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Power management based on ANFIS controllers in autonomous microgrids

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Abstract: In order to manage reactive power in islanded microgrids, this research suggests various power management strategies, including proportional and equal power sharing in droop control. The synchronous generators were the first to use the droop control. Additionally, this project converts the voltage source converter to droop control. Fuel cell and wind power generation systems are examples of dispersed generation systems. Only the fuel cell's rated active power may be taken into consideration in this article.
The ANFIS controller is proposed in this study, and its efficacy is contrasted with that of the PI controller.

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

I.INTRODUCTION

Renewable energy sources (RES), local loads, and energy storage based on batteries or super capacitors make up a microgrid (MG), a distinct system that generates and stores electrical energy. It is a fundamental component of contemporary and widely used smartgrids [1], [2], which also include electrical vehicle stations, intelligent buildings, etc. Every RES uses power electronics components, such as converters, whose numbers are steadily rising and whose costs are falling by 1% to 5% annually [3]–[7]. RES are often grid-connected, and numerous installations result in RES operating in parallel near one another. This is one of the reasons why the traditional structure of electrical power systems will eventually be changed in favor of new solutions that incorporate energy storage, distributed generation, protection, and control technologies, all of which will improve the systems' performance [8]. From the perspective of control and communication, MG is a very sophisticated system. Particularly when MG functions as an islanded system, it must accurately and efficiently control all converters in addition to managing power for local loads. During grid failures, the islanding mode of operation offers local loads an uninterrupted power supply. IEEE Standard 1547.4 [9] specifies the performance requirements for islanded MG. The MGs are now the ideal choice for RES integration due to the growing number of RES applications, their parallel operation, their close proximity (few kilometers), and their evolved islanded mode of operation. The foundational algorithms of ac MGs, as detailed in [10]–[20], are based on hierarchical droop control or master–slave control. Only one converter with a voltage control loop (VCL) functions as a master in the first solution, while the others are slaves to the current control loop (CCL). Sources with CCL regulate the generated power, and the master unit maintains the voltage amplitude and frequency within the point of common coupling (PCC). The inability to link additional VCL sources—the most widely used and well-liked RES solutions—to MG is a drawback of this solution. Numerous VCL sources are included in the second control option, droop control, which also offers the ability to link a wide variety of RES. Active and reactive power in relation to voltage frequency and amplitude droop on coupled impedances is the foundation of the droop control concept. Regretfully, appropriate reactive power sharing between converters linked to a common ac bus is not provided by the traditional droop control method with proportional droop coefficients. Only when active powers are equal and droop coefficients are carefully selected can equal reactive power sharing (ERPS) be achieved using the classical approach. Overload or reactive power circulation between converters results from the inability to regulate reactive power sharing when active powers fluctuate. Furthermore, the static trade-off between reactive power and voltage regulation is a crucial problem in droop control [21]. Overvoltage may result from the voltage droop on the converter's output impedance increasing in tandem with reactive power. Numerous other factors (such as the nominal apparent power, instantaneous active power, and nominal voltage of the converter) must be taken into account in the control system in order to offer suitable power sharing and reduce the danger of converter damage.

Reactive power sharing across parallel running converters in islanded ac MGs is described in relatively few works. The researchers concentrated on ERPS between all RES, which are often implemented as virtual impedances [15] or managed by the MG central control unit [20]–[22]. On the other hand, studies take into account reactive power sharing

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to improve transmission power losses using the proper optimization algorithm (such as particle swarm optimization), which can be disregarded in MGs; as a result, line impedances are low and distances are short.

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.

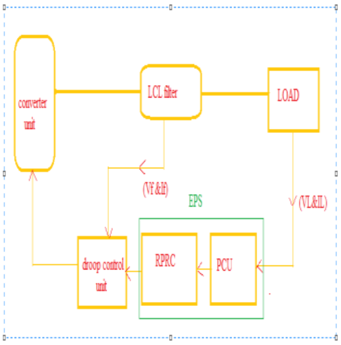

Fig 1 Block scheme of equal reactive power sharing.

