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# POWER FACTOR AND THD MITIGATION IN HYBRID AC-DC MICROGRID BY FUZZY CONTROLLER

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***Abstract—The paper presents the modelling and simulation of the power flow control strategy of a single-phase AC-DC Hybrid Micro-Grid (HMG). The proposed system topology for HMG contains two AC and DC zones delimitated by a bidirectional interlinking converter (BIC) in a full-bridge IGBT structure which is a regular H-Bridge inverter/rectifier. The switching pattern of BIC is provided from two power control loops and one voltage loop (Vdc) based on the DQ transformation theory. This control strategy allows, in a controlled matter, the transfer of both active and reactive power between the HMG and the public AC Grid. The fuzzy logic controller based on the fuzzy set theory provides a useful tool for converting the linguistic control from the heuristic or mathematical strategies; complex processes can be controlled in many situations effectively. But the most important and difficult point is how to obtain the proper control rules for a given system in the matter of fuzzy logic. In this paper, power factor correction is corrected to demand value by using a fuzzy logic controller under load changing for the electric power control system containing current unbalance i.e. load asymmetry. In the control system, reference reactive power value is determined by Fuzzy at various times of day as load changes with rising or falling trends.***

## I. INTRODUCTION

The uninterrupted power supply of the consumers in a hybrid AC-DC microgrid needs the development of a stable conversion system able to trigger the islanding procedure when an unexpected event occurs [1], [2], [3]. Another important aspect for modern HMG is the development of an energy flow control system that contributes to the power factor correction/compensation (PFC) for the local AC distribution public grid at the point of common coupling (PCC) by reactive current injection methods [4], [5], [6]. A single residential HMG could have a small contribution for PFC at the PCC for a local public grid, mainly because of the limited reactive power availability. In a specific local public, an increased number of HMG working with this strategy, by compensating the power factor at the common coupling point, could mean a more significant impact on the quality of the power distributed. The control strategy adopted in references [7], [8], [9], [10] are proposing a DQ synchronous reference frame control for single-phase systems, by transforming the AC signals into DC signals for the most effective form of processing. Some clear application [11], [12], [13] are using this transformation by using three control loops for the active-reactive power and output DC voltage. By comparison with these applications, the present work highlights the capability of this method, by operating either in rectifier or inverter modes, to adjust the phase of the current feed or injected from the AC Grid in order to compensate/correct the power factor at PCC.

PFCs are utilized in large numbers in household appliances as active front AC/DC converters that impose unit power factor, and provide the required constant DC voltage with the load. As an emulator of EPS' electric power quality, the PFC steps normally serve as an input current that is associated with the shifting rib, with a harmonic high-frequency distortion. In [24], the proposal is for a PFC variable input boost, which is digitally controlled. The resistance emulation behavior at different harmonic frequencies is altered to strengthen the stability of the grid. Previously, other PFC studies impressing sinusoidal input currents have been published (sinPFC). [24], [25] shall be employed by a sine-wave generator in the current loop for creating the relevant reference current in the single-phase systems. Like [26], the Sine Wave Generator can be replaced by the Phase-Locked Loop to generate the reference signals (PLL). In [27] a current sensor control system is employed with immunity to input voltage distortion. The three phases of PFCs[28] and [29] respectively are also used for these techniques. When modulation signals synchronize with the grid, harmonics are activated precisely using digital controllers to correct for the effects of distortion and adaptive controllers to detect the ideal response under distorted or non-distorted grid voltage. In terms of simplexes and reliability, the adoption of sensor less technology displays progress. For digital control performance, the circuits for the current meter, signals and a digital converter analogue are also eliminated if the resulting power factor is sufficient. The resulting control covers a broader portfolio as the current signal does not depend on the sensor size. Recently, several sensor less techniques were applied. The Vienna 3-phase rectifier is equipped with a voltage without an adjustable sensor control system[30]. An artificial sensor less input tension approach is described in a Look-Up Table [31] (LUT). The load area extends with a more advanced technique for pre-duty cycle sequence calculation, provided that the reference is sinusoidal[32] with no input voltage or current acquisition. A new, interleaved, sensor-less topology technology with multi-phase [33] [34] is enhanced. Since the inductive current form of the input depends on the voltage, the distortion in the input voltage generates a distortion of the input current through resistance emulator technology.

