

Modeling and Control of Four Leg Three Level Neutral Point Clamped Converter for Battery Energy Storage System

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Abstract: This paper deals with the rising interest for circulated age dependent on Renewable Energy Sources (RES) has prompted a few issues in the activity of utility networks. The microgrid is a promising answer for take care of these issues. A committed energy stockpiling framework could add to a superior combination of RES into the microgrid by smoothing the inexhaustible asset's irregularity, improving the nature of the infused power and empowering extra administrations like voltage and recurrence guideline. However, due to energy/power technological limitations, it is often necessary to use Microgrid Storage Systems. A second order sliding mode controller is proposed for the power flow control of a microgrid, utilizing a Four Leg Three Level Neutral Point Clamped (4-Leg 3LNPC) inverter as the main interface between the RES/BESS and the microgrid. The adequacy of the proposed method for the microgrid system power flow control is contrasted with an established PI control plot and is demonstrated through simulation and tentatively utilizing a 4 Leg 3LNPC model on a test bench.

Keywords - Microgrid, hybrid energy storage system, battery energy storage system, inverters, space vector modulation, matlab software,;

I. INTRODUCTION

The expanding entrance of DG is changing administration of the grid from brought together to decentralized plans, making a few difficulties that must be cautiously tended to so as to keep the electrical lattices appropriate activity. High infiltration of sustainable power source can prompt soundness and power quality issues because of the stochastic idea of RES, for example, wind and sun oriented vitality. The microgrid idea, which can be characterized as a little scale powerless electrical lattice that can work both in associated and islanded mode, has been widely contemplated as an answer for RES reconciliation. The feeble idea of a microgrid suggests the utilization of an Energy Storage System (ESS) to build RES entrance and protect its solidness. The utilization of an ESS coordinates imperatives, for example, acceptable data transfer capacity, greatest evaluations, current/control most extreme angle and the quantity of cycles. In the event that these imperatives are not regarded it can prompt an emotional lifetime decrease of the ESS, or in specific cases, to its annihilation. The utilization of a Hybrid Energy Storage System (HESS) offers the essential exchange off for expanding the lifetime of each ESS while likewise expanding the worldwide explicit vitality and intensity of the entire framework the principle structures presently found in the writing to coordinate a HESS into a network. The latent topology a) demonstrates an absence of control of the power stream too as the ESSs State of Charge (SOC). The coasting b) and c) parallel topologies are dynamic topologies that utilization DC/DC converters to oversee vitality streams straightforwardly. They are as of now being utilized inside the business and satisfy an exclusive requirement (stress decrease and explicit power/vitality improvement. Parallel topology offers the best adaptability yet the utilization of a few DC/DC converters influences the worldwide effectiveness.

II. WORKING ANALYSIS OF NPC CONVERTER

In this paper, the power flow the executives of a HESS made out of a Li-Ion battery and a Vanadium Redox Battery (VRB) is examined in a microgrid setting. The 4 Leg 3L-NPC inverter has been decided to interface the HESS with the microgrid because of its low THD, high effectiveness and its capacity to oversee uneven AC stacks through the fourth leg. The goal of the paper is to demonstrate that by adding the fourth leg to a 3L-NPC converter and utilizing another DC side control methodology it is conceivable to achieve both quick and proficient DC control sharing between the two ESSs and the RES, and in the meantime improves the AC side power quality. The fundamental commitment of this paper lies in the DC control stream controller which permits HESS power flow control and DC current harmonics suppression. The new model for 4-Leg 3L-NPC auxiliary points of confinement proposed in is surveyed. The adequacy of the proposed framework has been tried through reproductions and tested utilizing a research facility model.

