A Tariff for Local Reactive Power Supply

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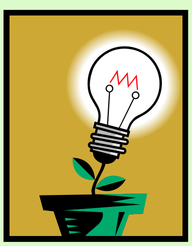
A Tariff for Local Reactive Power Supply

- Why is the need for dynamic reactive power growing and why do we need a tariff?
- What are the conventional sources and sinks for reactive power?
- What is local voltage control?
- Static vs. dynamic reactive power and their role in system operation.
- How could customers participate?
- Cost of Supply – Customer, System Operator and Utility Viewpoints
- Value of Supply – System Operator and Utility Viewpoints

Reactive Power Supply Is an Ancillary Service

•Reactive power supply is one of a class of power system reliability services collectively known as *ancillary services*, and is essential for the reliable operation of the bulk power system.

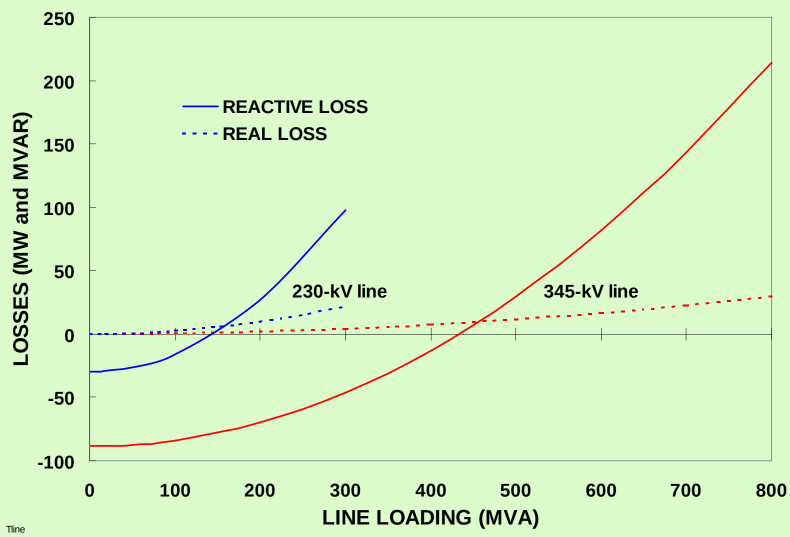
- Reactive power flow wastes energy and capacity, and causes voltage drop. To correct lagging power flow, leading reactive power (current leading voltage) is supplied to bring the current in phase with voltage.
- Reactive power can be supplied from either static or dynamic VAR sources (capacitors or generators).



Why is the need for local dynamic reactive power growing?

- The transmission and distribution systems are being operated under higher load levels, and reactive power absorption is proportional to the square of the current flow.
- There are growing instances of “micro voltage collapse” in distribution systems.
- Newer loads are causing higher peaks and worse power factors. (CFLs have a PF of 0.5)
- Load growth on existing circuits has created unforeseen voltage problems.

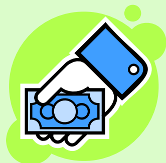
Transmission Line Inductance and Capacitance Are Much Larger Than Resistance – Voltage Is A Local Issue



Why do we need a tariff?

•Since deregulation, the same physical transmission and distribution resources are available but they are spread among multiple commercial entities with differing commercial objectives. Some of the planning linkages between different parts of the system have become less transparent as they have been parceled out between different participants.

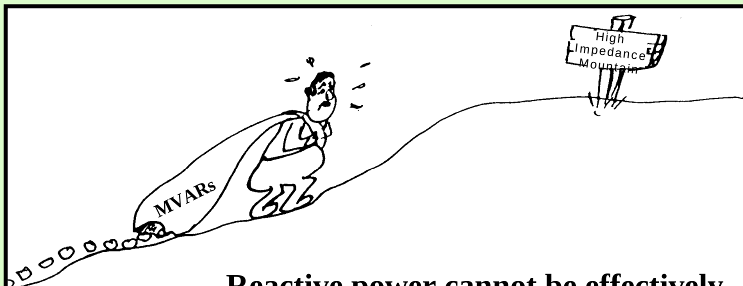
- At the CAISO all loads directly connected to the ISO Controlled Grid have to maintain specified power factor band of 0.97 lag to 0.99 lead, for which they are not compensated.
- Unless otherwise specified by contract terms, generating units at the ISO are required to maintain a minimum power factor range within a band of 0.90 lag (producing VARs) and 0.95 lead (absorbing VARs) power factors.