Various approaches to address these challenges are being offered including an active line current detecting phase of the power factor adjustment technology. The main benefits are: The following 1)Small kind of input wave distortion. 2) Unity power factor. 2. 3) Output DC tension control. 3) While the single-phase boost converter is more costly than only diode correctors, it is a more efficient way to prevent power degradation in one-phase situations. Fig.1 shows a one-phase PFC converter, which in comparison with other topology is the simplest control system.

The typical PID controller has been utilized widely for management of the power supply circuit[3,4]. The PID is based on system modeling with a nominal item with constant parameters and perturbations, however with some alterations the results are horrifying. Intelligent controls have been used to solve this challenge to achieve robustness control and performance with parameter changes. Artificial neural networks [7] are used among these controllers' fuzzy logic [5,6]. The work analyses and develops a single phase of PFC boost based on a fuzzy logic controller that increases current loop efficiency and does not require the typical hysteresis controller to use the mathematical converter PFC[8]. MATLAB/Simulink assessed the proposed controls.

## II. Power factor

The power factor is defined as the ratio of active power (Pact), i.e., the power consumed by a load, to apparent power (Papr): Power factor (PF) = active_power / apparent_power = Pact／Papr --- Equation 4-1 Active power (Pact) is the amount of power consumed by a load whereas apparent power (Papr) is the amount of power transferred from a power supply. Apparent power (Papr) can be expressed as follows:

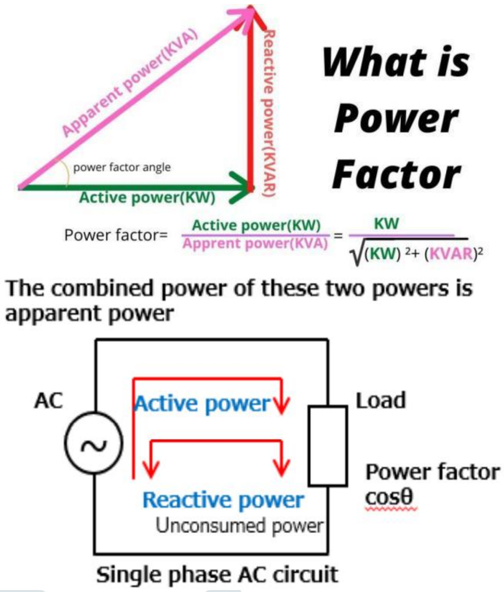
$$P_{apr} = \sqrt{active\_power^2 + reactive\_power^2}$$

$$\sqrt{{P_{act}}^2 + {P_{rea}}^2}$$

where reactive power (Prea) is the amount of power that is not consumed by a load. Therefore, the power factor can be expressed as follows

$$\text{Power factor } PF = \frac{P_{act}}{\sqrt{{P_{act}}^2 + {P_{rea}}^2}}$$

The power factor is equal to the cosine of the phase difference between voltage and current (i.e., the phase angle between apparent power and active power) as shown in Figure 4.1. Therefore, the product of voltage and current (i.e., power) is converted into energy. When AC voltage is applied to an inductive or capacitive load results in a phase difference between voltage and current. This phase difference changes the rate of conversion to energy. The power factor is the ratio of the power converted into energy to apparent power.




