ANFIS based MPPT and Droop Controller for Power Sharing in Interline Power System

M.Gowri[1] V.Vinothkumar[2] Dr.K.Punitha[3]
[1]P.G. Scholar [2]Assistant Professor [3]Professor
[1,2,3]Department of Electronics and Electrical Engineering
[1,2,3]P.S.R.Rengasamy College of Engineering for Women, Sivakasi, India

Abstract— Recent years have seen a rapidly growing number of hybrid neuro fuzzy based applications in the process engineering field, covering estimation, modeling and control among others. By this technology integrates distributed generations, energy storage elements and loads. In this paper, dynamic performance enhancement of a grid consisting of wind turbine was investigated using permanent magnet synchronous generation (PMSG) and photovoltaic (PV). In order to maximize the output of solar array and wind, maximum power point tracking (MPPT) technique was used by an adaptive neuro-fuzzy inference system (ANFIS). These proposed methodology based reference model is trained to generate maximum power corresponding to varying the values of solar and wind. Simulation results reveal that the response of proposed ANFIS based MPPT method is more accurate and fast as compared to the conventional techniques like Incremental Conductance (IC). The analytical and simulation results of this research are presented to validate the concept. The proposed method also precedes the performance of the error reduction by the function of droop control method which exist the equal power sharing. The improved droop control can share active and reactive power to improve the power quality of the grid and also have a good dynamic performance.

Key words: ANFIS, MPPT, Droop control, Photovoltaic and Wind power generation, Active and Reactive power control, Interline power system, Voltage Regulation

NOMENCLATURE

- ISC Short Circuit Current
- ID Diode Current
- VD Diode Voltage
- Rs Internal Series Resistance
- Ns Number of cell in series
- Pw Power
- ρ Air density
- $A\omega$ Swept area
- Cp Power Coefficient
- Λ Tip Speed Ratio
- Δ power angle
- P Real Power
- Q Reactive Power

I. INTRODUCTION

Nowadays, the world is looking for energy alternative sources as the energy demand continues to grow. Wind, PV, MTG are three of the most promising renewable power generation technologies due to their advantages. However, each of the aforementioned technologies has its own drawbacks. Interconnection networks of distributed energy resources, energy storage systems and loads define an MG that can operate in stand-alone or in grid-connected mode [1, 2]. An MG is disconnected automatically from the main distribution system and changed to islanded operation when a fault occurs in the main grid or the power quality of the grid falls below a required standard. In the grid connected mode, the grid dominates most of the system dynamics and no significant problem needs to be addressed except the power flow control, whereas in the islanding mode, once the isolating switch disconnected the utility from the MG [3, 4].

Developing PV energy sources can reduce fossil fuel dependency [5]. In recent years, many different technics have been applied in order to reach the maximum power. The most prevalent technics are perturbation and observation (P&O) algorithm [6, 7], Incremental conductance (IC) [8, 9], fuzzy logic [10, 11] and artificial networks (ANN) [12]. According to the above mentioned researches, the benefits of perturbation and observation algorithm and incremental conductance are: 1 – low cost implementation, and 2 – simple algorithm. The depletion of these methods is vast fluctuation of output power around the MPP even under steady state, resulting in the loss of available energy [13].

Using fuzzy logic can solve the two mentioned problems dramatically. In fact, with fuzzy logic controller, proper switching can reduce oscillations of output power around the MPP and losses. Furthermore, in this way, convergence speed is higher than the other two ways mentioned. Neural networks can be integrated with fuzzy logic and through the combination of these two smart tools, a robust AI technique called ANFIS can be obtained. In [14], the structure of ANFIS has been used, but one of the major drawbacks in these articles is that they were not connected to the grid in order to ensure the analysis of system performance, which was not considered.

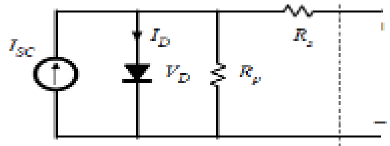

Fig. 1: Equivalent circuit for PV cell

In terms of wind power generation system (WPGS), it is proposed as one of the outstanding renewable energy sources. One of the approaches used to reach the MPP is pitch angle control, in which small turbines with low power delivery are not possible due to mechanical difficulties in production.

