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RESEARCH ARTICLE

OPTIMIZATION OF FAULT CURRENT LIMITER PLACEMENT USING ETAP SOFTWARE

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ABSTRACT

Due to the increasing power demand, the security and safety of power systems have become major challenges. Distributed energy resources have been established for solving the problem. The fault current may exceed the capacity of circuit breakers (CBs); leading to damage to CBs and even cascading incidents such as blackouts. A fault current limiter (FCL), which can be used to reduce the current surges, has attracted considerable attention from utilities. Penetration of distribution generation is inevitable one. So that to ensure the safety of the circuit breakers, super conducting fault current limiters are modeled to limit the fault current well within the limit.IEEE 30 bus system has taken as a test system for fault current limiters operation by study performed in Electrical Transient Analyzer Program.

INTRODUCTION

Many solutions have been suggested to minimize the impact of the fault current, solutions which include reconfiguring the power system (Duggan, 2008; Jager, 2008),installing a current-limiting reactor (CLR), increasing CB capacity, and using FCLs .To meet more generation and capacities of growing load demands for system expansion, FCLs employed in a power system. The network topology may not be needed to change (Lee *et al*., 2008). While there exists a tie switch, the network topology can also be reconfigured flexibly through the tie switch to mitigate power congestion without violating fault current limitation and extra power loss (the type with superconducting device) (Noe *et al*., 2008). Reconfiguration of system by adding new power apparatus or replace existing one can thus be avoided to obtain economic benefits. The operators and planners of a transmission or distribution system may have more alternatives to ensure the system security and reliability. Reference (Mohseni, 2011) presents the benefits of an FCL connected Between two buses and it will reduces the network congestions. with implementation of superconducting FCL TRV values of CBs are higher when SFCL is present in the circuit. Moreover; FCLs have been shown to improve system reliability and generation dispatch efficiency. The FCL is used as a detecting element and protective device. A Study indicates that the FCL can be installed on the neutral line of a transformer’s secondary and third windings (Cho, 2012). The FCL bedding at an isolated operation point between a utility and a customer system with synchronous generators is discussed in (Kim, 2016). The authors suggest that the longer the interconnecting time, the more flexible the customer system operation with more capacity margin.

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Considerable research has focused on the positive impact Of an FCL on smart grids. In smart-grid applications, an increasing number of distributed energy sources, such as diesel generators, renewable resources, and Energy storage systems are integrated with power systems. Reference (Jo, 2015) discusses the benefits of different types of FCLs installed at different locations. When the FCLs positioned appropriately, it solves the protective in coordination problem caused by distributed generators (DGs).and the authors observe that the optimal placement of the FCL not Only reduces the fault current surge, but also increases the installation capacities of power plants. Due to the deployment of the FCL more transfer capacities of the transmission or distribution system can be done. An effective approach is, therefore, essential in system planning for utility, or even a large power consumer to determine the optimal location(s) for the FCL installation in their system at minimal cost, while meeting all the system constraints.

Allocation of the cost due to the FCL installation to those who benefit is similar to the capacity investment cost sharing in power wheeling. A few types of objective functions are used, considering reduction of fault current (Chen *et al*., 2004), and minimization of the reactance value only (Zare *et al*., 2013), the number of FCLs and shunt reactance (Shahbazi *et al*., 2011; Mohseni, 2011)), or the transmission power loss and reactance (Iioka, 2008; Im *et al*., 2014). However, these functions don’t have a comprehensive consideration including the efficiency and economy. Moreover, it is difficult to optimize the position of the FCLs in a large power system because of the presence of huge combination of placement candidates to be considered. In addition, even though the power flow and fault current calculations are Time consuming, some locations or areas not needing an FCL is under investigation. Computations for these candidates are, therefore, a waste of time (Zhang, 2014), and a scanning tool is required. Teng and Lu recommend a sensitivity factor for sorting the candidates in. Although the use of this method reduces the time taken to run the optimization algorithm by reducing the search space, it still requires considerable time, because it involves a Trial-and-error assessment as the effect of the FCL on the voltage drop of the healthy buses has not been considered in previous studies on the placement optimization problems. Also, existing methods are not sufficiently effective for devising an optimization plan for a large power system network. The aim of the paper is to propose a method to achieve the optimal placement of the FCLs at minimal cost from a system point of view. This paper modeled the IEEE 30 Node distribution test feeder using the commercial ETAP software. Simulated results obtained using load flow and short circuit studies are presented and discussed.

Types of Fault Current Limiter

Current Limiter

These are in research state of their development, they are easy to implement in distribution system but they are quite expensive due which are not encouraged to be implement on larger level.

