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California ISO Renewable Integration Study in Support of the California Air Resources Board for Meeting Assembly Bill (AB) 1318

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July 20, 2012

California ISO
Shaping a Renewed Future

1. Introduction

In support of the directives of Assembly Bill 1318 (AB 1318, Perez, Chapter 285, Statutes of 2009), the California Independent System Operator Corporation (ISO) conducted production simulations to evaluate the performance of resources in the L.A. Basin and to identify incremental system-wide capacity needs to manage variations between load and supply on the ISO's system. The simulation relies on the Plexos model that the ISO is using in connection with its renewable integration study efforts as well as the long-term procurement plan proceedings before the California Public Utilities Commission. The modeling methodology and assumptions were reviewed by stakeholders participating in these processes. In addition, the ISO had submitted testimony in the Commission's proceedings based on the simulation results of the model.

2. Modeling Assumptions

1) Production simulation methodology

Plexos is production simulation optimization software. It finds the minimum cost solution to meet demand, including variable generation cost, as well as start-up and shut-down costs. Generation unit commitment decisions are also made in the optimization. The simulation runs chronologically through all hours of year 2020 in hourly intervals. The simulation enforces generating unit constraints, including ramp rate, start-up time, minimum run and minimum down time.

2) Structure of the model

This model has zonal configurations for the entire Western Electricity Coordinating Council region. There are total 25 zones, eight of them in California. The ISO is divided into four zones, PG&E-BayArea Bay Area, PG&E-Valley, SCE, and SDG&E.

The model assumes that there is no transmission constraint inside of each zone but transmission limits between the zones are enforced. The transmission limits between any two zones reflect the maximum simultaneous direct transfer capabilities between the two zones.

Each zone has a load forecast that can be met by generation from units inside the zone and from generation outside the zone. Imports are subject to the transmission limits into the zone. Besides load, there are also requirements for ancillary services (regulation-up, regulation-down, spinning reserve, and non-spinning reserve) and load following (up and down) capacity for the ISO and for other California balancing authority areas.[1]

The requirement for spinning reserve equals 3% of total load. Non-spinning reserve requirement is also 3% of load. A tool developed by Pacific Northwest National Laboratory (PNNL) was used to calculate the requirements for regulation and load

[1] A sensitivity case was developed in which the zones outside California also have ancillary services and load following requirements.

following up and down based on 1-minunte forecasts and forecast errors of load as well as solar and wind generation.

Ancillary service requirements can be met by generation capacity that is on-line and can ramp to the required capacity level within 10 minutes. Some units can also provide non-spinning reserve while they are off-line based on their start-up and ramping capability within 10 minutes. Load following requirements can be met by generation capacity that is online and can ramp to the required capacity level within20 minutes. Inter-hour energy changes can be met by generation capacity that is online and can ramp to the required capacity level within 60 minutes. The ramping capability of each generating unit that is online contributes to the energy, ancillary services and load following requirements.

3) Base data of the model

The ISO developed the model based on the WECC Transmission Expansion Planning Policy Committee (TEPPC) model version PC0 dated March 21, 2011. Data for California reflects renewable portfolios identified in Table 1 and load scenarios developed in connection with the CPUC's long-term procurement plan proceeding.[2]

Table 1. Renewable Portfolios for 2020

Scenario	Region	Biomass/ biogas	Geothermal	Small Hydro	Solar PV	Distributed Solar	Solar Thermal	Wind	Total
Trajectory	CREZ-North CA	3	0	0	900	0	0	1,205	2,108
	CREZ-South CA	30	667	0	2,344	0	3,069	3,830	9,940
	Out-of-State	34	154	16	340	0	400	4,149	5,093
	Non-CREZ	271	0	0	283	1,052	520	0	2,126
	Scenario Total	338	821	16	3,867	1,052	3,989	9,184	19,266
Environmentally Constrained	CREZ-North CA	25	0	0	1,700	0	0	375	2,100
	CREZ-South CA	158	240	0	565	0	922	4,051	5,935
	Out-of-State	222	270	132	340	0	400	1,454	2,818
	Non-CREZ	399	0	0	50	9,077	150	0	9,676
	Scenario Total	804	510	132	2,655	9,077	1,472	5,880	20,530
Cost Constrained	CREZ-North CA	0	22	0	900	0	0	378	1,300
	CREZ-South CA	60	776	0	599	0	1,129	4,569	7,133
	Out-of-State	202	202	14	340	0	400	5,639	6,798
	Non-CREZ	399	0	0	50	1,052	150	611	2,263
	Scenario Total	661	1,000	14	1,889	1,052	1,679	11,198	17,493
Time Constrained	CREZ-North CA	22	0	0	900	0	0	78	1,000
	CREZ-South CA	94	0	0	1,593	0	934	4,206	6,826
	Out-of-State	177	158	223	340	0	400	7,276	8,574
	Non-CREZ	268	0	0	50	2,322	150	611	3,402
	Scenario Total	560	158	223	2,883	2,322	1,484	12,171	19,802
High Load	CREZ-North CA	3	0	0	900	0	0	1,205	2,108
	CREZ-South CA	30	1,591	0	2,502	0	3,069	4,245	11,437
	Out-of-State	34	154	16	340	0	400	4,149	5,093
	Non-CREZ	271	0	0	283	1,052	520	0	2,126
	Scenario Total	338	1,745	16	4,024	1,052	3,989	9,599	20,763

