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Role of Demand side Management in Reliability of Distribution Network

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Abstract— Demand side management (DSM) is of the most important feature of modern smart grids, enable the utility companies and customers to efficiently use the available power. Load are shifted from peak demand hours to off peak hours, that minimize the pressure on grid and make it most efficient and reliable. In this paper the reliability of a distribution network is tested for different scenario. In first scenario, base case the reliability is tested without demand side management in term of different reliability parameters. In second case part of load which is noncritical load, is shifted to off peak hour and reliability is tested that shows improvement in reliability. In third scenario the percentage of load shifted is increased and reliability is calculated. Similarly, the reliability of system is tested for different percentage of noncritical load shifted to off peak hours. Based on calculation of different scenarios, the best DSM scenario is evaluated that gives the best reliability and high efficiency of the system.

Keywords: Demand side Management (DSM), Smart Grid, Distribution Network, Peak Demand.

I. INTRODUCTION

Demand side management is one of the most important features of smart grid that enable the electricity provider to manage high load demand within the available energy resources. Based on the daily load demand of consumer noncritical loads are shifted from peak hours to off peak hours, this make the load demand curve flattened and hence the pressure on grid is minimized. Distribution network is a key part of the power system that facilitate the energy supply to the consumer from distribution grids. The reliability of this network is very important for continuous supply of electricity. So applying demand side management to distribution system make it an efficient, robust and reliable [1]. Demand side management encourage renewable energy (RE) integration in the system. The demand response (DR) strategy is used based on day ahead electricity prices provided by the utility companies to shift load to the low prices hours while fulfilling the customers need that help electricity consumer to reduce their electricity bills[2]. The residential loads controllable, uncontrollable and electric vehicle (EVs) are optimized through particle warm optimization (PSO), considering the realistic constrains and then the electricity bills are compared for different DR which shows a significant reduction in electricity bill [3]. Demand side management is used for residential peak shaving with integration of demand response and vehicle to home (V2H) [4]. With the advancement in transportation system the conventional vehicles are being converted to electrical vehicle (EV). However, these vehicles bring more pressure to the power grid especially to the distribution level. Energy management system (EMS) equipped with energy meter used DSM and charge management scheme of EV to limit the peak energy consumption [5]. The communication infrastructure between the distribution operator and household consumer monitor the peak demand and charging status of the vehicle, peak shaving is done through V2H based on charging status of vehicle. Effective DSM reduce loading stress on distribution system and its components that improve system reliability and therefore reduces the probability of failure [6]. So, applying DSM make the distribution system reliable that benefit both the customer and electricity providers. Customer have the choice to manage electricity consumption and reduce their electricity bills. Similarly, peak demand is reduced that benefit the electricity provider in saving their capital and operational cost. Demand side management is used for efficient energy use and elimination of energy wastage in a photovoltaic wind hybrid energy system which are not connected to the grid [7]. The daily load profile and the climate data is carefully observed which gives the total energy demand and the energy generation. Based on this data energy is managed by shifting demand from peak hours or the time of energy use is shift to off peak hours using load management unit [8]. Therefore, this management system increases the power efficiency, increase system reliability and prevent system failure. Demand side management greatly improve power system small signal stability and improve the performance of transmission and distribution system [9]. The small signal stability problem occurs as the steady increase in rotor angle due to insufficient synchronizing and damping torque. DSM is used to efficiently manage the available power by shifting loads from peak load time to offpeak time, so this ensure that total demand is managed and not to endanger the system performance in case of any fault. This improve distribution system performance, increase reliability and stability of the system [10].

II. Methodology

The methodology include a distribution system modeling in DIgSILENT, performing load flow analysis and reliability analysis. Demand side management is applied by shifting loads from peak hours to off-peak hours.

A. Modeling IEEE 33 Bus Distribution System

To assess the reliability of system a 33-bus model of distribution system is designed in DIgSILENT software which is an advance state of the art software for designing power system generation, transmission and distribution system. The propose system is a 1 MW radial distribution system and the power is supplied from an external grid. The external grid and main bus are slack (SL) bus that are taken as refence with voltage of 1 p.u and angle of zero degree. The system is designed such as it consists of three feeder and a total of 33 buses that distribute power to the consumer at 11KV. Distribution transformer of different rating based on consumer demand are installed on all buses to stepdown the voltage to the 400V and 230V for consumer use.

Table 1. System Components

No. of Busbars	34
No. of Lines	63
No. of Terminals	33
No. of Transformer	33
No. of Loads	66
No. of customer per load	2--16
Total Peak Load	1 MW
Total Losses in System	93KW

The loads consist of residential and small commercial load. Therefore, loads of different active and reactive power demand are connected to the system having total demand of 1MW. Load flow analysis is carried out to find the voltages magnitude, angle, currents, active and reactive power of all buses. Complete model of the system is shown the following figure.