## III. Harmonics

A harmonic is a distortion contained in the sinusoidal AC current waveform and is defined as a component having a frequency that is an integer multiple of its fundamental frequency. The nth-order harmonic is the nth multiple of the fundamental frequency. A harmonic is a sine waveform with a frequency that is an integer multiple of the fundamental frequency. A sine waveform without distortion consists of only the fundamental frequency and no harmonics. All waveforms with distortion contain harmonics. The waveform of the mains power supply with harmonics is distorted. Distortion is caused by the rectification and smoothing circuits at the input of electronic systems. Harmonics generated by an electrical or electronic system might adversely affect electrical facilities and other systems (e.g., the heating of phase-advancing capacitors and reactors). Noise is a phenomenon similar to harmonics. In a broad sense, harmonics are also noise. However, noise is not associated with the power supply frequency. Harmonics are always a function of the power supply frequency.

$$(1 + THD_V^2)(P_{PQE}^{out})^2 < (P_{PQE}^{out})^2 + 2P_{PQE}^{out}P_{harm}$$

because this mode results in higher PF at the PCC than the resistive emulator mode. This condition can also be expressed as

$$THD_V < \sqrt{2}\sqrt{\frac{P_{harm}}{P_{PQE}^{out}}}$$

## IV. Lc filter

The LC filter is also known as the low-pass second-order filter. It was installed at the AC side of the designed solar PV system and EV charging system. It can block high-frequency signals and allow only low-frequency signals to pass through it [33]. Figure 6 shows the basic configuration of an LC filter. The switching frequency (fsw) is 10 kHz. The cut-of frequency (fc) of the LC filter is the allowable frequency signals upper limit, and it should be less than 1/10th of fsw [33]. Meanwhile, one research [35] has reported that the fc value is recommended to be more than 1/14th of the fsw for less attenuation effect. By considering less attenuation effect and within 0.3% distortion as in IEEE1547 guidelines [35], a mathematical equation for fc and fsw expressed by Eq. (11):

$$\frac{f_{sw}}{k} < f_c < \frac{1}{10} f_{sw} \text{ where } k \simeq 14$$

As to prevent less than 3% voltage drop across the Lfilter, the size of Lfilter is calculated by Eq.

$$L_{filter} < \frac{0.03 U_{inv}}{I_{L\max}(2\pi f_s)}$$

Lg=0.08 mH,

Rg = 60 mΩ.

where ILmax is the maximum RMS load current value, and Uinv is the unfltered output voltage of the DC/AC converter. Finally, the size of Cflter is calculated as per Eq. (13) [33]:

$$C_{filter} = \frac{1}{(2\pi f_c)^2 . L_{filter}}$$

## V. SYSTEM DESCRIPTION

The topology of the residential single-phase Hybrid Micro-Grid are shown in Fig. 1, where the two AC and DC circuits are delineated via the bidirectional interlinking converter (BIC). The AC circuit contains the AC grid, the point of common coupling (PCC), islanding switch, the AC load and an LCL passive filter. The DC circuit contains the capacitive filter (C), the DC load and the renewable sources and/or storage element (DC Source). The bidirectional interlinking H-bridge converter (BIC) ensure transfer from/to the AC and DC circuits. For the bidirectional interlinking converter, the energy management is defined by three individual operation cases. For the first two cases, the scenario allows the controlling of the reactive power and the third case is highlighting the operating at unity power factor. The Rectifier operating mode (case 1) allows the electrical energy to be transferred from the AC Grid to the DC-grid, feeding all the electrical DC consumers. The AC Load is directly powered from AC Grid and DC Load and is interfaced to the DC-link Voltage by a power electronic converter. In the Inverter operating mode (case 2), the DC Source directly powers the DC load, while the AC load through the interlinking converter, at the same time allowing the energy flow in AC Grid. Inverter with islanding operating mode (case 3) is like the previous one, except that the AC-DC hybrid microgrid is islanding during to unexpected event (defect occurrence, quality condition failure, independent micro-grid operation), with no physical connection to the AC public grid. In this case scenario the DC Source ensures the power supply of both consumer's type.