For this effort, the ISO used the 33% Trajectory High-Load scenario for 2020. This scenario reflects a combination of future uncertainties, including increased load growth

[2] *See generally* http://www.cpuc.ca.gov/PUC/energy/Procurement/LTPP/LTPP2010/2010+LTPP+Tools+and+Spreadsheets.htm

and lack of performance from demand side management resources. The Trajectory High-Load scenario also has 1,497MW of additional renewable resources when compared to the Trajectory Base Load scenario to meet the 33% Renewable Portfolio Standard target.

4) New resource assumptions

This study uses the results of the once through cooling (OTC) studies conducted by the ISO in the 2011-2012 transmission planning process. The OTC studies identify 3,173 MW resource needs in local capacity areas. This amount reflects the total low end of the range of needed new or repowered local resources for the Trajectory case in the San Diego (373MW), Los Angeles Basin (2,370MW) and Big Creek Ventura areas (430MW). Based on the findings of the OTC studies, the ISO added two 500 MW combined cycle generating turbine (CCGT) units and eighteen 100 MW gas turbine (GT) units to SCE zone. The ISO added one 373 MW CCGT unit to SDG&E zone. Table 2 compares the characteristics of these new resources, also referred to as Local Capacity Requirement (LCR) resources, with similar existing units.

Table 2. Characteristics of New Resources and Other Existing Similar Units

Resource[3]	Max/Min Capacity (MW)	Full-Load Heat Rate (Btu/kWh)	Ramp Rate (MW/min)	Forced Outage Rate (%)[4]	Maintenance Rate (%)	Start-up Time (hour)	Start-up Cost ($)
SCE NEW GT	100/40	9,191	12.0	7.24	10.0		1,200
SCE NEW CCGT	500/200	7,000	7.5	4.96	10.0	2	44,520
SDGE NEW CCGT	373/200	7,000	7.5	4.96	10.0	2	44,520
Gateway (CCGT)	530/265	7,000	10.0	10.00	10.0	2	24,411
Sentinel (GT)	106/43	9,191	12.0	10.00	10.0		1,000

Chart 1. Comparison of Ramp Rates by Unit Type

[3] SCE NEW CCGT represents two identical CCGT units, SCE NEW GT represents eighteen identical units, and SDGE NEW CCGT represents one unit.

[4] Forced outage rates of the new resources are based on NERC Generating Availability Data System 2006-2010 average EFORd, CCGT for all MW sizes and GT for 50 plus MW. The ISO set the forced outage rate of existing units at 10% to match total MW outage in California in 2020 with the ISO monthly minimum actual MW outage in 2010.

