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Hybrid GFL-GFM Control for Converter-Dominated Power Systems: A Systematic Survey and Open-Source Implementation

Zilin Zhuang†, Ayman AlZawaideh†, Srdjan Lukic†, and Hantao Cui†

***Abstract*—With the large-scale grid integration of inverter-based resources (IBRs), power systems are rapidly transitioning toward a converter-dominated paradigm. This trend motivates hybrid grid-following (GFL) and grid-forming (GFM) control to combine fast power regulation with improved voltage and frequency support. This paper reviews classical GFL-GFM foundations and provides a structured taxonomy of hybrid GFL-GFM strategies for both converters and systems, including switching-type, dual-source, loop-augmented, and system-level categories. A parallel-branch hybrid architecture, which was recently approved by the Western Electricity Coordinating Council, is then introduced. In this model, the GFL and GFM branches operate concurrently under a coordinating plant controller. Both the REGFM_C1 converter control model and the REPCGFM_C1 plant control model have been implemented and made available in the open-source ANDES simulator. Case studies on Single-Machine Infinite-Bus system and the IEEE 14-bus system validate the effectiveness of the implementation by demonstrating rapid reference tracking and effective voltage and reactive power responses to disturbances.**

***Index Terms*—Grid-following control, grid-forming control, hybrid converter, stability and control**

I. Introduction

POWER systems worldwide are undergoing a rapid transition to operate with a significant percentage of inverter-based resources (IBRs). As the percentage of synchronous generators continues to decline, power system dynamic performance continues to change [1]. For example, system inertia and short-circuit capacity decline as more synchronous generators retire. The changing system dynamics has challenged the traditional "strong grid" assumption and revealed new stability and performance issues across multiple time scales [2]–[4].

IBR controls are broadly categorized into grid-following (GFL) and grid-forming (GFM) strategies. GFL control is more conventional and commonly used to deliver a predefined amount of power to a strong AC grid. A key characteristic is the use of PLLs to follow the external voltage waveform, so that the injection current can be calculated. While GFL control is mature and widely deployed, it has limited ability to actively regulate grid voltage and frequency. This becomes a challenge in weak grids, where the grid voltages can be significantly affected by the converter current injections, potentially inducing oscillatory behavior or even instability. In contrast, GFM control regulates terminal voltage magnitude and angle (or, equivalently, frequency) via droop or virtual synchronous machine (VSM) control to create voltage-source-like behavior. However, GFM control still has shortcomings, such as power oscillations under strong grid conditions, slow power response, and inability to track the maximum power point [5], [6].

At the same time, GFL and GFM control strategies offer complementary advantages. Relying on either GFL or GFM mode does not allow IBRs to simultaneously achieve fast power control and grid stability support as the grid operating conditions change. From a control-design perspective, the two schemes share common building blocks, including the power control loops and inner current loops, and show notable structural similarity and duality [6]. Therefore, it is promising to integrate the grid-forming features into the mature GFL foundation to obtain the benefits of both. Meanwhile, both GFL and GFM introduce new challenges and ideas in modeling and analysis, such as at the converter level [7], [8] and the system level [9]. The current development necessitates a systematic review and study to understand its impact on practical systems. Despite some advances in hybrid GFL-GFM control, existing works, such as control types, modeling, and simulation, have not yet been adequately summarized and organized to provide readers with sufficient insights.

This paper aims to provide a literature review of the state of the art in hybrid GFL-GFM control and a performance benchmark using open-source software. The main contributions are:

- A structured taxonomy of hybrid GFL-GFM control strategies is developed, covering converter-level and system-level implementations, with representative architectures and their practical motivations clearly identified.
- A unified discussion of modeling and dynamic behaviors for hybrid GFL-GFM converters is provided, with highlights on common control building blocks, structural duality, and stability implications.
- WECC-approved hybrid GFL-GFM converter and plant controller models (REGFM_C1 and REPCGFM_C1) are implemented in the open-source ANDES simulator [10]. This model is also used to develop performance benchmarks in the Single-Machine Infinite-Bus system and the IEEE 14-bus system for voltage and frequency response.

The remainder of this paper is organized as follows. Section II reviews the foundations of classical GFL and GFM control with the similarities and differences highlighted. Section III presents a taxonomy of hybrid GFL-GFM strategies for converters and systems and discusses the distinguishing characteristics. Section IV reports simulation case studies, and Section V draws conclusions.

