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A Review on Adaptive Active Damper for Improving the Stability of Grid-Connected Inverters

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ABSTRACT

When a grid-connected inverter is linked to a weak grid, the system may be instable. An active damper may be linked to the point of common coupling (PCC), which replicates a virtual resistor to damp the resonance and so stabilise the system. With this design, the active damper may further minimise its power loss by not responding to low-frequency harmonic components generated by the grid background harmonics. The active damper is also examined for a harmonic-current-reference compensation approach to better mimic the virtual resistor across a wider frequency range.

Keywords: Grid-connected inverter, weak grid, stability, active damper, point of common coupling.

I. INTRODUCTION

In order to deal with climate change and the energy issue, the renewable energy production, notably the solar and wind power, is expanding quickly. In general, grid-connected inverters play a vital role in injecting high-quality electricity into the grid as the interface between renewable energy and the grid. Figure 1 shows a typical multi-parallel grid-connected inverter setup.[1]

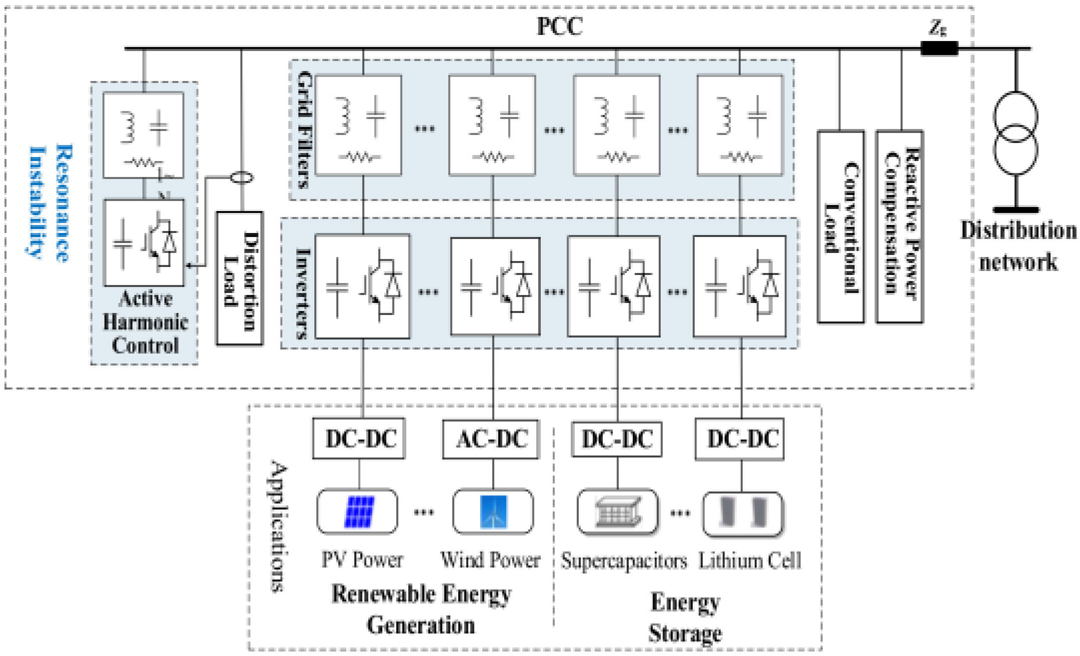

Figure 1: Fundamental configuration of multi-parallel grid-connected inverters system

While multi-parallel grid-connected inverters have accelerated the growth of distributed generation, the complicated coupling between the grid and inverters has resulted in resonance, which is a potential problem. Additionally, the resonance in a multi-parallel inverter system may cause additional issues, such as breaking relay protection devices and jeopardising electrical grid safety.

