Improvement of Power Quality in Radial Distribution Network and Its Protection by Using Distributed Generation

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***Abstract*—Distributed Generation (DG) is expected to play a key role in the residential, commercial and industrial sectors of the power system. DG provides an alternative to the traditional electricity sources and can also be used to enhance the current electrical system. The technologies for DG are based on reciprocating engines, photovoltaic, fuel cells, combustion gas turbines, micro turbines and wind turbines. The DGs are becoming increasingly popular due to their low emission, low noise levels and high efficiency. Some of the main applications of DG are to provide support and reliability to the power system in a grid-connected mode or isolated mode. With the growing use of DG, it is very important to study its impact on residential distribution network operation. In this paper, to improve the voltage profile and impacts of installing DG on a residential distribution circuit are explored.The proposed methodology is based on continuation power flow (CPF). The work is focusedon analyzingthe installation of DG on distribution network operation including voltage analysis, electric losses and reliability of the system. Various DG penetration levels and the impact of distributing the DG across several locations are explored. The impacts of installing DG on any one phase on the voltage profiles of the unbalanced three-phase distribution network are investigated.**

***IndexTerms*—Distributed generation, Distributed network, Voltage stability, Voltage limits.**

I. I.INTRODUCTION

The electrical power system fault levels increase due to the increasing of electrical power demand. To increase the reliability of power supply, the electric power systems are interconnected to each other to give and take the electrical power. However, once a fault occurs, the fault current flows also from the interconnected grids. The interconnection of the power system is restricted to a certain extent so that the fault current will not exceed a circuit breaker (CB) capacity and the fault point can be rejected from the power system by the CB not to expand the influence of the fault when it occurs [1]. The wind-turbine power generation (WTPG) is one of the representative renewable energy systems. Since the WTPG is based on wind energy from natural forces similar to other renewable energy resources, it does not lead to a pollution-problem as the conventional fuel such as oil does so. Furthermore, it has the main advantage of requiring the lowest maintenance costs [2].

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With the rapid development of the WTPG and its increased capacity, the level of the associated short-circuit current during a fault will be increased in the distribution system [3], [4].This increased short-circuit current can have a negative effect on the entire power grid including the WTPG with respect to the stability. Therefore, the WTPG may need to be disconnected from the power network in order to prevent damage during the fault [5], [6].With the increasing demand of electrical power, power systems are becoming larger and more interconnected. As a consequence, the fault current increases and transient stability problems become more serious. Hence, in order to maintain the stability of the power system, replacement of substation equipment or changes in the configuration of the system or installing fault current limiter will be necessary [2]. In addition, to overcome the high fault current, the traditional methods, in the last decades followed by using current limiting fuses, series reactors or high impedance transformers and replace or modify the parameterization of existing equipment (such as transformers, circuit breakers, etc.), adjusting the system for the new fault duty and fault current limiters. Some of these alternatives may, however, create other problems such as loss of power system stability, high cost and increase power losses and ultimately leads to decreased operational flexibility and lower reliability [7]–[10]. With advances in switch technology that have made them appropriate for the voltage and power levels necessary for power applications, power electronic switches can be utilized to build devices that could maintain repeated operations with high reliability and without wearing out [11].

The DG term is used to describe small distribution system close to the point of consumption. Such generators may be owned by a utility or more likely by a customer who may use the entire portion or perhaps all of it to the local utility combustion turbine generators, internal combustion engines and generators, photovoltaic panels, and fuel cells. Solar thermal conversion, stirling engines, are considered as DG. When the penetration of DG is high, the generated power of DG units not power flow in the distribution network consequence, the connection of DG to the grid may different technical issues, e.g. voltage profiles quality, stability etc..[8] In spite of the benefits of utilizing DG units within of the system efficiency and the improvements in the technical and operational challenge units into MV distribution networks are needed. Moreover, in more details with respect to the generation types. Optimization of the MV distribution networks with a large penetration of DG is also needed therefore the utilities can get more benefits[9].