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

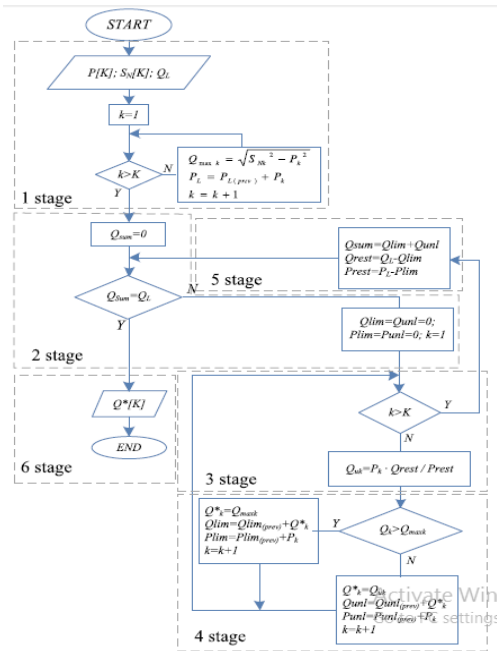

Fig.2 Flow chart

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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.

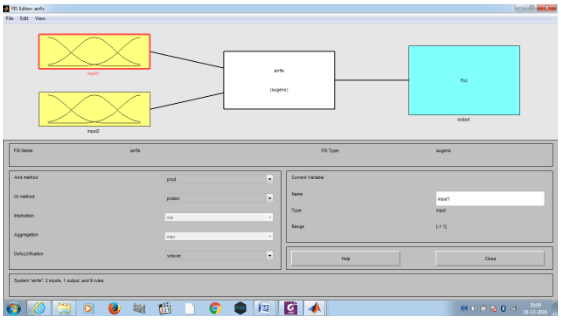

Fig.3 ANFIS Controller structure

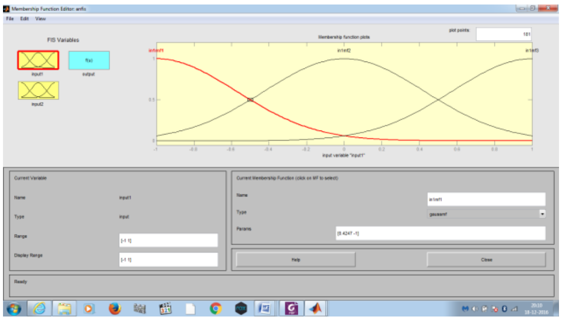

Fig.4 input1 membership function

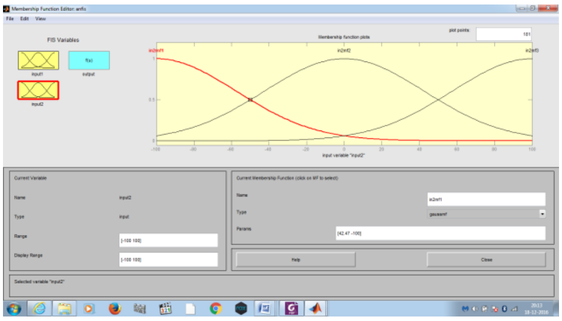

Fig.5 input2 membership function

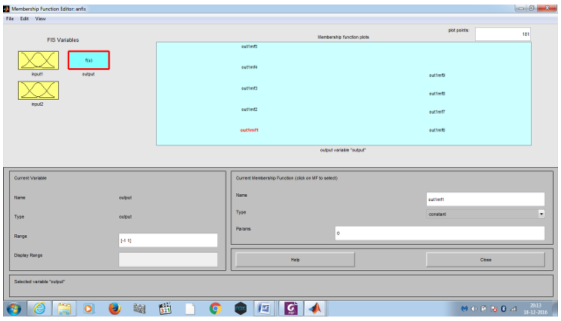

