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Simulation and reduction of permanent fault in the distribution networks by adopting Fault Current Limiters (FCL)

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Abstract
Occurrence of short Circuit in power networks followed by suddenly increase in Fault current is one of power networks problems. Such strong and sudden currents cause damage to the devices of power system grids and subscribers. In order to limit short circuit currents and to reduce its adverse effects, the fault current limiters (FCL) is used. In distribution networks in order to reduce the number of interruption or continuation of recloser is used that according to studies it several times switches on and off the fault current with certain time intervals. Continuous short circuit current switching on and off resulted from persistent errors by recloser leads to resonance thermal and mechanical stresses in distribution systems. In this study, a field study has been conducted on a medium voltage feeder having recloser and its simulation using MATLAB software and then we scrutinize the impacts of FCL application on transient recovery of voltage and current caused by recloser performance.

Key words: the fault limiters, recloser, transient, resonance, FCL

Introduction

In order to have Continuous and highly reliable electricity transmission, there is a need for appropriate protection. In the system by separating the components which errors have occurred in the protection would be done. (2) Occurrence of short circuit in the networks according to the high voltage and low impedance between the load and source causes the strong current. (3) This strong current is causing following problems for the system. (4, 5)

a- High mechanical stresses due to electromagnetic forces created in lines and devices.

b- Thermal stresses.

c- Flash voltage over the network and decrease in power quality.

The high fluctuation of voltage and current has been harmful to subscribers' received power quality and reduces the lifetime of network devices and system reliability.(8, 9)

To solve the above problems we should come up with an arrangement to limit the fault current. Adopting fault current limiters is one of the new methods to reduce the level of short circuit in the power systems. (6) These devices have been installed in series circuit and experience no impedance during a normal flow through the system. However, by the occurrence fault and short circuit currents it shows lots of impedance and prevents sharp increases in short-circuit current.(7) that finally leads to transient recovery of voltage and current.

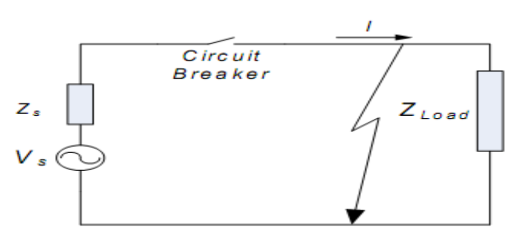
Moreover, the network protection against these disturbances has been of great importance for researchers which has resulted in new devices and solutions. One of these devices is recloser. They are able to detect and eliminate transient errors occurring in distribution network.

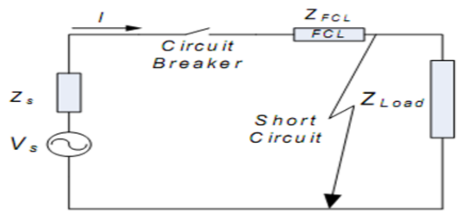
Most of the researches about recloses have been conducted on theoretical basis to investigate the benefits of using them.(2, 10) In this study we have investigated realistically and empirically the effects of the recloser on the network and using fault current limiters in it and their impact on transient recovery of voltage and current and Eliminate the adverse effects of protective equipment specially recloser. The model network is a real 25-bus network which belongs to the Great Tehran Electrical Distribution Company.

1- current limiters

Fault current limiters are devices which are installed in series circuit and show no impedance (Zero in the ideal case) during a normal flow through the network and also show big impedance (infinite in the ideal case) during a strong current and prevent the sudden increase of fault current. Almost all of available current limiters operate by entering large impedance in series circuit with the system and the only difference is in the method of making and inserting this impedance into the system(7).Short circuit in Figure 1 shows the presence and absence of current limiters.

A) In absence of current limiters





According to Figure 1, flow line without FCL (Equation 1) and with FCL (Equation 2), can be wrote as follows (parameters according to Fig. 1)

$$I_{line} = \frac{V_x}{Z_x + Z_{LDAD}} \quad (1)$$

$$I_{fault} = \frac{V_\alpha}{Z_\alpha + Z_{FCL} + Z_{fault}} \quad (2)$$

And Fault current would be like this:

$$I_{fault} = \frac{V_\varepsilon}{Z_\varepsilon + Z_{fault}}, here \ , Z_{fault} \leq Z_{load} \quad (3)$$

Generally, a short circuit limiters mode should have the following characteristics (12):
1- - Immediate response after the occurrence of a short circuit.
2- Return to the normal condition within a short time after the fault clearing and preparedness for the next short circuit.
3- Low cost of building.
4- No voltage and power drop in normal operation mode of network.
B) In presence of current limiters
5- The Power of cuts short circuit level up to at least 50%.
6- High reliability All kinds of current limiters can be divided to three groups of: Passive, static and hybrid.
Figure 2 shows a passive resistance FLC.

