SOCIOECONOMIC ANALYSIS OF IMPLEMENTING SMART GRID TECHNOLOGIES

John E. SAYMANSKY
West Virginia University – USA
John.Saymansky@mail.wvu.edu

Ali FELIACHI
West Virginia University – USA
alfeliachi@mail.wvu.edu

John Ed SNECKENBERGER
West Virginia University – USA
John.Sneckenberger@mail.wvu.edu

ABSTRACT

A broad socioeconomic analysis is applied to assess the cost and benefits of implementing smart grid technologies to enhance the reliability and resiliency of the power grid in the state of West Virginia, USA. To address the issues of reliability and resiliency a smart grid implementation plan is devised based on a gap analysis. The gap analysis serves as an asset management tool to identify potential smart grid technologies that may be employed to improve reliability and resiliency. The gap analysis also serves as a mechanism to identify regulatory, governmental and consumer impediments to the implementation of a smart grid. A list of proposed solutions is identified to eliminate or minimize the gaps providing for functional smart grid within the next twenty years.

INTRODUCTION

West Virginia (WV) is well below the national average in grid reliability despite the more than $ 450 million annual capital expenditures by the state's utilities on electrical infrastructure. The integral components that make up the electric grid in WV are aging rapidly because they are being used in ways that increase equipment stress resulting in accelerated wear and unexpected equipment failures. This stress makes the whole system more susceptible to critical failures. Loads are at risk due to a system that delivers power from large centralized power generation facilities to a relatively lower density consumer base in a mountainous terrain over an aging infrastructure. The current infrastructure lacks dynamic system re-configuration and distributed resources. Outages on the state's distribution system must be identified by sending crews into the field in response to customer calls. This often requires an extended period of time to identify the failure and restore service to customers. This paper addresses these problems by employing a Gap Analysis to identify the most cost effective upgrades to the current system to enhance its intelligence and reliability and move it into the realm of a smart grid. A broad-based economic analysis factoring in the social costs and benefits is employed to assess the true economic cost of these modifications and to identify any policy change that may be needed to entice the state's public utilities to make the additional capital investments required to improve the reliability of the state's power system.

CURRENT STATE OF THE STATE OF WEST VIRGINIA POWER GRID

Understanding the current state of WV's assets, technologies, applications and processes is a key input to the gap analysis and the ultimate determination of the solution sets needed for achieving a West Virginia Smart Grid vision. More than 98% of the customers in West Virginia are served by two utilities, American Electric Power (AEP) or Allegheny Power (AP). The predominant distribution system is composed of overhead radial feeders protected by electromechanical relays, reclosers, and fuses. Less than half of the distribution substations have fully functional SCADA (Supervisory Control and Data Acquisition) connectivity. Additionally, few intelligent sensors or monitoring devices are installed at the distribution level in the state. The transmission system also has a very limited number of intelligent devices and sensors and there are no FACTS (Flexible AC Transmission) devices or Wide Area Measurement System (WAMS) installed. This is not surprising since there are virtually no integrated communication systems allowing for bidirectional communication between consumers and utilities. Where communications do exist there is not widespread coverage, typically not enough bandwidth to use for any advanced applications, and no connectivity to most residential and commercial customers. WV's role as a major exporter of power may be attributed to its abundance of coal and water, its relatively low population, and the fact that all of the utilities are merchant generators who are members of PJM. This provides them with the ability to sell their inexpensive energy in the PJM wholesale electricity markets to supply nearby metropolitan loads located on the east coast.

Generation

WV is a major producer of electric power in the Eastern United States and is physically located near the many metropolitan load centers in New York, Pennsylvania, Delaware, and Maryland. As illustrated in Figure 1, coal-fired power plants account for nearly all 90% of WV's electricity generation [1]. The remaining 10% is comprised of natural gas, hydro and wind generation units. Of the more than 16,500 MW of power generated in the state, approximately 80% is exported.

