# DETERMINATION OF DISTRIBUTED RESOURCES BENEFTIS IN A RESTRUCTURED INDUSTRY USING SYSTEM ANALYSIS METHODS

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## *SUMMARY:*

This paper discusses emerging distributed resources technologies (distributed generation and distributed storage) and identifies some of the power system operations benefits that may result from the increased deployment of these new technologies.

Most of the published information about new distributed generation and storage technologies focuses on first costs or capacity costs per kW, emissions data, availability data, and efficiency data. This kind of information will be needed by individual customers or groups of customers, to assist in making cost benefit decisions concerning distributed resources. However, making decisions about the deployment of distributed resources purely from the perspective of individual customers, does not necessarily help in addressing the new challenges of system operations in the open access, competitive, restructured electric power industry.

The thesis of this paper is that, after sufficient research, incentives should be provided to ensure that distributed resources are deployed to enhance system operations. Several system operations enhancements are possible. For example, the problem of increasing network congestion caused by increased power marketing, can be alleviated by the proper deployment and dispatch of distributed generation facilities. As another example, the energy lost in line losses, can be significantly reduced if system considerations are taken into account in deploying distributed resources. Other examples are cited in this paper. Distributed resources can facilitate the transition to regional reliability coordination, and help in addressing the new challenges associated with "global warming" and carbon dioxide emissions. This paper identifies areas in which research is needed to assist in making decisions about the optimal deployment of distributed technologies.

Finally, the results of preliminary studies are presented here to show the benefits that can be derived from using distributed resources from a power system operations point of view. These results are based on power flow studies using practical data representative of actual units.

## *POWER GENERATION TECHNOLOGIES:*

During the late 1960’s and early 1970’s, in the United States, the electric utility industry focused on installing large central station fossil and nuclear plants to achieve “economies of scale” and to keep up with rapid load growth. Today most of the electricity generated in the United States continues to be produced by the power generation units that were installed during the 60’s and 70’s. Currently load growth is much slower, on the order of one to two percent per year, but many aging generating plants need to be replaced or refurbished.

During the last decade, there has been a trend toward installing smaller gas-fired and combined-cycle units. These units are less expensive in terms of first costs, produce reduced emissions, and reduce the risk of investors during the current transition to deregulation and increased competition. It is likely that this trend will continue during the next few years and an increasing percentage of the generating mix will be from gas-fired generating units.

Looking to the future, electric power industry experts at the Electric Power Research Institute and the National Science Foundation believe that the emphasis in the power generation field will shift toward the development and deployment of “distributed generation” technologies. Geographically dispersed generating units may provide a more cost effective, more energy efficient, environmentally superior option – especially if combined with the new improved distributed storage technologies discussed in the next section of this paper. Some of the distributed generation options currently being considered include:

- Microturbines, resembling the turbochargers used in automobiles. The new microturbines are likely to be available in various sizes from 25 to 100 kW.
- Diesel engines are currently available in various sizes and are capable of producing up to 6,000 kW of power. In the future diesel engines may play an important role in providing standby power or for T&D support.
- Fuel cells, having the potential to further reduce emissions and offer high efficiency, are now commercially available. R&D is likely to produce fuel cells producing higher power outputs, up to 3,000 kW.
- Photovoltaic devices, are becoming less expensive. Some energy experts believe that photovoltaic devices

will be deployed in large quantities on the rooftops of houses and businesses to meet residential and commercial energy needs.

- Internal combustion engines, using conventional technologies, may provide up to 2,000 kW. Internal combustion engines are well suited for commercial cogeneration applications.
- Combustion turbines, using conventional technologies, may used more extensively to provide T&D support and for industrial applications. Dispersed large combustion turbine units could represent a viable replacement for aging central station units because they can provide as much as 100,000 kW.

## *DISTRIBUTED STORAGE:*

- The efficiency and effectiveness of the new distributed generation technologies can be improved by coupling them with new distributed storage technologies. Some of the distributed storage options currently being considered include:
- Batteries utilizing new technologies will have storage capacities as great as 5,000 kWh. Batteries may be deployed not only to store the energy from distributed generation but also to improve voltage regulation and power quality.
- Flywheels providing 700 to 1000 kW for a few seconds arenow being demonstrated. Some energy experts believe that flywheels could be mass produced to complement new distributed generation systems.
- Ultracapacitors, are envisioned as means of providing "ride-through capabilities." Multi-cell modules may potentially provide the power and energy needed in most distributed generation applications.

