Improving The Reliability of the Distribution Network with The Approach of Load Response Resources in The Presence of Distributed Generation Resources

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Abstract

Traditionally, distribution networks are radial in topology and passive in nature. Over the past few decades, there has been tremendous interest in non-conventional energy sources, largely driven by dwindling fossil fuel supplies and increasing global warming concerns. The purpose of this research is to manage and improve the reliability of the distribution network with the approach of load response resources in the presence of scattered production resources. In this research, we also considered the effect of storage devices on the congestion and observed that the storage devices act as a load when there is no congestion in the network and draw power from the network and are charged, but in a situation where the congestion in the network is high. They act as a source of power production and are discharged and injected into the power grid, which in turn reduces congestion.

Keywords: reliability, distribution network, load response, distributed generation resources

1. Introduction

Electric energy cannot be widely stored at the level of the power system, so the amount of production capacity available at all times must be equal to or greater than the total load of the system's consumers. At some times during a year, the amount of power consumption of the system will increase drastically, and in this situation, without taking into account the response, the amount of production capacity required to provide power and save these hours will increase. Meanwhile, the cost of installing power plant units is very high and time-consuming. However, with the implementation of load response programs, the amount of consumption during peak hours by consumers who are willing to reduce their consumption will be reduced, and as a result, spending additional costs to create production capacity for a short period of time will prevent excessive load increase every year. Load accountability forms a major part of consumption management programs. Because the nature of these programs is very suitable for adapting to the new power system management structure. Today, these programs are considered as a suitable solution to solve some problems of restructured power systems. Load response can change the form of electric energy consumption in such a way that the peak load of the system is reduced and the consumption is transferred to non-peak hours. The implementation of load response programs can improve the utilization of the power system from an economic point of view, maintaining the reliability and efficiency of the retail and wholesale markets.

The integration of any type of resource into the distribution network makes it an active network. There are many advantages due to DG integration such as reduction of power losses, improvement of voltage profile, stability, reliability, cost saving, etc. [3]. These positive effects of DG resources mainly depend on the location and size of DG resources in the distribution network [4]. But due to the higher penetration rate of DG resources, including technical, commercial and regulatory challenges, there can be some disadvantages [5]. One of the most important topics among them is protection coordination [6]. In [7], the importance of replacing protective devices due to the higher penetration of DG sources is discussed. Under certain conditions, the fault current can exceed the minimum or maximum range [8]. Protection failures due to high penetration of DG can be mainly of two types, i.e., undesired shutdown or failure during fault [9]. With the introduction of more and more DG resources on the distribution side, the network topology is changing from radial to mesh. For a mesh network, traditional analysis methods do not provide accurate results. [10] Figure (1-1) shows a typical active distribution network. The output of renewable energy sources and the load profile are usually stochastic in nature and this uncertainty must be considered in the planning stage. [11] The impact of renewable DG output changes when integrated with the grid is taken care of by pumped storage units, plug-in electric vehicles (PEVs) with vehicle-to-grid (V2G) capability, battery storage devices, diesel generators, etc. [12]. If not properly planned, the increased use of PEVs can lead to the deterioration of system reliability, mainly due to the increased system load condition during vehicle charging. Grid-connected battery swapping stations with V2G capability improve reliability [13].

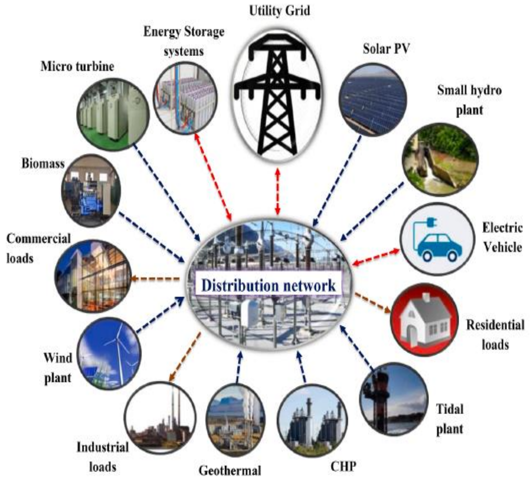
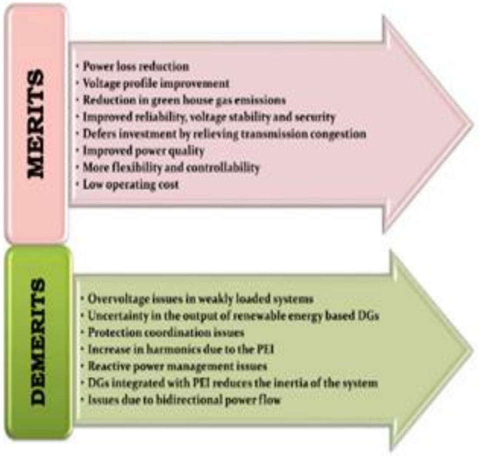