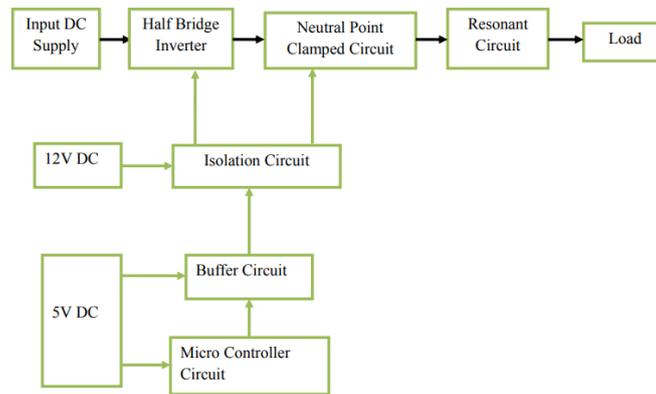


Fig: 1. Block Diagram of 4 leg 3 level NPC converter

III. MODELLING OF MICROGRIDS AND BATTERY ENERGY STORAGE SYSTEMS

The general structure of an electrical interconnected system is presented in which can be divided into three main sectors: generation, transmission and distribution systems. The interconnection of several generation units to provide energy to the end consumers sets up a complex network, which first approaches were established around the early 20th century. For many decades this system was controlled by semi-automatic mechanical methods, based on a demand-driven operation. By that, the inertia of the huge electrical generators incorporated in the generation sector are fundamental to ensure the stability of the system, as their stored energy (inertia) allows to overcome unfavorable transients conditions, such as temporal failures or connection/disconnection of large loads. Furthermore, the inductive nature of the long transmissions lines facilitates the control of frequency and voltage magnitude along the system. Thereby, the active power delivered by generators can be directly associated to the control of the system frequency, while its reactive power, along with the use of reactive passive elements, is associated to the control of the voltage magnitude at the different bars of the interconnected system. Under this scenario, the three actors of the system were clearly identifiable and coordinated by a Transmission (TSO) and Distribution System Operator (DSO) to maintain a stable operation of the system. In 1920 the first mercury arc valve based rectifier came into the market and was implemented in several low and high power industrial applications, such as: rectification for public lighting, railway applications, and High Voltage Direct Current Systems (HVDC) or battery chargers. It was not until the 60's, with the introduction of solid state semiconductors, that low-power mercury arc valves were replaced by solid stated semiconductors. Consequently, with the fast development of solid state semiconductors, in 1975 they became also available in the market for of high-power ranges, leaving obsolete the mercury arc valves.

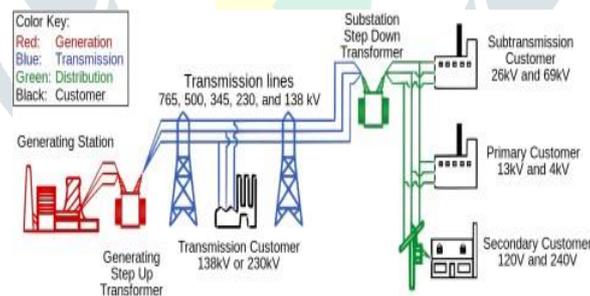


Fig: 2. Simple representation of a typical electrical system composed of Generation, Transmission and Distribution sectors.

▪ Power Quality

Power quality approximately characterized, as the investigation of fueling and establishing electronic frameworks to keep up the trustworthiness of the power provided to the system. IEEE Standard 1159 characterizes control quality as [2]: The idea of fueling and establishing touchy hardware in a way that is appropriate for the task of that equipment. In the IEEE 100 Authoritative Dictionary of IEEE Standard Terms, Power quality is characterized as . The idea of fueling and establishing electronic hardware in a way that is reasonable to the task of that equipment and perfect with the reason wiring systems and other associated hardware. Great power quality, be that as it may, isn't anything but difficult to characterize on the grounds that what is great power quality to an icebox engine may not be adequate for today's computers and other touchy loads.

