Wind/PV and Battery Energy Storage System Integrated UPQC Using Four Leg Three Level NPC Inverter

SATHISH.A[1], MOHANKUMAR.G[2]

[1]P.G Scholar, Department of EEE, PRIST UNIVERITY, Thanjavur, Tamil Nadu (Puducherry Campus)
[2]Assistant Professor& Head, Department of EEE, PRIST UNIVERITY, Thanjavur, Tamil Nadu (Puducherry Campus)

Abstract – *In this paper the power flow control of a HESS using a Four Leg Three Level Neutral Point Clamped (4-Leg 3LNPC) inverter RES/HESS microgrid is proposed. Renewable Energy Sources (RES) based distributed generation has led to several issues in the operation of utility grids due to raising demand. 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). The proposed circuit model is modeled by using MATLAB/simulink.*

Key Words: Renewable Energy Sources, Hybrid Energy Storage Systems (HESS), Four Leg Three Level Neutral Point Clamped (4-Leg 3LNPC)

1.INTRODUCTION

In order to keep the electrical grid's proper operation management of the grid from centralized to decentralized schemes creating several challenges due the increasing penetration of DG. Power quality issues due to the stochastic nature of RES, such as wind and solar energy due to high penetration of renewable energy can lead to stability. As a solution for RES integration a small scale weak electrical grid that is able to operate both in connected and islanded mode, has been extensively studied in the microgrid concept. An Energy Storage System (ESS) to increase RES penetration and insure its stability result of the weak nature of a microgrid. Admissible bandwidth, current/power maximum gradient maximum ratings and the number of cycles are the constraint of ESS integrates. If these constraints are not satisfied, it can lead to a destruction and dramatic lifetime reduction. By using Hybrid Energy Storage System (HESS) lifetime of each ESS can increased in turn increasing the global specific energy and power of the whole system.

The power converter topologies for microgrid in HESS into a grid as shown in figure 1. The passive topology a) shows a lack of control of ESSs State of Charge (SOC) and the power flow. The floating b) and parallel c) topologies are active topologies that manage energy flows directly by DC/DC converters. In Parallel topology offers the use of several DC/DC converters for the best flexibility but affects the global efficiency d) 3L-NPC topology can be used as a single power converter able to manage the power flow of a HESS, becomes more efficient while showing a lower current Total Harmonic Distortion (THD) acting as an interface between the RES and the grid.

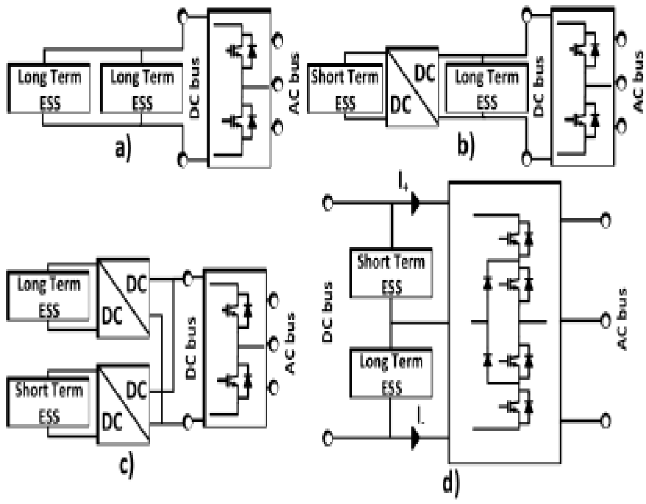

Figure 1 Power converter topologies for microgrid ESS hybridization (a) passive (b) floating (c) parallel (d) 3L-NPC topology

The following characteristics by the use of the 4-Leg 3L-NPC topology when associated with an adapted control strategy in a microgrid:

a) By unique power electronics interface the efficiency of RES and HESS integration to the microgrid increase.
b) For the switching frequency and AC filter components reduce AC side current harmonics when compared to a 2 level inverter.
c) Ripples involved by unbalanced AC loads to the high specific power ESS reduce HESS current harmonics caused by the floating middle point inherent to the NPC topology.
d) Compensation of AC side microgrid disturbances produced by unbalanced/nonlinear loads can be done by fourth leg in inverter configuration.

