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An improved VSG control strategy at switching performance optimization for a hybrid AC/DC micro grid by using ANFIS controller

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***Abstract:** In this paper an improved virtual synchronous generator control strategy is developed to optimize the switching performance from the grid tied mode to the islanding mode. The main aim of the controller to produce switching performance optimization in the hybrid ac/dc microgrid. In the conventional method several controllers used to reduce the switching frequency and the controller are like droop controller and pre-synchronize controller. The performance of a hybrid AC/DC coupled micro grid during the transition from the grid connected mode to the islanding mode based on a real system. By using this controller to improve the generator control strategy and synchronize the voltage and frequency. The performance of ANFIS controller base virtual synchronous generator control strategy evaluated by using MATLAB Simulink software.*

***Keywords:** Hybrid AC/DC micro grid, Switching performance, Virtual Synchronous Generator, Pre- Synchronization, ANFIS Controller.*

I. INTRODUCTION

In the recent past, we have observed an increase in number of distributed generations put into utilization through microgrids. This microgrid can be divided into three forms namely AC microgrid, DC microgrid and Hybrid AC/DC microgrid. In order to improve power quality problems like harmonic current, economic aspects like reduction of power loss, other things like difficulty in controlling caused by multi stage AC/DC or DC/AC transformations in pure AC microgrid or DC microgrids, the hybrid microgrid gains more attention since it has more practical and economical.

In [1], this paper presents a new concept for building integration in MGs with zero grid-impact so improving the MG efficiency. These aims are shown to be achievable with an intelligent system, based on a DC/AC converter connected to the building Point of Coupling (PC) with the main grid. This system can provide active and reactive power services also including a DC link where storage, generation and loads can be installed. In [2], A highly integrated and reconfigurable micro grid tested is presented in this paper. The micro grid tested contains various distributed generation units and diverse energy storage systems. Apart from electrical power, it can also provide energy in forms of hydrogen and thermal energy.

In [3], Microgrids are able to provide a coordinated integration of the increasing share of distributed generation (DG) units in the network. The primary control of the DG units is generally performed by droop-based control algorithms that avoid communication. In [4], the idea of operating an inverter to mimic a Synchronous Generators (SG) is motivated and developed. Using synchronverters, the well-established theory used to control SGs can still be used in power systems where a significant proportion of the generating capacity is inverter based. Synchronous can easily operate also in island mode, and hence, they provide an ideal solution for micro grid (or) smart grid.

In [5], this paper investigates the dynamic performance of a hybrid AC/DC microgrid during transition from grid-tied mode to isolated mode and vice versa. As the droop control method allows the system to operate under both grid-connected mode and islanded mode, it is adopted as the main inverter control strategy for observing the system's performance during mode switching. In [6], this paper a unified detection method for circulating currents and power sharing deviations is described. Then, the improved control strategy method for bi-directional converters in hybrid micro grid operated in island mode is presented to reduce circulating currents and power sharing deviations which include the improved virtual controller used to further reductions.

The architecture model used in this paper is one of the business models of the utility based microgrid framework, which is developed at Griffith University, Australia, as appeared in Fig. 1. This architecture contains low voltage conveyance frameworks with sustainable renewable energy source (RES) units. Viable burdens are from the business building N44 on Nathan grounds. The N44 building utilizes 15.5 kW PV boards in request to understand the pinnacle request shaving capacity. 60 kWh batteries and 12kW breeze turbines will be put into establishment to spare the wattage from the principle network. Also, a four-quadrant interlinking converter is likewise intended to be embraced, which may take into account the wattage and utilization of the Battery Energy Storage System (BESS).

A completely created reproduction model includes two parts: a DC sub grid including PV and battery; an AC framework joining wind turbine with the previous sub-grid. In the DC sub-grid, a PV module with coordinated lift converter is included. A lithium-particle BESS model joins the DC transport through a DC/DC converter so as to reproduce the genuine battery bank.

