CAISO Infrastructure Development in Support of California's 2045 Renewable Portfolio Standard Goals

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***Abstract*—There has been much talk recently not only about how to integrate renewable-based power plants, but also concerning how many of them are needed to serve California's growing power demands. Renewable power plants and their integration into the grid aim to mitigate climate change while still meeting customer demands, which is a pillar of modern living standards. What developed nations do will set the precedent for nations in emerging markets. To avert a climate disaster, it is important to focus on the utility scale of the problem coupled with policies needed to enact effective and impactful action plans to serve as model solutions. Ideally, a utility accurately forecasts how much additional generation is going to be needed at certain intervals into the future to accommodate load increases that accompany progressive industrialization and population growth. This paper discusses and compares the emerging technologies related to renewables and how they could contribute to the Net-Zero goal that California faces, coupled with the risk of climate change.**

I. Introduction

Historically, over the course of the last seven decades of the twentieth century, the power generated doubled every decade. This growth was accommodated by conventional energy sources that, at times, relied heavily on fossil fuel-based generation resources while, at other times, encouraged progressive approaches, namely, renewable energy [1]. Political influences, actions, and legislation have functioned as powerful tools for incentives and preventative measures.

It is crucial to estimate how much additional renewable power generation is needed to accommodate added power generation. This is expounded on in generation planning studies. The efforts to construct renewable power plants and the initiatives to integrate them into the grid aim to mitigate climate change while not sacrificing energy consumption, a pillar of modern living standards. What leading economies do now and soon will set the precedent for developing nations in emerging markets. Focusing on the local scale at the utility level then realizing what legislative actions are needed are the ingredients of an effective and impactful action plan, potentially serving as a model solution.

The California Independent System Operator (CAISO) was established as a non-profit, non-benefit corporation in 1997 to maintain reliability by providing access to the transmission system that covers approximately 80 percent of the state of California and a portion of Nevada, serving 32 million people [2]. The state of California is steadily and surely moving to a less-polluting, interconnected grid to reduce the impact of climate change while meeting consumers' needs for an environmentally friendly, economically viable, and resilient bulk electric system [2]. With California's ambitious and definite Renewable Portfolio Standards (RPSs) of becoming carbon neutral by 2045, this paper discusses the challenges, current research, and impact of technology aimed at this specific goal.

Who are the participants in CAISO's market? They include all the direct customers, regulatory bodies, government agencies, associations, advocacy groups, and the people of California and the broader West [2]. CAISO's plan will serve as the overarching principle and guide the priorities of internal and external efforts over the coming years. It will also support the work of deploying human as well as financial resources as efficiently as possible and ensure that the most pressing needs of the customers and stakeholders in California and throughout the region are met [2].

Ideally, a utility accurately forecasts how much additional generation is going to be needed at certain intervals in the future to accommodate load increases due to incremental industrialization and population growth. This paper discusses the emerging technologies related to renewables and how they could contribute to meeting RPSs while accommodating future needs. The main driver to increase power production capabilities is the estimates that CAISO posted in their "20 Year Transmission Plan." The CAISO area needs an added 120,000 MW of clean power generation over the next two decades to meet future demand and decarbonize the grid, as required by Senate Bill (SB) 100. Eligible carbon-neutral and renewable power sources must cover 100 percent of California's energy needs. More than a third of the total power generated today is via renewables and that is set to double by 2030, as outlined in SB 100 [4]. Fortunately, California has the highest concentration of battery energy storage in the world, which will buttress the efforts to ramp up renewables [2].

