Short Circuit Analysis of EHT Network and Solutions for De-Rated Equipment

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ABSTRACT

In any power system, load growth occurs due to increase in various activities including industrial expansion, infrastructure development, population growth etc. To meet power demand, the electrical network of utility company required addition in transmission lines, grid stations and power generation. The heavy current that flows due to short circuits causes different types of internal and external faults on the power system which may damage the equipment in the grid station if the fault is not cleared in time. The equipment in the grid station must have the capability to withstand the heavy short circuit level. If unusually high currents exceed the capability of protective devices in the power system, a short-circuit can cause the devices to explode like a bomb, which may ultimately result in collapse of entire system leading to brown out or black out. All these expansion leads to increase in short circuit levels. The short circuit current passes the high voltage, network equipment including circuit breakers, disconnectors, current transformers, potential transformers, surge arresters etc. The high voltage equipment's need to be check due to increase in short circuit current due to addition in power plants, auto transformers, power transformers and transmission lines. The equipment's that are already installed are required to withstand short circuit at all time. In the presented work, short circuit levels are calculated by using a software ETAP (Electrical Transient Analysis Program), followed with the analysis of existing equipment's as whether it can withstand the short circuit level. The proposed period of study is set to be 5 years (till year 2023). Furthermore, three different types of solutions are provided for the derating equipment in the K- electric 220V and 132KV transmission lines

Key Words: Short Circuit Level, Faults in Power System, rotective Devices, Load Growth, Power Demand, Electrical Transient Analysis Program, System Analysis, Black Out.

1. INTRODUCTION

The proposed research work which is implemented under the name of “Short-circuit analysis of EHT (Extra High Tension) network of K-Electric for five years (2018-2023) and solutions for de-rated equipment” is a simulation-based research work in which EHT Network of Karachi City is considered. The term EHT in our research work is used for 220 and 132KV.

K-Electric is the main vertically integrated power utility in Pakistan, managing all three categories generation, transmission and distribution [1]. Various researchers have performed their studies in this domain [2-4]. All the related data is taken from K-Electric. This research work is carried out through a prominent software ETAP and is based on the load flow analysis which is implemented for whole K-Electric network including 220, 132 and 66KV circuits so as to match the results of simulation. Further short circuit analysis is done on the network on different levels. The basic purpose is to find the de-rated equipment in K-Electric EHT Network. The de-rated equipment means the protective equipment which are present in the system has reduces its capacity since many years despite that system has expanded and may expand further. Equipment are usually chosen according to the system short circuit level at the time of installation which after sometime may have increased [5-9]. The equipment must therefore be changed for the effective working of the system. The research work has a provision for this, in which short circuit level of K-Electric existing EHT Network will be observed and solutions of de- rated equipment will be given as per the conditions.

2. POWER FLOW STUDIES

ETAP software has been used for the load flow study with the consideration of removing issues related to under voltage scenarios. The load flow study is used for calculating required size and location of capacitors for removing the issue of under voltage. What-if scenarios can be investigated by these studies specially related to sudden addition and removal of loads to the system. These studies also indicate the fluctuations in system voltages and capacity utilization of system equipment, under various contingencies.

Studies related to load flow are frequently used to pinpoint the necessity for the:

(a) Added generation.

(b) Inductive or Capacitive VAR (Volt-Ampere Reactive) support.

(c) The employment of capacitors and/or the reactors for maintaining the voltages of system within designated margins.

Power flow studies of the K-Electric system has done through these steps which are mentioned below.

- ➢ The analysis of technical aspects.
- ➢ Load Flow Study for the steady state stability.
- ➢ Stability analysis results are to be matched with the

K-Electric network data.

- Short circuit analysis to determine the magnitude of short circuit current.
- Short circuit levels that the system can produce under faulty condition.
- Comparing magnitudes with the ratings of interrupting, over current protective components.
- Sequence of events consisting of the initial loss of a single generator or transmission component.

3. LOAD FLOW AND ETAP SIMULATION

In this work, load flow study using ETAP software is carried out with an approach to overcome the problem of an under and over voltage at buses. Load flow studies using ETAP software is an excellent tool for system planning. A number of operating procedures can be analyzed such as the loss of generator, a transmission line, a transformer or a load. Load flow studies can be used to determine the optimum size and location of capacitors to surmount the problem of an under voltage. Also, they are useful in determining the system voltage sunder conditions of suddenly applied or disconnected loads.