Many voltage stability indices are based on the eigen value analysis or singular value decomposition of the system power flow Jacobian matrix. The main difficulty in this method is that Jacobian of NR power flow become singular at voltage stability limit (critical point) .A power flow solution near the critical point prone to divergences and error. Singularity in the Jacobian can be avoided by slightly reformulating the power flow equations and applying a locally parameterized continuation technique. During the resulting continuation power flow, the reformulated set of equations remains well conditioned so that divergence and error due to a singular Jacobian are not encountered.

II. SOLID STATE FAULT CURRENT LIMITER

Power quality problems are becoming more and more important for utilities due to growing number of sensitive loads. Short circuit results the large amount of current flow through the distribution network. The large fault currents flow may damage the series equipment, such as circuit breaker and other system components. The Fault current causes the voltage drop of a particular network. As a result, some industrial facilities experience production outage that results in economic losses. Therefore, utilities are currently exploring mitigation techniques that eliminate large fault current, increase the reliability of the power supply and improve the reliability and the system power quality. The most common ways to limit fault currents are the costly replacement of substation equipment's or imposition of changes in the configuration splitting power system that may lead to decreased operational flexibility and lower reliability. A novel idea is to use Fault Current Limiters to reduce the fault current to lower, acceptable level so that the existing switchgear can still be used to protect the power grid. An ideal FCL should have the following characteristics

a) Zero resistance/impedance at normal operation
b) No power loss in normal operation and fault cases
c) Large impedance in fault conditions
d) Quick appearance of impedance when fault occurs
e) Fast recovery after fault removal
f) Reliable current limitation at defined fault current
g) Good reliability
h) Low cost

The SSFCL structure offers a good way to control the fault current levels in distribution networks due to natural low losses in superconductors during the normal operation.

There are two chief kinds of SSFCLs: resonance based devices and impedance switched-in limiters. Resonance based limiters comprises devices recommended in [12]. The basic of their operation is that, because power is transferred at a fixed ac sinusoidal frequency, the impedance of a LC-resonant circuit can be tuned so that the impedance of the device during steady state operation is approximately zero. During a fault, power electronic switches isolate a capacitor or inductor from the device, introducing large impedance into the system. The limitations of resonance based limiters are that they can make voltage sags during faults, current limitation efficiency declines as distance from substation increases, large infrastructure for capacitors is required, and tuning of devices is essential to guarantee low impedance.

The principle of their operation is that impedance is located in series with the distribution line. A pair of gate-turn-off (GTO) thyristor switches are located in shunt with this impedance, and worked during alternate half-cycles of the voltage waveform to present a low impedance path. In case of a fault, the gating signals to the GTO switches are obstructed, resulting in large impedance being introduced into the system, limiting the current. However, these limiters introduce switching losses as the power flows through the power electronic switches during steady state operation and the long term reliability of these devices is questionable because of the continuous switching [18].Solid state fault current limiters (SSFCLs) are expected to enhance the quality and reliability of power systems by diminishing the fault current. Several studies on SSFCLs have been performed (for example, [19]–[22]). However, these studies were mainly about one type of SSFCLs (comprised only one of the L-type SSFCL or R-type SSFCL, not together). Therefore, the solid state fault current limiter (SSFCL) can be a solution to decrease the level of short-circuits currents during a severe fault that is increased by DGs (such as the WTPG and so on). SSFCLs cause no power loss in a steady-state situation and enhance the transient stability of the power system via suppressing the level of the fault current with the fast operation and very fast auto recovery. Furthermore, they can provide a good system damping for low-frequency oscillations corresponding to the other power system controllers as an example of a power system stabilizer (PSS) or a dynamic reactive compensator. In general, FCLs and also SSFCLs are classified into two states that are resistive SSFCLs (R-type SSFCL) and inductive SSFCLs (L-type SSFCL). An L-type SSFCL is used as an inductor to limit the fault level and is more efficient in suppressing the voltage drop during a fault (improve power quality). Moreover, an R-type FCL is constructed with a resistance and is more effective in consuming the acceleration energy of generators during the fault (improve power stability). Both functions lead to the improvement of the transient stability of the power system.

