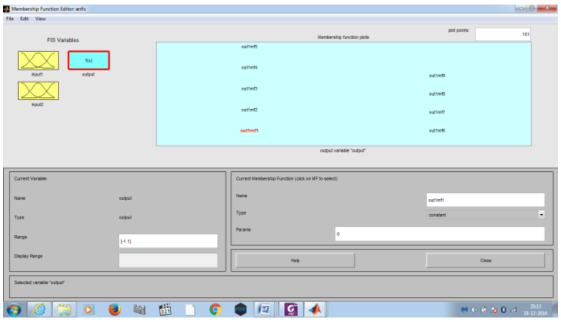

Fig.6 output membership function

IV. SIMULATION RESULTS

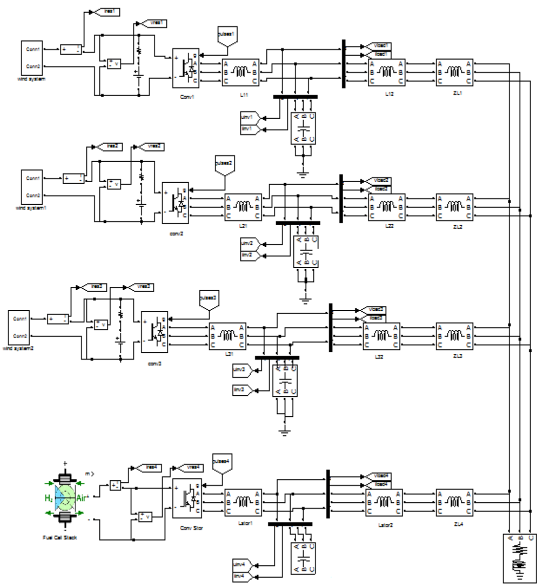

Fig.7 Block scheme of simulation model.

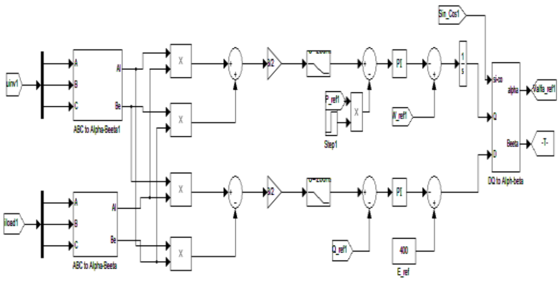

Fig.8 Discrete PI based droop control

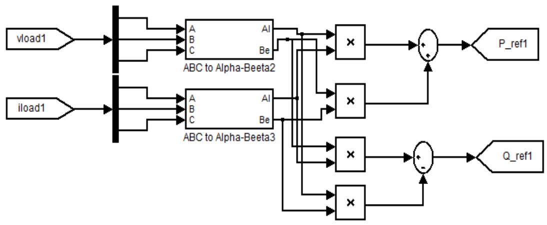

Fig.9 Equal power sharing

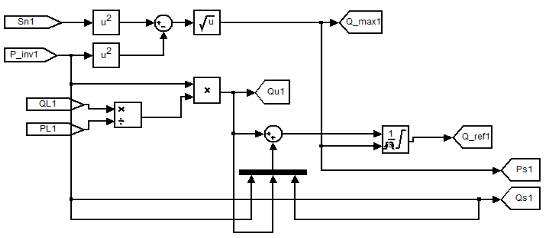

Fig.10 Proportional power sharing

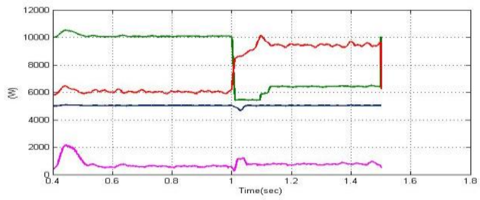

Fig. 11a Droop control

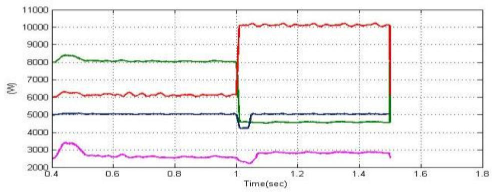

Fig. 11b Equal power sharing

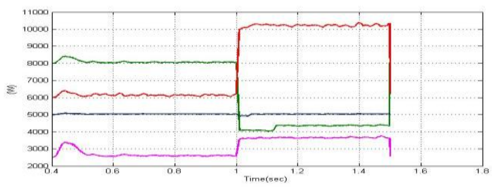

Fig. 11c Proportional power sharing

Fig.11 comparison of real powers shared by the converters with droop control (without PMT and with PMT)