Fig.1. A typical active distribution network.

The positive and negative effects of DG integration in the network are shown in Figure (2).


MERITS

- Power loss reduction
- Voltage profile improvement
- Reduction in green house gas emissions
- Improved reliability, voltage stability and security
- Defers investment by relieving transmission congestion
- Improved power quality
- More flexibility and controllability
- Low operating cost

DEMERITS

- Overvoltage issues in weakly loaded systems
- Uncertainty in the output of renewable energy based DGs
- Protection coordination issues
- Increase in harmonics due to the PEI
- Reactive power management issues
- DGs integrated with PEI reduces the inertia of the system
- Issues due to bidirectional power flow

Fig. 2. Effects of DG integration on the grid.

After the recent blackouts in various power grids around the world, access to reliable electricity has become the need of the day.

The complexity of the electric power system is increasing day by day due to the increasing integration of renewable DGs, especially on the distribution grid side. The uncertainty introduced into the system by these renewable DGs can have a detrimental effect on the reliability of the distribution network .[14] Hence reliability assessment and improvement techniques for distribution networks with renewable DG sources have been widely studied in recent years. The implementation of performance-based electricity pricing in some countries has also increased interest in distribution network reliability studies among researchers. In the literature, various reliability assessment methods have been proposed and are broadly classified as analytical and simulation-based approaches [15]. Definition of congestion and its effects in the power network.

Congestion can be defined as the filling of the permitted capacities or the use of the power network outside the permitted operating limits [8]. These limits can be related to the permitted bus voltage limits, generator production limits, transmission lines , the ranges of distribution lines and... In terms of the transmission network, congestion or congestion refers to a megawatt of overload in the network lines that occurs during the operation of the power system in conditions such as peak load or other emergency conditions such as outages of lines and generators [7]. The limitations of the transmission lines are generally complex and some of them can be omitted for the simplicity of the model, but the limitations mentioned below are among the most important limitations that need to be considered for congestion management [9]:

- Thermal limitations: the passage of electric current through the lines causes a part of the power to be lost and the line to heat up. Around a certain temperature, there is a possibility of permanent damage to the line. This heat is generated not only by active power but also by reactive power.
- Limits of the voltage range: the voltage limits define the boundaries of the operation, which limits the power passing through the lines. Considering the voltage limits, both active and reactive power loading of the transmission lines should be considered.
- Stability limits of transmission lines: the difference between the load voltage angle and the generator voltage is called "phase angle". When the phase angle reaches nearly 90 degrees, the power passing through the line decreases and causes instability. This value shows the limit of the physical stability of the lines. In general, angle stability is divided into two categories: small signal stability, which is the ability of the system to remain synchronous when small fluctuations occur; Transient stability, which expresses the system's ability to remain synchronous when a strong transient oscillation occurs.
- Limits of voltage stability: Voltage stability is the ability of the power system to keep the voltage of all buses within the permissible range under normal conditions or after encountering a disturbance. The main reason for voltage instability is the system's inability to supply reactive power [9].

In addition to the four physical limitations stated above, event limitations for line congestion must also be considered. Event analyzes with different simulations deal with potential emergency situations in the network [8].