II. GFL and GFM Control Fundamentals

This section reviews the two classical grid-interfacing paradigms, GFL and GFM control, to establish the background for hybrid converter discussion. In essence, GFL

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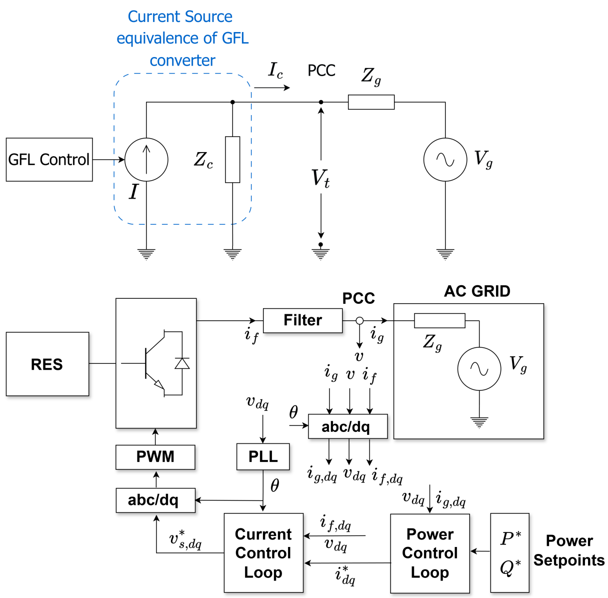

Fig. 1. Equivalent circuit and fundamental principle of GFL control

control regulates injected current while relying on the grid for synchronization, whereas GFM control regulates terminal voltage and provides self-synchronization. Hybrid solutions are thus motivated to take advantage of the complementary characteristics across different grid operating conditions.

A. GFL Control

Fig. 1 summarizes a typical GFL control architecture and its circuit interpretation. The Point of Common Coupling (PCC) voltage is measured and fed to a synchronous-reference-frame PLL to estimate the grid angle θ. Using θ, the measured three-phase signals are transformed into the dq frame, where active and reactive power can be decoupled and regulated. An outer power control loop generates the current references (i_d^*, i_q^*), and an inner current control loop, which is commonly based on proportional-integral (PI) controllers with decoupling terms, tracks these references and outputs the converter voltage reference $v^*_{s,dq}$ for Pulse Width Modulation (PWM).

From an equivalent-circuit perspective, a conventional GFL converter can be viewed as a controlled current source connected to the grid, typically in parallel with a relatively high output impedance shaped by the current loop and filters, which makes the converter behave closer to an ideal current source by reducing the sensitivity of the injected current to PCC voltage variations. Accordingly, the converter controls its power exchange primarily by shaping the magnitude and phase of the injected current with respect to the grid voltage. This current-injection nature explains why GFL control is widely used in strong grids for fast and accurate power tracking, but it may become sensitive to synchronization and impedance interactions in weak grids characterized by a low short-circuit ratio (SCR) or a large equivalent impedance at the PCC [11].

B. GFM Control

Fig. 2 shows a representative GFM structure and its circuit interpretation. Unlike GFL, GFM control aims to directly

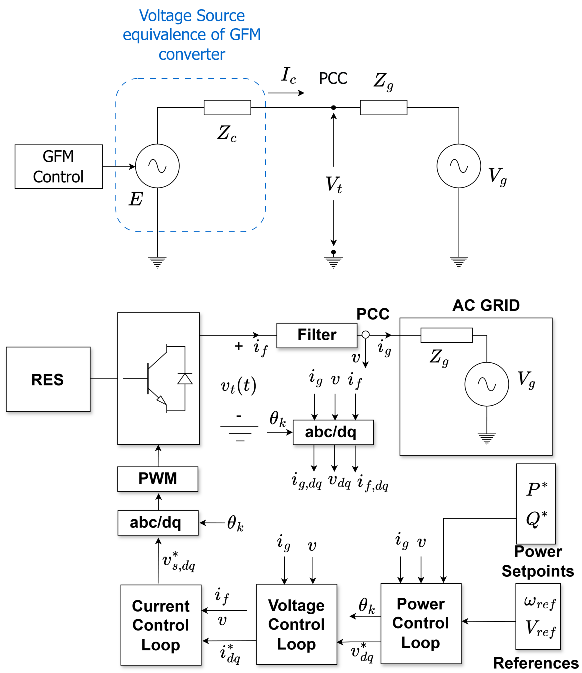

Fig. 2. Equivalent circuit and fundamental principle of GFM control

regulate the converter terminal voltage (magnitude and phase), thereby enabling self-synchronization without relying on a PLL. In practice, a power control mechanism (e.g., P–ω and Q–V droop, virtual synchronous generator, or virtual oscillator control) updates the internal frequency/angle and voltage references (ω_{ref}, V_{ref}, or an internal angle θ_k). A voltage control loop then produces a current reference, which is tracked by an inner current loop to generate the modulation voltage for PWM.