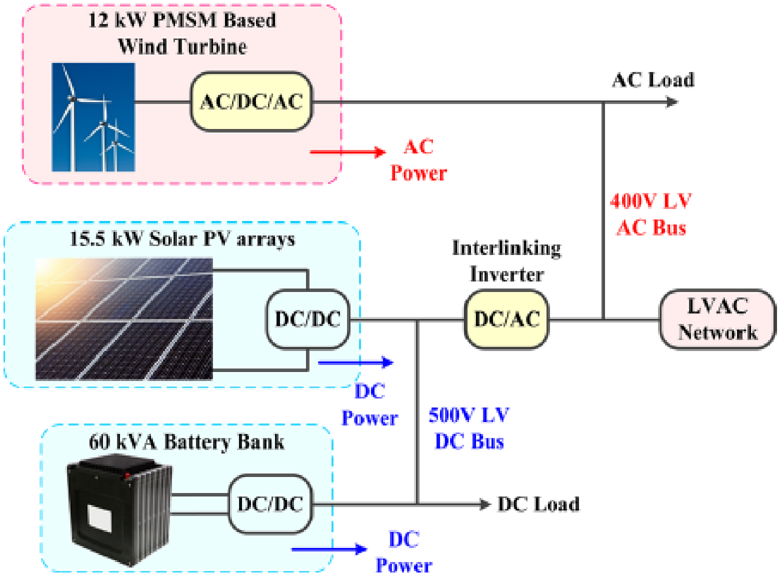

Fig. 1: Basic Hybrid microgrid system configuration of N44 Building, Griffith

The DC microgrid uses a bi-directional converter for the association with the AC transport, which permits a bidirectional power-stream. The DC sub-grid with a major limit can be considered as the primary generation unit in this examination which works under the master - slave control procedure (VSG control). The breeze turbine is a detached age source which is associated with the AC transport legitimately under a slave control procedure (P-Q control). It generally produces the yield based on the utility lattice or the area control error (ACE) unit. The recreation model setup is appeared in Fig. 2.

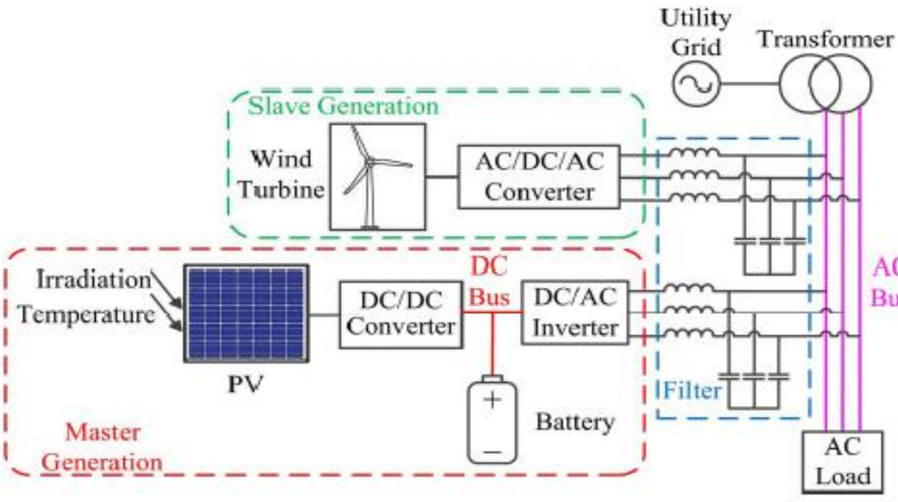

Fig.2. Simulation model of the hybrid micro grid

II. BASIC PRINCIPLE OF VSG CONTROL METHOD

The virtual synchronous generator control strategy goes for emulating the exhibition of an ordinary synchronous generator (SG). In this manner, the RESs and the DERs can undoubtedly take an interest in the guideline of framework's recurrence and voltage under network associated mode. A VSG-based inverter comprises of two sections: an outside circuit which is known as the power part appeared in Fig.3, and an interior controller which is delegated the electric part.

The DC transport in the power part is required to be steady. Either a DC-transport voltage controller or a battery vitality stockpiling could be acquainted with accomplish such capacity. The controller is created dependent on the numerical model of a synchronous machine. The recurrence control circle complies with the swing condition given by:

$$\frac{dw}{dt} = \frac{1}{j}\left(\frac{P_{ref} - P_e}{w_n} - D_p \Delta w\right) \qquad (1)$$