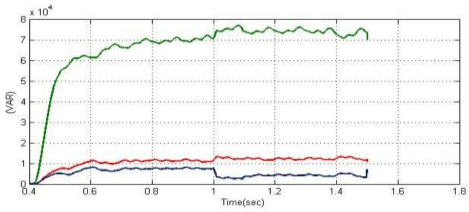

Fig. 12a Droop control

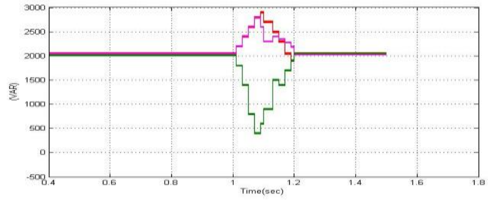

Fig. 12b Equal power sharing

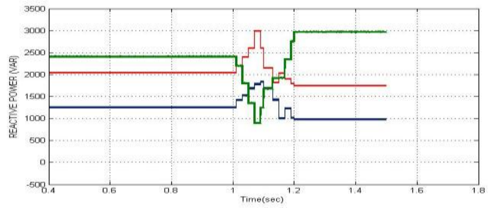

Fig. 12c Proportional power sharing

Fig.12 Comparison of reactive powers shared by the converters with droop control (without PMT and with PMT)

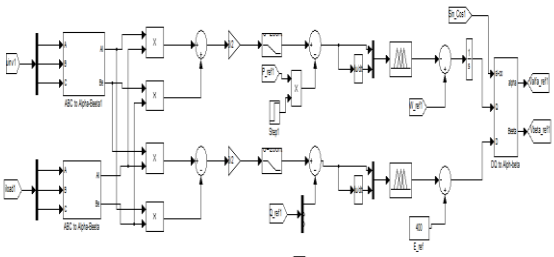

Fig.13 ANFIS based droop control

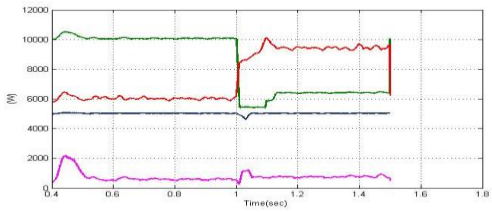

Fig. 14a Droop control

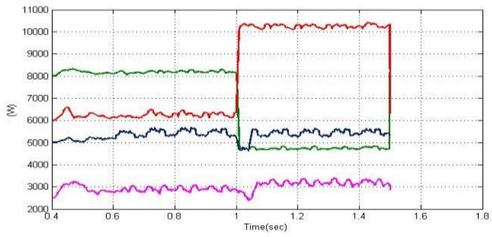

Fig. 14b Equal power sharing

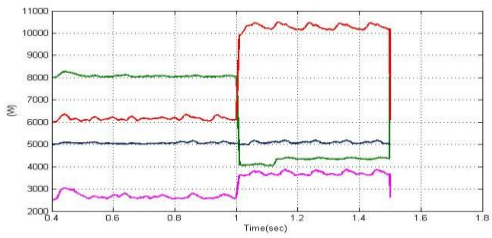

Fig. 14c Proportional power sharing

Fig.14 Comparison of real powers shared by the converters with droop control (without PMT and with PMT)

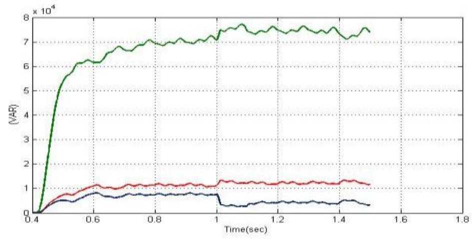

Fig. 15a Droop control

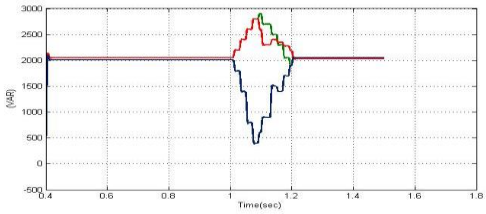

Fig. 15b Equal power sharing

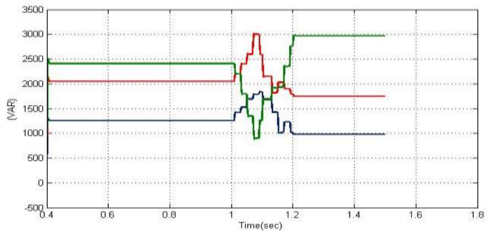

Fig. 15c Proportional power sharing

Fig 6.10 Comparison of reactive powers shared by the converters with droop control (without PMT and with PMT)

V. CONCLUSION

This project presented different power management techniques such as equal power sharing, proportional power sharing in droop control for reactive power management in islanded microgrids. In this project wind power generation and fuel cell power generating systems are used as distributed generation systems. The simulation ware carried out in order to examine different power management techniques in islanded mode of operation. The droop control used the both discrete PI and ANFIS controller's. The results indicated that the performance of power management techniques is better as compared to classical droop. The performance with ANFIS controller is better as compared to discrete PI controller.

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