This paper propose ANFIS based droop control method and MPPT for I-PV and Wind systems in which both active and reactive power are used to control the PCC voltage. The necessary active power for the compensation is drawn from the interconnected feeder via the PV solar plant inverter. A study to evaluate the performance of the novel droop control method is accomplished using MATLAB / Simulink simulation. The paper is organized as follows.

All rights reserved by www.ijsrd.com

System Configuration is discussed in Section II. System Model is given in Section III. Section IV discusses the Result and Discussion. Section V concludes the paper.

II. SYSTEM CONFIGURATION

A. PV Power Plant

The solar cell arrays or PV arrays are usually constructed out of small identical building blocks of single solar cell units are shown in fig 1. They determine the rated output voltage and current that can be drawn for some given set of atmospheric data. The rated current is given by the number of parallel paths of solar cells and the rated voltage of the array is dependent on the number of solar cells connected in series in each of the parallel paths [11].The characteristics of solar cell and diode explained in following equations:

$$I_{SC}-I_D-(V_D/R_s)-I_{PV}=0 \quad (1)$$

$$I_D=I_o(e^{(V_D/V_T)}-1) \quad (2)$$

$$V_{PVcell}=V_D-(R_s*I_{PV}) \quad (3)$$

$$V_{PV}=N_sV_{PVcell} \quad (4)$$

B. Wind Power Plant

Wind energy is one of the classic mass synchronous generator models combined with turbine models for rotor and aerodynamic energy, converter models for the back to back converter and dc link. Wind energy penetration in the grid increases then the additional challenges are being revealed that are quick response to grid disturbances, real power and reactive power control based on the frequency and voltage control. The power calculation and the tip speed ratios are defined in the following equation

$$P\,w = 1/2\,\rho\,air \cdot A\,r \cdot c\,p\,(\lambda\,\vartheta) \cdot v_w^{3} \quad (5)$$

$$\lambda = w_{rot} \times r/v_w \quad (6)$$

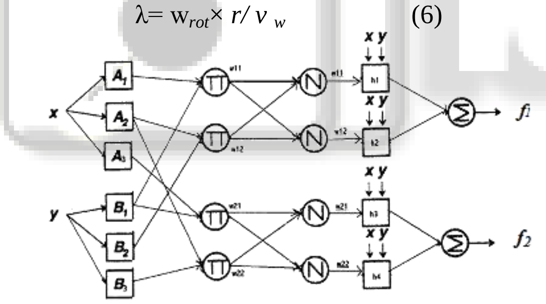

Fig. 2: Architecture of the ANFIS structure

C. Droop Control Method

Droop control strategy is proposed to enhance the dynamic performance of the parallel inverters in micro grids without communication wire interconnections. A wireless controller is developed by taking the active and reactive current as the control variables, the droop control variables is taken to ensure the power sharing accuracy and additional terms are added to the droop controller to enhance the dynamic performance[7].

D. ANFIS Estimator

Adaptive Network-Based Fuzzy Inference Systems (ANFIS) is used to solve problems related to parameter identification. This parameter identification is done through a hybrid learning rule combining the back-propagation gradient descent and a least-squares method. It is a kind of adaptive network in which each node performs a particular function of the incoming signals, with parameters updated according to given training data and a gradient-descent learning procedure. This hybrid architecture has been applied to the modeling and control of multiple-input single-output (MISO) systems is shown in fig 2.

III. SYSTEM MODEL

In this section determines the function of ANFIS, MPPT and active power generation determines the real power output at the point of common coupling (PCC) depended on frequency deviations of the DG and the reactive power regulator controls the voltage of the equivalent DG-bus in addition the reactive power of the load was also compensated at the terminal.