2. MODELLING OF THE 4-LEG 3L-NPC INVERTER

The schematic representation of the 4-Leg 3LNPC inverter used as a HESS interface for RES and HESS integration to a microgrid as shown in Figure4. This topology requires the Renewable energy source to be a current source and it could be adapted if placed either after grid-side converter of a back to back set up for wind turbines or Maximum Power Point Tracking (MPPT) converter for a solar plant. The 4 Leg 3L-NPC inverter used as an active power in a non-linear control strategy is developed as an active filter. However, the 4-Leg 3L-NPC inverter used both as a power filter and a HESS interface for RES integration into the grid. The 4 Leg 3LNPC inverter has been chosen due to its low THD, high efficiency and its ability to manage unbalanced AC loads to interface the HESS with the microgrid through the 4th leg.

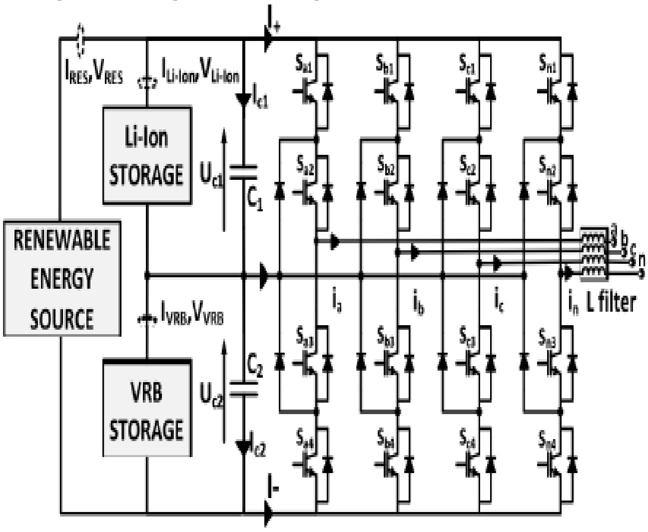

Figure 2 HESS/RES interface-4-Leg 3L-NPC topology

By adding the fourth leg to a 3L-NPC converter using a new DC side control strategy at the same time improve the AC side power quality it is possible to reach both fast and efficient DC power sharing between the two ESSs and the RES. The 4-Leg 3L NPC inverter has 3^4 = 81 different switching states that produce different voltage vectors. The vectors generated power flow sharing control among the HESS by more than one switching state are called redundant vectors.

2.1. MODELLING OF THE ESSS

The HESS is comprised of a Li-Ion battery and a VRB. The VRB technology benefits from the decoupled Specific power which depends on the its specific energy and stack characteristics. This technology is suited to long term energy Storage with a good round trip efficiency of around 90%. This technology has also been developed for high power standalone applications in recent years and the use of these two technologies realizes a high specific energy and high power HESS.

2.2 VRB MODEL

The equivalent circuit of the VRB as shown in figure2. Proposed circuit has a rated voltage at 50% of SOC and open circuit, a maximum charge/discharge current and a rated power in the VRB circuit. The model of the VRB is based on the dynamic model, as the transient behaviors of the system are analysis; capacitance of the electrode is taken into account.

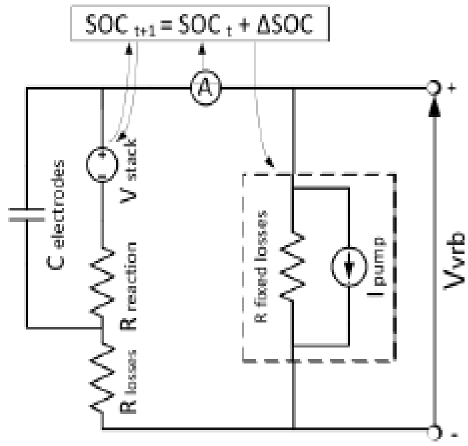

Figure 3 VRB Model

2.3 LI-ION MODEL

The Li-Ion model used in this proposed system module is shown in figure4. This model is implemented in MATLAB/Simulink within the Sim Power Systems library. The battery at 80% of SOC and open circuit is realized with strings of series modules connected in parallel to build an ESS. The Li-Ion battery benefits from a moderate self-discharge of 1-5% per day and high specific power.