DPGS grid-connected inverters play a crucial role in delivering high-quality current to the power grid as the interface between DPGS and the grid. Even though it is supposed to be stable on its own, a grid-connected inverter may have instability issues owing to the significant range in grid impedance when coupled to a weak grid via the point of common coupling (PCC). [2]

Control System of Grid Connected Invertors

Although PI controllers can only handle DC-valued error signals, three-phase inverters are generally analysed in the d-q-domain. The inverter's simplified control system is shown in Figure 2. The duty ratios d_{abc} determined by the outside control system are sent into the PWM block, which generates the switching signals for each phase. [3]

A phase-locked-loop (PLL) regulates the output current of an inverter in synchronisation with the grid's alternating current. The dq-transformation requires knowledge of the estimated phase. The current control block outputs duty ratios, which govern the output currents of the inverter in accordance with the reference value. In addition, to get the PV generator to operate at its optimal operating point, the reference signal in PV inverters is determined using DC voltage control. Depending on the DC voltage, the PV-maximum generator's power point (MPP) may be established. Thus, the DC-voltage control reference signal is tuned such that PV-generator MPP may be achieved. It's vital to remember that the duty ratios d-d as well as d-q of the inverter switches are the basis for all inverter management. [4]

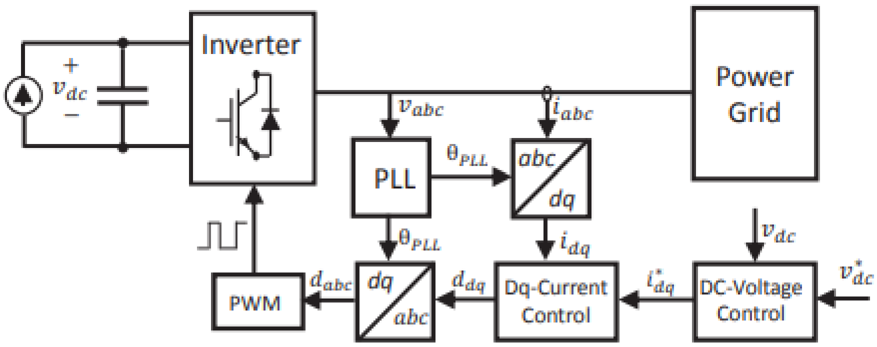

Figure 2: Simplified inverter control system

In this thesis, the control approach is a cascading control system. Ideally, the inner control loop of a cascaded control system should respond to changes in its reference quicker than that of the outer control loop. In reality, a faster control loop translates to a larger cross-over frequency. In order to perform open loop transfer functions, various closed loop control systems must first be recognised and then processed. [5]

II. LITERATURE REVIEW

(Z. Li et al., 2022) [6] In medium and high voltage grid connections, NPC (neutral point clamped converter) is commonly utilised the fact that it's lightweight, has fewer moving parts, and is straightforward to operate This study presents an improved LCL-type NPC indirect current control technique. The LCL filter's resonant peak is reduced, and tracking accuracy is improved, by altering the reference current. As a result of the non-PLL control approach being introduced and the link between state variables being established, the control structure may be optimised to only need two sets of sensors. To compensate for the latency in digital control, the classic differential operator has been enhanced. There is a reduction in phase deviation from 7^o to around 1^o and a reduction in transient reaction time of 1/3 compared to the standard approach, as shown by these experiments.

(Amir et al., 2022) [7] Stochastic grids are seeing huge voltage fluctuations nowadays because of their intermittent nature and the increasing penetration of hybrid renewable resources. This has resulted in power quality issues in the "smart microgrid network". As a consequence, assessing and controlling dynamic performance is essential to maintaining grid safety. In order to keep the distributed generating network and also the grid side network in balance, a d-q controller method is proposed.

(Lu et al., 2021) [8] For "single-phase AC–DC power factor correction (PFC) converters," a low-bandwidth control voltage loop is usually utilised, which removes the second harmonic component of output voltage but worsens dynamic performance of the load, on AC–DC PFC converters. Multi harmonic aberrations in the input current as well as the output voltage would result from the voltage loop's large bandwidth. A "multidimensional harmonic current feedforward compensation control (MHCFC) method" has been proposed in this study in order to minimise multi harmonic distortion of the PFC system employing a high-bandwidth condition of the voltage loop and also to increase dynamic performance too. Multi-dimensional band-pass filters collect the odd harmonics of the input current and turn them into even harmonic compensation signals to mitigate the detrimental effects of the output voltage's even harmonics.