▪ Harmonics as Power Quality Problem

Harmonic disturbances come generally from equipment with a non-linear voltage/current characteristic. These days an extensive piece of modern, business and household loads is non-direct, making the mutilation level on the low-voltage supply

organize a genuine concern. Over the long haul, increasingly more hardware is being utilized that makes sounds in power systems. Then again, increasingly more equipment is being utilized that is defenseless to breakdown because of harmonics. PCs, correspondence hardware, and other power systems are generally defenseless to breakdown or loss of effectiveness because of the impacts of harmonics. For example, in electric engines, consonant flow causes AC losses in the core and copper windings. This can result in core heating, winding heating, torque throbs, and loss of effectiveness in these engines. Harmonics can likewise result in an expansion in capable of being heard clamor from engines and transformers and can energize mechanical resonances in electric engines and their loads. Harmonic voltages and flows can likewise cause false stumbling of ground blame circuit interrupters (GFCIs). These gadgets are utilized widely in habitations for nearby insurance close machines. False activating of GFCIs is an aggravation to the end client. Instrument and hand-off transformer precision can be influenced by harmonics, which can likewise cause irritation stumbling of circuit breakers. Harmonics can influence metering too, and may incite both negative and positive mistakes. High-frequency exchanging circuits, for example, exchanging power supplies, control factor revision circuits, and movable speed drives make high-frequency switching that are not at products of line frequency. Harmonic distortion can be considered as a kind of contamination of the electric energy which can cause issues if the total of the consonant flows surpasses certain points of confinement.

▪ Sliding Mode Control

This paper deals with the principles of sliding mode control and their application to power converters. The power converters that are taken up for the application are dc-to-dc electrical power converters, and electromechanical power converters. In power converters a high premium is placed on the efficiency of power conversion, besides the steady state and dynamic performance requirements. As a result the topologies used in power conversion applications rely on high speed switches for efficient operation. The power conversion topologies with signal processing systems, and brings out the most important feature of power converters, namely dynamic structural changes brought about because of their switching nature. Such systems are nonlinear and time variant. The switching property makes the power converters prime candidates for the application of the theory of Variable Structure Systems (VSS). VSS theory results in a time domain description of switching converters. Sliding mode control complements VSS as an effective analysis and design tool. The concept of sliding mode control relies on a firm understanding of the system in terms of system states and the state space or the phase space. In order to appreciate thoroughly the basic principles involved, simple second order systems exhaustively, and brings out the relevant features of sliding mode control. These concepts are then extended to general higher order systems. In the past the switching converters had been analyzed using the technique of state space averaging. State space averaging method essentially developed linear, small signal, frequency domain models of the nonlinear power converters. The power converters are then analyzed using the theory of VSS. The sliding mode control principles are then applied to develop practical design criteria for the control of dc-to-dc converters. Experimental results are then presented. Another major area of power processing application is the electromechanical power conversion. Such systems consist of switching power converter and electromechanical actuators (dc or ac motor). In the past such systems have been analyzed separately - a model for the power converter and a model for the motor. Sliding mode control can be used as an integrated control approach for such composite systems Practical design criteria for the speed control of these machines are developed. Experimental results verifying the design strategy are presented. This section discusses the extension of the sliding mode control to synchronous motors. The possibility of loss optimization under different operating conditions is then presented.

IV. EXPERIMENTAL ANALYSIS AND SIMULINK MODEL

In order to validate the proposed three-dimensional SVM and the over modulation algorithm presented in this chapter, this section is divided in three parts. Firstly, the proposed three-dimensional SVM algorithm is tested in a four- leg NPC converter. The algorithm is implemented in open-loop and in open circuit under different scenarios to show the effectiveness of the algorithm. Secondly, the control over the dc-link voltage is analyzed under different unbalanced and non-linear loads. Finally, the proposed over modulation algorithm is also tested under different conditions.