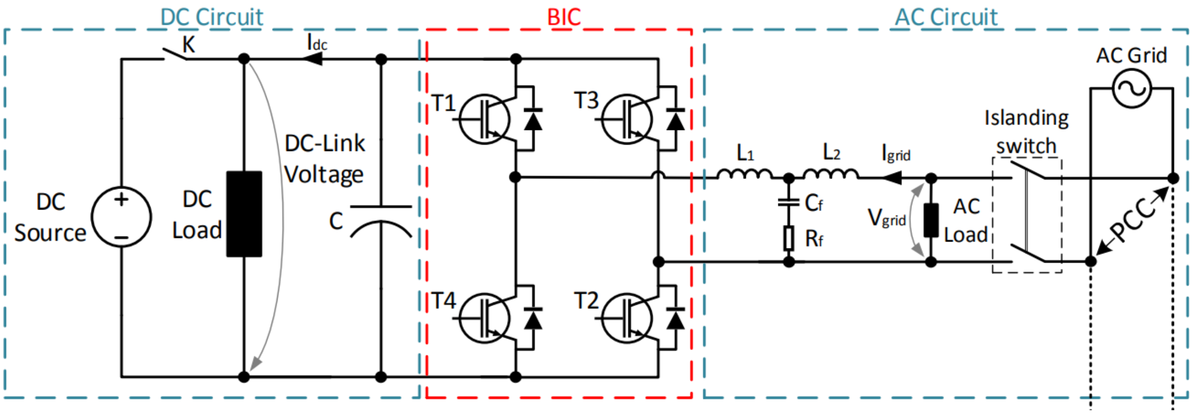



Fig Proposed Block diagram

## VI. CONVERTER CONTROL STRATEGY

The control strategy based on the reactive power control (Fig. 2) is using as measured inputs the AC voltage signal at the PCC (Vgrid), the input current (Igrid), the DC voltage (Vdc) and the DC current (Idc). These signals are also presented in Fig. 1. By applying the single-phase DQ transformation for the Vg and Ig signals, the Vd and Vq voltages and Id and Iq currents are being obtained in DQ rotation references frame. The references control signals are the DC voltage (Vdc_ref), the active power (Pref) which is obtained using to DC-link current and voltage and the reactive power (Qref) defined by the AC public grid. The outputs of this control system are the PWM signals for switching the interlinking converter transistors. The first control loop regulates the DC voltage (Vdc) obtaining the required reference for the IDC_ref DC current. This is accomplished by comparing the DC voltage (Vdc) to the required reference (Vdc.ref), obtaining a steady state error that is compensated by PI1 controller. The outputs of P-Q calculation block are measured value of the active (P) and reactive (Q) powers base on equation (1). These signals will be compared with the references for the power control (Pref, Qref) and the results are being compensated by PI2 and PI3 controllers, returning the references for the two current control loops (Id_ref, Iq_ref) [14]. The outputs of PI4 and PI5 controllers represents the signals (Vdm, Vqm), that after their Įù transformation will become the inputs for the sinusoidal PWM generator (PWM).