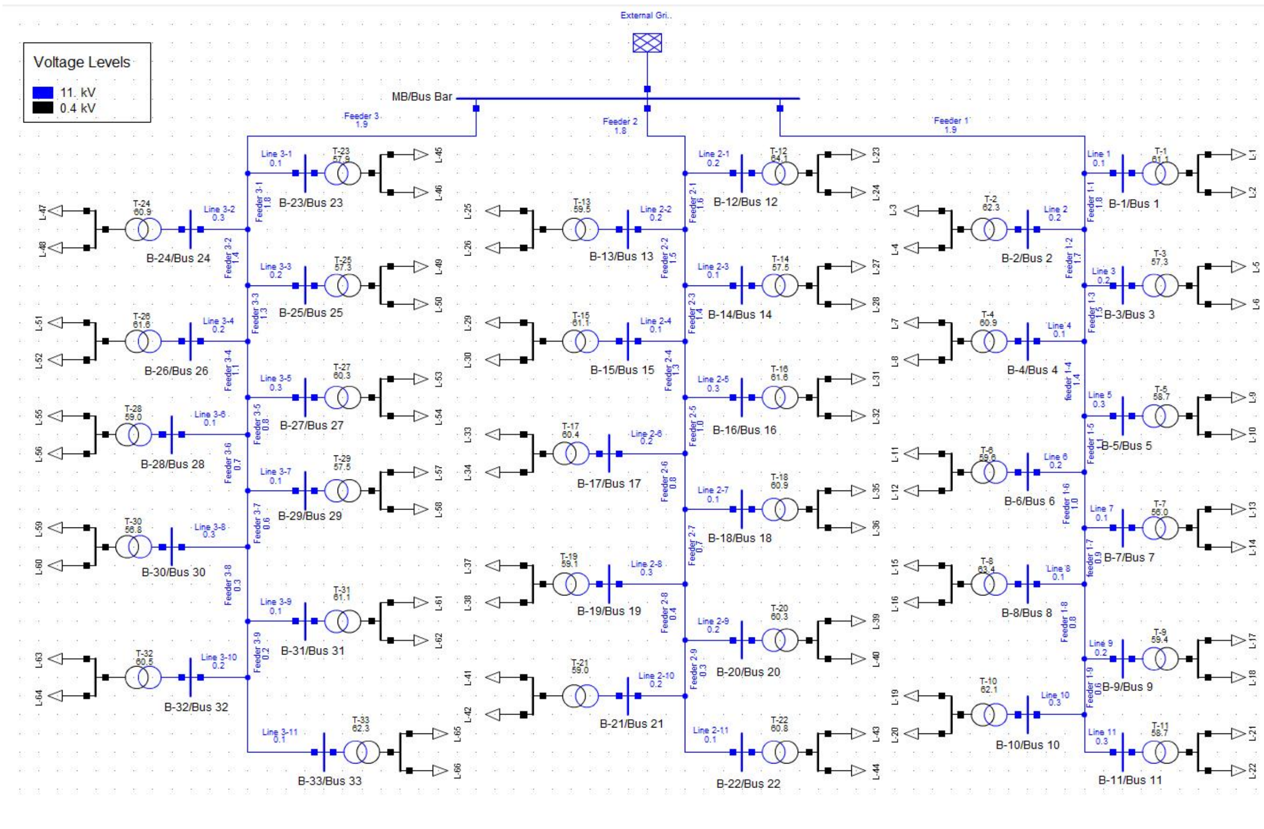

Figure 1. System Model

B. Load Flow Analysis

Load flow analysis is the most important and essential tool while doing power system planning and operation. The bus voltages, load angle, currents, active power and reactive power of the system is evaluated. That gives the loading condition of each component and ensure their operation within the optimum range. Moreover, the maximum capability of each component is finding, so that it can carry the load of adjacent component if it fails due to any faults. Load flow analysis is done by solving complex mathematical equations through an algorithm. Newton Raphson algorithm is used for load flow analysis which is built-in simulator in power factory.

1) Newton Raphson Method

Newton Raphson is an efficient load flow analysis algorithm based on solution set of simultaneous nonlinear equations. In power factory we define bus data, line data, generation data and load data, then load flow analysis calculate bus voltage, load angle, active and reactive power, current flow and the power losses in system.

