FERC Technical Conference on Reactive Power

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The August 2003 blackout brought to the forefront a host of issues related to reactive power and associated voltage control. The USA-Canada Blackout Report identified reactive power deficiencies in the midwest region as one of the direct contributory causes of the blackout and recommended action on this subject. Con Edison appreciates the opportunity for making specific recommendations on (1) acknowledging reactive power's contribution to reliability, (2) financially compensating reactive power production capability and (3) improving the scheduling of reactive power.

Con Edison agrees with the four high level recommendations contained in the FERC staff white paper on reactive power:

- Reactive power reliability needs should be addressed locally, based on clear national standards;
- These needs should be procured in an efficient and reliable manner;
- Those who benefit from the reactive power should be charged with it; and
- All providers of reactive power should be paid on a nondiscriminatory basis.

We would recast some of the above recommendations into the following shorter-term specific observations:

- Reactive power is critical for system reliability to maintain system voltages within safe operating limits;
- It is important that an adequate amount of reactive power capability is scheduled and made available to grid operators;
- Generation reactive power capability must be determined and verified through periodic testing;
- Suppliers must be encouraged to maintain the reactive power capabilities of their generating units in good working order as well as its unhindered deliverance;
- Compensation mechanisms must reflect the value of reactive power service required to operate the system reliably;
- Market power considerations are specially pertinent in designing bid-based reactive power markets because reactive power does not travel far; accordingly, dispatching reactive power is akin to dispatching real power that is required to support load pockets; and

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[2] The author gratefully acknowledges the contribution to the concepts expressed in this document by his colleague Edwin Thompson as well as those of many other individuals that have patiently discussed with him this subject, which is critical to our restructured industry.

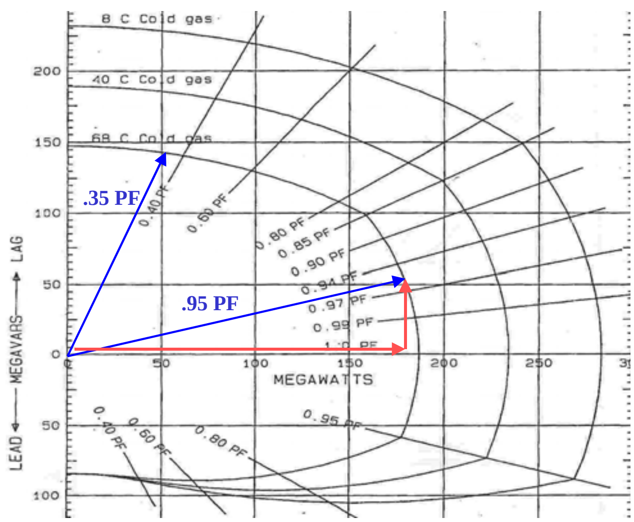
▪ Suppliers must not be financially harmed when instructed by operators to decrease their real power output in order to increase reactive power production.

Based on the above considerations Con Edison recommends the following general framework:

1. **<u>Reactive power's criticality for system reliability must be acknowledged</u>**
Sufficient reactive resources must be scheduled to control voltages under normal and contingent conditions. As such, it must be mandatory for all generators connected to the system to supply reactive power. Reactive capability must be tested periodically so that system operators know what resources they can count on. Testing is also needed to establish a basis for compensating suppliers. Reactive power suppliers must be required to follow the instructions of system operators at all times regarding reactive production levels. Similarly, compensation for reactive power must be structured in a way that does not harm suppliers for following the instructions of the system operator.

It is important to note that different types of equipment provide different levels of reactive power capability to the system. Consider the following typical Generator Capability (or "D") curves for a generator capable of operating between 50-175 MW during summer conditions. At 175 MW the generator is capable of producing 0-50 MVARs lagging corresponding to a 1.0 – 0.95 power factor. At 50 MW, the unit is capable of producing up to 140 MVARs (corresponding to a 1.0 - 0.35 power factor). If this same unit were driven by a gas turbine, it would only operate at the 175 MW level and produce no more than 50 MVARs lagging. Similarly, it is critical to test and measure summer and winter reactive power capability at various MW output levels because the curves shift to the right with lower gas temperatures.