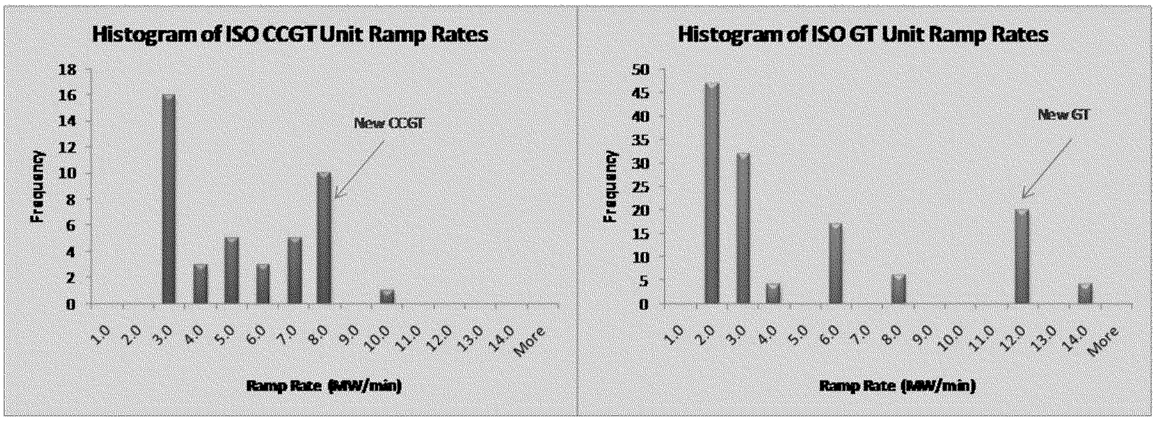


Chart 1 presents a comparison of ramp rates of the modeled new CCGT and GT resources in SCE and SDG&E's zones with the ramp rates of other units of the same type in the ISO area. As shown in the chart, the modeled new CCGT and GT resources generally have higher ramp rates (i.e., more flexible) than other existing units.

3. Summary of simulation results

The ISO conducted simulations for year 2020 with two separate model runs.

The first model run is called production cost run and the second is called need run. The difference between the two runs is in the values of regulation and load following requirements. In the production cost run regulation and load following (up and down) requirements have hourly values as calculated by the PNNL tool. In the need run, regulation and load following (up and down) requirements are set to monthly maximum value of each hour. For example, the regulation-up requirements of hour 1 of all 31 days in January are set to the maximum of the hourly requirement calculated by the PNNL tool for hour 1 of the 31 days in January.

The production cost run produces the results of generation output, costs, ancillary service and load following requirements, as well as imports and exports. The need run is used to identify ramping capacity shortages and capacity needs. The purpose is to ensure that the fleet has sufficient capability to meet a wide range of expected conditions for each month. In this section all results, except ramping capacity shortages, are from the production cost run. Ramping capacity shortage is the results of need run.

1) Utilization of the new resources

Table 3 reflects the monthly and annual capacity factors of the new resources as well as the average capacity factors of existing CCGT and GT units in the ISO area (excluding the new resources).

Table 3. Comparison of Monthly Capacity Factors

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE NEW GT	9.5	11.2	10.0	9.8	12.0	16.5	20.3	17.9	7.9	10.0	8.0	10.2	11.9
SCE NEW CCGT	53.1	60.0	61.4	64.2	59.4	64.1	73.7	83.4	80.9	66.9	61.1	68.3	66.4
SDGE NEW CCGT	49.2	62.1	55.9	20.4	72.6	76.5	69.0	87.4	83.7	50.9	37.8	20.3	57.1
Gateway (CCGT)	52.0	45.6	55.3	48.7	45.5	56.1	62.8	55.2	60.1	56.2	60.3	60.7	54.9

Sentinel (GT)	22.1	20.3	17.2	18.3	21.1	19.6	20.4	19.1	11.6	16.2	16.0	12.1	17.8
GT Average	10.9	10.7	8.0	10.8	10.9	12.0	11.2	9.5	6.6	8.4	9.3	10.4	9.8
CCGT Average	48.5	45.9	40.6	39.8	36.1	40.2	62.0	65.4	55.1	51.0	49.6	51.9	49.4

The new resources have higher capacity factors than the average of the same type of units in the ISO area. This outcome is expected because the new resources are more flexible and have lower forced outage rates than most of the existing CCGT and GT units. The new resources' heat rates are also lower than the average of the existing CCGT and GT units.

Compared to Sentinel, the SCE NEW GT has higher start-up cost. As a result, it has a lower capacity factor. For GT units running at low capacity factor, the difference in forced outage rates does not have a significant impact on utilization. The new CCGT resources run more than Gateway unit. In this case, the higher forced outage rate does make a difference.

Of the two new CCGT resources, SDGE NEW CCGT has a lower capacity factor than the SCE NEW CCGT. This outcome is likely due to the ramp range (the range between minimum and maximum capacity). The SDGE NEW CCGT has 173 MW while the SCE NEW CCGT has 300 MW of range per unit. Since both have the same start-up cost and ramp rate, in certain circumstances the optimization may choose to commit the unit with the larger ramp range over the unit with the smaller range.