In circuit terms, a GFM converter is commonly modeled as a controlled voltage source behind an output impedance (set by the filter and virtual-impedance shaping). This voltage-source behavior allows the converter to contribute to grid voltage support and stable operation in weak-grid conditions. However, when connected to a very stiff grid, such as a grid with a small equivalent impedance seen from the PCC (high SCR), the system can resemble the parallel interaction of two voltage sources (the grid and the converter), which may reduce stability margins in some operating conditions. This tradeoff, together with the complementary properties of GFL, provides the key motivation for hybrid GFL-GFM converters that blend current-injection and voltage-forming capabilities.

III. Review of Hybrid GFL-GFM Control Strategies for Converters and Systems

A. Classification of Different Strategies

Hybrid GFL-GFM converters aim to reconcile the closed-loop behaviors of two fundamentally different sources: (i) *grid-following* current regulation synchronized by a PLL, and (ii) *grid-forming* voltage regulation with self-synchronizing angle/frequency dynamics. From a control-structure viewpoint, most hybrid designs are constructed by combining a current-regulating subsystem and a voltage-regulating sub-

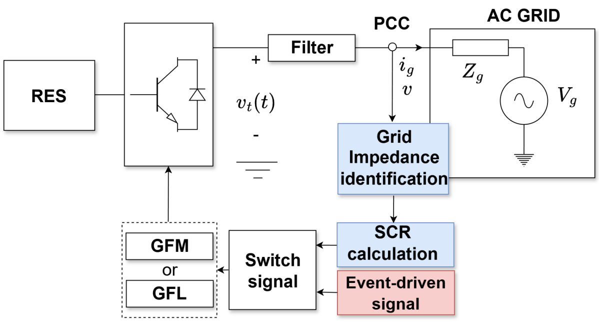

Fig. 3. Operating principle for the switching type hybrid control

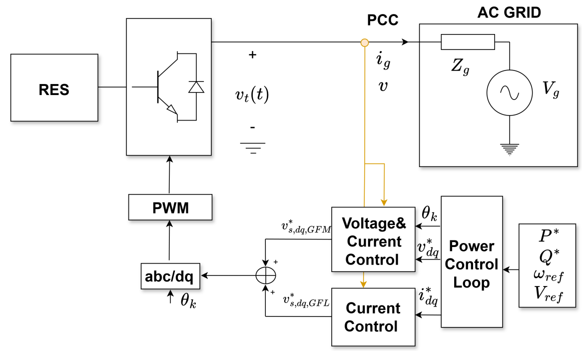

Fig. 4. Structure of the dual-source mode, series-fusion type controller

system through switching, blending, loop augmentation or system-level combination. A practical taxonomy is:

1) Switching type: As is shown in Fig. 3, switching type hybrids operate the converter in *either* GFL or GFM mode and switch between them according to measured or estimated grid conditions or events, resulting in a piecewise-controlled hybrid dynamical system. Hence, stability depends not only on the modal stability of each mode, but also on the switching logic and state consistency at transitions, such as the angular and frequency alignment and the controller-state initialization.

(i) Condition-based: This category targets robustness under large SCR (or grid impedance) variations and typically switches between a current-source mode in strong grids and a voltage-source mode in weak grids. To make such switching practical, the focus is less on inventing new loops and more on making the two modes share as much control logic as possible and making the transition transient-free. Practical designs therefore emphasize switchability: the two modes reuse the same fast inner current regulation while switching only the outer objectives and synchronization mechanism (PLL-based versus power-based) [12], [13]. To suppress switching transients, “bumpless transfer” is achieved by aligning references and initializing controller integrator states so the new mode starts from a consistent operating point [14]. To avoid frequent toggling near the threshold, some schemes add a deadband/dwell residence region between pure GFL and pure GFM settings [15].

(ii) Event-driven: In this category, switching is triggered by abnormal events such as faults, ride-through requirements, or protection coordination. During the event, the converter temporarily exits its normal power-regulation mode and enters a fault-support mode: it either (a) regulates the local voltage/frequency while enforcing a current limit, or (b) injects a prescribed fault current to facilitate conventional protection and then returns to the pre-fault mode after clearing [16], [17]. Since ride-through functions, such as low-voltage and high-voltage ride-through, and current limiting effectively introduce extra modes. The resulting multi-mode switching can yield different transient behaviors, motivating switching-aware modeling and stability criteria [18].

