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Study of Voltage Stability

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Abstract: Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. A system inters a state of voltage instability when a disturbance such as increase in load demand, or change in system condition causes a progressive and uncontrolled drop in voltage. The management of power systems has become more difficult than earlier because power systems are operating closer to security limits. One of the serious problems in power systems that can threaten the concept of power systems reliability and security is voltage instability. Therefore in recently the analysis of voltage stability is very important.

This paper discusses study of voltage stability, and the eastern section of national Grid of Sudan (NGS) is selected as case study. Load flow analysis for the eastern part of NGS in the base case is done, and the results show that the voltage values are within rang.

The results present a high voltage drop after fault occurrence in Halfa bus, and the all voltage buses are about 0.5 pu, which may lead to voltage instability. Simulation is done usin ETAP software.

Key words: voltage stability, voltage collapse, Fault, voltage drop, ETAP

I. INTRODUCTION

The aim in power systems operation is to maintain electrical power with acceptable voltage and frequency to consumers at minimum cost. Reliability and security are very important parameters for power system and should be satisfied, reliability means a system with adequate reserves to meet changing energy demand, and security means that during contingencies, the system could recover to its original state and supply the same quality service as before.

All these objectives can be achieved by proper planning, operating and control of generation and transmission system. But one of the major problems in power system that can prevent achievement of these objectives, is voltage instability [1]. Therefore special analysis and attention should be given to voltage stability.

Because power systems are operating closer to their limits, voltage stability assessment and control, although it is not a new issue, is now receiving especial attention.

The study of voltage stability can be analyzed under different approaches, but specially, the assessment of how close the system is to voltage collapse can be very useful for operators. This information on the proximity of voltage instability can be given through Voltage Stability Indices. These indices can be used online to enable the operators to take action or even to automate control actions to prevent voltage collapse from happening or offline for the designing and planning stages [2].

In principle there are two methods commonly used for voltage stability analysis, dynamic and static analysis.

Dynamic analysis uses time domain simulation to solve nonlinear system differential algebraic equations (this method shows how different devices and control affect voltage stability), Static analysis (in this method the system is modeled by means of power flow equation and determine the system condition at which the equilibrium point of power equation disappeared) [2].

Byung Fia Lee and Kwang Y. Lee present dynamic and static voltage stability enhancement on power systems [9]. Where static voltage stability limits determination is discussed by C.K. Babulal, P.S.Kannan and J. Maryanta [10]. Andrzeg Wiszniewski presents a new criteria of Voltage Stability margin for the load shedding [11].

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II. VOLTAGE DROP

Voltage drop is the decrease of electrical voltage as current flows within an electrical circuit. The drop leads to a lower voltage at the endpoint. When current passes through an electrical circuit, a voltage drop occurs due to the resistance or impedance to the flow of the current. The resistance or impedance is usually due to the passive elements such as the transmission cables, connection points, contacts, and other factors. Generally, the amount of resistance or impedance in the circuits determines the level of the voltage drop.

A common analogy to illustrate a voltage drop is water flowing along a hose pipe. The further away from the connection tap, the stream of water becomes weaker as it flows out. This is also true for electricity, the longer the distance from the electric source, the weaker the voltage will be due to the losses along with the transmission and distribution networks. In practice, the longer the transmission cables, the more the voltage drop

2-1 Factors Affecting Voltage Drop:-

The voltage drop in an electrical circuit increases with the resistance of the various components along the current path. As such, any issues that affect the resistance or impedance such as temperature will also have an effect on the voltage. For example, during hot weather, the high temperature increases the resistance of the conductors and consequently the voltage drop. One property that influences the voltage drop is resistivity, ρ, which is the measure of how a material or conductor opposes the flow of current. The resistance of a material is directly proportional to the resistivity, expressed in ohms meter.