(Esmaeili & Asadi, 2021) [9] This paper proposes "a sliding mode controller based on robust model reference adaptive proportional-integral (RMRA-PI) control for a stand-alone voltage source inverter (SA-VSI)". The adaptive sliding law is used to govern the PI controller's coefficients in two control loops in the proposed controller. Under a variety of load and uncertainty settings, this technique is utilised to maintain the inverter's output voltage while reducing overall harmonic distortion. With the use of "Lyapunov's theory and Barbalet's lemma," this study demonstrates the stability of the controller under consideration. Under abrupt load changes and uncertainty, the suggested controller works well in voltage regulation, such as minimal THD. In addition, the suggested controller's results are compared with those of a PI controller to demonstrate the system's efficacy.

(J. Peng et al., 2021) [10] Double-feed wind power systems may benefit from adaptive sensing control technology, according to this study. This study investigates how wind turbines work in connection to the concept of monitoring the most wind energy possible. No load and power generation simulation models are constructed using the concept of independent modelling and time-sharing since the operational condition and control strategy of "a doubly fed wind power producing system" are different before and after grid connection. As a result of an external stimulation, the wind farm power system's ferromagnetic resonance model is chaotic, and a multiscale technique is needed to compute the approximate solution at the resonance of major parameters and to define steady-state solutions as well as stability criteria.

(Teng et al., 2021) [11] Power electronic devices make up the grid-connected inverter, a key part of a microgrid system that has low output impedance and no physical inertia. An unstable system might result from a substantial current effect during the grid connection transition. Nonlinear control is presented in response to these issues in order to allow the "grid-connected inverter to transition between grid-connected mode and island mode." There are mechanical equations that describe the virtual inertia and damping of the synchronous motor's rotor in the linear control section and their related mathematical models are introduced. It is built by merging the integral sliding mode control technique with backstepping control method for nonlinear control purposes.

(Kurdianto & Ilman, 2020) [12] Harmonic distortion is becoming increasingly prevalent due to the electrical system's increased non-linear load. Harmonic reduction is often accomplished with the use of active power filters (APF). P-q theory is being used in the study to determine the reference current. For the generation of the anti-harmonics current, a reference current is employed to govern the "active power filter switching pattern". Total harmonic distortion may be reduced from 27.47 percent to 1.66 percent by using a reference current created in the simulations.

(Srivastava & Singh, 2019) [13] When it comes to harmonics in the electricity grid, there's nothing new. All throughout electrical power system history, technocrats introduced this phenomenon. As the number of non-linear loads in the system grows, so does the need to maintain power quality in a power distribution system. Non-sinusoidal harmonics are present in the current drawn by such "non-linear loads". For this reason, it is vital to correct for the undesired harmonics in order to improve the system's overall performance. It has been discussed in this study how to deal with harmonics in the distribution system.

(Pereira et al., 2019) [14] The number of non-linear loads connected to the electrical grid has skyrocketed during the last several decades. Harmonic currents can't be mitigated using hydro and thermal power sources. As solar systems become more integrated into the grid, their power electronic converters may be utilised to provide auxiliary services like harmonic current adjustment. Harmonic currents may be detected and compensated for using the "Second Order Generalized Integrator (SOGI)" paired with a phase locked loop structure in this study. Additional harmonics may be detected based on their amplitude, as well. The effectiveness and usefulness of the harmonic current compensation approach is shown by examining its application in both single and three-phase PV inverters.

(X. Li et al., 2019) [15] Nonlinear vibration control is achieved by the use of particle dampers. Although the particle damper's performance is greatly influenced by its surface properties, it is difficult to study and consider these factors because of their complexity. To begin, this paper outlines the steps necessary to develop a theoretical model of a particle dampener. The suggested theoretical model revises the Hertz contact theory's dynamic equation and energy dissipation coefficient to account for the friction of particles. To ensure that the theoretical model is sound, a contrastive collision model based on finite elements is built. Particle damper performance may be affected by a variety of circumstances, and some suggestions on how to improve particle damper performance are presented.

III. CONCLUSION

Research on grid-connected inverters has been mentioned before in this publication. Such a power-electronics-based AC system may be stabilised using an active damper approach. It has been stated that a number of active stabilising solutions exist, although the majority of them are part of the inverter's control system. The adaptive active damper can automatically generate a virtual resistor to damp the resonance at the PCC and enhance and stabilise the grid-connected inverters under poor grid conditions after a literature analysis.

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