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Calculation and comparison of circuit breaker parameters in Power World Simulator

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ABSTRACT
A circuit breaker has ratings that an engineer uses for their application. These ratings define circuit breaker performance characteristics. A good understanding of Ratings allow the electrical engineer to make a proper comparison of various circuit breaker designs.
In this research work, the different ratings of circuit breaker were calculated. The other objective of this work was comparison between ratings of existing circuit breaker and calculated ratings in POWER WORLD SIMULATOR. Further, the impact of time delay in circuit breaker was studied. These calculations were performed for rated current of 400 & 630 Amps. The results performed in POWER WORLD SIMULATOR were shown better and information gained from the analysis can be used for proper relay selection, settings, performances and coordination.

I. INTRODUCTION

A circuit breaker is piece of equipment which can make or break a circuit either manually or by remote control under normal conditions, break a circuit automatically under fault conditions, make a circuit either manually or by remote control under fault conditions.

A circuit breaker has three ratings viz. breaking capacity, making capacity and short time capacity. Breaking capacity is current r.m.s that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions. Recovery voltage is the normal frequency r.m.s voltage that appears across the contacts of the circuit breaker after final arc extinction. The breaking capacity is always stated at the r.m.s value of fault current at the instant of contact separation. It is expressed in units of MVA.

Making capacity is the peak value of current during the first value of current wave after the closer of circuit breaker. The making capacity depends upon ability to withstand and close successfully against the effects of electromagnetic forces. These forces are proportional to the square of maximum instantaneous current on closing. It is expressed in terms of kA.

Short-time rating is the period for which the circuit breaker is able to carry fault current while remaining closed. The short-time rating of a circuit breaker depends upon its ability to withstand electro-magnetic force effects and temperature rise. The circuit breakers have a specified limit of 3 seconds when the ratio of symmetrical breaking current to the rated normal current does not exceed 40. However, if this ratio is more than 40, then the specified limit is 1 second.

The circuit breakers are classified into below categories-
OIL CIRCUIT BREAKER which employ some insulating oil for arc extinction.
AIR- BLAST CIRCUIT BREAKER in which high pressure air-blast is used for extinguishing the arc.
SULPHUR HEXAFLURIDE CIRCUIT BREAKER in which sulphur hexafluoride gas is used for arc extinction.
VACUUM CIRCUIT BREAKER in which vacuum is used for arc extinction.
The circuit breaker used in this work is SF6 Circuit Breaker. Vacuum Circuit Breaker incorporates a specially designed and completely sealed Interrupter to perform its basic function of opening as well as closing when called upon to do so, both under normal operating conditions and under fault conditions such as short circuit. Since, SF6 offers the highest insulating strength; it has far superior arc quenching properties than any other medium.
The calculation of circuit breaker ratings is based on the symmetrical fault or three phase fault. A fault which gives rise to equal fault currents in the lines with 120 degree displacement is known as three phase fault or symmetrical fault. Faults could happen when a phase establishes a connection with another phase, lightning, insulation deterioration, wind damage, trees falling across lines, etc.
The effects of fault on power system are:
1. Due to overheating and mechanical forces developed by faults, electrical equipments such as bus-bars, generators and transformers may be damaged.

2. The voltage profile of the system may be reduced to unacceptable limits as a result of fault. A frequency drop may lead to instability.
These ratings are used by the engineer to determine the ability of the circuit breaker to protect it and other devices and to coordinate with other circuit breakers so the system will trip selectively. These calculations are performed on 132 kV transmission system, Kotakpura for 400 and 630 Amps.

The single line diagram of 132 kV transmission systems, Kotakpura is shown in figure1.

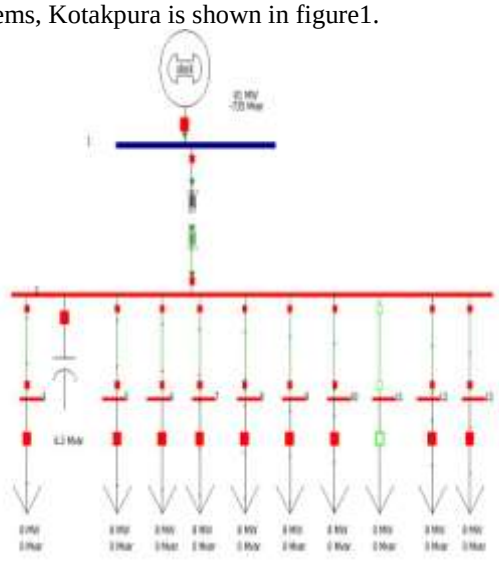


Figure1: 11- Bus 132 kV transmission systems

II. PROBLEM FORMULATION

A. Calculation of circuit breaker parameters

The bus model of 132kv substation, kotakpura is implemented and executed using POWER WORLD SIMULATOR. All calculations are performed in per unit system. By imposing the three phase balanced fault, fault current is calculated in Power World Simulator. Different formulae for calculation of circuit breaker parameters are given below:

1. Breaking capacity = $\sqrt{3}\times V\times I\times 10^{-6}$ (MVA)
Where,
V is line voltage in volts
I is the rated breaking current in Amps

2. Rated Symmetrical breaking Current

$$= \frac{Rupturing\ \ capacity}{\sqrt{3}\times \text{rated voltage}} \text{ (kA)}$$

3. Making capacity
= 2.55 × symmetrical breaking current (kA)

4. AC component of short circuit current
= √2 × symmetrical breaking current (A)

5. DC component of short circuit current
= 50% of AC component of short circuit current
Or
$= \frac{1}{2} \times$ AC component of short circuit current (A)

6. Short time rating
= √ [(AC component of short circuit current/√2)^2 + (DC component of short circuit current)^2] (kA)

B. IMPORTANT DEFINITIONS

ARC VOLTAGE: It is the voltage that appears across the contacts of the circuit breaker during the arcing period.
RESTRIKING VOLTAGE: It is the transient voltage that appears across the contacts at or near zero current during arcing period.
RECOVERY VOLTAGE: It is the normal frequency r.m.s voltage that appears across the contacts of the circuit breaker after final arc extinction.
BREAKING CAPACITY: It is current r.m.s that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions.
MAKING CAPACITY: The peak value of current during the first cycle of current wave after the closure of circuit breaker is known as making capacity.
SHORT-TIME RATING: It is the period for which the circuit breaker is able to carry fault current while remaining closed.
NORMAL CURRENT RATING: It is the r.m.s value of current which the circuit breaker is capable of carrying continuously at its rated frequency under specified conditions.

C. Standard Parameters

TABLE I: THREE CORE ARMOURED CABLE (COPPER CONDUCTOR) PARAMETERS AS PER IEC 60502-2.

Normal operating voltage (kV rms)	**Rated voltage (kV rms)**	**Rated power-frequency withstand voltage (kV rms)**	**Rated lightning impulse withstand voltage1.2/50 µs 50 Hz(kV peak) list 1 list2**
10 t0 11	12	28	60 75

TABLE II: IMPULSE AND POWER FREQUENCY WITHSTAND VOLTAGE AS PER IEC 60071 AND 60298

Nominal Area of conductors	**Thickness of Insulation**	**Conductor resistance (R)**	**Conductor Reactance (X)**	**Shunt Charging Capacitance (B)**
300 sq.mm	3.4 mm	0.0797 Ω/km	0.086 Ω/km	0.53 µF/km

III. RESULTS AND DISCUSSION

The single line diagram of 132 kV transmission systems, Kotakpura is shown in figure1. Table III & V shows the calculated circuit breaker parameters of 11 bus 132 kV transmission system using POWER WORLD SIMULATOR. Table IV shows comparison between existing circuit breaker ratings and calculated ratings. Graph I & II shows the impact of time delay on frequency of circuit breaker.

TABLE III: CIRCUIT BREAKER PARAMETERS FOR RATED CURRENT 400AMP

bus number	**short circuit current (kA)**	**Breaking capacity (MVA)**	**Rated Symmetrical breaking Current (kA)**	**Making capacity (kA)**	**AC component of short circuit current(A)**	**DC component of short circuit current(A)**	**short time rating (kA)**
1	2.795	639.02	2.794	7.1247	3.95	1.975	3.42
2	31.321	596.74	31.325	79.88	44.3	22.15	38.36
3	40.194	765.8	40.2	102.51	56.85	28.43	49.24
5	40.195	765.8	40.2	102.51	56.85	28.43	49.24
6	40.195	765.8	40.2	102.51	56.85	28.43	49.24
7	40.195	765.8	40.2	102.51	56.85	28.43	49.24
8	40.195	765.8	40.2	102.51	56.85	28.43	49.24
9	40.195	765.8	40.2	102.51	56.85	28.43	49.24
10	40.195	765.8	40.2	102.51	56.85	28.43	49.24
12	40.195	765.8	40.2	102.51	56.85	28.43	49.24
13	40.195	765.8	40.2	102.51	56.85	28.43	49.24