2-2 Effect of Voltage Drop:-

Voltage drops lead to unstable and unreliable power supply which can cause various operational, financial, and environmental problems and losses. Usually, operating below recommended limits can cause sensitive or critical electrical and electronic systems to fail and reduce operational efficiency. On the extreme, the persistent voltage drop may result in a complete shutdown of equipment or plants hence causing huge financial losses to the consumer. The utility company will also suffer due to the lost opportunity to sell power to the consumer during the shutdown.

Most of the electrical equipment can operate effectively with supply voltages variations of up to 10%. However, some sensitive equipment such as those in telecommunication, computing, medical, and similar applications requires a more constant and stable supply for normal operation. Also, the effects of voltage drop on some machinery and equipment operations may be too huge to ignore.

III. VOLTAGE COLLAPSE AND VOLTAGE INSTABILITY

Voltage collapse problems normally occur in heavily stressed system. It is the process by which a sequence of events leads to low unacceptable voltage profile in a significant part of power system (partial) or all parts of power system network [3].

Voltage instability implies an uncontrolled decrease in voltage due to a disturbance. The transfer of power through transmission network is accompanied by voltage drops between the generation and consumption point in addition to reactive power constrain. In the normal operating condition these drop are in the order of a few percent of the nominal voltage.

One of the tasks of power system planner and operator is to check that under heavy stress condition all the bus voltage remain within acceptable value. In some cases, however in the time following a disturbance the voltage drop may be large and the all system will be threatened. All these events refer to voltage instability. [3].

IV. CLASSIFICATION OF VOLTAGE STABILITY

Instability can be in forms of progressive voltage fall or raise of some buses, voltage instability is a result of load loss in area where voltage reaches unacceptable low values.

Also progressive drop in bus voltage can also be associated with rotor angle going out of the step. The main factor contributing to voltage instability is voltage drop that occurs when active and reactive power flow thought inductive reactance (transmission network).Also the voltage instability can come from load disturbance (power consumed by the load tends to be restored by action of distribution voltage regulators and tap changer transformer) [4].

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Voltage stability based on the size of disturbance can be classified to:

1. Large-disturbance voltage stability refers to system ability to maintain steady voltage following large disturbance such as faults, loss of generation .
2. Small-disturbance voltage stability refers to the system ability to maintain steady voltage when it subjected to small perturbation such as incremental changes in the system load.

Also the voltage stability can be classified into two categories:

1. Short-term voltage stability refers to dynamics that occurs due to fast acting load such as induction motor.
2. Long –term voltage stability refers to dynamics that occurs due to slower acting equipment such as operation of transformer tap changer [4].

V. METHODS OF VOLTAGE STABILITY ANALYSIS

Many algorithms have been proposed for voltage stability analysis. Most of the utilities depend on conventional load flows for such analysis. Some of the proposed methods are concerned with voltage instability analysis under small perturbations in system load parameters. The analysis of voltage stability, for planning and operation of a power system, involves the examination of two main aspects:

1- How closed the system is to voltage instability.
2- When voltage instability occurs.

The key contributing factors such as the weak buses, area involved in collapse and generators and lines participating in the collapse are of interest

Many techniques have been proposed for evaluating and voltage stability using steady state analysis methods. Some of these techniques are P-V curves, Q-V curves, modal analysis, minimum singular value and sensitivity analysis, reactive power optimization , artificial neural networks , neuro-fuzzy networks , reduced Jacobian determinant, Energy function methods, etc[5].

5-1 Q-V Curve Technique :-

Q-V curve technique is a general method of evaluating voltage stability. It mainly presents the sensitivity and variation of bus voltages with respect to the reactive power injection. Q-V curves are used by many utilities for determining proximity to voltage collapse so that operators can make a good decision to avoid losing system stability. In other words, using Q-V curves, enables the operators to know the maximum reactive power that can be added to the weakest bus before reaching minimum voltage limit or voltage instability. Furthermore, the calculated MVAR margins could relate to the size of shunt capacitor or static VAR compensation in the load area [5]

5-2 P-V Curve:-

The P-V curves, active power-voltage curve, are the most widely used method of predicting voltage security. They are used to determine the MW distance from the operating point to the critical voltage [5].

