HESS Micro Grids Integration for Power Quality Improvement using Fuzzy logic controller

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Abstract:

This project proposes a fuzzy based for HESS micro grids integration for power quality improvement. The system incorporates clean energy generation along with power quality improvement thus increasing functionality of the system. Rising demand for distributed generation based on Renewable Energy Sources (RES) has led to several issues in the operation of utility grids. The microgrid is a promising solution to solve these problems. A dedicated energy storage system could contribute to a better integration of RES into the microgrid by smoothing the renewable resource's intermittency, improving the quality of the injected power and enabling additional services like voltage and frequency regulation. However, due to energy/power technological limitations, it is often necessary to use Hybrid Energy Storage Systems (HESS).In this paper the use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (formed by a two Li-Ion batteries) in a microgrid context has been investigated. A new model of the structural limits is presented and implemented to exploit the entire capability of the 4-Leg 3L-NPC converter to insure a maximum power division between the two ESS. A non-linear 2-SMC scheme has been designed and tuned to control the zero sequence injection in the modulating signals in order to control the power flow of the HESS. Simulation and experimental results proved the capacity of the proposed control strategy to manage a HESS in order to improve the power quality and stability as well as to control the renewable energy injected into a microgrid. The investigation of the limits of the topology showed a power exchange capability among this fuzzy enables its application to control in conditions of distorted voltages. Threshold values of existing and proposed methods has been compared and the proposed threshold value is less than the existing system. Hence by using the fuzzy logic controller in proposed system reduced the voltage and current threshold values. So that improves the performance of operation in proposed system. The proposed method is verified by simulating the system in Matlab 2013a Simulink with combination of linear and nonlinear loads.

I. INTRODUCTION

The increasing penetration of DG is changing management of the grid from centralized to decentralized schemes, creating several challenges that must be carefully addressed in order to keep the electrical grid's proper operation. High penetration of renewable energy can lead to stability and power quality issues due to the stochastic nature of RES, such as wind and solar energy. The microgrid concept, which can be defined as a small scale weak electrical grid that is able to operate both in connected and islanded mode, has been extensively studied as a solution for RES integration. The weak nature of a microgrid implies the use of an Energy Storage System (ESS) to increase RES penetration and insure its stability [1]–[3].

The use of an ESS integrates constraints such as admissible bandwidth, maximum ratings, current/power maximum gradient and the number of cycles. If these constraints are not respected it can lead to a dramatic lifetime reduction of the ESS, or in certain cases, to its destruction. [4], [5]. The use of a Hybrid Energy Storage System (HESS) offers the necessary trade-off for increasing the lifetime of each ESS while also increasing the global specific energy and power of the whole system [6], [7]. Fig. 1 shows the main structures currently found in the literature to integrate a HESS into a grid.

The passive topology a) shows a lack of control of the power flow as well as the ESSs State of Charge (SOC) [8], [9]. The floating b) and parallel c) topologies are active topologies that use DC/DC converters to manage energy flows directly. They are already being used within the industry and fulfill a high standard (stress reduction and specific power/energy enhancement [7], [10]–[12]). Parallel topology offers the best flexibility but the use of several DC/DC converters affects the global efficiency [13]. Finally, despite a lower flexibility when compared to the parallel topology, the 3L-NPC topology d) can be used as a single power converter able to manage the power flow of a HESS, acting as an interface between the RES and the grid.
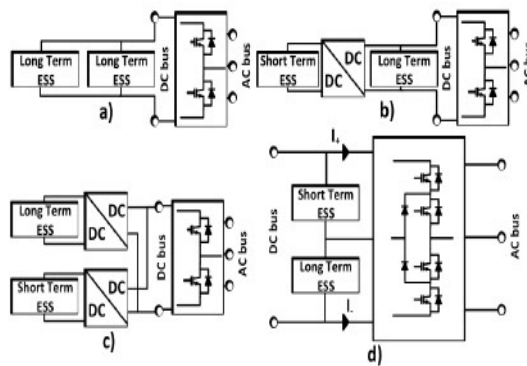
Figure. 1 Power converter topologies for micro grid ESS hybridization passive (b) floating (c) parallel (d) 3L-NPC topology

Due to the reduced voltage applied on the switches and an increased number of voltage levels, the 3L-NPC topology becomes more efficient while showing a lower current Total Harmonic Distortion (THD) [13] than an equivalent two level inverter. Several works have been carried out on ESS hybridization using multilevel topologies, including the 3 Leg 3L-NPC [13]–[15]. In [13], a PI controller is designed to control the power flow of a batteries whereas a Super Capacitor (SC) provides the fast variation of power with both parallel and 3 Leg 3L-NPC inverters. It is shown that, beyond the limits of the 3L-NPC topology, the efficiency and THD improvement make this topology suitable for ESS hybridization.