Such switching is often triggered by requirements driven by grid code and current-limiting. It may cause transient instabilities and delayed responses, calling for switching-aware modeling and criteria, and this also heavily relies on impedance detection and estimation. Because switching introduces inherent discontinuities, treating the dynamics as smooth can be misleading near switching surfaces. Modeling based on hybrid automaton combined with state-estimation tools provides a principled way to capture guard/reset events and improve dynamic state estimation [19].

2) Dual-source mode: Unlike switching-type schemes, dual-source mode combine a current source and a voltage source (GFL and GFM) to realize a continuous mixture of current-source and voltage-source characteristics. A representative implementation is to blend or sum modulation references from a GFL branch and a GFM branch, which can be viewed as a convex combination or a structured parallel interconnection with weighted modulation. Two important practical variants are the series-branch and parallel-branch hybrid control, in which one physical inverter emulates two coordinated virtual converters in series or parallel: a GFM voltage-control branch and a GFL current-control branch.

(i) Series fusion: Series fusion cascades one control path as a reference/compensation to the other so that only one main command is ultimately applied as Fig. 4 illustrated; the power control loop incorporates both GFL and GFM type power regulation mechanisms in a single cascaded loop, where the GFL-derived voltage compensation summed with the GFM voltage command to form one final PWM reference. Typical examples include: unifying Power Synchronization Control (PSC) and vector current control through minor PSC modifications plus a hybrid PLL-power synchronization loop, forming a “continuum” between GFL and GFM behaviors [20]; adding a lightweight cross-coupling/virtual-admittance compensation (e.g., active-susceptance injection) to enhance damping and maintain stability over a wide grid-strength range without resorting to hard mode switching [21]; introducing practical power-dynamic decoupling paths to suppress SCR-dependent power-coupling resonances in stiff grids, thereby enlarging stability margins and allowing higher synchronization-loop bandwidths [22].

(ii) Parallel fusion: As shown in Fig. 5, parallel fusion runs a GFL controller and a GFM controller at the same time, and then combines their commands into one final modulation voltage reference. A simple way to explain it is to use a blending factor $k_{GFM} = 1 - k_{GFL} \in [0, 1]$: the GFL branch mainly enforces power and current tracking (useful for maximum power point tracking (MPPT) and steady-state regulation), while the GFM branch contributes voltage and

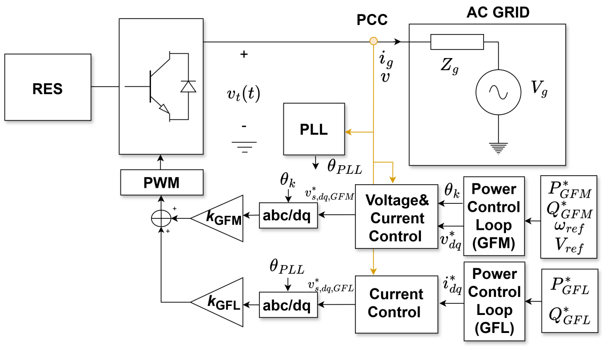

Fig. 5. Structure of the dual-source mode, parallel-fusion type controller

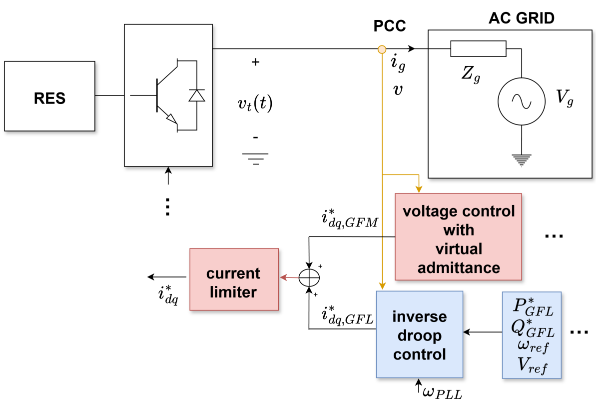

Fig. 6. Control strategies for external characteristic compensation

frequency support; changing k_{GFM} yields a smooth trade-off between the two behaviors. This idea is often formalized as a hybrid control converter, where one physical converter is designed to look from the PCC as if a GFL unit and a GFM unit were connected in parallel [23], [24]. To improve robustness across grid-strength variations, the blending can be scheduled by a strength indicator and may include an intermediate "residence" region to avoid rapid weight changes. A key practical issue is current limiting: once the converter hits its current limit, the voltage-support action can lose authority and the PCC voltage may become weakly controllable, which can noticeably reduce transient stability [25].

Compared with switching-type designs, dual-mode hybridization avoids discontinuities, but introduces nontrivial cross-coupling between the two branches and increases the control complexity; therefore, impedance shaping and frequency-domain modeling are commonly used to reason about robustness across wide SCR ranges.