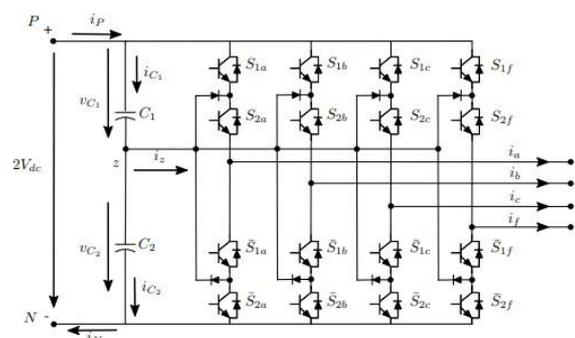


Fig. 3. Electrical diagram for a four-leg NPC

A four- leg NPC converter arises as a promising new solution for implementation of GPUs. The fourth leg provides an extra path to control zero-sequences components. Moreover, the topology reduces the switching frequency of each device compared with a standard solution, allowing a higher efficiency, higher sampling rate and higher harmonics compensation. Furthermore, the higher number of levels at the output voltage allows using a smaller output filter and therefore a less bulky solution with lower reactive power consumption

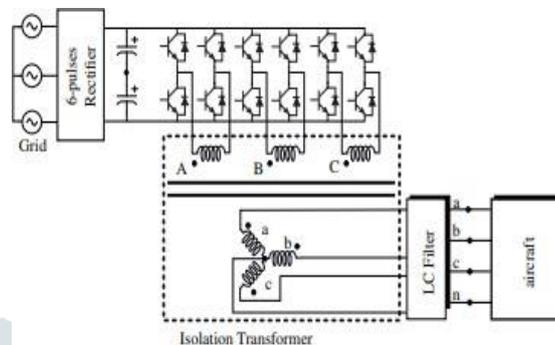


Fig: 4. 6 Legs conveter used as standard solution for a 4-wired 400 Hz ground power unit

A small output LC filter, designed with a resonance at 2.4 kHz, is connected to the output of the converter. A single-loop resonant controller is implemented to control the output voltages of the GPU, compensating third, fifth, seventh, ninth and eleventh harmonics. The three-dimensional SVM algorithm along with the over modulation method proposed in Chapter 5 are used to synthesize the output voltages. Furthermore, using the redundant vectors of the four-leg NPC and the measurement of the dc-link voltages and output currents, a Proportional-Integral controller is implemented to balance the voltages on the dc-link capacitors

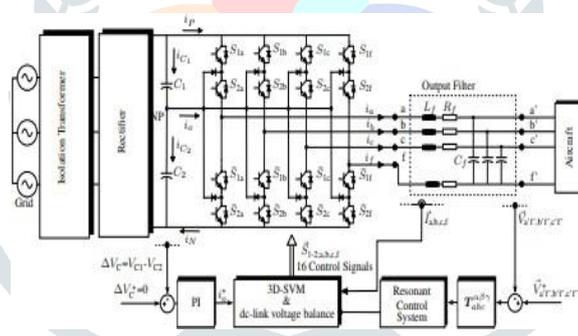


Fig: 5. Control scheme for the proposed 4-leg NPC used as GPU

The simulink model of proposed hybrid system can be seen below in fig. 5 and the NPC converter can be understand from the below fig. 6. The simulink results are shown below with their various characteristics.