Another particularity of this topology is the floating DC link middle point voltage which involves voltage ripples at three time the fundamental frequency (i.e. 150 Hz) [16]–[20]. The harmonic magnitudes are directly linked to the modulation technique used, as well as the DC link filter characteristics [21], [22]. These voltage ripples coupled to highly unbalanced AC loads may cause large DC current harmonics which may increase electromagnetic interference (EMI) and impact ESSs lifetime due to increased thermal losses [23], [24]. This effect could be exacerbated by a degraded DC link filter. The 4-Leg 3L-NPC used as an active power filter is also extensively studied in the literature [19], [25]–[28]. Thanks to the 4th leg this inverter is able to produce zero sequence currents in addition to direct and negative ones. This characteristic enables compensation for the increasing number of unbalanced loads (monophasic customers, electric vehicles…) and single phase generators (small wind/PV units).

In [19], [27], [29] several modulation techniques and redundant vector selection methods are used to balance the capacitor voltages in power filter application. In [27], the AC side predictive control of a 4 Leg 3L-NPC inverter in isolated mode improves the performance and the power quality. In [30] a non-linear control strategy is developed for a 4 Leg 3L-NPC inverter used as an active power filter.

However, the 4-Leg 3L-NPC inverter used both as a power filter and a HESS interface for a RES integration into the grid is not addressed in the literature.

The use of the 4-Leg 3L-NPC topology when associated with an adapted control strategy in a micro grid context presents itself as a promising solution due to its ability to combine the following characteristics:
• Increase the efficiency of RES and HESS integration to the microgrid through a unique power electronics interface acting as an active power compensator able to smooth the RES by acting on the HESS [13]
• Reduce AC side current harmonics (for the same switching frequency and AC filter components when compared to a 2 level inverter) [31]
• Reduce HESS current harmonics caused by the floating middle point inherent to the NPC topology and move the ripples involved by unbalanced AC loads to the high specific power ESS [32]
• Compensation of AC side microgrid disturbances produced by unbalanced/nonlinear loads thanks to the fourth leg [19]

In this paper, the power flow management of a HESS composed of a two Li-Ion batteries are investigated in a microgrid context. The 4 Leg 3LNPC inverter has been chosen to interface the HESS with the microgrid due to its low THD, high efficiency and its ability to manage unbalanced AC loads through the 4th leg. The objective of the paper is to prove that by adding the fourth leg to a 3L-NPC converter and using a new DC side control strategy it is possible to reach both fast and efficient DC power sharing between the two ESSs and the RES, and at the same time improve the AC side power quality. The main contribution of this paper lays in the DC power flow controller which allows HESS power flow control and DC current harmonics suppression. The new model for 4-Leg 3L-NPC structural limits proposed in [33] is assessed. The effectiveness of the proposed system has been tested through simulations and experimental tests using a laboratory prototype.

II.EXISTING SYSTEM

1. HESS AND 4-LEG 3L-NPC MODELING
In order to design and assess in simulation a control strategy able to manage the DC power flow within the HESS and at the same time improve the AC power quality, the investigated system has first been modeled, taking into account the objective of the study, i.e. the transient behavior.

A. Modeling of the ESSs

The investigated HESS is formed of a two Li-Ion batteries. The Li-Ion battery benefits from a high specific power and moderate self-discharge (1-5% per day). This technology has also been developed for high power standalone applications in recent years [35].

A. Li-Ion model

The Li-Ion model used in this work is based on the module presented in [39]. This model is already implemented in MATLAB/Simulink within the Sim Power Systems library. The battery is realized with strings of series modules connected in parallel to build an ESS of 825 V/ 30Ah (at 80% of SOC and open circuit).