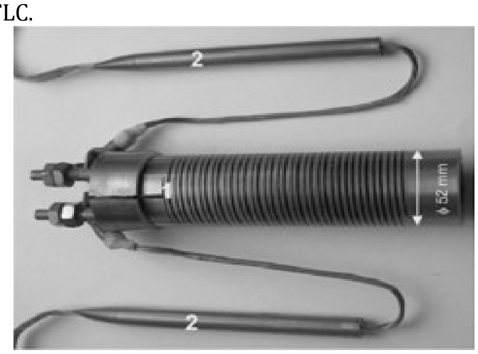


Figure 1: A sample made resistive fault current limiter

3 Distribution network protection and thermography

3.1 Network protection and protective devices

Occurrence of short Circuit in power networks results in strong current. So one way to diagnosis of short circuit is to measure the amount of current and if the value exceeds a certain threshold, it means the occurrence of abnormal conditions in the network.Relay: protective relay is an element that according to network parameters such as current, voltage or frequency of the network, detects Normal from abnormal situation and in the condition of an abnormal situation steers circuit breakers or power switches to separate elements that are subject to error or poor performance. Depending on the type of protection, the relay function is determined.Recloser: Errors occurred in the aerial distribution networks are mainly transient and it is possible that these errors get resolved in the shortest possible time. In order to reduce black out and reconnect lines in the short time, reclosers are applied. Recloser is a kind of tool, which can detect the overcurrent in the phase to phase and phase to earth short circuit and in this case and after a predetermined time it cuts off the current and then automatically reconnects it, so that the line is in the circuit again. If an error which make recloser operates at the beginning still exists, then after a certain number reconnecting, relay still keeps the circuit in a cut off state.(1)One of the main negative effects of adopting reclosers in the network causes mechanical and thermal stresses into the all connections and networking devices for the occurrence of permanent errors in the downstream buses of recloser. If a permanent error occurs downstream of recloser in the network recloser powers the line according to predetermined settings several times with a predetermined period of time. Since the error is still there in the network probably, strong currents of short-circuit pass distribution lines for several successively that these strong current reaches up to 10 times bigger than rated current feeder and it causes severe mechanical and thermal stresses along the fault current. These stresses cause an increase in problem areas and reduce the lifetime of the network equipment, so recloser with having many advantages can also be considered as a cause for fluctuation in network. To overcome this problem we use fault current limiters.

3.2 Thermography in the Power network:

Passage of strong short current due to the mechanical and thermal stresses causes weak points in the network equipment. The weak points have higher temperature than other parts of the network that is not detectable by the naked eye; to identify and solve this problem we use Thermo vision cameras to take pictures in the infrared range. Thermography in power networks helps us to find problematic points of them, mostly in the connection points of devices including at junction of underground cable network to air grids(on the head point of cables), connection of the transformer to the network, the connection of network ending points by jumpers and etc. Figure 3 shows an example of application of Thermography in the distribution network. By surveying of pictures taken of distribution network it has been cleared that Lines of distribution networks that are protected by recloser have significantly bigger number weak points compared to those which does not have it.

4- Transient recovery of voltage and current by FLC

The sample network examined is that of 20 KV feeders of the Great Tehran Electrical Distribution Company that is one of the sampled 63 kV output feeders Posts.

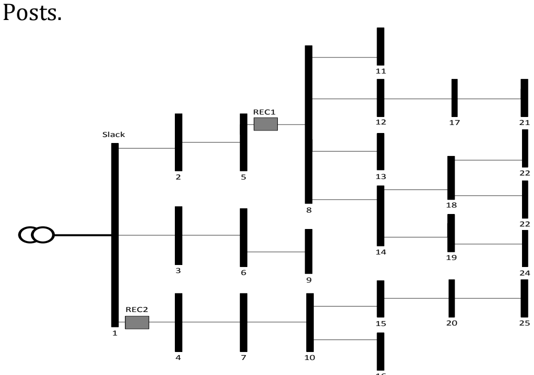


Figure 2 :Single line diagram of the sample network (sampled)

Given the number of different types of sample network electrical malfunction and the rate of increase in fault current in phase to phase case we apply a permanent fault of phase to phase kind into the network. Recloser cuts off its downstream network twice in the fast mode in the periods of 0.4 and 0.7 second and In the third case it powers the network in the time of 1.4 seconds that due to the electrical malfunction not being fixed, it would be placed in lock out mode.In Figure 4 the Instantaneous bus current is shown (1). As can be seen in the fault case the peak current has reached 1620 amps. Effective bus voltage and current can also be seen in Figures 5 and 6. The sharp increase in current causes a voltage drop in the system buses; this reduces the quality of the network.