Fuse

Fuse is a very effective, efficient interrupting device that can be used as current limiter. It is very inexpensive and practical. The problem within this area of being effective is limited because it can limit 40K volts and 200A of current.

Busbar Splitting Fault Current Limiter

Bus Coupler circuits breakers are used but they can be used

for a temporary strategy or an emergency situation, so can't be kept intact with substation all the time.

Current limiting reactor

it is the most economical and practical method. Its effects the reliability of substation are on a negligible level. Hardware in this approach is quite large in size .so it occupies huge space and stability of voltage can be degraded in this system.

Solid state fault current limiter

These are in research state of their development, they are easy to implement in distribution system but they are quite expensive due which are not encouraged to be implement on larger level.

Neutral reactor

Implementation of these reactors is also a good option to deal with fault current. It works best when it has to deal with earth/ground currents.

High Impedance of Transformer

Changing the Impedance of the existing transformer is Impractical.

Distribution Generation

The location of distributed generation is defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter. Distributed generation, also distributed energy, on-site generation (OSG) or district/decentralized energy is electrical generation and storage performed by a variety of small, grid-connected devices referred to as distributed energy resources (DER). Conventional power stations, such as coal-fired, gas and nuclear powered plants, as well as hydroelectric dams and large-scale solar power stations are centralized and often require electric energy to be transmitted over long distances. Due to contrast distributed energy resources systems are decentralized, modular and more flexible technologies are located close to the load they serve and it having capacities of 10 MW or less. There are multiple generation and storage components contains in this system. In this instance they are referred to as hybrid power systems.

Effects of distributed generation on electric power systems

Distributed generation (DG) is a term that refers to the production of electricity near the consumption place. The effects of distributed generation are short circuit levels are increased, load losses change, voltage profiles change along the network, voltage transients will appear, congestions can appear in system branches, power quality and realibility may be affected and the networks protections may not function properly. A load flow analysis is done for the IEEE 30 system in which a distributed generator is added, that is on-grid or off-grid. Solar Photovoltaic (SV) generators are introduced as Distributed Generators (DGs) at various nodes and the impacts of DGs that produces real and reactive power losses, voltage profile, phase imbalance and fault level of distribution system is studied.

Comparison of fault with and without FCL installed

The functions of SCFCL are listed below:

In normal operation, resistance value of the SC unit is approximately zero. The load current thus goes through SC unit with nearly no power loss;

Once a fault occurs, as the fault current exceeds a threshold, resistance of the SC unit increases dramatically based on designed material characteristics. The fault current thus goes through the shunt reactor unit instead and is largely Limited. The SCFCL model is built accordingly in ETAP software to achieve the functions mentioned above. Figure. 3(a) shows that the FCL superconducting (SC) unit in normal operation possesses zero impedance and the normal load current flows through the FCL SC unit. Once the fault current exceeds the designed operating threshold of the FCL as shown in Figure. 3(b), the impedance of the SC unit (SC) spurts to an extremely large value of 24 Ω from zero. Almost all the fault current transfers to the alternative Path via shunt reactance due to the impedance distribution of the SC unit and shunt reactor of FCL. By designing appropriate impedance of the shunt reactor (Zsh), like 1.02 + j19.89 Ω in the example, the FCL limits the first-cycle peak fault current of 19.5 kA in case of without FCL to well below the given threshold of 16 kA with FCL for subsequent cycles.

In addition to limiting fault current, the FCL also has the feature of preventing the voltage level of the secondary side of the transformer from zero due to the three phase fault as simulated in the example. As depicted in Figure. 3(c), the voltage at the secondary side of the transformer is the voltage across the FCL shunt reactor, a voltage which is not zero during the fault. The merit of this feature is to have less voltage variation at the upstream of faulted location, as the system is subjected to a fault. The IEEE 30 bus system then proposes traditional fault current calculations method, which is used to sort the feasible solutions and optimize the fault current limiters to limit the fault current value well within the limit.