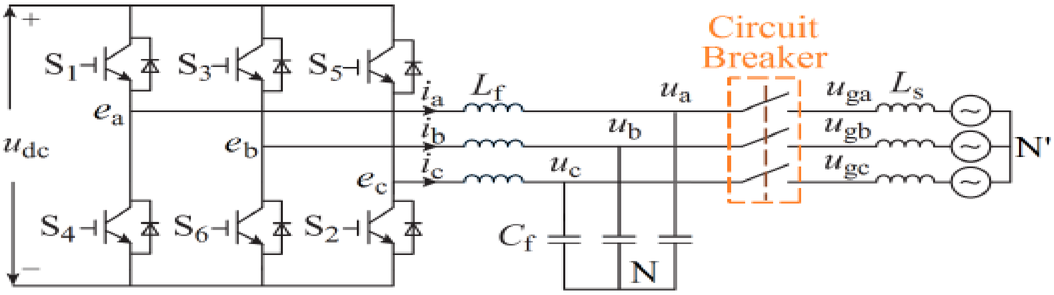

Fig. 3 Power part of a VSG controller

The voltage control circle can be set by the following condition [11]:

$$e = \frac{1}{K_s}\left[D_q\left(V_{ref} - e\right) + \left(Q_{ref} - Q_e\right)\right] \tag{2}$$

Where P_{ref} and Q_{ref} are the reference dynamic power and responsive control; P_e and Q_e are the VSC dynamic power and receptive power yield; J is the virtual moment of inertia; ω_n is the reference angular frequency ; ω is the virtual frequency of the output voltage; Δω is the difference between ω_n and ω; e is the three-phase back electromotive force (EMF) and V_{ref} is the reference voltage. D_p and D_q are droop coefficient of the frequency loop and voltage loop respectively, and K is the integrator gain. The reference dynamic power can be produced from the recurrence representative as indicated by the standard of hang control. In any case, as indicated by, the recurrence senator may diminish the latency of the framework. In this manner, the recurrence control circle can be re-examined by evacuating the representative area and setting the dynamic power straightforwardly. In expansion, the voltage control part may receive a proportional integral (PI) controller so as to keep the voltage stable during transient cases. Along these lines, a disentangled VSG inward controller is created as appeared in Fig. 4.