2. Modeling of the 4-Leg 3L-NPC

Fig. 2 shows the schematic representation of the 4-Leg 3LNPC inverter used as a HESS interface for RES and HESS integration to a microgrid. This topology requires the RES to be a current source and in particular, could be adapted if placed either after a Maximum Power Point Tracking (MPPT) converter for a solar plant, or instead of the grid-side converter of a back to back set up for wind turbines. For this study the RES is considered as a current source injecting into the DC bus.
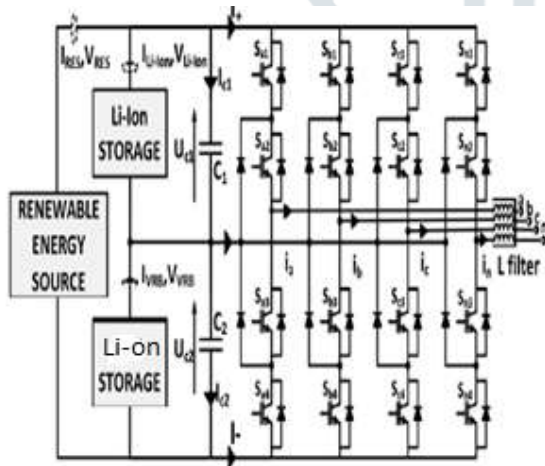
Figure.2 4-Leg 3L-NPC topology used as a HESS/RES interface

The 4-Leg 3L NPC inverter has $3^4 = 81$ different switching states that produce different voltage vectors defined by (3). The vectors generated by more than one switching state are called redundant vectors and allow power flow sharing control among the HESS.

III.PROPOSED METHOD

A. Block Diagram

A new model of the structural limits is presented and implemented to exploit the entire capability of the 4-Leg 5L-NPC converter to insure a maximum power division between the two ESS. A non-linear 2-SMC scheme has been designed and tuned to control the zero sequence injection in the modulating signals in order to control the power flow of the HESS.

Simulation and experimental results proved the capacity of the proposed control strategy to manage a HESS in order to improve the power quality and stability as well as to control the renewable energy injected into a microgrid. The investigation of the limits of the topology showed a power exchange capability among this fuzzy enables its application to control in conditions of distorted voltages.
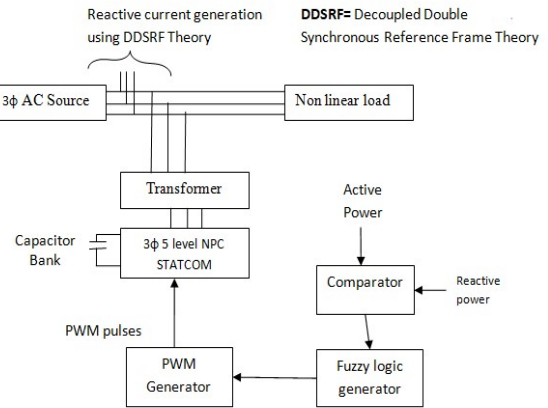

Figure.3 proposed block diagram

Fuzzy Logic is a particular area of concentration in the study of Artificial Intelligence and is based on the value of that information which is neither definitely true nor false. The information which humans use in their everyday lives to base intuitive decisions and apply general rules of thumb can and should be applied to those control situations which demand them. Acquired knowledge can be a powerful weapon to combat the undesired effects of the system response.

In most applications there are some points which lie in the common area. Information which lies within the common area has to be studied, stored, and used to quantify and to classify the data. This allows for smart manipulation of the data structure in order to make inference to a solution. Information which falls in that common area can be ranked, aged, and "best guess" made after evaluation of this "gray" information. Another advantage of Fuzzy Logic controllers is to quantify the input signal in a sometimes "noisy" environment. This noise, which tends to corrupt the integrity of the actual signal, is dealt with through the common sense of the competent operator. Mathematically, the information must be judged and prepared for use in decision making. If an operator took the time to plot the process information on an X-Y coordinate system, the operator could visually apply a curve fit to the data and come up with a fairly accurate generic representation.

Mathematically, fitting a curve of lower order would produce a fairly inaccurate representation. Therefore, a higher order curve fit would be appropriate to accommodate the noisy signal. Fuzzy Logic attempts to emulate what the human response would be and apply the most intelligent fit to the data.

Conventional computing is based on Boolean logic, meaning everything is represented as either zero or one. In some situations this leads to oversimplification and inadequate results. Fuzzy logic controllers, and by extension, fuzzy control, seeks to deal with complexity by creating heuristics that align more closely with human perception of problems.