Fig.6 output membership function

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IV. SIMULATION RESULTS

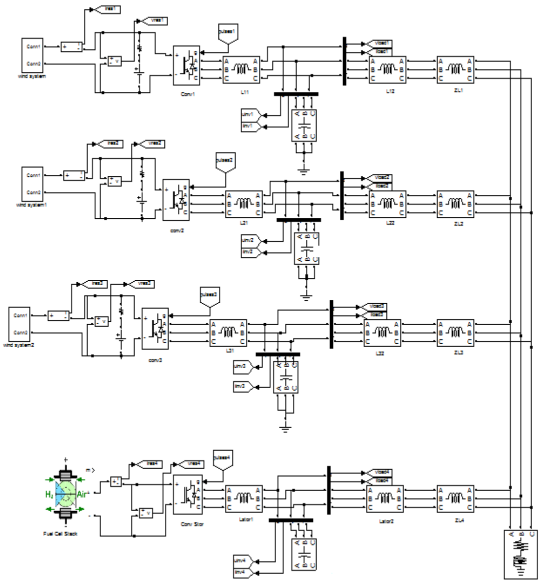

Fig.7 Block scheme of simulation model.

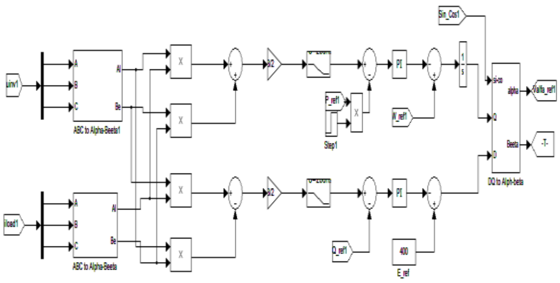

Fig.8 Discrete PI based droop control

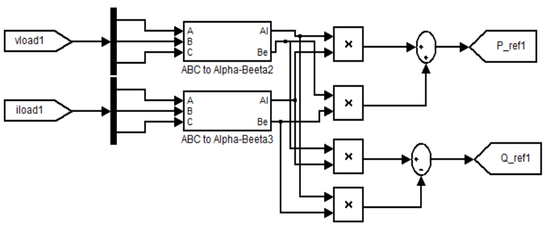

Fig.9 Equal power sharing

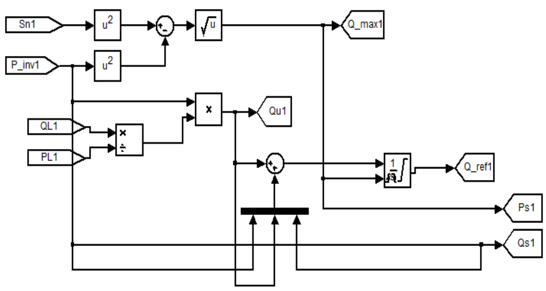

Fig.10 Proportional power sharing

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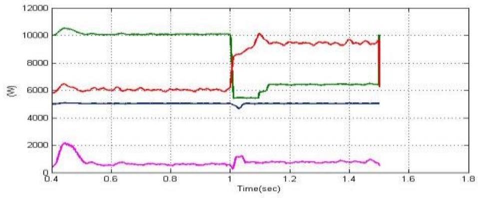

