

Regional Electricity Markets in China

A review of China Southern Grid's proposed regional market design

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Summary

Over the past decade, Southern China has been at the forefront of the development and implementation of electricity market rules

From mid-2022 to July 2023, the South China Energy Regulatory Office of the National Energy Administration (国家能源局南方监管局), the China Southern Grid Dispatch Center (CSGDC, 中国南方电网电力调度控制中心) and the Guangzhou Power Exchange (广州电力交易中心有限责任公司) released a series of documents proposing a regional electricity market design for the China Southern Grid region. This report provides a brief review of the proposed market design. The report is based primarily on the June 2023 Southern China Regional Electricity Market Operation Rules (Draft for Comment) (南方区域电力市场运营规则) (“*Market Rules*” or “*Rules*” in this document), but to some extent draws on multiple “*detailed implementation*” (实施细则) and other documents as well.

Regional electricity markets can enhance reliability, lower emissions, integrate renewable energy at lower cost, more fairly allocate costs, and improve price and cost transparency. The *Market Rules* are an important first step in advancing a regional electricity market for Southern China. They lack clarity in some key areas, however, and have not yet fully addressed several important design issues, the most important of which are:

- A potentially flawed settlement system.
- Cash imbalances for market operators (power exchanges) caused by entities that are not settled at spot market prices.
- The lack of regional dispatch control.
- Considerations around regional resource adequacy.
- Market price regulation and oversight.

None of the issues identified in this report, including those not explicitly mentioned, are insurmountable. The report outlines potential strategies for addressing these challenges. In addition to concrete design issues, less tangible considerations, such as political support and education for market participants on rules and strategies, will serve as important foundations for fostering and sustaining active participation in the regional spot market.

The report is organised into three sections:

- **Regional market design.** Reviews the regional market design proposed in the *Market Rules* and, to a lesser extent, the detailed implementation documents.
- **Market price regulation and oversight.** Examines price limits that may be imposed on the regional market and the potential oversight process for dealing with market manipulation.
- **Conclusions and recommendations.** Identifies and summarises priority areas for improving the *Market Rules*.

Regional market design

The proposed regional electricity market design is based on three principles, each dictates the operation of various parts of the electricity market:

- For contract markets, “two-tiered markets with orderly coordination” (两级市场、有序衔接).
- For spot markets, “unified clearing and coordinated operations” (联合出清、协同运作).
- For ancillary service (AS) markets, “step-by-step consolidation with close coordination” (分布融合、紧密衔接).

Contract market design

Contract settlement

In the *Market Rules*, electricity medium and long-term (MLT) contracts (中长期合同) consist of four types of transactions: (1) planned interprovincial transactions (跨省优先计划交易), (2) market-based interprovincial transactions (跨省中长期市场化交易), (3) market-based intraprovincial transactions (省内中长期市场化交易), and (4) grid company default procurement (电网企业代理购电交易). These are consistent with the design of existing MLT contract markets in China.

Currently, and as described in the *Rules*, at least the first three transactions are centrally settled. Interprovincial contracts are settled by the Guangzhou Power Exchange; provincial contracts are settled by the corresponding provincial power exchanges.

Contract settlement is part of a **three-settlement system**: contracts are settled at the contract price; deviations from the contracted quantities in the day-ahead markets are settled at the day-ahead price; lastly, deviations from the day-ahead cleared quantities are settled at the real-time price.¹ This three-settlement system uses “power curves” (分时电力曲线) — contracted energy (e.g., MWh per month) translated into hourly supply and demand (MWh per hour) — to measure deviations for day-ahead market settlement. With a single pricing zone, this approach is similar to contracts for differences (CfDs).²

¹ Both provincial and interprovincial transactions would be settled using this approach. The original text is: 中长期交易电量按照中长期交易价格结算; 日前现货出清结果与中长期电能量交易电量之间的偏差电量, 按日前现货电能量交易形成的跨省日前价格结算; 实际执行与日前现货出清结果之间的偏差电量, 按实时现货电能量交易形成的跨省实时价格结算。

国家能源局南方监管局. (2023, 2 June). 南方区域电力市场运营规则 (试行) (征求意见稿) [Southern China Regional Electricity Market Operation Rules (Trial)(Draft for comments)]. <http://nfi.nea.gov.cn/adminContent/initViewContent.do?pk=4028811c878cd78f01887b3a4ef000be>.

² For generation and loads (separately), the total contract and day-ahead market settlement over some period t will be $\sum_i \sum_t Q_{it}^C \times P_i^C + (Q_{it}^{DA} - Q_{it}^C) \times P_t^{DA} + (Q_{it}^{RT} - Q_{it}^{DA}) \times P_t^{RT}$, where Q_{it}^C is the quantity for contract i at time t , P_i^C is the price for contract i , Q_{it}^{DA} is the quantity that clears the day-ahead market, P_t^{DA} is the day-ahead price at time t , Q_{it}^{RT} is the quantity that clears the real-time (spot) market, and P_t^{RT} is the real-time (spot) price at time t . Rearranging terms gives $\sum_t \sum_i Q_{it}^C \times (P_i^C - P_t^{DA}) + Q_{it}^{DA} \times (P_t^{DA} - P_t^{RT}) + Q_{it}^{RT} \times P_t^{RT}$. The first term pays the difference between contract(s) and day-ahead market price (forward premium), the second term pays the difference between day-ahead and real-time (day-ahead premium), and the third term is real-time market settlement. This three-settlement approach guarantees contract revenues, per the power curve, regardless of whether a generator operates, but generators may need to buy back their power curve schedules if they do not clear the market. Multiple contracts for the same generator or load require separate settlements for each generating unit or load.

However, because the regional spot market will be dispatched nodally and settled at locational marginal prices (LMPs), it is unclear how this three-settlement system would work in practice. Settling contracts and spot markets incrementally through a three-settlement system is equivalent to paying generators at the delivery node price, rather than at the generator node price (see sidebar). This approach could create large cash imbalances for both the regional and provincial power exchanges and is unlikely to be sustainable (see Appendix 1).

A more ideal approach, potentially aligning with the intention of the *Rules*,³ would be to settle all day-ahead generation (load) at day-ahead generator (load) node prices, settle real-time generator (load) deviations from day-ahead quantities at real-time generator (load) node prices, and use contracts for differences only to pay the difference between contract and nodal prices at quantities agreed upon in the contracts. The example in the appendix illustrates the difference between these two approaches. The next section on spot market design discusses issues around congestion costs and risk allocation in spot markets.

Transmission limits in contract markets

Accounting for transmission limits in contract markets may seem to be a way to limit spot market settlement imbalances, but if limits are based solely on contract paths (i.e., without the foundation of power flow models), transmission limits are neither very accurate nor meaningful. The *Rules* and detailed implementation documents are unclear and somewhat contradictory about whether and how contract markets will account for transmission limits. In the *Rules*, the only MLT transactions subject to transmission security review are planned interprovincial

Incremental versus Nodal Settlement

Consider a hypothetical example, in which a generator at node A has a 300 yuan/MWh contract with a load for 500 MW at node B, for delivery at node B.