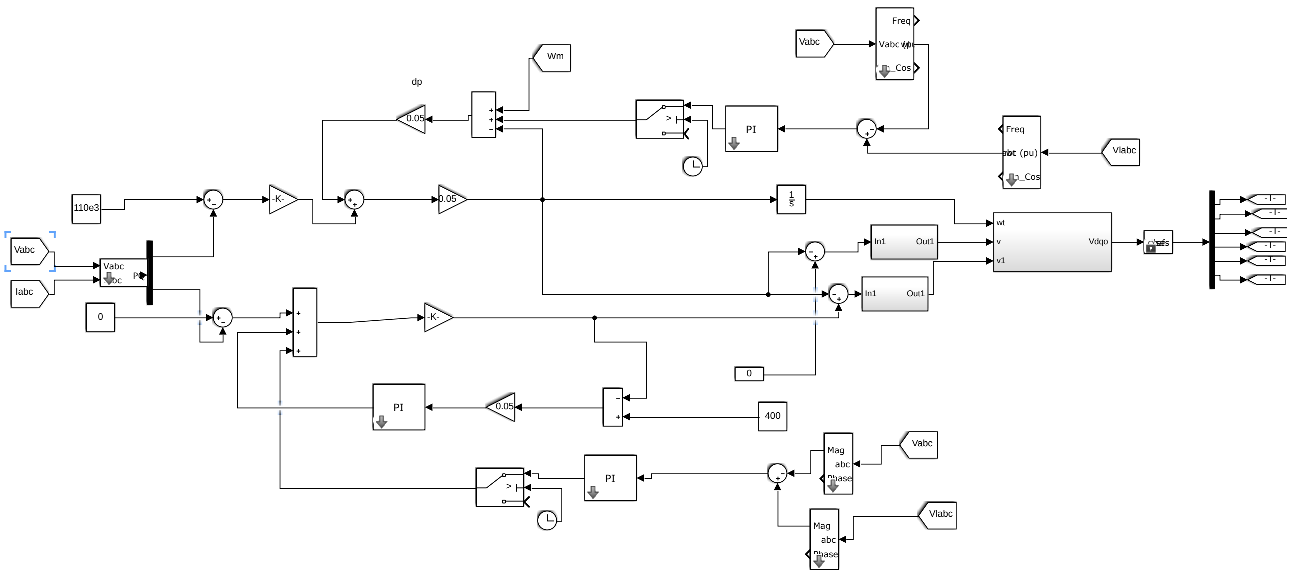

Fig.4. Improved VSG Control

III. PRE-SYNCHRONIZATION METHOD FOR VSG

The microgrid is required to be islanded following a shortcoming or then again unsettling influence on the principle lattice. As indicated by IEEE Std. 1547, when the framework voltage veers off from 0.88 p.u. to 1.1 p.u. or then again, the framework recurrence fluctuates from 49.3 Hz to 50.5 Hz, the lattice can be considered as insecure. Until the framework is changed in accordance with ordinary, the microgrid is prepared for the re-association with the framework. In any case, unforeseen effects would occur during the re-association process if the micro grid's voltage and the network's voltage are conflicting. It is important to affirm that the microgrid voltage to be at a similar dimension to the utility lattice prior to the association. In this manner, a pre-synchronization procedure is fundamental for the microgrid to manage the voltage to a similar phase of the utility network. A self-synchronize technique for the VSG has been proposed to synchronize the inverter with the framework naturally. Be that as it may, there is a prerequisite for the microgrid framework to set the reference power yield at 0 which means the framework would offer no age during the synchronization procedure. Such circumstance isn't permitted in a few cases, for example, a uninterruptible power supply framework. For this situation, an appropriate pre-synchronization strategy for the improved VSG controller for the network association intention is required.

The essential point of the prescient synchronization technique is to control the recurrence, the abundancy and the stage point of the yield voltage. As the VSG strategy has effectively taken these factors levelled out, suitable control rationale ought to be implanted. Since the stage point is relatively related to rakish recurrence, when the stage point is settled, the recurrence must be settled too. In this manner, an amended recent synchronization technique which manages the stage point so as to manage the recurrence is proposed as appeared in Fig.5. More often than not, the microgrid works under the framework voltage level so as to keep the ordinary activity of the hardware. In the specific circumstance, it isn't fundamental for the microgrid to direct the voltage to a similar dimension of the matrix. In any case, a voltage controller is as yet fundamental for the synchronization process since the stage edge guideline can influence the voltage. Accordingly, two PI controllers have been added to the VSG controller design. The reference stage edge èg and voltage $V_g$are gotten from the utility matrix esteems. Through the PI controllers, the microgrid yield voltage point èm and abundancy V_m track the reference an incentive so as to accomplish the synchronization work. At the point when there is a necessity for the microgrid to reconnect to the utility network, the switches in stage edge controller and voltage controller are shut. Either the stage edge or the yield voltage has been directed to a similar dimension with the primary network, the switch ought to be turned off once more. At the point when the two qualities achieve a similar dimension to the primary matrix, the microgrid is prepared to associate with the utility network.