$$\begin{cases} P = V_d I_d + V_q I_q \\ Q = V_d I_q - V_q I_d \end{cases}$$

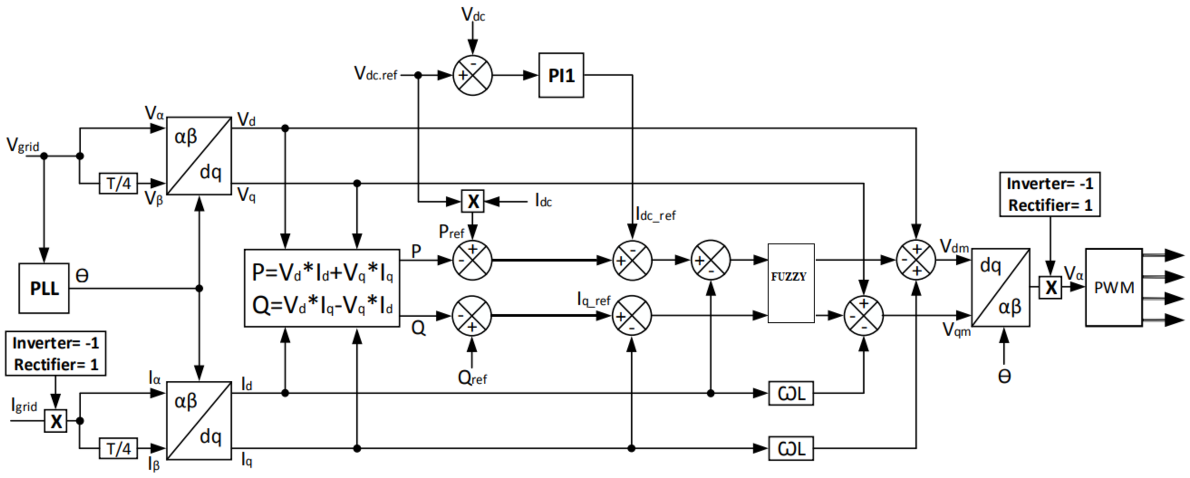



Fig Strategy schematic diagram of the Proposed controller.

### VII. Single Phase Bus Voltage Controlling with Fuzzy Logic Controller

By managing condenser load and discharge, the Ac voltage control system is intended to maintain a stable reference value for this tension. The major drivers of the variation of capacitor voltage are the conversion switching losses and the load change between converter output. The value of the reference currents compensates any energy fluctuations in the condenser to vary this voltage. As illustrated in fig.1, the loop inputs contain the reference voltage. Recently, fuzzy logical control units have demonstrated an excellent process management strategy. There are two advantage points for the fuzzy logic controller: strength. Increased controller ingredients and non-linearity are allowed and there is no need for a mathematical model[12]. The usual proportional integral controller in this study was replaced by a fuzzy logic controller utilized to manage the output dc boost converter voltage. This is because the variables utilized are linguistic, rather than logical variables near the present human language. The theory of fuzzy logic is automatic theory. In order to specify particular information regarding system activity, the linguistic factors are moreover handled by rules. The theory of fuzzy logic consequently consists of the identify various volumes by components of potential theory from the controlling system which so-called fuzzy functions.

Several separate rules are in place. The outcomes are various. In the following measures, the inflatable system does not linearly connect a sector with a scale output:

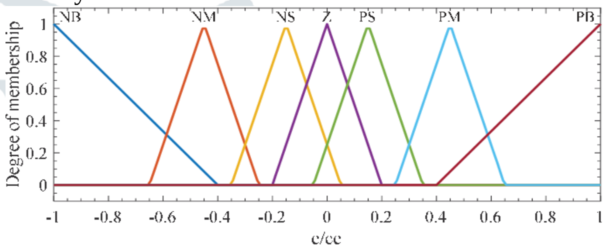



Fig. 4. Input MFs.

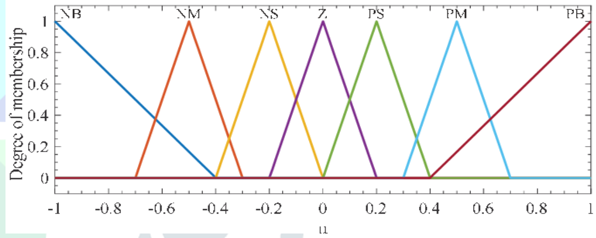



**Fig 4**. Fuzzy rules and membership functions.

The proposed PFC fuzzy logic controller is illustrated by Figure2. The fuzzy controller error and variation are used for instantly entering the kth sample. The current amplitude is the output of the fuzzy system.

In order to normalize error and alter errors, the dc bus voltage is adapted to the current I* reference $i_a$ amplitude.

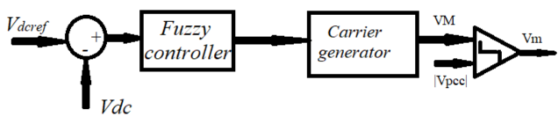



Fig4. Proposed Fuzzy Logic Controller.

In the proposed controller configuration, the $V_{dc}^{ref}$ is compared with the $V_{dc}$, Where $V_{dc} = V_{dc}^{ref}$ the specified reference level.

here the expression is given as:

$$V_{dc} = \frac{(1-d)}{R}$$

is similar to the NLC control law or the Linear Peak Current-Mode (LPCM) control.