3) Loop-augmented type: Instead of explicitly combining two mode structures, loop-augmented strategies start from a baseline GFL or GFM controller and add dedicated loops to "borrow" missing capabilities. Two major subfamilies are:

(i) External Characteristic Compensation: As shown in Fig. 6, these designs inject additional auxiliary signals into the outer control loops. A common approach is to augment GFL controllers with inverse droop control or GFM controllers with current-feedforward to enhance its power response and support capabilities. Such switchless architectures facilitate seamless transitions between grid-connected and islanded modes [26]

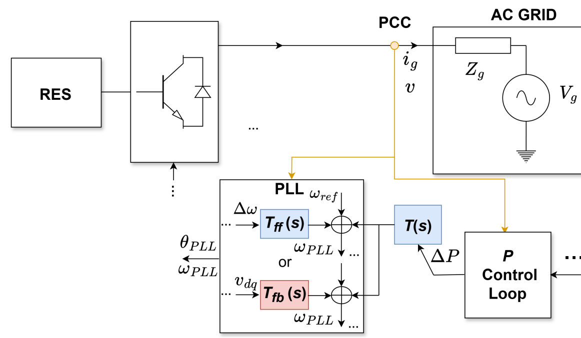

Fig. 7. Control strategies for synchronization augmentation

and allow for universal dual-port control that balances grid support with MPPT [27]. Advanced multi-input multi-output (MIMO) feedback designs utilize sensitivity shaping to parameterize the controller as a continuum, providing Lyapunov-certified robustness against parameter uncertainty [28].

From loop-shaping perspectives, compensation effectively modifies the converter's closed-loop output impedance around the fundamental frequency, enabling better steady-state support and/or faster transients. The trade-off is that additional loops can increase interaction among control channels, which complicates parameter tuning and may reduce the transparency of stability margins when grid impedance varies. Moreover, in weak grid conditions, voltage support capability and stability still cannot be adequately guaranteed.

(ii) Synchronization augmentation: Recognizing that synchronization dynamics dominate weak-grid stability, this approach, as shown in the Fig. 7, hybridizes the PLL and power-synchronization mechanisms directly by feedback $T_{fb}(s)$ or feedforward loop $T_{ff}(s)$. Adaptive weighting of the synchronization angle can improve small-signal stability [29]. Recent innovations include fusing droop-based GFM and PQ-based GFL logic to reshape positive-sequence impedance [30], and saturation-driven synchronization that adjusts the participation of PLL and PSC based on current limiter states to enhance fault recovery [31].

4) System-level type: Hybridization can also be realized at the plant and system level by coordinating a mixed population of GFL and GFM units or retrofitting part of a plant with GFM functionality. Since the structure of physical hybrid system is often similar and connected in a network, the literature is more naturally organized by the system-level tasks being addressed across how to allocate, tune, assess, and schedule GFM authority. In this setting, the key control-theoretic question becomes allocation and overall stability: how much GFM authority (voltage/frequency regulation and damping) is required, and how it should be distributed to shape the aggregate plant impedance and the dominant system modes.

(i) Planning and allocation: System-level studies investigate how many GFM converters are needed, where they should be placed, and how inertia/damping or fast frequency response should be allocated to achieve desired small-signal margins and equivalent grid strength [5], [32]. Optimization-based formulations further treat GFM ratio and placement as decision variables to enhance stability or energy dissipation [33].

(ii) Plant-level tuning and coordination: In hybrid plants,

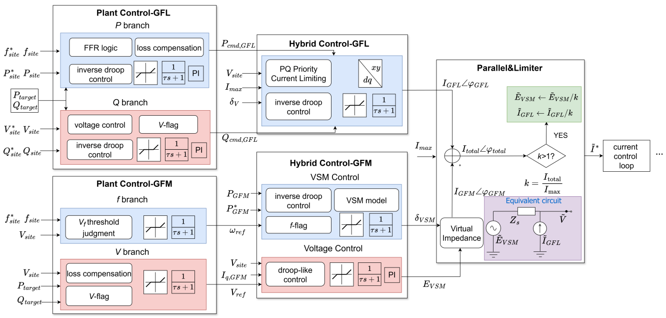

Fig. 8. Control strategies of WECC-approved hybrid converter model

GFM tuning can be highly sensitive to operating conditions and grid strength, calling for systematic tuning procedures [9]. When coupling is significant, mode interaction may dominate oscillatory behavior, motivating damping-oriented co-design and mutual damping enhancements to mitigate modal resonance under varying SCRs [34], [35].