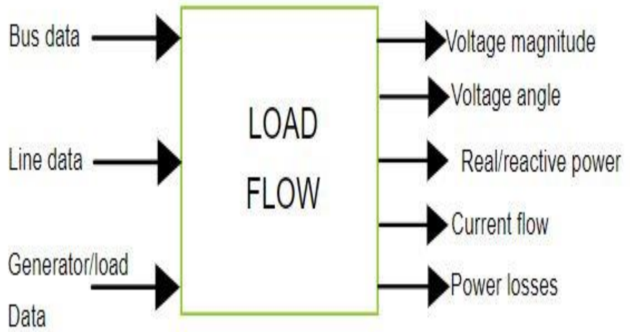

Figure 2. Load Flow

The iteration to solve the following mathematical equation of load flow analysis gives the active power, reactive power and load angle of the system.

$$S_i = VI^* = P + jQ \tag{1}$$

$$P - jQ = \sum_{j=1}^{n} Y_{ij}\, V_j V^* \tag{2}$$

Where Y_{ij} are the elements of bus admittance matrix

Here

$$Y_{ij} = |Y_{ij}| \angle Q_{ij} \ \ and \ \ V = |V| \angle \delta \tag{3}$$

$$P - jQ = \sum_{j=1}^{n} |Y_{ij}|\,|V_j||V| \angle(Q_{ij} + \delta_j - \delta) \tag{4}$$

$$P = \sum_{j=1}^{n} |Y_{ij}|\,|V_j||V|\, cos(Q_{ij} + \delta_j - \delta) \tag{5}$$

$$Q = -\sum_{j=1}^{n} |Y_{ij}|\,|V_j||V|\, Sin(Q_{ij} + \delta_j - \delta) \tag{6}$$

Where n is the number of buses and i= 1, 2, 3….n

After calculating the active power, reactive power and load angle the bus voltage, currents and power losses are calculated for the system.

C. Daily Load Demand

Daily load demand curve shows the hourly energy demand and consumption of power system. The proposed system is a distribution system, consist of residential and small commercial consumer. The load demand is low during daytime when peoples are in their workplaces, the demand increases when they arrive back and the system experience peak demand. Following figure shows the daily load demand of the system.

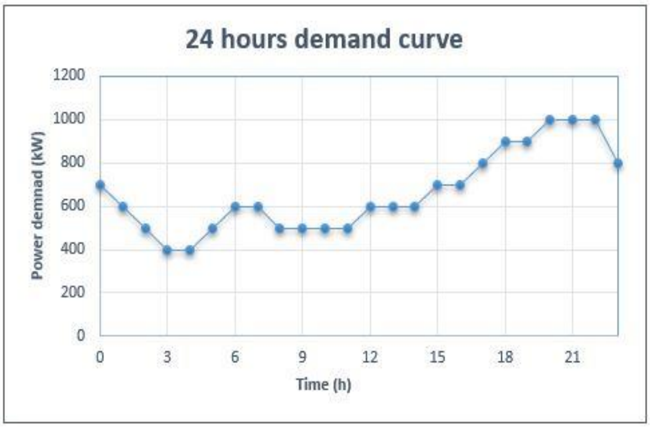

Figure 3. Daily Demand Curve

D. Reliability Analysis

Reliability analysis is a statistical method to determine the total load interruption in power system during certain period of operation. Load interruption are defined by several parameters that depend on number of customers, total connected load, duration of interruption, amount of power interrupted, frequency of interruption, repair time and probabilities of interruption. For reliability analysis in power factory, first a stochastic model is created for all components and for single line fault, then feeder is defined for reliability and switches are configured. Next the number of customers, interruption cost, priority, load transfer and shedding are defined, and reliability assessment is run.

Table 2.Reliability Analysis User Input Data

Component	Failure Rate	Mean Repair Time
Busbar	0.008/year for each terminal 0.015/year per connection	7 hours
Line	0.015/(km,year)	15 hours
Transformer	0.003/year	18 hours

III. Applying Demand Side Management

Demand side management is one of the important features of modern smart grid that enables electricity utilities to efficiently manage the available energy and fulfill customer demand without disturbing their life comfort. To apply DSM to the network, first the daily load demand curve is plotted based on power consumption of consumer. The major part of system consists of residential consumer that has low power demand during daytime because peoples went to their duties at that time and their demand increases in evening when they come back. Now to apply DSM, loads are shifted from peak demand hours to off-peak. Initially 5% load are shifted, and reliability of the system is analyzed. Then the percentage of load shifted is increased gradually to 7%, 10%, 15% and finally 20%, the reliability assessment is done for all DSM strategy in term of SAIDI, SAIFI and ENS.

IV. Results

The research work consists of reliability evaluation of the system. Reliability of the system is evaluated in term of SAIFI, SAIDI and ENS. Initially reliability analysis is done for base case without load shifting. After that different percentage of non-critical load are shifted from peak hours off peaks hours and reliability is analyzed. The results of reliability parameters obtained for different case are following.

A. System Average Interruption Frequency Index (SAIFI)

SAIFI indicates that how often a customer experience interruption during a specific defined period. So smaller is the SAIFI index less will be the interruption in system. The result of SAIFI obtained for different DSM scenarios are compared with base case of peak demand. The comparisons are shown in the following figure, when the load is shifted from peak demand hours the system interruption decreases. A point come where the SAIFI become minimum, which shows less interruption and high reliability. In our case SAIFI become minimum at 15% load shifting, that bring 14% reduction in SAIFI as shown below.