2. Congestion management methods in the power network

Congestion management refers to all things that are done to prevent the occurrence of congestion or to release the transmission and distribution capacity, which means removing the existing congestion. With a more comprehensive definition, any operation that ensures the balance of load and production conditional on freeing the capacity of the lines is called congestion management. Congestion management of transmission lines, as one of the key tasks of the network operator, is a process that ensures the use of the transmission network within the permitted limits of operation. In general, congestion management can be a systematic solution for production planning and adaptation. and consumption should be considered. In restructured systems, the main goal in congestion management can be considered a set of rules and procedures that guarantee sufficient control over producers and consumers, to maintain an acceptable level of safety and reliability of the power system along with The maximum economic efficiency of the market is at the time of transmission network limitation and can provide sufficient economic signs for the long-term growth of the system. These laws must have characteristics such as being inviolable, transparent and fair, the network operator must be able to solve the problem of congestion management with a competitive approach. in such a way that the maximum possible use of the transmission network is realized and at the same time the largest amount of exchanges is possible in the most economical way possible; That is, in theory, the confrontation of different market forces makes it possible to provide the right to use the condensed line for the user provided that he attaches the highest value to it. [11]

Congestion of system can in some cases lead to the creation of market power for some market participants. This issue can interfere with the creation of a free electric energy market and delay its progress. Since congestion management is very dependent on the market and without market considerations, it does not have the necessary validity, the compilation of this set of rules has been done in different ways in the world, which has led to the presentation of various methods in congestion management based on the market. From a general point of view, existing congestion management methods can be divided into two categories, before congestion under the title of preventive congestion management methods2 and after congestion under the title of corrective congestion management methods. In the following, these methods are briefly explained [10].

The main methods of congestion management in transmission networks

Based on the review of available sources, in general, the main methods of congestion management in corrective congestion management methods can be briefly divided as follows:

1) auction-based methods

2) methods based on pricing

3) Methods based on reuse

4) load shedding and use of load response programs

5) Using tap transformers and phase changers and using tools (FACTS)

6) Using scattered production resources

3. Problem Data

Data related to DGs, ESSs and WTs are given in tables (1) to (6) for 33-base and 85-base IEEE networks. The capacity of the distribution feeder, which is supplied from the upstream network, is assumed for the 33 bus and 85 bus networks, respectively, for active power P_max=1 pu and P_max=1 pu و P_max=1.5 pu and for reactive power Q_max=0.8 pu و Q_max=0.7 pu. For both 33-bus and 85-bus networks, the number of DGs, ESSs, and WTs is 2, 4, and 2 units, respectively.

Table 1.DG data for 33-base network

Encouragement coefficients ($)	Posation	Qmin(Kvar)	Qmax(Kvar)	Pmin(kw)	Pmax(kw)	DG
1/1	6	0	100	0	200	1
1/34	11	0	100	0	200	2
½	16	0	100	0	200	3
1/42	22	0	100	0	200	4

Table 2. ESS data for the 33-base network

Posation	Pdmin (KW)	Pdmax (KW)	Pcmin (KW)	Pcmax (KW)	SOCmin (KWh)	SOCmax (KWh)	ESS
13	0	40	0	40	40	200	1
21	0	20	0	20	20	100	2

Table 3-4. WT data for 33-base network

Encouragement coefficients ($)	Posation	Pmin(kw)	Pmax(kw)	WT
1/1	24	0	450	1
1/2	29	0	650	2

Table .4 Data of DGs for 85-base network

Encouragement coefficients ($)	Posation	Qmin(Kvar)	Qmax(Kvar)	Pmin(kw)	Pmax(kw)	DG
1/1	23	0	130	0	130	1
1/34	47	0	130	0	130	2
½	81	0	130	0	130	3
1/42	53	0	130	0	130	4

Table 5. WT data for 85-base network

Encouragement coefficients ($)	Posation	Pmin(kw)	Pmax(kw)	WT
1/1	24	0	320	1
1/2	32	0	210	2

Simulation results on IEEE 33 bus network in deterministic space

Congestion management modeling in this thesis is implemented on IEEE 33 bus system. Figure (5) shows the single-line diagram of the IEEE 33-bus network. This network has 33 buses, 33 branches and its total load is 3.715 MW and 2.300 MW. The number of DGs used is 4 units, which are located in 〖dg〗 _4. are located and their capacity is 200 (kw) each for active power production and 100 (var) for reactive power production. Also, there are 2 storage units in this system, which are ESS1 and ESS2. They are located in busses 21 and 13, respectively, and their capacity is 100 (kw) and 200 (kw), finally, there are 2 wind turbine units named WT1 and WT2 located in busses 24 and 29. Their power output is (kw) 450 and (kw) 650 respectively. For preuniting parameters and variables, V_base=12.66 KV and S_base=1 MVA.