This paper proposes a new SSFCL that have both features of the L-type SSFCL and R-type SSFCL. This means that the proposed SSFCL works as an L-type SSFCL and also R-type SSFCL that is called an LR-type SSFCL and can improve stability and quality of the power system together. This paper also investigates the effectiveness of the proposed SSFCL in the presence of the WTPG (for avoiding the replacement of the existing protection devices with different ratings and/or changing their operations) and compares its performance with other types of SSFCLs.

In Solid-State Fault Current Limiter model in Fig.1 fault current limiter is applied by using thyristor -based power electronics components/elements when a fault occurs. Normally, limiter is not activated. IGCT-based Half-controlled Bridge Type FCL was presented in[8]. This model comprises the main components: DC reactor (L2), two diodes (D1,D2), two IGCTs(T1,T2) and current limiter reactor (L1). Under normal operating conditions, IGCT T1 and T2, the diodes D1 and D2 remain in conduction. All current flows through the diode and IGCT Bridge. Positive and negative cycles pass by one cycle. The current flowing from L1 is constant and voltage drop is zero. When there is a fault, T1 and T2 are OFF. After a matter of milliseconds, all current flows through limiting reactors L2.

Here, L1 DC reactors are used to reduce voltage drop that arises from use of power electronics components. A ZnO arrestor that is parallel to L2 can also be employed to eliminate the operating over- voltage [15].This model is considered to obtain the benefits of using FCLs in our study.

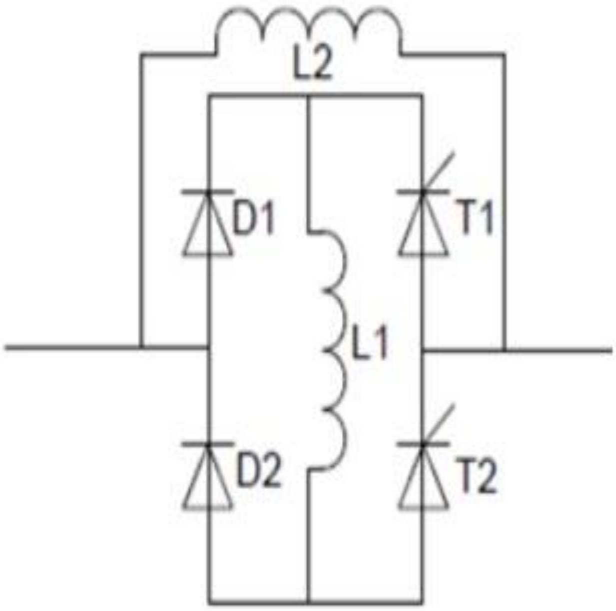


Fig.1. Circuit Diagram for SSFCL

III. DG PLACEMENT ALGORITHM

Different recommended locations for integration of DG forincreasing the amount of loads which can be supplied from the system through enhancing the VLL of the system are the main objective of the suggested methodology. The proposed algorithm is depicted in Fig. 2. The methodology starts with execution of CPF to specify the VLL of the base case of the system and identify the first node which reached the low voltage limit. Then the DG unit with a certain power is integrated at that node and after that the CPF is executed. Therefore, another node can be obtained and then the DG units' power is dispersed between the resulted nodes according to their loads, then the VLL is checked. This process is continued until no improvement is obtained and as a result the methodology will be ended. Different steps of the proposed algorithm are summarized as follows:

Step 1: Identifying the first node reached the low voltage limit in the network using CPF.
Step 2: Integrating the DG units at that node and examine the VLL of the network.
Step 3: Running the CPF with DG.
Step 4: Identifying another node which reached the low voltage limit using CPF.
Step 5: Dispersing the DG power between the recommended nodes according to their loads.
Step 6: Running the CPF with DG.
Step 7: Examining the VLL with the existence of the different number of DG units.
Step 8: Go to step 4 if an improvement in VLL is achieved otherwise go to step 9.
Step 9: End.

