# Reactive Power Requirements for Asynchronous Resources

# Issue Paper and Straw Proposal

March 5, 2015

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## Issue Paper and Straw Proposal

## 1. Executive summary

The ISO is launching this initiative to propose a uniform requirement for asynchronous resources to provide reactive power capability and voltage regulation. This proposed new approach will replace the current system impact study approach to assess whether asynchronous resources must provide reactive capability. The current approach has several shortcomings, and the ISO proposes to remedy these shortcomings through a uniform requirement.

Since the ISO previously proposed a similar requirement in 2010, the rapid expansion of asynchronous resources has resulted in high ratios of asynchronous to synchronous generation during a portion of the operating day. In other words, renewables are rapidly displacing the conventional generating facilities that have historically provided reactive power support to maintain voltage levels required for the efficient delivery of real power to serve electric load.

As the supply of synchronous generation declines, the current interconnection system impact study approach used to identify when asynchronous resources must provide reactive power capability has increased in importance. Given the changes to the resource fleet that the ISO is experiencing, the current approach carries with it the risk that once an asynchronous project interconnects and is commercially operable, actual system conditions could be far different from the conditions the ISO studied during the interconnection process, thereby leaving the grid with a reactive power deficiency. To mitigate the shortcomings of the current approach would require an increase in the overall process timeline as well as an increase in the cost of interconnection studies.

Instead, the ISO is proposing to adopt, on a going forward basis, a uniform requirement for asynchronous resources to provide reactive power capability and voltage control. Requiring asynchronous resources to have the capability to provide reactive support and control voltage schedules at the point of interconnection is a more reliable, efficient, and equitable approach than examining this issue through a system impact study. The ISO is informed that manufacturers routinely include this capability in standard inverters used by asynchronous resources and therefore this approach creates virtually no incremental capital costs for interconnection customers. This proposed approach is also consistent with approaches adopted by other jurisdictions.

# 2. Introduction

Clean, renewable generation is increasingly displacing the conventional generating facilities that have historically provided reactive power support. This displacement trend is fully expected to continue well into the future.

Reactive power is necessary to energize high voltage transmission facilities and transmit power in an alternating current electric transmission system, while maintaining voltage stability on the system that connects generation to load.

Electric power that flows on transmission and distribution lines is composed of two components: real power and reactive power. Real power is measured in Watts (W) and reactive power is measured in Volt Amps Reactive (VAR). Real power serves electric loads and is necessary to keep the lights on and run devices such as air conditioners. Reactive power, on the other hand, is essential to maintain voltage levels and enable real power to serve electric load efficiently. Real power and reactive power function in an integrated, interdependent, and inseparable manner in a modern, widespread alternating current (AC) electric grid.

Because of this interdependency, an AC electric system normally must have the right amount of reactive power to support delivery of real power. Conventional synchronous generation resources are a primary source of reactive power on the transmission system. If the right amount of reactive power is not available to the interconnected grid, unstable conditions that jeopardize delivery of power to end-use customers will result. Moreover, a mismatch in the amount of reactive power needed will degrade the ability for any generating source, including renewable sources to operate. Adequate reactive power is therefore fundamental to the operation of generation. Without adequate supplies of reactive power, the electric grid may also malfunction or even catastrophically fail due to voltage collapse. Likewise, without the capability to absorb reactive power, voltage levels can exceed acceptable operating limits causing equipment to trip off line. Absent the individual resource providing the necessary reactive power to support stable operation of the grid to which it connects, some other source must provide this reactive power. The individual resource not supplying or absorbing reactive power therefore becomes a burden to other resources connected to the grid, to the grid operator, or both.

Virtually any type of properly equipped generating facility can supply the reactive power needs of the system, as supplemented by transmission equipment. Synchronous generators—those with a mechanical rotor that rotates in synchronism with the system frequency and produces both real and reactive power in response to system needs—have traditionally provided this capability. This is for two main reasons: (1) this is the type of central station generation that was installed based on economies of scale and around which much of the current grid was developed; and (2) using more efficient generating facilities designed and built for the combined purpose of generating both real and reactive power avoids the additional cost of providing reactive power resources to transmission facilities. Examples of synchronous generating facilities include nuclear power plants, large hydro plants and natural-gas fired generators such as peaking units and combined cycle units.

The shift to sustainable and renewable energy sources, including solar photovoltaic and wind as well as energy storage, is increasing the proportion of generators on the system that do not use mechanical rotors rotating in synchronism with the system. These resources do not inherently have reactive power capability unless the inverters used to condition the output of asynchronous plants have this capability included as an integrated feature.[1] However, the electric system must still have sufficient reactive power to support delivery of real power.

Because generation resources are a primary source of reactive power on the transmission system, the proliferation of asynchronous resources, in conjunction with the retirement of large more centralized synchronous generators closer to the load centers, is significantly changing the landscape of the interconnected power grid and impacting the need for and location of reactive power resources.

Table 1 below shows the actual/expected increase in variable energy resources (VERs) through 2024.

**Table 1 – Actual/expected VERs within the ISO footprint through 2024 (MW)**

| | ***2011*** | ***2012*** | ***2013*** | ***2014[2]*** | ***2024[3]*** |
|---|---|---|---|---|---|
| Large Scale Solar PV | 182 | 1,345 | 4,173 | 4,512 | 7,663 |
| Small Solar PV[4] | | | | | 3,564 |
| Solar Thermal | 419 | 419 | 419 | 1,051 | 1,802 |

[1] It is important to note that current production of inverters to serve asynchronous generation includes this reactive capability because the manufacturers design to serve the needs of their prospective customers throughout the world. Only in a select minority of world energy systems (including California) is reactive power not required of all generators. In the case of inverters, manufacturing to meet the needs of a minority market is not cost-effective; so, manufacturers currently include the capability for reactive power in virtually all inverters in today's market.

