A Review on Power System Management Based on Smart Grid

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Abstract - The advancement in power electronics and digital control technology, the DG systems can be actively controlled to enhance the system operation with improved PQ at PCC. The use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which deteriorate the quality of power. A converter is being used which can be used both as a rectifier and an inverter. A battery is used as a storage system which stores the extra energy produced from the grid and supplies it back to the grid when needed. A bidirectional converter is used which can be used both as Homer generates output power productions and power consumptions.

I. INTRODUCTION

Electric utilities and end users of electric power are becoming concerned about meeting the growing energy demand. 75 percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. There has been an enormous interest in countries on renewable energy for power generation. The market liberalization and government's incentives have accelerated the renewable energy sector growth.

Renewable energy source (RES) distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it poses a threat to network in terms of stability, voltage regulation and power- quality (PQ) issues. The DG systems are required to comply with technical and regulatory frameworks to ensure safe, reliable and efficient operation of network. The advancement in power electronics and digital control technology, the DG systems can be actively controlled to enhance the system operation with improved PQ at PCC. The use of power electronics based equipment and non- linear loads at PCC generate harmonic currents, which deteriorate the quality of power.

1. DISTRIBUTED GENERATION

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized facilities, such as fossil fuel (coal, gas powered) nuclear or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and negatively affect the environment.

For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace. In addition, such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling. Distributed generation is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed.

Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers and large complex plants to reduce pollution. However, modern embedded systems can provide these traits with automated operation and renewable, such as sunlight, wind and geothermal. This reduces the size of power plant that can show a profit.

1.1 Distributed energy resource

Distributed energy resource (DER) systems are small-scale power generation technologies (typically in the range of 3 kW to 10,000 kW) used to provide an alternative to or an enhancement of the traditional electric power system. The usual problems with distributed generators are their high costs. One popular source is solar panels on the roofs of buildings. The production cost is $0.99 to 2.00/W (2007) plus installation and supporting equipment unless the installation is Do it yourself (DIY) bringing the cost to $6.50 to 7.50 (2007).

This is comparable to coal power plant costs of $0.582 to 0.906/W (1979), adjusting for inflation. Nuclear power is higher at $2.2 to $6.00/W (2007).[4] Some solar cells ("thin-film" type) also have waste disposal issues; since "thin- film" type solar cells often contain heavy-metal electronic wastes, such as Cadmium telluride (CdTe) and Copper indium gallium selenide (CuInGaSe), and need to be recycled.

As opposed to silicon semi- conductor type solar cells whichis made from quartz. The plus side is that unlike coal and nuclear, there are no fuel costs, pollution, mining safety or operating safety issues. Solar also has a low duty cycle, producing peak power at local noon each day. Average duty cycle is typically 20% .

Another source is small wind turbines. These have low maintenance, and low pollution. Construction costs are higher ($0.80/W, 2007) per watt than large power plants, except in very windy areas. Wind towers and generators have substantial insurable liabilities caused by high winds, but good operating safety. In some areas of the US there may also be Property Tax costs involved with wind turbines that are not offset by incentives or accelerated depreciation.

Wind also tends to be complementary to solar; on days there is no sun there tends to be wind and vice versa. Many distributed generation sites combine wind power and solar power such as Slippery Rock University, which can be monitored online.

Distributed cogeneration sources which uses the natural gas-fired micro turbines or reciprocating engines to turn generators. The hot exhaust is then used for space or water heating, or to drive an absorptive chiller [6] for air-conditioning. The clean fuel has only low pollution. Designs currently have uneven reliability, with some makes having excellent maintenance costs, and others being unacceptable. Co generators are also more expensive per watt than central generators.

They find favor because most buildings already burn fuels, and the cogeneration can extract more value from the fuel. Some larger installations utilize combined cycle generation. Usually this consists of a gas turbine whose exhaust boils water for a steam turbine in a Rankine cycle. The condenser of the steam cycle provides the heat for space heating or an absorptive chiller. Combined cycle plants with cogeneration have the highest known thermal efficiencies, often exceeding 85%.

In countries with high pressure gas distribution, small turbines can be used to bring the gas pressure to domestic levels whilst extracting useful energy. If the UK were to implement this countrywide an additional 2-4 GWe would become available.(Note that the energy is already being generated elsewhere to provide the high initial gas pressure - this method simply distributes the energy via a different route.)Future generations of electric vehicles will have the ability to deliver power from the battery into the grid when needed. This could also be an important distributed generation resource.

DES directly supply loads with power (standalone mode or standby mode), while, when DES have surplus power or need more power, this system operates in parallel mode to the mains. Therefore, in order to permit to connect more generators on the network in good conditions, a good technique about interconnection with the grid and voltage regulations should overcome the problems due to parallel operation of Power Converter for applications to DES.