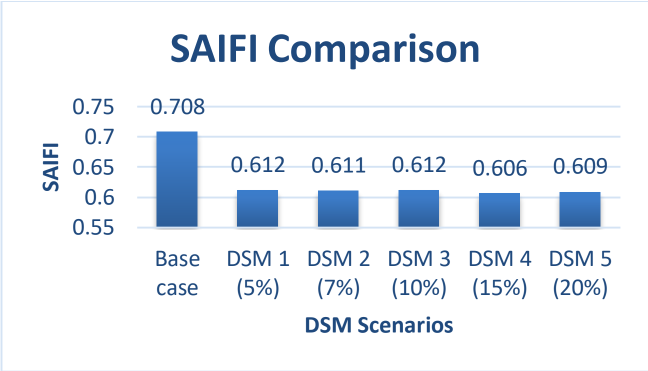

Figure 4. SAIFI Comparison

B. System Average Interruption Duration Index (SAIDI)

SAIDI indicates the interruption duration of a customer during a specific period. The result of SAIDI obtained for different DSM scenarios previously are compared with base case. The comparisons are shown in the following figure, when the load is shifted from peak demand hours the interruption duration decreases. At a specific point SAIDI become minimum, which shows less interruption duration and high reliability of the system. The SAIDI become minimum at 15% load shifting as shown in the following figure. This bring 14% reduction in SAIDI.

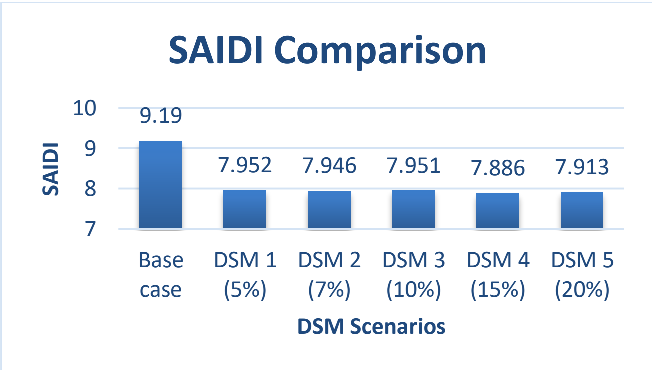

Figure 5. SAIDI Comparison

C. Energy Not Supplied (ENS)

ENS shows the energy not supplied to the load during a specified period. The result of ENS are obtained for different DSM scenarios and compared with base case. The comparisons are shown in the following figure, when the DSM is applied, and load are shifted from peak demand hours the ENS decreases. At 20% load shift its value is smallest, which shown the higher reliability of the system at that point.

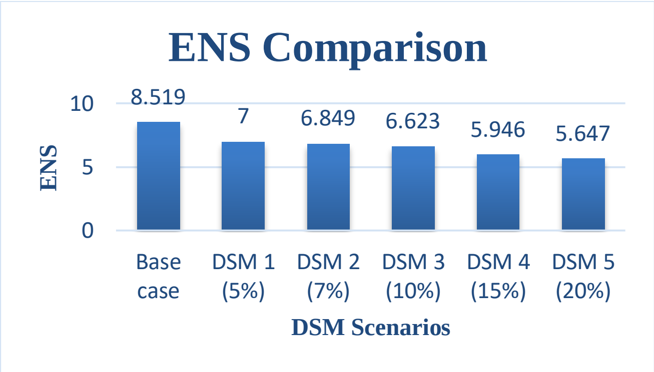

Figure 6. ENS Comparison

CONCLUSION

Distribution system is key part of power system that plays important role of transferring power to the customer premises. Reliability of this network is very important to ensure continuous power supply. The main objective of this research is o find most optimum and reliable operation of the proposed distribution system, for this a model is designed in DIgSILENT Power Factory. Load flow analysis is performed to find the loading of each component in the system and to ensure it safety. Load flow analysis is also used to find the maximum loading capability of the system. The reliability analysis of the system is performed for different casese. First the reliability analysis is done for base case. After that DSM is applied and different percentages of noncritical load is shifted from peak-hour to off-peak hours From reliability results it is concluded that for 15% of load shifting while applying DSM, the system have less interruption and reliability of the system is higher. So, the system operates in most optimum condition. This optimum operation condition is used for better system performance and high reliability.

In future, the proposed system can be modeled with the integration of renewable energy resources and distribution generation. The distributed generation will perform peak shaving and fulfill customer demand locally. This system can also be modeled with the integration of V2G and V2H. The vehicle will be charged during off peak hours and then used for peak shaving during peak hours of high demand.

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