[2] Values for 2011-2014 are from: https://records.oa.caiso.com/sites/mqri/Records/Renewable%20Daily%20Watch/2014%20Renewable%20Watch/12-2014%20Renewable%20Reports/20141229_DailyRenewablesWatch.pdf

[3] Values for 2024 are from: http://www.caiso.com/Documents/Aug13_2014_InitialTestimony_ShuchengLiu_Phase1A_LTPP_R13-12-010.pdf (Table 9)

[4] Less than 20 MW and connected to the ISO controlled grid.

| Table 1 – Actual/expected VERs within the ISO footprint through 2024 (MW) | | | | | |
|---|---|---|---|---|---|
| | ***2011*** | ***2012*** | ***2013*** | ***2014[2]*** | ***2024[3]*** |
| Wind | 3,748 | 5,800 | 5,894 | 5,894 | 7,028 |
| *Total* | 4,349 | 7,564 | 10,486 | 11,457 | 20,057 |

# 3. Stakeholder process

The ISO has scheduled a stakeholder conference call for March 13 from 9:00 a.m. to 11:00 a.m. (Pacific) to discuss this issue paper and straw proposal with stakeholders. Following the call, the ISO requests that stakeholders submit written comments to InitiativeComments@caiso.com by 5:00 p.m. (Pacific) on March 20. Table 2 outlines a tentative schedule for this stakeholder initiative.

| Table 2 – Stakeholder process schedule | | |
|---|---|---|
| **Step** | **Date** | **Activity** |
| Issue paper and straw proposal | March 5 | Post issue paper and straw proposal |
| | March 13 | Stakeholder web conference |
| | March 20 | Stakeholder comments due |
| Revised straw proposal | April 8 | Post revised straw proposal |
| | April 16 | Stakeholder meeting or web conference |
| | April 30 | Stakeholder comments due |
| Draft final proposal | May 21 | Post draft final proposal |
| | May 28 | Stakeholder meeting or web conference |
| | June 11 | Stakeholder comments due |
| Board approval | July 16-17 | ISO Board meeting |

# 4. Regulatory background

In 2010, the ISO filed a tariff amendment with FERC to adopt a uniform reactive power and voltage control requirement to large (over 20 MW) asynchronous resources seeking to interconnect to the ISO grid.[5] The ISO argued that the transformation of the electric grid justified these proposed requirements because the ISO would need the reactive power support of an increasing number of asynchronous resources to replace the reactive support provided by existing synchronous resources that were being "crowded out" or displaced. FERC rejected the ISO's proposed tariff revisions without prejudice.[6] FERC determined that the ISO's supporting documents did not explain adequately why system impact studies are not the proper venue for identifying power factor requirements for wind generators and why the ISO must implement a broad requirement, without confirmation of system need as verified from the appropriate system studies, applicable to all asynchronous generators.

However, the ISO has found that the system impact study approach does not provide a sufficient range of scenarios or time to assess reactive power needs in the context of the transformation of the ISO's resource mix. In addition, the system impact study cannot model every operating scenario such as over-generation conditions during which the ISO will need resources to absorb reactive power. The current system impact study process balances the needs of interconnection studies with an interconnection customer's needs for a timely and efficient interconnection process. Given sufficient time and resources – which translates to increased interconnection study deposit by developers and an increase in the overall process timeline – the ISO could conduct more exhaustive studies, explore significantly more scenarios, and likely make a finding in each and every case that a resource would need to provide reactive power capability to safely and reliably interconnect to the grid. Such increased costs, inefficiencies in the study

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[5] California Independent System Operator Corporation tariff amendment in FERC docket ER10-1706 dated July 2, 2010. http://www.caiso.com/Documents/July2_2010Amendment-modifyinterconnectionreqsapplicable-largegenerators.pdf

[6] *California Indep. Sys. Operator Corp.* 132 FERC ¶ 61,196 (2010) at PP45-48; 54-55. http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=12426191

process and corresponding delays to interconnecting renewable energy resources are all counterintuitive to the state and federal goals for clean energy. As such, the current interconnection study process does not afford this amount of time or resources to complete such studies. However, absent a more comprehensive level of studies to determine that all resource interconnections will meet mandated reliability standards as well as established practices for planning and operations, core responsibilities for assuring reliability must still be fulfilled. Accordingly at this time, the ISO believes it cannot make the finding that resources can safely and reliability interconnect to the grid without providing reactive power capability.

On rehearing, FERC determined that the ISO did not provide adequate evidence to support its assertion that wind and solar photovoltaic generators will displace synchronous resources on the ISO's transmission system in a timeframe and manner that supports the proposed tariff revision.[7] Notwithstanding FERC's determination, empirical evidence described in this issue paper and straw proposal reflects that asynchronous resources are displacing synchronous resources on the electric grid. FERC rejected the ISO's proposal to require these resources to provide reactive power capability without a demonstration of need in a system impact study. But a system impact study relies heavily on the assumptions of future conditions and does not afford sufficient opportunity to assess all operating conditions. As the ISO has observed, actual system conditions – both peak and off peak -could be far different from the conditions studied.

The ISO filed a petition for review of FERC's orders in the DC Court of Appeal and asked the court to hold the petition in abeyance pending the outcome of a technical conference at FERC on whether asynchronous generators should be subject to a uniform requirement to provide reactive power capability. Since holding its technical conference and soliciting comments, FERC has not taken any further action in the proceeding.