## *INTEGRATION OF DISTRIBUTED RESOURCES INTO SYSTEMS:*

Several issues should be considered in order to effectively integrate distributed resources into existing power systems.

1) There is a need to design interfaces and standard approaches to permit distributed resource technologies from multiple manufacturers to be used in a "plug and play" fashion. Standardization can reduce costs, improve operating performance, and encourage more rapid deployment.

2) There is a need to assess the impact of distributed resources on system reliability. Depending on the degree of distributed resources penetration, the component reliability of the various technologies, and future reserve margins, there could be increased or decreased service reliability relative to the current central supply situation.

3) With distributed resources local equipment may be needed to control the electrical frequency of supply to clocks, synchronous motors, and other electrical equipment that is sensitive to frequency deviations. In addition, new techniques may be needed for frequency control in interconnected power systems.

4) When distributed control systems are used with distributed resources it is possible that there will be conflicts with control systems used by energy distribution companies, transmission companies, independent system operators, and other "market participants." For example, local control systems may call for reducing distributed generation when overall system control systems require increased generation to meet peak demands.

5) New power system planning tools may needed in systems with a large number of distributed resources. There is a need to consider both the new economic opportunities associated with industry restructuring and the new control related problems resulting from the increased use of distributed resources.

6) Customers who own or operate distributed resources will need guidance and training concerning the electrical safety hazards posed by the new devices. Customers should also recognize their impact on the overall performance and integrity of power systems.

7) The current methods for steady state and transient stability analysis are based on assumptions that may not apply in systems with distributed resources. These methods generally assume all A.C. systems, large inertial constants, and groups of synchronous machines swinging together coherently. There is a need to consider new methods for stability analysis and stability control using distributed resources and new power electronics devices.

8) Current research, focusing on the increased use of variable speed drives and other power electronic loads, will need to have a broader focus to incorporate distributed resources considerations. Depending on the amount of distributed resources, new problems of unbalance and increased harmonic content may manifest themselves. New methods are needed for the analysis and control of power quality in distributed resources systems.

9) The regulatory mechanisms employed in the United States are currently being examined in the context of the transition to open access and deregulated electricity markets. There is a need to consider the role of federal, state, and local regulation with distributed resources. Scenarios should be considered in which customers, or groups of customers, are encouraged to install distributed resources to achieve system benefits.

10) The environmental consequences of the increased use of distributed resources need to be examined. New strategies for system planning and system operations can reduce the adverse environmental effects of electric power production and delivery. The current environmental programs addressing SO2 emissions, CO2 emissions, EMF, noise pollution, and solid waste streams have been designed around the traditional approach of having large centrally located power supplies and radial power distribution systems.

11) The methods currently used for maintenance scheduling, unit commitment and economic dispatching should be reviewed recognizing that having distributed resources may create new opportunities. Distributed resources may be committed as part of a unit commitment strategy to attain higher levels of economic efficiency. Distributed resources may be used in the economic dispatch to obtain increased reliability or improved environmental performance.

12) The system security applications and tools used in control centers should be redesigned to incorporate distributed generation and storage considerations. For example, the list of contingencies considered may be augmented to include failures in distributed resources equipment. Operator actions during blackouts may include using both utility owned and customer owned distributed resources. Distributed resources could also be incorporated in strategies to restore service or in strategies to switch to “island operations.”

13) Load forecasting methods should account for the increased use of distributed resources. New artificial intelligence methods or artificial neural networks approaches may be used to recognize patterns for loads in systems with distributed resources.

14) The DC power that is increasingly needed for home and business computers, telephones, and other electronics may be supplied directly from distributed resources systems. Inverters may be installed to meet AC requirements. The benefits of having access to DC power without rectification need to be compared with the challenges posed from having DC distribution systems.

15) Having distributed resources at the customer end of radial lines will complicate power system protection and relaying. However, the increased capability of the new micro-processor based relays may make help in addressing these more sophisticated protection problems. The traditional philosophies of protecting lines and generators to maintain customer service may change with distributed resources.

## *ILLUSTRATION OF DISTRIBUTED GENERATION BENEFITS:*

In order to illustrate how distributed generation can benefit system operations, two system conditions were simulated using power flow analysis and ETAP software (For more information about “ETAP” see reference number [3]). The first system condition represented the traditional (existing) case with power generation located at some distance from load centers. The second system condition represented the installation of distributed generation at load centers. As would be expected, the effect of installing distributed generation was to reduce the loads, reduce line flows and reduce line losses. This can be seen by comparing figures 1 and 2.