If the day-ahead and real-time clearing price is 250 yuan/MWh at node A and 350 yuan/MWh at node B, and if the generation and load are exactly 500 MW in day-ahead and in real time, in the three-settlement approach the generator will earn $+150,000 \text{ yuan/h} (= 500 \text{ MW} \times 300 \text{ yuan/MWh} + 0 \text{ MW} \times 250 \text{ yuan/MWh})$ and the load will pay $-150,000 \text{ yuan/h} (= -500 \text{ MW} \times 300 \text{ yuan/MWh} + 0 \text{ MW} \times 350 \text{ yuan/MWh})$.

With nodal settlement, the generator earns $+\$125,000/\text{h} (= 500 \text{ MW} \times 250 \text{ yuan/MWh})$ from the spot market and pays the load $-\$25,000/\text{h} (= [\$300/\text{MWh} - \$350/\text{MWh}] \times 500 \text{ MW})$ for the contract for differences, for a net settlement of $+\$100,000/\text{h}$. The load pays $-\$175,000/\text{h} (= 500 \text{ MW} \times 350 \text{ yuan/MWh})$ in the spot market and earns $+\$25,000/\text{h} (= [\$350/\text{MWh} - \$300/\text{MWh}] \times 500 \text{ MW})$ from the contract for differences, for a net settlement of $-\$150,000/\text{h}$.

In three-settlement, the market operator assumes congestion risk for contracts; with nodal settlement, market participants assume this risk.

³ The *Rules* state that “contract transactions will be linked to the spot market through contracts for differences” (中长期电能量交易结果通过差价合约结算机制与现货电能量交易进行衔接), that “congestion costs for interprovincial contracts should be accounted for separately and negotiated between buyers and sellers” (跨省中长期交易合约对应的阻塞费用单独计算, 由合同双方自行协商承担方式), and “... the reference point for settling interprovincial transactions will be the border flow gate in the importing province, and the border flow gate should include all nodes in the province” (现阶段, 跨省中长期交易的结算参考点取相应送电类别在受端省(区)的落地关口, 落地关口包括该送电类别在受端省(区)所有落地节点). These may suggest a nodal approach to settlement, rather than a simple three-settlement one in which transactions are settled incrementally. With incremental settlement, there are no congestion costs for contracted energy, for instance.

transactions, which can be curtailed if they exceed transmission transfer capability.⁴ All other transactions are only checked for basic feasibility (e.g., generator capacity limits).

In the detailed implementation document for contract market, however, contract markets are subject to transmission capacity constraints, with transmission capacity allocated to the transactions. What this allocated transmission capacity represents (e.g., is it a transferrable right, does it carry over into the spot markets) and how transmission limits would be implemented in practice, is unclear. It may be less complex and more efficient to let market participants manage congestion risk in contract markets rather than setting *ex-ante* limits.

Overall design

The *Rules* create separate interprovincial and provincial contract markets. While the coexistence of a regional, LMP-based spot market alongside a mixture of provincial and regional contract markets may strike a balance between political forces and economic efficiency, it also constrains market liquidity and has the potential to create confusion. For instance, a buyer in Dongguan, Guangdong would need to evaluate prices in a range of provincial and interprovincial contract markets without confidence that prices would remain stable.

A more efficient yet politically challenging approach would involve consolidating the provincial power exchanges into a single exchange (the Guangzhou Power Exchange). This strategy would include standardising centralised contracts, settling them at designated trading hubs, allowing market participants to choose delivery points in bilateral contracts and publishing trading hub prices along with detailed LMPs so that market participants can more easily evaluate their options for MLT contracting. In this case, a buyer from Dongguan looking for a two-year contract for power delivered within Guangdong (perhaps Guangdong South) in the regional contract market would be indifferent to whether the power was generated within or outside of Guangdong.

The *Rules* emphasise that planned interprovincial transactions have priority dispatch (discussed in the next section). These transactions are remnants of earlier non-market-based agreements among provinces, including the West-East electricity transfer (西电东送) and the Three Gorges transfer. Many projects in these agreements are direct current (DC) lines connecting individual power plants to Guangdong – they are not grid-to-grid transfers and are more akin to power plants operating in Guangdong than transfers between provinces. The scale of planned transactions is large, which means that they are likely to be a drag on

⁴ However, the *Rules* also state that MLT contracts will be allocating transmission capacity based on “transaction sequence” (成交顺序). The detailed implementation for contract market specify that the sequence refers to: (1) the timing of the transaction (longer-term transactions have priority), (2) if the same time, the kind of transaction (bilateral, matched, auction in that order), and (3) if the same time and kind, priority status (planned transactions and clean energy have priority).

market efficiency in both contract and spot markets.⁵ However, price signals can provide a powerful force for transitioning away from these kinds of legacy arrangements.

Thus far, the *Market Rules* and the detailed implementation documents provide reasonable clarity regarding the participation of non-thermal generation and electricity storage in contract and spot markets but are less clear on the specific methods and timing.⁶ In principle, the existing contract market design could be workable for all resources, but it may require more generic power curves and a shift in the mindset of market participants on what power curves represent — from expected delivered power to a means to shape financial contracts and manage spot market risk.

In centralised contract markets, power curves are already standardised using a “typical” power curve (典型曲线), which helps to increase market liquidity. But to be useful for all resources, these typical power curves will need to be more generic (e.g., on-peak/off-peak). In bilateral markets, allowing flexibility in power curves would enable market participants to figure out the best way to manage and allocate risk. For instance, a wind seller and buyer may not want to use a year-ahead hourly forecast as the power curve in their contract, preferring instead to use something simpler and manage spot market risk through other means. Allowing for flexibility also appears to be the approach taken in the detailed implementation for contract markets.⁷

Spot market design

The spot market design is based on a security-constrained, nodal economic dispatch covering the entire China Southern Grid footprint. The spot market includes a **bid-based day-ahead energy market** with security-constrained hourly scheduling and a **bid-based real-time energy market** with security-constrained 15-minute dispatch. Market participants have three pathways to participate in the spot market: (1) full optimisation (完全优化) through quantity-price bids, including unit commitment; (2) partial optimisation (区间优化) through

⁵ The key issue in dealing with legacy arrangements in spot markets is transmission service, which affects both the ability to deliver energy and capacity in contracts and the cost of doing so. In the U.S., MISO (“Grandfathered Agreements”) provides a reference for how legacy agreements can be managed in a regional spot market when the volume of those agreements is large.

⁶ The *Market Rules* appear to envision market participation by non-thermal generation as a longer-term development, whereas the detailed implementations for spot market and for contract market appear to envision participation upon inception of the regional market. In its “market development” (市场发展) section, the *Market Rules* have language about creating pilots for wind, solar and storage to participate in markets (开展风电、光伏等可再生能源、抽水蓄能和独立储能等参与电力市场试点). The detailed implementation for spot market (现货电能交易实施细则) state that all resources except run-of-river hydro and nuclear should bid into spot markets (燃煤、燃气、水电、风电、光伏等交易单元采用报量报价方式参与现货交易). The detailed implementation for contract market (中长期电能交易实施细则) state that power curves for clean energy could be based on clean energy forecasts (购售电主体也可参照用电侧历史用电曲线、清洁能源消纳预期、用电需求等) and give priority to clean energy transactions in allocating transmission capacity (同类别标的同交易类型电量按照清洁能源优先顺序成交).