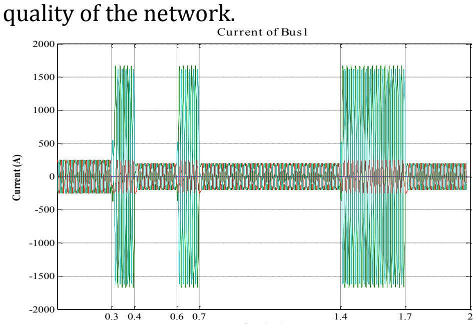


Figure3: Instantaneous bus current no.1

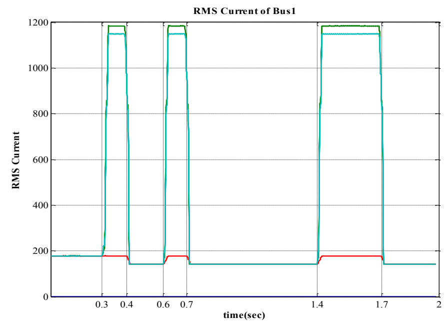


Figure 4: Effective bus current no.1

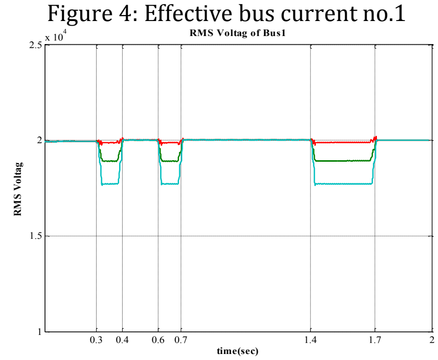


Figure5: effective bus voltage no.1

These strong currents that cause severe stress in the network and it also cause great fall in voltage of slack bus since the fault is a permanent and occurred in the downstream of recloser, it switches network on and off three times, although does not fix the electrical malfunction, in every time of connection the current increases to approximately 1200 amp. To solve this problem using two types of passive and static current limiter has been suggested:

a- Passive current limiter: In this model, only the capacitor, inductor and surge arrester have been used and all these devices there abundantly in domestic distribution network. Furthermore, simulation results confirm the ability of the model to reduce the fault current rate. In Figures 8, 9 and 10, espectively, instantaneous flow, the effective current and voltage at bus 1 are shown. As can be seen in the fault case the peak current has reached 790 amps.

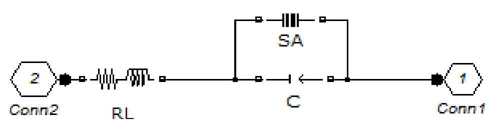


Figure6: Passive Fault current limiter

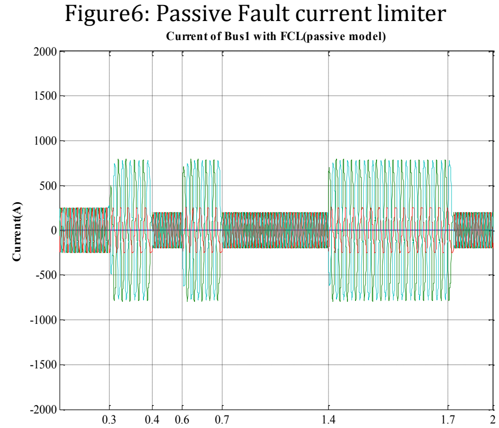


Figure7:Instantaneous bus current1 (passive model)

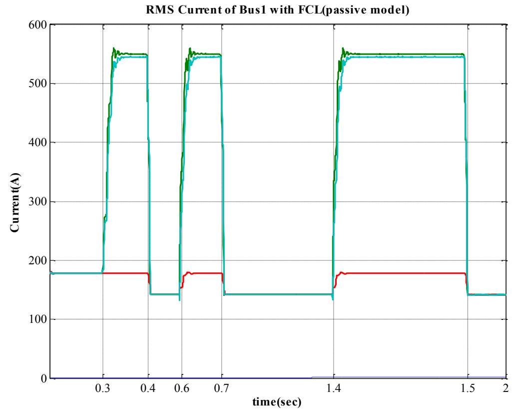


Figure8 :Effective bus current (passive model)