Fig. 11a Droop control

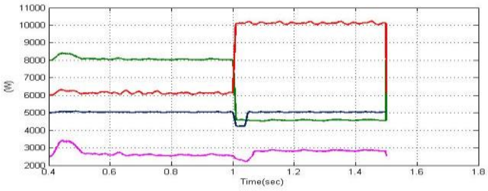

Fig. 11b Equal power sharing

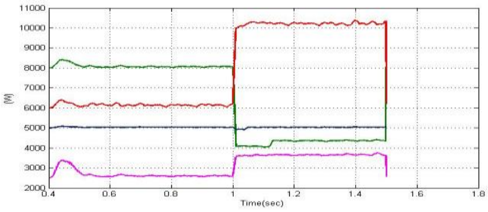

Fig. 11c Proportional power sharing

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

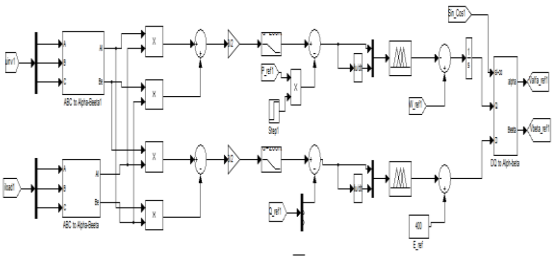

Fig.12 ANFIS based droop control

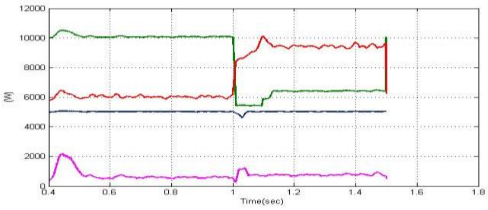

Fig. 13 Droop control

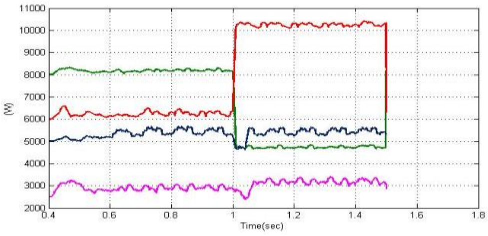

Fig. 14 Equal power sharing

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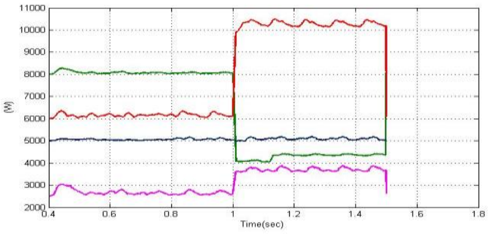

Fig. 15 Proportional power sharing

Fig.13-15 Comparison of real powers shared by the converters with droop control (without PMT and with PMT)

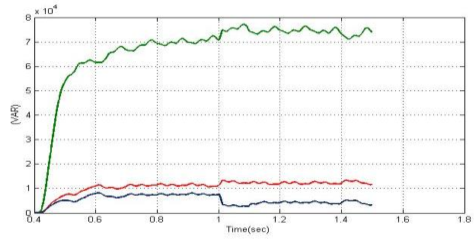

Fig. 16 Droop control

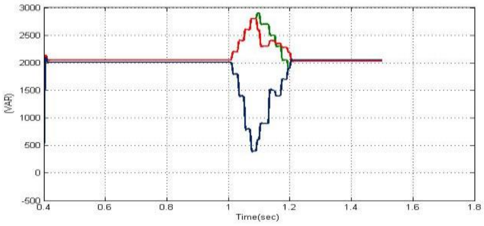

Fig. 17 Equal power sharing

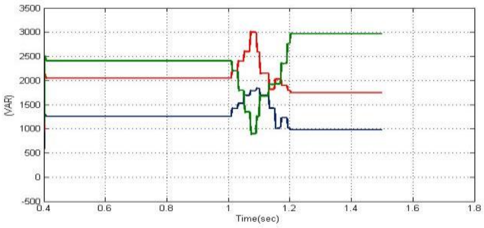

Fig. 18 Proportional power sharing

Fig 16-18 Comparison of reactive powers shared by the converters with droop control (without PMT and with PMT)

V. CONCLUSION

Several power management strategies, including proportional and equal power sharing in droop control for reactive power management in islanded microgrids, were demonstrated in this study. This project uses fuel cell power generating systems and wind power generation as distributed generation systems. The purpose of the simulation was to investigate various power management strategies in islanded mode of operation. Both the discrete PI and ANFIS controllers were employed for the droop control. The findings showed that power management strategies outperform classical droop in terms of performance. When compared to a standalone PI controller, the ANFIS controller performs better.

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