Among the reasons examined in the ISO's earlier stakeholder process for not requiring asynchronous resources to provide their share of reactive requirements are the following: (1) inverter technology has not advanced sufficiently to reliably provide

[7] *California Indep. Sys. Operator Corp.* 137 FERC ¶ 61,143 (2011) at PP 10-11. http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=12820086

reactive and voltage control; (2) there is an abundance of reactive power and voltage control provided by synchronous generating facilities; and (3) the cost is too high and may inhibit the entry of new, asynchronous technologies (including non-greenhouse gas emitting resources).

The landscape has changed since FERC issued its orders, and the considerations identified above are no longer valid. First, modern inverter technology enables asynchronous resources to serve as a reliable source of reactive power and voltage control. Second, additional empirical evidence reflects that asynchronous resources are rapidly displacing synchronous resources in the generation mix with a corresponding reduction in the supply of reactive power and voltage control. Third, the cost picture has changed—some inverter manufacturers now include the capability to provide or absorb VARs as a standard feature. Only when the wind or solar resource is operating at the maximum rated output capabilities of the inverter will there be lost revenue due to providing VARs instead of MWs, assuming that the inverters are sized to provide this maximum power at unity power factor only. This fact may drive developers to oversize the inverter ratings of the facility, but the ISO understands this is a common practice to meet contractual output levels.

At present, FERC allows jurisdictional transmission providers to require large wind generators, as a condition of interconnection, to provide reactive support based on a demonstration in an interconnection system impact study that the system needs reactive support from the generator to ensure efficient and reliable operation of the transmission system.[8] FERC has also applied this rule to solar photovoltaic resources.[9] Although the ISO is not proposing to apply separate rules to wind resources and other asynchronous resources such as solar photovoltaic or battery storage, the ISO solicits comment on whether it should or not.

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[8] *Interconnection for Wind Energy,* Order No. 661, FERC Stats. & Regs. ¶ 31,186, at 50-52 (2005) ("Order No. 661"); *Interconnection for Wind Energy*, Order No. 661-A, FERC Stats. & Regs. ¶ 31,198, at PP 41-46 (2005) ("Order No. 661-A").

[9] *See e.g*. *Nevada Power Co*., 130 FERC ¶ 61,147 (2010) at PP21-27. http://elibrary.ferc.gov/idmws/common/OpenNat.asp?fileID=12279145

# 5. Description of the current approach

Consistent with FERC's directives, the ISO continues to use a case-by-case, system impact study approach to assess whether asynchronous resources must provide reactive power supply/absorption capability. The ISO conducts this as part of the interconnection process, and it requires an assessment of asynchronous resources within a cluster to determine whether a resource needs to provide reactive power capability to interconnect to the system based on a range of operating conditions. For asynchronous resources within the cluster study process, the ISO must identify if a resource needs to provide reactive power capability in order to safely and reliably interconnect the resource.[10] If the ISO identifies such a need, then the resource must have at least a +/- 0.95 power factor range at its point of interconnection. If the study results do not demonstrate this need, the ISO does not require the resource to provide reactive power capability or impose a requirement to control voltage at the resource's point of interconnection.

The current study methodology in the ISO generation cluster study was reviewed by stakeholders and subsequently adopted in 2011. A reactive power capability deficiency analysis is performed in each cluster Phase II interconnection study to determine:

- Whether the asynchronous facilities proposed by the interconnection projects in the current cluster are required to provide 0.95 leading/lagging power factor at the Point of Interconnection (POI).
- Whether network upgrades, including system VAR resource, are needed to mitigate reactive power deficiency.

First, the ISO conducts the study assuming unity power factor for the asynchronous facilities of the new interconnection projects in the current cluster. Based on two

[10] Asynchronous resources using the ISO's independent study process must provide reactive power capability without the need for the ISO to determine the need for that capability though an interconnection system impact study. *Cal. Indep. Sys. Operator Corp.*149 FERC ¶ 61,100 (2014). http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=13674514

scenarios, a Peak and an Off-peak, with and without current cluster projects. Four base cases are developed for each study group:

- Case 1: Peak pre-cluster base case without the current cluster projects.
- Case 2: Peak post-cluster base case with the current cluster projects modeled at unity power factor.
- Case 3: Off-peak pre-cluster base case without the current cluster projects.
- Case 4: Off-peak post-cluster base case the current cluster projects modeled at unity power factor.

Second, contingency analysis is performed on all four base cases. The study results will determine:

- Whether the addition of current cluster projects causes normal condition voltages out of the allowable normal min/max range.
- Whether the addition of current cluster projects causes post-contingency voltages out of the allowable post-transient min/max range.
- Whether the addition of current cluster projects causes excessive voltage deviation from the pre-contingency level.

Third, the ISO further analyzes critical contingencies that result in excessive voltage deviation using the post-transient power flow. In particular, the ISO might perform an additional analysis to determine the post-transient voltage stability. If a significant amount of power transfer occurs, the pre-contingency power transfer can be increased according to applicable voltage performance criteria of the Western Electricity Coordinating Council. The post transient voltage stability analysis will determine:

- Whether the system has sufficient reactive margin according to the planning standards.

If the results indicate reactive power deficiencies, the ISO requires the asynchronous generators in the current cluster study group to provide 0.95 leading/lagging power factors at the Point of Interconnection.

Next, the ISO modifies the four base cases above to model the required reactive power capability. The same contingency analysis and post-transient voltage stability analysis are conducted again. If the study results still indicate reactive power deficiencies, transmission system upgrades will be required to mitigate the problem.

Using this approach, the ISO has assessed 187 asynchronous projects (approximately 17,000 MW) through mid-2014 requesting interconnection to the ISO controlled grid and found that almost three-fourths of these projects (approximately 12,000 MW) were required to provide reactive power capability. This means that slightly more than one-fourth of these projects were not required to provide reactive power capability. In contrast, a uniform requirement would require that going forward all asynchronous resources provide reactive power capability.