Fuzzy logic provides a way of dealing with imprecision and nonlinearity in complex control situations. Inputs are passed to an "inference engine" where human or experienced-based rules are applied to produce an output.

The proposed DDSRF current controller scheme is shown in Figure 3. The dc value of one sequence is the value for the opposite sequence oscillations amplitude. On the other hand, the Park´s transformation is applied over the angular position difference of both frames with the aim of obtaining the estimated oscillation waveform. The DDSRF current controller filters the corresponding opposite sequence current to obtain its dc value and decelerate (if the sequence to be compensated is the positive one) or accelerate (if the sequence to be compensated is the negative one) by two times the rotating frequency (considering also the initial voltage phase shift) in order to estimate the undesirable oscillations. The low-pass (LP) filter for obtaining the mean value does not have a high selectivity because in steady-state conditions, the decoupled current is free from oscillations and matches its dc value.

IV SIMULATION RESULTS

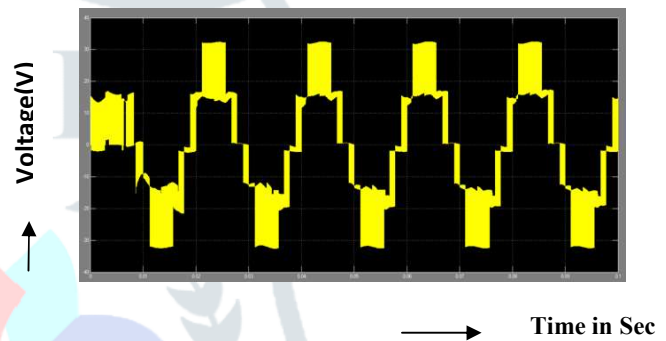### 4.1 EXISTING SYSTEM

Internal circuit of pulses
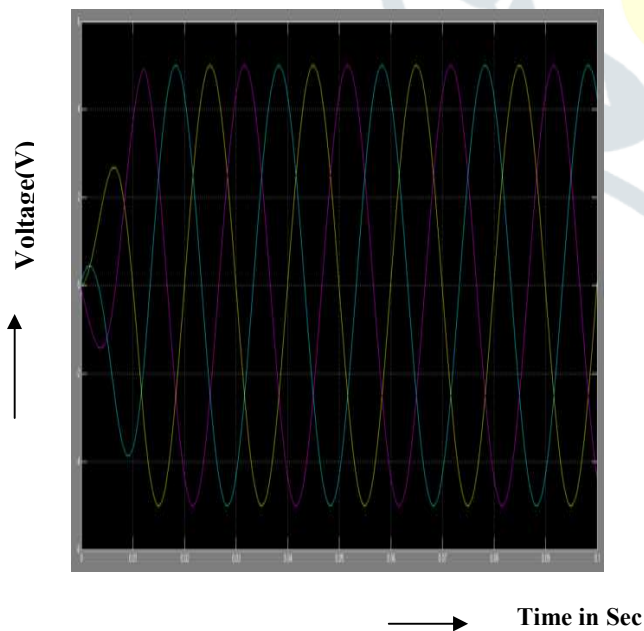
The above figure represents the triggering pulses for the inverter

