Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

Hybrid Energy Storage System Micro gridsIntegration for Power Quality Improvement UsingFour-Leg Three-Level NPC Inverter and Second-Order Sliding Mode Control

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Abstract:
Rising demand for distributed generation based on renewable energy sources (RES) has led to several issues in the operation of utility grids. The micro-grid is a promising solution to solve these problems. A dedicated energy storage system could contribute to a better integration of RES into the micro-grid 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, a second-order sliding mode controller is proposed for the power flow control of a HESS, using a four-leg three-level neutral-point-clamped (4-Leg 3L-NPC) inverter as the only interface between the RES/HESS and the micro-grid. A 3-D space vector modulation and a sequence-decomposition-based ac-side control allow the inverter to work in unbalanced load conditions while maintaining a balanced ac voltage at the point of common coupling. DC current harmonics caused by unbalanced load and the NPC floating middle point voltage, together with the power division limits, are carefully addressed in this paper. The effectiveness of the proposed technique for the HESS power flow control is compared to a classical PI control scheme and is proven through simulations using a 4-Leg 3L-NPC inverter.

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 micro grid concept, which can be defined as a small scale weak electrical grid that is able to operate both in connected and is-landed mode, has been extensively studied as a solution for RES integration. The weak nature of micro grid implies the use of an Energy Storage System (ESS) to increase RES penetration and insure its stability. 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,

In certain cases, to its destruction. 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. 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. 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) than an equivalent two level inverter. Several works have been carried out on ESS hybridization using multilevel topologies, including the 3 Leg 3L-NPC.

The 4-Leg 3L-NPC used as an active power filter is also extensively studied in the literature. 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 [several modulation techniques and redundant vector selection methods are used to balance the capacitor voltages in power filter application. In, the AC side predictive control of a 4 Leg 3L-NPC inverter in isolated mode improves the performance and the power quality.
In 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

II. DESCRIPTION

2.1 Micro-grid:

A micro-grid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A micro- grid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

2.2 Inverter:

Solar inverters convert DC voltage of solar modules into AC voltage regulated amount and frequency, timed with network voltage. Inverters that used for connection of PV modules with network are divided into voltage inverters and electrical inverter, and based on regulation, are divided on current controlled and voltage regulated inverters

2.2.1 Four leg NPC inverter:

The four-leg 3L-NPC (4-Leg 3L-NPC) used as an active power filter is also extensively studied in the literature. Thanks to the fourth 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, etc.) and single-phase generators (small wind/PV units).

