A Novel Approach for Reliability Analysis of Power System Configurations

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Abstract: - Reliability is always a concern for Power Systems. Reliability is a compromise between security and dependability. Security is the ability to properly restrain from tripping when not called for. Dependability is the ability to trip when required. While security is not improved by increased redundancy, dependability is. Clearly, the impact on the power system when a power transmission circuit and protective devices are not functioning when required is much less severe when there is a redundant transmission circuit & protective devices that takes over the job. If the two redundant transmission circuit and protective devices are of equal performance, there should be no detrimental effect at all on power system operations, and a non-functioning device would just need to be repaired or replaced. The Power industry applies a "no single point of failure" criteria for Power system networks. Reliability is commonly achieved by configuring the Power Transmission lines various circuits and protective devices placement schemes. For Power system networks and component devices, the preferred method of meeting reliability requirements has been to use physically separate, redundant transmission circuits and protective devices.

Hence, this paper is examining redundancy requirements for Power system transmission circuits and protective devices configuration in System and presents a new approach for evaluating the reliability of system.

Introduction:-

The function of an electric power system is to satisfy the system load requirement with a reasonable assurance of continuity and quality. The ability of the system to provide an adequate supply of electrical energy is usually designated by the term of reliability.

The concept of power system reliability is extremely broad and covers all aspects of the ability of the system to satisfy the customer requirements. There is a reasonable subdivision of the concern designated as „system reliability‟, which is shown in Figure 1.

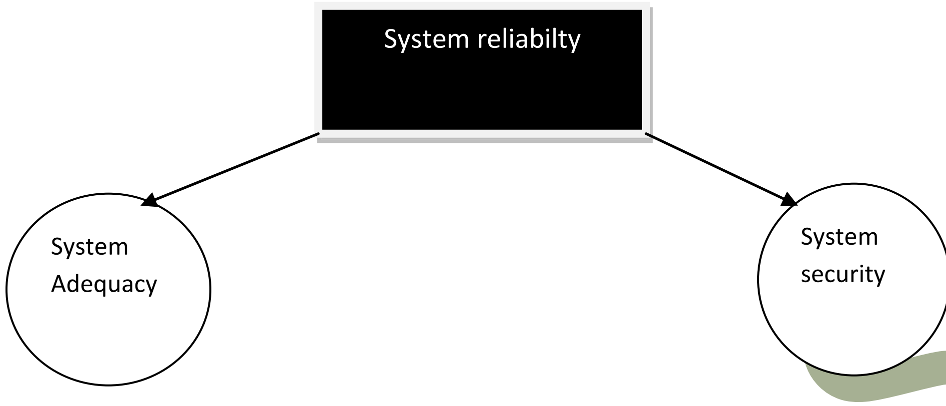

Figure 1 System reliability

Subdivision of System Reliability:-

Figure 1 represents two basic aspects of a power system: system adequacy and security. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer load demand. These include the facilities necessary to generate sufficient energy and the associated transmission and distribution facilities required to transport the energy to the actual consumer load points. Security relates to the ability of the system to respond to disturbances arising within that system. Security is therefore associated with the response of the system to perturbations. Most of the probabilistic techniques presently available for power-system reliability evaluation are in the domain of adequacy assessment. The techniques presented in this paper are also in this domain.

Reliability

"Protective equipment has to operate as many times as the fault available in the networks" Reliability is a product of two factors; dependability and security. For transmission line circuits and protective devices, dependability is defined as the ability to isolate for a fault within its protective zone while security is the ability to restrain from isolating when there is no fault in the power system zone.

While not practical to use, it could be of interest to illustrate the concepts by looking at the two extremes; 100% dependability and 100% security. 100% dependability would be achieved by a power system that is in constantly isolated state, hence there is no possibility that there would be a fault that would not be detected. 100% security would be achieved by disabling the power system entirely so that it could not isolate. From this it can be seen that while high dependability and high security are desirable, they will both have to be less than 100%. Generally, an increase in dependability will decrease security and vice versa.

Dependability:-

For the power system, dependability is easy to define and to measure. Any zone fault that is not isolated by the protective device is considered lack of dependability. The reciprocal of dependability could be called "failure to isolate" .
For example, if a system has a dependability of 99%, the failure to isolate would be 1% which means that of 1 out of 100 faults in the power system zone would not be tripped by the Scheme.