Why do we need a tariff, contd.?

- The CAISO load and generation power factor specifications are not based on local power system requirements nor do they accommodate (or compensate) differences in reactive power delivery capability.
- Having the distribution substations at a slightly leading PF would improve capacity on the transmission system.
- Providing local supplies of dynamic reactive power would reduce losses, increase capacity, and increase the margin to voltage collapse.

Transmitting Reactive Power



Reactive power cannot be effectively transmitted across long distances due to high I^2X losses.

Reactive Power Sinks

- Reactive power absorption occurs when current flows through an inductance. Inductance is found in transmission lines, transformers and induction motors.
- The reactive power absorbed by a transmission line or transformer is proportional to the square of the current.
- Because of this, it is difficult to supply reactive power over long distances, it “Does Not Travel Well”.
- Dynamic reactive power supplied locally, near the load, has more of an impact than when supplied from distant generators.

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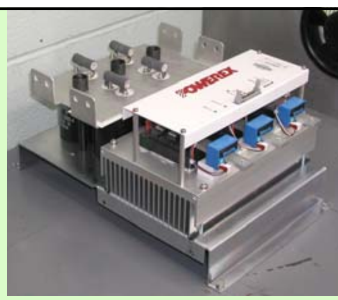

Dynamic Reactive Capacity Would be Installed with Distributed Energy (PV, Fuel Cells, Microturbines)

- Dynamic sources at the distribution level would help to regulate local voltage.
- Dynamic reactive power is theoretically available from any inverter based equipment such as photo voltaic, fuel cells, microturbines and adjustable speed drives.
- The only change would be a larger inverter, and inverter control capable of performing voltage regulation.
- However, the installation is usually only economical if reactive power supply is considered during the design and construction phase.

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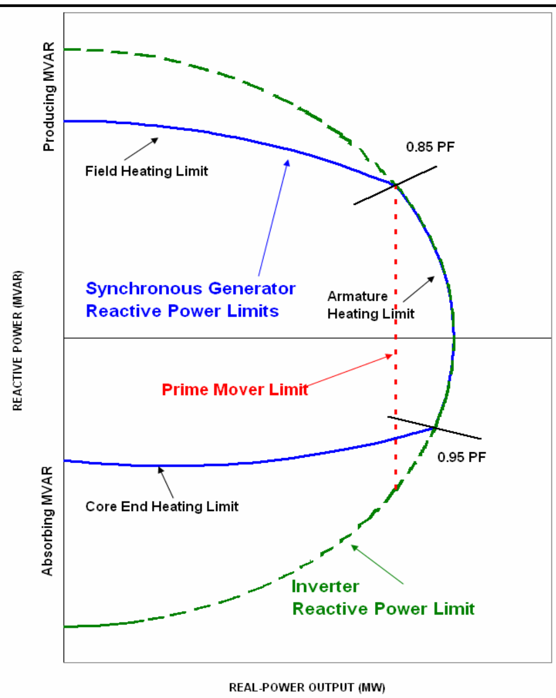
Capstone (30kW) opened to show major assemblies

Distribution Level Dynamic Reactive Power May Be Provided by:

- Engine generators equipped with 0.8 PF generators with exciters capable of voltage regulation.
- Fuel cells, photo voltaic systems and microturbines equipped with inverters capable of operation at reduced PF and voltage regulation control.
- Adjustable speed motor drives with active front ends controlled to regulate voltage.

Generator and Inverter Reactive Power Limits



Local Supply of Reactive Power

- Voltage Control: Supply of local reactive power will elevate voltage, absorption of local reactive power will depress voltage.
- Customers could be provided with a voltage schedule which would guide them in the production of local reactive power. The voltage schedule would simply tell the customer what local voltage to control to based on the time of day. The customer would supply or absorb reactive power, to the extent of his capability, to meet the schedule.
- In some areas, the voltage schedule would be adjusted on a seasonal basis.