Table 1. The table represent the short circuit study with or without DG system

Fault current Limiting Methods	Losses from Load flow KW	kVar	Short Circuit Current (KA)
Without DG	76.1	152.2	14.2
With DG	17.5	350.2k	24.9

Table 2.The table represents the comparison of current limiting method in the short circuit study

Fault current Limiting Methods	Losses from Load flow in the system KW	kVar	Short Circuit Current(KA)
Unit Transformer	147. 7	2018	19
Series Reactor	130.8	2550	17.5
Superconducting FCL	17.5	350.2	17.5
Bus bar splitter	153	3594	19.4
Is limiter	9	175.2	14.2

Unit Transformer Method

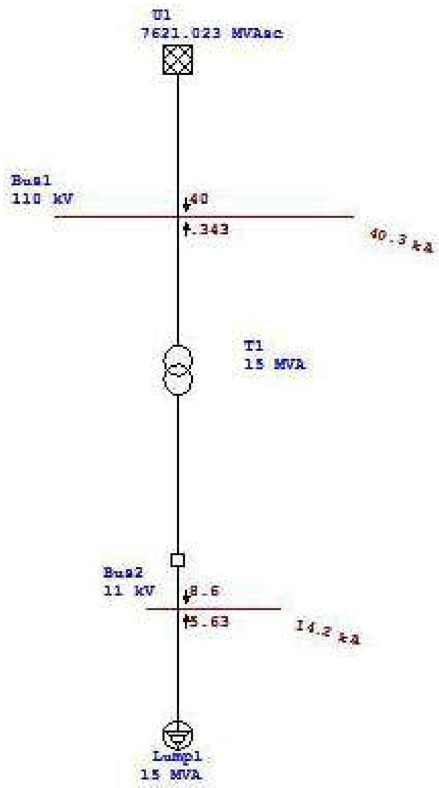


Fig.1.Single line diagram of IEEE 30 bus system Without using DG

Figure.1.unit transformer method is also knows as per unit transformer, because the expression of system quantities as fractions of a defined base unit quantity.

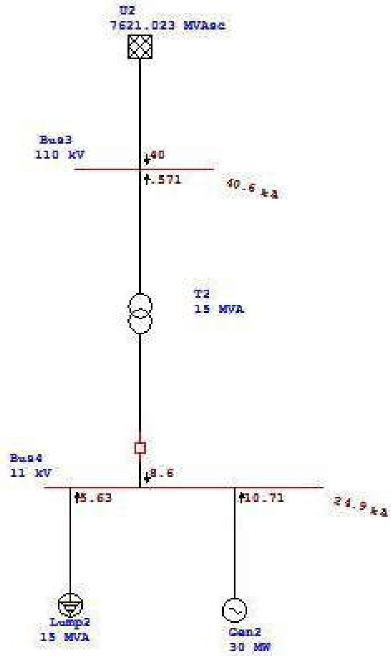


Fig. 2. Single line diagram of IEEE 30 bus system with DG

A per-unit system provides units for; power, voltage, current, impedance and admittance. The advantages of this method is the voltage can be controlled easily and it may affect the system performance, due to the losses occurrence in the system .But the major drawbacks is that the above method is that requirement of parameters is high and it leads to extend of the substation, therefore the cost of the unit transformer is increased. So it is not preferred widely. Consideration: From Figure.1. There is no distribution generator, the fault current value is 14.2KA.it doesn't exist the short circuit current rating, as the circuit breaker rating is 20 KA. Figure.2. the short circuit current rating is 24.9KA.It exists the short circuit rating, as the rating increased due to the installation of distribution generator.

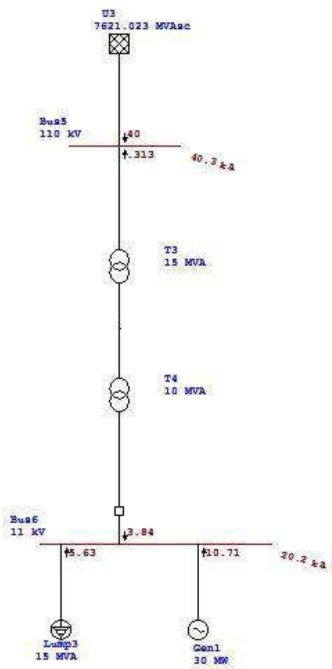


Fig. 3. Single line diagram of IEEE 30 bus system using unit transformer method

It leads to the replacement of the switchgear and also leads to the failure of the system. So, the unit transformer is added in series in the transmission line. In order to avoid the above causes of the system this is show n below Figure.3.
Without using

Series Fault Current Limiter Method

It is one of the most economical and practical approach. Its effects on the reliability of substation are on a negligible level. Hardware in this approach is quite large in size so it occupies huge space and stability of voltage can be degraded in this system. Consideration: Figure, 3 there is an installation of distribution generator I the system. And the short circuit rating is 24.9KA.sice the ratings is increased than the switch gear rating and not so replace the breaker we are going for the placement of limiter in the system.Figure.,4.due to the placement of series reactor .the withstanding capacity is limited, But the continuous losses will be across the reactor I the system and the short circuit rating is reduced as 17.5KA.the series fault current limiter method is cost efficient ad place requirement for the adding the limiter in the system is less ad so the limiter acts much faster than the other limiter but lesser than the super conducting fault current limiter.