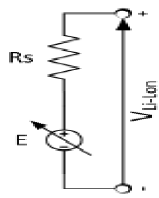

Figure 4 Li-Ion cell Model

3. SIMULATIONS AND RESULTS

The proposed Hybrid PV/Wind & Battery Storage are simulated using MATLAB/simulink to obtain the results as shown in figure5.

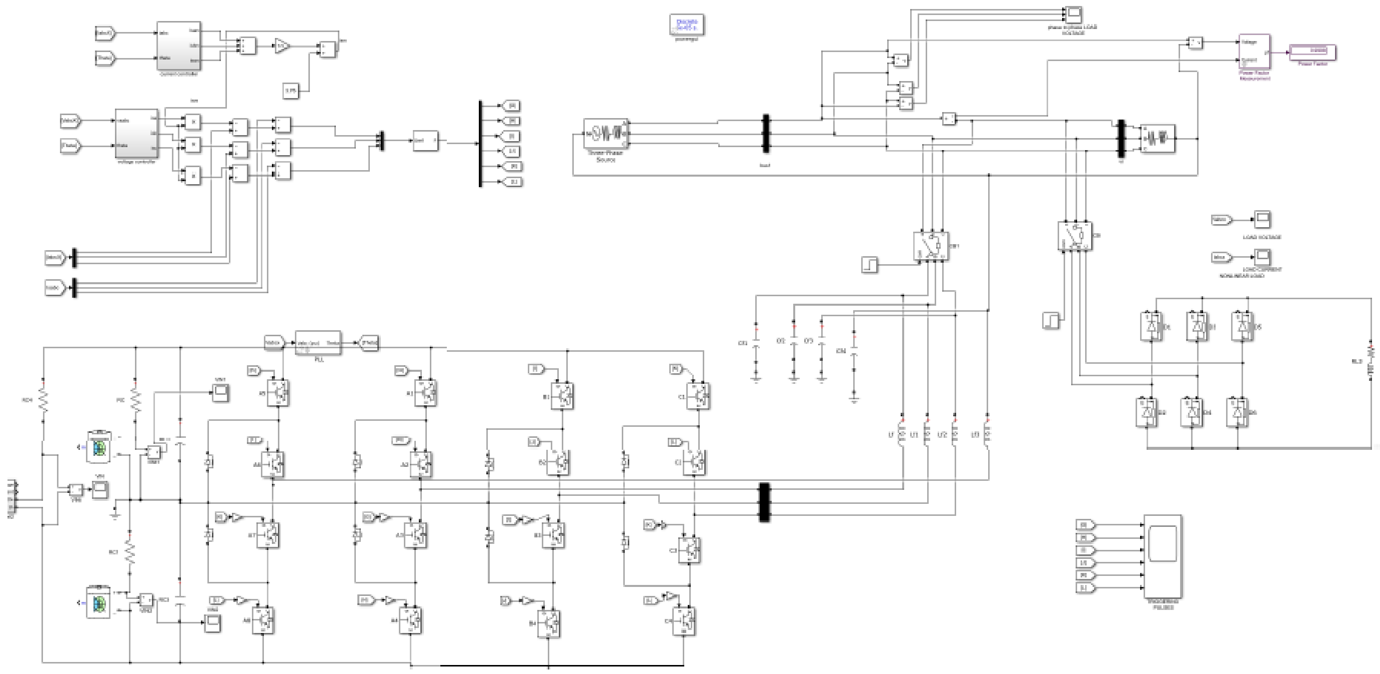

Figure 5 Overall Simulation Circuit – Hybrid PV/Wind & Battery Storage

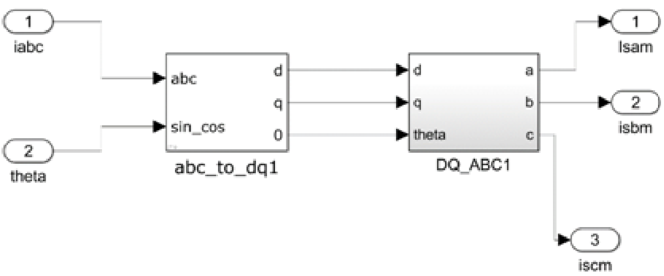

Figure 6 Voltage Controller

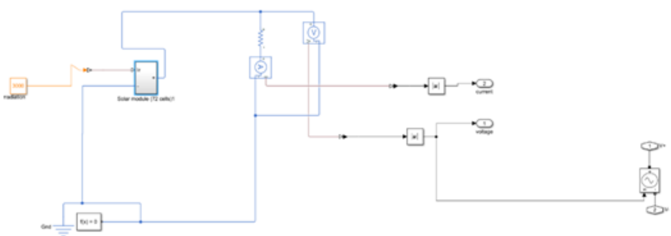

Figure 8 Solar Panel

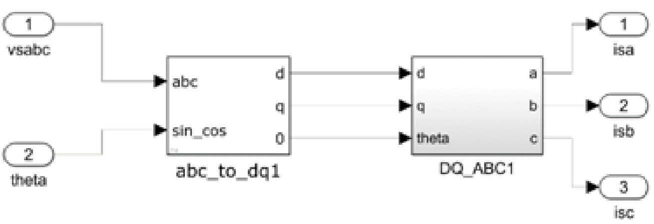

Figure 7 Current Controller

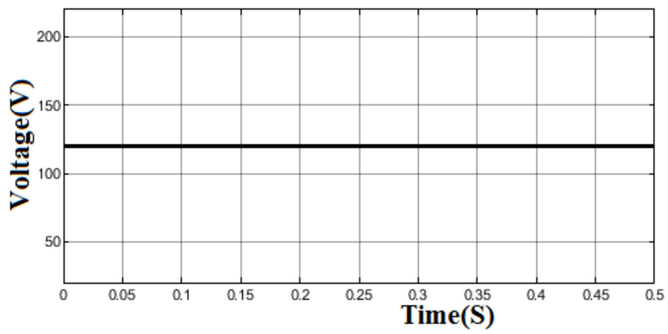

Figure 9 Input Voltage

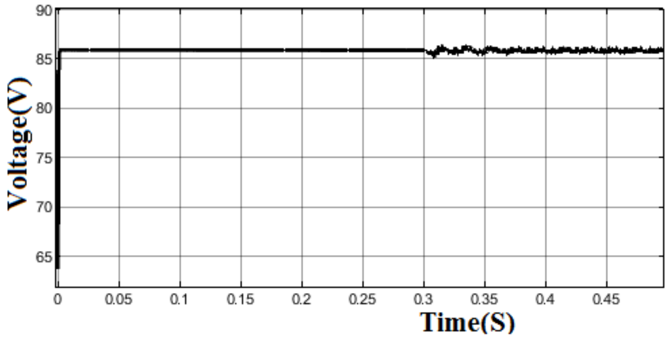

Figure 10 Battery-I Voltage

