Pumped Storage for the Distributed Generation Market

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Introduction

In 2001 the writer became concerned over how the U.S. would be able to sustain its economic growth over the next 25 years, given the large increments of new electricity capacity which would be required. A solution to this major challenge seemed to be especially difficult given several critical realities: 1) natural gas supplies were not keeping pace with the growing demand; 2) our transmission and distribution infrastructure required significant upgrade investments; 3) environmental compliance rules would require large investments for any new, "clean-coal" plants as well as for retrofits of the existing coal units; 4) new nuclear generating plants were not considered a feasible option; 5) new capacity generated from "renewables" was the clear choice for growth although these typically small incremental additions could only provide a small percentage of the total annual new capacity requirements.

Given the magnitude of the hurdles to overcome to assure our economic growth, I looked "outside the box" for potential new technology approaches to help reduce somewhat the size of the new annual capacity additions which would be required. This process started with a clear recognition of the importance of "distributed generation"(DG) in the overall solution. I was also intrigued by the large existing excess power reserves during off-peak hours. If these reserves could be stored for use during peak demand periods, a new source of capacity additions will have been found.

Electric Power Supply vs. Demand (2005)

The basic macroeconomic principle of the inelastic impact upon the price of a product for which demand has equaled or exceeded supply has been proven time and again for many products in varied markets. This is currently being demonstrated with the dramatic price increases of oil and natural gas and was also demonstrated in the recent past for electricity in regional markets experiencing short supplies.

Electricity demand growth in the U.S. has historically tracked very closely to annual GDP growth. Therefore, if we assume a 3 percent annual GDP growth, a total of 22,000 MW of new generation capacity must be added to our grid systems each year if we are to avoid huge annual price increases. Growth projections from the EIA 2005 Forecast indicate an average growth of 14,000 MW per year. This is based upon a 3 percent annual GDP growth and only 1.9 percent corresponding increase in electricity demand. I believe, for planning purposes, since there will be years like 2005 when actual GDP growth will be 3.5-4.0 percent, a good target would be 20,000 MW per year.This assumes that the new generation will be added in the most effective locations so as to address the regional load demand centers which need the new capacity the most. Clearly, the nation's transmission and distribution infrastructure is not adequate to handle the new capacity in many of the high demand zones. This reality has been one of the main driving forces behind the strategy to significantly increase installation of "Distributed Generation" sites.

New Generation Capacity Solutions

The EIA Forecast predicts that the capacity increases over the next 20 years will come from:

- New gas-fired----------------------60 percent
- New coal-fired (most after 2010)—87 GW
- "Modest" increase in new nuclear
- New "renewables"total increase of 15 GW

The annual growth of 20 GW is not significantly impacted by new "renewables" since even the predicted 36 percent increase in total "renewables" capacity will still only represent 8 percent of total generation in 2025. (Also, sources such as wind generation often cannot be installed close to major load centers and thus are dependent on available transmission infrastructure.) The current and projected shortage of natural gas supplies also casts some doubt on the prediction of 60 percent of total new capacity coming from natural gas generation. Therefore, in order to sustain economic growth, we must plan more new "clean coal" plants and new nuclear capacity as well as some new LNG-fueled generation.

These strategies, even if embraced immediately, carry the following inherent challenges:

1) nuclear plants will require at least an 8-10 year lead time before startup;
2) "clean-coal" plants require a 4- year span before startup;
3) adding LNG facilities in the short-term will allow some additional but very expensive gas- fired capacity with the undesirable long-term impact of more dependency upon foreign sources for another fuel in addition to oil.

The following summary of new Generation Technology Choices is derived from the EIA Forecast report:

	Lead-Time(yrs)	**Installed Cap. Cost ($/KW)**
Small (fossil) Distrib. Gen.	2-3	~900
"Renewables"(Solar,Hydro,Wind)	2-4	1,134 – 4,467
Comb. Turb.- Combined Cycle	3	560
Fuel Cells	3	4,250
Scrubbed Coal	4	1,213
IGCC	6	1,402
Advanced Nuclear	9	1,957

Given the need for new capacity and recognizing some of the negative aspects of the above alternatives, another source must be added to the list for an interim period of roughly 15 years. Such an alternative is to tap the existing off-peak excess capacity of base–loaded plants and "green" power sources which exist in most regional markets. One proven method of storing bulk electricity from off-peak hours until the high-demand hours each day is known as "pumped storage". These plants typically have involved large capacities and are hydro or compressed air- based requiring specific land topography/geology and as such do not lend themselves to the small capacity sizes and dispersed locations required for DG applications.

"Potential Energy" For Small Pumped Storage Applications

On March 1, 2005 a Patent was awarded for a "Potential Energy Storage System"(PESS). The intent of the system is to allow the "pumped-storage" concept of generation to be introduced into the urban/suburban electricity markets in a unique manner via small-scale units which fit with the "distributed generation" approach. However, utilizing PESS installations in a size range from 250 KW to 1 MW as opposed to the existing large commercial "pumped storage" plants still places this technology above other storage technologies such as supercapacitors, high power or long duration flywheels and various battery technologies when both power rating and discharge time at rated power are considered. This approach to DG would allow sustained growth in high load demand centers without the immediate need for new, large central station generating plants. Presumably, it would also delay the need for upgrading "wires" in the local area.