中国南方电网电力调度控制中心 广州电力交易中心有限责任公司. (2022, 4 August). 南方区域电力市场现货电能交易实施细则 (试运行 1.0 版) (南方电网总调 (2022)8号 附件3) [Southern China Regional Electricity Market Detailed Implementation for Spot Market (Trial Version 1.0)].

中国南方电网电力调度控制中心 广州电力交易中心有限责任公司. (2022, 4 August). 南方区域电力市场中长期电能交易实施细则 (试运行 1.0 版) (南方电网总调 (2022)8号 附件2) [Southern China Regional Electricity Market Detailed Implementation for Medium and Long-Term (MLT) Contracts Market (Trial Version 1.0)].

⁷ The detailed implementation states that “power curves for bilateral contracts are to be negotiated between the two parties” (双边协商采用自定义分解曲线).

quantity-price bids over a limited operating range (e.g., 200 MW for a 600 MW facility); (3) no participation (不参与优化). Initially, spot market participation by loads will be limited to bidding quantity but not price in the day-ahead market.

Cost imbalances

The *Rules* appear to allow generators and loads to participate in the spot market voluntarily (pathway 3), and leave open the option for provinces to join the spot market at different times.⁸ Generators and loads that do not participate in the spot market have their schedules set by provincial dispatch organisations using power curves, though it is not clear how deviations from schedule and congestion costs for non-participating generators would be settled. Provinces that do not participate in the spot market are still required to submit schedules to the China Southern Grid Dispatch Center, which would include any interprovincial flows as constraints in its spot market optimisation. Again, however, it is not clear how deviations from the schedule would be settled. Allowing simultaneous participation in contract markets and voluntary participation in spot markets could create opportunities for gaming and cost-shifting.⁹ Congestion and imbalance costs to the power exchanges, if not paid for by market participants, could cause financial stress to these organisations and lead politicians and market participants to lose faith in the market. The *Rules* lump congestion costs and other differences between what generators are paid and what loads pay into a single category of “**cash imbalances**” (不平衡资金). They distinguish between provincial imbalances and interprovincial imbalances. Provincial imbalances include any differences between payments to and from generators, including differences that result from congestion and those that result from loads – presumably mainly grid company default service (电网代购电) providers – that may not be settled at spot market prices.¹⁰ Provinces would develop a mechanism for allocating these costs. Interprovincial imbalances are due to price differences between exporting and importing nodes. Interprovincial imbalances would be settled through contracts and bilateral arrangements between provinces.¹¹

Management of these cash imbalances is probably the largest weakness of the market design proposed in the *Rules*. The *Rules* appear to assume that imbalances within and between provinces due to congestion, energy imbalances and partial market settlement will

⁸ The text states that “while the regional market is being developed, import export curves between participating and non-participating provinces will be constraints in the real-time optimization” (在区域市场建设过程中, 已纳入区域现货市场的省(区)与暂未纳入区域现货市场的省(区)之间的送受电曲线, 作为区域现货电能交易边界条件).

⁹ For instance, loads could sign contracts with generators in lower-cost areas that they know to be undeliverable and push the higher costs of real-time re-dispatch to serve their load (congestion costs) onto other loads. This problem was a key reason for moving to gross pool, LMP-based markets in the U.S.

¹⁰ The *Rules* define cash imbalances as cash imbalances that result from differences in energy and prices between generators and loads (区域市场不平衡资金是指发电侧与用户侧因电量、电价差异在电费结算中所产生的资金偏差). Based on the description in the *Rules*, these differences could result from deviations from contracts that are not settled in the markets, differences in generation and load settlement that arise from the three-settlement system (including congestion costs), and differences between wholesale and retail settlement that result from, for instance, frozen rates for residential and smaller commercial customers.

¹¹ This includes interprovincial transactions and may include planned transactions. The *Rules* use the term “interprovincial export classes” (各省间送电类别) that is not defined elsewhere within the document or online but seems to refer to defined arrangements between provinces. For these transactions, buyers and sellers would allocate cash imbalances based on ratios (各省间送电类别形成的不平衡资金由购售双方按比例分摊或分享).

be easy to isolate and manage internally within provinces, but this is unlikely to be the case in a regional wholesale market.

China's own experience with power pools and California's experience in the early 2000s illustrate that cash imbalances can cause markets to fail.¹² The two prerequisites for managing cash imbalances are (1) clear and consistent spot market prices and (2) retail pass-through of wholesale market costs. For a regional market design, the goal should be to ensure that the regional market operator (in this case, Guangzhou Power Exchange) is revenue-neutral and that its only sources of revenue "non-neutrality" are congestion rents and marginal transmission losses.

Addressing imbalances

Market designers in Southern China must deal with a challenging problem: how to allow the regional market to grow organically (voluntarily) over time, both in terms of individual market participants and provinces, while ensuring that the mix of non-market and market participation does not lead to market failure by, for instance, leading to power exchange insolvency or system blackouts. At some level, however, this requires prices and incentives, at least on the margin, to be aligned with the need for reliable operations rather than allowing some participants to avoid all exposure to the spot market. There are likely to be three main groups of non-participants that would require special attention in the market design, each of which may need a separate solution:

- **Planned generation** could be settled at contracts for differences at the generator node, ensuring that generators are guaranteed the contract price, with any deviations from contract settled at market prices at the generator node.¹³
- **Imports and exports from non-participating provinces** — either within or outside the Southern region and not including planned generation — could be settled at the border LMP of the participating province or provinces, with no spot market settlement of internal transactions in the non-participating province. With contracts for differences, only deviations from scheduled imports and exports would be exposed to spot market prices because there is a single price node for settlement.
- **Other non-participants**, including grid companies providing default service, could be price takers in the market, with deviations from contract settled at nodal prices and congestion costs managed by contract buyers and sellers or, in the case of grid companies, by settling them at load nodes. In cases where market participants are at the same node or in the same price zone, spot market exposure would be mostly limited to deviations from schedules.

¹² These two power pools were in the Northeast and Eastern regional grids. Anecdotally, they collapsed because of challenges in passing on higher fuel costs. More recently, the inability to pass on wholesale costs has been a challenge in several electricity markets throughout China. See 范若虹 [Fan Ruohong]. (2022, 4 November). 电费窟窿是怎样产生的 [How the Hole in Electricity Fees Came About]. *财新周刊*, 第43期.

¹³ This approach will guarantee contract revenue for the generator at the generator node, which seems appropriate given that many of these projects were developed to provide low-cost power to more affluent provinces and spur development in poorer ones.