The passage of SB 100 in the California Senate stipulates substantial tax incentives to encourage startup companies to enter the market of commercial renewable energy. What this does is ripens the startup enterprise landscape for fundraising via venture capital firms, investment banks, and financial institutions; subsequently, it lowers the barriers to entry for new players while established companies can also benefit from such structures [1] [3]. This will serve to encourage innovative technologies that further increase penetration of electric transportation and other industries, as stated in SB 100 [3]. On top of the significant investment needed to drive this increased load as well as replace existing generation, in the form of manufacturing throughput of fleets of electric vehicles, massive amounts of transmission infrastructure are needed to accommodate the new capacity flowing through the grid. The inclusion of offshore and onshore wind generation plants and large-scale solar farms will stipulate the type of transmission lines to be built and navigate towards generation pockets and distant resources.

Significant encouragement and considerations are taking place to make an energy transition toward renewable resources instead of conventional resources. Renewable resources have the power to meet the added national and global requirements for electricity [3]. Power from solar energy, alongside wind energy, has the potential to compensate for a major division of non-renewable energy stresses. In addition, solar energy is heavily weighted to shape the electricity supply and distribution methods on a federal and state scale in the U.S. [3]. The high reliability of solar energy compared to other renewable resources is due to several important considerations. These considerations are the high concerns of immediate solutions to minimize greenhouse gasses and other causes of climate change, the state renewable energy portfolio standards, investment tax credits from state agencies and banks, technological development, and the continuous decrease in cost of photovoltaic (PV) modules and other equipment.

II. Challenges

The issues that the transmission system and grid face, which operates under CAISO as well as the Los Angeles Department of Water and Power (LADWP), have changed over recent years and are exacerbated by a significant increase in the rate of growth and penetration of renewables [3]. In the U.S., electricity generation accounted for 32 percent of the nation's carbon dioxide emissions in 2019 [5]. Greenhouse gas (GHG) emissions raise a huge alarm to save the climate and the environment. The U.S. produces 6,558 million metric tons of CO_2, which negatively impacts climate change and global warming [5].

Challenges stem not only from electrification of industries, such as transportation, but also decarbonization of the power system. The major challenges for realizing the CAISO plan and the state of California's RPSs are the following:

1. Transparency: Entities such as CAISO should provide more information publicly regarding where resources are able to connect to the grid with minimal or no network upgrade requirements. An informed stakeholder base can assist to shape their procurement activities towards areas and resources that are better positioned to achieve necessary commercial operation dates [3]. This communication, being technical in nature yet comprehensible to the public, is required for equitable understanding of the need for this plan, starting prior to execution. Garnering public support, since the goal is increasing sustainability and continuing modern standards of living while being stewards of the environment, is the purpose.
2. Lead-time and right-of-way transmission: An overlooked bottleneck in the timeline to achieve goals outlined in the RPS, primarily on the transmission front, is the lead times for right-of-way acquisition and environmental permitting. An inspirational shift of outlook is shown in the novel approach by CAISO to strategically compose a 20-year plan that can account for transmission planning in a realistically holistic manner.
3. Ecosystem impacts: Some environmental impacts that renewable projects cause are land disturbances; impacts to soil, water and air resources; impacts to wildlife habitat; and visual, cultural, and socioeconomic impacts on nearby communities [3]. Vocal interest groups are enthusiastic about the preservation of potential power generation sites, even if they are purposed for renewable energy development. Managing the landscape, protecting wildlife, and conserving the natural environment is the great balancing act that must be faced.

A new perspective is a powerful tool that has shown to be impactful. The severity of these challenges has been realized and, in return, leadership from CAISO has sought informed perspectives. This is shown in the collaboration with California Public Utilities Commission (CPUC) and the California Energy Commission (CEC). A clever outcome of this novel approach is the accurate context that it provides to the problems which supports how to analytically find the solutions with the correct framing.

The overall undertaking "will stress all aspects of the resource planning, procurement, engineering, supply chain, and construction. It will also accelerate the need for new transmission approvals, permitting and construction" (5). "[T]he ISO has escalating challenges arising from existing supply conditions, the need to accelerate and then sustain the pace of procurement and interconnection to meet climate goals…. Accordingly, the ISO must 'get in front' of these issues and move forward with transmission planning and generation interconnection process enhancements" to address "an 'overheated' generation interconnection queue" (8) [3].