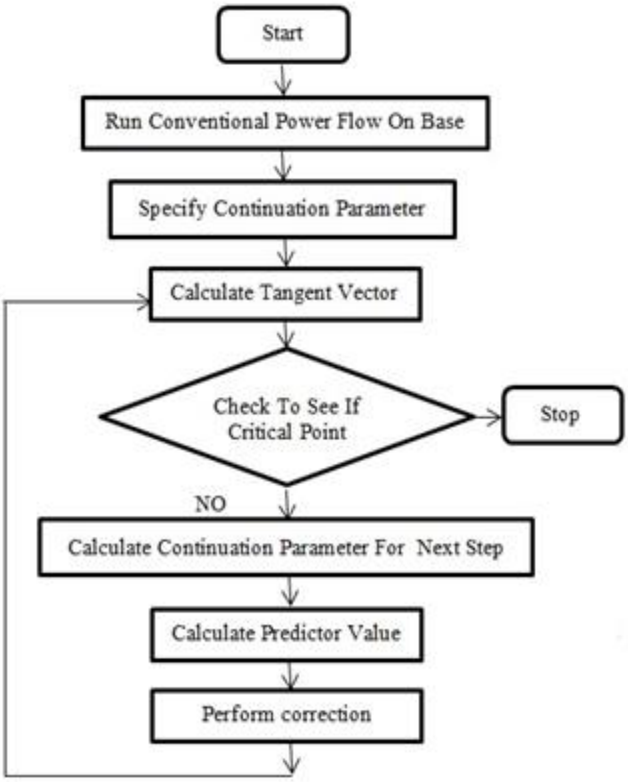


Fig.2. Flow Chart for Continuation Power Flow

IV. SIMULATION STUDY

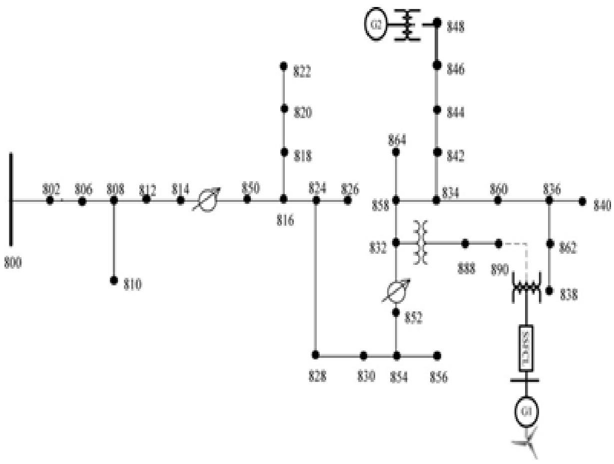


Fig.3. One-line diagram of the test feeder system.

When a 100 ms three-phase short-circuit is applied to the infinite bus in Fig. 3 at 10 s, Fig. 4 shows the rotor current at the time of fault.The rotor angular velocity of the synchronous generator at the critical clearing time is shown in Fig. 5 in four cases (with the SSFCLs and without SFCL).