Among these issues, the most challenging is likely to be how to deal with default service and residential rate impacts. The *Rules* envision that provinces could use non-market generation to meet as much of this demand as possible, contract for the expected remainder and allocate any additional costs to industrial and commercial customers. Provinces will indeed need to deal with market imbalances, but a condition to joining the market should be that all metered demand — and thus all deviations from contracts — will be settled at spot market prices. Without this condition and commitment, it is unclear how a regional market can be sustainable. Even if spot market bidding is limited at first, settling energy imbalances and congestion at market prices is an important first step in aligning incentives and operations and encouraging more generators and provinces to participate in the spot market (see sidebar). Dispatch centres, power exchanges and government agencies may need to support training for market participants to educate them on market participation and rational bidding strategies: even generators with contracts will want to bid their full output into the spot market.

Dispatch control

In the real-time market, CSGDC will dispatch resources according to schedules and market optimisation every 15 minutes across the region. The *Rules* appear, however, to maintain China's traditional control structure for dispatch, with separate regional and provincial dispatch centres and continued provincial control over provincial generators.¹⁴ The rights and responsibilities section states that provincial dispatch centres are still responsible for provincial balancing and appears to assume that they are responsible for AS provision.¹⁵ The *Rules* require provincial dispatch centres to implement real-time dispatch instructions but allow them the flexibility to deviate from real-time dispatch within the 15-minute dispatch interval for reliability reasons.¹⁶ The *Rules* do not specify what happens if generators or dispatch centres do not follow 15-minute dispatch signals or if provinces do not meet their frequency balancing obligations.

Incentives for market participation

A hypothetical 200 MW generator with a contract for 350 yuan/MWh and a fuel cost of 320 yuan/MWh, who does not participate in the spot market, is likely to forego potential earnings if spot markets clear at prices lower than 320 yuan/MWh.

If the generator has fuel costs of 320 yuan/MWh and day-ahead and real-time prices clear at 300 yuan/MWh, the generator's total net income if it does not bid into the spot market and clears the market will be 6,000 yuan/h (= 200 MW × [350 yuan/MWh – 320 yuan/MWh]). Its net settlement if it bids into the spot market (and does not clear) will be 10,000 yuan/MWh (= 200 MW × 350 yuan/MWh + (0 – 200 MW) × 300 yuan/MWh).

¹⁴ This traditional control structure is “unified dispatch, management by level” (统一调度、分级管理).

¹⁵ The text states that “provincial dispatch centres are responsible for balancing management and organizing intraprovincial AS transactions; CSGDC will work with provincial dispatch centres to implement spot market and AS market transactions” (各省(区)中调负责本省(区)电力电量平衡管理, 组织省(区)内电力辅助服务交易。南网总调会同各中调按照调管范围负责现货电能交易、电力辅助服务交易结果执行).

¹⁶ The original text is: 电力调度机构可根据电网实际运行情况和系统安全稳定运行与电力供应保障需要, 按照安全第一的原则对机组的实时调度计划、跨省送受电计划等进行调整.

Regional markets that are effective (for variable renewable generation and efficiency overall) do not require regional frequency balancing, but they do require regional dispatch control. For instance, in the Western Energy Imbalance Market (WEIM), the California Independent System Operator (CAISO) sends five-minute dispatch signals to individual generators, but participating utilities are still responsible for frequency balancing through automated generation control (AGC) systems. The CAISO's five-minute dispatch instructions, however, are physically binding, meaning that generators that do not follow these instructions are assessed penalties for uninstructed deviation and may be found in violation of the CAISO tariff, in which case they may lose their eligibility to participate in the CAISO market. Without clear penalties for non-compliance with dispatch instructions, generators (and provincial dispatch centres) can "self-dispatch" (e.g., a generator dispatched for 100 MW could generate 120 MW). Self-dispatch creates larger balancing needs and potential reliability issues within dispatch intervals, as well as opportunities for gaming, and has been an issue in electricity systems from California to India.¹⁷

In principle, CSGDC could send automated dispatch signals directly to generators based on real-time market cleared quantities. The provincial dispatch centres add an unnecessary layer of complexity. Even if the provincial dispatch centres are responsible for sending dispatch signals to generators, CSGDC can still set penalties for non-compliance with real-time dispatch signals to ensure that its real-time dispatch instructions are physically binding. Even if the provincial dispatch centres are still responsible for final balancing within 15-minute intervals, there should be a limited number of situations (e.g., multiple contingency events) in which provincial dispatch centres would need to change the CSGDC's real-time dispatch beyond what could be managed through provincial AGC systems. CSGDC's market rules should explicitly clarify what these situations are and require provincial dispatch centres to document any situation in which they override CSGDC's dispatch instructions. Ideally, emergency dispatch instructions should come from CSGDC rather than the provincial dispatch centres. The reliability benefits of regional dispatch and control were a key driver behind the development of regional transmission organisations (RTOs) in the U.S.

The *Rules* do not state explicitly that real-time settlement will be based on metered supply and demand. Metered real-time settlement at real-time prices aligns market prices (incentives) and system control (reliability), giving generators an incentive to be available when needed and to follow the system operator's instructions. For instance, a generator that needs to be dispatched for emergency reasons within the dispatch interval or a generator that is providing regulation energy could not have done better by withholding energy from the real-time energy market and getting paid for providing energy or other services within the dispatch interval. The market rules should ideally clarify that metered energy is the basis for final settlement and that all deviations from schedules cleared in day-ahead markets will be settled at real-time prices.

¹⁷ As long as prices are aligned with reliability needs, self-dispatch is generally not an issue: generators have an incentive to operate in line with system needs. However, in CAISO's case, generators discovered that they could influence real-time prices by withholding in both day-ahead and real-time and then over-generate (i.e., generate in excess of dispatch instructions) in real-time at higher prices. India's deviation settlement mechanism (DSM), which is a system of penalties and rewards tied to system frequency, was intended to address self-generation issues in a multi-state (regional and now national) electricity system.

Ancillary services markets design

The Rules propose bid-based regional markets for three AS products — frequency regulation, contingency reserves and “peaking” services (调峰辅助服务) — but are light on details. It does not appear that the Rules envision a centralised AS market in which CSGDC procures all AS for the region. Instead, the Rules suggest AS transactions occur between provinces, with provincial dispatch centres responsible for managing their own AS.¹⁸ For instance, the Guangdong provincial dispatch centre could procure some of its contingency reserves from the Yunnan provincial dispatch centre. In general, the only AS product that is likely tradeable in this way is contingency reserves. If provinces have different definitions of AS products (e.g., ramp time for spinning reserves) and some have AS markets whereas others do not, trading AS across provinces will be complex and may not be worth the effort.

As an alternative, it may be more strategic to focus efforts on developing the regional spot energy markets before trying to develop regional AS markets. For contingency reserves, waiting to develop a regional market would not preclude an interprovincial reserve-sharing mechanism if this did not already exist. The regional spot energy markets would help to facilitate regional contingency reserve sharing by ensuring that replacement energy is delivered to areas that experience generator or transmission outages. Contingency reserve sharing does not necessarily require a regional market for reserves, though it does require standard reserve definitions.