Security:-
"Security is the ability not to trip when not called for".(protective equipment has to operate under abnormal conditions only) To put a number on security is not as easy as for dependability. A simple method would be to compare the number of false trips for faults external to the protected zone by device component as compared to the total number of external faults. However, this does not consider other phenomena; false trips due to relay failure, trips on stable power swings, inrush currents or other phenomena that are not necessarily classified as power system faults. Even an „external fault‟ is not readily defined as it depends on what extent of the adjacent power system is included in the fault count.

Selectivity and discrimination:-

(A) Unit or Zone Protection: - protection system designed to operate a particular unit like transformer, generator & transmission lines etc. It is called unit protection.
Ex: - Buccholz relay & differential relay

(B) Non-Unit/not Zone protection:- used to protect the equipment in its own zone & also for the fault outsiders zone also called secondary or backup protection.
Ex: - Distance protection relay & over current relay.

Time Grading: - "Time difference between primary and secondary protective equipments has to be maintained for proper coordination between the protective devices is called time grading." It is adjusted by adjusting the distance between plunger & trip contacts in the over current relay.

Redundancy:-
Redundancy is defined as „the existence of more than one means for performing a given function‟. It is obvious that protective device and transmission system dependability can be increased by added redundancy as if one of the systems does not trip for an in-zone fault. If a fault occurs and is isolated from a backup (or redundant) protective device and transmission system, the fact that the primary protective device system did not operate does not constitute. A mal -operation. The reason for this is obvious; as long as the fault is correctly tripped, there is no reason to investigate whether all parts in the protective device system actually operated as intended.

Reliability of a Circuit breaker system:-

The circuit breaker is just one component that needs to function correctly for the transmission system to operate as intended. Other components are: relay, measuring transformers, battery system, control circuits, protection devices and any communications channels. While it is of interest to examine the performance of all these components, this paper will discuss only circuit breaker system reliability.

Mal operations caused by circuit breaker devices can have many causes:
a) Equipment electrical hardware & mechanical parts failure
b) Relay measuring limitations
c) Incorrect settings or improper application
d) Control wiring problem

Equipment hardware & mechanical parts failure:-

The use of redundant circuit breaker systems will greatly improve dependability for equipment failures. Security could be adversely affected by added redundancy, but the likelihood is small. There is a risk that a electrical hardware failure could cause a false trip before being taken out-of-service by the self-supervision, but this is not a very common occurrence. For hardware failures, the choice of identical or different redundant systems would make little difference. Exceptions would be if there is a common mode failure or a design flaw that would be affected by common external factors.
The mechanical parts failure or malfunction of main & auxiliary contacts of the circuit breaker , interlocking & closing or opening mechanism cause a false operation.

Relay measuring limitations:-

Redundancy will not improve dependability for relay measuring limitations unless they are of different design, or at least use different settings, eliminating the possibility of identical limitations in both devices. This fact has influenced the practice of applying different measuring principles, and designs, for the Main 1 and Main 2 circuit breaker schemes. Recognizing that it might be difficult to design a scheme that would cover all conceivable system fault conditions, it has been common to apply two schemes to complement each other. As correct fault clearing requires just one main protection to operate properly, this practice has proved to be very effective.

Incorrect settings or improper application
Incorrect settings and improper application will affect both dependability and security. A redundant device or function will improve dependability but it will also decrease security. The large number of additional functions available in the multi-function devices may have a greater negative impact on security than the relatively marginal improvement in dependability. Many of these functions are for back-up and are rarely called on to operate, but an incorrect setting may cause a false trip.

Control wiring problems:-

Control wiring problems can be divided into different categories; relay, battery, measuring transformer, and breaker trip and communication circuits. Some of these can be made redundant while others may be too costly to consider. A second communication channel will greatly improve protection scheme dependability but may be difficult to realize. Adding redundancy in the protection equipment itself can improve dependability for control wiring.

