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Cascading Failure in Power Grid

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Abstract— In today's world with the amount of increase in population the amount of consumption of power has been project for utility of more and more vital role. Hence to provide power to consumer end with reliability it becomes essential for interconnection of power grid. An interconnected power system consists of control areas which are connected to each other by tie lines. In power system, generators are synchronized with each other. Many generators are cascaded and made a grid called regional grid. The regional grids are synchronized with each other and made a National grid. The Frequency disturbance of one area are transferred to adjacent areas, resulting in overall disturbance. The Power System needs to be operationally secure, i.e. with minimal probability of blackout and equipment damage. The large blackouts are occurs in power grid, formally it is been occurred by the disturbance in load connection. Because of the increased in load the generators shifts the excess load to the next one in the result the last generator or bus will get heavily loaded hence whole system will not be able to work in such a condition hence the system will get collapse and the huge blackout has been occurred. This paper deals with the power system stability and cause of large cascading tripping.

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I. INTRODUCTION

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. The electric power which is generated is stepped up to a higher voltage-at which it connects to the transmission network[1]. The transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local distribution network).

A robust transmission system is critical for the transport of power from generating stations to demand centre. Today, with system loading much closer to design limits, the loss of a transmission corridor could unbalance the grid, risking power swings or even unwanted cascade tripping. A blackout in an electric system means that the complete system collapses. Such a blackout affects all electricity consumers in the area. It can originate from several causes. One example is the loss of generation, e.g. the trip of a power plant that causes a mismatch between production and load. This puts a strain on other generators, resulting in under-frequency in the system while it "catches up", and may result in the further loss of other generators. In general, one initial event that might even is considered as minor, leads to a second event, a third and so forth, with increased stresses on the system which finally collapses.

Cascade tripping of generators usually occurs during a voltage decline on the system when, in attempting to increase reactive power output, field current limiters operate to trip the unit leading to a rapid cascade tripping or failure is a failure in a system of interconnected parts in which the failure of part can trigger the failure of successive part. It means that failure in one part of system may quickly spread into entire system. During the last decade, many electric power grids have suffered from enormous cascading failures leading to major disasters in different parts of the world. Such disasters resulted in blackouts that left millions of people without electric energy[2].

Many types of triggers can disturb the normal functionality of the electric grid including but not limited to the voltage dips (voltage sags), brief voltage increases (swells), and transient events. In addition to the voltage faults that can harm the control devices and motor speeds, the instability of the frequency of generated voltage with large deviation may lead to synchronization of the generators and hence, the amount of generated electric power reduces dramatically. Moreover, the weather storms and lightening may lead to shutting down some substations and damaging power transmission lines[3]. The main question, how robust is the electric power grid to resist cascading failures?, opens research areas for investigation. A cascading failure takes place when a single or multiple faults happen in the grid, and the stress on the transmission lines increases. The stress on the transmission line is the number of transmission loading relief procedures (TLR) in which the loads on the faulty lines is shifted to other lines. There are many different types of interactions by which failures can propagate during the course of a blackout.

Blackouts are traditionally analyzed after the blackout by a detailed investigation of the particular sequence of failures. This is good engineering practice and very useful for finding and correcting weaknesses in the power system. We take a different and complementary approach and seek to analyze the overall probability and risk of blackouts from a global perspective.

This paper is simply deals with the common mans reliable satisfaction of electricity, now a days the electricity generation, transmission and distribution has the inculcate procedure to enomrous power supply to the consumer[3]. The function of a power grid is to retain the supply to be destination and also sustained within the slandered frequency limit. In this project the case study of the seven bus system is the example of the system over load and tripping of the generators. The heavily loaded line of the system is carrying the load beyond the capacity and then gets tripped. The role of the generators which is been used are the same as we have in our power system

II. CASCADIMG FALIURE

A blackout in an electric system means that the complete system collapses. Such a blackout affects all electricity consumers in the area. It can originate from several causes. One example is the loss of generation, e.g. the trip of a power plant that causes a mismatch between production and load. This puts a strain on other generators, resulting in under-frequency in the system while it "catches up", and may result in the further loss of other generators[2]. Another example is an overload of the transmission system caused by congestion, forcing an overloaded power line to trip, causing ncreased loading of other lines those results in additional trips, and – in the end – a voltage collapse due to the high impedance in the weakened grid. In general, one initial event that might even is considered as minor, leads to a second event, a third and so forth, with increased stresses on the system which finally collapses[8].

Cascade tripping of generators usually occurs during a voltage decline on the system when, in attempting to increase reactive power output, field current limiters operate to trip the unit leading to a rapid cascade tripping or failure is a failure in a system of interconnected parts in which the failure of part can trigger the failure of successive part. It means that failure in one part of system may quickly spread into entire system[4]

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III. CAUSES OF BLACKOUT

There are several reasons which lead to cascading failure in power system. There is several technical as well as natural reasons for cascading failure[5]. Natural reasons pay more roles in failure. Technical reason includes voltage drop, over increased load, relays failure etc. natural reasons include storm, and earthquake, thunders and lightening etc. the following will elaborate the same.