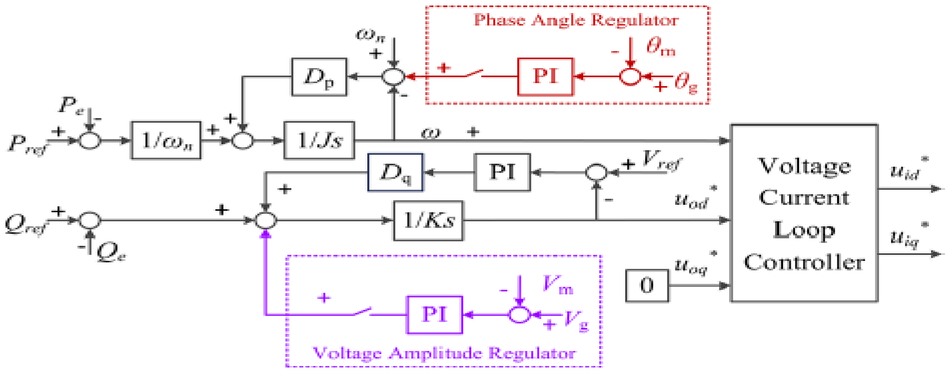

Fig.5.Improved VSG controller with predictive synchronization method

A. Pre-synchronization and grid-connection by using PI controller:

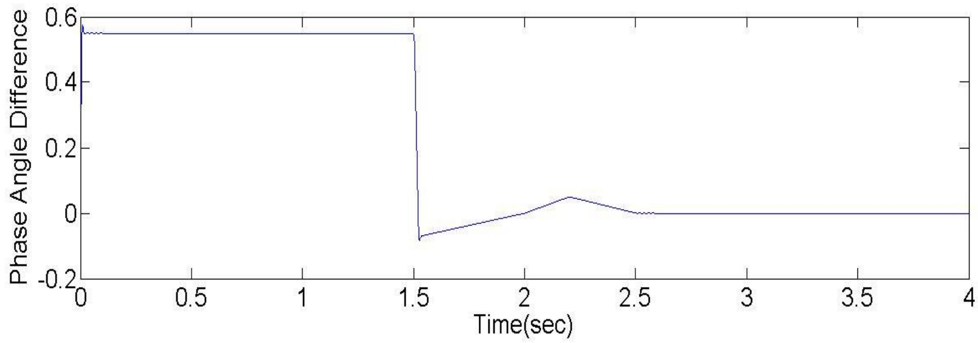

Fig.6.Phase-angle difference between the grid and the microgrid

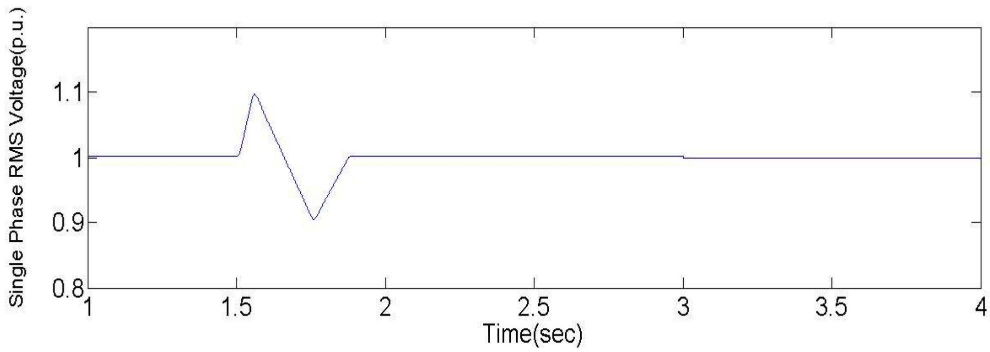

Fig.7. AC voltage of the microgrid from stand-alone mode to grid-tied mode

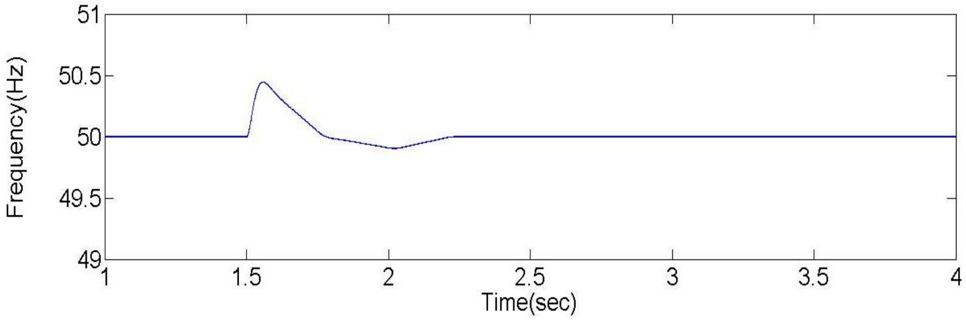

Fig.8. Microgrid frequency from stand-alone mode to grid-tied mode

The performances of the hybrid microgrid are shown in Fig. 9-Fig. 11. When the pre-synchronization process starts, the phase angle difference is regulated to 0 very soon. Due to the change of the phase angle, the frequency varies during the regulation while the change of the frequency ranges from 49.9 Hz to 50.6 Hz, which is also acceptable. There is a big overshoot occurred in the voltage during the synchronization.

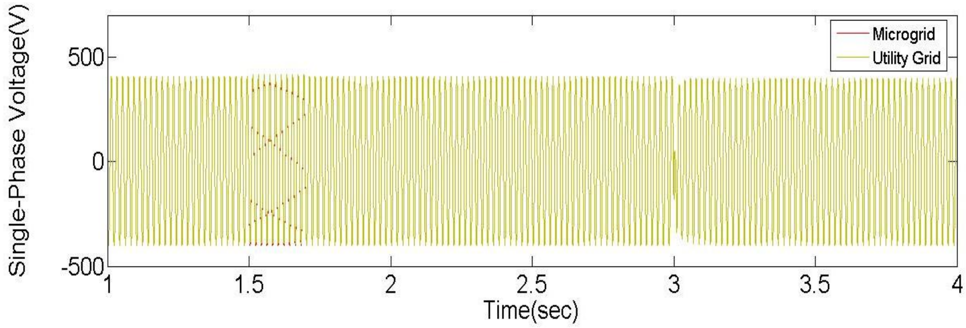

Fig.9.AC voltage variation during pre-synchronization

However, with the adoption of the voltage amplitude regulator, the voltage can recover to normal value quickly within 0.25 Sec. The voltage deviates from 0.92 p.u. to 1.12 p.u. After the synchronization regulation, the microgrid is connected to the utility grid at 3 Sec. The variation process of the microgrid AC voltage is shown in Fig. 12. The figure presents how the microgrid is synchronized to the main grid. It can be seen that the phase angle can be regulated to the same level within 20 cycles.