If CSGDC assumes responsibility for regional dispatch control and frequency regulation, it will begin to make more sense for CSGDC to procure AS regionally and operate centralised markets for AS. If the day-ahead and real-time energy market is established, AS markets and procurement can be co-optimised with procurement. The three most important AS products will be: (1) frequency regulation reserves, (2) spinning contingency reserves and (3) non-spinning contingency reserves. Peaking services are not a reserve (capacity) product and should be procured through the energy markets.¹⁹

AS costs are currently allocated to generators rather than to loads. From a beneficiary pays perspective, loads should pay for these costs. In the U.S., AS costs are typically allocated among loads on a load ratio share (share of load) basis. The transition to load payment for AS costs could be part of the shift to regional AS procurement and markets.²⁰

¹⁸ The rights and responsibilities section of the *Rules* states that CSGDC is only responsible for interprovincial AS transactions and that each provincial dispatch centre is responsible for organising intraprovincial AS transactions (南网总调统筹协调区域现货电能交易、跨省与省(区)内电力辅助服务交易协同规范运行, 组织区域现货电能交易和跨省电力辅助服务交易; 各省(区)中调负责本省(区)电力电量平衡管理, 组织省(区)内电力辅助服务交易)。

¹⁹ Peaking ancillary services allow generators to pay other generators to reduce output, potentially to low generation load factors. These transactions would be internalised in a spot energy market: generators report their economic minimum generation levels to the market and system operators, which optimise dispatch while accounting for generator constraints.

²⁰ The *Rules* appear to be heading in this direction; they state that “according to a ‘who supplies receives payment, who benefits pays’ principle, establish an AS cost sharing mechanism, gradually moving toward a mechanism where loads share the costs of AS” (按照“谁提供、谁获利; 谁受益、谁承担”的原则, 建立健全辅助服务收益共享和成本分摊机制, 逐步建立电力用户参与的辅助服务分担共享机制)。

Resource adequacy

The *Rules* do not explicitly discuss regional resource adequacy. Currently, resource adequacy is the responsibility of provincial planners.²¹ If provinces are not resource-adequate, provincial dispatch centres may need to curtail load. Load curtailment has been relatively common in China during some periods over the past two decades. The lack of discussion on resource adequacy in the *Rules* suggests that a Southern regional electricity market would, at least initially, maintain this status quo.

However, regional spot energy and AS markets do create some new stressors for resource adequacy, and it will be helpful to think these through. From a market design perspective, the most important questions are: to what extent can generators withhold from the spot market? For instance, consider a situation in which regional electricity demand is very high, such as during a heat wave or cold snap that affects the entire region, and there are limited supply resources available. Should hydro generators in Yunnan be allowed to bid very high prices (e.g., at or above the offer cap) or simply not bid into the market during these periods, to ensure there is enough within-province generation to meet local demand in a later hour? What would happen if these generators had contracts with loads or provincial government agencies in Guangdong but were forced to withhold power by provincial officials?²²

In a regional spot electricity market, provinces are more interconnected both in terms of economics and markets, but also in terms of short-term and longer-term reliability. Even if not explicitly discussed in the Market Rules, it would be useful for the South China Energy Regulatory Office, CSGDC and the Guangzhou Power Exchange to consider scenarios where the system is stressed due to lack of supply or higher than normal demand, for instance during summer peak events (迎峰度夏), and whether the market design will be robust to these scenarios.

It would also be useful to consider longer-term strategies to ensure that the region remains resource adequate as participation in spot markets continues to grow. Questions to address include determining which entities will be responsible for system-wide resource planning, which entities will be responsible for investing in and signing contracts with new resources, and how can reserves be shared across the region to take advantage of load and resource diversity.

Transmission costs

The Rules are largely silent on transmission costs and their allocation. Costs for interprovincial transmission were negotiated as part of a framework agreement among Southern provinces and were mostly allocated to higher-income provinces. The potential

²¹ Some resources that are likely counted toward resource adequacy within provinces are external to them. For instance, resource adequacy in Guangdong relies on the availability of generators outside of the province, but many of these are directly tied to the Guangdong network and are, for all intents and purposes, within Guangdong.

²² This appears to have happened in several provinces in 2022. See Fan (2022), Footnote 13.

reallocation of these costs as a result of spot market participation appears to be a concern to some provinces.²³

The Rules do appear to maintain the current approach to charging for interprovincial transmission on a transaction basis, which, with a regional spot market and no physical transmission rights, may be problematic.²⁴ Presumably, interprovincial transmission costs would be allocated based on interprovincial contracted energy – according to the Rules, transmission fees are not included in market optimisation. However, there may be little relationship between contracted energy and actual power flows, and market participants will already pay for transmission through congestion costs. As a result, it remains unclear what buyers or sellers would receive in exchange for paying for transmission.²⁵ Charging for transmission on a transaction basis may also lead to rate “pancaking” and discourage cross-border trade.²⁶

In general, there appears to be a persistent misconception among parts of China’s electricity industry that cross-border trade is only cost-effective if the generation plus average transmission cost in the exporting province is lower than the generation cost in the importing province.²⁷ From an expansion (long-run marginal cost) perspective, this may be true; but from an operations (short-run marginal cost) perspective, it is not. For instance, if the marginal cost of generation in Yunnan is 300 yuan/MWh, the marginal cost of generation in Guangdong is 320 yuan/MWh, and the transmission fee (cost) between them is set at 100 yuan/MWh, the cost-minimising regional dispatch will still be for Guangdong to import from Yunnan. Guangdong should import from Yunnan as long as the price difference between them is larger than marginal transmission losses. Fixed costs for existing transmission are sunk and should not affect marginal decision-making.

An alternative approach to allocating the costs of interregional transmission would be to allocate to provinces based on a combination of historical arrangements and estimated reliability and economic benefits, and to loads within a province based on shares of monthly

²³ For instance, Guangxi’s Electricity Market Plan states that provincial agencies will encourage regional market participation as long as the “poverty alleviation electricity agreement” is maintained (在落实省间扶贫电量协议的基础上，鼓励区内发电企业、售电公司（批发交易用户）根据区内供需情况参与省间市场化交易；积极融入南方区域电力市场，按照区域市场有关方案和规则参与试运行)。

广西壮族自治区工业和信息化厅. (2022, 13 December). 2023年广西电力市场交易方案的政策解读 [Policy Interpretation of 2023 Guangxi Electricity Market Trading Plan]. http://gxt.gxzf.gov.cn/xxqk/fqzc/zcjd_8292605/t14279694.shtml.

²⁴ The Rules state that “transmission fees to interprovincial transmission (including losses) will be settled on the basis of actual imported demand; transmission and distribution fees in exporting provinces will be settled on the basis of demand within their borders” (跨省输电费（含核定损耗）按照实际确认的跨省受电量结算，送端省（区）内输配电费按照实际确认的送出关口跨省电量结算). This could also refer to allocation between provinces rather than allocation to individual loads.

²⁵ For instance, in cases where loads pay for transmission and contracts are settled at the generator node, loads would pay both the average cost of transmission and congestion costs. If contracts are settled at the load node, loads paying for transmission is akin to buying a financial transmission right (the right to earn nodal price differences), but loads would need to pay an average cost, and administratively set the cost of transmission to earn this right – administratively set even on a cost basis because the conversion of yuan/MW-yr costs to yuan/MWh requires an implied capacity factor for the transmission line or path.

²⁶ A load in an importing province would need to pay for local transmission, transmission infrastructure between provinces and some amount of the higher voltage transmission system in the exporting province.