The need for a diverse yet robust system of renewable power generation helps solve "consequences of major power disruptions in a vast economy increasingly reliant on electricity" [2]. Therefore, there is a vital need to maintain flexibility because, as technologies evolve through innovation, a certain level of adaptability is required for their strategic implementation. The flexibility comes from eclectic renewable power generation resources. If those challenges are overcome, then the likelihood for an infrastructure project of this magnitude to succeed is favorable and carries precedent for other utilities, private or public, to carry suit.

III. Current Research Activities

Renewable energy integration focuses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies, and demand response into the electric distribution and transmission system. With much of the southwestern U.S. ripe for renewable power generation, specifically wind and solar, CAISO's plan relies on the cross-state construction of renewables followed by integration into the grid [3]. Although not common in the U.S., high-voltage direct current is seen as an attractive option for interstate grid interconnection since it allows the generating units to be asynchronous. This widens the margin within which frequency stability must be maintained throughout the interconnected system.

"The [CA]ISO started with the SB100 Core statewide high electrification load projection, in which the 2040 peak load is 82,364 megawatts (MW). This is an 18,288 MW, or 28.5 percent increase from the CEC's Integrated Energy Policy Report (IEPR) 2020 load forecast of 64,076 MW in 2031" (1) [3]. The following outlines key resources and their expected contribution to the 2040 energy grid, as stated in the SB100 starting point scenario:

- Battery energy storage: 37,000 MW
- Long-duration energy storage: 4,000 MW
- Utility-scale solar: 53,212 MW
- In-state wind: 2,237 MW
- Offshore wind: 10,000 MW
- Out-of-state wind: 12,000 MW
- Geothermal: 2,332 MW

The main report outlines which specific transmission projects are in the works and when they are needed for supporting the load flowing across the interconnection. The peak load times are also modelled based on studies and trends that serve as baseline examples. Contingency analysis is also conducted to account for normal system operation.

A key performance driver lies in the potential of the offshore and onshore wind integration grid required for north coast wind development. This will require coordination with the offshore wind potential in the Pacific Northwest. Transmission lines connected at various interconnection points within the CAISO system could potentially facilitate coordination with LADWP and other utilities for bringing in additional out-of-state wind that they may require for their resource portfolios [3].

"To meet these needs, the Starting Point called for 37 GW of battery energy storage, 4 GW of long-duration storage, over 53 GW of utility-scale solar, over 2 GW of geothermal, and over 24 GW of wind generation – the latter split between out-of-state and in-state resources. The bulk of the in-state resources consist of offshore wind. These total 120.8 GW. The [CA]ISO identified the system needs by mapping resources to the appropriate regions, identifying the transmission additions necessary to add those resources to the grid, and then examining the need to deliver those resources over the bulk transmission system" (2) [3].

Installing transmission infrastructure is, by any measure, no trivial task, both financially and for a myriad of engineering reasons. That is why lead times of eight to ten years are considered reasonable or even optimistic.

In 2021, the CAISO transmission plan was based on state agency-provided forecasts calling for approximately 1,000 MW of additions annually over the next ten years. In 2022, the plan is based on a 10-year projection adding 2,700 MW per year, and current drafts being proposed for next year's plan call for over 4,000 MW per year [6]. "The resource development industry came forward with a record-setting number of new interconnections requests in April 2021, with 373 new interconnection requests being received in the ISO's Cluster 14 open window, layered on top of an already heavily populated interconnection queue" (7) [3].

Following closely the planned projects that incrementally move CAISO and its subsidiaries closer to achieving RPSs within the time range it originally set out can be considered a realistic measure of the progress seen by the ongoing activities

IV. Impact of Technologies

"The Starting Point for the CAISO 20-year Transmission Outlook identified the resource development that could meet these needs as well as a projected reduction of 15,000 MW of natural gas-fired generation" (2) [3]. Surely changes will impact the industry between the inception of the plan and the year 2040 and, naturally, those changes will be managed by adapting plans around the baseline architecture in subsequent updates and the CAISO's annual transmission planning processes [3].