The PESS concept basically replaces the fluid head typically created by a large water reservoir above a turbine / pump prime mover in a "hydro" application with the weight of a commercial structure supported on a series of hydraulic cylinders. The support steel of the structure would be designed so that the support columns are vertically movable by hydraulic cylinders working from a common fluid header system. A reversible pump/turbine driven by a motor / generator using off-peak power (during night hours) would provide the fluid pressure required to lift the structure from its "at rest" elevation to about + 10 – 15 feet. The weight of the structure would then provide the pressure head at the hydraulic motor inlet to generate power on demand during the daylight hours, gradually decreasing its elevation by approximately 1 – 1.5 feet per hour. The first systems will most likely be in the 250 – 500 KW size range with the generated power being sold in the cogeneration mode or simply utilized only to supply the internal electricity demand of the structure itself. Depending on the structure's footprint, it would probably not exceed 4 – 6 floors high in order to eliminate any potential problems related to vertical stability.

Although specially designed vertical guides for the building columns will be incorporated into the structure, a controlled small horizontal relative movement between the building and its foundation can be accommodated. This feature provides an advantage in earthquake-prone zones. Some of the unique PESS building design features are:

- Hydraulic support cylinders at the foundation level
- Flexible connections to all external utilities and local grid

- Local load demand /distribution control system
- External lateral support guides
- “Floating” ramp-type entry/exit

All system equipment as well as the hydraulic fluid reservoir are mounted on the basement floor of the building and thus would not change elevation during the pumping or generation cycles. Equipment and hardware are intended to be “commercially available”, thus not requiring any special development.

The key benefits to be derived from PESS technology are:

- utilization of off-peak power decreases need for new, central generation plants;
- reduced/deferred need for upgraded transmission infrastructure and associated permitting;
- increased capacity factor for existing generation assets;
- reliable, uninterruptible, predictable-cost power for the PESS user/owner;
- “zero-discharge”, distributed generation units available at the load demand sites;
- higher relative percentage of “green” power (including storage from off-peak hours) can be utilized during peak demand hours, thus increasing total net “green” power;
- higher wind generator capacity factor when integrated with electricity storage;
- inherent earthquake damage resistance.

The cost of power from a PESS installation must bear the burden of efficiency losses from the “pump-up/regenerate” cycle. This requires a fair negotiated cost rate for the off-peak power from the local electricity supplier. The incentive to provide a workable cost rate would be driven by : “economy of scale” for base-loaded generation assets and their higher capacity factors during off-peak hours. Also, the local grid will experience decreased line losses during peak demand periods (due to the DG mode of operation) and could use the PESS source for system stability during upsets or emergencies.

Summary

The need to add 20 GW of new capacity annually in the U.S. over the next 20 years in order to sustain our 3+ percent annual GDP growth presents a major dilemma from a planning standpoint. Recent realities have shown that reliance upon new natural gas capacity to provide sixty percent of the need is a significant risk from an availability perspective even if the large continuing increases in price could be absorbed. Also, even with large forecasted increases in “renewables” capacity (+ 15 GW total), these technologies will still only supply a small percentage of the need.

Increased emphasis on new clean-coal plants must be initiated as soon as possible since the lead-time for this technology is four years. More nuclear plants are also needed and planning for these must start now, given the nine year lead-time. However, even if these initiatives are taken quickly, it appears that another source of new peak capacity with short lead-time is required. This challenge dictates that we seek to find a way to tap into the existing large off-peak reserves in order to shave peak demand.

The primary intent of the “pumped potential energy” approach to electricity storage is to reduce daily peak demand. However, it can also serve as an emergency backup power source for distribution systems protection and also to increase the capacity factors of renewable generation sources such as wind which has variable output characteristics. Its application will be in small increments of typically less than 1 MW which is typical of the Distributed Generation market.

Since there is no “rocket science” to be developed, PESS technology can be commercialized in a relatively short time span. Potential funding sources to support a “proof-of-concept” model test program are currently being investigated as an interim step. It is hoped that funds can be specifically earmarked for “Energy Storage” technology development under the new U.S. Energy Policy.

For a full-scale demonstration, a new project developer / architect with a planned structure construction project into which the system can be installed and demonstrated is being sought. This project would also require the participation of a local GENCO which is willing to negotiate a fair price reduction for the off-peak power in order to help offset the efficiency loss of the pump-up / regenerate cycle. PESS sites will benefit from the recent progress being made on connectivity rules / standards. Also, it would appear that a regulated utility could actually own the PESS even though it might be installed in a structure owned by others. This being the case, the system could be added to its rate base.