SIMULATION RESULTS

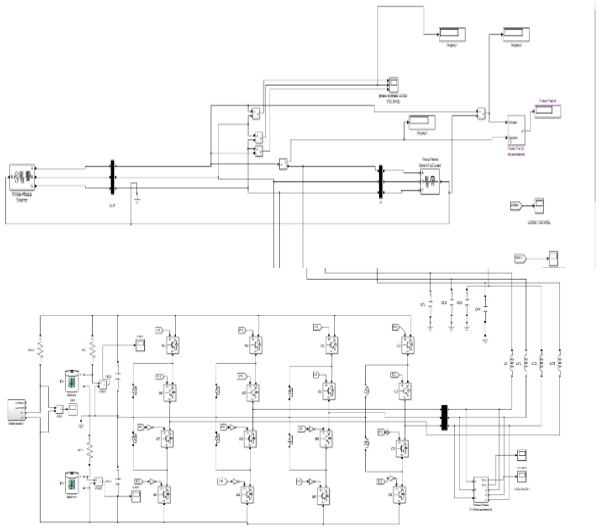

Fig 2.1 4 leg NPC inverter

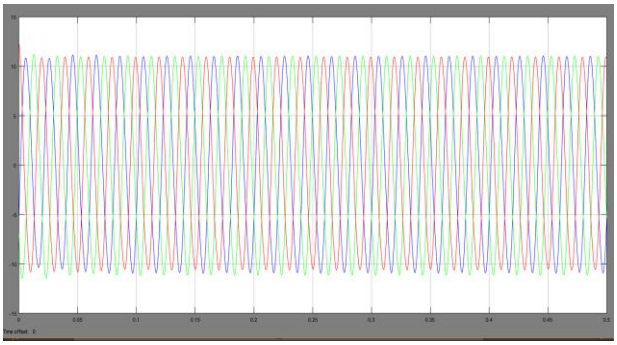

Fig 2.2 Load current Four leg NPC inverter

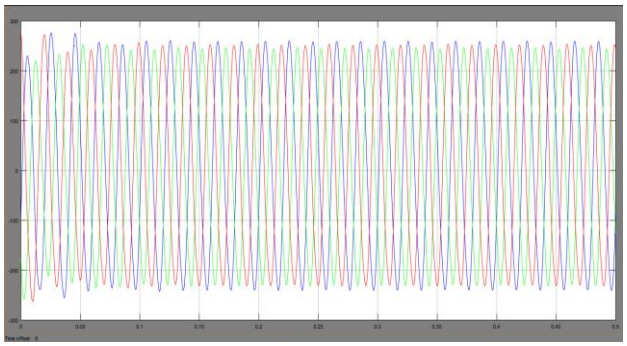

Fig 2.3 Load voltage Four leg NPC inverter

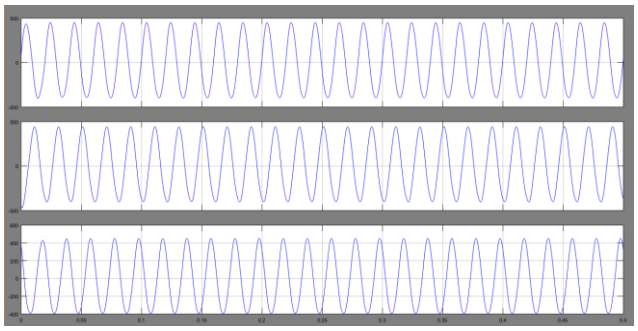

Fig 2.4 Phase voltage Four leg NPC inverter

Four leg NPC inverter with nonlinear load connection

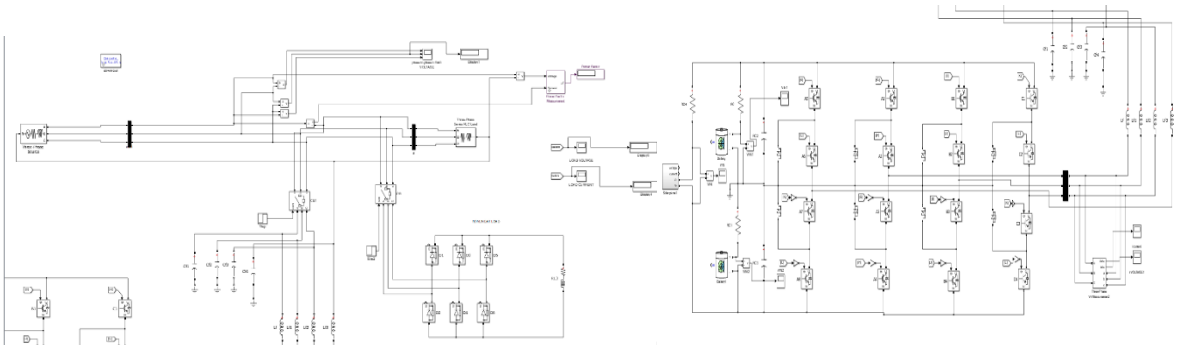

Fig 7.12 Four leg NPC inverter with nonlinear load connection

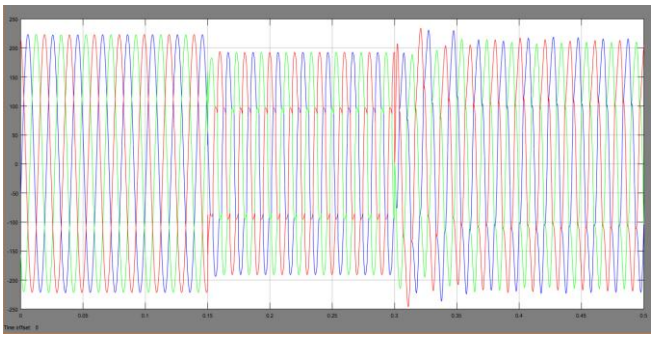

Fig 7.14 Load voltage Four leg NPC inverter with nonlinear load

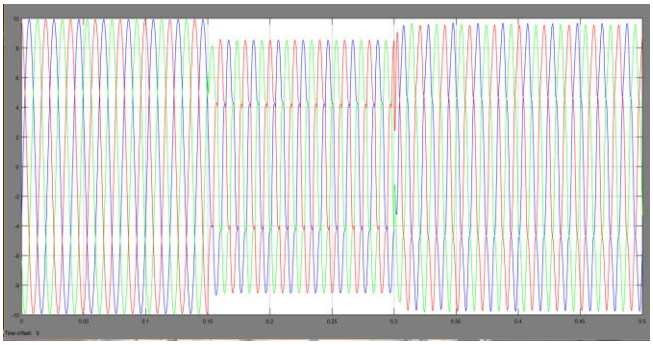

Fig 7.15 Load current Four leg NPC inverter with nonlinear load

III. CONCLUSIONS

In this project, the use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (formed by a VRB and a Li-Ion battery) in a micro grid context had 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 nonlinear 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. Furthermore, the fourth leg of the converter allows the unbalanced load issue to be addressed, and, thus, enable active power filter capabilities. The investigation of the limits of the topology showed a power exchange capability among 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 micro grid.

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