1.2 Distributed Energy Systems

Today, new advances in technology and new directions in electricity regulation encourage a significant increase of distributed generation resources around the world. As shown in Fig. the currently competitive small generation units and the incentive laws to use renewable energies force electric utility companies to construct an increasing number of distributed generation units on its distribution network, instead of large central power plants. Moreover, DES can offer improved service reliability, better economics and a reduced dependence on the local utility.

Distributed Generation Systems have mainly been used as a standby power source for critical businesses. For example, most hospitals and office buildings had stand-by diesel generation as an emergency power source for use only during outages. However, the diesel generators were not inherently cost- effective, and produce noise and exhaust that would be objectionable on anything except for an emergency basis.

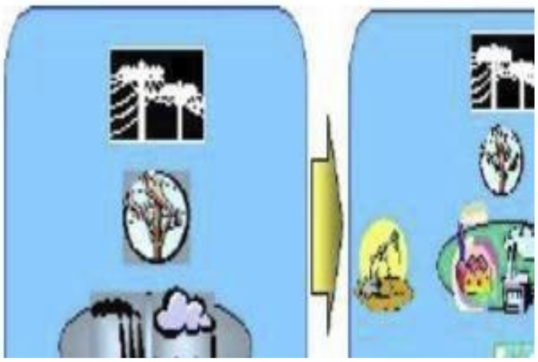

Fig. 1: A large central power plant and distributed energy systems

Meanwhile, recently, the use of Distributed Energy Systems under the 500 kW level is rapidly increasing due to recent technology improvements in small generators, power electronics, and energy storage devices. Efficient clean fossil fuels technologies such as micro-turbines and fuel cells, and environmentally friendly renewable energy technologies such as solar/photovoltaics, small wind and hydro are increasingly used for new distributed generation systems. These DES are applied to a standalone, a standby, a grid-interconnected, a cogeneration, peak shavings, etc. and have a lot of benefits such as environmental-friendly and modular electric generation, increased reliability, high power quality, uninterruptible service, cost savings, on- site generation, expandability, etc.

1.3 Problem Statements

DES technologies have very different issues compared with traditional centralized power sources. For example, they are applied to the mains or the loads with voltage of 480 volts or less; and require power converters and different strategies of control and dispatch. All of these energy technologies provide a DC output which requires power electronic interfaces with the distribution power networks and its loads. In most cases the conversion is performed by using a voltage source inverter (VSI) with a possibility of pulse width modulation (PWM) that provides fast regulation for voltage magnitude. Power electronic interfaces introduce new control issues, but at the same time, new possibilities. For example, a system which consists of micro-generators and storage devices could be designed to operate in both an autonomous mode and connected to the power grid. One large class of problems is related to the fact that the power sources such as micro turbines and fuel cell have slow response and their inertia is much less.

It must be remembered that the current power systems have storage in generators' inertia, and this may result in a slight reduction in system frequency. As these generators become more compact, the need to link them to lower network voltage is significantly increasing.

However, without any medium voltage networks adaptation, this fast expansion can affect the quality of supply as well as the public and equipment safety because distribution networks have not been designed to connect a significant amount of generation.

Therefore, a new voltage control system to facilitate the connection of distributed generation resources to distribution networks should be developed. In many cases there are also major technical barriers to operating independently in a standalone AC system, or to connecting small generation systems to the electrical distribution network with lower voltage and the recent research issues includes:

1. Control strategy to facilitate the connection of distributed generation resources to distribution networks. Efficient battery control.
2. Inverter control based on only local information. Synchronization with the utility mains. Compensation of the reactive power and higher harmonic components.
3. Power Factor Correction.
4. System protection.
5. Load sharing.
6. Reliability of communication.

7. Requirements of the customer. DES offers significant research and engineering challenges in solving these problems. Moreover, the electrical and economic relationships between customers and the distribution utility and among customers may take forms quite distinct from those we know today.

For example, rather than devices being individually interconnected in parallel with the grid, they may be grouped with loads in a semi-autonomous neighborhood that could be termed a micro grid is a cluster of small sources, storage systems, and loads which presents itself to the grid as a legitimate single entity. Hence, future research work will focus on solving the above issues so that DES with more advantages compared with tradition large power plants can thrive in electric power industry.

1.4 Problem Description

These new distributed generations interconnected to the low grid voltage or low load voltage cause new problems which require innovative approaches to managing and operating the distributed resources. In the fields of Power Electronics, the recent papers have focused on applications of a standby generation, a standalone AC system, a combined heat and power (cogeneration) system, and interconnection with the grid of distribution generations on the distribution network, and have suggested technical solutions which would permit to connect more generators on the network

in good conditions and to perform a good voltage regulation. Depending on the load, generation level, and local connection conditions, each generator can cause the problems described in the previous chapter.

