"COMPARATIVE ANALYSIS OF THE VSC (VOLTAGE SOURCE CONVERTER) CONTROL APPROACH AES-FLL AND GRID SYNCHRONIZATION APPROACH"

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Abstract

AES-FLL (Advanced Extremism-Seeking Frequency Locked Loop) control with DC-offset-rejection capability for power quality improvement is proposed. The attributes of the AES-FLL are a precise estimation of fundamental load current with low steady-state oscillations, fast dynamic response, DC-offset rejection capability and low THD. Further, the AES-FLL is capable of extracting the fundamental component of grid voltages and generates harmonic free reference grid current under weak grid conditions. Moreover, reactive power compensation, harmonics mitigation, unity power factor and coordinated power flow operation are accomplished using the AES-FLL control approach. A seamless transition is achieved from the grid-connected operating mode to the standalone operating mode during the grid outage to ensure power continuity. The grid synchronization is achieved through the LPN-PLL (Low-Pass Notch Filter Phase Locked Loop) control approach. Comparative analysis of the VSC (Voltage Source Converter) control approach AES-FLL and grid synchronization approach LPN-PLL with the conventional methods is presented. The performance of the micro grid is demonstrated by simulation and then presented a prototype experimental validation under nonlinear loads.

Keywords – AES-FLL (Advanced Extremism-Seeking Frequency Locked Loop), Micro grid (MG), grid voltages, Power Quality Control, LPN-PLL.

INTRODUCTION

GENERAL

Microgrid (MG) requires smooth and efficient interfacing of RESs such as PV (Photovoltaic) and wind into the conventional power system. MG offers scaling benefits for the network operator, aggregation of various RESs and storage units [1]. In the generic form, the primary objective of the MGs is to deliver reliable energy. It also reduces the transmission losses and burden on the transmission network due to the proximity establishment. The intermittent nature of PV generation and wind energy jeopardize the reliability of power, but the integration of MG with the power grid and battery (in autonomous mode) alleviates the uncertainty. The PV generators and wind energy are evidenced to be cutting-edge technology as they provide energy security. PV generators and wind power generators run below capacity in the absence of the maximum power point (MPP) algorithm [2]. Thus, to emphasize the higher efficiency in fluctuating and overpowering environments, an Incremental and Conductance (INC) MPP tracking algorithm is used in this work.

In MG, rapid variation in power generation and load demand has urged to address the challenges of power unbalance and frequency variation. To overcome this, the integration of batteries is essential in an MG. In [3], Philip et al. have reported an MG where the battery is integrated into the system without using a bidirectional DC-DC converter (BDC). The direct integration hampers the battery life and leads to the presence of the second harmonic component in the battery current [4]. Thus, in this work, the battery is interfaced through a BDC. Further, the BDC control regulates the DC-link voltage.

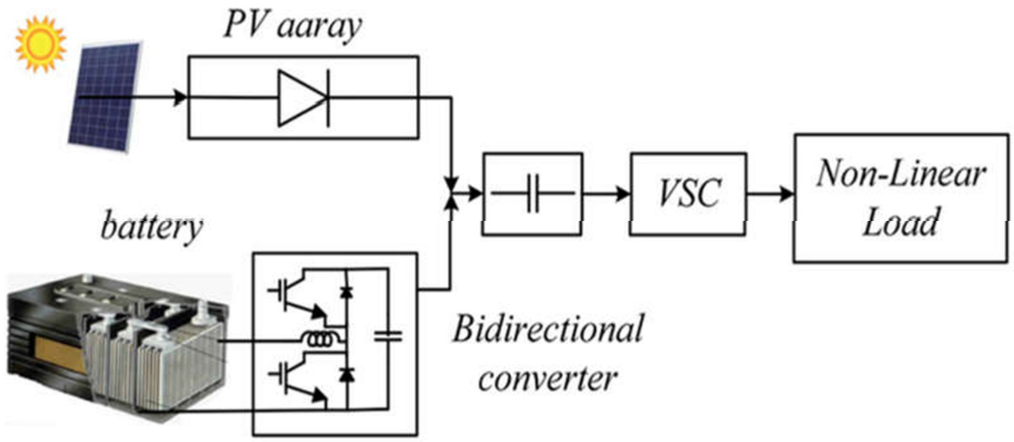

Figure-1 System architecture in autonomous mode

Objectives of the Study

- Analysis of the VSC (Voltage Source Converter) control approach AES-FLL and grid synchronization approach LPN-PLL with the conventional methods is presented.
- The performance of the micro grid is demonstrated by simulation.

LITERATURE REVIEW

Shikha Gupta et al [2022] A seamless transition is achieved from the grid-connected operating mode to the standalone operating mode during the grid outage to ensure power continuity. The grid synchronization is achieved through the LPN-PLL (Low-Pass Notch Filter Phase Locked Loop) control approach. Comparative analysis of the VSC (Voltage Source Converter) control approach AES-FLL and grid synchronization approach LPN-PLL with the conventional methods is presented. The performance of the micro grid is demonstrated by simulation and then presented a prototype experimental validation under nonlinear loads.