A. Active and Reactive Power Control

In an expression can be derived for the reactive power to cancel the double-frequency oscillations. In addition, a current vector, which is orthogonal to the grid voltage vector, can be obtained. Thus, this offers the access to independently control the reactive power if the inverters are required to exchange a certain amount of reactive power with the grid. In this case, the reactive power reference is not zero anymore, and it should be set as the desired value according the grid requirements once the grid fault is confirmed. The real and reactive power functions are characterized in the following equation:

$$P = (V_1V_2\sin\delta)/X \quad (7)$$

$$Q = (V_2(V_2 - V_1)\cos\delta)/X \quad (8)$$

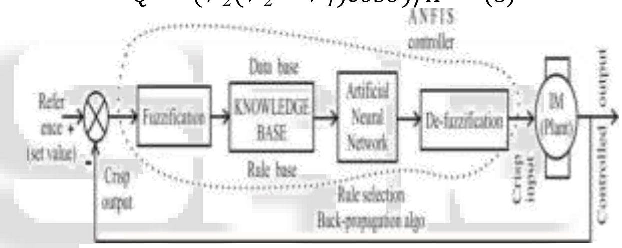

Fig. 3:.Block Diagram of ANFIS Control scheme

$$\delta \approx (PX)/(V_1V_2) \quad (9)$$

$$(V_2 - V_1) \approx (QX)/V_2 \quad (10)$$

B. ANFIS Control Scheme

To start the design of the controller using the ANFIS scheme, first, a mathematical model of the induction motor plant along with the controller mathematical model is required, which can be further used for simulation purposes. The block diagram of the developed controller is shown in fig. 3. The fuzzification unit converts the crisp data into linguistic variables, which is given as inputs to the rule-based block. The set of 49 rules is written on the basis of previous knowledge or experiences. The rule-based block is connected to the neural network block. Back-propagation algorithm is used for NN training in order to select the proper set of rule base. For developing the control signal, training is a very important step in the selection of the proper rule base. Once the proper rules are selected and fired, the control signal required to obtain the optimal outputs is generated.

C. MPPT Scheme

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from

All rights reserved by www.ijsrd.com

a varying source. IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. In incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O. ANFIS based MPPT controller is extremely fast with good dynamics and the gain in the output power is significantly higher at all solar irradiance conditions. So, the ANFIS based control is an effective tool to track and extract maximum power from solar PV module.

D. Implementation of ANFIS Based MPPT and Droop Control

Flow chart for implementation of ANFIS based maximum power point tracker is shown in fig.4. ANFIS generates the set of fuzzy rules in order to produce appropriate output for different values of inputs. Parameters of membership functions are adjusted or changed till the error is reduced to minimum value. Once all the parameters of membership function are adjusted, the ANFIS model becomes learning model which is ready to be used in MPPT control scheme. But before using ANFIS learning model for MPPT control, its results are checked by using checking data which is different from training data. Again if error produced is more than desired value, parameters of membership functions are adjusted to bring down the error.

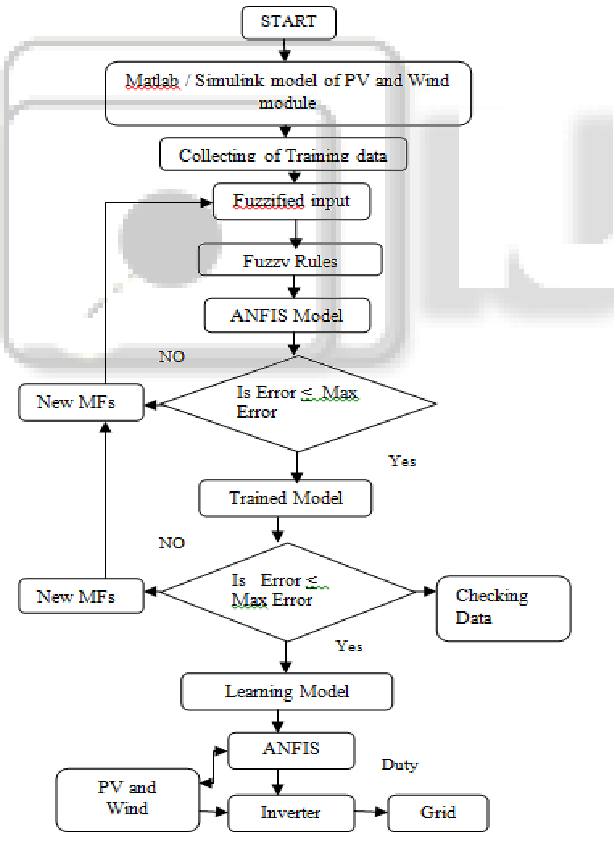

Fig. 4: Flow Chart of ANFIS based MPPT scheme

adjusted or changed till the error is reduced to minimum value. Once all the parameters of membership function are adjusted, the ANFIS model becomes learning model which is ready to be used in MPPT control scheme. But before using ANFIS learning model for MPPT control, its results are checked by using checking data which is different from training data. Again if error produced is more than desired value, parameters of membership functions are adjusted to bring down the error.