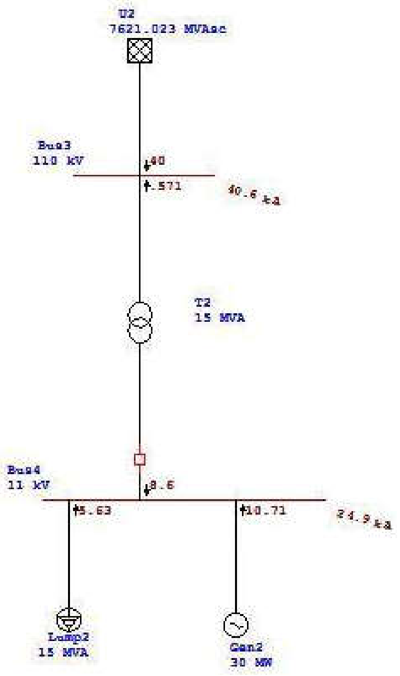


Fig.4. Single line diagram of IEEE 30 bus system without series reactor method

Superconducting Fault Current Limiter Method

SCFL is a self-acting system and this type of limiter protects grid operating equipment from damaging current peaks during faults events and it is one of the methods to solve conflict between rated value of circuit breaker and fault current. During the fault a high temperature SCFL is the solution to reduce the short circuit current level.

Consideration

Figure.7.there is an installation of distribution generator in the system. so that the short circuit current ratings is increased beyond the switch gear ratings as the ratings are 20KA and 24.9KA.so there is a requirement of placement of fault current limiter In the system.

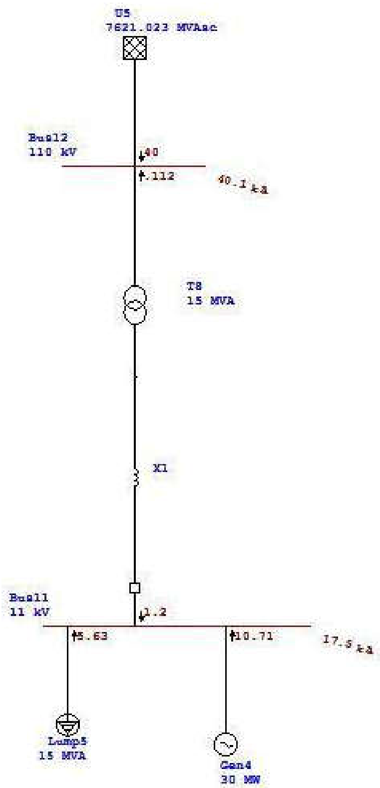


Fig. 5. Single line diagram of IEEE 30 bus system with using series reactor method

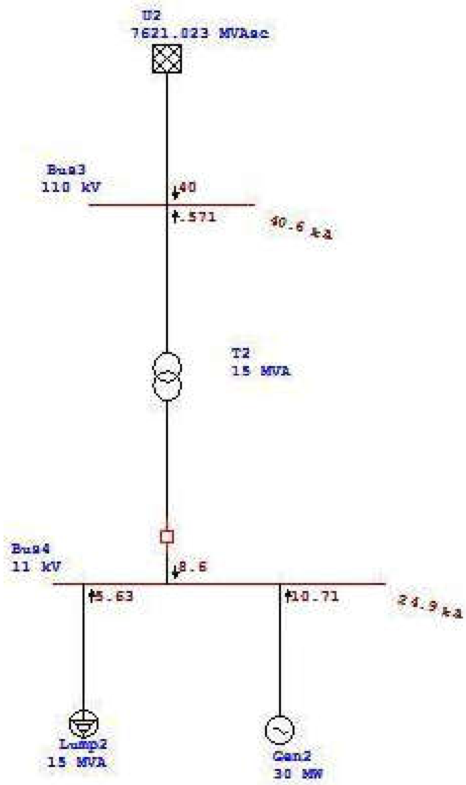


Fig.6. Single line diagram of IEEE 30 bus system Without using superconducting FCL method

The occurrence of continuous losses will not be there in the system. The SCFL are used as the current limiting reactors In the Figure.,6.since the SCFL is a fast reacting limiter so that the time consumption and also the requirement of place is also greatly reduced. The only drawbacks are that the cost of the super conducting fault current limiter is much higher than all other types of limiter used in the system.