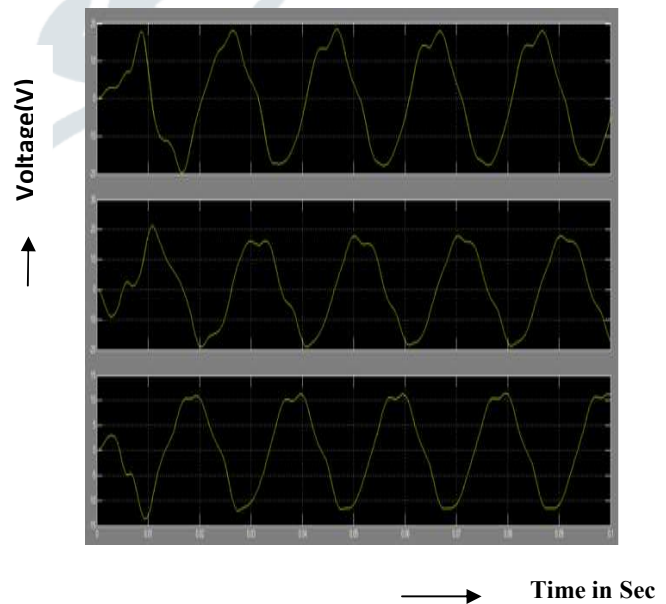*Subsystem internal pulses*
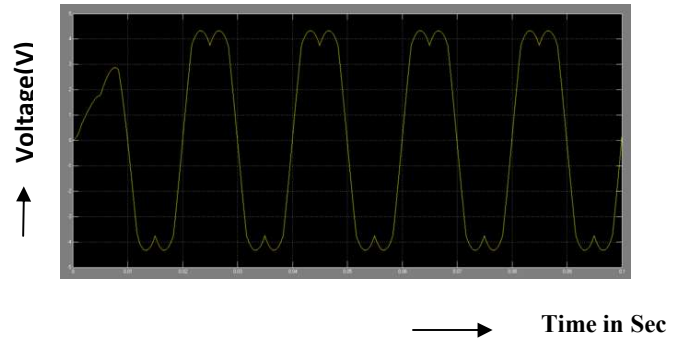
The above figure represents the internal pulses for the subsystem
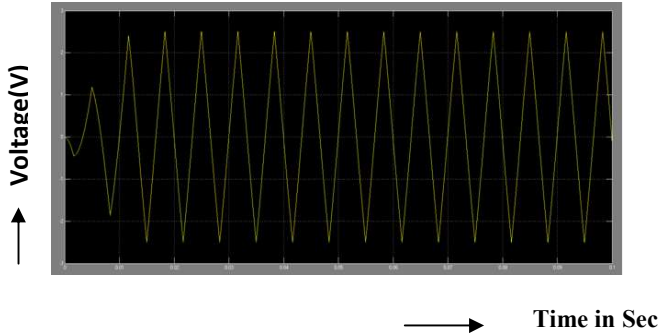
Output voltage wave form

The above figure represents the renewable energy storage system voltage waveform

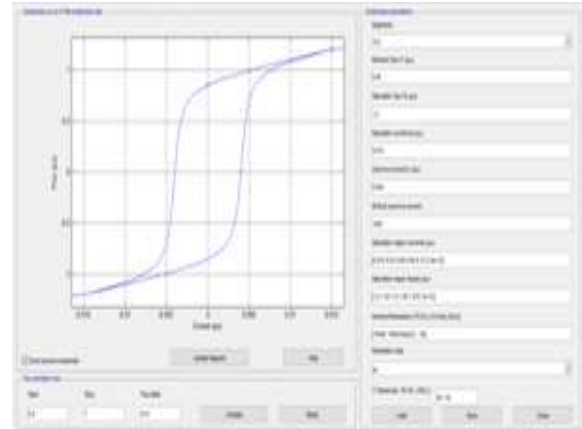*Phase voltage wave form at load side*

The above figure represents the measurement of each phase voltage in load side
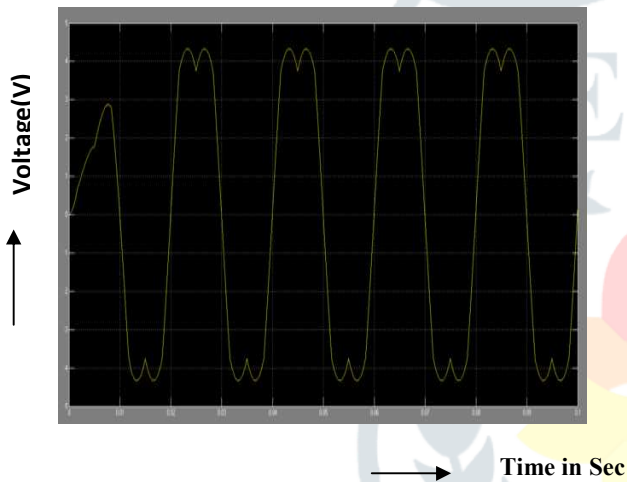
Step response in LTI viewer