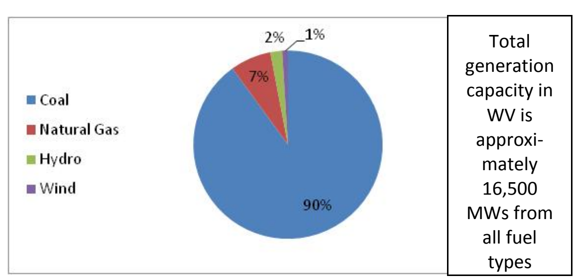

Fig. 1: WV generating capacity by fuel type [1]

Although there are consumer-owned back-up generators located at sites throughout the state, the actual numbers are not known and they are incapable of operating in a grid connected mode. Additionally, there are no incentives in place to entice customers to provide utilities access to this generation. Available distributed generation capacity is also constrained by the allotment by class of consumer in WV. Most of this generation would be expected to be owned by commercial and industrial customers. However, the number of these classes of customers in WV is well below the national average, as shown in Table 1. The typical distribution between the classes of consumers is 1/3 residential, 1/3 commercial and 1/3 industrial.

TABLE 1: WV CONSUMERS BY CLASS [2]

Residential	848,099
Commercial	130,612
Industrial	11,972
Other	938
Total	**992,559**

The transmission and distribution system was designed and built to deliver power in one direction only.

Transmission

West Virginia transmission is predominately owned and operated by American Electric Power (AEP) and Allegheny Power (AP) [3]. The AP transmission system in WV consists primarily of 500 kV and 138 kV lines. The AEP transmission system in WV is composed of 138 kV, 345 kV, and 765 kV transmission lines. There are 364 transmission substations from 69 kV up to 765 kV, most of which are monitored by Supervisory Control and Data Acquisition (SCADA) systems.

Distribution

The distribution system in WV is primarily composed of the assets of the two major utilities, AEP and AP. The distribution system of AEP in WV consists of approximately 21,150 miles of primarily 12 kV and 34 kV systems that are stepped down to the customer supply voltage at or near the customer point of delivery with about 22 customers per mile on average in AEP's service territory. The distribution system of AP in WV consists of approximately 26,163 miles of primarily 13 kV and 34 kV circuits that are stepped down to the customer supply voltage at or near the customer point of delivery with nearly 18 customers per mile on average in Allegheny Power's service territory.

Reliability Data for the State of WV

Reliability was measured using IEEE 1366 indices. West Virginia customer interruptions for both companies were nearly twice the national average of 106 minutes per year based on the Customer Average Interruption Duration Index (CAIDI). CAIDI can also be viewed as the average restoration time. Based on WV CAIDI figures the average time to restore a power outage in WV was more than 3½ hours. The number of customer complaints to the WV Public Service Commission (PSC) has exhibited a slight general trend upwards over the past decade as illustrated in Figure 2. Notice that there were approximately twice as many complaints in 2008 as there were a decade ago.

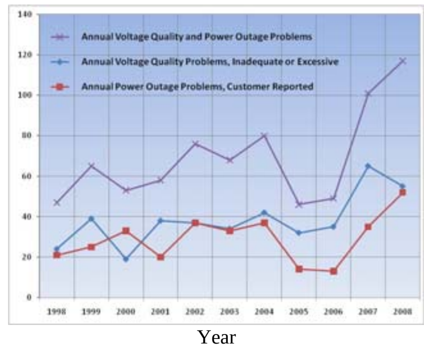

Fig. 2: WV Electricity Service Problems

Substations

There are a total of 813 substations in the state of WV, 449 of which are part of the distribution system. Less than half of these substations are monitored by SCADA systems.

PROPOSED SMART GRID SOLUTIONS

The same reliability and resiliency deterrents that have lead to the state's problems also make the state well suited for the application of distributed resources and smart grid technologies. To address the issues of reliability and resiliency, a smart grid development plan was constructed based on a gap analysis which considered the current state of the grid in WV and an attainable future state with added smart grid features to enhance reliability and resiliency developed by a team of experts. Table 2 provides a list of the identified gaps and the proposed solutions.

