An Anfis Controlled Modified Unified Interphase Power Controller (UIPC) For Hybrid Grid

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ABSTRACT

This work introduces a new approach for power flow control of interconnected AC-DC micrograms .By implementing a ANFIS (adaptive neuro fuzzy) controlled modified unified interphase power controller (UIPC) for Power Quality Improvement which uses three power converters in each phase, is modified so that a reduced number of power converters is implemented for power exchange control between AC-DC microgrids. The modified structure includes one power converter in each phase, named as), and a power converter which regulates the DC bus voltage, named as bus power converter (BPC). A Adaptive fuzzy logic controller is used in the control structure of the LPCs. The MATLAB simulation results confirm the effectiveness of the proposed power flow control strategy of the improved UIPC for hybrid microgrids.

KEYWORDS: *Line Power Converter (LPC), Bus Power Converter (BPC), Unified Intephase Power Controller (UIPC)*

I. INTRODUCTION

An alternating current-direct current (AC-DC) hybrid microgrid provides an effective way to solve the problems caused by large-scale distributed generation and DC load access, and this microgrid has become the mainstream of distribution network terminal development. With the large-scale operation of distributed generation, the progress of power electronics technology and the large amount of DC load access, the traditional AC distribution network has been unable to meet the demand for power system development. The DC distribution network has certain advantages in energy transmission and fast control, which can improve system stability and reduce the utilization of power electronic devices such as converters. Therefore, to meet the demand for a high proportion of distributed generation access and a large amount of DC load access, collaborative optimization planning between AC/DC hybrid microgrids and AC/DC distribution networks has become a research hotspot in recent years . However, research on the interconnection structure, operation control and fast protection of the two hybrid power grids by domestic and foreign scholars is still in the initial stage, and a large number of problems of coordinated planning and control need to be solved urgently

A. Control of microgrids

Control of microgrids becomes a critical issue for ensuring reliable operation of the microgrid. A variety of research has been conducted particularly on the subject of the control system and power management in order to improve the system stability . Each AC and DC microgrid has different hierarchical controls, but those could be generalize into three levels in reference to the hierarchical control standard of international society of automation (ISA)-95: (1) the primary control is based on the droop method, including an output-impedance virtual loop; (2) the secondary control allows the restoration of the deviations produced by the primary control; and (3) the tertiary control manages the power flow between the microgrid (MG) and the external electrical distribution system.

B. Control Strategy for AC/DC Hybrid Microgrids

The AC microgrid is connected to the main grid through the LPCs which their DC buses are linked and can operate in capacitance mode(CM) or inductance mode (IM). In hybrid AC/DC microgrids, AC and DC buses are connected through interlink AC/DC bidirectional converters (ICs). The IC should be able to control and manage power properly in both operating mode, grid-connected mode and stand-alone mode . Operating the microgrid in stand-alone mode would lead to more challenges, particularly when the imbalance of generation and consumption happen because of flexible load and DERs. Various droop control methods have been proposed to maintain the system stability by sharing power between AC and DC subgrids, as in . Incorporating an energy storage system into the IC will improve its control performance; meanwhile, DC link capacitors support the voltage regulation

II. SYSTEM CONFIGURATION

Control of nonlinear systems based on conventional mathematical tools is a difficult problem because no systematic tools are available to deal with ill-defined and uncertain systems. By contrast, a fuzzy inference system employing fuzzy if-then rules can model the qualitative aspects of human knowledge and reasoning processes but lacks standard design procedure to employ precise quantitative analyzes. Neural networks work by detecting patterns in data, learning from the relationships and adapting to them. This knowledge is then used to predict the outcome for new combinations of data . In particular, the control technique based on fuzzy modeling or fuzzy identification was first systematically introduced by Takagi and Sugeno , has found numerous applications in fuzzy control, for medical diagnosis , decision-making and solve problems based on data mining . However, there are some basic aspects of this approach which are in need of better understanding. More specifically, the lack of standard design procedure and optimization process to transform human knowledge or experience into rule base and the data base of the fuzzy inference system. It is hard to interpret tuning of membership function so as to minimize output error index and to choose appropriate network"s structure.

A. Adaptive Network based Fuzzy Inference System

The adaptive network based fuzzy inference system (ANFIS) is a data driven procedure representing a neural network approach for the solution of function approximation problems. Data driven procedures for the synthesis of ANFIS networks are typically based on clustering a training set of numerical samples of the unknown function to be approximated. Since introduction, ANFIS networks have been successfully applied to classification tasks, rule-based process control, pattern recognition and similar problems. Here a fuzzy inference system comprises of the fuzzy model proposed by Takagi, Sugeno and Kang to formalize a systematic approach to generate fuzzy rules from an input output data set.

