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Investigations of Unbalanced Radial Distribution Network By Considering Load Growth

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ABSTRACT: The present paper investigates the unbalanced radial distribution network under load growth. The present study addresses the performance with respect to bus voltage profile, system power loss, index of voltage stability (IVS) and energy loss. The basic objective of this paper is to identify the bus which is most sensitive bus in reference to voltage collapse. The bus which is most sensitive to voltage collapse is serving as candidate bus for DG placement. Basically, in most of the related literature it is observed that balanced radial distribution system performance has been investigated. In this study a load which is varying with time along with it's load growth is considered. The considered load compared with real time load. This fact is very crucial for further expansion of existing systems. In this research paper different types of load profile such as commercial, industrial and residential are considered for analysis. The proposed formulations are tested on 25-bus unbalanced radial distribution network.

Keywords: Real time load profile, Index of voltage stability, Time varying load, Different types load, load growth

I. INTRODUCTON

The basic requirement of the power system is that to deliver power in a reliable and secure manner. It is the basic fact that load demand is a variable parameter and it is changing at every moment due to this reactive power demand and not remains constant. As we know that the imbalance of reactive power leads to voltage instability or voltage sag and swell. Therefore, this issue should be addressed efficiently. The other issues also arise due to variable load demand like transfer capacity of transmission lines along with environmental and economic constraints. Additionally, as it is a much-known factor that when distributed generations are integrated into the distribution system the voltage profile of the system is changed. Moreover, stability of voltage profile is one of the important parameters which requires proper attention by researchers' community across the world. For stable operation of power system and level of voltage profile remain in prescribed limit. This investigation is very crucial in order to analyze the unbalance distribution system. This is clear that distribution systems are loaded heavily as compare to other system. Further, at the voltage stability limit the stability of sum buses decreases rapidly in case of small change in load increment in this case voltage collapse is not controllable this event cause blackout condition. Occurrence of voltage collapse phenomenon is presented commonly now a day because load and reactive imbalance is generally noticed. Basically, in many incidents the total blackout is observed because of lack of reactive power. Therefore, voltage collapse phenomenon is crucial factor which is to be addressed in effective manner. The operating condition should predict efficiently in order to avoid the voltage collapse condition. For this a thorough analysis of voltage stability problem is essential.

It is observed that majority of power systems operate very near to stability limits. And it is very important that to make trade-off between efficiency and security at proper level. The basic and foremost priority of power system operation is to provide power in prescribed limit and within acceptable limit of voltage and frequency to customers at affordable cost. Therefore, it is mandatory that efficient knowledge of current system operating is very crucial with reference of voltage stability limit. This basic requirement of assessment of system whether the system is functioning in feasible reason or it lead towards total outage of line if there is any small change in system loading. Additionally, the calculation of bus voltage profile is very essential to assess the system loading condition. For this PV curves may be good tool for assessment of system operating conditions as well as system behavior at various levels of system loading. Further, assessment of voltage collapse condition provides the information about voltage stability margin (VSM).

II. LITERATURE REVIEW

In this section described the investigations related to voltage stability and voltage collapse conditions are performed by various researchers are performed. The authors of references [1-17], addresses the issue related to voltage stability and voltage collapse conditions this is the aspect which can help to assess the further investigations and planning of existing distribution system. Haque [1], proposed a fast method for balanced radial distribution system in order to determine voltage collapse conditions. Moghavvemi, et al. [2] proposed a line / bus stability-based index these indices are achieved by load flow equation's solution in terms of reactive power at receiving end and the active power line equation at receiving end by reducing in equivalent network in two-bus. Chakravorty and Das [3] addressed a novel stability index-based method in this method bi-quadratic equation. These equations are used to calculate magnitude of voltage profile and power in the branch which connected at the sending and receiving ends. Augugliaro et al. [4] presented two new methods which are capable to calculate indicators of voltage collapse points. These points are used to identify weakest bus where there is most chance of voltage instability. Further, this phenomenon is extended to evaluate maximum loading capacity. Gobina et al. [5] highlighted an analytical approach to voltage collapse proximity determination is proposed for radial networks. The author of [6, 7, 8, 9] all proposed the method of assessment of voltage stability for balanced radial distribution network and determined most sensitive bus. Kamel et al. [10] proposed a generalized voltage stability index for modeling of load demand specially ZIP load and thus a voltage stability assessment is performed on the basis voltage collapse point indicator. Suai et al. [12] highlighted a global sensitivity-based analysis the sensitivity of correlated distributed generation with voltage stability. Further, authors applied the Nataf inverse transform to sample correlated distributed generation. Oner and Abur [13] investigated voltage stability problem which lead towards blackouts and developed a methodology for improvement resilience of power grids. Moreover, authors also proposed a algorithm to find out minimum number of distributed generations which are to be placed in order to maintain voltage stability under any type of contingency. Giorgos et al. [14] addresses a control schemes for distribution system further this control scheme is very helpful in assessment of voltage stability and loadability limit for larger power system. Because of this system performance gets enhanced. Monteiro et al, [15] proposed a new area-based method to assess the voltage stability of distribution system and increase system performance. Khaled [16] highlighted a novel method based on sensitivity technique to assessment the real time voltage stability. Guoteng et al. [17] proposed graph convolution network based novel method which is based on machine learning framework to address the prediction of short-term voltage stability online