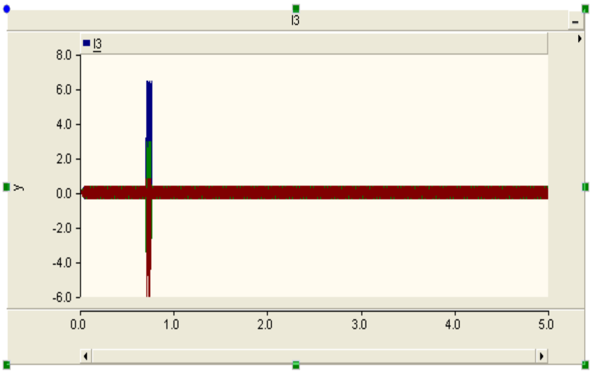


Fig.4. Faulted Current without SSFCL

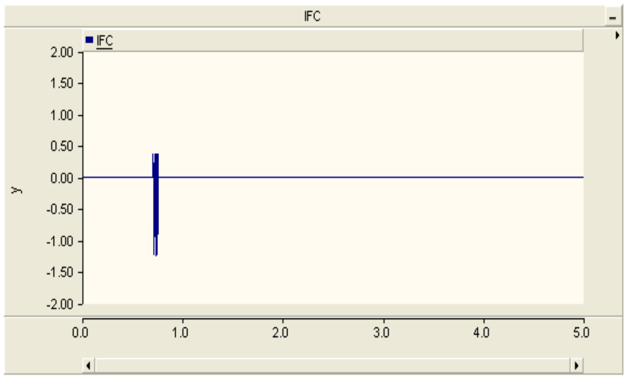
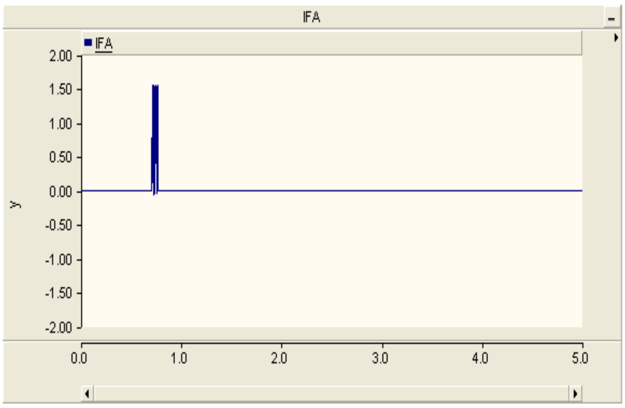


Fig.5. output current waveform for each phase

As shown in this figure, the generator was most accelerated during the fault without SSFCL and least accelerated with the SSFCL-R and SSFCL-LR. Therefore, the SSFCL-LR has the features of the SSFCL-R and enhances the stability of the power system by restraining the changes of the rotor angular velocity. Moreover, the terminal voltage drops from 1 pu to below 0.01 pu during the fault. Conversely, the terminal voltage with the SSFCL-L and SSFCL-LR was kept about 0.7 pu during fault. The ability of the SSFCL-LR to suppress the voltage drop is not degraded via attaching the variable resistance in parallel. Furthermore, the surge voltages seen at the start of the current limiting performance with SSFCL without variable resistance or without ZnO were eliminated with the SSFCL in the presence of the variable resistance. This means that the operates like ZnO. Therefore, the SSFCL-LR has the features of the SSFCL-L and improves the power quality of the power system.



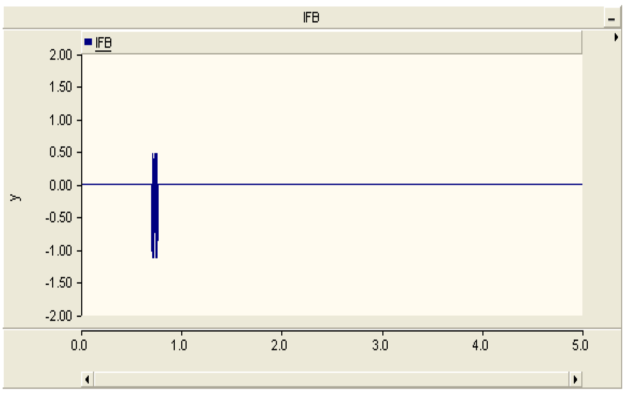


Fig. 6 shows the generator power during the fault. The electric energy transferred to the infinite bus was too small without SSFCL because the generator voltage was low. However, the SSFCL-R and SSFCL-LR prevent the voltage drop and so the electric power can be transferred to a certain extent through. Moreover, the electric energy (P (W)) is consumed in the variable resistance of the SSFCL-LR and the resistance of the R-SSFCL. Hence, the acceleration energy is much more reduced. Therefore, the critical clearing time with the SSFCL-R and SSFCL-LR is longer than without the SSFCL-LR or even with the SSFCL-L. In addition, it is shown in the result of Fig. 7 that the a-phase current of the WTPG increases to 6.74 pu at its maximum during the fault without the SSFCL-LR. However, the corresponding value is almost the same as that of steady-state operation when the system operates with the SSFCL-LR. Fig. 6 shows the across voltage and currents of the proposed SSFCL in the simulation results.

