International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Smart Grid Simulation of Renewable Energy Integration and Demand Response Analysis

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Abstract: ***The development of the Smart Grid concept is the pathway for assuring high reliability, control and management requirements in future electric power distribution systems. The proposed vision of introducing viable Smart Grid at various levels in the Indian power systems has recommended that an advanced automation mechanism needs to be adapted. Smart grids have been proposed as a way to increase grid robustness and reduce consumption peaks and at the same time decrease electricity costs for the end users. The aim is to develop simulation models for smart grids focusing on smart houses. Smart industries which are used to test if it is possible to reduce consumption peaks and at the same time increase grid stability. This paper proposes and develops a flexible simulation framework to study the behaviors and impacts of smart grid enabled renewable energy source at demand side, introduce demand response and analyzes the impact of renewable energy on demand response and load balancing.***

Keywords: Smart grid, Renewable Energy (RE), Demand Response (DR), Demand Side Management (DSM)

1. Introduction

IN the modern smart grid, the diversity of loads and the demands for highly efficient consumption, as well as the use of renewable energy (solar, wind, biomass energy, etc.) generation and grid connection technology through the power electronics interfaces, have brought great challenges to governing power quality. Compared with the traditional power system, the micro grid or distributed power plant, which integrates a variety of energy inputs, multiple load characteristics, and varied energy conversion technologies, is a nonlinear and complex system with inter-coupling of chemical energy, thermodynamics and electrodynamics. Meanwhile, due to the limitation of natural resources, the distributed generations (DGs) appear the features of intermittency, complexity, diversity and instability. Accordingly, some new problems with novel features occur in maintaining power quality. Therefore, power quality control theory and technology will play an important role in ensuring the stable and secure operation of the power grid when micro grids or distributed power plants are connected to it. In the Indian national program for long and medium-term scientific and technological development (2010-2030), it is specifically mentioned that the analysis, detection, and control technology for power quality should be a priority objective in the energy field, and it is highly recommended to promote to renewable source and to control the power quality actively.

Electric power systems constitute the fundamental infrastructure of modern society. Often continental in scale, electric power grids and distribution networks reach virtually every home, office, factory, and institution in developed countries and have made remarkable. The connection of distributed resources, primarily small generators at the moment, is growing rapidly. The extent of interconnectedness, like the number of sources, controls, and loads, has grown with time. In terms of the sheer number of nodes, as well as the variety of sources, controls, and loads, electric power grids are among the most complex networks ever made.

2. General Features of Smart Grid

The term “smart grid” refers to the use of computer, communication, sensing, and control technology which operates in parallel with an electric power grid for the purpose of enhancing the reliability of electric power delivery, minimizing the cost of electric energy to consumers, and facilitating the interconnection of new generating sources to the grid

A smart grid may be defined in a number of ways. In simple words, smart grid is an electric grid that employs monitoring, control, communication, and self-healing capabilities to efficiently deliver reliable, economic, and sustainable electricity services. Smart grid has different aspects and can be characterized as follows:-

- “Self-healing” from power disturbance events. Enabling active participation by consumers in de-response
- Operating resiliently against physical and cyber attacks.
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently.

End-to-end electric power system (from fuel source, to generation, transmission, distribution, and end use) of the future will:

- Allow secure and real-time 2-way power and information flows
- Enable integration of intermittent renewable energy sources and help decarbonizes power system
- Enable effective demand management, customer choice, secure and efficient operation of the grid
- Enable the secure collection and communication of detailed data regarding energy usage to help reduce demand and increase efficiency.

3. Demand Side Power Management

Smart Grid demand side power management describe following attributes-

- Deployment and integration of demand response, demand side resources and energy efficiency resources.
- Deployment and integration of distributed resources and generation, including renewable resources.
- Deployment of smart technologies for metering, communications concerning grid operations/status and distribution automation.
- Adoption of Demand Side Management (DSM) techniques like volt/VAR control, voltage reduction, etc.
- Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, etc.