The above figure represents the step response of RES voltage in LTI viewer

Step response voltage wave form

The above figure represents the step response of voltage waveform

Step response

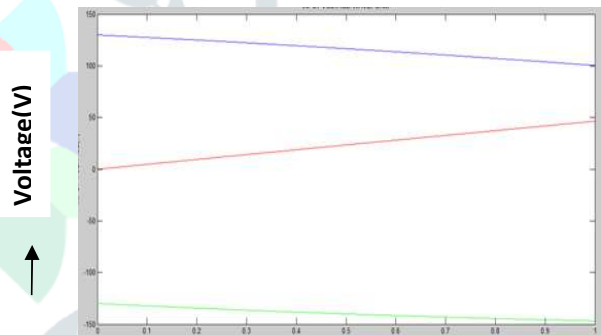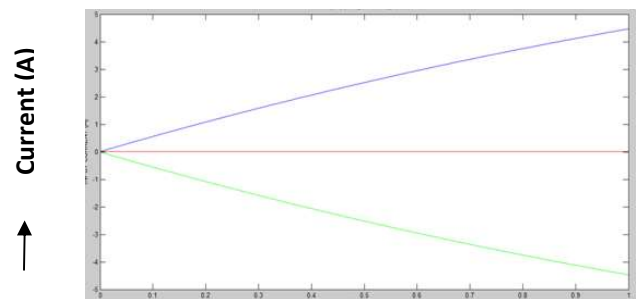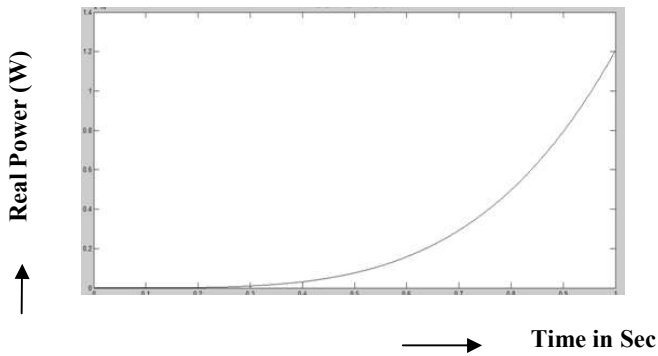The above figure represents the step response for the switches in LTI Viewer

Hysteresis graph

The above figure represents the hysteresis graph

4.2 PROPOSED METHOD

The proposed results simulated based on source code. The corresponding results at differnt points from the proposed simulink model shown below.

Input voltage wave form

The above figure represents the input voltage waveform at source side
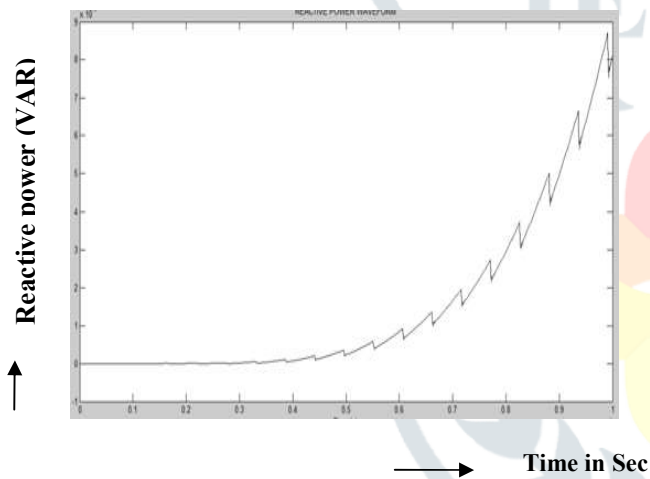
Input current wave form

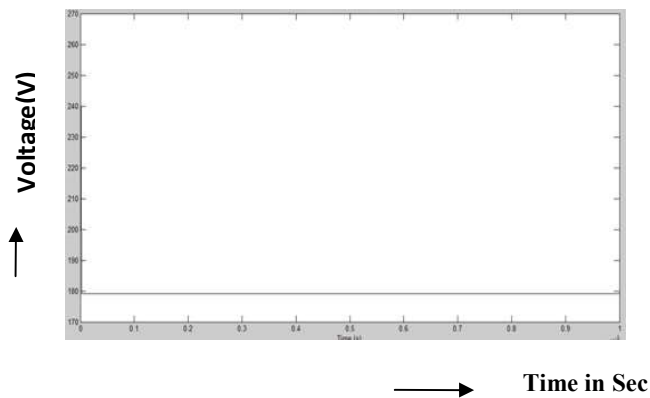The above figure represents the input current waveform

Real power waveform

The above figure represents the real power waveform

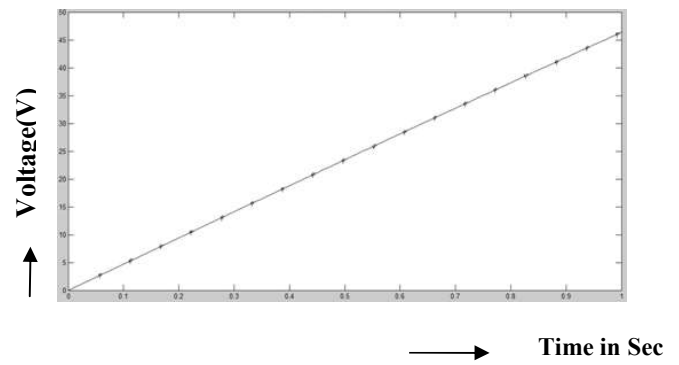### *Reactive power wave form*

The above figure represents the reactive power waveform.