IV. RESULT AND DISCUSSION

Fig.5 shows the module of Photovoltaic and Wind System. PV connects to the inverter through the ideal switch and the inverter which get the pulse from the subsystem generating reference signal. The generated pulse transmits through the transformer. RL and RC filters are connected in the transmission line for reducing the harmonics generation.

First, the design of PV module current and Insolation is the input and voltage & Power is the output. The specification of the PV module is consist of varies parameter like short circuit current, open circuit voltage, current and voltage at maximum Power and By pass diode for forward and reverse bias operation. Constant inputs such as current and isolation are given to the module which provides voltage and power as its output.

Second block is wind module given to the module which provides voltage and power and DC voltage which consists of wind turbine and Permanent Magnet Synchronous Generator. Pitch angle and Wind speed are the constant inputs. In which pitch angle is absent so the PMSG which act as the motor and generate torque which given to the generator and induced torque produced power.

AC and DC voltage generate by the Interline system. The generated voltage is given to the controller for the equal sharing real and reactive power according to the control technique. Pulse generation by the reference signal according to the Discrete Phase Locked Load developing bandwidth. Then it will give as the input for the inverters to switching device. In which voltage and current of the Interline power system with equal power sharing and voltage regulation are achieved by the droop control method. The main aspect of the real and reactive power sharing in the grid connected system will gives higher power reliability and higher power quality. The goal of controlling the grid side is keeping the DC link voltage in a constant valve regardless the production of power magnitude.

Matlab/Simulink model of PV module is used to generate the training data set for ANFIS by varying the short circuit current in steps of 5A from 10A to 25A and the solar irradiance level in a step of 50 W/m2 from 100 W/m2 to 1000 W/m2. For each pair of operating temperature and solar irradiance, maximum available power of PV module is recorded. Thus in total 709 training data sets and 1000 epochs are used to train the ANFIS reference model. The training error is reduced to approximately 6%. ANFIS constructs a fuzzy inference system (FIS) by using input/output data sets and membership function parameters of FIS are tuned using the hybrid optimization method which is a combination of least-squares type of method and back propagation algorithm.

V. CONCLUSION

The presented study was a kind of modeling and analysis of an Interline power system consisting of PMSG wind turbine, PV, ANFIS based droop control and MPPT. Variation of wind speed and irradiance and also, the enhancement of dynamic performance of Grid were considered. The simulation results in the grid connected mode showed that using ANFIS controller could dramatically reduce the disadvantages of the previous approaches. In fact, this

All rights reserved by *www.ijsrd.com*

research suggested that using ANFIS controller could decrease oscillations of power output around the MPP and increase the convergence speed to achieve the MPP. Also, the presented controller in the wind system, by adding wind speed as an input signal of fuzzy logic, could have a faster and smoother response. The benefit of fuzzy controller is that it keeps the turbine output in an admissible value and can prevent more mechanical erosion and fatigue and also, the dynamic performance of PMSG can be improved.