(iii) Modeling and stability assessment frameworks: To support analysis across control types, unified frequency-domain modeling and equivalence studies reduce conservatism and clarify the applicability of impedance/admittance representations [7], [8], while quantitative coupling/decoupling conditions enable more interpretable and decentralized criteria [36]. Complementary to model-based assessment, engineering-oriented strength metrics have been developed for coexistence GFL-GFM systems, augments effective-SCR with PCC voltage deviation and reactive-voltage sensitivity to better indicate critical voltage-stability thresholds [37]. For diagnostic insight, some extended frameworks introduce a virtual synchronization node to quantify PLL and virtual synchronous generator participation [38]. More generally, (P, Q) to (ω, V) interaction models describe multi-VSC networks with arbitrary topologies and support targeted oscillation suppression [39].

Beyond small-signal analysis, manifold-based approaches quantify large-disturbance margins in mixed GFL-GFM systems [40]. Moreover, forced oscillations and multi-time scale coupling may arise and be overlooked under conventional time-scale separation assumptions [3], [41].

(iv) Operation and dispatch: At the operation layer, control mode can be treated as a grid service by embedding dynamically switchable GFL-GFM allocation into stability-constrained scheduling, enabling cost-effective, time-varying GFM penetration [42]. In practice, mode driven by grid codes changes and GFM saturation/limiting can create multiple transient patterns, calling for switching-aware system-level criteria [18]. Application-specific architectures further exploit differentiated GFL-GFM roles, such as cascaded PV-energy storage systems under decentralized PLL-less schemes [43].

B. WECC-Approved Model

Motivated by industrial practice and the need for open, reproducible studies, WECC and their partners focus on a *parallel fusion and external characteristic compensation hybrid* structure in which a voltage-forming (GFM) branch and a current-following (GFL) branch coexist inside one inverter and are coordinated by a plant-level controller, as shown in the Fig. 8 [44], [45]. In this architecture, both GFM and GFL controls work in parallel, and they do not switch between the GFM and GFL controls. The plant model includes a GFM branch that generates voltage and frequency references, and a GFL branch that contains real and reactive power regulation, voltage control, and loss compensation. The positive-sequence inverter model combines a GFM branch (voltage control and VSM) and a GFL branch (typical GFL control) in parallel, with a k-factor limiter that proportionally reduces both branch currents to keep the total positive-sequence output current within limits. And, the plant controller sends $P_{\mathrm{cmd,GFL}}$ and $Q_{\mathrm{cmd,GFL}}$ to the GFL branch, and sends V_{ref} and ω_{ref} to the GFM branch. It's worth mentioning that the model is algebraically in the phasor domain, and also includes very detailed and practical designs, such as V/f settings, fast frequency response logic, loss compensation, PQ priority, and various limiting modules.

In the case studies, we implement the above WECC-approved hybrid GFM model and evaluate its dynamic performance through time-domain simulations.

C. Discussion

Several open issues remain for hybrid GFL-GFM converters, systems and their deployment: (i) Currently, the GFL system remains dominant, and as GFM is gradually incorporated, using Loop-augmented type or System-level type methods for large-scale analysis and improvement is usually the most convenient and cost-effective approach; (ii) Systematic, robustness-oriented, data-driven tuning rules and control strategies that avoid weak-grid and strong-grid instability without over-conservatism; (iii) As a highly promising technology in engineering, it is necessary to further research and improve the new dual-source mode to enhance power grid stability and grid support capabilities; (iv) How do various multi-time scale constraints within new energy generation clusters (such as energy constraints, power output, current limits, and stability constraints), the GFM-to-GFL ratio between clusters, and the upper-level optimization control and communication units work together? (v) Protection coordination remains challenging because hybrid controls may reshape fault-current magnitude, phase, and timing through mode logic, current limits, and ride-through functions. Practical bottlenecks include reliable grid-strength/event detection, branch coordination, limiter-induced interactions, and validation across EMT and phasor-domain models.

IV. Case Study

In this section, we validate the effectiveness of the WECC-approved model via time-domain simulations on two benchmark systems: a single-machine infinite bus (SMIB) system and the IEEE 14-bus system [46]. All studies are conducted in ANDES, a Python-based tool for symbolic power-system modeling and numerical analysis, which enables efficient modeling and simulation and supports control design for large-scale systems [10], and the WECC detailed inverter and plant models `REGFM_C1` and `REPCGFM_C1` are used with properly selected parameters and consistent initialization.