As described above, the ISO's system impact studies reflect base cases that include assumptions relating to load, resources that are online and transmission facilities in service. As the ISO's electricity grid continues to change with increasing amounts of variable energy resources and distributed energy resources, these assumptions may not in all cases identify the need for reactive power capability.

Given the short timeframe provided for performing the technical analysis in the ISO interconnection studies, the above process – although extensive – is not as comprehensive as the technical analysis conducted in the ISO's annual transmission planning process. One of the major objectives of the transmission planning process is to identify transmission system voltage deficiencies. For example, the most recent draft ISO transmission planning process study plan calls for the ISO to study nineteen different study years, seasons, and load levels over a ten year planning horizon. All of these scenarios will be analyzed for transmission system voltage deficiencies. This compares to the two scenarios described above for the GIDAP reactive power requirement study. The ISO would need to undertake roughly ten times more study work to make the interconnection system impact study comparable to the transmission planning process and at a cost that is roughly ten times the study cost that is currently charged from interconnection customers. The increase in study effort would prevent the ISO from performing a cluster study within the current time frames. In addition, the cluster windows would not be able to be opened every 12 months and would not be coordinated with the transmission planning process any longer.

Incidentally, the nineteen reliability study scenarios described above do not include the policy driven studies described in the study plan which will be considering additional scenarios focusing on 33% RPS stress scenarios and 50% renewable scenarios. The policy driven studies can also identify voltage problems requiring reactive support resources, and include substantial engineering time and cost.

# 6. Issues with the current approach

The case-by-case, system impact study approach to assess whether asynchronous resources must provide reactive capability has several shortcomings. A system impact study may not require that every project provide reactive power capability because it may conclude that there will be sufficient reactive power on the transmission system due to the capabilities of existing generators with reactive power capability and other reactive power devices on the transmission system. However, a glaring weakness with this approach is that such a study cannot reasonably anticipate all operating conditions in which resources with reactive power capability or reactive power devices on the transmission grid will be out of service – either due to retirement, or forced or planned outage – at the time reactive power needs arise. The case-by-case approach relies heavily on the assumptions of future conditions, which may not prove true. For instance, the study does not necessarily identify operating conditions that involve significant transmission or generation outages that could occur as a result of maintenance or unexpected equipment failure. The study also does not identify unplanned retirements that could occur before the end of a resource's useful life. Once an asynchronous project is interconnected and is commercially operable, actual system conditions could be far different from the conditions studied.

System impact studies do not – and cannot within current process timelines – cover all operational scenarios or future conditions that may require a resource to provide reactive power capability.[11] Interconnection studies are time consuming and iterative in

[11] April 17, 2012 FERC Technical Conference on Reactive Power Resources (AD12-10-000), Transcript at 20:23-21:15. http://www.ferc.gov/CalendarFiles/20120426074709-AD12-10-04-17-12.pdf

nature.[12] If the ISO were to study all possible operating conditions, potential outage schedules, and potential retirements for existing resources to more comprehensively assess the need for an asynchronous resource to provide reactive power support and absorption capability, the cost and time required for the system impact study process would increase. The ISO estimates that to enhance its system impact study efforts to account for a more robust set of operating conditions would take at least another four months of study for each interconnection cluster at an additional cost of approximately $2 million for each interconnection cluster. Currently, the ISO must complete the interconnection study processes within 205 days. To study a more robust set of operating conditions would expand this process, extend the timeframe and increase the cost of interconnection studies for future renewable resources.

In order to complete these system impact studies in a timely and cost–effective manner it is simply impractical to identify and examine all possible operation conditions. This is a shortcoming because deficiencies in reactive power support and absorption may not always occur during system peak but often can occur on days with high levels of variable energy resources and low demand periods or during periods when transmission infrastructure is out of service. In addition, a significant portion of the generating fleet is out on maintenance during the non-summer months, which places a level of subjectivity in studying off-peak operating scenarios because of the various combinations of resources out on maintenance, load levels and asynchronous production levels.

If an unstudied operating condition occurs that results in unanticipated reactive power needs, then asynchronous resources lacking the capability to provide reactive power support and absorption may adversely impact the voltage stability of the system by leaning on existing reactive support to deliver real power. Absent sufficient voltage, asynchronous resources may face operational issues (*e.g*. wind facilities may have to operate at lower than optimal levels until they could provide voltage control even though interconnection studies did not detect voltage issues).[13] By interconnecting to the transmission system without a sufficient reactive margin at its point of

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[12] *Id.* at 17:8-16.

[13] *Id*. 150:24-152:16.

interconnection, an asynchronous resource may degrade both the system and its own operations.[14]

Once a system impact study identifies a need for reactive power support in a queue cluster and requires asynchronous resources within that cluster to provide reactive power, these resources essentially compensate for all earlier queued resources for which the transmission provider did not identify a reactive power need. This "leaning" of asynchronous resources without reactive power capability on the reactive power support of other resources and reactive power devices increases the burden on the system. It also raises questions regarding the inequities between resources that have incurred costs to provide reactive support to the transmission system and those resources that have not, based on the mere happenstance of when they were studied. Moreover, transmission planning process studies may later identify a need to add a system reactive power device that could have been avoided if earlier queued resources had been required to provide reactive power capability.

Lastly, the system impact study approach potentially introduces unknown investment risks because customers with asynchronous generating projects in the ISO's queue only learn of the need to provide reactive power during the second phase of the ISO's interconnection studies. In contrast, applying uniform reactive power and voltage control requirements for asynchronous generating facilities provides up-front cost certainty for investors and developers.

Because of these issues, the ISO is proposing to adopt a uniform requirement for asynchronous resources to provide reactive power capability and voltage regulation, rather than continuing to rely on the current system impact study approach.