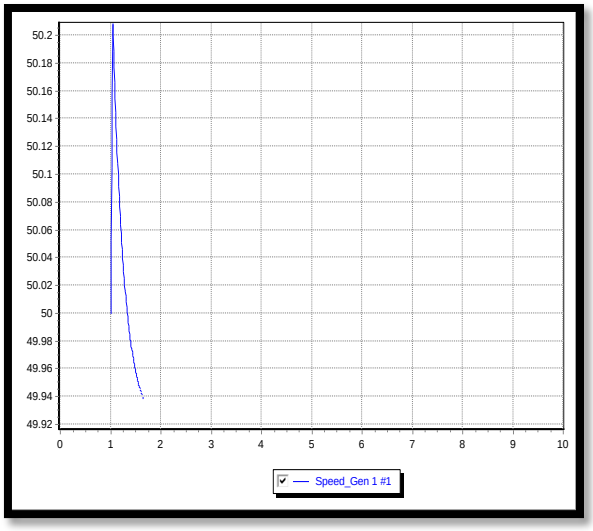
TABLE IV: COMPARISON BETWEEN EXISTING AND CALCULATED CIRCUIT BREAKER RATINGS

Parameters	Existing circuit breaker ratings	calculated ratings using power world simulator
Rated voltage (kV)	12	12
Frequency (Hz)	50	50
Rated current (A)	630	630
Making capacity (kA)	62.5	79.96
Symmetrical breaking capacity (kA)	25	31.4
Short time rating for 3 seconds (kA)	25	38.41
Operating Duty cycle	O-0.3-CO-3-CO	O-0.3-CO-3-CO

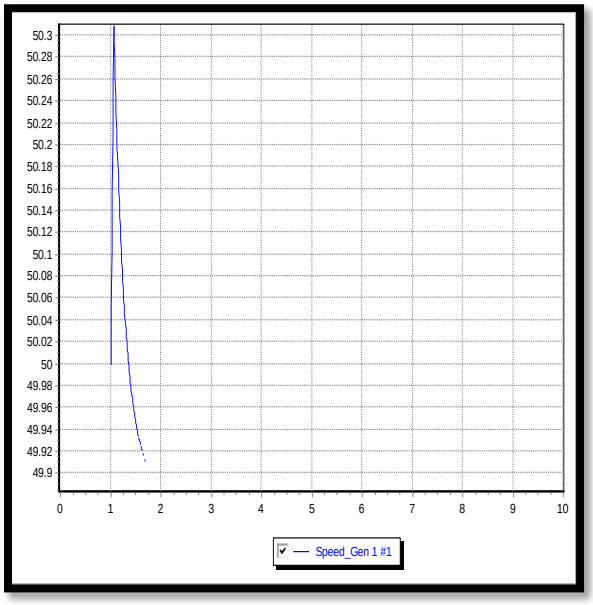
TABLE V: CIRCUIT BREAKER PARAMETERS FOR RATED CURRENT 630AMP

bus number	**short circuit current (kA)**	**Breaking capacity (MVA)**	**Rated Symmetrical breaking Current (kA)**	**Making capacity (kA)**	**AC component of short circuit current(A)**	**DC component of short circuit current(A)**	**short time rating (kA)**
1	2.798	639.7	2.797	7.1323	3.956	1.978	3.425
2	31.356	597.4	31.359	79.9654	44.35	22.175	38.41
3	39.386	750.4	39.391	100.447	55.71	27.855	48.246
5	39.386	750.4	39.391	100.447	55.71	27.855	48.246
6	39.386	750.4	39.391	100.447	55.71	27.855	48.246
7	39.386	750.4	39.391	100.447	55.71	27.855	48.246
8	39.386	750.4	39.391	100.447	55.71	27.855	48.246
9	39.386	750.4	39.391	100.447	55.71	27.855	48.246
10	39.386	750.4	39.391	100.447	55.71	27.855	48.246
12	39.386	750.4	39.391	100.447	55.71	27.855	48.246
13	39.386	750.4	39.391	100.447	55.71	27.855	48.246

In Table IV, Comparison between existing circuit breaker ratings and calculated ratings using power world simulator is performed. It is concluded that by using POWER WORLD SIMULATOR TOOL we can get better results than existing results. On account of these results, further selection of equipments can be done.



Graph I: frequency versus time graph for 2 cycles



Graph II: frequency versus time graph for 3 cycles

When three phase balanced is imposed on bus three, the effect on frequency is more for 3 cycles as compared to 2 cycles. Therefore, time to clear fault is greater for 3 cycles as compared to 2 cycles as shown in graph I & II above.

IV. CONCLUSION

As power system designing is very serious issue and complex in nature, so it very necessary to design a system with excellent protective system. Now- a - days, the parallel transmission lines are increasing which leads to decrease in resistance. As a result, impedance of system is also decreasing and hence short circuit level is increasing day by day. To avoid this problem the circuit breaker should be able to withstand the short circuit currents. In this paper, circuit breaker parameters are calculated and compared with existing circuit breakers ratings. Hence, better results are calculated using POWER WORLD-SIMULATOR.

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