5-3 Loading Margin:-

The most basic and widely accepted index to assess the proximity to the voltage collapse is loading margin .This index is defined as the amount of additional load following specific load increase pattern that may cause voltage collapse. The loading margin can be calculated by starting at given operating condition and increasing load with small increments and re-computing load flow at each increment until the voltage collapse is reached. The loading margin is then the total additional load[5].

5-4 Power Flow Solution:-

Power flow studies, commonly known as load flow, form an important part of power system analysis .They are necessary for planning, economic scheduling, and control of existing system as well as planning its future expansion. The problem consists of determining the magnitudes and phase angle of voltages at each bus and active and reactive power flow in each line.

In solving a power flow problem, the system is to be operation under balanced conditions and single-phase model is used. Four quantities are associated with each bus. These are voltage magnitude (v), phase angle , real power (P) and reactive power (Q) [8].

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VI. FACTORS LEADING TO VOLTAGE INSTABILITY IN POWER SYSTEMS

The main factors that may lead to voltage instability of electrical power systems are as follows:

1. Large distance between generation and load (length increase the magnitude of drop).
2. Inability of the power system to meet the demand for reactive power.
3. Power due to a mismatch between load demand and supply of reactive power
4. Progressive fall or rise of the voltage at some buses.
5. Loss of load in an area, or tripping of transmission lines and other elements by their protective systems.
6. Heavily stressed and/or weak power systems.
7. The voltage collapse problem may be aggravated by excessive use of shunt capacitor compensation.

VII. VOLTAGE STABILITY AND POWER SYSTEM OPERATION LIMITS CONSTRAINTS

The rapid increase in load demand forces power systems to operate near critical limits due to economical and environmental constraints. In economic constrain aspect, investment costs of generation and transmission systems play great role in power market in order to be competitive in power market therefore, systems will operate at critical limits since investment costs are high and all this will make construction of new power plants and transmission lines, and operation of existing ones should be carried out efficiently.

Environmental constraints have negative effect on construction of new power plants and transmission lines. Great portion of the energy produced is consumed by big cities. Most of the time, it is impossible to build generation units near crowded cities which causes significant loss of energy due to long transmission lines. Since generation and transmission units have to be operated at critical limits voltage stability problems may occur in power system when there is an increase in load demand. In voltage stability problem some or all buses voltages decrease due to insufficient power delivered to loads the result may be a partial or complete blackout [1].

VIII. SIMULATION RESULTS AND DISCUSSION

8-1CaseStudy:-

The case study is the eastern section of National grid of Sudan (NGS) which contains 14 buses, 8 transmission linen ,2 generating units,8 load buses,6 transformers and one power grid (Sudanese – Ethiopian link).
Figure (1) shows the line diagram of the case study

