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Research paper



Congestion Management in a Restructured Power System Using Solar Photovoltaics

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Abstract

The modern power grid is one of the most complex engineering machines in existence. There is a continuous transformation in the grid conditions that necessitate variations in the electricity production. Energy is a remarkable donor in environmental change, representing around 60 percent of the aggregate worldwide greenhouse gas outflow. Lessening the carbon force of energy, the share of non-conventional energy sources in the worldwide vitality blend is relied upon to expand supportability. So renewable energy is one of the most capable results for taking care of expanding energy demand. This paper proposed a method to lessen the congestion in the deregulated environment. The congestion in the transmission lines is identified by optimal power flow (Newton Raphson) method. Congestion in the transmission lines is lessened by connecting a dispersed generating unit called as Solar Photovoltaic at PQ (load) bus. A way to decide the ideal position of a Dispersed Generating unit has been suggested based on the Line Relief Sensitivity (LRS) based attitude. The effectiveness of methodology has been validated using standard IEEE 30 bus system.

Keywords: *Deregulated Power System, Dispersed Generating Unit, Line Relief Sensitivity, Optimal Power Flow*

1. Introduction

Energy is essential for the monetary growth of a nation and it is the most far-reaching measure of a wide range of effort by people and nature. The origin of energy is structured into two categories namely non-renewable and renewable energy sources. The Energy crisis is because of the development of the total populace and the standard of living people. The improvement of a nation is measured as far according to per capita consumption of power (electrical energy). With respect to the improvement in the electrification of communities, the per capita electricity consumption has been increased in India for the past decades [16]. The electric power system covers the development and application methods for analysis, simulation and control of electrically integrated system by means of development in the scientific and technical side. This includes generation, transmission, distribution and use of electric energy in addition to operation and planning of electric power systems.

Restructuring of electricity is a approach towards changing standards and directions that control the power industry to give clients the decision of power providers who are either retailers or merchants by allowing competition. In another word, Deregulation can be defined as an unbundling of vertically combined utility. The challenging issue of the deregulated era is the network congestion. Congestion or Overloading is a term that comes to power system from financial matters in conjunction with deregulation. In the deregulated environment, a power system is said to be "congested" when some predetermined working requirements (for instance line current, transport voltage size, and so on) are damaged or violates the limits. Congestion may likewise bring about counteracting new contracts, infeasibility in existing and new gets, extra blackouts, shakiness, and imposing a business model of costs in a few districts of energy frameworks.

Many researchers have concentrated on the deregulated environment of the power system to sack the congestion occurred in the system. Now a days, there are various types of deregulated power system models are available and different congestion management methodologies are used in it. Guguloth et al [1] have developed a method to relieve the congestion by optimally placing the distributed generation unit based on Transmission Line Relief. Uma Velayutham et al [2] have proposed a way to reduce the total cost and get rid of the congestion in a power system by optimally sizing and positioning of a FACTS device namely interline power flow controller (IPFC). Mohammad Amin Hozouri et al [3] have concentrated on the curtailment cost, total social cost for wind energy and storage unit revenue by non-dominated sorting genetic algorithm II and the results are verified on IEEE Reliable Test System. Tak Niimura et al [4] have formulated a procedure for transmission network congestion management by using a mixture of load restriction and generation dispatch. V. Gomathi et [5] al have proposed an algorithm for congestion management in a deregulated environment by placing the wind energy generator, additionally the Locational Marginal Pricing (LMP) and Social benefit for the system has been calculated and the results are compared with and without Renewable Energy Sources (RES) under pool and bilateral market operations. Huiling Li et al have [8] concluded an algorithm based on the combination of power from the wind and Pumped Hydro to decrease the wind power curtailment and the variation caused in the wind power on the power grid. Swati Gupta et al [9] have proposed an optimization technique based on Radial Basis Function Neural Network (RBFNN) to penetrate the DG at IEEE 69 bus distribution system to curtail the power loss and to improve the voltage profile of the same system.

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This work describes the congestion management method in re-structured power system with Distributed Generation Unit. The congestion has been created by varying the load on the system. The optimal location of the DG unit for the test system has been formulated and the results have been presented. The detailed modelling of distributed generating unit have been discussed in Section 2. The optimal placement of DG unit is presented in Section 3. The method has been validated in a test system and the results are shown in section 4. In Section 5, the conclusion and future scope of this paper have been discussed .