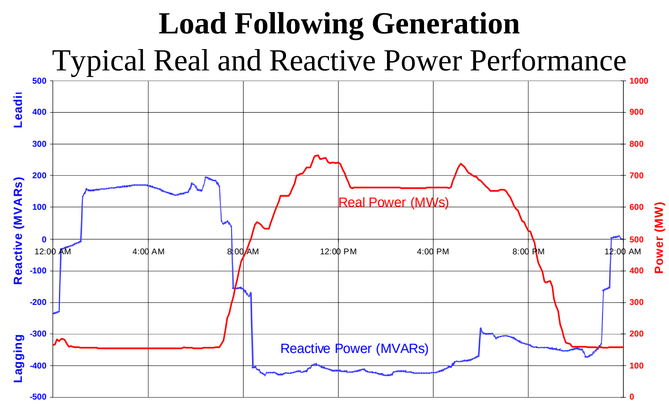
Typical Generator Capability Curve

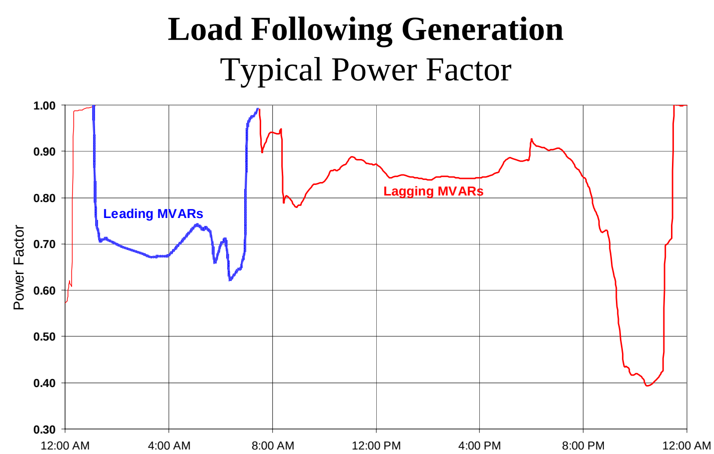


2. **<u>Compensation design should be cost based, should reflect the reliability value provided and should encourage the maintenance of reactive power capability</u>**
A competitive market for reactive power is difficult to design given that reactive power does not travel far and therefore market power mitigation measures must be

considered. It is not readily apparent how to assign an incremental cost to a reactive power bid and at the same time consider market power issues. A cost-based approach is more appropriate at this time with penalties for non-performance. In addition to being compensated on a cost basis for reactive power, generators should also be compensated for lost opportunity costs associated with real power if they are being asked to reduce real power output in order to increase reactive power output. Generation should be financially indifferent in following the instructions of system operators.

Generators that can follow load by increasing or decreasing its output accordingly are typically hydro and coal/oil/gas steam units. Graphically we can expect such a generator to respond to daily load patterns as follows:

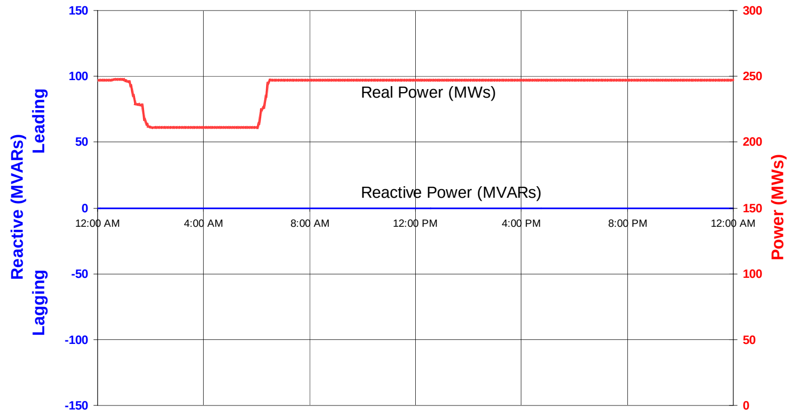




There are also generating units that are considered as “base load” such as nuclear and gas turbines, the real power output of which does not normally vary with the time of day. Typical performance of these kind of units is different from load following units, although their contribution to controlling voltages is just as important. Curves for such units are as follows:

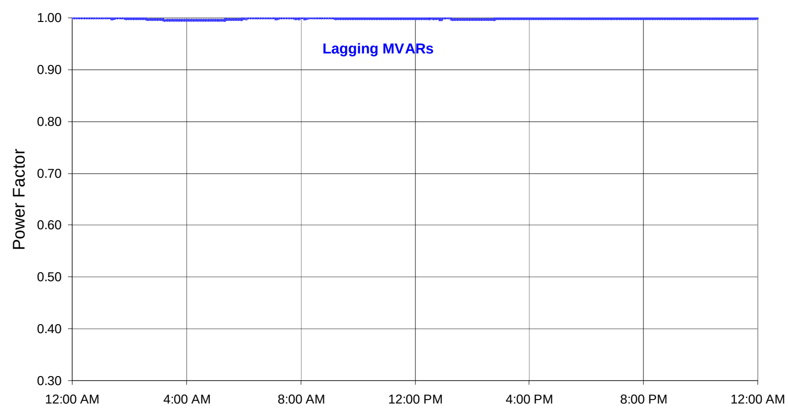
Base Load Generation

Example Real and Reactive Power



Base Load Generation

Typical Power Factor



In designing a compensation scheme it must be recognized that load following generation can provide a greater service to the system in helping control voltages than base load units. At peak load conditions most units will be operating close to their 100% output, which coincides with the time when their lagging reactive capabilities are needed the most. To promote load following ability, additional compensation should be made available for the additional MVARS that can be produced at lower levels, such as 65% and 40% of maximum output. Base load units are normally only eligible for payments for lagging or leading MVARs they can produce at their 100% real power output level. Load following units can produce additional leading MVARs at 40% of their maximum output and should be eligible for receiving additional revenues for this capability. For these reasons we advocate a compensation scheme designed around the following characteristic:

Reactive Capability			
Unit Output (MW)		**Payment Rate per MVAR Capability**	
Lagging	100%	at 100%	highest
Lagging	65%	excess over 100% level	intermediary
Lagging	40%	excess over 65% level	lowest
Leading	100%	at 100%	highest
Leading	40%	Excess over 100% level	highest

The actual rates can be different in each market region depending on what other sources of revenues might be available for generators. In the absence of competitive bidding, rates must be made to reflect operating costs to maintain reactive power related equipment in good working order. Rate design must encourage generators to maintain their units' capability to produce as many MVARs as they can at various MW levels. To be eligible for compensation the generator must have an Automatic Voltage Regulator (AVR). Concomitant with this rate design based on tested capability must also be penalties for non-performance when called upon by system operators. It should also be noted that the proposed rate design treats all units comparably regardless of ownership.

3. **Reactive power must be optimally scheduled simultaneously with the scheduling of real power**

Experience in New York has shown that there are times when system voltage profiles are lower than customary, while still being within safe limits. Planning studies, however, do not find similar conditions. The main difference between these two scenarios is that operational observations show voltages that are the result of generation resources scheduled by the NYISO while planning studies consider all generation as potentially available to produce reactive power to maintain voltages within desired limits.

Most control area and all ISO/RTO scheduling systems consider the optimization of real power production cost. For example, the NYISO's scheduling system (both day-ahead and in-day), minimize real power production cost (energy, reserves and regulation) subject to real power constraints on transmission line loadings (under normal and contingent conditions), reserve and regulation levels, and various other related constraints. Often, transmission line capabilities are lowered as a proxy for making real-power scheduling systems commit additional units and to reserve transmission line capability for reactive power flows. Internally to all currently working scheduling systems is the use of a DC representation of the system, mainly to keep computation times to reasonable levels.

DC representations have been shown to be adequate in modeling real power flows but are known to be inadequate in the modeling of both real and reactive power flows. The latter requires an AC representation, which increases computational burden. However, it is our opinion that with ever-increasing computational capabilities, we now have the level that can support scheduling systems with an AC representation.

AC representations would make it possible to directly model voltage constraints. In other words, scheduling systems would optimize real power production costs subject to all constraints we presently model and, in addition, would also model constraints to maintain voltages within specific bands at different system locations, under normal and contingent conditions. The effect of such modeling would be the efficient (optimal) scheduling of units to have enough reactive power capability available to control voltages within reliable limits for a reasonable set of foreseeable system conditions.

It is recommended that control area operators be required to enhance their real power scheduling systems to directly recognize reactive power resources and associated voltage limits constraints. Developers of such systems must consider meeting all production grade computational products criteria. As an interim measure, until such automated scheduling systems are in place, operators must be required to manually evaluate the need for scheduling the additional reactive resources needed for the reliable control of voltages within limits at all locations, at both normal and contingent conditions, even though such manual selections would not be optimal. Simply reacting after the fact to poor voltage conditions could diminish system reliability and would be less economically efficient.

Conclusions

Con Edison makes herein three recommendations on the subject of reactive power:

1. Make the provision of reactive power mandatory for all generators as well as all units responding to system operator instructions, require periodic testing for operators to know what resources they can count on and as a basis for compensation;
2. Design a cost based compensation strategy that encourages generation owners to maximize reactive capabilities of their units, results in fair payments with penalties for non-performance, recognize the different reactive power contribution of base load and load following units, provides for loss opportunity compensation when appropriate and pays all units in a comparable manner; and,
3. Model optimal real power scheduling systems to include system voltages / reactive power constraints to ensure that resulting commitments and dispatching of generating units result in the grid having the reactive resources it requires to reliably control voltages