Load flow studies determine if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are over loaded. Load flow studies are often used to identify the need for additional generation, capacitive, or inductive VAR support, or the placemen to capacitors and/or reactors to maintain system voltages within specified limits.

Some of the screenshots of simulation work is shown in Fig 1. The Fig. 1 is the whole semantic of utility company network created using ETAP software. It Contains 66, 132 and 220 kV buses layout with generators feeding the system.

Fig. 2 shows the load flow data on CCP (Competition Commission of Pakistan) bus which consists of six generators four of which are rated at 40MW and are operating at a reactive power of 29.8 MVAR with current outflows of 2404 Amperes and after the stepping up of the voltage levels the reactive power drops down to 27.8MVAR and current out flows to 125.7 Amperes. The remaining two generators are operating at 15 MW with reactive power equal to 15.3 MVAR which drops down to 14.1 MVAR and the current outflows from 1064 Amperes drops down to 53.2 Amperes. The CCP is operating at 222.5 kV.

Fig. 3 shows the load flow data on Dhabajee bus with connected loads.

There are a total of two power transformers connected as loads on the Dhabeji grid rated at 16 and 27 MVA. The active power being drawn out 14.4 and 24.3 MW respectively. The reactive power being 6.97 11.8 MVAR respectively. The currents being 64.4 115.8 Amperes respectively. The bus operating voltage is found to be 129.1 kV.

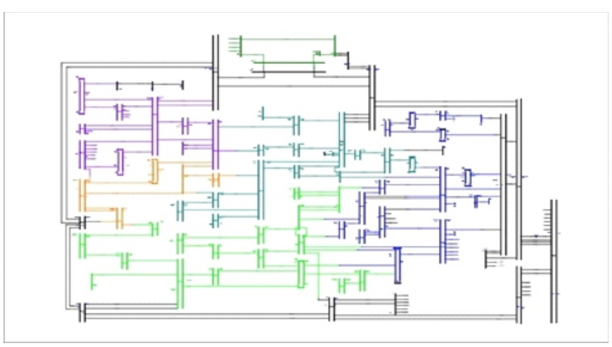

FIG. 1. NETWORK DIAGRAM ON ETAP SOFTWARE

4. SHORT CIRCUIT ANALYSIS

4.1 Short Circuit Faults

When the insulation of the system fails at one or more points or a conducting object comes into contact with alive point, a short circuit or a fault occurs.

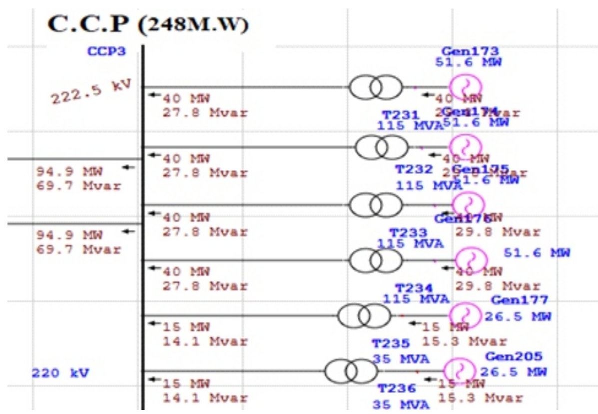

FIG. 2. LOAD FLOW CCP BUS USING ETAP SOFTWARE

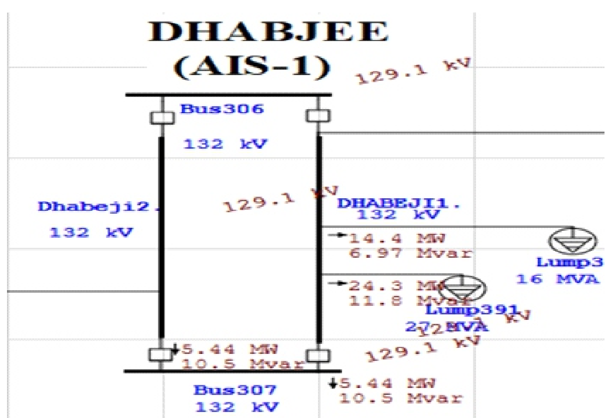

FIG. 3. LOAD FLOW ON DHABAJEE BUS USING ETAP SOFTWARE

There are mainly two character of faulting in the electrical power system. Those are:

- Symmetrical faults or balanced three phase faults
- Unsymmetrical faults or unbalanced faults.