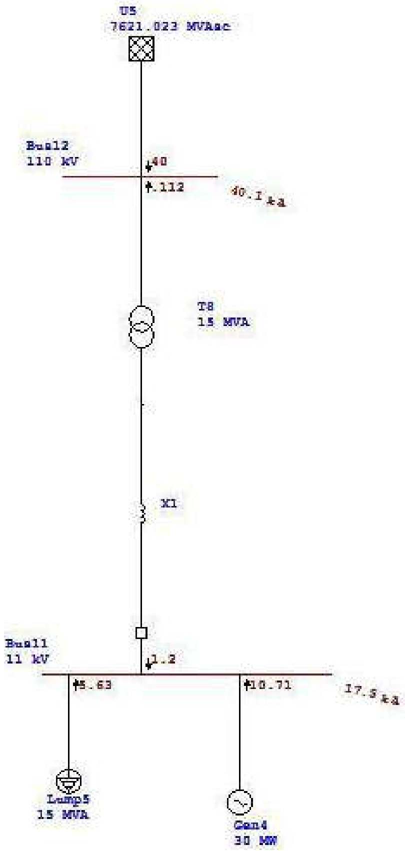


Fig.7. Single line diagram of IEEE 30 bus system with superconducting FCL method

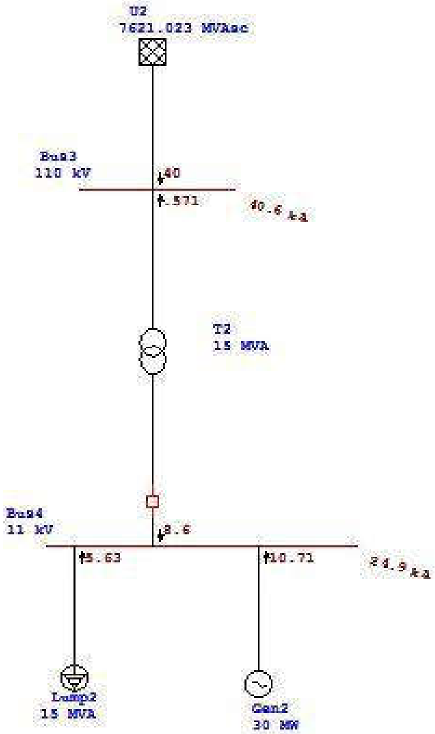


Fig.8. Single line diagram of IEEE 30 bus system Without Using bus bar splitter method

Bus Bar Splitter Method

It is commonly known as the network splittig method. Bus Coupler circuits breakers are used but they can be used for a temporary strategy or an emergency situation, so can't be kept intact with substation all the time.