A Dynamic Stability Loss at Short Circuit Occurrence

Dynamic Stability is lost in the case when, owing when there is a difference between the turbine and generator powers, the rotor‘s acceleration is not compensated at tripping the fault, to eliminate this losses ain transmission line the fast protection is provided, including also elements for liquidation of circuit-breaker and protection failures. Usually, these faults are eliminated within the time period of 200 ms.

B Accompanying Voltage Drop Avalanche

An avalanche begins simultaneously with frequency decline in the system partdue to lacking of active power. In the process of accompanying voltage drop avalanche the excitation of synchronous machines increases, due to which the reactive power deficit decreases. If this deficit is too large, the voltage can drop considerably, which causes additional frequency decrease.

C Large Scale Outage of Generators Due To Overload At Transmission Voltage Drop Avalanche

The transmission voltage drop avalanche in a network creates an impression of reactive power deficit. In reality, nosuch kind of deficit exists initially. The transmission voltage drop avalanche will develop at network overloading with active power; as a result, the increase in reactive power losses will be proportional to the current squared. This result in rise the reactive power flows (absent at normal operation) that could further result in a voltage drop. In this case the voltage drop is not the cause but the consequence of a network having been overloaded with active power; therefore the load shedding by under-voltage does not usually give the sought-for result[4].

D Static Stability Loss Due To Voltage Decrease

When a grid cross-section is overloaded under stationary condition to unpredicted rise in the power flow. Usually, in such a situation the operational condition is estimated as pre-emergency, and for the overload liquidation the reserve mobilisation and load shedding at the power receiving end of cross-section are used; otherwise the voltage drop at this place can happen, followed by stability loss and cascading outages of generating sources. The problems associated with voltage drop and the corresponding reaction of generating sources deserve special attention and are considered in §0.

E Dynamic Stability Loss at Tripping A Heavily Loaded Line

Also in this case, stability is lost owing to the network overload. Since this happens within seconds, for the overload liquidation fast actions are needed to maintain stability − for example, action on a generating source‘s equipment at the power sending end of the overloaded cross-section. Short-term turbine fast-valving is mostly used at TPPs. As concerns hydro turbines, their off-loading is hindered by insufficient operational speed of the control systems. Besides, these units can be switched off if necessary.

F Multiple Tripping Of Line Due To Wire Sagging And Short Circuit

When transmission lines are overloaded, the temperature of metal conductors increases; this effect is enhanced under hot and sunny weather conditions. This results, the temperature rise causes additional conductor sagging. If the distance to ground becomes small or under the line there are trees (bushes), conductors can be sagging into them, which may result in faults-to-ground. Such a fault cannot disappear in itself, so no automatic re-closing is possible. The transmission lines working in parallel take on the power thus becoming overloaded, and the processes repeat in a cascade-like manner.

IV. PREVENTION METHODS

Among the widely used System Protective Scheme (SPS) applicable to voltage instability are:

- Under frequency controlled load shedding
- Under voltage controlled load shedding scheme.
- Automatic switching (ON/OFF) of shunt reactors and capacitors
- Overvoltage control
- Under voltage control
- Generation rejection; where one or more generating units are tripped by SPS
- Remote load shedding.
- Systematic studies on network voltage and frequency regulating systems, and verifying the correct setting and system controllability during severe perturbations are critical[5].

- Protection coordination studies on a regular basis as System conditions change. Coordination studies between generator protective devices and the transmission system devices are also critical and should be included in the Routine system studies[6].

A] Load Shedding

Two types of load shedding schemes based on system frequency and bus voltage magnitudes are used. Under frequency load shedding: This is widely used to preserve the security of both the Generation and transmission system during disturbances. When reduction in system frequency fall below 49Hz Under frequency relays would be activated and after a short time delay TD without recovering a tripping signal would be issued to trip a circuit breaker with a specific load disconnected from supply.

B] Tap Changer Operation and Blocking Scheme

EHV/HV and HV/MV power transformers are usually equipped with on-load tap changers (OLTC). Each OLTC is accompanied with a tap changer panel with automatic voltage regulator relay. The secondary side voltage is monitored via a potential transformer and fed into the AVR (Automatic Voltage Regulator). If the controlled voltage is below /above the dead-band, the tap changer would tap up/ down and its operation can be automatic or manual.

C] Shunt Capacitor Bank

Shunt capacitor banks (SCBs) are widely used in transmission and distribution networks to produce reactive power support. Located in relevant places such as in the vicinity of load centers the use of SCBs has beneficial effect on power system performance: increased power factor, reduced losses, improved system capacity and better voltage level at load points. Shunt capacitor banks are protected against faults that are due to imposed external or internal conditions.