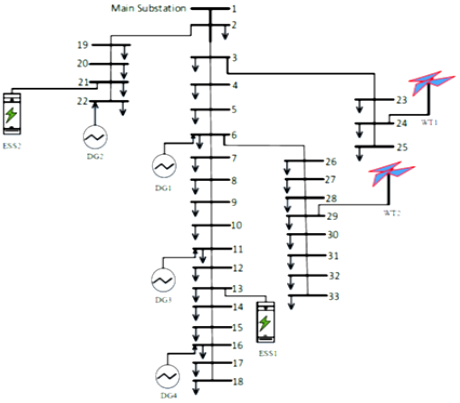


Fig .5. Radial distribution network of 33 bases along with DGs, ESSs and WTs

The profile of the 34-hour consumption load curve and the wind speed pattern are shown as the input data of the simulation in Figure (6).

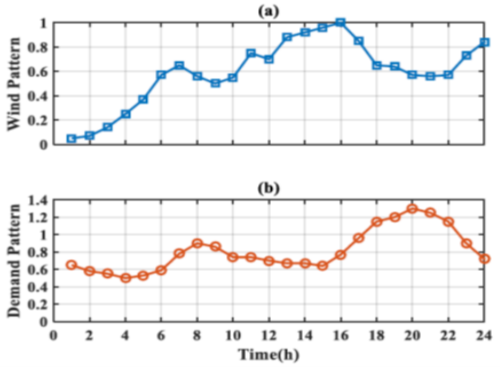


Fig.6. wind speed pattern (a) and load pattern (b) [18]

If we consider the output power of WTs as a parameter and input and the maximum capacity of WT1 = 0.45 pu and WT2 = 0.65 pu, then the output power of WT1 and WT2 according to the proposed wind speed pattern for 24 hours in The decompression time will be as shown in figure (7).

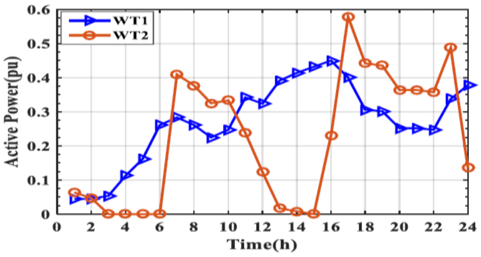


Fig. 7. Production power of wind units

Figure (8) shows the status of clearing network congestion and the time of network congestion for different hours.

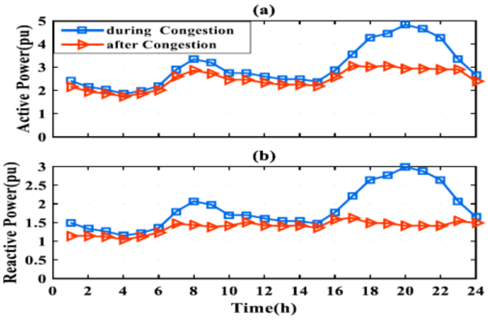


Fig. 8. The total active power consumption of the load in all buses at the time of congestion and the time of decongestion (a) and the total reactive power of the load in all buses at the time of congestion and the time of decongestion (b)

As can be seen in Figure (8), the congestion in the network has been significantly resolved, for example, for hours 18 to 22 and for part (a) where the network congestion is at its peak and the network is under stress and full pressure. In these hours, the amount of active power consumed by loads is mostly in the amount of 3 pryunits, if for the state before the congestion is removed, these values are in the range of 4 to 5 pryunits. In general, the decompression load curve for part (a) mostly controls the loads in the range of 1.5 to 3 priunits, while for part (b) it is more in the range of 1 to 1.5 priunits to create compaction. fix the problem

Figure (9) shows the amount of power produced by DGs to relieve congestion. In this figure, it can be seen that for hours 18 to 22 for part (a) and (b) when the congestion is at its peak value, the production power of DGs is also at its maximum capacity for these hours to solve the related congestion. In fact, the ups and downs in Figure (9) respectively indicate more or less participation of DGs to relieve congestion, for example, for hour 4, when a decrease is observed in the graph for both active and reactive power, it shows that in this hour congestion The grid is low and the DGs have produced less power.