2) Contribution to ancillary services and load following (total and average per hour)

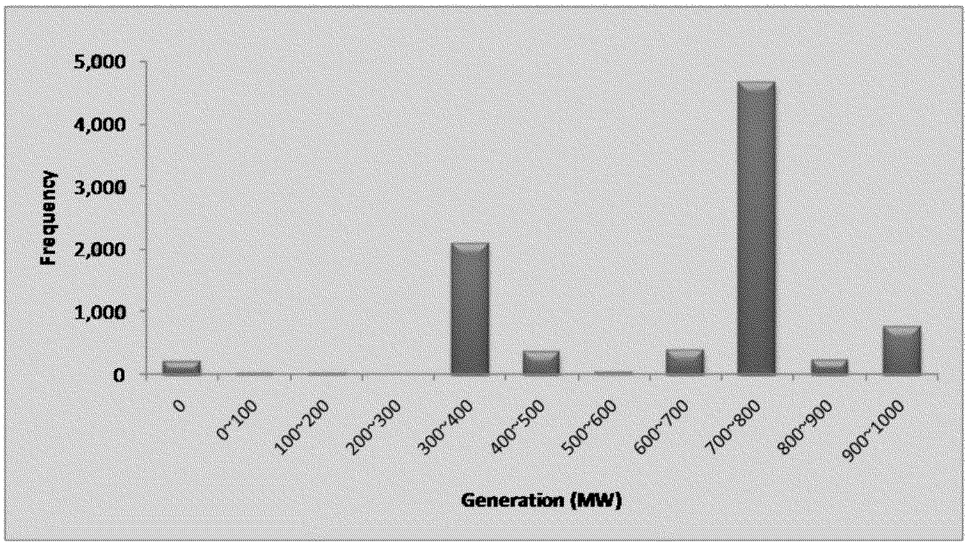
Besides producing energy, the new resources also contribute to meet ancillary service and load following requirements. Table 4 has the annual total contributions to ancillary services and load following by the new resources.

Table 4. Ancillary Service and Load Following Contribution (GWh)

Resource	LF Down	LF Up	Non-Spin	Reg-D	Reg-U	Spin
SCE NEW GT	23.9	537.3	1.9	32.1	320.0	914.8
SCE NEW CCGT	1,888.0	849.2	0.5	101.8	11.6	577.2
SDGE NEW CCGT	264.9	217.8	0.0	202.7	78.6	56.4

Chart 2. Histogram of SCE NEW CCGT Hourly Generation[5]

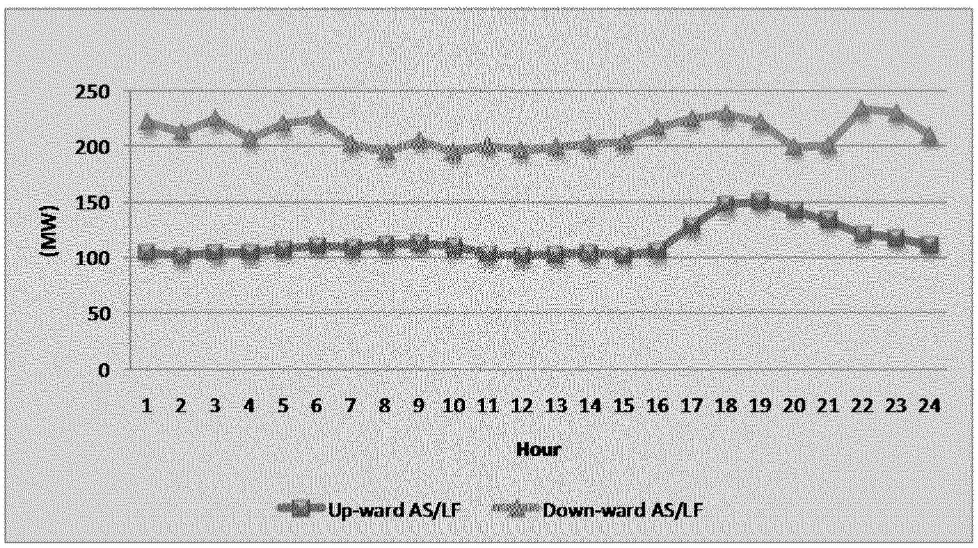
[5] This chart reflects the total generation of two identical CCGT units under the name SCE NEW CCGT. Each has a 200 MW minimum capacity and 2 hours start time. At the end of first hour in the start-up process a unit will generate 100 MW. Therefore there is generation between 0 and 200 MW in the chart. Zero generation means both units are in outage mode.



Contributing to upward ancillary services and load following requires the resource to maintain certain headroom in dispatch. On the other hand, to contribute to downward regulation and load following the resource must be dispatched above its minimum capacity. Contribution to ancillary services and load following is not reflected in the capacity factor of the resource, but should be counted in its utilization.

As shown in Chart 2, the SCE NEW CCGT runs mostly in the range of 700–800 MW out of its 1,000 MW maximum capacity. The headroom allows the resource to provide upward ancillary services and load following between 100 and 150 MW each hour on average (see Chart 3). This new resource also provides 200 to 230 MW of downward ancillary service and load following each hour. This results mainly due to the flexibility of the new resource. These capabilities are important to the reliability of the system, especially during the high load and fast ramping hours in the late afternoon.