Dynamic Reactive Power and System Operation

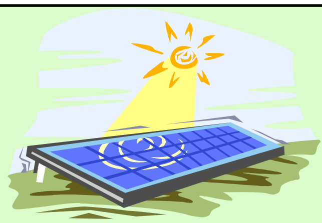
- The power system must be continuously ready to deal with sudden contingencies. The sudden loss of a large generator can simultaneously deprive the power system of a supply of reactive power and increase the system's reactive power demand as transmission line loadings shift.
- Planning studies and real-time analysis tools tell the system operator how much dynamic reactive reserves are required, and in what locations, to assure that the power system will remain stable and avoid voltage collapse in the event of any credible contingency.
- The system operator operates the static and dynamic reactive resources to both maintain system voltages and assure that sufficient reserves are continuously available to respond in the event of a contingency.
- If reactive reserves from generation are used to support distribution system voltage, significant losses can occur.

Distribution Systems Should Properly Regulate their Own Voltage

- The Root Cause Analysis Review Team for the July 1999 Low Voltage Condition performed a detailed study of unpredicted low voltage conditions. The report stated that "VARs from the transmission system should not be used to support distribution voltage."
- The distribution system could present a slightly leading power factor to the transmission system during times of system stress. This practice would translate to less reactive support being required from generators and more efficient system operation.
- Customers would also improve their own power quality and expand the margin to "micro voltage collapse".

Costs and Savings Using an Analysis of a Hypothetical Circuit

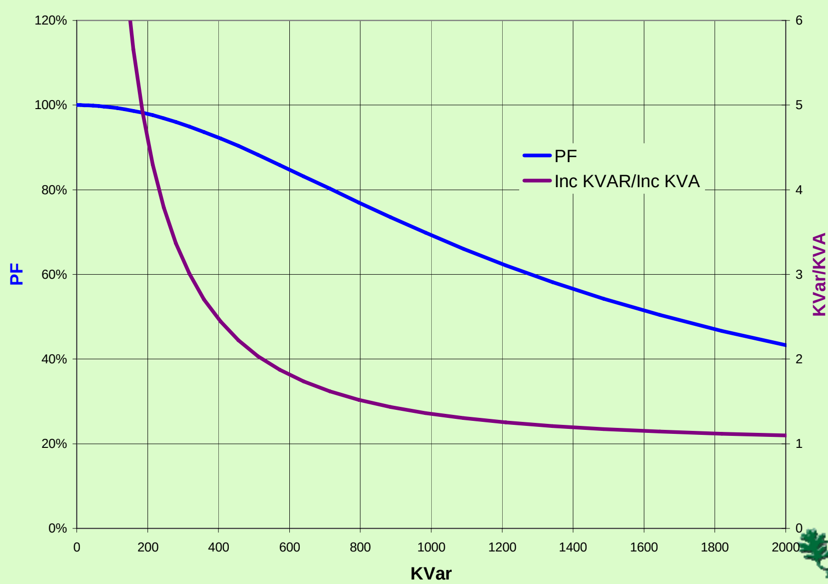
- We find that if the inverters of photovoltaic systems or the generators of combined heat and power systems were designed with capability to supply dynamic reactive power, they could do this quite economically, perhaps at a cost of $5 per kVAR on an annualized basis.
- The savings from the local supply of dynamic reactive power would be in reduced losses, increased capacity, and decreased transmission congestion. The net savings may be as much as $10 per kVAR on an annualized basis.
- A reasonable purchase price or tariff may be somewhere between these two numbers.