This power flow analysis illustrates that distributed resources can be used to relieve transmission congestion. Transmission congestion is one of the most pressing system operations concerns in the transition to a restructured, market based, competitive industry. Transmission operators will need methods to address the increased power purchases and sales over transmission systems which have accompanied the transition to the new open access business environment. Dispatching distributed resources may be seen as an alternative to canceling economic transactions or having to redispatch central generation.

Distributed resources also provide potential advantages as a means of reducing capital requirements and minimizing the financial risks associated with making new capacity investments. In fact, the use of distributed resources may represent the ultimate evolution of the trend toward competition and cooperation among utilities and non utility generators. Distributed generation provides a means of opening up generation markets and decentralizing decision making about electric system planning.

## *CONCLUSIONS:*

Large, central station, generation is not going to be replaced by distributed resource systems “overnight.” However, new distributed resources technologies are rapidly improving and becoming more cost competitive with traditional technologies. In addition, industry deregulation and increased emphasis on environmental performance can be seen as motivation for the increased the use of distributed resources. Some U.S. experts believe that distributed generation technologies may represent ten to thirty percent of the new generation installed by the year 2010 [10].

This paper has presented some of the opportunities and threats posed by distributed resources as seen from a system operations point of view. The results of power flow studies were included to indicate that distributed resources can enhance system operations by reducing line flows and line losses.

The importance of the world-wide trend toward the increased use of distributed resources and dispersed generation has been recognized by the leading technical and professional societies. Notably, CIRED has formed a working group on dispersed generation to gather data from a number of countries and assess the impacts.

New power system planning and operating tools and additional data will be needed to effectively use the new distributed technologies and take full advantage of the system benefits which are possible. However, the technical challenges associated with the increased use of distributed resources may be less formidable than the institutional challenges. Adopting new technologies and new business models will be difficult as regulatory bodies in the United States struggle with the challenges of electric power industry restructuring and improving environmental performance.

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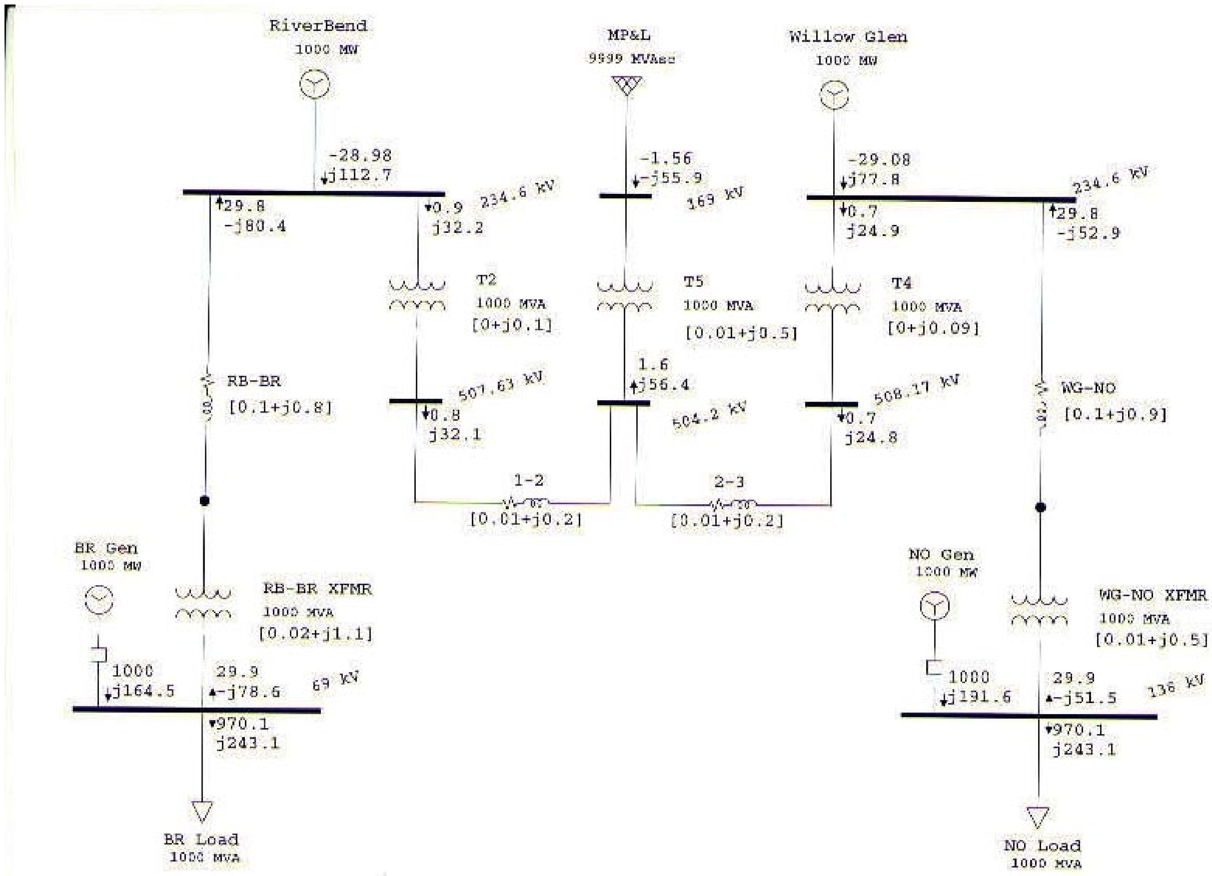