A. Demand Response

Demand response (DR) refers to mechanisms to manage the demand from customers in response to supply conditions, for example, having electricity customers reduce their consumption at critical times or in response to market prices. There has been a recent upsurge in interest and activity in demand response, primarily due to the tight supply conditions in certain regions of the country that have created a need for resources that can be quickly deployed. Demand response can broadly be of two types, incentive-based demand response and time-based rates. Incentive based demand response includes direct load control, interruptible/curtails able rates, demand bidding/buyback programs, emergency demand response programs, capacity market programs, and ancillary services market programs.

Time-based rates include time-of-use rates, critical peak pricing, and real-time pricing. Incentive-based demand response programs offer payments for customers to reduce their electricity usage during periods of system need or stress and are triggered either for reliability or economic reasons. A range of time-based rates is currently offered directly to retail customers with the objective of promoting customer demand response based on price signals. These two broad categories of demand response are highly interconnected, and the various programs under each category can be designed to achieve complementary goals.

B. Demand Side Power Management

"Demand-side power management is the planning, implementation and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e., changes in the time pattern and magnitude of a utility's load. Utility programs falling under the umbrella of demand-side management include load management, new uses, strategic conservation, electrification, customer generation and adjustments in market share."

Demand-side management is even more encompassing than the above definition implies because it includes the management of all forms of energy at the demand side, not just electricity. In addition, groups other than just electric utilities (including natural gas suppliers, government organizations, nonprofit groups, and private parties) implement demand-side management programs. In general, demand-side management embraces the following critical aspects of energy planning:
Demand-side management will influence customer use. Any program intended to influence the customer's use of energy is considered demand-side management.

Demand-side management must achieve selected objectives. To constitute a desired load shape change, the program must further the achievement of selected objectives.

Demand-side management will be evaluated against no demand-side management alternatives. The concept also requires that selected demand-side management programs further these objectives to at least as great an extent as no demand-side management alternatives, such as generating units, purchased power or supply-side storage devices. In other words, it requires that demand-side management alternatives be compared to supply-side alternatives. It is at this stage of evaluation that demand-side management becomes part of the integrated resource planning process.

Demand-side management value is influenced by load shape. Finally, this definition of demand- side management focuses upon the load shape. This implies an evaluation process that examines the value of programs according to how they influence costs and benefits throughout the day, week, month, and year.

C. Integration of Renewable Energy Source

In case of smart grid, Renewable Energy has been one of the rising trends in the field of Energy engineering. Renewable energy system has its source over the renewable resources such as solar, wind, tidal, wave, biomass etc. Power extraction through tidal and wave energy is bounded due to less availability; lack of technological Improvements these components, incorporating the applicable criteria that Follow. Distributed RE sources may potentially delay upgrade of transmission and distribution infrastructures with increasing demand. Therefore, RE resources at the residential level should be utilized to get the most benefits out of residential demand response (DR) programs.

4. Distribution end Power Management

Demand side centric flexible simulation framework proposed a simulation framework that is open to integration of different components under the smart grid infrastructure, and puts more emphasis on the residential demand side of the story.

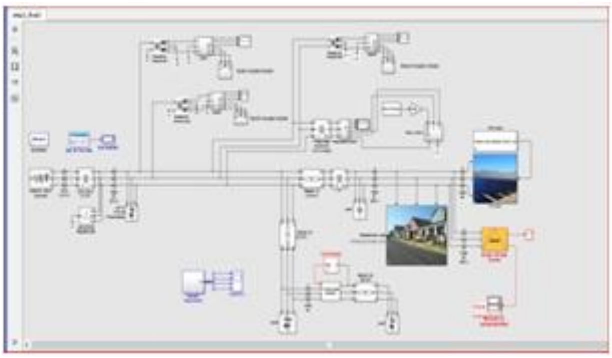

Figure 1: Distribution End with PV's Integration to Grid

This framework aims at providing an easy interface for implementing different appliance coordination algorithms and performing simulation tests with minimal effort.