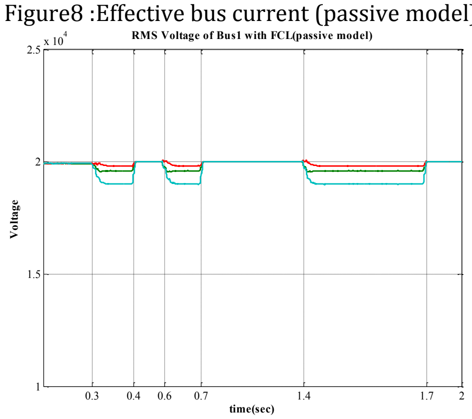


Figure9: Effective bus voltage no.1 (passive model)

b- Static current limiter: This model is more complex and requires a control circuit and a power thyristor, although, due to high reliability (due to having two parallel current paths), Inductor and capacitor being less likely to get damaged and high lifetime of the system (thyristor being off in the normal operation of the network) it is economical.

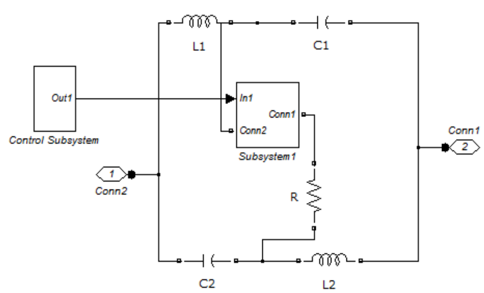


Figure10: Static fault current limiter

In Figures 12, 13 and 14, respectively, instantaneous flow, the effective current and voltage at bus 1 are shown. As can be seen in the fault case peak the current has reached 615 amps.

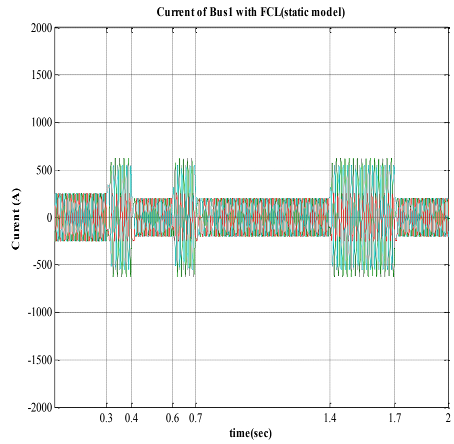


Figure11: Instantaneous bus current no.1 (static model)

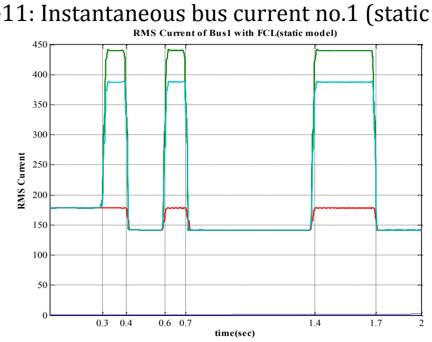


Figure12: Effective bus current no.1 (static model)

Nice features of this type include dividing voltage and current into the inductor, capacitor and resistor during fault occurrence that result in the longevity and reliability of the above elements.

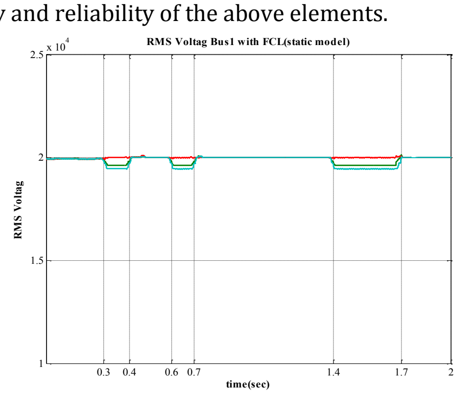


Figure13: Effective bus voltage no.1 (static model)

Conclusion

Occurrence of fault in the distribution network causes dramatic increase in current and decrease in the voltage of network. This leads to excessive temperatures of lines and connections that are in the path of fault current, and it causes arched points at clamps, jumpers and lines. Moreover, installation of recloser that plays an important role in reducing the number of transient network faults; it is the reason for Thermal and mechanical stresses in confrontation with permanent faults. To overcome this negative performance of reclosers it is suggested that we use current limiters in the network and with choosing two types of current limiters (passive and static types) we simulated the network sample in MATLAB. The results proved reducing the amount of fault current and recovery of system voltage by applying the proposed FCL. Of the two types of limiters the static one showed better performance and reliability compared with the passive type.

Finally, it is suggested that we consider adopting fault current limiters in distribution systems which have recloser because it eliminates the negative impacts of recloser performance and improving current and voltage temporarily.

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