# 7. Case studies: San Diego/Imperial Valley

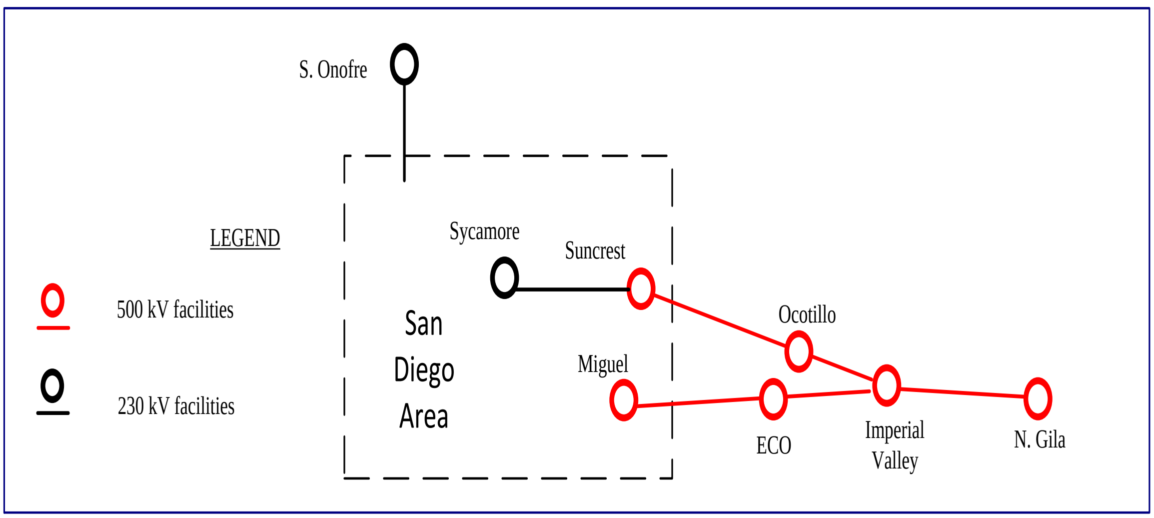
A recent ISO interconnection system impact study failed to find the need for a new asynchronous resource interconnecting at the Ocotillo substation in Imperial County, California to provide reactive power capability because the study did not model

[14] *Id*. 43:4-18.

unexpected operating conditions that actually occurred. Based on the results of the system impact study, the resource was allowed to interconnect without an obligation to provide reactive power capability. The resource reached commercial operation in 2013. At the time of the interconnection study, the ISO reasonably assumed that the San Onofre Nuclear Generating Station (SONGS) would operate at least through 2024, its relicensing date. However, as is now known, SONGS unexpectedly retired in June 2013.

Figure 1, shows the approximate locations of the Ocotillo and SONGS facilities. The dotted line reflects the San Diego transmission constrained load pocket.

**Figure 1 – Simplified Diagram of the transmission serving the San Diego area**




In its 2013-2014 transmission planning process, the ISO studied its system with SONGS out-of-service. As part of those studies, the ISO identified a voltage criteria violation at the Suncrest substation following an N-1 contingency of either the Imperial Valley – ECO or ECO – Miguel 500 kV lines. This voltage deficiency triggered the need for a 300 MVAR static VAR compensator at the Suncrest substation. An additional assessment showed that if the asynchronous resource at Ocotillo were providing reactive power through its inverters, the reactive power need at Suncrest would have been reduced by 50 MVAR.

Although the ISO would still have identified a reactive power need in its transmission plan based on the closure of SONGs, that need would have been reduced had the ISO determined that resources at the Ocotillo substation needed to have reactive power capability. While SONGS reflects an extraordinary closure, the fundamental point is that transmission providers cannot foresee each and every retirement or operating scenario on its system. A smaller resource that retires may also create an unexpected reactive power deficiency. For example, a two month outage at a combined cycle or the loss of a transmission element may easily create unforeseen voltage issues that require the capability to supply or absorb reactive support.

Another ISO interconnection system impact study failed to find the need for a new asynchronous resource interconnecting at the Imperial Valley substation in Imperial County, California to provide reactive power capability because the study did not model unexpected operating conditions that actually occurred. Imperial Valley substation has both synchronous and asynchronous generation connected to it. The asynchronous generation was not required to provide reactive power. In order to reduce flow on heavily loaded transmission lines the ISO identified the need to bypass series capacitors on two nearby 500 kV lines. The loss of one of these 500 kV lines requires the tripping of generation at Imperial Valley substation. However, it was found that tripping the synchronous generation instead of the asynchronous generation resulted in voltage problems. Therefore, the ISO was required to design a generation tripping scheme to only trip the asynchronous generation.

While transmission providers can mitigate this deficiency by authorizing new transmission elements, this process involves an unavoidable time lag and results in the costs being applied to all transmission ratepayers rather than generating resources. This may also create inequities as between conventional resources and resources that do not have a reactive power requirement. Adoption of uniform requirements for reactive power capability and voltage control at the time of interconnection helps mitigate potential reactive power deficiencies that may affect the ability of resources to deliver real power.

# 8. Over-generation conditions

Failure of asynchronous generators to provide reactive power capability can also have implications during over-generation conditions. Based on an analysis of data for 2014 (see Table 3 below), the ISO had to curtail between 116 MW and 740 MW of resources on certain days due to over-supply. During over-supply conditions, the ISO will solicit scheduling coordinators to submit decremental bids as mitigating measures, dispatch down flexible resources based on their decremental bids, and utilize exceptional dispatch to reduce production as needed. If remaining asynchronous resources in operation do not have reactive power capability, the ISO system will face a greater risk of voltage issues.