2. Modeling of Distributed Generation Unit

PV generator is one of the non-conventional energy sources, which supplies DC current at a voltage level of 48 V. The most common modeling of PV system is current modeling and it is used to characterize the output of a PV generator. In this paper, the single diode series-parallel resistance model is considered. The equivalent circuit of a PV Cell is shown in Figure 1 [6, 7, 17]:

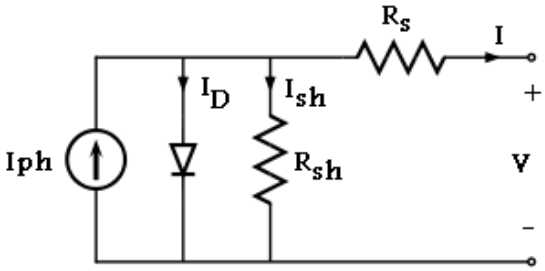


Fig. 1: Single diode Lumped circuit model for PV system

The output current from the PV can be determined as follows [6, 7, 17]:

$$I_{out} = (N_{PP} * I_P) - (N_{PP} * I_{ms} * I_{dc}) - I_{pl} \quad (1)$$

$$I_{dc} = e^{\left(\frac{V/N_{SS} + I_{out} * R_{SS}/N_{SS}}{I_{df} * V_{TV}}\right)} - 1 \quad (2)$$

$$I_{pl} = \left(\frac{V * N_{PP}/N_{SS} + I_{out} * R_{SS}}{R_{PP}}\right) \quad (3)$$

$$V_{TV} = \left(\frac{N_{ss} * K_{BC} * T_{OC}}{q_{CE}}\right) \quad (4)$$

Where, Iout=Output Current, KBC=Boltzmann Constant, qCE=Charge of an Electron, T=Operating Temperature in Kelvin, VTV=Diode Thermal Voltage, RSS=Series Resistance, RPP=Shunt Resistance, Nss, and NPP are the Number of PV modules in series and Parallel respectively. The Module Saturation Current of the PV can be determined by [17]:

$$I_{ms} = I_{mrs}\left(\frac{T_{oc}}{T_{roc}}\right)^3 \exp\left(\frac{q_{CE} * E_{bg}}{I_{df} * K_{BC}}\left(\frac{1}{T_{roc}} - \frac{1}{T_{oc}}\right)\right) \quad (5)$$

Where Imrs is the Reverse Saturation Current, Troc is the reference temperature (298 Kelvin), Idf is the Ideality factor and Ebg is the Band Gap. The module reverse saturation current and the photocurrent can be determined by [17]:

$$I_{mrs} = \frac{I_{shc}}{\left(\exp\left(\frac{V_{opc}}{I_{df} * V_{TV}}\right) - 1\right)} \quad (6)$$

$$I_p = \left(I_{shc} + \left(K_{sci} - \Delta t\right)\right) * \left(\frac{G_{ir}}{1000}\right) \quad (7)$$

Where Ishc and Vopc is the Short circuit current and open circuit voltage of the solar cell respectively. Ksci is the short-circuit current of the cell. Gir is the Irradiance of the sunlight.

3. Optimal Placement of Distributed Generation (DG) Unit

Distributed Generation (DG) generate power from renewable energy sources (wind, photovoltaic, tidal, mini-hydro, etc.) and it is any little scale control era innovation that gives electric power at a site nearer to the client than focal station era. Operation of DG gives advantages to the utility administrators, conveyed era proprietors and purchasers regarding dependability control supply, transmission misfortune remuneration, lessening in transmission system development and improvement of sustainable influence era. Distributed Generation, while not another idea, is starting to end up plainly to a greater extent a reality as the innovation advances. Presently DG exists in battery-operated devices, portable generators, and automobiles. In this paper, DG is used for relieving congestion in the transmission line, where the congested line has been found by Power Performance Index (PPI) and the finest location of DG has been identified by the LRS based method. The congestion in the system can be found by the PPI and it is denoted by [5, 9, 10]:

$$PPI = \frac{\text{Actual Power flow in the Line}}{\text{Rated Capacity of the Line}} \quad (8)$$

If the PPI for a line is above 1, then the line is supposed to be overloaded. Line Relief sensitivity can be defined as the inverse of Transfer Distribution Factors (TDFs). Both LRS and TDFs are used to connect the DG unit to the respective buses [1,5]. In other words, LRS can be defined as the ratio between excess power flow on the transmission line and the new generation at load bus, the power injected at each load bus is taken and the sensitivity ratio is calculated accordingly. The LRS factor at load bus for a congested line, i-j is S_{ij}^{k} and is calculated by [1,5]:

$$S_{ij}^{m} = \frac{\Delta P_{Gij}}{\Delta P_m} \quad (9)$$

The excess power flow on transmission line i-j is given by

$$\Delta P_{Gij} = P_{Gij} - P_{Fij} \quad (10)$$

Where, Actual power flow through the transmission line i-j, Flow limits of transmission line i-j. The new generation at load bus can be calculated by