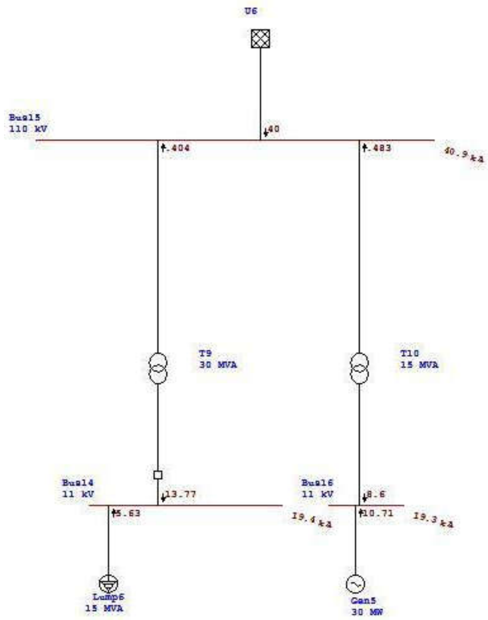


Fig. 9. Single line diagram of IEEE 30 bus system with bus bar splitter

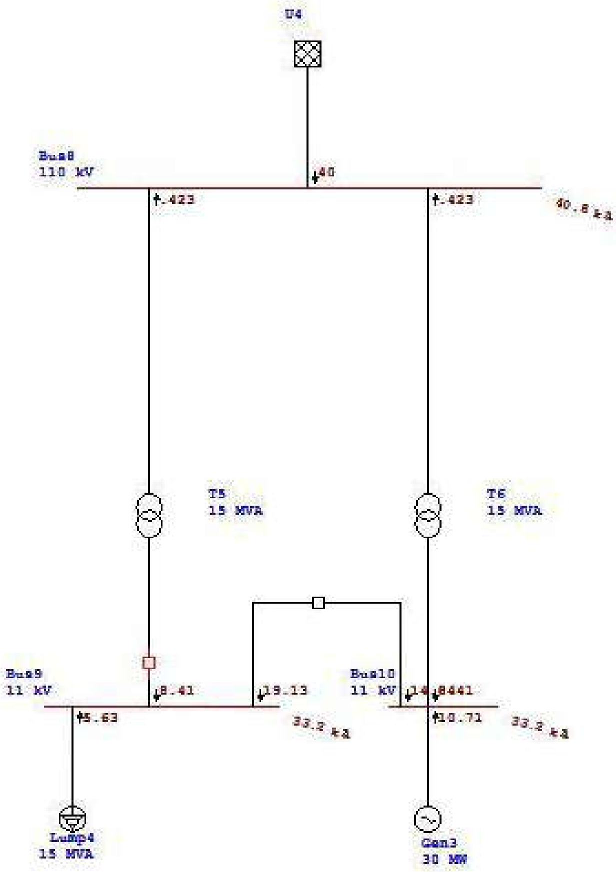


Fig.10. Single line diagram of IEEE 30 bus system without Using is limiter Method

Consideration

Figure.9.there is a installation of distribution generator and the short circuit current rating is 24.9KA,the distribution generators won't be utilied by the localized loads directly. so to reduce the losses in the system. there is a requirement of place of fault Current limiter in the system. refer Figure.,8 the figure shows the placement of limiter in the bus bar and also the addition of the parameters like transformer of rating 11MVA which is connected in parallel to the 33MVA transformer.

In the bus bar splitting technique, the fault current won't be increased beyond the limit in the existing system. but the losses will get increases due to the parallel connection of transformer. the bus bar splitig method is more expesive and not so widely used.

Is Limiter Method

Is limiter method is also known as the fast acting circuit breaker. It a fault current limiting device, It is used to reduce the short circuit current ratings. It is a non linear device. It has the advanced fault current limiter for complex application. The design of the fast acting limiter is that it composed of two types of current paths connected together in parallel. Consideration: Figure. 10 .The circuit diagram is similar to the bus bar splitting method but the short circuit rating varies as 33.2KA.to reduce the SCC values, the fault current limiter is added along with the newly added circuit breaker refer the

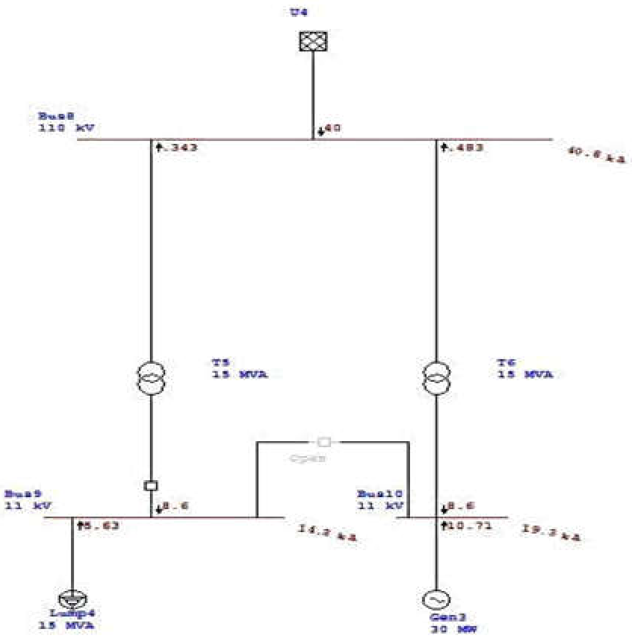


Fig.11. Single line diagram of IEEE 30 bus system is limiter method

Figure.11. Now the ratings is reduced as 19.3KA ad there will to be the requirement of replacement of circuit breaker since the breakers are with I the limit. Due to the newly implementation of the circuit breaker (CBs) the cost is increases exponentially and becomes higher. But the circuit breaker will acts 3ms, so that the fault current never ever reaches its peak value at any situation.

Case Studeis

S:NO	BASE CASE	WITH DG WITHOUT FCL	WITH DG WITH FCL
Site 1	9KA	30.6KA	13.8KA
Site 2	8.2KA	31.4KA	11.6KA
Site 3	11.4KA	19.5KA	12.8KA

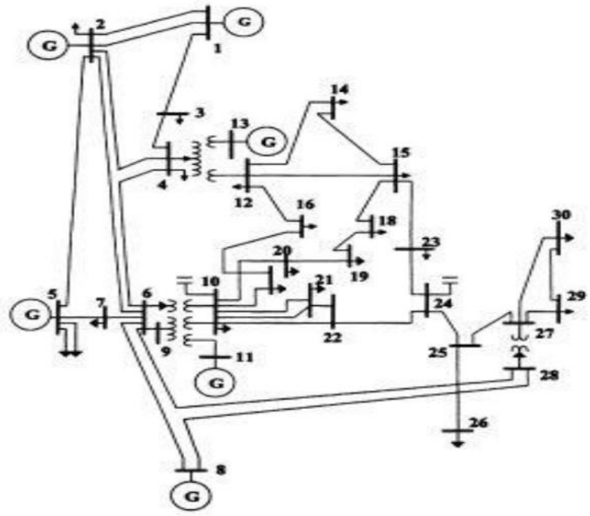
To verify the proposed method for the optimal FCL placement and the approach is tested on the IEEE 30 bus system. This method uses ETAP software as simulation tools.