**Table 3 – Summary of Manual Curtailment**

| Date | Curtailed (MW) | Curtailed (MWh) | Duration of Curtailment (Minutes) | Reason |
|---|---|---|---|---|
| 2/19/2014 | 116 | 262 | 170 | Supply/Demand Balance |
| 3/7/2014 | 123 | 123 | 60 | Supply/Demand Balance |
| 4/12/2014 | 427 | 200 | 30 | Supply/Demand Balance |
| 4/27/2014 | 740 | 1,142 | 90 | Supply/Demand Balance |

By the end of 2014, wind and solar installed capacity within the ISO's balancing authority reached approximately 11,457 MW and the ISO expects at least an additional 3,151 MW of large solar PV, 3,564 MW of small solar PV and 1,134 MW of wind resources will interconnect by the end of 2024 (Refer to Table 1). Although the ISO's peak demand is gradually increasing, the minimum demand on the system is not increasing proportionately, and the minimum demand level is not expected to increase much higher than 20,000 MW by 2021 because of technological advancement in energy efficiency and environmental policies to conserve energy.

The data suggests that on some days, especially on weekends and holidays, the ISO's supply portfolio may consist of largely asynchronous resources that have displaced synchronous resources. The frequency of these over-supply conditions is expected to further increase with the addition of more distributed solar PV resources because more load would be displaced at the distribution level. If some of these resources do not have reactive power capabilities, the ISO system will face a greater risk of experiencing voltage issues.

# 9. Uniform requirements adopted in other jurisdictions

To ensure adequate voltage on their transmission systems, other jurisdictions have adopted a uniform reactive power requirement for asynchronous resources. For example, the Electric Reliability Council of Texas, Inc. (ERCOT) adopted a reactive power standard to integrate the build out of competitive renewable energy zones and support the transfer of that supply within the ERCOT region.[15] Specifically, ERCOT determined that imposing uniform reactive power obligations across all generation types was necessary because of challenges presented by the integration of significant amounts of renewable generation in locations that are distant from load centers. The ISO faces similar circumstances because it is also integrating significant amounts of asynchronous resources. In the case of ERCOT, applying a uniform reactive power standard to asynchronous resources avoided a situation in which projects interconnecting later in time needed to wait for additional reactive power resources to compensate for unstable voltage conditions on the grid.

Other jurisdictions in North America have also adopted uniform reactive power requirements.[16] For example, the Independent Energy System Operator (IESO) in Ontario, Canada requires renewable generators to provide reactive power continuously in the range of 0.95 lagging to 0.95 leading at the point of connection based on rated active power output, without the need for a determination in system impact study that

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[15] April 17, 2012 FERC Technical Conference on Reactive Power Resources (AD12-10-000), Written Statement of Jeff Billo http://www.ferc.gov/EventCalendar/Files/20120417082804-Billo,%20ERCOT.pdf

[16] April 17, 2012 FERC Technical Conference on Reactive Power Resources (AD12-10-000), Transcript at 120:18-121:13.

this is required for safety and/or reliability. The IESO also has voltage control requirements that apply to renewable resources.

The California Public Utilities Commission (CPUC) recently issued a decision adopting modifications to Electric Tariff Rule 21 to capture the technological advances offered by today's inverters. In Decision 14-12-035,[17] the CPUC noted that as greater numbers of renewable generating resources interconnect with the grid, the influence of inverters will grow. The CPUC further noted that today's inverters have many capabilities including:

- The generation or absorption of reactive power so as to raise or lower the voltage at its terminals.
- Delivery of power in four quadrants, that is, positive real power and positive reactive power; positive real power and negative reactive power; negative real power and negative reactive power; and negative real power and positive reactive power.
- The detection of voltage and frequency at its terminals and the ability to react autonomously to mitigate abnormal conditions: to provide reactive power if the voltage is low; to increase real power output if the frequency is low.

The CPUC decision requires that inverters installed after the effective date[18] of the requirements adopted in the decision should comply with the updated standards applicable to all inverters.

In addition, PJM Interconnection recently proposed *pro forma* interconnection agreements to require that wind and non-synchronous generators interconnecting with PJM's system after May 1, 2015 meet certain voltage and frequency ride through requirements and must have the ability to provide dynamic reactive support. The ISO understands PJM plans to request that FERC approve these requirement in the near future.

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[17] Issued December 18, 2014, in CPUC Rulemaking 11-09-011.

[18] The later of December 31, 2015, or 12 months after the date the Underwriters Laboratory approves the applicable standards.

# 10. Inverter cost and capability

The cost of including reactive power capability as a percentage of project costs is relatively small.[19] Some entities contest this fact and argue that applying a uniform reactive power requirement to asynchronous resources creates significant capital and operational costs.[20]

The ISO recognizes the possible concern that a uniform requirement for asynchronous resources to provide reactive power capability and voltage regulation could impose higher inverter costs on those projects that would otherwise avoid such requirements through the system impact study approach currently in use. It was in this context that the ISO conducted some outreach with inverter manufacturers such as General Electric and Siemens to learn more. The ISO found the following:

- Approximately 5 percent of total plant cost is attributable to inverters and associated equipment (e.g., transformer, controller). This is a sunk cost because all asynchronous resources must have inverters. Given the sunk costs, the incremental costs for adding reactive power capabilities are significantly less.
- Reactive power capability is now a standard feature of inverters used in both wind and solar PV applications and there is no additional cost for reactive power capability. Typically, these inverters are capable of providing 0.95 leading and lagging power factor at full real power output at the point of interconnection.

Based on these observations, the ISO believes the additional costs, if any, due to a uniform requirement would likely be *de minimis*. The ISO invites stakeholder comment on this issue.

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[19] *Id*. at 141:10-124:6.