Load Models

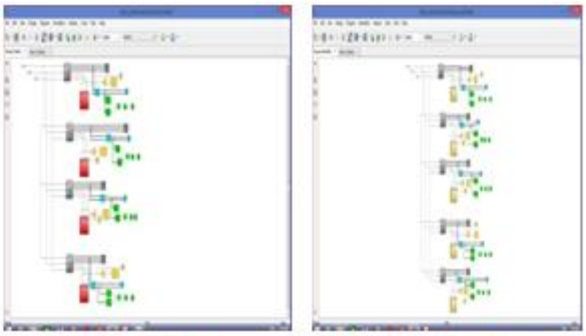

Figure 2: Load Neighborhood Model

5. Simulation Results

Load data

Smart grid power system incorporating residential homes, residential industry with electric appliances from the demand side and renewable energy generation mix representing the distribution side. Solar power was added to the distribution end, industry, and homes.

Figure 3: Load data

RE was added to the distribution end, industry's, homes and it changes demand Response and peak demand. Demand response in principle can enhance the overall system operation. Positive outcomes are especially associated with the increased level of penetration of variable renewable electricity generation made possible by demand response and grid operation reliability**.**

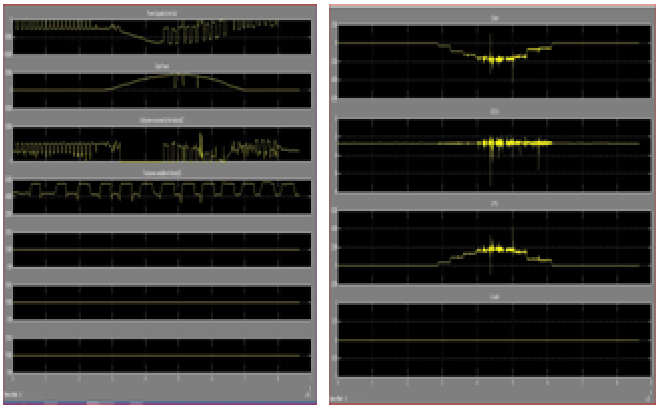

Figure 4: Effect of RE on Voltage current and Power Plot

Integration of Renewable source at distribution end to reduced power demand and improves grid stability and reliability with much reliable and secure the grid sudden change in load. It help to improves voltage profile, active power and reactive power and also improve voltage regulation and grid efficiency.

In addition to optimization of Smart grid operation, the controller has to perform several critical activities which are common for any type of control architecture. Some of the key issues to be taken care of by the controller especially during islanded mode of operation are as follows.

a. ***Voltage and current control*****:** During operation the primary or intermediate energy sources have to be controlled to adjust voltage and current to match the operation of loads connected in the grid. In worst case, the load should be disconnected by the controller.

b. Supply and Demand Balance: This is more of an optimization function during grid connection operation. However in the islanded mode, available storage should be used. In addition, the 8 controller should incorporate demand response events during this phase of operation to ensure reliability and security of the whole or part of the system.

c. ***Power Quality*****: Power quality*****:*** should be maintained for grid in islanded operation with sufficient supply of reactive energy to shrink voltage sags. The energy storage devices should react rapidly to frequency and voltage change by charging/discharging.

6. Conclusion

There is significant potential to increase the functionality of typical demand-side management measures, typical demand response strategies, and typical implementation of building-level distributed energy resources by combining them in a cohesive, networked package that fully utilizes smart energy-efficient endues devices, advanced whole-building control systems. Analyzes the introduction effect of demand side management such as improvement rate of supply and demand balance and increasing quantity of renewable energy, Easy setting change of the grid and demand side condition by the adoption of module architecture and effective simulation is possible.

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