Ieee 30 bus systems

This system consists of 5 Generators with three different voltage level buses of 132kV, 33kV and 11kV and four transformers. Each transformer consists of 100 MVA.

All the CB in the assumed to be 16 kA, which thus results in the overcapacity of fault current issues on the busses 24, 29,30 and cloverdle 3_27. Table.3.The table represents the base case, with DG without fault current limiter ad with DG with fault current limiter for all the sites of IEEE30 bus system.

Circuit Diagram for Ieee 30 Bus Systems



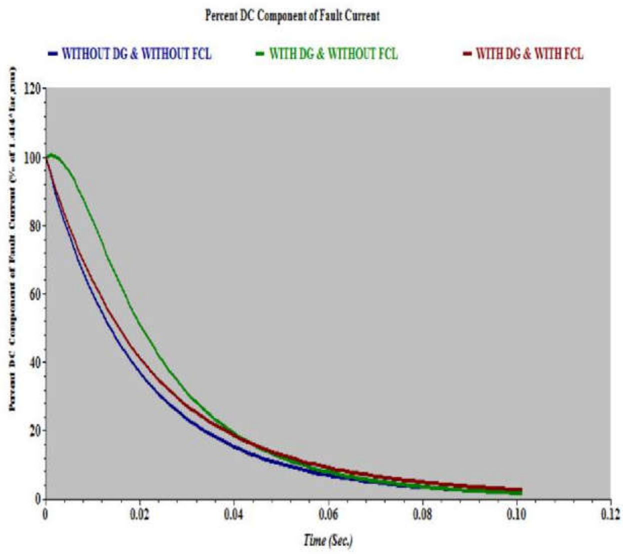


Fig.13.thegraphofpercentagedccomponent (%of 1.414*Iac,rms) vs time(secs)

Dg Site-3

It is the combination of both the ac and the dc component which is shown in the above Figure.13. The green slope in the Figure.13. indicates the presence of distribution generators and absence of limiter. Due to Distribution generators DC component is much higher than other buses which makes fault current value much higher.As the value is high ,so the limiter is placed which is shown as the red line slope in the Figure.13.as the limiter is placed the slope is gradually decreases' in the system. when there is no distribution generator and no limiter is connected and placed in the Figure.13.The slope is predominantly decreases' which is shown on blue colour slope in the Figure.13. Percentage is practically calculated by the use of formula.it is the ratio of dc component to the product of squre root of 2 and rms ac current and which is nothing but dc component.

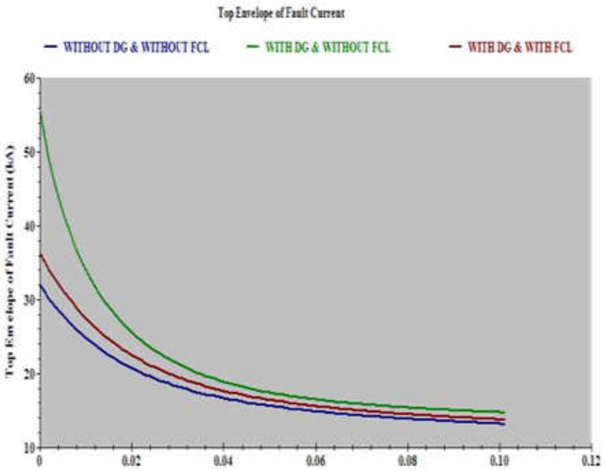


Fig.14. the graph of Top envelope of fault current (KA) vs time (secs)

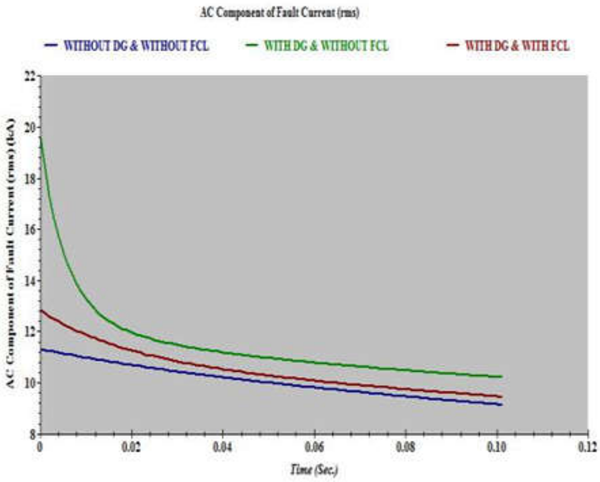


Fig. 15. The graph of AC component of fault current (KA) vs time (secs)