The second term, $V_{PCCH}/R$ , corresponds to line harmonic voltage distortion and factor k allows the $THD_V$to be considered. The duty cycle command is obtained by comparing the digitized signals $i_{av}(t)$ and a leading-edge saw-tooth carrier signal $V_m(t)$ was given as:

$$v_m(t) = V_m\left(1 - \frac{t}{T_{sw}}\right) - k\frac{v_{PCC,H}}{R}R_s, \quad 0 \le t \le T_{sw}$$

where $V_m = R_s V_{dc}/R$. For the current sensor-less application, $R_s$ = 1 Ω is arbitrarily adopted, where the value R changes with the load and is set by the outer voltage loop with $V_m$.

## VIII. SIMULATION MODEL AND RESULTS

The simulation model (Fig. 3) of single-phase AC-DC Hybrid Micro-Grid was simulated in Matlab/Simulink software and it is based on the HMG topology (Fig. 1) and control structure (Fig. 2). In case 2 and 3 (inverter mode) the measured value of the Igrid and the modulating signal VĮ must be shifted with 180 degrees by multiplying them with constant -1 (Fig. 2). In the case 1 (Rectifier operating mode) the Igrid is the same with the measured value and the VĮ is the related signal by dq to Įü transformation block. The Vü is not used for PWM modulating and is ignored.

The LCL filter was tunned using the passive method which consists in adding a series damping resistance (RF) in parallel with capacitor filter (CF). The figure 4 shows the effects in frequency domain of the LCL passive damping compared to the LCL filter without damping [15].

The islanding operating mode (case 3) is obtained by monitoring the total harmonic distortion (THD) of the voltage at the PCC, when THD exceeds 2% the case 3 is activate [16]. The Grid synchronization (figure 4) with the AC Grid is achieved in case 1 and 2 by phase-locked loop (PLL) Simulink block [17]. In case 3 the control is synchronized through a sinusoidal signal (Sine Wave) with a frequency of 50 [Hz]. For this case the Igrid is composed only by the AC load current.

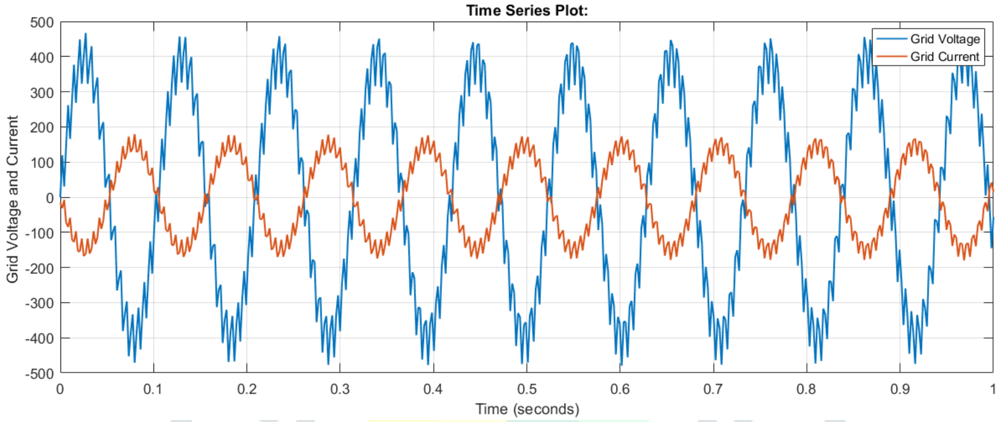



Fig. 7. Existing method Islanding mode. Grid Voltage and grid current of AC Load.