D] Under Voltage and Undercurrent Protection

Once disconnected from the system, the SCB cannot be reconnected immediately due to the trapped charge within the capacitor units. Otherwise, catastrophic damage to the circuit breaker may occur. To discharge the bank, each individual capacitor unit has a resistor to discharge the trapped charge within 5 minutes. Under voltage or undercurrent protection function with a time delay is used to detect the bank going out of service and prevent closing the breaker until the set time has elapsed. This delay prevents tripping of the bank for system faults external to the bank. The under voltage or undercurrent function should be set so that it will not operate for voltages that require the capacitor bank to remain in service[7].

V. SIMULATION

The simulate is done on a seven bus system in a power world simulator software and obtain a results at different operating condition which are follows.

A] Power System at Saturation Point

The fig 1 shows that the generator is connected with bus no 1, 2 and 4 synchronously. It can observe that if load at bus 4 increasing in step, then the generator can sustain the surplus load up to a certain preset limit after that they reach their maximum production limit. The transmission line with orange color shows that they reach their saturation point and if we further go on increasing the load it will cause the overloading in the line.

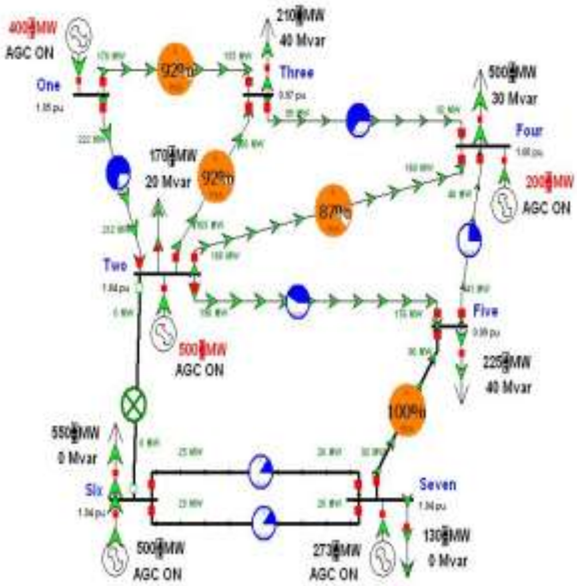

Fig 1 Power System at Saturation Point

B] Overloading Condition

. Fig 2 shows the overloading condition. In this condition the bus 4 is loaded heavily and hence due to this the load increases beyond the generation limit at the top area. Hence the top area overdraws the excess power from the bottom area through the tie line, hence the tie line between bus 5-7 is over loaded with 142%.

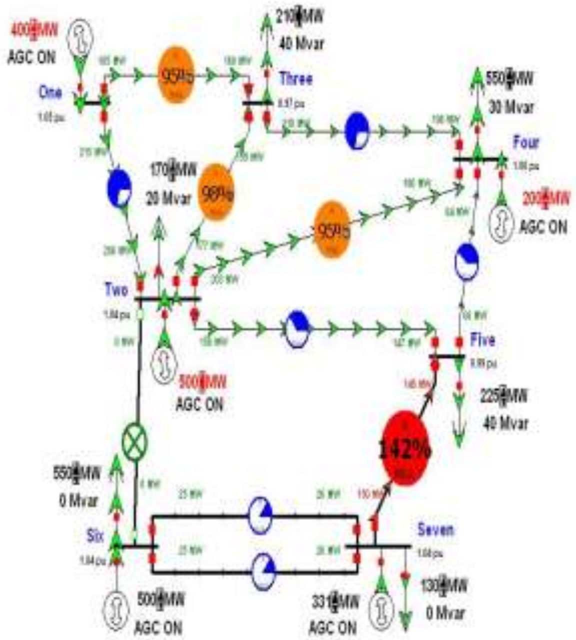

Fig 2 System Overloading Condition

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C] Tripping of Line and Its Effect

Fig 3 shows the tripping of line and its effect. In this case the tie line from bus 7 to bus 4 has tripped due to the overloading. Now after tripping of this line, the loads which is transferred through the tie line between bus 5-7 is transferred to other components and hence the generator load at bus no 2 and hence get overloaded from 500MW to 681MW and hence it cause overloading.