IV. PROPOSED ANFIS CONTROLLER

The proposed system used a controller based on ANFIS to ensure a proper transition during the operation mode switching from islanding mode to grid-tied mode. 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. For using the ANFIS as somewhat of a more productive and perfect way, one can use the best parameters obtained by innate calculation. ANFIS: Artificial Neuro -Fuzzy Inference Systems

1. ANFIS are a class of adaptable systems that are in every practical sense indistinct to fluffy surmising structures.
2. ANFIS address Sugeno e Tsukamoto padded models.
3. ANFIS uses a mutt getting the hang of figuring.

In the field of mechanized reasoning neuro-padded surmises blends of misrepresentation neural structures and woolen help. Neuro-cushy hybridization comprehends a cream sharp structure that synergizes these two strategies by joining the human-like reasoning style of padded structures with the learning and connectionist structure of neural frameworks. Neuro-padded hybridization is generally named as Fuzzy Neural Network (FNN) or Neuro-Fuzzy System (NFS) in the formed work. Neuro-fluffy structure (the more standard term is used from this time forward) wires the human-like reasoning style of woolen systems utilizing cushy sets and a semantic model including an approach of IF-THEN padded principles. The fundamental thought of neuro-fluffy structures is that they are regardless of what you look like at it approximates with the ability to ask for interpretable IF-THEN rules. The possibility of neuro-delicate structures wires two clashing necessities in cushy showing up: interpretability versus precision. Inside and out that truly matters, one of the two properties win. The neuro-warm in padded demonstrating research field is isolated into two zones: semantic delicate exhibiting that is centered around interpretability, generally the Mamdani show; and right fluffy showing that relies upon precision, in a general sense the Takagi-Sugeno-Kang (TSK) delineate. Tending to fuzzification, fluffy inciting and defuzzification through multi-layers feed-forward connectionist structures. It must be called attention to that interpretability of the Mamdani-type neuro-cushy frameworks can be lost. To redesign the interpretability of neuro-padded frameworks, certain assessments must be taken, wherein fundamental parts of interpretability of neuro-cushy structures are in like way broke down. An advancing examination line watches out for the information stream mining case, where neuro-padded structures are sequentially invigorated with new moving toward precedents on demand and on-the-fly. Accordingly, system revives don't simply consolidate a recursive change of model parameters, yet also a dynamic advancement and pruning of model with a particular ultimate objective to manage thought drift and logically changing structure lead adequately and to keep the structures/models "in the current style" at whatever point.