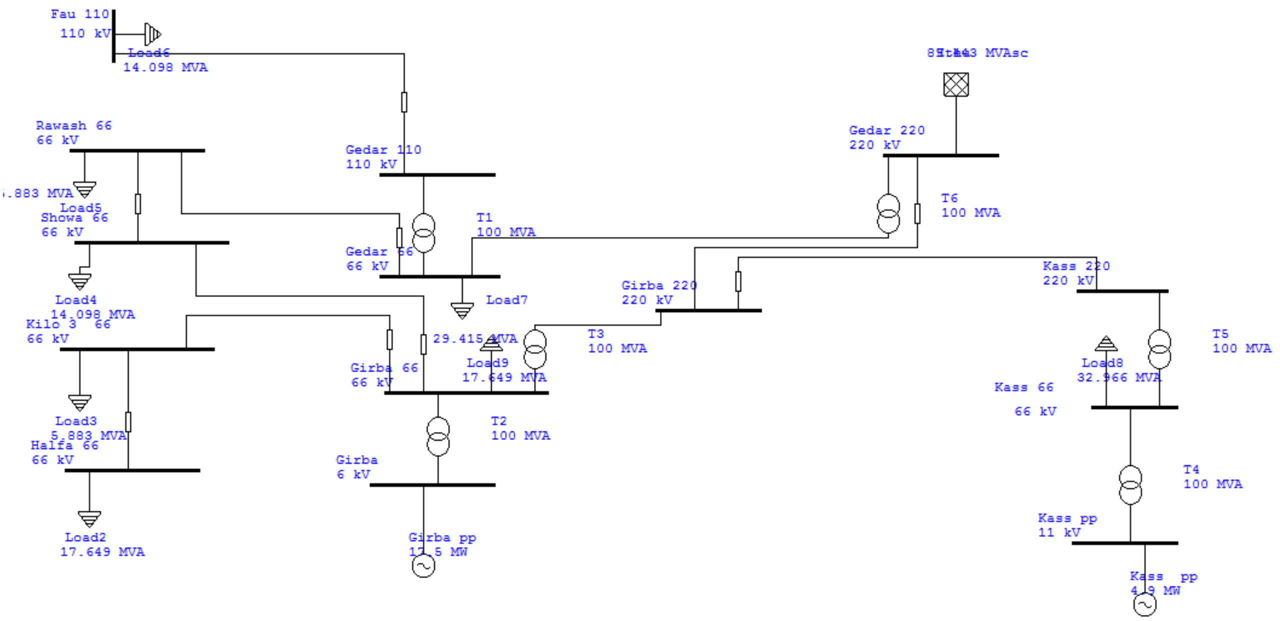

Figure (1): Single line diagram of the case study

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Load flow is done in bas case (during normal operation), and the values of buses voltage magnitude are determined. After that a fault (short circuit) is occurred at Halfa bus , and then a load flow is done to determine the buses voltage magnitude values. The values of voltage magnitude during normal operation and after fault occurrence at Halfa bus are shown in tables (1) and (2) respectively.

Table (1): Buses Voltage Magnitude during Normal operation (base case)

Buses	**Nominal KV**	**Voltage (pu)**
Fau 110	110	0.94
Gadar 66	66	0.99
Gadar 110	110	0.99
Gadar 220	220	1
Girba	6	0.99
Girba 66	66	0.99
Girba 220	220	1.002
Halfa 66	66	0.903
Kass 66	66	0.99
Kass 220	220	0.99
Kass pp	11	0.989
Kilo 3 66	66	0.98
Rawash 66	66	0.95
Showa 66	66	0.93

Table (2): Buses Voltage magnitude after fault occurrence at Halfa bus.

Bus ID	Nominal **KV**	**Voltage (pu)**
Fau 110	110	0.559
Gadar 66	66	0.559
Gadar 110	110	0.559
Gadar 220	220	0.56
Girba	6	0.551
Girba 66	66	0.534
Girba 220	220	0.55
Halfa 66	66	0
Kass 66	66	0.562
Kass 220	220	0.557
Kass pp	11	0.567
Kilo 3 66	66	0.507
Rawash 66	66	0.553
Showa 66	66	0.547

Table (1) shows that the voltage magnitude of all buses is within range and accepted.

Table (2) shows that the voltage magnitude of all buses are closed to 0.5 pu which presents an excessive high voltage drop which may lead to voltage instability.

IX. CONCLUSION

Power systems operation becomes more important as the load demand increases all over the world. This rapid increase in load demand forces power systems to operate near critical limits. Since generation and transmission units have to be operated at critical limits voltage stability problems may occur in power system when there is an increase in load demand. Voltage instability is one of the main problems in power systems. These problems may lead to occurrence of serious blackouts in a considerable part of a system. This can cause severe social and economic problems.

Voltage stability evaluation is necessary to guarantee and maintain acceptable voltage levels during normal operation and after small or large disturbances.

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The results show that the voltage magnitudes of the buses in base case (normal operation) are closed to 1.0 pu , since that the least value is 0.93 pu and the highest value is 1.002 pu.

After the fault occurrence at halfa bus, the results show that there is a problem in the voltage balance, and the all buses voltage are closed to 0.5 pu.

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