[20] *See e.g.* Comments of the American Wind Energy Association in response to the April 22, 2014 workshop on Third Party Provision of Reactive Supply and Voltage Control and Regulation and Frequency Response Services filed in FERC Docket AD 14-7 at 7-8. http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=13567273

# 11. Straw proposal

The ISO proposes to adopt a uniform requirement for asynchronous resources to provide reactive power capability and voltage regulation. The ISO believes that adopting a uniform reactive power and voltage control requirement for asynchronous resources will promote renewable integration and grid reliability. A uniform reactive power standard enhances the reactive capabilities on the system compared to an ad hoc approach based on site specific requirements determined at the time of interconnection.[21] Indeed, NERC's Integration of Variable Energy Resource Task Force conducted a special reliability assessment that recommends that NERC consider revisions to reliability standards to ensure that all generators provide reactive support and maintain voltage schedules.[22] Requiring all interconnecting resources to provide reactive capability will remedy the shortcomings of the current approach and ensure distribution of the reactive power control throughout the system.[23]

The ISO proposes to apply these new rules on a going-forward basis to those resources that interconnect through the GIDAP.[24] The ISO believes that the appropriate balance between harmonizing reactive power requirements and existing customer expectations is to apply this new policy beginning with interconnection customers in the first queue cluster having an interconnection request window following the effective date of the tariff revisions. Thus, the ISO is proposing to exempt projects already in the ISO interconnection process and existing individual generating units of an asynchronous generating facility that are, or have been, interconnected to the ISO controlled grid at the same location from these new requirements for the remaining life of the existing

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[21] April 17, 2012 FERC Technical Conference on Reactive Power Resources (AD12-10-000), Written Statement of Jeff Billo at 4-6. http://www.ferc.gov/EventCalendar/Files/20120417082804-Billo,%20ERCOT.pdf

[22] NERC Specific Reliability Assessment: Interconnection Requirements for Variable Generation at 2-3: http://www.nerc.com/files/2012_IVGTF_Task_1-3.pdf

[23] April 17, 2012 FERC Technical Conference on Reactive Power Resources (AD12-10-000), Transcript at 20 at 17:7-22.

[24] New interconnection requests to the ISO grid are governed by the Generator Interconnection and Deliverability Allocation Procedures (GIDAP) approved by FERC in 2012. The GIDAP rules are contained in ISO Tariff Appendix DD.

generating unit. The ISO proposes, however, that generating units that are replaced or repowered, must meet these new requirements.

The ISO's straw proposal consists of the following elements:

1. Technical requirements for Asynchronous Generating Facilities:

    a) An Asynchronous Generating Facility shall be designed to have an over-excited (lagging) reactive power producing capability to achieve a net power factor from 0.95 lagging up to unity power factor at the Point of Interconnection, at the Generating Facility's maximum real power capability.

    b) An Asynchronous Generating Facility shall be designed to have an under-excited (leading) reactive power absorbing capability to achieve a net power factor from 0.95 leading up to unity power factor at the Point of Interconnection, at the Generating Facility's maximum real power capability.

    c) Asynchronous Generating Facilities shall provide dynamic voltage response between 0.985 leading to .985 lagging at rated MW capacity at the Point of Interconnection as specified in Attachment 1.

    d) Asynchronous Generating Facilities may meet the power factor range requirement at the Point of Interconnection by using controllable external dynamic and static reactive support equipment.

    e) Within the dynamic reactive capability range, Asynchronous Generating Facilities shall vary the reactive power output between the full sourcing and full absorption capabilities in a continuous manner.

    f) Outside the dynamic range of .985 leading to .985 lagging, and within the overall reactive capability range of .95 leading and .95 lagging, the reactive power capability could be met at full real power capability with controllable external static or dynamic reactive support equipment.

2. Operational requirements for Asynchronous Generating Facilities: When the plant real power output is at its maximum capability, the Asynchronous Generating Facility shall have the capability to provide reactive power at .95

lagging for voltage levels between .9 per unit and unity power at the Point of Interconnection. Likewise, the Asynchronous Generating Facility shall have the capability to absorb reactive power at .95 leading for voltage levels between unity power factor and 1.1 per unit at the Point of Interconnection.

3. Voltage regulation and reactive power control requirements for Asynchronous Generating Facilities:

    a) The Asynchronous Generation Facility's reactive power capability shall be controlled by an automatic voltage regulator (AVR) system having both voltage regulation and net power factor regulation operating modes. The default mode of operation will be voltage regulation.

    b) The voltage regulation function mode shall automatically control the net reactive power of the Asynchronous Generating Facility to regulate the Point of Interconnection scheduled voltage assigned by the Participating TO or ISO, within the constraints of the reactive power capacity of the Asynchronous Generation Facility.