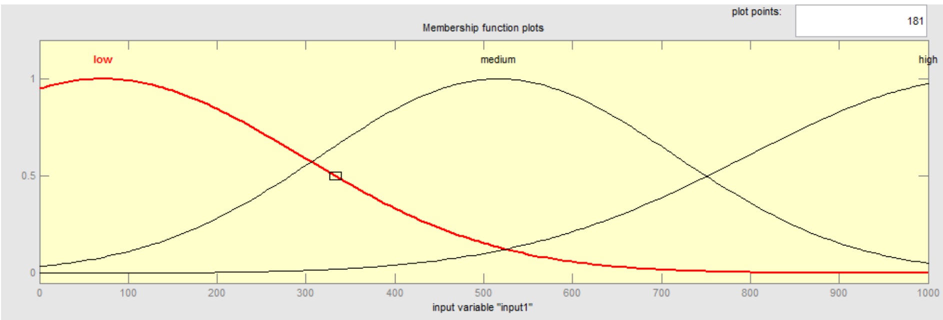

Fig.10. Input 1 membership function

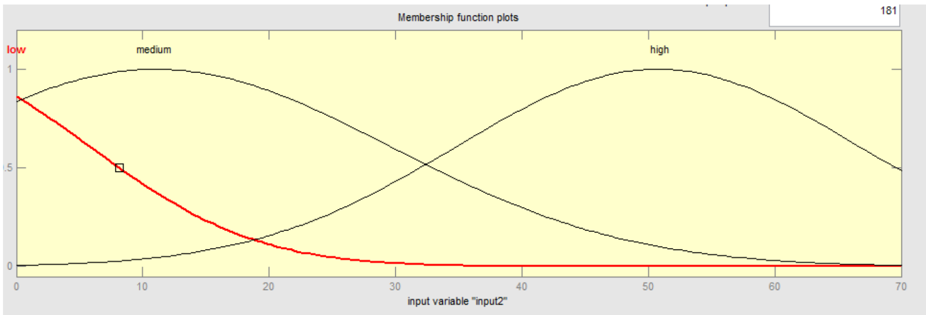

Fig.11. Input 2 membership function

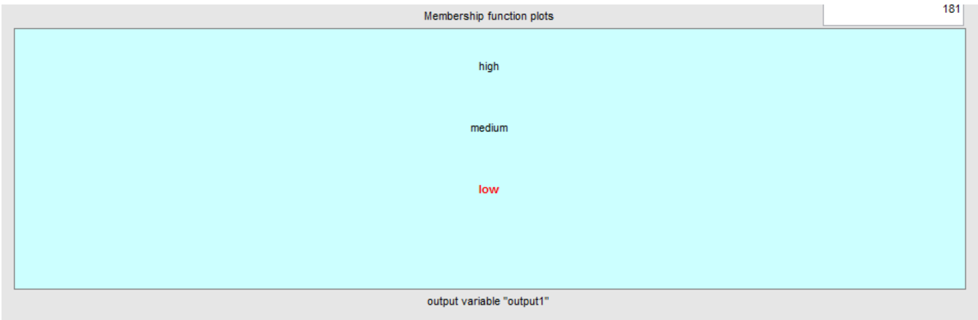

Fig.12. Output membership function

TABLE I
Fuzzy Rule Base

dP / P	**Low**	**Medium**	**High**
Low	Low	Medium	HIGH
Medium	Medium	High	High
High	High	High	High

V. SIMULATION RESULTS AND DISCUSSIONS

A. Pre-synchronization and grid-connection by using ANFIS controller

In this method, the pre-synchronization process is taken over by the ANFIS controller for matching the voltage and frequency of the islanded system with that of the grid voltage and grid frequency.