ANFIS structure For simplicity, it is assumed that the fuzzy inference system under consideration has two inputs and one output. The rule base contains the fuzzy if-then rules of Takagi and Sugeno's type as follows:

If x is A and y is B then z is f(x,y)

where A and B are the fuzzy sets in the antecedents and z = f(x, y) is a crisp function in the consequent. Usually f(x, y) is a polynomial for the input variables x and y. But it can also be any other function that can approximately describe the output of the system within the fuzzy region as specified by the antecedent. When f(x,y) is a constant, a zero order Sugeno fuzzy model is formed which may be considered to be a special case of Mamdani fuzzy inference system [144] where each rule consequent is specified by a fuzzy singleton. If f(x,y) is taken to be a first order polynomial a first order Sugeno fuzzy model is formed. For a first order two rule Sugeno fuzzy inference system, the two rules may be stated as: Rule 1: If x is A1 and y is B1 then f1 = p1x + q1y + r1 Rule 2: If x is A2 and y is B2 then f2 = p2x + q2y + r2 Here type-3 fuzzy inference system proposed by Takagi and Sugeno is used. In this inference system the output of each rule is a linear combination of the input variables added by a constant term. The final output is the weighted average of each rule's output. The corresponding equivalent ANFIS structure is shown in Fig.

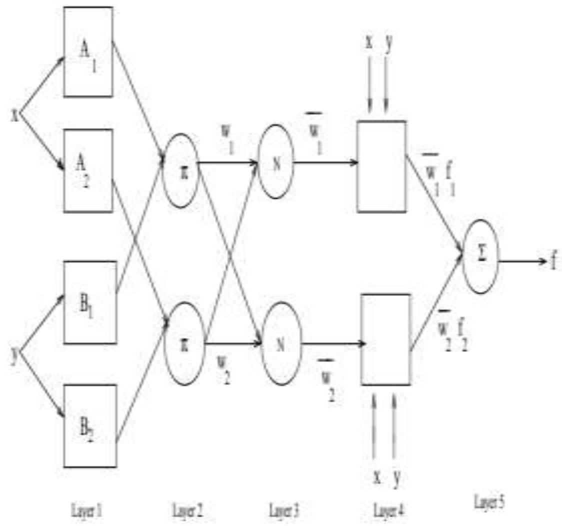

Fig.1 Type-3 ANFIS Structure

Derivation of the Initial Fuzzy Model As described earlier, in ANFIS based system modeling for a set of rules with fixed premise parameters, identification of an optimal fuzzy model with respect to the training data reduces to a linear least-squares estimation problem. A fast and robust method for identification of fuzzy models from input-output data was proposed by S.L.Chiu . This method selects the important input variables when building a fuzzy model from data by combining cluster estimation method with a least squares estimation algorithm. The method follows in two steps : i) First step involves extraction of an initial fuzzy model from input output data by using a cluster estimation method incorporating all possible input variables. ii) In the next step the important input variables are identified by testing the significance of each variable in the initial fuzzy model.

Learning Algorithm of ANFIS Neuro-adaptive learning techniques endow with a method for the fuzzy modeling procedure to learn information about a data set. It computes the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. The parameters associated with the membership functions changes through the learning process [19]. In order to more efficiently cope with real world problems, the task of the learning algorithm for this architecture is to tune all the modifiable parameters, to formulate the ANFIS output match the training data. Toimprove the rate of convergence, the hybrid network can be trained by a hybrid learning algorithm combining least square method and gradient descent method can be used. The least squares method can be used to identify the optimal values of the consequent parameter on the layer 4 with premise parameter fixed. Gradient vector provides a measure of how well the fuzzy inference system is modeling the input/output data for a given set of parameters. When the gradient vector is obtained, any of several optimization routines can be applied in order to adjust the parameters to reduce some error measure When the premise parameters are not fixed, then the search space becomes larger and the convergence of the training becomes slower. The hybrid algorithm is composed of a forward pass (LSM) and a backward pass (GDM). Once the optimal consequent parameters are found, backward pass starts. In the backward pass, errors are propagated backward and the premise parameters corresponding to the fuzzy sets in the input domain updated by gradient descent method . ANFIS uses a combination of least squares estimation and back-propagation for membership function parameter estimation