TABLE 2: IDENTIFIED GAPS AND PROPOSED SMART GRID SOLUTIONS [2]

Gap	Solutions
Technology	• Advanced Meter Infrastructure • Information Technology Integration • Demand Response • Distribution Management Systems • Distributed Energy Resource • Transmission Management Systems
Regulatory/ Governmental	• Inclusion of Smart Grid investments in rate base • Rate structures that encourage DER, DR and differentiated PQ • Federal and state funding of related R&D • Change in regulatory policy to create incentives or remove dis-incentives for investment Decisions based on socioeconomic analysis • Recovery of Smart Grid-driven stranded capital

Gap	Solutions
Consumer	• Consumer Education • Access by all consumers to the electrical market • DER interconnect standards • HANs and consumer agents • Standardized transfer of market information

ECONOMIC COST AND BENEFITS OF WV SMART GRID

The potential benefits and costs of the smart grid technologies identified in the gap analysis were quantified and monetized. Cost estimates were developed using published vendor data for the proposed solutions. Estimates of annual operational and maintenance costs were derived from data provided by utilities. Algorithms were developed to derive and to annualize benefits in instances where direct values were not available in published reports or obtainable from utilities. For example, the economic values for job creation as well as the number of jobs created related to smart grid investments in the state were derived using an IMPLAN model of WV. Reliability benefits for reduced consumer losses were derived by using Electric Power Research Institute [4] estimates for the cost of power outages and adjusting the values for inflation, distribution automation (DA) and smart grid device penetration and the percentage of preventable events with smart grid devices. Although space limitations preclude discussion of the derivation of all benefits associated with smart grid investments, the values for the most significant benefits are presented in Table 3.

TABLE 3: WV SMART GRID SOCIOECONOMIC BENEFITS BY CATEGORY [2]

Category	Benefit	$M/YR
Reliability	Reduced Consumer Losses	$898
	Reduce Power Quality Events	$131
Economic	Reduce Price of Electricity	$399
	Job Creation	$215
	Consumer Sales of DER Resources	$175
	Increased Energy Sales as Exports	$7
	Reduced Transmission Congestion	$1
	Increased Transportation Fuels Business	$5
	Consumer Conservation	$20
	Operational Savings	$194
Environmental	Reduced Emissions	$7
Security	Reduced Blackout Probability & Dependence on Foreign Oil	$13
Safety	Reduce Hazard Exposure	$1
Total		**$2,066**

From Table 3 it can be seen that the socioeconomic benefits generated from the smart grid investments total more than $2 billion annually which is approximately equal to 4.5% of the 2008 real WV GDP of $46.3 billion [5]. These smart grid investments would generate approximately 1900 jobs over the life of the project with annual estimated benefits to the WV economy of $215 million. When categorized by the recipient of the benefit the largest portion of these benefits are shown to accrue to consumers and society and the smallest proportion to be in the form of operational benefit to the utility as illustrated in Figure 3.

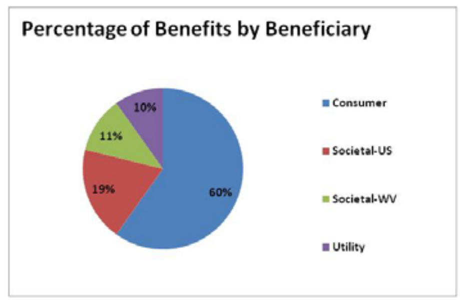

Fig. 3: Smart Grid Benefit Share [2]

This presents a problem if the investment decision were to be based solely on the utilities' cost and benefits because the burden of the capital investment cost falls upon the utilities while the majority of the benefits accrue to consumers and society. This results in the net benefits from the utilities' perspective being negative as illustrated in Figure 3 and in a benefit to cost ratio of less than one. Thus the likelihood of utilities making smart grid invests would be extremely low. Utilities cannot justify the majority of smart grid investments based on their returns on investment alone given the current market structures that exist in many states as exemplified by the West Virginia case. Policies are therefore needed to provide utilities with a mechanism to capture a share of the benefits accruing to consumers and society in order to stimulate smart grid investments.

