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ANALYSIS OF POWER LOSS IN THE DISTRIBUTED TRANSMISSION LINES OF SMART GRID

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Abstract - *From past decades, the demand for electricity is rapidly increasing. Science and technology with all its miraculous advancements has fascinated human life to a great extent that imagining a world without these innovations is hardly possible. An integrated environment with distributed generation sources, a good transmission management system, Outage management system etc. are also inevitable in this environment. All these have to be brought into the existing power grid in a very cost effective manner. A smart grid is an evolved grid system that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved. Smart grid will make use of technologies such as state estimation that improve fault detection and allow self healing of the network without the intervention of technicians that will ensure more reliable supply of electricity and reduced vulnerability to natural disaster or attacks. By monitoring it can provide information about power flow and demand and help to identify the cause of power system disturbances. Conventionally, the electricity power has one side of work flow which is from the supply to demand side. However, the purpose of future grid is to ensure the flow of electricity supply and demand should be in bi-directional way.*

Key Words: **Smart grid, power loss, transmission lines**

1. INTRODUCTION

Electrical energy is very imperative for everyday life and a backbone for the Industry. The power grid forms a bridge between electrical suppliers and consumers through interconnected networks. The electrical power grid consists of three main parts:

i) Generating plant for electric power.
ii) Transmission of the electric power.
iii) Distribution of the electric power.

The definition of smart grid is the networks that can intelligently integrate the behavior and actions of all users connected to it such as generators, transmission and consumers. Smart grid should have the ability to improve safety and efficiency, make better use of existing assets, enhance the reliability and power quality, reduce dependence on imported energy, and minimize costly environmental impact.

A smart grid is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources.

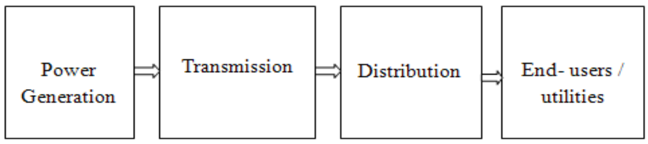

Fig1: Diagram of an electric power transmission system

Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid. Roll out of smart grid technology also implies a fundamental re-engineering of the electricity services industry, although typical using of the term is focused on the technical infrastructure. Numerous contributions to overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including demand-side management, for example turning off air conditioners during short-term spikes in electricity price, reducing the voltage when possible on distribution lines.

Demand response support allows generators and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators, cuts wear and tear and extends the life of equipment, and allows users to cut their energy bills by telling low priority devices to use energy only when it is cheapest. Currently, power grid systems have varying degrees of communication within control systems for their high-value assets, such as in generating plants, transmission lines, substations and major energy users. In general information flows one way, from the users and the loads they control back to the utilities.

The utilities attempt to meet the demand and succeed or fail to varying degrees (brownout, rolling blackout, uncontrolled blackout). The total amount of power demand by the users can have a very wide probability distribution which requires spare generating plants in standby mode to respond to the rapidly changing power usage. Demand response can be provided by commercial, residential loads, and industrial loads.

2. OVERVIEW OF SMART GRID AND TRANSMISSION LINES

Smart grid technologies emerged from earlier attempts at using electronic control, metering and monitoring. Once the power is generated from the alternator, it is send to the typical substation in the power plant where they step up the voltage by using the step-up transformers for transmission purposes. As the voltage is stepped up, it reduces the transmission losses. It is then sent to the power grid from where it is then transmitted to different cities. All the power generated in different places by different methods is stepped up and sent to a common place called the grid.

Next-generation transmission and distribution infrastructure will be better able to handle possible bi-direction energy flows, allowing for distributed generation such as from photovoltaic panels on building roofs, but also the use of fuel cells, charging to/from the batteries of electric cars, wind turbines, pumped hydroelectric power, and other sources. Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues. A smart grid aims to manage these situations.