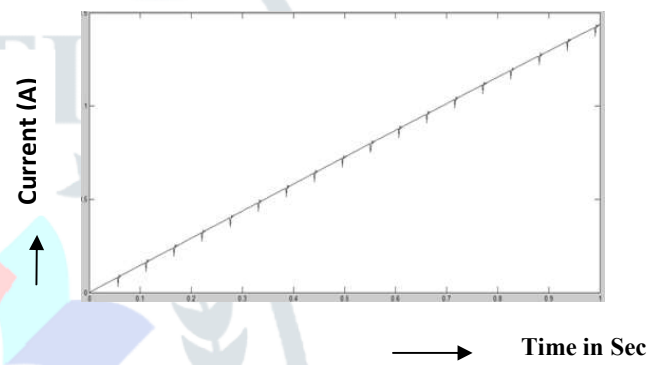### **DC link Voltage**

The above figure represents the Dc link voltage in the capacitor waveform
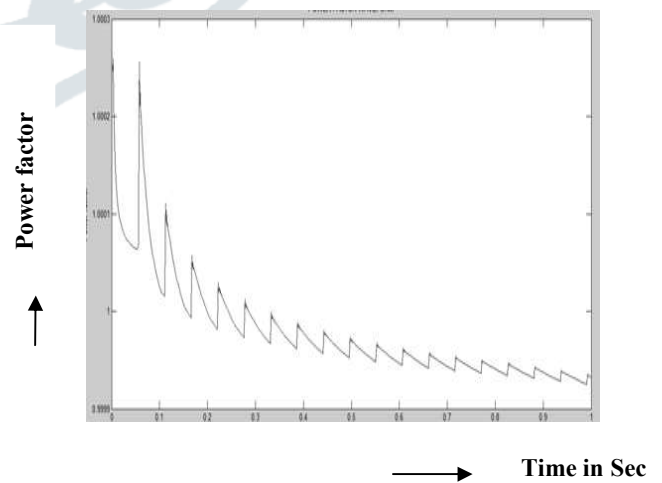
Output voltage at load side

The above figure represents the load side voltage waveform

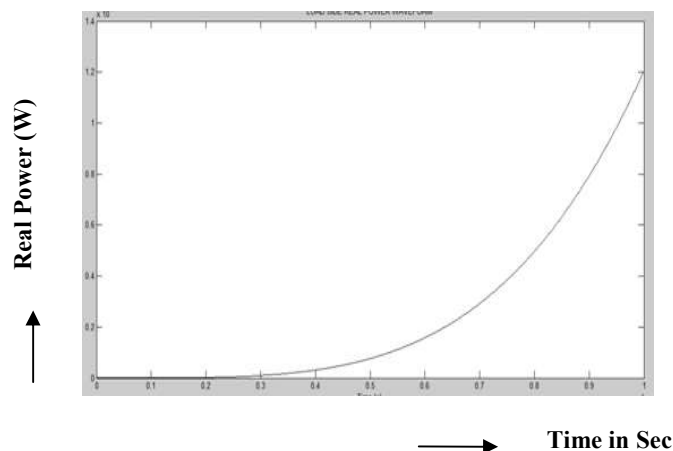### *Output current at load side*

The above figure represents the load side current waveform
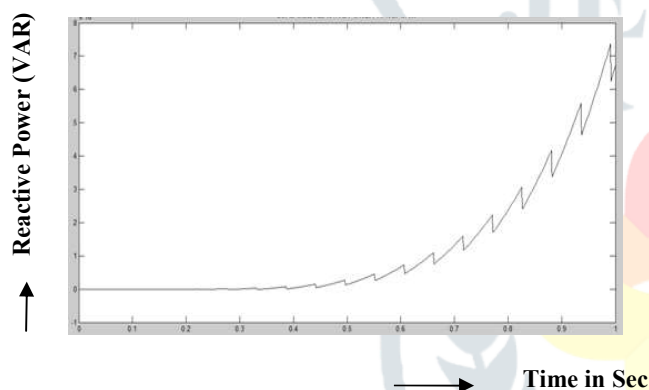
Power factor waveform at load side