4.2 Effect of Short Circuit Faults

The Over Current: After the occurrence of fault, a very low impedance path is created for the current flow. Due to this, very high current s being drawn from the supply, which causes the tripping of relay, also damage components and insulation of equipment.

Risk to the Operating Workers: Fault existence can also bring shocks to the persons. The Severity of shocks be governed by the voltage and current at the location of fault and may also lead to the death.

5. DAMAGE OF EQUIPMENT

The heavy currents due to the short circuit fault result in the damage of components, can burn completely and this leads to inappropriate working of the equipment or device. At times substantial fire can cause complete equipment burnout.

Study on K-Electric Network: Electrical fault is an abnormal status, caused by equipment failures such as transformer and rotating machine, human errors and environmental conditions. Theses faults cause interruption to electric flows, equipment amends and even cause death of humans, birds and animals.

The existing condition of grid stations at 220 KV of K-Electric is not much satisfactory with regards to the increased short circuit current levels. The protection scheme of K-Electric was designed years ago primarily in regards to the short circuit level of that time. However, the system has expanded in terms of generators and loads, which contributes towards increased short circuit level of each grid. The existing protection scheme may not be able to operate correctly for some grid stations, as there is an increase in the short circuit current level. This happens due to the gap between designed protection scheme current carrying capacity and the short circuit current level of grid stations. As the main concern of this research work is to provide solution for 220 KV grid stations of K-Electric , therefore the concentration of the research work revolves mainly around the 220 KV network. There are ten grid stations of 220 KV in K-Electric limited.

Respective Results: The results of our studies for different 220 KV grid stations are depicted in Table 1 showing all the grids that needs immediate replacement.

The following results are obtained using ETAP, by inserting the generator and transformer ratings/ parameters.

As observed from Table 1, at BQPS-1 (Bin Qasim Power Station), BQPS-II, ICI (Imperial Chemical Industries), KDA (Karachi Development Authority) and Pipri West, the protective equipment rating is shown to be 40 KA but the existing short circuit level at the grid is exceeding the rated capacity of the breaker, thus, the protective device needs immediate replacement.

TABLE 1. RESULTS OF SHORT CIRCUIT LEVELS AT 220KV GRIDS

Grid Stations	Existing Short Circuit Current Level (KV)	Protective Equipment Rating (KV)	Identification of Protective Equipment/Scheme
BQPS-I	43.29	43.29	De-Rated
BQPS-II	43.29	40.00	De-Rated
Baldia	40.5 0	40.00	Not De-Rated
CCP, KPC (Knowledge, Practices and Coverage)	19.08	40.00	Not De-Rated
ICI	42.24	42.24	De-Rated
KCR (Karachi Circular Railway)	23.90	23.90	Not De-Rated
KDA	42.90	42.93	De-Rated
Lakazar	23.00	40.00	Not De-Rated
Maripur	24.40	40.00	Not De-Rated
Pipri West	43.39	40.00	De-Rated

6. SOLUTION TO REDUCE SHORT CIRCUIT LEVELS

General Solution: The topography of the power system networks continues to change as country's economy grows and consumption increases. The major impact is the increase in short circuit currents in the power system due to the growth of the power system and the expansion of the complex transmission network. The increased short circuit current affects every protective power system equipment that causes heat loss and mechanical stress. This is because the protection system was designed many years ago according to the expected short circuit current, but the current short circuit is due to the expansion of the power system network and the load growth. To address this problem, we must reduce the power system network's short circuit current. Some techniques are used to reduce the short circuit currents. They are as listed below:

(i) Technique-1: Split bus bars
(ii) Technique-2: Split network
(iii) Technique-3: Use of current limiter
(iv) Technique-4: Change the neutral earth policy
(v) Technique-5: Changing some lines from AC-DC
(vi) Technique-6: New transmission network
(vii) New protection scheme

Types of Solutions: They can be classified into three main categories as following:

Interim/Immediate Solution: An interim solution is a problem-solving technique that uses the fastest solution available to the given problem. This solution is not permanent and can ever betray.