$$P_m^{New} = P_{old,m} + \frac{S_{ij}^{m}}{\sum_{i=1}^{N} S_{ij}^{p}} \Delta P_{Gij} \quad (11)$$

where, After DG is connected at Load bus k, Before DG is connected at load bus k, Sensitivity of power flow on line i-j due to

generation change at load bus k by Connected DG unit, N: Total no of load buses in the system. The lower the LRS the more impact of a single MW power transfer at any two buses. Therefore, based on the LRS values the load curtailment or generate power by DG at load in required amounts at the load buses in order to eliminate the transmission congestion on the congested line i-j, Calculate LRS of the system with respective congested line and find the most negative LRS at load bus, which is the most ideal position for connecting the DG in the power system.

4. Results and Discussion

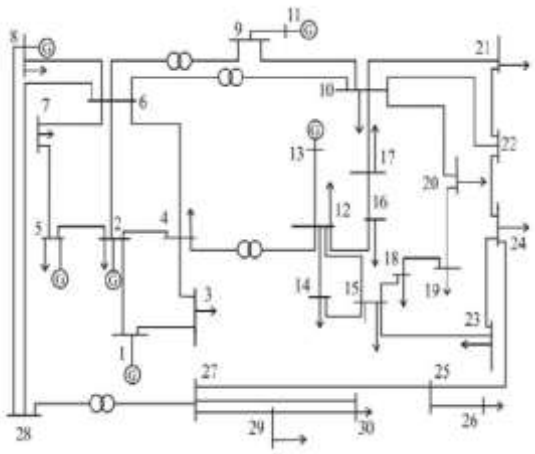


Fig. 2: Standard IEEE 30 Bus System

The standard IEEE 30 bus system shown in Fig 1 has been taken as a test system in a deregulated power system. The data for test bus system, which consists of 41 transmission lines with six generators, are taken from [15]. The standard test system is on 100 MVA base. The congestion in the system has been formed by changing the loads (amplified by 50% from the rated load) at all the load buses. After varying the load in the system, solve Newton Raphson based Optimal Power Flow and check for the power flow in all the lines. The lines 1 (1-2), 2(1-3), 3 (2-4), 6 (2-6), 7 (4-6), 10 (6-8), 18 (12-15), and 15(4-12) are congested due to transfer limit exceeds and calculate the PPI for the congested lines. The power performance index is calculated by using the formula 7. DG Unit has taken the counteractive action. The placement of the DG is found through Line Relief Sensitivity index using the formula 9. The PPI value and LRS value for the congested line is shown in Table 1.

Table 3: PPI and LRS Values for congested lines

Line	Bus Number		Power flow Limit	Actual Power flow	PPI Value	LRS Value
	From	To	MVA	MVA		
1	1	2	130	299.86	2.3066	-1.3066
2	1	3	130	136.69	1.0514	-0.0514
3	2	4	65	69.05	1.0623	-0.0623
6	2	6	65	94.169	1.4487	0.02756
7	4	6	90	109.14	1.2126	-0.2126
15	4	12	65	69.47	1.068	0.00750
10	6	8	32	48.724	1.5226	0.25039
18	12	15	32	33.4657	1.0458	-1.0961

From the above table, it has been seen that the line 1 (from bus 1 to 2) and line 10 (from bus 6 to 8) are seen to be heavily congested. The suitable bus to place the DG is Buses 6, 8, 4, 12 and 15. These buses are load bus and it can be changed to generator bus by placing a DG (Solar Photovoltaics) with the suitable rating. The capacity of Solar Photovoltaics place in the buses is shown in table 4.

Table 4: The capacity of Solar Photovoltaics

Bus No	4	6	8	12	15
Capacity (MW)	35	35	35	15	15

After the optimal placement of the solar PV in the corresponding buses, again solve Newton Raphson based Optimal Power Flow and check for the power flow in all the lines.

5. Conclusion

Congestion Management is a major issue in deregulated power systems. In this paper, a transmission congestion management technique has been proposed. A Standard IEEE 30 bus systems have been modeled in a deregulated environment, where the congestion in the transmission line is determined by Newton Raphson method based optimal power flow solution. The Dispersed Generation Unit can be connected at load bus, which can help to reduce the line flows in heavily loaded lines. It is must to obtain the optimal location of DG unit for better performance of the system. The results presented in this paper show that Line Relief Sensitivity index used for determining the optimal location of DG unit. The congestion in transmission lines of IEEE 30 bus test systems is alleviated by connected optimal placement of Dispersed Generation unit at load buses.

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