III. SIMULATION RESULTS

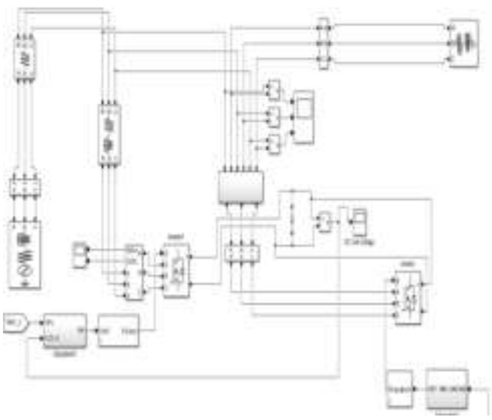

Fig .2 Simulation model

Figure.2 depicts the overall working model of our proposed system using MATLAB Simulink

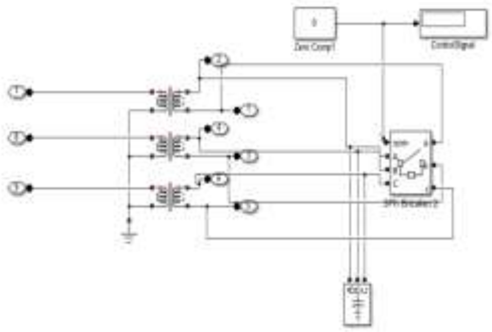

Fig.3 schematic grid

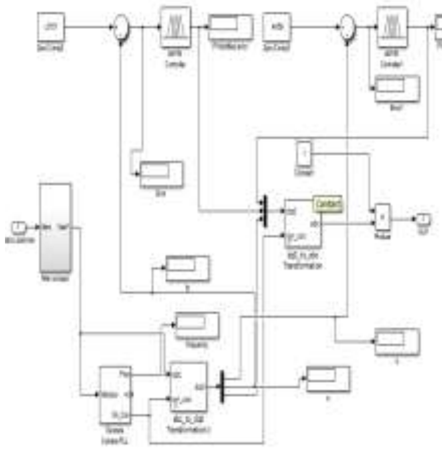

Fig.4 ANFIS loop

ANFIS controller for closed loop power flow controller.

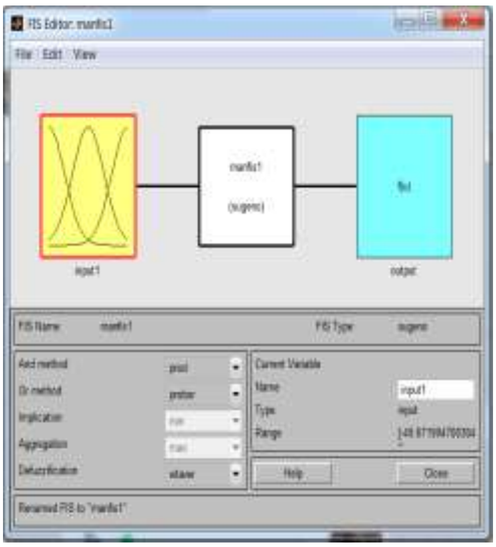

Fig.5 ANFIS command window

The membership function assigned for our ANFIS control system. It shows final grid voltage and current waveform by ANFIS controller

IV. CONCLUSION

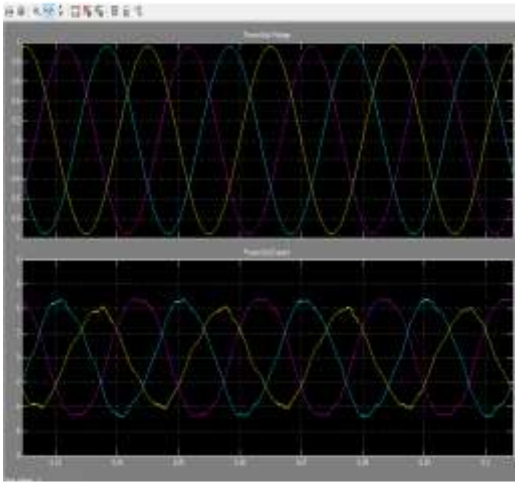

Fig.6 Grid Output Voltage

The hybrid microgrid structure is the most probable option in the future smart grids to gather together the renewable resources as well as AC/DC loads. This is due to the fact that this structure has the merits of both AC and DC microgrids simultaneously. One conventional problem with this structure is the power exchange control between interconnected AC and DC microgrids. In this work, a ANFIS controlled UIPC solution has been proposed as a superior alternative to the parallel-connected power converters which have brought many problems. A modified structure of the UIPC has firstly been proposed and then effective control strategies have been introduced for the modified UIPC. The simulation results validated the modified model as well as the power exchange control performance between AC and DC microgrids.

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