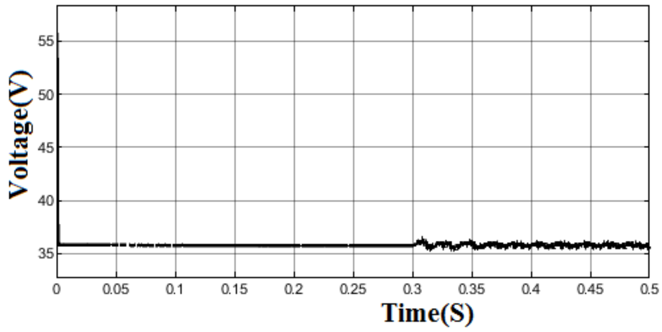

Figure 11 Battery-II Voltage

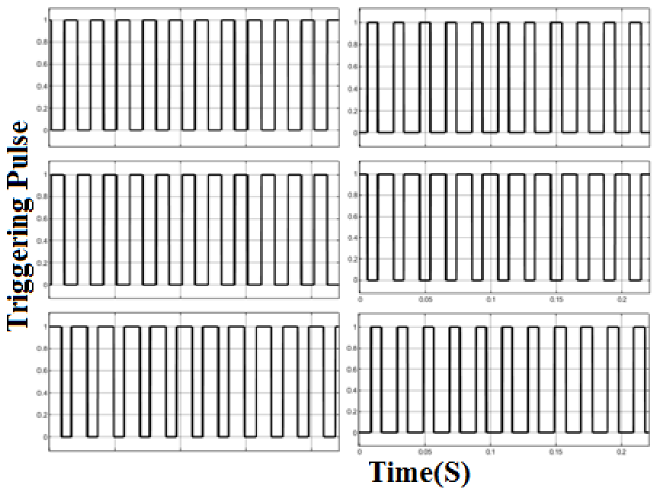

Figure 12 Triggering Pulse

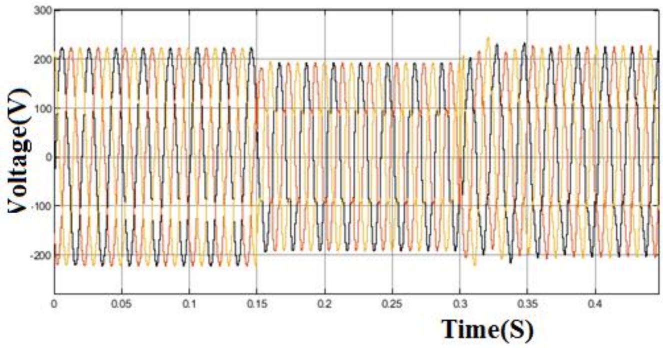

Figure 13 Output Voltage

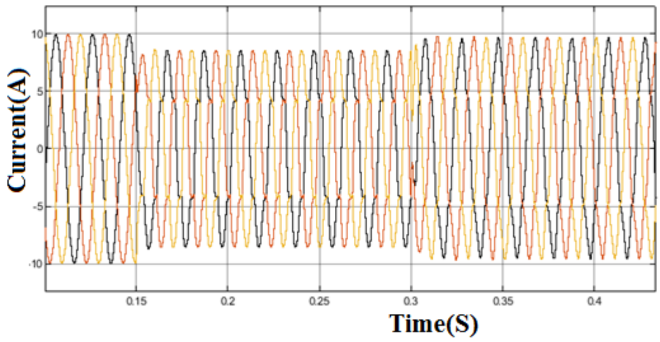

Figure 14 Output Current

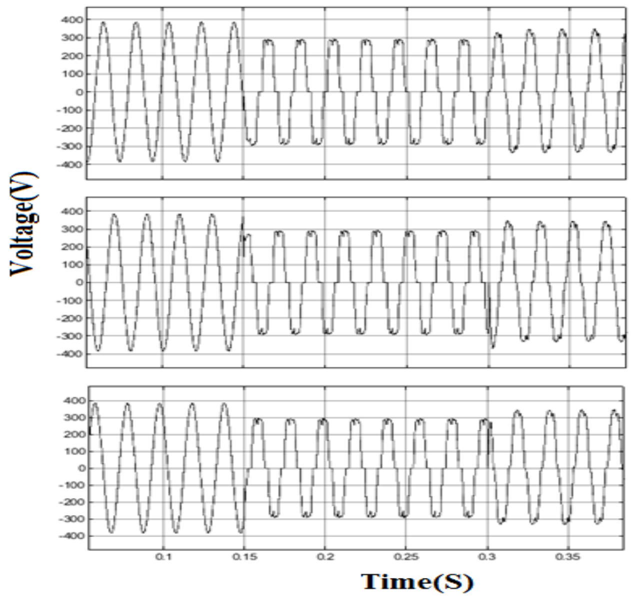

Figure 15 Phase to Phase Output Voltage

4. CONCLUSION

In this paper the use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS combination of VRB and a Li-Ion battery in a microgrid was simulated and their output characteristics are verified. The proposed 4-Leg 3 L-NPC converters make sure a maximum power between the two ESS. The fourth leg of the converter allows the unbalanced load issue and thus enables active power filter capabilities. Simulation results 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.

REFERENCES

[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/Supercapacitor 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 supercapacitors 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-ultracapacitor 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.

BIOGRAPHIES

A.SATHISH Received the Engineer degree in 2007 from Annamalai University, Chidhambaram, Tamilnadu. From July 2012 to till now Working as Assistant Engineer /O&M/Sittampoondi in Gingee Division, TNEB Working hard. Her Specialization in TNEB is Operation & Maintenence in Distribution Network.