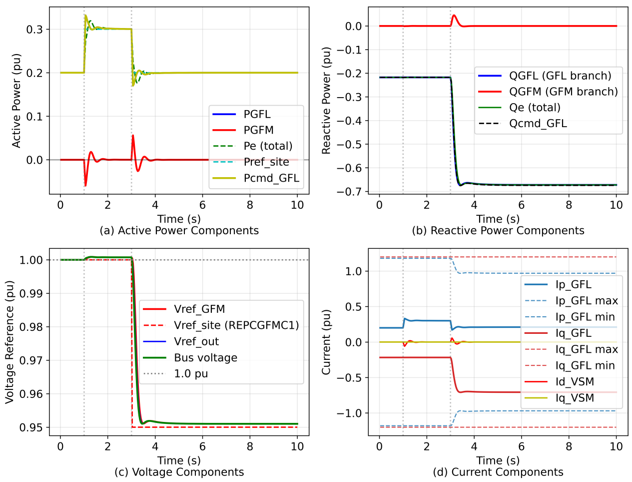

Fig. 9. SMIB case: response of the WECC-approved hybrid model to active-power and voltage-reference changes

A. Case Study 1: SMIB System

First, the hybrid converter is connected to a SMIB system. The active-power reference is stepped from 0.2 per unit (p.u.) to 0.3 p.u. at $t = 1$ s and then ramped back to 0.2 p.u. by $t = 3$s. Meanwhile, a 5% drop is applied to the voltage reference V_{ref} at $t = 3$s. These tests emulate command variations from upper-level control and dispatch and are used to examine the tracking and transient responses of the converter models. As shown in Fig. 9, the GFM branch reacts to the decrease in V_{ref} by reducing reactive-power output, consistent with voltage regulation behavior. The steady-state active and reactive power setpoints of the GFM branch are dispatched to zero, while the GFL branch maintains its d- and q-axis currents within the prescribed dynamic bounds throughout the transients. Moreover, key internal variables closely follow the references generated by the plant model, and the overall response settles rapidly after each command change.

B. Case Study 2: IEEE 14-Bus System

Next, we consider the IEEE 14-bus benchmark with standard parameters and all original devices retained. The hybrid converter is connected to the remote Bus 14. A step load increase of 40 MW is applied at Bus 9 at $t = 2s$ to evaluate the converter response under a sudden disturbance. As shown in Fig. 10, the GFM branch provides fast and noticeable active-power support immediately after the disturbance, helping arrest the transient deviation. The bus voltage also recovers within a short time window, where the voltage-support function (enabled by the GFM mechanism) plays a dominant role. Similarly, throughout the process, the current remained within the dynamic limit, and the converter state was able to track the reference value generated by the system model well, which verified the effectiveness of the implemented model under load disturbances in a multi-machine system.

V. Conclusion

This paper surveyed and tutorialized hybrid GFL-GFM control for converter-dominated grids, motivated by the complementary strengths and limitations of classical grid-following and grid-forming paradigms. A taxonomy was developed to organize the literature into switching-type, dual-source, loop-augmented, and system-level strategies. We further described a practical, WECC-approved parallel-branch hybrid architecture in which GFL and GFM branches operate concurrently and are coordinated by a plant controller with realistic limiting and priority mechanisms.

To illustrate system-level behaviors and provide a reproducible study path, we implemented the corresponding plant and inverter models and evaluated them on two benchmarks. Overall, the results corroborate that parallel-branch hybridization can combine fast power regulation with enhanced voltage and frequency support in a single coordinated structure.

Future work should further clarify robustness-oriented tuning rules across wide grid-strength ranges, develop analysis methods that explicitly account for limiting and multi-time scale coupling, and support operation-layer decisions on how to allocate and schedule GFM authority in large-scale hybrid systems while respecting multiple constraints.