Shubhra and Singh [2020] have presented a grid interfaced PV-battery MG. The presented system is heavily dependent on grid availability. Furthermore, during the nighttime, PV energy is not available, therefore, to achieve continuous energy, a wind energy generator is integrated into this topology. In the class of variable speed generator, permanent-magnet synchronous generator (PMSG) has a rising stake in the wind energy generation sector since it offers a more realistic prospect of multiple-pole design to realize gearless operation.

F. Shahnia *et al* [2020] was study the gravities of economic and population progression, propel the upcoming energy needs. For ever-increasing electricity demand, renewable energy sources (RESs) turn out to be a significant contributor to energy in modern society. Micro grid (MG) requires smooth and efficient interfacing of RESs such as PV (Photovoltaic) and wind into the conventional power system. MG offers scaling benefits for the network operator, aggregation of various RESs and storage units.

PROBLEM STATEMENT AND PROPOSED METHODOLOGY

The MG comprising PV array, wind and battery energy sources is designed with the intended aim as follows:

The AES-FLL control approach's advanced feature is DC rejection capability. Besides, it gives a faster dynamic response, better filtration ability and reduced steady-state error in comparison to conventional controls. The designed system is capable of reactive power compensation, voltage regulation, unity power factor and maintains THD of the grid current as per the IEEE-519 standard.

The AES-FLL algorithm improves the quality of power available at the user end by reducing current harmonics in the grid currents at distorted and unbalanced grid voltages and under highly distorted nonlinear load.

Under grid-connected mode, the proposed micro grid work in power equilibrium during transients. The transients may occur due to a change in load or a change in generating capacity of the integrated RES.

The paper presents a robust, seamless transition approach. Hence, this micro grid seamlessly undergoes a standalone mode during a grid outage and maintains power reliability. The transition becomes challenging under nonlinear loading conditions in grid-integrated mode. The VSC of the micro grid compensates for reactive power locally, and active power is supplied by the interfaced energy sources and the grid in grid-connected mode. While in standalone mode, the shape of the PCC voltage is sustained by voltage control.

The recoupling of MG with the grid is accomplished through the active synchronizing control approach. LPN-PLL estimates the grid voltage angle and islanded grid voltage angle. This synchronization method is robust to the harmonics and polluted grid environment.

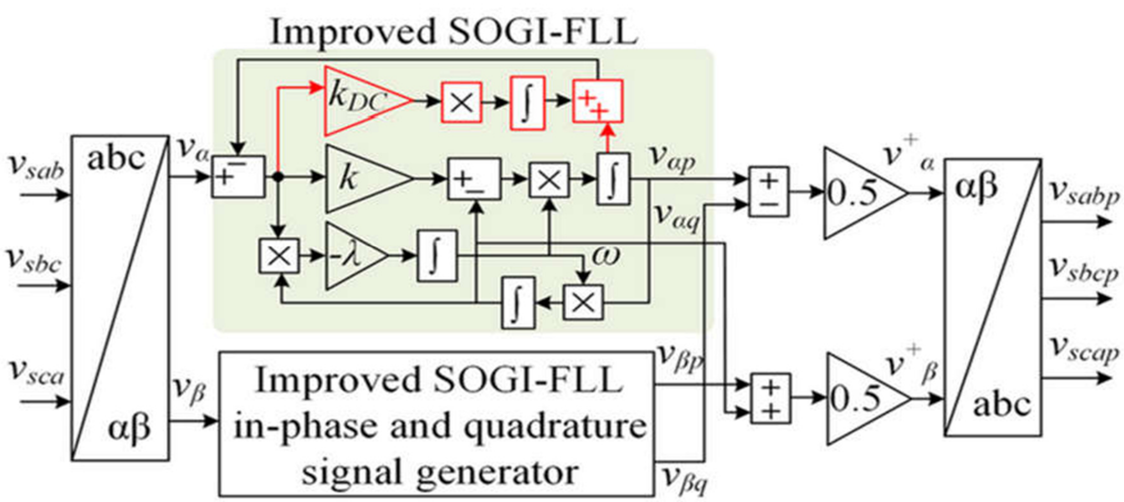

Figure -2 Positive sequence estimation using improved SOGI-FLL

RESULT AND DISCUSSION

This section demonstrates the test results and simulation results in off-grid and grid-integrated mode with transient conditions such as PV array insolation change, wind speed variation and load variation. The behavior of the system is analyzed based on the battery charging/discharging current (I_B), PV panel current (I_{PV}), load demand current (i_L), grid voltage (V_G), grid current (i_G), grid power (P_G), load demand power (P_L), battery power (P_B), VSC current (i_{VSC}), PCC voltage (V_{CCP}) and PV

Test results

To establish the accurate performance of presented MG and control techniques, a laboratory prototype is set up as shown in Fig. 9. Experimental results validate the performance of MG under nonlinear load through all possible operating conditions such as load unbalancing, solar perturbation, wind speed variation, grid synchronization and de-synchronization. The MG operates with regulated AC and DC bus voltages and performing power equilibrium under varying environmental and load changes.

CONCLUSION

The performance of WES-PV-BES-based MG with presented control techniques has been demonstrated in grid-connected and autonomous mode under weak grid conditions. The effectiveness of the VSC control technique under all possible transients has been presented through the test results. The controller is capable of improving the quality of power and compensating for the reactive power. It also gives unity power factor operation and provides an uninterruptible power supply to the nonlinear load.

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