Reliability Analysis of circuit breaker in Double circuit Transmission lines:-

The Circuit Breakers CB1& CB3 are connected in a series sub circuit & CB2 & CB4 are connected in series in another sub circuit & both are connected in parallel to form the double circuit transmission lines as shown in figure5. Each circuit breaker system can be in a functioning state or in a non-functioning state. Hence, every circuit breaker can be assigned a Boolean variable which can assume a value 1 if it is functioning & a value 0 if it is not functioning. Similarly, when some of these circuit breakers are connected in parallel combinations, the output event can also be represented by a Boolean variable capable of assuming either a value 1 or 0.

Construction of Fault Tree:-

The starting point is the occurrence of a single, well defined undesirable event of failure or the non-functioning (F) of the system. This undesirable event occurs as a result of the combinations of undesirable events at the levels of circuit breakers & groups of circuit breakers. If a Boolean variable is associated with each basic event, then the undesirable final event for Boolean variable can be obtained.

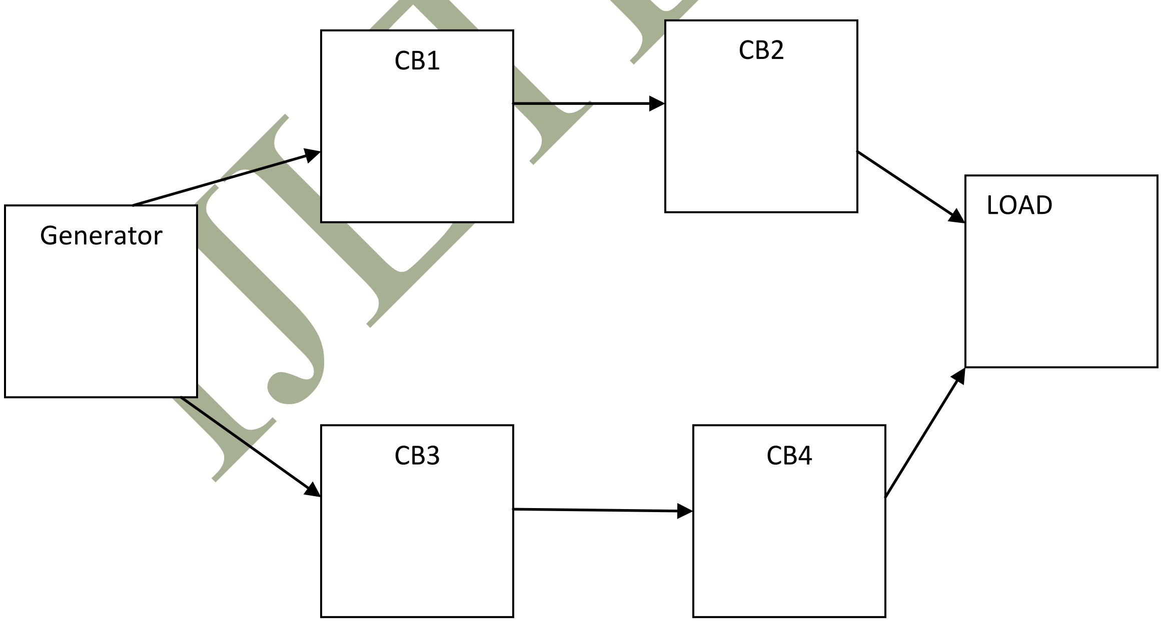

Figure Double circuit Transmission lines

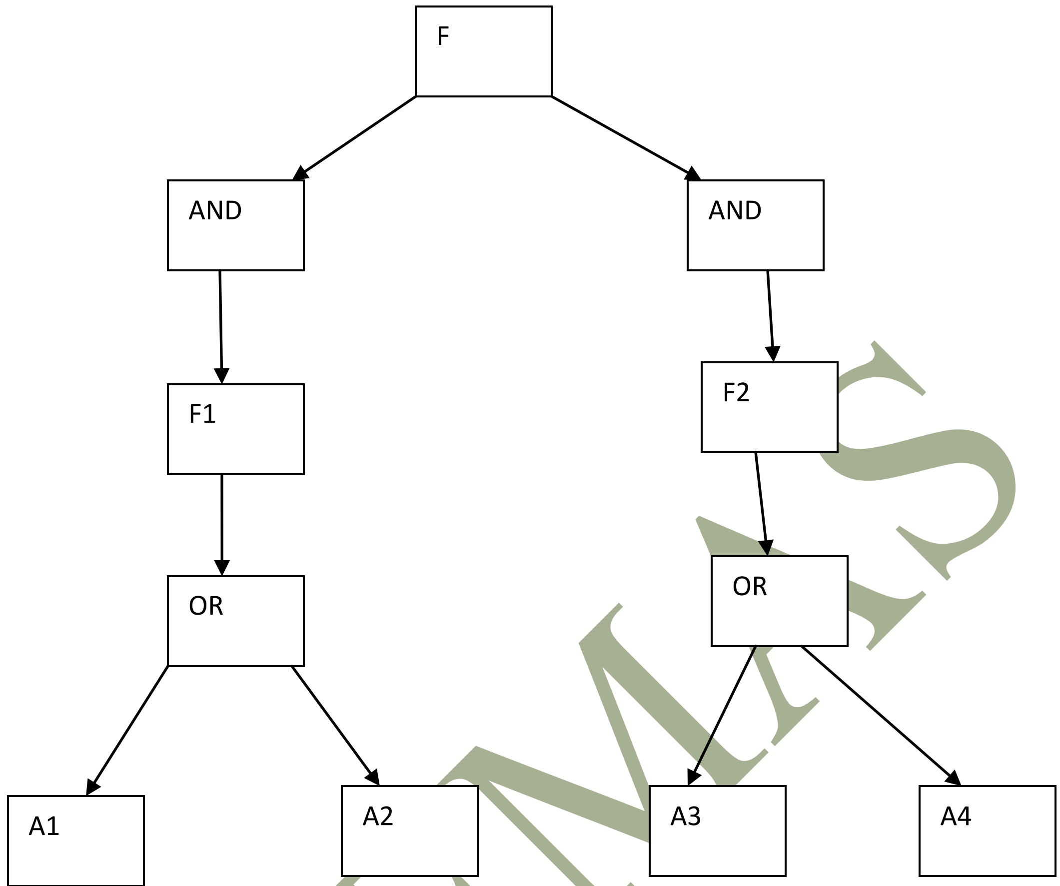

Figure Fault Tree Diagram

In the Fault Tree diagram of Figure 6, the Boolean variables associated are

A1: Failure of Circuit Breaker CB1,

A2: Failure of Circuit Breaker CB2,

A3: Failure of Circuit Breaker CB3,

A4: Failure of Circuit Breaker CB4,

The failure of CB1 or CB3 causes the failure of sub-system 1.
In the language of Boolean algebra, the occurrence of A1 or A3 causes event F1 to occur, thus