Table -1: Comparison of Traditional Grid and Smart Grid

Traditional Grid	Smart Grid
Centralized Generation	Distributed Generation
Electromechanical	Digital
Failures and Blackouts	Adaptive and Islanding
Lack of real time monitoring	Extensive real time monitoring
Slow Reaction time	Extremely quick reaction time
Manual Restoration	Self-healing
One way Communication	Two way communication
No energy Storage	Energy Storage
Total control by Utility	Increased customer participation

A smart grid is a modern electric system, which uses communications, sensors, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It offers consumers increased choice by facilitating opportunities to control their use of electricity and respond to electricity price changes by adjusting their consumption and also it includes diverse and dispersed energy resources and accommodates electric vehicle charging. It facilitates connection and integrated operation. In short, it brings all elements of the electricity system production, delivery and consumption closer together to improve overall system operation for the benefit of consumers and the environment. The steps involved in supply of power are:
1. Generator supplies both real and reactive power down to the customer's location.
2. The ideal design is to have the transformer or supply feeders supply as much as Real power (MW) as they are rated for.
3. Other sources such as capacitor banks and line charging should then supply the Reactive power (MVAR) necessary to result in the transformer power factor being close to the unity.

In the traditional grid, the failure rate can only be reduced at the cost of more standby generators. In a smart grid, the load reduction by even a small portion of the clients may eliminate the problem. The smart grid helps to prevent outages, reduce storm impact, and restores service factor when outage occurs.

Engineers design transmission networks to transport the energy as efficiently as feasible, while at the same time taking into account economic factors, network safety and redundancy. Transmission efficiency is greatly improved by devices that increase the voltage, (and thereby proportionately reduce the current) in the line conductors, thus allowing power to be transmitted with acceptable losses. The reduced current flowing through the line reduces the heating losses in the conductors. According to Joule's Law, energy losses are directly proportional to the square of the current. Thus, reducing the current by a factor of two will lower the energy lost to conductor resistance by a factor of four for any given size of conductor.

3. CHALLENGES IN SMART GRID

Communication between each component in the smart grid is extremely important to maximize the use of available electrical power in a reliable and cost effective way. Therefore, how to efficiently manage the new, intelligent power system and integrate it into the existing system has become one of the main challenges for the smart grid infrastructure. The Key Challenges for Smart Grids are: Strengthening the grid, Enhanced intelligence, Communications, Integrating intermittent generation, moving offshore, capturing the benefits of DG and storage and Preparing of plug-in hybrid vehicles.

Renewable Energy Sources (RES) are intermittent in nature hence; it is therefore a challenging task to integrate renewable energy resources into the power grid. Further these challenges can be categorized into technical and non-technical issues, where

A. Technical Issues

1. Power quality
   a. Harmonics
   b. Frequency and voltage fluctuation
2. Power fluctuation
   a. Small time power fluctuations
   b. Long time or seasonal power fluctuations
3. Storage
4. Protection issues
5. Optimal placement of RES
6. Islanding.

B. Non- Technical Issues

1. Due to scarcity of technical skilled workers.

2. Less availability of transmission line to accommodate RES.

3. RES technologies are excluded from the competition which discourages the installation of new power plant for reserve purpose.

4. TRANSMISSION LOSSES AND OBSERVATIONS

Line faults may be caused due to over current or earth fault. Over current fault occurs. If there is a connection between two phase lines. Earth fault is due to the earthing of phase line through cross arm or any other way. Transmitting electricity at high voltage reduces the fraction of energy loss to resistance, which varies depending on the specific conductors, the current flow, and the length of the transmission line. For a given amount of power, a higher voltage reduces the current and thus the resistive losses in the conductor.

In general, losses are estimated from the discrepancy between power produced and power consumed; the difference between what is produced and what is consumed constitute transmission and distribution losses, assuming no theft of utility occurs.