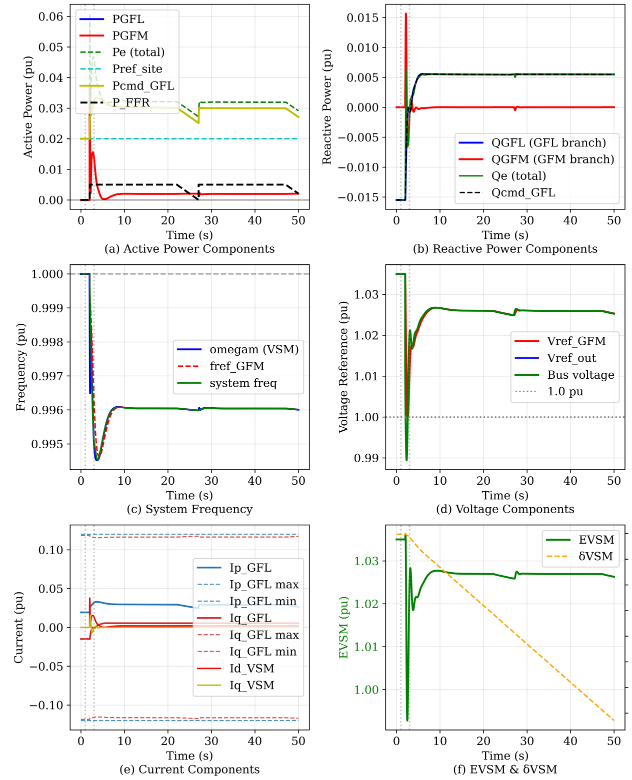

Fig. 10. IEEE 14-bus case: frequency/voltage and power responses to a load step

VI. AI Usage Disclosure

ChatGPT 5.2 was used and only used for grammar and spell checking.

Acknowledgment

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I. Review #17A

A. Paper summary

The paper reviews GFL and GFM control strategies for IBRs before delving into the Hybrid GFL-GFM control strategies. Finally, case studies on the IEEE-14 bus, SMIB systems are presented as validation.

B. Comments for authors

The paper is very well-written and easy to follow, and presents detailed overviews of the classical and hybrid control strategies. It classifies the hybrid controls and presents detailed case studies. A few comments:

- There are a few grammatical errors (”requirements drive by grid code”) and missing references in places (search for [xx]). The authors are encouraged to fix these.
- Though the authors present detailed hybrid strategies, the simulation results only present the WECC-approved models. For a more comprehensive simulation study, the authors can present and compare the results from the series-fusion type controller and the switched-mode type controller.
- Can the authors comment on the protection coordination for these hybrid controls and the implementation bottlenecks/challenges that such schemes may face?

C. Summarize your recommendation in one to two sentences

The paper is a very comprehensive survey of the hybrid GFL-GFM controls and will be a solid contribution to the conference.

— Bala Kameshwar Poolla

II. Review #17B

A. Paper summary

This work is a literature review of the hybrid GFL-GFM control and it also provides a performance benchmark for one control architecture using an open-source tool (ANDES).

B. Comments for authors

Very nice overview manuscript! Please consider the following comments/suggestions:

- “[xx]” appears in certainly places in the text.
- IV case study: “In this chapter” should it be “In this section”?
- The authors provide an informative overview of GFL-GFM control architectures. They managed to create a good synthesis/overview despite the 6-page limitation.
- It would be very helpful to include a table that compares all the architectures discussed using features/characteristics as columns. Including columns for advantages and disadvantages could be insightful too.
- It would strengthen the work to compare the performance of all the reviewed control strategies under different events/conditions. This would be very valuable for the community. This analysis could help draw apples-to-apples conclusions about these architectures. However, it is a substantial effort and I am not necessarily suggesting this is needed for acceptance.

C. Summarize your recommendation in one to two sentences

I would recommend creating a summary table to be able to easily compare architectures. This can be very insightful for the community as it would discuss and compare across a set of features/conditions, which could enable drawing broader conclusions.

— Patricia Hidalgo-Gonzalez

III. Review #17C

A. Paper summary

This paper provides a well-structured, timely, and practically relevant survey of hybrid GFL–GFM control strategies, complemented by open-source implementation and validation.

B. Comments for authors

The paper addresses a critical and emerging problem in modern power systems. The motivation is clearly articulated and the survey on hybrid GFL-GFM is well structured. The inclusion of WECC-approved models and their implementation in ANDES is a also major strength.

There are several placeholder citations such as “[xx]” in the paper, which should be corrected. While the taxonomy is good, the paper lacks quantitative or structured comparison across categories. Also, adding a short paragraph comparing with prior surveys and highlighting what is new would be helpful.

C. Summarize your recommendation in one to two sentences

I recommend some minor revisions, including missing placeholder citations, some language polishing, and stronger quantitative comparison would improve an already solid contribution.

— Xin Chen

IV. Brief response to reviewers (optional)

V. Brief summary of changes made to the final paper

We sincerely thank the reviewer for the constructive comments. The manuscript has been revised accordingly, as summarized below:

- An appropriate reference was added at the end of Section II-A, and the incorrect citation was removed.
- Grammatical and tense-related errors throughout the manuscript were corrected, and the description of the SMIB and IEEE 14-bus case studies in the Abstract was revised for clarity.
- Section III-C was expanded to discuss protection coordination and practical implementation challenges, including fault-current characteristics, grid-condition detection, branch coordination, limiter interactions, and cross-domain model validation.
- The simulation figures were reformatted, and the disturbance magnitude in the IEEE 14-bus case study was increased to more clearly demonstrate the controllers' dynamic performance.
- The author information, affiliations, and funding acknowledgment were updated.