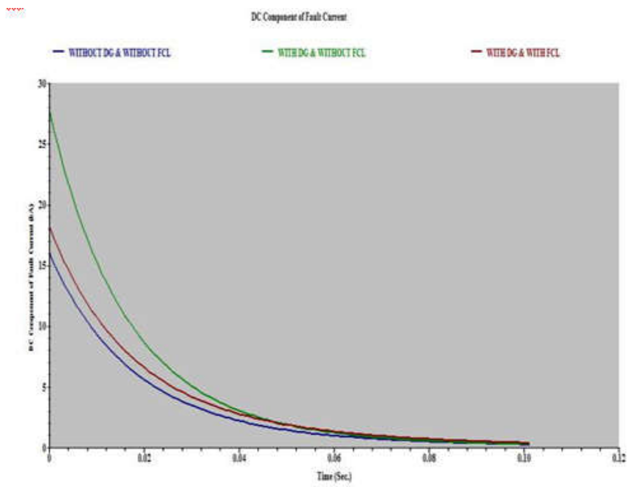


Fig.16. The graph of DC component of fault current (KA) vs time (secs)

Top envelope is nothing but curve which is touching the peak point of the total fault current. Ac component is due to the fault occurs in the system AC component presents in the system which is having decaying gradually with respect to time. From the above Figure.15: it is shown that the dc component slope is drawn for three cases.

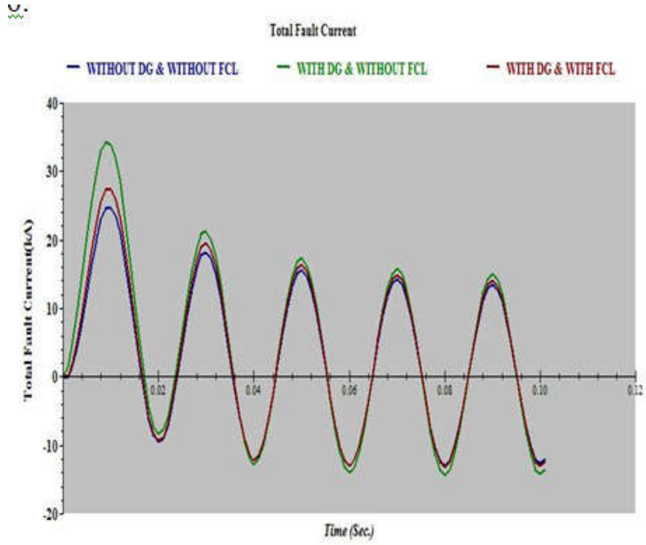


Fig. 17. the graph of Total fault current (KA) vs time(secs)

The value is much higher when compared to the other two cases. Since the case 1 as the slope for placement of fault current limiter. The AC component of fault current is practically calculated by the use of formula. It is the square root of the square of the N no. of current. Dc component is due to the fault occurs in the system DC component presents in the system which is having decaying gradually with respect to time. From the above Figure.16: it is shown that the dc component slope is drawn for three cases. The value is much higher when compared to the other two cases. Since the case 1 as the slope for placement .the graph is drawn between the dc component Vs time. All the three cases values are decreases and become constant after the value ranges between 0.5 to 0.6. From the above Figure.17.It represents the total fault current is the summation of Symmetrical fault current and DC Component .

Conclusion

In summary, the proposed approach has the following improvements of the previous researches as mentioned. Super conducting fault current limiters are effectively used in IEEE 30 bus system fault current limited within the limit and it ensures safety of circuit breakers. Actual price-determining factors of FCL placement are explicitly taken into consideration, such as the FCL number. The reactance value and the voltage drop across FCL. The proposed method has been tested on IEEE 30-bus system and compared with the existing approach to have better performance in terms of less number of FCLs installed. To me*et al*l the constraints. Moreover, the proposed method has also been applied to a realistic power system to solve the over-capacity fault current issues at minimal investment cost needed.

Future Scope

The aim of the paper is to propose a method to achieve the optimal placement of the FCLs at new generating units. Which will helps to increase the power transfer capability of transmission system and operating the distributed generation with effective manner.

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