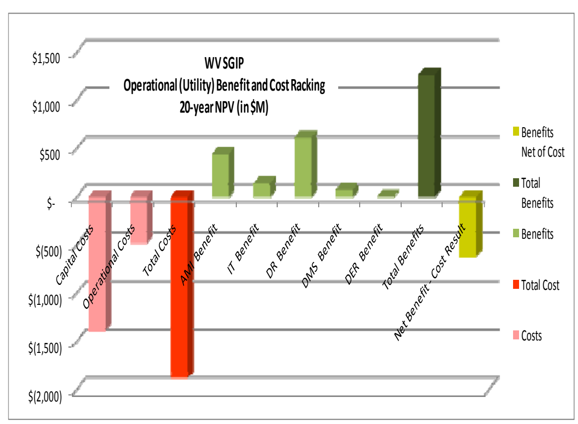

Fig. 4: Utility Net Benefits [2]

Those who benefit from such programs should pay for them. To elevate the free rider problem, tariffs need to be restructured in a fashion that provide the utilities with the ability to capture a sufficient portion of the benefits accruing to society and the consumer to justify capital investment in smart grid technologies. As can be seen from Table 4, if rates were restructured to enable the utility to capture a portion of the market benefits that would be realized by customers and society, smart grid investments could easily be justified.

TABLE 4: ECONOMIC ASSESSMENT OF THE WV SMART GRID INVESTMENT [2]

Economic Assessment of the West Virginia Smart Grid Investment Units = Million $			
Present Value @ 8% Discount Rate	**Society**	**WV**	**Utility**
Total Capital Expenditure	$1,878	$1,878	$1,878
Operational Benefits	$1,263	$1,263	$1,263
Consumer Benefits	$7,493	$7,493	----
WV Societal Benefits	$1,479	$1,479	----
US Societal Benefits	$2,389	----	----
Total Benefits	**$12,624**	**$10,235**	**$1,263**
Benefit/Cost NPV Ratio	**6.72**	**5.50**	**0.67**

If all benefits are factored into the investment decision, the benefits to cost ratio becomes 6.72. However if the U.S. societal benefits are excluded the benefits to cost ratio fall to 5.50.

CONCLUSIONS

The rugged terrain and sparse population present a unique set of challenges for managing assets and maintaining reliable service in the state. These same reliability and resiliency deterrents make the state well suited for the application of distributed resources and smart grid technologies. To address the issues of reliability and resiliency a smart grid implementation plan is devised based on a gap smart grid investments would significantly improve the reliability of the electric grid in WV. Based upon the smart grid solutions proposed in the study the number of consumer complaints to the WV PSC are projected to decrease significantly in the future as illustrated in Figure 5 (graphs 2 and 3; graph 3 being the ideal case, and graph 2 is a more conservative case). However, it is difficult to justify smart grid investments from the utilities' prospective, as can be seen from the benefits to cost ratio of 0.67 in Table 4.

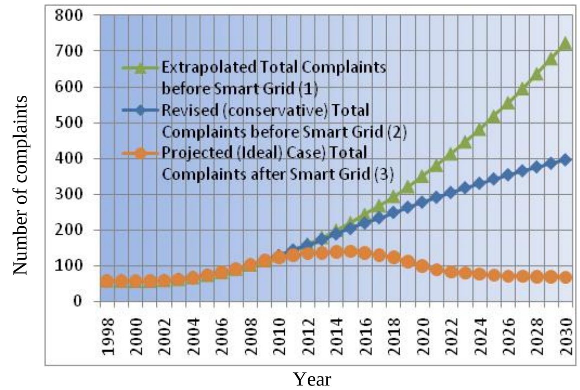

Fig. 5: Projected Future Consumer Complaints

A recovery mechanism which provides a sufficient return to the utility for the benefits that consumers and society would receive would facilitate these investments. A balanced approach of regulation and legislation with an emphasis on flexibility will position the state for future economic growth by providing reliable power for all consumers of the future.

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