Solution for Short Period: A short-term solution is a problem-solving technique that uses sustainable solutions rather than interim solutions. This solution could be permanent, but it can only survive until the near future.

Solution for Long Period: Along-term solution is a problem-solving technique that uses the most significant and durable solution of the given problem. The methods used in this solution are permanent and could solve the problem forever. It is one of the most sustainable solutions. This solution could be expensive.

Typical and Quantitative Analysis for Solution: The techniques involved in reducing short circuit current are categorized as solutions reliability and network reliability, as shown in Table 2.

TABLE 2. TYPICAL ANALYSIS FOR SOLUTIONS

Techniques	Solutions Reliability	Network Reliability
Splitting of Bus bar	Solution for short term	Maximum
Splitting of Network		Medium
Use of Current Limiter		Maximum
Change of Neutral Earth Policy	Interim solution	Minimum
Changing some lines from AC-DC		
New transmission network	Solution for long term	Maximum

Implementation on K-Electric Network: The existing K-Electric condition does not coincide with the above-mentioned solutions. Since the technology of changing neutral earth policy cannot work for this case, this technique usually works close to the distribution side and for asymmetrical faults that are not the scope of this research work. Other new transmission network techniques and the new protection scheme would impose an unfeasible high cost on K-Electric. Therefore, the remaining techniques that include changing certain lines from AC-DC, splitting bus bars and using the current limiter are considered much more practical for the K-Electric network.

Identification of Derated Equipment in 220KV Network: Each 220 KV grid stations have been analyzed in detail. On the basis of our study, the identification of the de-rated equipment at each grid station of 220 KV network of K-Electric is carried out, which is described above in respective results.

Apparent Replacement Plan: The replace-ment plan for some grid station at 220KV, which can be shown in Tables 3.

TABLE 3. APPARENT REPLACEMENT PLAN

No.	Grid Station	Required Immediate Action	Suggested Future Action
1.	BQPS-I	Interim Solution	Long Term Solution
2.	BQPS-II		
3.	Baldia		Short Term/Long Term
4.	ICI		Long Term Solution
5.	CCP	Nil	No Action until the system is expands
6.	KCR		
7.	KDA	Interim Solution	Long Term Solution

On the basis of above analysis, implementation of following techniques has been suggested to reduce or cater the problem of increased level of short circuit current at each grid station of 220 kV network of K-Electric shown in Table 4.

TABLE 4. APPARENT REPLACEMENT PLAN USING TECHNIQUE

Grid Station	Interim Solution	Short Term Solution	Long Term Solution
BQPS-I	Split Bus bar	Current Limiter	Current Limiter/New Protection Scheme
BQPS-II			
Baldia	No Immediate Action Required	Split Bus bar/Current Limiter	
ICI	Split Bus bar	Use of Current Limiter	
CCP	No Immediate Action Required	No action required in future until the system has not expanded	No action required in future until the system has not expanded
KCR		Split Bus bar/Current Limiter	Current Limiter/New Protection Scheme
KDA		Current Limiter	
Lalazar		Split Bus bar/Current Limiter	
Maripur		Split Bus bar/Current Limiter	
NKI		Current Limiter	
Pipre West	Split Bus bar		

7. CONCLUSION

It has been concluded from the studies that the short circuit levels of Karachi are increasing with time and hence there is a need for are placement plan. The need of replacing the breakers to a larger capacity is very necessary as many of the breakers on the 220 KV transmission side are near to saturation. They must be replaced so that the breakers may operate properly for more 8-10 years. The current rating of the circuit breakers are 40 KA.

The main reason of system equipment failure is usually the implementation of low design margins. Power electrical equipment is subjected to two types of stresses.

(i) Electrical Stress: The equipment may go out of service due to excessive voltage, current or power.

(ii) Thermal Stress: Due to equipment's own and nearby equipment's energy dissipation.

A reduction in electrical stress results in a corresponding reduction in thermal stresses. The system's reliability consequently increases. In this research work, the reliability of system is increased by introducing comparatively high design margins, i.e. design capacity over anticipated stress. The reliability of the system can be improved by implementation of a comprehensive derating policy. Neglecting this may result in degraded performance and accelerated failure.

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