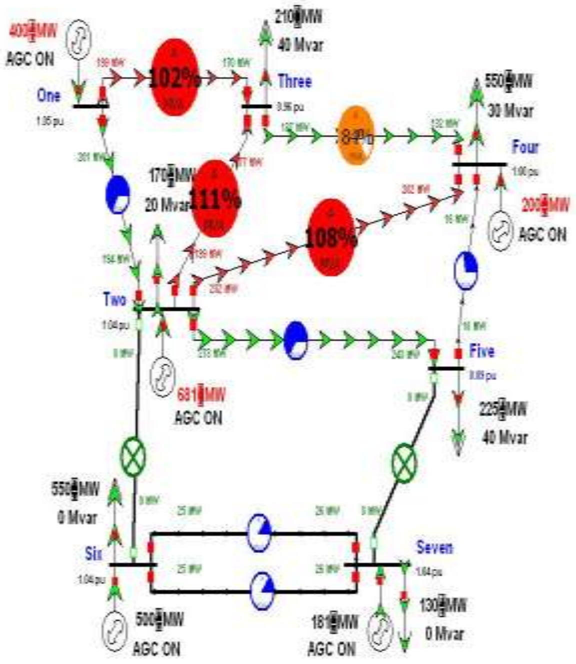

Fig 3. Tripping Of Line from Five to Seven

D] Tripping of Generator and Its Effects

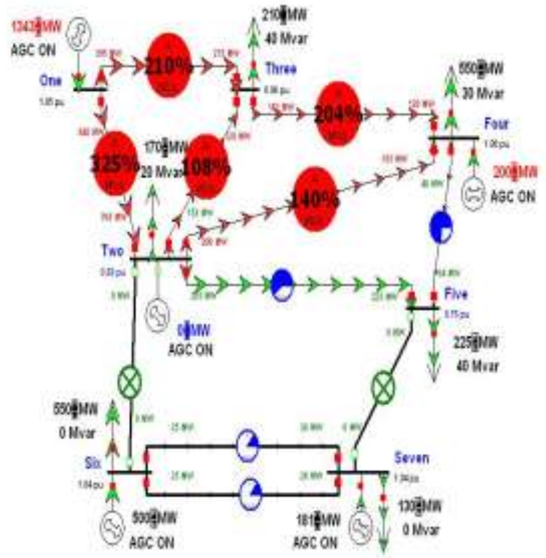

Fig 4. Tripping of Generator at Bus Two

Fig 4 shows the tripping of generator and its effects. Due to the overloading of generator at bus two cause tripping of generator at bus 2. Thus the load of generator of bus 2 generally shifts to the adjacent generator of bus 1. The load of the generator at bus 1 increases from 400MW to 1343MW which is beyond its limit. Up to a certain point it can bear the load i.e. overload and after that it cannot bear the load and the generator at bus 1 will get trip.

E] System Blackout

This condition shows the complete system blackout. All generator of top area has been tripped. Now there is no production of power at top area. Bottom area is working because it is isolated from the top area. As shown in fig 5

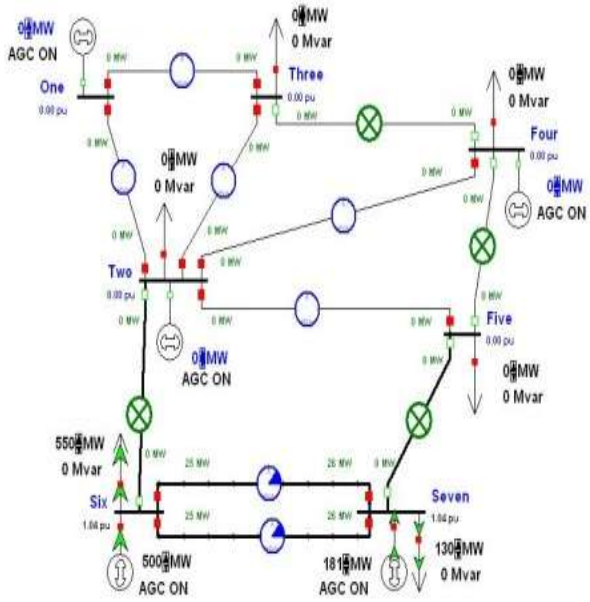

Fig 5 Top Area's System Blackout

VI. CONCLUSION

An electrical grid is an interconnected network for delivering electricity from supplier to consumer end. The main task of interconnecting of transmissions system is to adequate power from one ac system during normal condition and also during the emergency condition and maintains system security. However HVDC links Gives asynchronous interconnections and have a distinct superiority over ac links. Electrical utility benefits from its nature of being large and interconnecting utility allows the economics of scale. Secondly it can draw power from generator reserve from different region in order to maintain continuity, reliable power and diversify its loads. In a two area interconnected power system is connected through a tie line. In case of two area system it is assume that each area is individually strong and are connected by weak tie line. In modern power system, stability is the ability of the electric power system for a given initial operating condition, to regain a state of operating equilibrium after being subjected to physical disturbance. If it is not maintained then it result in cascading tripping. Cascade tripping of generator during voltage decline on the system when in attempting to increase reactive power out, field current limiters operate to trip the unit leading to a rapid cascade tripping or failure.

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