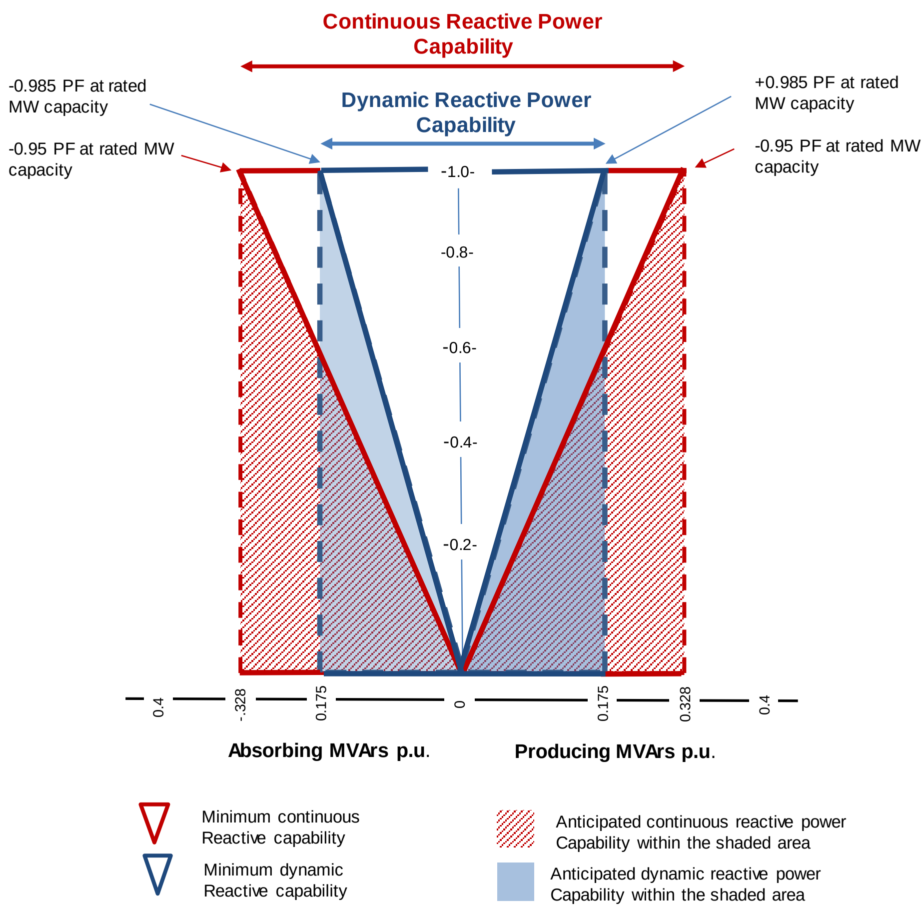
    c) The ISO, in coordination with the Participating TO, may permit the Interconnection Customer to regulate the voltage at a point on the Asynchronous Generating Facility's side of the Point of Interconnection. Regulating voltage to a point other than the Point of Interconnection shall not change the Asynchronous Generating Facility's net power factor requirements set forth in Section A. iii of Appendix H. (See Attachment 3).

    d) The ISO, in coordination with the Participating TO, may permit the Interconnection Customer to regulate the voltage at a point on the PTO's side of the Point of Interconnection. Regulating voltage to a point other than the Point of Interconnection shall not change the Asynchronous Generating Facility's net power factor requirements set forth in Section A. iii of Appendix H. (see Attachment 3)

    e) The Interconnection Customer shall not disable voltage regulation controls, without the specific permission of the ISO, while the Asynchronous Generating Facility is in operation.

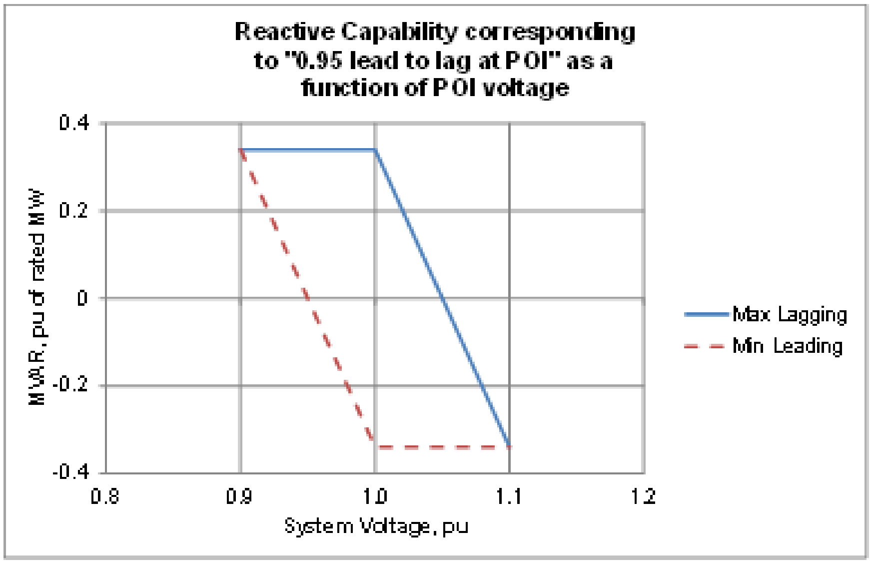
The ISO invites stakeholders to propose refinements to these requirements and invites comment on whether consideration should be given to applying different interconnection requirements based on resource type (e.g., wind versus solar PV). The ISO also solicits comments on whether new power purchase agreements require project developers to provide these capabilities.

# Attachment 1 - ISO's Proposed Reactive Power Requirement




*Note:* In the figure above, the red and blue isosceles triangles show the expected reactive capability of the Asynchronous Generating Facility at the point of Interconnection. At maximum real power capability of the Facility, the expected dynamic reactive capability should be between 0.985 lagging to 0.985 leading. Also, at maximum real power capability, the overall expected continuous reactive capability should be between 0.95 lagging to 0.95 leading. As shown in the figure above, as the real power output decreases both the dynamic and continuous reactive capabilities also decreases.

# Attachment 2 - Reactive Power Capability vs. Voltage Characteristics




*Note:* The figure above specifies that when the real power output is at its maximum capability, the Asynchronous Generating Facility shall have the capability to provide reactive power at 0.95 lagging when voltage levels are between 0.90 per unit and unity power at the Point of Interconnection. The capability to provide reactive power decreases as the voltage at the Point of Interconnection exceeds unity power factor.

Likewise, the Asynchronous Generating Facility shall have the capability to absorb reactive power at 0.95 leading when voltage levels are between unity power factor and 1.1 per unit at the Point of Interconnection. The capability to absorb reactive power decreases as the voltage at the Point of Interconnection drops below unity power factor.