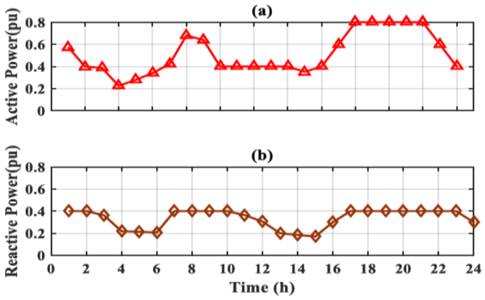


Fig .9. The sum of all the active power generation (DGs) (a) The sum of all the reactive power generation DGs (b) after removing congestion

4. Conclusion

Congestion is defined as a violation of physical limits, security and reliability in the power system or to - use of the power network outside the permitted limits of operation. These limits can be related to bus voltage, generator production limits, transmission and distribution line limits, etc. The problem of congestion in the distribution network is raised as a voltage problem and an overload problem, so that the voltage of the buses must be within the defined limits, usually 10% higher or lower than their nominal voltage, and the loading of the distribution lines must be be very close to the thermal limits of the power system. The effects of congestion in the distribution network make it possible to create additional outputs in the network, cause damage to the electrical equipment in the system, increase the price of electrical energy in some areas, reduce social welfare, frequent blackouts, etc. In order to solve or reduce the problems of voltage drop, overvoltage and overload in the distribution network, the distribution system operator (DSO) must implement congestion management methods in the network to resolve network congestion.

In this article, we presented congestion management in intelligent distribution networks by considering the uncertainty caused by the load and production of DGs in two deterministic and random spaces with the presence of storage devices and wind units for two IEEE 33-bus and 85-bus networks. . The main approach of the thesis is based on congestion management in intelligent distribution networks due to the comprehensive response of loads and increasing the production of DGs. As shown from the results, the proposed model manages congestion in both deterministic and random spaces. In the deterministic and random space, in two cases, taking into account the emission constraint and without considering the emission constraint, we investigated the effect of load response and increasing the power generation of DGs. Decongestion was effective, while without taking into account the pollution constraint, the increase in the power generation of DGs is more than the load response on decongestion. They can produce any amount of power, so to solve the congestion, the load response should be increased, but in the case of not considering the emission limit, the production rate of DGs is higher, which makes DGs produce power in any amount that they have transfer capacity, so in this case More than load response, it has an effect on congestion relief. For times when the congestion in the network is high, as we have seen in the results, all DGs produce power at their maximum value and the responsiveness of loads reaches its maximum value. As mentioned earlier, the type of load response program is the type of incentive-based load response programs and direct load control method (DLC). In this method, we considered the cost coefficients for the loads and DGs, which makes the loads and DGs participate in decongestion according to these cost coefficients, and the distribution network operator makes the corresponding planning to minimize the total cost of decongestion. objective function to do.

The total cost of decongestion, as it was obtained from the results, is higher in the deterministic space than in the random space, which was the reason that in the deterministic space, we force loads and DGs according to predetermined conditions, which may be due to the conditions is not too close to the real one, participate in decongestion, while in the random space, we plan by considering scenarios to more accurately simulate the real conditions, which in turn reduces the total cost of decongestion in the random space compared to the deterministic one. It is possible that pollution also had an effect on the costs, so that in the case of taking pollution into account, the total cost of decongestion and the cost of load response was higher than the case without considering pollution, but the cost of power generation of DGs in the case Considering the pollution restriction was lower than the case without considering the pollution restriction. In this work, we also showed the voltage profile for the state after decompression, as it was seen from the simulations, this curve was smoothed, in fact, in the decompression mode, we see the depression and non-flatness of the voltage curve, but after decompression By increasing power generation in DGs and load response, we flattened the voltage curve in high congestion points, which in turn led to better voltage management. Also, in this thesis, we also considered the effect of storage devices on the congestion and we observed that the storage devices act as a load when there is no congestion in the network and draw power from the network and are charged, but in the case where the congestion is The grid acts as a source of power generation and discharges and injects into the power grid, which in turn reduces congestion. This effect of storage devices is shown in the discussed results, which are discharged during peak hours and It relieves network congestion.

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