²⁷ See, for instance, 刘连奇 [Liu Lianqi]. (2023, 13 September). 结算在即 南方区域电力现货市场设计寻优 [Settlement on the horizon: Concerns of the Spot Market Design in China Southern Grid]. 电联新媒 <http://www.sgcio.com/news/haiwaidianli/116574.html>.

coincident peak transmission system demand or monthly transmission system energy demand.²⁸ This approach is consistent with a beneficiary-pays principle since all loads in importing regions benefit from lower wholesale prices that result from transmission. It also addresses the difficulty of allocating transmission costs on a transaction basis and the obstacles that transaction-based transmission costs may present to efficient use of the transmission system.

Market price regulation and oversight

Spot market price regulation

The detailed implementation for spot market specifies that generating units participating in the spot market will receive a spot market clearing price determined through the market, while those who do not participate in the spot market receive the on-grid power price, which is determined administratively.²⁹ The detailed implementation place price regulation from two separate perspectives. First, offers submitted to the day-ahead market are subject to the offer price ceiling and floor (电能量申报价格上下限).³⁰ The detailed implementation allow these offer limits to be dynamically adjusted based on market conditions. In Guangdong, for example, the offer price ceiling is refreshed weekly based on the price of primary energy sources (implying gas and coal prices).³¹ Additionally, the spot market clearing price is also subject to a ceiling and floor (市场出清价格上下限), independently applied to each LMP. When the locational clearing price exceeds the market clearing limits, the LMP is adjusted to the market clearing limits.³²

Information about the actual values of the offer limits and the market clearing limits is sparse and often unclear. It is also unclear why there are two distinctive price limits. Based on various news reports and observations from the Guangdong spot market daily reports, it appears that the provincial spot market price ceiling for both offer and clearing prices is set at 1.5 yuan/kilowatt-hour (kWh), while the price floor is at 0 yuan/kWh. The regional spot market

²⁸ In the U.S., most transmission providers charge on a coincident peak (CP) basis using CPs from multiple months.

²⁹ The original text is: 市场机组指电能量交易中通过市场方式形成价格的发电机组; 非市场机组指不通过市场方式形成价格, 执行政府规定上网电价的发电机组。

³⁰ The original text is: 发电交易单元在日前电能量市场中申报的电能量价格不能超过核定电能量申报价格上下限范围。

³¹ 洪嘉琳 [Hong Jialin]. (2022, 11 November). 广东电力现货市场连续结算运行一周年 [Guangdong spot market marks one year of continuous settlement operation]. <https://www.hxny.com/hd-80320-0-50.html>.

³² The original text is: 当市场出清得到的节点电价超过市场出清价格上限时, 该节点在该交易时段的节点电价用市场出清价格上限代替。当市场出清得到的节点电价低于市场出清价格下限时, 该节点在该交易时段的节点电价用市场出清价格下限代替。

has a separate price ceiling of 3 yuan/kWh.³³ For comparison, the weighted average clearing price in the Guangdong spot market for Jan.-Jun. 2023 is 0.484 yuan/kWh.³⁴

The spot market's offer and clearing price regulation in the Southern Grid rules would benefit from careful examination, as overly constrained prices may interfere with scarcity pricing signals. Scarcity pricing sends important signals for market efficiency and renewable integration. The market design should exercise caution to ensure that the price limits do not obstruct these signals.

In specific scenarios, such as when market power poses a significant challenge and a comprehensive market monitoring and power mitigation framework is not in place, a clearing price ceiling may be justified as a measure to control market power. However, the current lack of clarity regarding the calculation method for offer and clearing price regulation prompts vigilance on the part of policymakers. Setting the price ceilings too restrictively may reduce the effect of price signals, restrain system flexibility and disrupt rational investment cues.

Meanwhile, a price floor is more difficult to justify. Negative prices can play a crucial role in reflecting market conditions, indicating the availability of renewable resources, the need to retire noneconomic resources and encouraging investment in demand-side resources.³⁵

MLT contract price regulation

In 2021, the NDRC and the National Energy Administration (NEA) jointly published a document about on-grid electricity price, stating that, "In principle, all coal-fired power generation enters the electricity [MLT contract] market, with the on-grid power price determined through market transactions within the range of 'base price + fluctuation'".³⁶ The base price depends on the cost of coal, and the fluctuation range is currently set at 20% up or down.

On the other hand, the *Market Rules* mention a transaction price limit applicable to MLT contracts.³⁷ The Market Rules do not explicitly establish a direct connection between the "base price + fluctuation" contract price limit dictated by the national policy and the transaction price limit outlined in the Southern Grid Market Rules. However, the upper and

³³ 张婷 [Zhang Ting]. (2023, 20 October). 政策解读 | 电力现货市场建设的强心剂——《关于进一步加快电力现货市场建设工作的通知》印发 [Policy Interpretation | A booster for the construction of the electricity spot market — "Notice on Further Accelerating the Construction of the Electricity Spot Market" is issued]. <https://mp.weixin.qq.com/s/G9t71bHTTrRs2OzzQqWLiW>. 武巍楠 [Wu Weinan]. (2023, 13 July). 省间电力现货价格上限降至3元/千瓦时! [The upper limit of interprovincial electricity spot price is reduced to 3 yuan/kWh!]. <https://mp.weixin.qq.com/s/6-qC-h6YLvsma69pumYccw>.

³⁴ 广州电力交易中心有限责任公司. (2023, August). 广东电力市场2023年半年报告 [Guangdong Electricity Market 2023 Semi-annual Report]. <https://pm.qd.csq.cn/views/page/downloadfile/infoAdmin/info/20230830110731/广东电力市场2023年半年报告20230830110818.pdf>.

³⁵ For more discussion, see Regulatory Assistance Project. (2023, 8 June). 浅谈“负电价”的正面价值——访睿博能源智库项目主任Max Dupuy [A brief discussion on the positive value of "negative electricity prices" - Interview with RAP program director Max Dupuy]. <https://www.raonline.org/blog/negative-pricing-discussion-cn/>.

³⁶ The original text is: 燃煤发电电量原则上全部进入电力市场, 通过市场交易在“基准价+上下浮动”范围内形成上网电价。国家发展改革委. (2021, 11 October). 国家发展改革委 关于进一步深化燃煤发电上网电价市场化改革的通知 (发改价格(2021) 1439号) [Notice on further deepening the market-oriented reform of on-grid electricity prices for coal-fired power generation]. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202110/t20211012_1299461.html.

³⁷ The original text is: 中长期电量交易应考虑但不限于以下约束条件: 成交价格上下限, 可申报发电量上下限, 可申报用电量上下限等。

lower limits for the average transaction price of annual contracts (a part of the MLT contract structure) in Guangdong resemble the structure defined by the national policy. It sets the base price at 0.463 yuan/kWh, with a price ceiling of 0.554 yuan/kWh and a price floor of 0.372 yuan/kWh (equivalent to $\pm 20\%$ of the base price).³⁸ This suggests that the Southern Grid regional market will inherit the MLT contract price regulation established by the national policy.