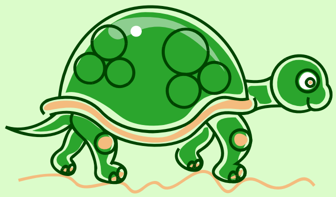


Example of a Customer Owned 500 kW PV System

- Conventional PV inverters are designed with a 1.0 PF. But why not design with a 0.8 PF and ability to regulate voltage?
- Photovoltaic Inverter, Output Rated 500 kW, 0.8 Power Factor, 625 kVA.
- The additional 125 kVA, at a cost of $200/kVA, represents an additional cost of $25k.
- With a power factor of 0.8, the inverter can supply 375 kVAR both leading and lagging.
- The total incremental cost to the customer on an annualized basis for supplying dynamic reactive power is then $6/kVAR.

For a Slight Change in PF, there is a Big Change in kVAR Capacity





Distribution Utilities Typically Rely on Capacitors and Slow Tap Changers to Supply Reactive Power

- Caps are cheap, the annualized net present value, or Capacity Cost, is $2.8/kVAR for reactive power supplied from distribution capacitors.
- However, this is only for static service.
- Dynamic reactive power can improve customer voltage regulation, prevent damaging overvoltages, and help in energy conservation.
- However, utilities are phasing out synchronous condensers because of the losses and maintenance costs.

How Can We Quantify the Savings for Customer Based Dynamic Reactive Support?

- The supply of reactive power at the load will reduce the circuit current. Since the real power loss is I squared R, the circuit loss will be reduced.
- The transmission line flow will be reduced. This is equivalent to having a distribution or transmission line with bigger thermal capacity rating. The saved line capacity may be converted to savings for importing more inexpensive power using this line, compared with dispatching expensive local units near the load.
- An increase in power factor from 0.9 to 0.95 can increase the maximum transmission capacity – stability limit - by 15%. The saved line capacity may be converted to savings for importing more inexpensive power from this line, the entity that benefits is the local distribution company.
- Total annualized savings for a hypothetical San Francisco distribution circuit are $2.50/kVAR.

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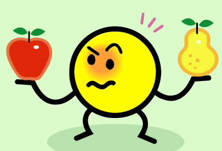
Total dollar value of local reactive supply on an annual basis.

- The average gross voltage support rate was found by a survey to be about $4.50/kVAR year annually.
- The total value for our hypothetical circuit including reduced losses, impact to net import and voltage support service is then $7/kVAR year.



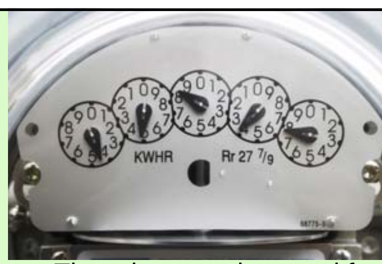
Annualized Cost Estimate for Three Alternate Supply Methods

- $19/kVAR to back fit an Active Front End on ASDs
- $5/kVAR (Oversizing the Generator on the Engine Generator)
- $6/kVAR (Oversizing the PV inverter)

What Is an Appropriate Payment on an Annualized Basis?

•Midpoint between the lowest costs and estimated value would be about $6/kVAR.

- It would be too complicated to attempt to contract with every single Distributed Energy Resource based on their cost of providing reactive power. One of the biggest complicating factors is the changing cost of inverters; it is predicted that PV inverter prices are going to drop significantly soon. It would be much better to contract based on a uniform price paid to all distribution company customers.
- If adequate dynamic reactive reserves already exist in an area, more do not have to be purchased. If dynamic reactive reserves are needed, they can be contracted for at the fixed rate that is known to be economical for the distribution system operator, but which will still be above the cost of supply for the customer, and will help amortize the cost of his photovoltaic or combined heat and power system.



In Conclusion

- There is a growing need for local dynamic reactive power to expand the margin to voltage collapse, reduce distribution losses, and even supply reactive service at the transmission substation.
- This could be done using a local inverters controlled to a voltage schedule supplied by the distribution company.
- At present, using an analysis of a hypothetical circuit, we find the benefits to sometimes outweigh the costs.
- Utilities in need of more dynamic reactive supply on a circuit could contract with customers, at a fixed rate, to supply this need as required.
- As the cost of inverters comes down, this practice could save energy, release capacity and enhance reliability, as well as providing an additional revenue stream for customers considering alternative energy resources.