Chart 3. Average Hourly AS/LF Contribution by SCE NEW CCGT



3) Number of starts of the new resources

With the increase in intermittent renewable resources interconnecting to the ISO, the system needs to deploy more flexible conventional resources to respond to the variations of renewable generation. That may cause some resources to cycle more. Cycling of generation resources depends on many factors such as start time, ramp rate, minimum run and down time, and start-up cost. More flexible ones may cycle more. Units with lower start-up costs may see a higher number of starts than units with higher start-up costs.

Tables 5 shows the number of starts of the new resources, similar units, and the average of existing CCGT and GT units in the ISO area (excluding new resources).

The results show much higher number of starts for GT units than the CCGT units. SCE NEW GT resources have higher start-up costs than Sentinel unit, which may have resulted in a lower number of starts for the SCE NEW GT resources.

The new CCGT resources have lower number of starts than Gateway unit. As shown in Table 2, the Gateway unit has a higher ramp rate. It is easier to cycle than the new CCGT resources. More importantly, the higher start-up cost makes new CCGT resources uneconomic to cycle compared to Gateway unit.

Table 5. Comparison of Number of Starts[6]

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE NEW GT	26.2	20.3	21.8	20.9	18.7	16.8	25.4	27.4	20.8	24.8	24.1	25.3	272.6
SCE NEW CCGT	3.0	3.0	3.0	2.5	1.0	2.0	1.5	0.0	0.0	2.5	2.5	2.0	23.0
SDGE NEW CCGT	2.0	3.0	3.0	2.0	1.0	1.0	1.0	0.0	0.0	2.0	1.0	3.0	19.0
Gateway (CCGT)	6.0	8.0	6.0	8.0	5.0	4.0	5.0	5.0	4.0	6.0	3.0	3.0	63.0
Sentinel (GT)	54.0	44.0	40.0	42.0	46.0	39.0	32.0	28.0	22.0	35.0	29.0	34.0	445.0
GT Average	8.0	7.9	8.7	7.4	6.9	5.6	12.8	10.8	6.0	6.7	6.9	7.8	95.5
CCGT Average	3.7	3.7	4.3	3.8	3.4	3.6	5.0	4.8	3.0	4.7	3.7	3.8	47.4

4) Additional system-wide capacity shortage

With the 3,173 MW new resources added, the need run of the ISO's simulation still finds a 1,251 MW shortage in the 20-minute load following up requirement. Additional flexible capacity is necessary to meet the load following up requirement. As the Plexos model has a zonal configuration, it does not determine where the additional capacity should be added. From a flexibility perspective. The ISO does not believe the additional capacity needs to be in the LA Basin. Based on historical patterns, however, it may be a better fit if some of the residual need were located south of path 26. These results do not consider the possibility of operating without the generating units at the San Onofre Nuclear Generating Station.

The ISO has previously identified a need for 4,600 MW of capacity in the operational relevant Trajectory High-Load scenario.[7] In the simulation supporting that determination,

[6] This is the average number of start of each of the units under each new resource name.

the ISO assumed that the 4,600 MWs would comprise flexible GT units without forced and maintenance outages. Since then, the modeling of demand response resources has improved. Some of the high cost demand response resources have a 4-hour minimum time together with limited energy usage. These limitations prevented the demand response resources being fully utilized. At some peak load hours, the demand response resources cannot be deployed as the remaining energy is insufficient to run for 4 hours. In this study the ISO has relaxed the 4-hour minimum run time limit, thereby reducing the ramping capacity shortage during the peak load hours.

This study did not evaluate the frequency response and inertial benefits of the new resources or needs for frequency response and inertia in the ISO system generally. The ISO has conducted a study to analyze the system wide frequency response requirement under higher renewable scenarios. A study report can be found on the ISO website at http://www.caiso.com/Documents/Report-FrequencyResponseStudy.pdf.

4. Conclusion

Based on the production simulation, the flexibility of new resources is very important to reduce the shortage in ramping capacity. With the new resources that the ISO modeled, there remains a 1,251 MW shortage in meeting the 20-minute load following up requirement. Alternatives to the observed shortages including adding flexible resources at locations that are deliverable to the system load should be considered Due to historical patterns of Path 26's north to south flow constraint it may be desirable to locate at least a portion of the residual need for flexible resources south of Path 26.

[7] The ISO also previously ran the other 4 CPUC scenarios. The results did not show need for capacity.