The CEC is anticipated to have a more significant role in determining predicted resource requirements beyond the 10-year window, by leading the analysis as part of its obligations under SB 350 [1]. The 20-year approach is surprisingly less structured, which is by design less rigid, and shows firm deadlines with clear requirements and achievable financial figures that yield emission reduction, which is the dynamic vision needed. It supports informal yet meaningful conversations to be had in the future and does so by providing common points of interests that outline the purpose of these successive conversations. The pace, frequency, and complexity of discussions will increase over the lifetime of the projects.

The incorporation of intelligent electronic devices (IEDs) and smart inverters will be essential for the grid integration of renewable energy sources. IEDs can keep track of operating conditions, monitor the power system, and communicate with other IEDs. Demand response, which ramps up and down the power delivered or redistributed throughout the grid to specific load-demanding areas or facilities, continuously adjusts the call for increased and decreased generation. Batteries address the inherent intermittency issue with renewable energy.

The most notable features that need safekeeping are system-critical IT infrastructure. The devices responsible for monitoring the system, communicating extremely valuable information in a timely manner, and recording the events that take place throughout the power system all rely heavily on robust IT systems with redundant communication channels. It is important to use technology that is adaptable so that when new communication standards are written and protocols that are more efficient are devised, the communications system is upgradeable.

A real-time energy supply market called an energy imbalance market (EIM) provides services for power generation and transmission. The ability to boost economic efficiency through centralized, automated, and regionally distributed generation economic dispatch is one of the key advantages of such markets. While balancing the interests of resource providers and end-user customers, market prices should reflect the scarce and constrained conditions on the system and fairly pay resources for the services they deliver. A sound business model will make or break mega-infrastructure changes. The money to be invested, although great in magnitude and estimated to cost $30 billion according to the "20 Year Transmission Outlook," should not be a deterrent because it will be financed and collected over the system lifetime. For more data regarding the cost estimates of varying transmission developments, refer to the full "20 Year Transmission Outlook." Furthermore, the sustainable grid will unlock potential for continuing innovation and increasing the quality of life enjoyed by communities [3].

Additionally, EIM makes use of a variety of resources, which in turn enables it to compete and provide energy at the lowest cost. The growing diversity among market players will keep a power structure strong enough to support all the players capable of engaging at the wholesale level [2]. The markets are used to optimize the economic aspect of energy markets.

V. Conclusion

To best solve the significant issues, namely climate change sustaining human development, facing the energy industry in California, we should accurately narrow down what exacerbates the negative consequences. To successfully manage this unprecedented transformation, CAISO must carefully consider both the short- and long-term. Following that, a collaborative effort is needed to iteratively eliminate these factors by replacing them with enduring solutions. These steps, if done consistently, should curb the severity of the precarious path the environment is heading towards. Moreover, federal and state agencies play a vital role in the solution process. The governmental bodies are mechanisms for implementing necessary financial support, oversight, and resource allocation needed to seize a better energy future.

The strongest case can be made that maintaining fiscal restraint across the energy industry will be a crucial performance indicator for attaining energy policy objectives. It is crucial that we prepare for change while swiftly grasping and effectively integrating innovative technologies [3].

A transparent process of developing the resource planning forecast that considers potential transmission costs, integrated load forecasting, and generation resource planning serves as a beneficial baseline resource profile. The CPUC, which takes the lead in creating resource predictions for the 10-year planning horizon, is one of the state energy organizations on which CAISO heavily depends for input on resource planning [3]. Moreover, these data points only serve as guiding signals about what decisions are best suited to solve issues as they arise at different progressions throughout the grid transformation process. Refining these choices in collaboration with state agencies and stakeholders will create the most affordable answers to satisfy California's dependability and clean energy goals [3].

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VII. Biographies

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