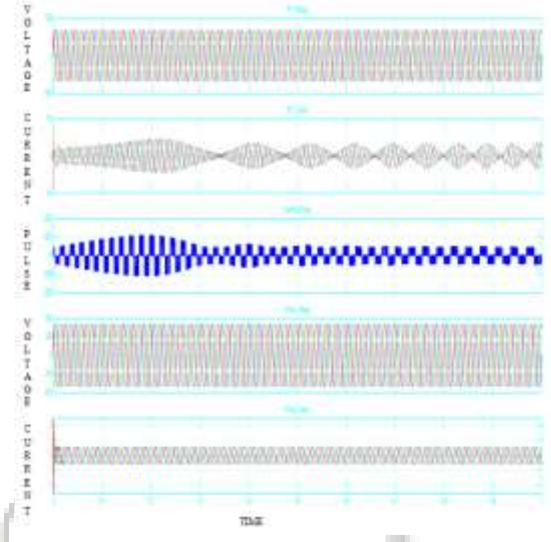

Fig. 5: Dynamic performance using ANFIS based Droop Control Method

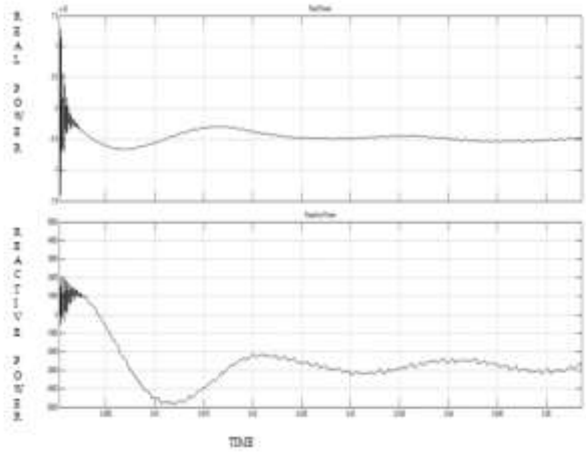

Fig. 6: Power sharing using droop control method

Due to the proposed fuzzy controller, it was possible to smooth wind power fluctuations well. Smoothing wind power inside the MG improved the dynamic response of the MG subsequent to the islanding occurrence. The output power of the MTG in the fuzzy controller had a larger value with less oscillation than PI controller because the fuzzy controller increased the pitch angles of wind turbines, which smoothed the output power.