Market monitoring and market power mitigation

Both the *Southern Grid Market Rules* and the detailed implementation documents outline provisions for market monitoring and market power mitigation. Notably, the detailed implementation for spot market represent a significant advancement by establishing reference prices (参考价格) and approved costs (核定成本) for individual generation units. These parameters, among other purposes, are used for market power monitoring and mitigation processes.³⁹ However, no information can be found regarding the calculation methods for reference prices or approved costs.⁴⁰ To support this measure, a detailed, well-defined method for determining the reference prices should be developed and published, specifying, among other things, the categories of cost components that need to be included in the calculation.⁴¹

The reference price contributes to another important market monitoring provision: the automated market power screening and mitigation mechanisms. The detailed implementation for spot market specifies various market power screening tests, namely, the “behavioural test” (行为测试) and the “market impact test” (影响测试). These tests compare the offer prices against the reference prices and serve as the basis for automatically screening the bidding price to shield against market manipulation. In addition, the system also requires the monitoring of bidding prices for the last 30 days. If the most recent bidding from a particular unit exceeds the 30-day average by a certain ratio, the most recent bid will automatically convert to the 30-day average.

While a standardised procedure to mitigate market manipulation is a positive step forward, some implementation details remain unclear and certain aspects may pose challenges. For instance, the 30-day average rule may interfere with the efficient formulation of hourly and daily scarcity pricing.

³⁸ 广东省能源局 国家能源局南方监管局. (2022, 14 November). 广东省能源局 国家能源局南方监管局关于2023年电力市场交易有关事项的通知 (粤能电力(2022) 90号) [Notice on matters related to electricity market transactions in 2023]. <https://www.yd380v.com/article-2976.html#>.

³⁹ The original text is: 核定成本:指基于发电交易单元的发电成本核定的发电成本价格(单值)或发电成本曲线。核定成本用于计算发电交易单元运行补偿费用、实时发电计划偏差收益回收等数据,以及用于市场力监测与缓解等环节。

⁴⁰ It is possible that they are established but not publicised. The only searchable result on reference price is published by Zhejiang province, where the Annual reference price is the weighted average of annual contract trading. 浙江电力交易中心. (2023). 2023年浙江电力市场年度参考价 [Annual reference price of Zhejiang electricity market in 2023]. <https://m.bjx.com.cn/mnews/20230130/1285073.shtml>.

⁴¹ For example, it could state that generator investment and fixed operation and maintenance costs should not be included in the reference cost level.

The national level Basic Rules of the Electricity Spot Market give relative local power exchange and market operator the authority to investigate and recover excess income above the “reasonable income level” under the oversight of the NEA, if necessary,⁴² and the detailed implementation for spot market states that additional post-market-clearing procedures are to be “researched” to further monitor and analyse market activity.⁴³ However, the *Rules* do not mention the appointment of an independent third-party monitoring organisation.^{44,45}

Conclusions and recommendations

The *Market Rules* are an impressive achievement and an important first step: they propose a comprehensive, detailed regional market design for the Southern China region. With targeted fixes, these rules could support the vision of a regional electricity spot market that enhances reliability, lowers emissions, integrates renewable energy at lower cost, fairly allocates costs and improves transparency. The report identified several areas where greater clarity and improvements in market design might lead to better outcomes.

- **Nodal settlement.** If truly settled incrementally, the three-settlement system will likely lead to significant cash imbalances for market operators. A more financially sustainable approach would be to use a two-settlement system, settle generation at generator nodes, settle loads at load nodes, and use contracts for differences to settle price differences between contract and market prices at the agreed upon delivery node.
- **Market settlement for non-participants.** A key challenge for regional spot market design will be how to insulate non-participating provinces, loads and generators from spot market prices, while at the same time ensuring that market prices are meaningful and market operators remain financially viable. In the near-term, the most straightforward way to do this will be to settle non-participants at spot market prices on the margin: settling imbalances with non-participating provinces at border LMPs; settling planned generation imbalances at generator node LMPs; and settling non-participating load imbalances at load node LMPs. An overarching goal for spot market design should be to make market operators revenue-neutral, which can only be accomplished if non-participants pay market prices on the margin. This means that a precondition for provinces joining the spot market

⁴² The original text from the *Basic Rules of the Electricity Spot Market* 由国家能源局派出机构、省（区、市）价格等有关主管部门根据职责作出市场干预决定...

国家发展改革委, 国家能源局. (2023, September). 电力现货市场基本规则(试行) [Basic Rules of the Electricity Spot Market (Trial)]. <https://www.ndrc.gov.cn/xxqk/zcfb/ghxwj/202309/P020230915357678894853.pdf>.

⁴³ The original text from the *Market Rules* is: 研究开展滥用市场力电厂超额收益测算与回收。

⁴⁴ The appointment of a third-party agency was required in the 2019 “Guangdong Electricity Market Supervision and Implementation Measures” to be responsible for market result analysis, market rules modification, violation investigation, etc.

国家能源局南方监管局. (2019, 7 May). 关于征求南方(以广东起步)电力现货市场配套监管实施办法及监管指引意见的函 (南方监能市场函(2019) 78 号), 附件一: 《广东电力市场监管实施办法》 <http://nfi.nea.gov.cn/adminContent/initViewContent.do?pk=402881e569d686de016a8fef7c19007d>.

⁴⁵ The appointment of a third-party agency was also mentioned in the “Notice on Further Accelerating the Construction of the Spot Electricity Market”. The notice quotes, “The primary responsible entity should commission a third-party organisation with professional capabilities and experience to conduct an assessment and produce an official assessment report.” It is likely that the purpose of the assessment is to evaluate the spot market’s readiness to enter formal operation after over a year of trial operation.

国家发展改革委办公厅 国家能源局综合司. (2023, 12 October). 关于进一步加快电力现货市场建设工作的通知 (发改办体改(2023) 813号). https://www.gov.cn/zhengce/zhengceku/202311/content_6913560.htm.

must be that they will commit to paying wholesale market costs regardless of what happens to wholesale market prices. Exposing non-participants to spot market prices on the margin can provide incentives for increasing demand bids and supply offers in the spot market, which will increase liquidity and lead to more meaningful prices.

- **Market participation models for non-thermal generation and energy storage.** The proposed market design can accommodate all resources, though it is unclear as to whether all resources would be able to participate in the spot market from the outset. It would be useful to incorporate different participation models (e.g., forecast-based resources, reservoir hydro, battery storage) in dispatch and settlement software from the outset rather than trying to do so later, even if non-thermal resources are initially only able to participate in the spot market through pilots.
- **Regional dispatch control.** Continued sharing of dispatch authority between CSGDC and provincial dispatch centres could create issues for reliability and for variable renewable generation integration if dispatchable generators do not follow CSGDC dispatch instructions. For a regional real-time market, it will be important for CSGDC to have full regional dispatch control (including at the five-minute level) even if it is not responsible for AS procurement and frequency balancing within dispatch intervals. Settlement of all metered supply and demand at real-time prices would help to align supplier incentives and operational needs.
- **AS markets.** The regional AS market design proposed in the Market Rules is provincial AS procurement with trading among provinces. It is not clear that this is worth the effort, relative to something like a non-market-based contingency reserve sharing agreement. In the near-term, it may make more sense to focus on the spot energy market and allow a regional AS market to take shape alongside it as the provinces get more comfortable with a regional system operator.
- **Resource adequacy.** Under the status quo, provinces are responsible for their own resource adequacy and curtail load if they are short. However, it is important to recognise that a regional spot market will begin to tie together resource adequacy across the region. At a minimum, in the near-term, it will be useful to think through market rules governing supply withholding when the system is operating under stressed conditions. In the longer-term, a regional approach to resource adequacy could reduce the total amount of generation needed to reliably meet demand and lower total investment costs.
- **Transmission costs.** Costs for interprovincial transmission appear to still be charged on a transaction basis, which may be problematic in a regional market with nodal dispatch. An alternative approach that would be more consistent with the Market Rules would be to allocate transmission costs to provinces and charge all loads within a province for transmission costs on the basis of coincident peak use of the transmission system or energy demand.