2. RENEWABLE ENERGY SOURCES

Energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat is termed as renewable energy. The most common definition is that renewable energy is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed. Renewable energy is a subset of sustainable energy.

2.1 Renewable Energy Development in India

India has done a significant progress in the power generation in the country. The installed generation capacity was 1300 megawatt (MW) at the time of Independence i.e. about 60 year’s back. The total generating capacity anticipated at the end of the Tenth Plan on 31-03- 2007, is 1, 44,520 MW which includes the generation through various sectors like Hydro, Thermal and Nuclear. The power generation in the country is planned through funds provided by the Central Sector, State Sector and Private Sector.

The power shortages noticed is of the order of 11% . In the opinion of the experts such short fall can be reduced through proper management and thus almost 40% energy can be saved. It has been noticed that one watt saved at the point of consumption is more than 1.5 watts generated. In terms of Investment it costs around Rs.40 million to generate one MW of new generation plant, but if the same Rs.40 million is spent on conservation of energy methods, it can provide up to 3 MW of avoidable generation capacity.

There are about 80,000 villages yet to be electrified for which provision has been made to electrify 62,000 villages from grid supply in the Tenth Plan. It is planned that participation of decentralized power producers shall be ensured, particularly for electrification of remote villages in which village level organizations shall play a crucial role for the rural electrification programme.

Since the availability of fossil fuel is on the decline therefore, in this backdrop the norms for conventional or renewable sources of energy (RSE) is given importance not only in India but has attracted the global attention. Evolution of power transformer technology in the country during the past five decades is quite impressive. There are manufacturers in the country with full access to the latest technology at the global level. Some of the manufacturers have impressive R&D set up to support the technology.

3. ARCHITECTURE OF THE MODEL

For modeling the smart grid mainly three renewable energy sources have been used which are solar PV, wind and biomass energy. The system is designed considering a community having 30 apartments. In load calculations, it has been considered that each apartment has 8 lights, 4 fans, 1 TV, 1freeze, 3 laptops, 1 iron, 1 blender and 1 pump. For each apartment 2 lights and 1 fan have been considered to be fixed loads and for home appliances, others loads are assumed to be variable loads. A converter is used which can be used both as a rectifier and an inverter. A battery is used as a storage system which stores the extra energy produced from the grid and supplies it back to the grid when needed. Figure 1 shows the block diagram of the smart grid where monitoring and energy storage are used for design. Three resources, one bidirectional converter, one battery as a storage system are used along with two types of the load

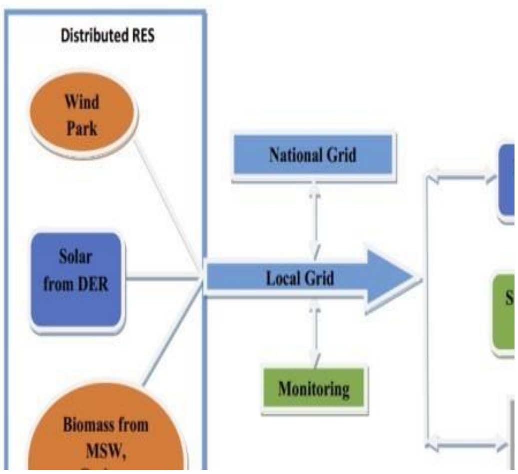

Fig. 2 proposed model

The load calculations are done using standard forms of the utilities. The HOMER based analysis focuses on balancing as well as the maximization of power production and consumption. Figure 2 shows the HOMER implementation of the mode

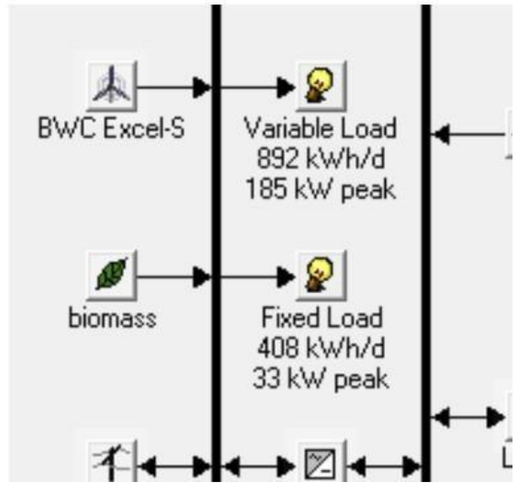

Fig. 3 distribution set up

The designed model shown in the figure [3] is then analyzed using MATLAB. Then GUI is used to design a user friendly, smart meter simulation model. The developed GUI model -'sMeter_v2015a' can take input time data variables and then show the total consumption, solar, wind, biomass output, total production, total sell & buy in based on the real time data. The user has the flexibility to change the time and observe the response faster and have an approximate idea how much electricity can be stored or supplied.

4. CONCLUSION

This thesis has presented a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a3-phase 4-wireDGsystem. It has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. This is review paper for the proposed survey research.

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