The total quantity of electricity loss in transmission, substation and distribution with a given period in an electric supply area or power grid is called electricity line loss or line loss. The percentage of the electricity line loss in the electric supply is called the line loss rate, and its calculation formula is as follows:

Line loss rate = [Electric Supply – Power Sales Quantity] / [Electric Supply] x 100% ------- Eqn (1)

Calculation of Electric Energy Loss:

Electric Energy Loss ΔA (kW.h) is the integral of active power loss to time within a period, that is

$$\Delta A = \int_0^T \Delta P(t)\,dt \times 10^{-3} \qquad \text{------- Eqn (2)}$$

For resistance heat loss, the above equation can be rewritten as

$$\Delta A = \int_0^T I^2(t) R(t)\,dt \times 10^{-3} \qquad \text{------- Eqn (3)}$$

Factors that affect the resistance, and thus loss, of conductors used in transmission and distribution lines include temperature, spiraling, and the skin effect. The resistance of a conductor increases with its temperature. Temperature changes in electric power lines can have a significant effect on power losses in the line. Spiraling, which refers to the increase in conductor resistance due to the way stranded conductors spiral about the center, also contributes to increases in conductor resistance. The skin effect causes the effective resistance of a conductor to increase at higher alternating current frequencies.

Under excess load conditions, the system can be designed to fail gracefully rather than all at once. Brownouts occur when the supply power drops below the demand. Blackouts occur when the supply fails completely. Rolling blackouts (also called load shedding) are intentionally engineered electrical power outages, used to distribute insufficient power when the demand for electricity exceeds the supply.

A lack of electrical energy storage facilities in transmission systems leads to a key limitation. Electrical energy must be generated at the same rate which it is consumed. A sophisticated control system is required to ensure that power generation very closely matches demand. If the demand for power exceeds supply, the imbalance can cause generation plant(s) and transmission equipment to automatically disconnect and/or shut down to prevent damage. Electric transmission networks are interconnected into regional, national, and even continent wide networks to reduce the risk of such a failure by providing multiple redundant, alternative routes for power to flow should such shut downs occur. Transmission companies determine the maximum reliable capacity of each line (ordinarily less than its physical or thermal limit) to ensure that spare capacity is available in the event of a failure in another part of the network.

5. ADVANTAGES AND APPLICATIONS

5.1 Advantages

1. Smart grid enables better energy management by integrating isolated technology.
2. It enables proactive management of electrical network by automatically detecting and accordingly responding to the problems.
3. It can exactly determine from where the power has been stolen which was not able in the conventional power grid.
4. It provides power to the high priority based applications by easily routing the power distribution with less effort and time.
5. Smart grid improves power reliability, quality and also helps to reduce green house gas emissions.
6. It also provides a helping hand in expanding development of renewable and distributed energy sources.

5.2 Applications

Most transmission lines are high-voltage three-phase Alternating Current (AC), although single phase AC is sometimes used in railway electrification systems. High-Voltage Direct-Current (HVDC) technology is used for greater efficiency over very long distances (typically hundreds of miles). HVDC technology is also used in submarine power cables (typically longer than 30 miles (50 km)), and in the interchange of power between grids that are not mutually synchronized. HVDC links are used to stabilize large power distribution networks where sudden new loads, or blackouts, in one part of a network can result in synchronization problems and cascading failures.

Electricity is transmitted at high voltages to reduce the energy loss which occurs in long-distance transmission. Power is usually transmitted through overhead power lines. Underground power transmission has a significantly higher installation cost and greater operational limitations, but reduced maintenance costs. Underground transmission is sometimes used in urban areas or environmentally sensitive locations.

6. CONCLUSIONS

There are several issues in smart grid. The progress in technology about Electrical distribution network is a non–stop process. The transition towards a smart grid from the current electric grid is one of the most important decisions to meet electric reliability, economy, efficiency and sustainability goals. A Smart Grid can evolve, only through a well structured grid, efficient, reliable and secure communication technologies and integrated intelligent decision making capabilities associated with the structure.

To provide more efficient capability in smart grid, it needs to have the combination of several technology including communications, power electronics, Embedded Systems and control system. Normally, in power transmission system losses get reduces, if the generated energy is nearly equal to the consumed energy. Power loss is reduced in Smart Grid where the quality of transmission lines has to be improved. An exposure to the characteristic of smart grid together with technologies required to build a smart grid will provide an efficient transmission system with low power loss in Electric Power Transmission System. Smart grid will be an outcome of an evolutionary development of the existing electricity networks with an optimized and sustainable energy system.

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