APPENDIX A

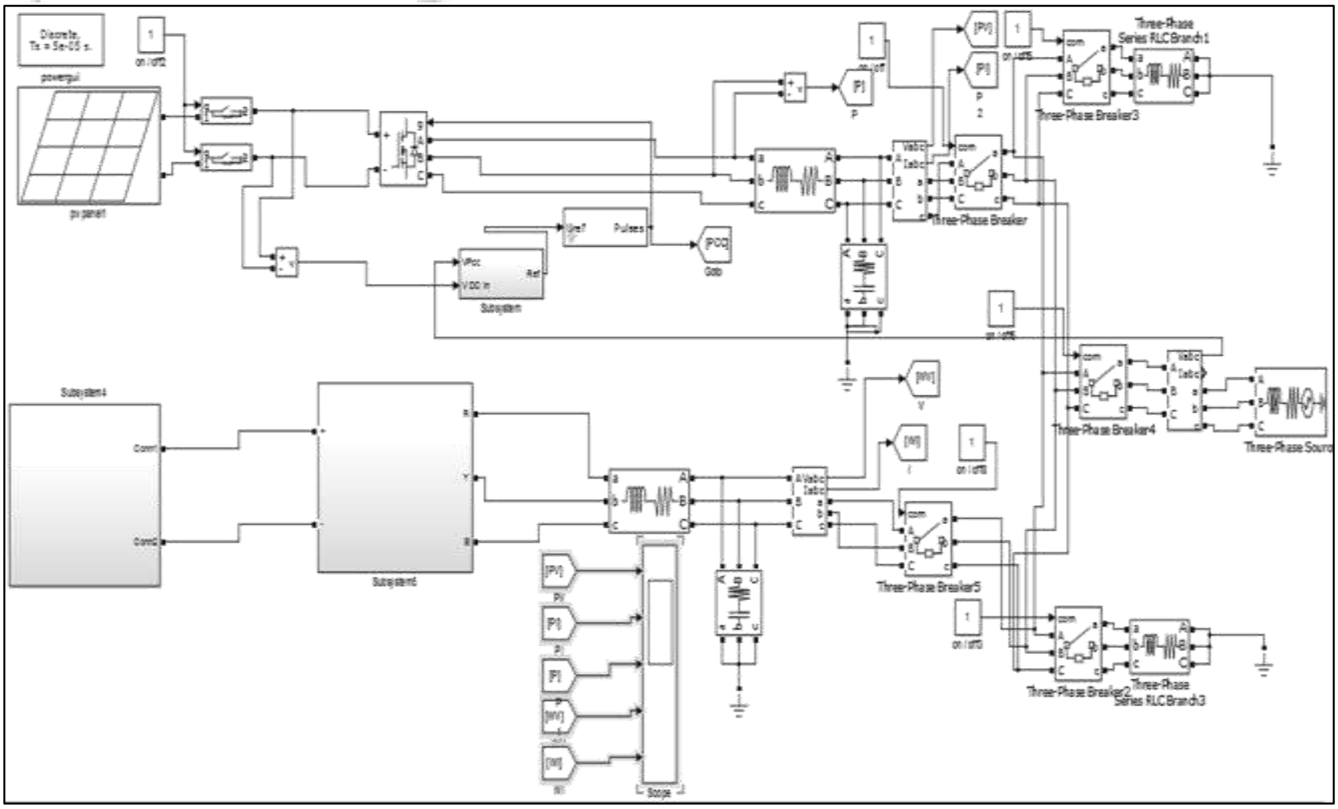

Fig. 7: ANFIS based Droop Control Method in I-PV and Wind system

REFERENCE

[1] Yongheng Yang, Wenjie Chen and FredeBlaabjerg "Advanced Control of Photovoltaic and Wind Turbines Power Systems" Springer International Publishing Switzerland 2014.

[2] CristianDragoşDumitru, Adrian Gligor "Modelling and Simulation of Renewable Hybrid power system using MATLAB/simulink environment" Scientific Bulletin of the PetruMaior" University of TârguMureş Vol. 7 (XXIV), no. 2, 2010, ISSN 1841-9267

[3] Ahmed Moawwad, VinodKhadkikar, JamesL.Kirtley, Jr.Fellow "Photovoltaic power plant as FACTS devices

All rights reserved by *www.ijsrd.com*

in Multi-feeder systems" IEEE Trans. Power Delivery July 2014.
[4] AhmedMoawwad, VinodKhadkikar, JamesL.Kirtley, Jr.Fellow "A New P-Q-V Droop Control Method for an Interline Photovoltaic (I-PV) Power System" IEEE Trans. Power Delivery, vol. 28, no. 2, pp. 658-668, Apr. 2013.
[5] Khadkikar,V and Kirtley,J,L, "Interline photovoltaic (I-PV) power system—A novel concept of power flow control and management," in Proc. Power Energy Soc. Gen. Meeting, Detroit, MI, USA, Jul. 24–29,2011, pp. 1–6.
[6] Anuroop.P.V, Radhakrishnan, SaravanaKumar.P.V, "Droop Control of parallel Inverters with LCL filter and Virtual output Impedance" International Journal of Advanced Research in Electrical Electronics and Instrumentation Engineering,Vol-2 ,issue 1, dec 2013.
[7] Brabandere.D,K, B. Bolsens, J. Van den Keybus, A. Woyte, J.Driesen, and R. Belmans, "A voltage and frequency droop control method for parallel inverters," IEEE Trans. Power Electron., vol. 22,no. 4, pp. 1107–1115, Jul. 2007.
[8] Ellis.A, Nelson.R, Von Engeln.E, Walling.R, Fellow "Reactive Power Performance Requirements for Wind and Solar Plants"
[9] Guerrero.J.M, Matas.J, De Vicuna.L.G, Castilla.G, and Miret.J,"Wireless-control strategy for parallel operation of distributed-generation inverters," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp.1461–1470, Oct. 2006.
[10] HuijuanLi,YanXu, SarinaAdhikari,D.tomRizy,Fangxing Li Philip Irminger, "Real and Reactive Power control of three phase single stage PV system and PV voltage stability" IEEE 2012
[11] LakshmanRao S. P, Dr. Ciji Pearl Kurian SMIEEE, Dr. B.K.Singh, AthulyaJyothi V "Simulation and Control of DC/DC Converter for MPPT Based Hybrid PV/Wind Power System" International Journal of Renewable Energy Research Vol.4, No.3,2014
[12] Mohammed Aslam Husain, Abu Tariq"Modeling of a standalone Wind-PV Hybrid generation system using MATLAB/SIMULINKand its performance analysis" International Journal of Scientific & Engineering Research,Volume 4, Issue11, November 2013
[13] Qing-Chang Zhong, "Harmonic Droop Controller to reduce the voltage harmonics of inverter,"IEEE Trans. Ind. Electron., vol. 60, No.3 march. 2013.
[14] W. Yao,M. Chen, J. Matas, J. M. Guerrero, and Z. M. Qian, "Design and analysis of the droop control method for parallel inverters considering the impact of the complex impedance on the power sharing," IEEE Trans. Ind. Electron., vol. 58, no. 2, pp. 576–588, Feb. 2011.

IJSRD