- **Price regulation.** The Market Rules, coupled with the detailed implementation documents, introduce multiple layers of price ceilings and floors to both the MLT contract market and the spot market. These price boundaries, along with other market monitoring and mitigation mechanisms, are important for ensuring market competitiveness. However, it is worth being cautious when designing these market control processes to ensure that the advantages of a market system, such as scarcity pricing, are not unduly constrained by excessive restrictions.
- **Market oversight.** The Market Rules do not yet clarify how mechanisms to mitigate market power in the regional spot market would be designed, which organisation would be responsible for monitoring and enforcing market rules, and whether there would be a third-party organisation responsible for market monitoring. It would be prudent to have the details of these and other market oversight issues worked out before the spot market begins operation.

Appendix: Three-settlement versus nodal settlement

Consider a region with two transmission nodes (A and B), with 200 MW of transmission capacity between them. The two regions have the following generation supplies.

	Maximum generation	Marginal cost
Node A		
Generator A (G.A)	1,000 MW	100 yuan/MWh
Node B		
Generator B (G.B)	500 MW	270 yuan/MWh
Generator C (G.C)	500 MW	350 yuan/MWh

Loads in nodes A and B have the following contracts with these three suppliers.

Buyer	Supplier	Amount	Price
Load A (L.A)	G.A	500 MW	150 yuan/MWh
Load B (L.B)	G.A	300 MW	200 yuan/MWh
Load B (L.B)	G.B	400 MW	300 yuan/MWh

In day-ahead and real-time (assuming they are equivalent for simplicity) during some hourly interval, L.A has 425 MW of demand and L.B has 825 MW of demand. Economic dispatch, incorporating transmission constraints will be:

Generator	Dispatch
G.A	625 MW
G.B	500 MW
G.C	125 MW

Market clearing prices will be 100 yuan/MWh in node A and 350 yuan/MWh in node B.

Settlement in a three-settlement system

In a three-settlement system, market settlement is incremental to contract settlement at generator and load nodes. Table 1 on the next page shows the settlement for each entity. The residual 25,000 yuan/h is an amount that the market operator owes to generators (i.e., is a net cost to the market operator).

Table 1. Example settlement in a three-settlement system

Entity	Contract	Market	Net
G.A	+135,000 yuan/h (= 500 MW × 150 yuan/MWh + 300 MW × 200 yuan/MWh)	-52,500 yuan/h (= [625 MW – 800 MW] × 100 yuan/MWh)	+117,500 yuan/h
G.B	+120,000 yuan/h (= 400 MW × 300 yuan/MWh)	+35,000 yuan/h (= [500 MW – 400 MW] × 350 yuan/MWh)	+155,000 yuan/h
G.C	0 yuan/h	+43,750 yuan/h (= [125 MW – 0 MW] × 350 yuan/MWh)	+43,750 yuan/h
L.A	-75,000 yuan/h (= -500 MW × \$150 yuan/MWh)	+7,500 yuan/h (= -[425 MW – 500 MW] MW × 100 yuan/MWh)	-67,500 yuan/h
L.B	-180,000 yuan/h (= -300 MW × 200 yuan/MWh + 400 MW × 300 yuan/MWh)	-43,750 yuan/h (= -[825 MW – 700 MW] × 350 yuan/MWh)	-223,750 yuan/h
Totals	0 yuan/h	+25,000 yuan/h	+25,000 yuan/h

Nodal settlement

With nodal settlement, market participants are settled at respective nodes and contracts for differences (CfDs) pay the difference between nodal prices, here settled at the load node.

The residual 50,000/h is paid to the market operator by loads, as seen in Table 2.

Table 2. Example settlement under nodal settlement

Entity	Market	CfD	Net
G.A	+62,500 yuan/h (= 625 MW × 100 yuan/MWh)	-20,000 yuan/h (= [150 yuan/MWh – 100 yuan/MWh] × 500 MW + [200 yuan/MWh – 350 yuan/MWh] × 300 MW)	+117,500 yuan/h
G.B	+175,000 yuan/h (= 500 MW × 350 yuan/MWh)	-20,000 yuan/h (= [300 yuan/MWh – 350 yuan/MWh] × 400 MW)	+155,000 yuan/h
G.C	+43,750 yuan/h (= 125 MW × 350 yuan/MWh)	0 yuan/h	+43,750 yuan/h
L.A	-42,500 yuan/h (= -425 MW × \$100 yuan/MWh)	-25,000 yuan/h (= [100 yuan/MWh – 150 yuan/MWh] × 500 MW)	-67,500 yuan/h
L.B	-288,750 yuan/h (= -825 MW × 350 yuan/MWh)	+65,000 yuan/h (= [350 yuan/MWh – 200 yuan/MWh] × 300 MW + [350 yuan/MWh – 300 yuan/MWh] × 400 MW)	-223,750 yuan/h
Totals	-50,000 yuan/h	0 yuan/h	-50,000 yuan/h

Comparison between three-settlement and nodal settlement

In nodal settlement, the market operator earns congestion rents, which will be transmission capacity (200 MW here) times the nodal price difference (250 yuan/MWh). In three-settlement, the market operator earns congestion rents plus the difference in internodal contracts multiplied by the nodal price difference.

$$R = T \times (P^A - P^B) + C \times (P^B - P^A)$$

where R is the market operator's residual cash flow after settling market participants, T is the transmission capacity between A and B, P^B is the price at node B, P^A is the price at node A, and C is contracted capacity from A to B. (If there were contracted capacity between B and A another term would be needed here, multiplied by $P^A - P^B$). In this case

$$R = 200 \text{ MW} \times (-250 \text{ yuan/MWh}) + 300 \text{ MW} \times (250 \text{ yuan/MWh}) = 15,000 \text{ yuan/h}$$

If infeasible contracts between nodes (contract > transmission capacity) can be limited, three-settlement and nodal settlement will lead to similar results but with opposite signs: rather than earning congestion rents, the market operator would need to pay them to generators. Presumably, market operators would need to collect these costs from loads as an uplift charge. In practice, it may also be difficult to impose transmission limits on contracts, as described in the text. For both of these reasons, a more straightforward approach to market settlement will be to use nodal settlement.



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