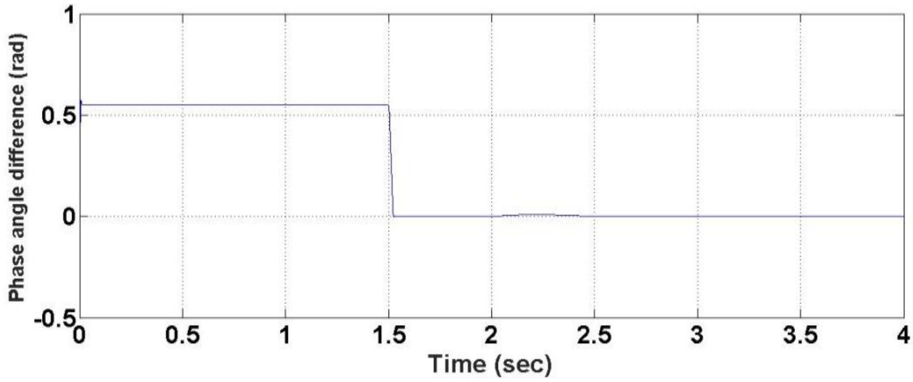

Fig.13.Phase-angle difference between the grid and the microgrid

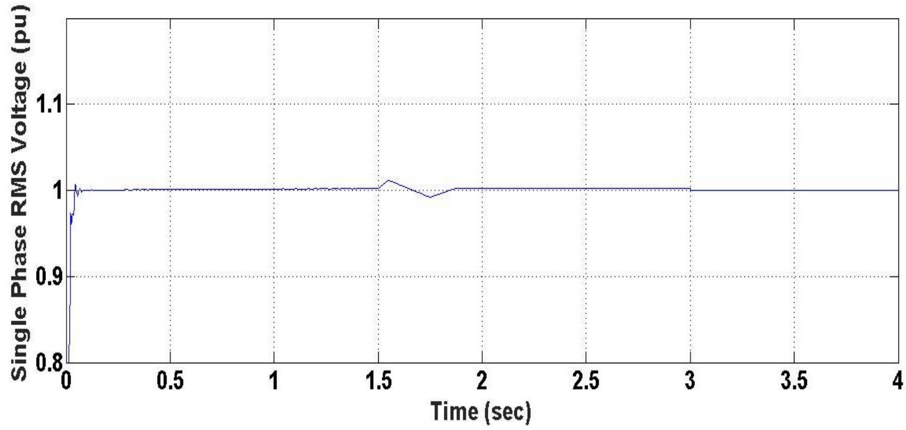

Fig.14.AC voltage of the microgrid from stand-alone mode to grid-tied mode

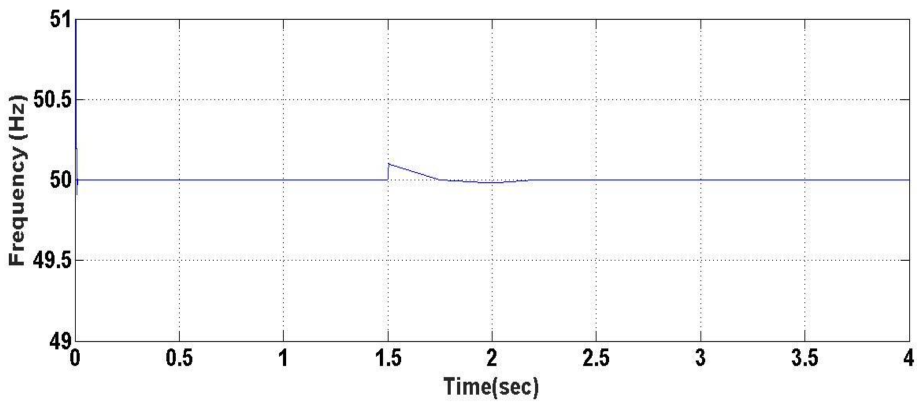

Fig.15.Microgrid frequency from stand-alone mode to grid-tied mode

The pre-synchronization method proposed in this paper is also testified. According to Fig. 5, when there is a requirement for the microgrid to connect to the utility grid, the switches in phase angle regulator and voltage regulator both turn on. In the simulation, the pre-synchronization regulators are put into operation at 1.5 Sec and the microgrid is connected to the grid at 3 Sec. The whole regulation process lasts for approximately 1 Sec. From Fig 13-Fig 15. When the pre-synchronization starts at 1.5 Sec, the phase angle difference is stable at 0. While the frequency is maintain 50Hz with in 0.2 Sec only. According to the figures, the phase angle, the frequency, and the voltage amplitude are all in the same level of the grid. The system achieves a smooth grid-connection without any big impacts on the performance of the overall system.

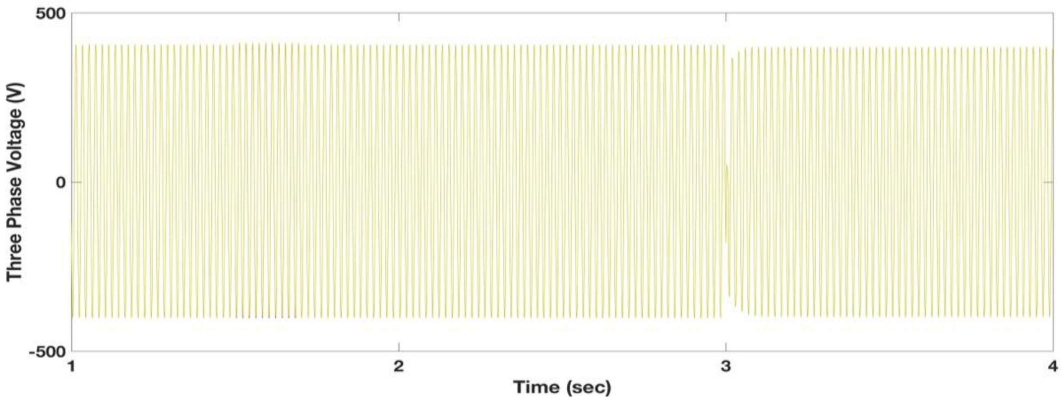

Fig.16.AC voltage variation during pre-synchronization

From fig.16. The variation process of the microgrid AC voltage, the figure presents the microgrid is synchronized to the utility grid at stating of pre-synchronisation process at 1.5 Sec and maintaining constant voltage 400V same as utility grid.

VI. CONCLUSION

This paper carried out the hybrid model of AC/DC interlinking converter situated in the Griffith University, Australia. Earlier research in this consent showed superiority of VSG control over droop control. This paper dealt with the improved control using ANFIS in the VSG control scheme. This improved control using ANFIS made possible of the reduction of variations in frequency and voltage during pre-synchronization process. This system is simulated using MATLAB Simulink software and results were compared of the improved VSG control using ANFIS to the VSG control using PI controller.

TABLE II
Comparison of parameters

Parameters	Existing values	Proposed values
Phase angle difference	0.12	0
Frequency Deviation	0.52Hz	0.1Hz
Three phase peak voltage(Under Balanced Condition)	420 V	400 V

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