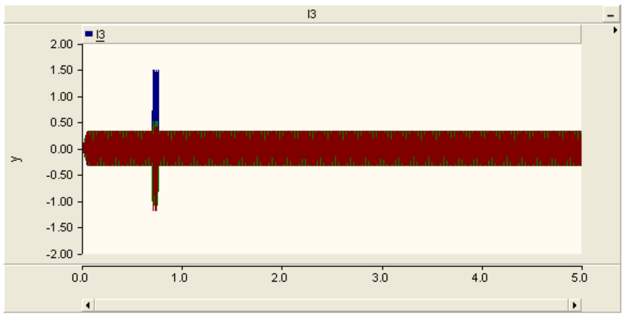


Fig.6. Faulted Current with SSFCL

V. CONCLUSION

Aboveallresultsshowsthatvoltagestabilitymargincanbefoundeasilyby CPF.The Weakestbus identificationis done bywithoutexcessivecalculation.Placementof distributed generationpowersourceswe get the following conclusions.

Dispersing the same amount of the DG power at different nodes of the network enhances the VLL of the network more than concentrating this power at one node.

More loads can be supplied with lower dispersed power of the DG when it compared with higher concentrated DG power.

Dispersing the same power of the DG does not approximately affect the VSLL of the network when it compared with integration of the same DG power at the weakest node.

Integrating the DGs at the recommended nodes helps to get more decreasing of the active and reactive power losses.

Thisresultissameaccurateastofind Busparticipation factorusingQVmodalanalysis.ThisCPFmethodismore accurateandsimpleforVoltagestabilityanalysis.

This paper studies the impact of the solid state fault current limiters on the power network.Diesel generation system have been investigated in this paper.Six bus test feeder system along with two induction generators.

The SSFCL efficiently protects synchronization of three lines to ground fault, compared with a system without any SSFCL.

REFERENCES

[1] Acharya N, Mahat P, Mithulananthan N,(2006) "An analytical approach for DG allocation in primary distribution network", Int J Electr Power Energy Syst., Vol.28,pp.669–678.

[2] Ajjarapu V, Christy C,(1992) "The continuation power flow: a tool for steady state voltage stability analysis", IEEE Trans Power Syst.,Vol.7.pp.416–423.

[3] Borges C, Falcao D,(2006) "Optimal distributed generation allocation for reliability, losses, and voltage improvement", Int J Electr Power Energy Syst., Vol.28,pp.413–420.

[4] Ghosh S, Ghoshal SP, Ghosh S,(2010) "Optimal sizing and placement of distributed generation in a network system", Int J Electr Power Energy Syst., Vol.32,pp.849–856.

[5] Gözel T, Hocaoglu MH,(2009) "An analytical method for the sizing and siting of distributed generators in radial systems", Electr Power Syst., Res ,Vol.79, pp.912–918.

[6] Haesen E, Espinoza M, Pluymers B, Goethals I, Thong V, Driesen J, et al,(2005) "Optimal placement and sizing of distributed generator units using genetic optimization algorithms", Electr Power Qual Util J,Vol.11,pp.97–104.

[7] Hedayati H, Nabaviniaki Sa, Akbarimajd a,(2000) "A new method for placement of DG units in distribution networks", In: 2000 IEEE PES power systems conference and exposition, pp. 1904–1909.

[8] Hedayati H, Nabaviniaki Sa, Akbarimajd a,(2008) "A method for placement of DG units in distribution networks", IEEE Trans Power Delivery, Vol.23, pp.1620–1628.