F1= (A1+A3) ……………………… (1)
Similarly, the occurrence of A2 OR A4 causes event F2 to occur, thus
F2= (A2+A4) ………………………… (2)
The occurrence of the final event F takes place when events F1 AND F2 occur, i.e.

F=F1.F2 ……………………………… (3)
Substituting the expressions corresponding to F1 and F2, we get
F= (A1+A3). (A2+A4)
= A1A2+A1A4+A2A3+A3A4 ………… (4)

The system obviously fails when
Circuit breaker CB1 and CB2 fail (corresponding to A1A2)
or
Circuit breaker CB1 and CB4 fail (corresponding to A1A4)
or
Circuit breaker CB2 and CB3 fail (corresponding to A2A3)
or
Circuit breaker CB3 and CB4 fail (corresponding to A3A4).

The plus sign in the Boolean expression stands for the OR operation.
The terms appearing in Eq. (4) are nothing but the minimal cut sets. The Boolean variables A1, A2,….are binary variables capable of assuming a value 0 or 1, the way these variables are used in a fault tree diagram is such that each of these variables has assumed a value 0, Indicating failure.
Thus, in Eq. (1), (2) and (3)

F1=A1+A3 = 0+0=0,
F2=A2+A4=0+0=0,
F=F1.F2=0.0=0.

Conclusion:-
This method proposed for enhancing the reliability of power system including the approach of successful path and failure path are useful for solving complex Interconnected Transmission line networks.
The system reliability is further increased due to the introduction of Distributed Generator The method developed for calculating the reliability for a sample two generator wind farm can be extended to large number of wind generators connected on the various network combinations in transmission lines to give uninterrupted power supply to the customers.

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