Power Quality Improvement Using Four Leg Three Level NPC Inverter

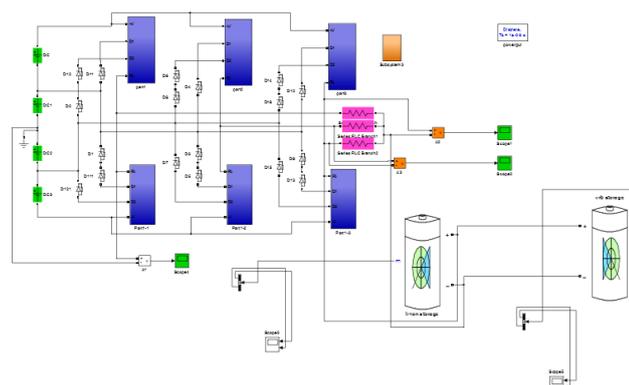


Fig: 6. Power Quality Improvements using four leg three NPC inverter

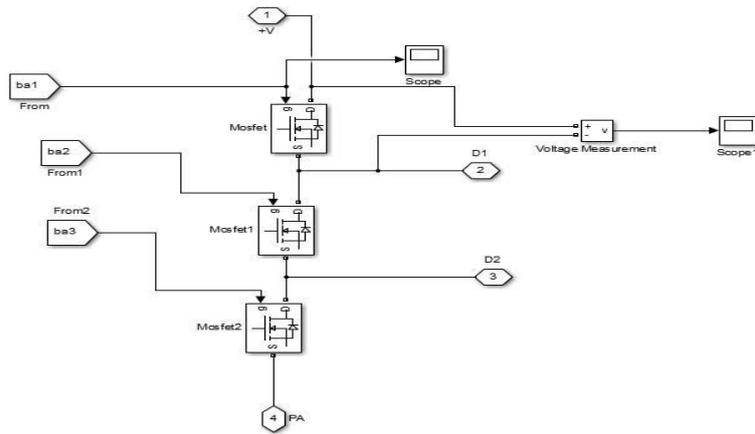


Fig: 7. Neutral point converter

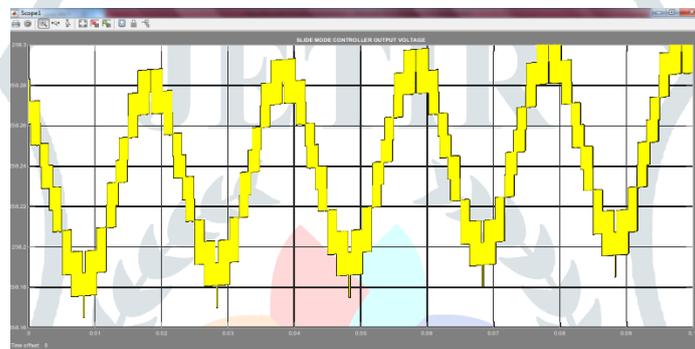


Fig: 8. Slide Mode Controller Output Voltage

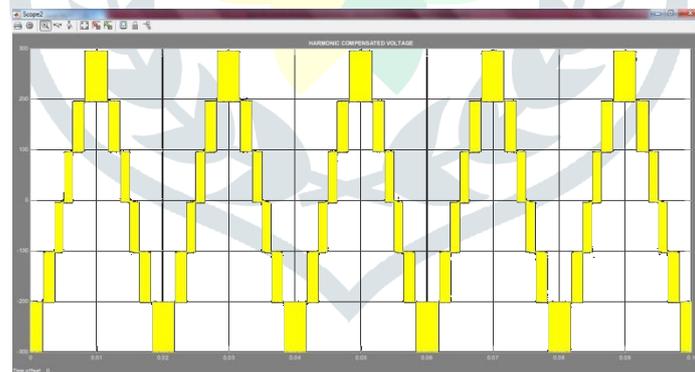


Fig: 9. Harmonic Compensation Voltages

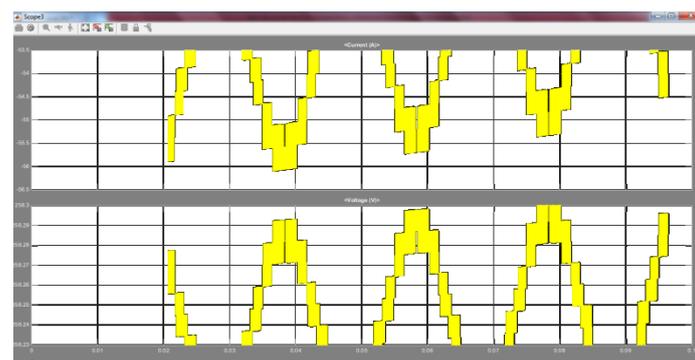


Fig: 10. Current and voltages output for 4 leg 3 level

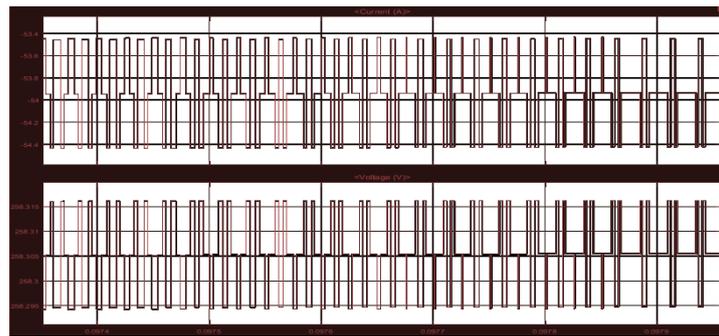


Fig: 11. Current and voltages output of Li-ion battery

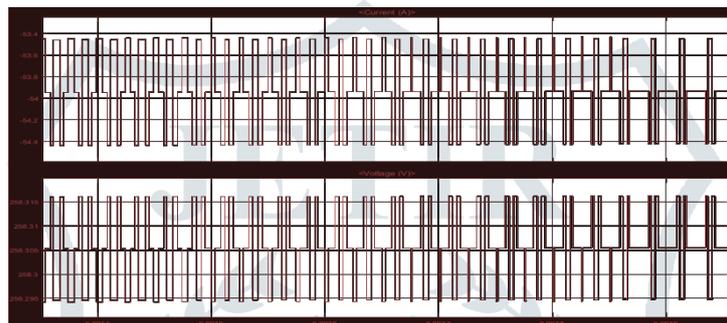
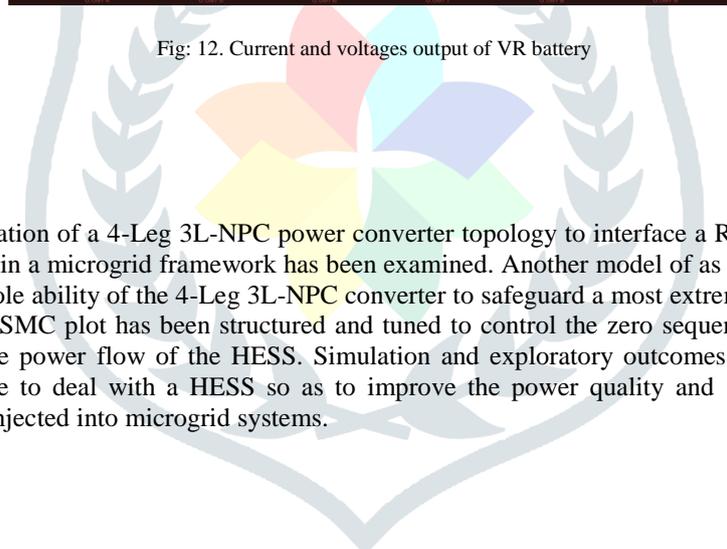


Fig: 12. Current and voltages output of VR battery



V. CONCLUSION

In this paper the utilization of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (framed by a VRB and a Li-Ion battery) in a microgrid framework has been examined. Another model of as far as possible is exhibited and actualized to abuse the whole ability of the 4-Leg 3L-NPC converter to safeguard a most extreme power division between the two ESSs. A non-linear 2-SMC plot has been structured and tuned to control the zero sequence infusion in the modulating signals so as to control the power flow of the HESS. Simulation and exploratory outcomes demonstrated the limit of the proposed control technique to deal with a HESS so as to improve the power quality and stability just as to control the sustainable power source injected into microgrid systems.

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