It observed from above discussed literature that most of the researchers have investigated the concept of voltage stability and voltage collapse condition and applied their formulations on balanced radial distribution system. Moreover, in this paper the analysis of voltage collapse and voltage stability problem is investigated and developed algorithm on unbalanced radial distribution system. Further, this paper also investigated the impact of different load means constant power load, constant current load and constant impedance load profile by considering load variation, this variation in the load varies according to seasons.

III. INVESTIGATIONS OF UNBALANCED DISTRIBUTION SYSTEM RESEARCH

In this section three phase system is considered for developing the formulations. First of all the load condition in three different phases are described as follows

$$MVAL_A = MVAL_A \tag{1}$$
$$MVAL_B = MVAL_B(1 - UB_L) \tag{2}$$
$$MVAL_C = MVAL_C(1 + UB_L) \tag{3}$$

Now we consider a small fraction (say 25%) of load on phase *B* is decreased and (say 50%) of load decreased in phase *C* in this case the load conditions in three phases become as follows

$$MVAL_A = MVAL_A \tag{4}$$
$$MVAL_B = MVAL_B(1 - UB_L) \tag{5}$$
$$MVAL_C = MVAL_C(1 - 2UB_L) \tag{6}$$

The meaning of symbols used in above equations is as follows

$MVAL_A$ is load in a phase *A*
$MVAL_B$ is load in a phase *B*
$MVAL_C$ is load in a phase *C*
UB_L is fraction of unbalanced load conditions

The value of UB_L is considered as 25%, basically the main objective of
From equation (1), (2), and (3), as it given that in first case load demand in phase A is not changing, this load demand decreasing in phase B while this load demand is increasing in phase C. due to load demand decreasing in phase B, power loss in phase b is decreasing and same time voltage profile in phase is enhanced. Further, in phase C power loss will increase and voltage profile in phase C will reduced due to load demand in phase C is increased. Moreover, from equation (4), (5) and (6) load demand in phase A is remain as it is, load demand in phase B is decreased while load demand in phase C is reduced by margin of twice than phase B. As load demand in phase B and C is decreasing due to this power loss in respective phase will also decreased and voltage profile in phase B and C will get improved. The basic fundamental of this section is that when change in load demand cause respective change in power loss and voltage profile.

IV. INDEX OF VOLTAGE STABILITY (IVS)

As it is observed that in current scenario most of the distribution system in power system is operating very close to their voltage stability limit. As so many factors are responsible for load changing and also load is one of the parameters which is not remains constant because at each moment load is changed. The load is combination of active and reactive power. As load change is directly associated to change in reactive power. Further, due to change in reactive is prime cause of change in voltage profile. The lack of reactive power lead towards voltage reduction further reduction in reactive power lead towards voltage collapse due to this voltage reduction also causes voltage instability. Moreover, to maintain voltage level in prescribed limit it is mandatory to supply the reactive power locally by means of capacitor bank and other devices which are capable to supply reactive power to ensure the voltage stability. The installation of reactive power compensation device is always challenging because if reactive power compensation devices are placed at inappropriate position then they cause voltage instability in the system. Therefore, it is most important that reactive power compensation devices always placed at optimum position. Therefore, to control the index of voltage stability (*IVS*) is expressed as follows. As distribution systems are operated in voltage stability limits, if reactive power is not supplied in adequate amount the voltage stability limit of system is not remain in stable domain. Therefore, it is necessary to incorporate the index of voltage stability (*IVS*)

$$I_i = \frac{V_j - V_i}{R_i + jX_i} \tag{7}$$

$$P_i + jQ_i = V_i I_i^* \text{ or } P_i - jQ_i = V_i^* I_i \quad \text{or } I_i = \frac{P_i - jQ_i}{V_i^*} \tag{8}$$

IVS is given as

$$IVS_i = \left|V_j\right|^4 - 4\left[P_i(i)R_i + Q_i(i)X_i\right]\left|V_j\right|^2 - 4\left[P_i(i)R_i + Q_i(i)X_i\right]^2 \tag{9}$$

Where, i and j receiving and sending end bus respectively, V_j and V_i voltage at sending and receiving end, P_i and Q_i are active and reactive power at receiving end, R_i and X_i resistance and reactance of i^{th} branch

V. RESULT AND DISCUSSION

The proposed algorithm is applied on unbalanced distribution system comprising 25 buses. The load profile considered as constant power, constant current and constant impedance (ZIP) type load. Further, the load growth is considered as seven percent.

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