**Figure 1. Traditional Power System with Generating Plants located far away from Load Centers.**

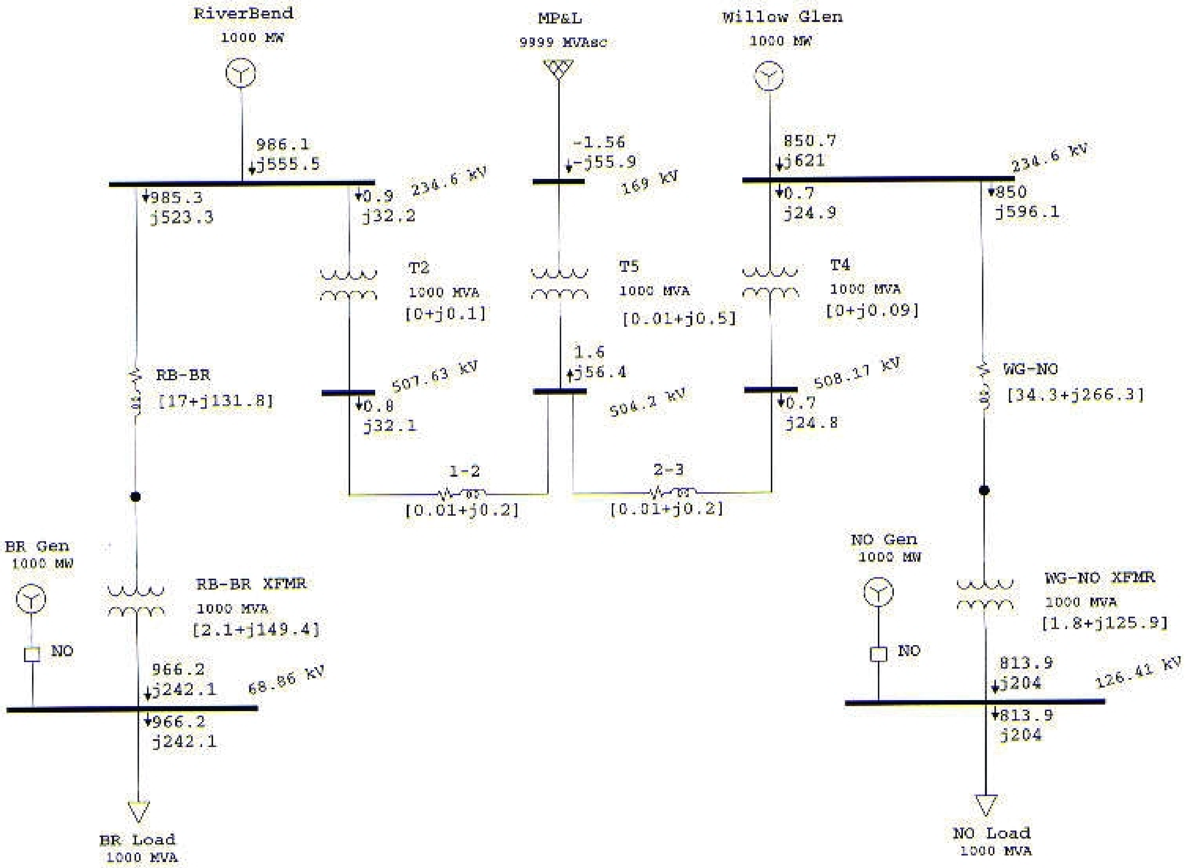


**Figure 2. Future Power System with Distributed Generation located near (or at) Load Centers to reduce Transmission Line Flows and Line Losses**