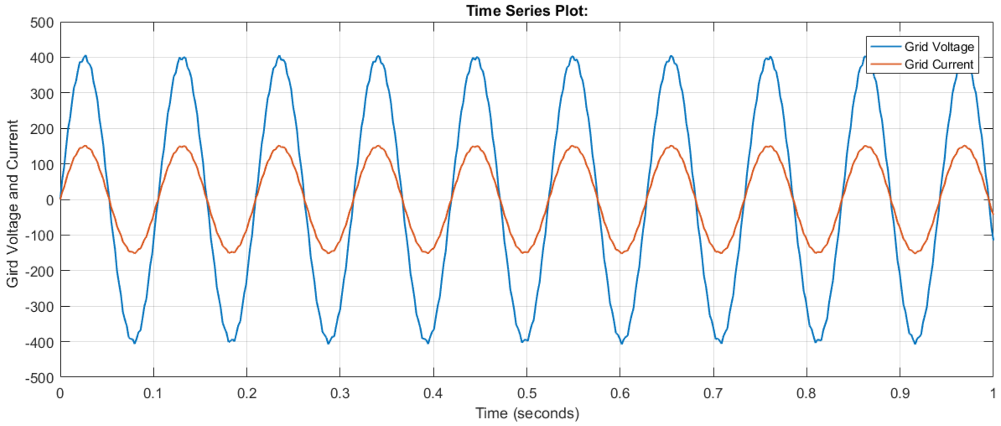



Fig. 7. Proposed method Islanding mode. Grid Voltage and grid current of AC Load.

The instantaneous power control is studied for each case described in second section of this paper. Figure 5 and 6 show the simulation results where a comparison is done between the AC grid currents (Igrid) at three situations regarding the reactive power control (resistive, inductive or capacitive character), while the Figure 7 shows the islanding case.

## CONCLUSION

This paper presents the simulation of an active and reactive power control strategy for a bidirectional interlinking converter in a single-phase AC-DC residential hybrid microgrid. The work is based on the compensation of the power factor at the point of common coupling with AC power grid. The simulation results highlighted the fact that the designed FL controller was able to perform within the desired specifications. The performance of the controller with variable induction motor(s) loads was found to be satisfactory. The simulation results clearly demonstrate that the controller was able to improve the PF of a dynamically varying plant, and was able to do so without overshooting the set point. The results from the simulation plots, amply demonstrate that this new approach to PF improvement represents a feasible solution. The FL controller scheme arrived at in this research could some day be implemented in an industrial plant environment that may require PF improvement with a high degree of accuracy. The reactive power is controlled regardless of the power flow direction allowing the power factor to be determined according to requirements imposed on the AC distribution grid. Future work proposes the practical implementation of the Hybrid Micro-Grid system described in this work.

## REFERENCES

[l] Procky and E. H. Mamdani, " A Linguistic Self-organising Process Controller " Automatica,

[2] The Notes of Reactive Power Compensation, TMMOB, The Chamber of Electrical Engineering, 1983, Istanbul.

[3] S. Ay, " A New Approach for Power-factor Correction in Power Systems Having Load Asymmetry " The Periodical of Yildiz Technical University, vol. 2 , pp.59-66, 1993, Istanbul.

[4] ON Semiconductor, Power Factor Correction (PFC) Handbook. Choosing the Right Power Controller Solution.

[5] ABB, Power Factor Correction and Harmonic Filtering in Electrical Plants, Technical Application Paper., 2008.

[6] Etienne TISON and Schneider Electric S.A, Electrical installation guide: According to IEC international standards, 2016.

[7] Nathan Weise, DQ Current Control of a Bidirectional, Isolated, Single-Stage AC-DC Converter for Vehicle-to-Grid Applications, 2013.

[8] U.A. Miranda, M. Aredes and L.G.B. Rolim, A DQ Synchronous Reference Frame Control for Single-Phase Converters.

[9] Xing Wan, Jie Ren, Tian Wan, Shi Jing, Sinian Xiong and Jiaxu Guo, "A Control Strategy of Single Phase Voltage Source PWM Rectifier under Rotating Coordinate," in International Conference on Power and Renewable Energy, 2017.

[10] Yicheng Liao, Zhigang Liu, Han Zhang and Bo Wen, "LowFrequency Stability Analysis of Single-Phase System With dq-Frame Impedance Approach—Part I: Impedance Modeling and Verification," IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 54, NO. 5, 2018.

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