The above figure represents the power factor waveform

Real power at load side

The above figure represents the load side real power waveform

Reactive power at load side

The above figure represents the load side reactive power waveform

C. *COMPARISON TABLE*

S.NO	Type of model	Existing method	Proposed method
1	THD (Current)	7.6	2.7
2	THD (Voltage)	4.1	1.6
3	Input Voltage, Current	100V, 15A	100V, 15A
4	Power Factor	0.88	0.96
5	Reactive Power	500VA	160VA
6	Voltage Source Inverter Level	Three Level	Five level
7	Current Control Technique	SRF Algorithm	DDSRF Theory
8	Voltage Control Technique	PI Controller	Fuzzy Logic Controller

The above table shows the threshold values of existing and proposed methods. It shows the proposed threshold value is less than the existing system. Hence by using the fuzzy logic controller in proposed system reduced the voltage and current threshold values. So that improves the performance of operation in proposed system.

VI CONCLUSION

Hence we have conclude that the Simulation and experimental results proved the capacity of the proposed control strategy to manage a HESS in order to improve the power quality and stability as well as to control the renewable energy injected into a micro grid. The investigation of the limits of the topology showed a power exchange capability among this fuzzy enables its application to control in conditions of distorted voltages. The proposed method performance is improved than the existing method.

REFERENCESS

[1] M. Yekini Suberu, M. Wazir Mustafa, and N. Bashir, "Energy storage systems for renewable energy power sector integration and mitigation of intermittency," Renew. Sustain. Energy Rev., vol. 35, pp. 499–514, Jul. 2014.

[2] S. Vazquez, S. M. Lukic, E. Galvan, L. G. Franquelo, and J. M. Carrasco, "Energy Storage Systems for Transport and Grid Applications," IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 3881– 3895, Dec. 2010.

[3] M. G. Molina and P. E. Mercado, "Power Flow Stabilization and Control of Microgrid with Wind Generation by Superconducting Magnetic Energy Storage," IEEE Trans. Power Electron., vol. 26, no. 3,
pp. 910–922, Mar. 2011.

[4] M.-E. Choi, S.-W. Kim, and S.-W. Seo, "Energy Management Optimization in a Battery/Super capacitor Hybrid Energy Storage System," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 463–472, Mar. 2012.

[5] G. Qiu, C. R. Dennison, K. W. Knehr, E. C. Kumbur, and Y. Sun, "Porescale analysis of effects of electrode morphology and electrolyte flow conditions on performance of vanadium redox flow batteries," J. Power Sources, vol. 219, pp. 223–234, Dec. 2012.

[6] X. Tan, Q. Li, and H. Wang, "Advances and trends of energy storage technology in Microgrid," Int. J. Electr. Power Energy Syst., vol. 44, no. 1, pp. 179–191, Jan. 2013.

[7] N. R. Tummuru, M. K. Mishra, and S. Srinivas, "Dynamic Energy Management of Renewable Grid Integrated Hybrid Energy Storage System," IEEE Trans. Ind. Electron., vol. 62, no. 12, pp. 7728–7737, Dec. 2015.

[8] T. A. Smith, J. P. Mars, and G. A. Turner, "Using super capacitors to improve battery performance," in 2002 IEEE 33rd Annual IEEE Power Electronics Specialists Conference. Proceedings, 2002, vol. 1, pp. 124– 128.

[9] R. A. Dougal, S. Liu, and R. E. White, "Power and life extension of battery-ultra capacitor hybrids," IEEE Trans. Components Packag. Technol., vol. 25, no. 1, pp. 120–131, Mar. 2002.

[10] T. Zhou and B. François, "Energy management and power control of a hybrid active wind generator for distributed power generation and grid integration," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 95–104, Jan. 2011.
[11] Z. Guoju, T. Xisheng, and Q. Zhiping, "Research on Battery Super capacitor Hybrid Storage and its application in MicroGrid," in Asia-Pacific Power and Energy Engineering Conference, APPEEC, 2010, pp. 1–4.