Analysis of the Fault Current Limiting Requirement and Design of The Bridge-Type FCL in the Multi-Terminal DC Grid

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Abstract- **This paper implements a fault current limiting(FCL) requirements and proposed a calculation method to determine the required dc reactor value, for the purpose of the converter continuous operation during dc faults. On this basis, the bridge-type fault current limiter (BFCL) using static non-linear controller was proposed for using in the dc grid, due to merits including minor negative influence on dc grid normal operation, fast response to dc faults and efficient coordination with the dc circuit breaker (DCCB). The parameter design principle of the bridge-type FCL for dc grid was also discussed. Then the scaled-down dc experiment test circuit was built to verify the working principle and performance of the bridge-type FCL. The simulation and experimental results are presented to clarify the theory and feasibility of the proposed FCL at different points of IEEE 30-bus power system, which manifest simple structure of the circuit and show feasibility of the proposed FCL.**

1. INTRODUCTION

Smart grid are being developed as the next generation power systems. These smart grids encompass interconnected microgrids, especially at the distribution level where Distributed Generations (DGs) are increasingly used. The DG technologies can be classified into power generation from Renewable Energy (RE) resources such as wind, photovoltaic, micro hydro, biomass, geothermal, ocean wave and tides, the clean Alternative Energy (AE) generation technologies such as fuel cells and microturbines, as well as the traditional rotational machine based technologies such as diesel generators. Due to several benefits of these sources such as cleanness and simple technologies, compounded with increasing demands for electrical energy and the exhaustible nature of fossil fuels, the RE and AE-based DGs play an important role in microgrids.

The microgrids can work in grid-connected or stand-alone operation modes. Particularly the stand-alone operation, although may only for very limited period, can provide improved reliability to the smart grids. Some other systems, such as electric vehicles can be considered as always operating in stand-alone mode. Due to the

stabilityimproving device to the power engineers and researchers throughout the world. Day by day, it is getting more attraction for its simple structure, low cost and feasible implementation characteristics. But, up to now, there is no detailed analysis of its proper and rigid control structure. Although there is an interesting work on the control structure of bridge type fault current limiter but the proposed control system lacks in viable implementation of generator responses as any control status. Moreover, it depends only on the grid current and

intermittent nature of renewable energy resources, other energy sources (such as diesel) and Storage Elements (SEs) are critical part to enable the stand-alone operation of microgrids or to smooth the microgrid power during grid connected operation. SEs can be classified into two categories: capacity-oriented energy storage and access-oriented energy storage. Capacity-oriented energy storage does not have fast response time and they are used for long-term energy balancing to buffer out low-frequency power oscillation of DGs output power and compensate intermittency of renewable energy sources in microgrids. Batteries, pumped hydroelectric systems, Compressed Air Energy Storage (CAES), and hydrogen storage are types of capacity-oriented energy storage. Access-oriented storage devices have fast response time and they are responsible for short time disturbances in microgrids, by providing the high-frequency component of power. They can supply or absorb the high-power transients with high power density Flywheels, supercapacitors, and Superconducting Magnetic Energy Storage (SMES) are considered as access-oriented storage devices.

The bridge type fault current limiter (BFCL) is currently a very much popular auxiliary

balanced and unbalanced permanent as well as temporary faults are considered. Simulations are performed by using the MATLAB/SIMULINK software. Moreover, instead of conventional reclosing, we considered the total kinetic energy based optimal reclosing of circuit breakers along with the static non-linear controlled bridge type FCL for improving the transient stability of the multi-machine power systems.

2. LITERATURE SURVEY

voltage responses which can change nonlinearly any time. The line current variation during fault is compared with a predefined threshold line current value, which can vary depending upon the systems nature and fault condition.

Therefore, as the power system is nonlinear in nature, a nonlinear controller for the bridge type fault current limiter will be reasonable from the view point of stability improvement of the power systems. As Static non-linear controller is a nonlinear controllerwith simplicity, it can be easily implemented for powersystem stability improvement. It is avery simple nonlinear controller based on simple "IF-THEN" logic. It resembles human decision making with its ability towork from approximate data and find precise solutions.

This paper proposes the static non -linear controlled bridge typeFCL to improve the transient stability of multi-machine powersystems. To the best of our knowledge, there is no applicationof any nonlinear controller for the bridge type FCL. So far, thebridge type FCL has been applied to stability improvement inwind generator system and single machine power system. But, there is no report available on the bridge type FCLapplication to the transient stability improvement of multi-machinepower system.

For demonstrating the effectiveness of the proposedStatic non-linear controlled bridge type FCL in transient stability enhancement, the IEEE 30-bus power system model has been used. Both

Nejabatkhahetal described an overview of power management strategies for a hybrid AC/DC micro grid system, which includes different system structures (AC-coupled, DC-coupled, and AC-DC-coupled hybrid micro grids), different operation modes, a thorough study of various power management and control schemes in both steady state and transient conditions, and examples of power management and control strategies. Finally, discussion and recommendations of power management strategies for the further research are presented.

Dragicevic Described the practical design aspects of DC MG technology concerning typical power hardware topologies and their suitability for different emerging smart grid applications. Then, an overview of the state of the art in DC MG protection and grounding is provided. Owing to the fact that there is no zero current crossing, an arc that appears upon breaking DC current cannot be extinguished naturally, making the protection of DC MGs a challenging problem. In relation with this, a comprehensive overview of protection schemes which discusses both design of practical protective devices and their integration into overall protection systems is provided. Closely coupled with protection, conflicting grounding objectives, e.g. minimization of stray current and common mode voltage are explained and several practical solutions are presented.

W. Zhang, R. Wang, and P. Mattavelli described a two-stage topologyusing a full bridge

in series with a bidirectional synchronous rectifierdc–dc converter as a single-phase ECC for dc Nanogrid, with asignificant reduction of the dc-link capacitor value. The operationanalysis and the design of passive components are provided. A bidirectionalcontrol system and the design process are also presentedin terms of the system requirement and the small dc-link capacitor.

D. Boroyevich, and P. Mattavelli described a complete discussion of several aspectsof system interface design for the grid-interface converter underboth single-phase and three-phase system conditions. A passiveplus active filter solution is proposed to accomplish the commonmode-related noises minimization as well as a dramatic reductionof the converter system volume.

A complete filter design procedures are also presented inaccordance with the EMI and power quality regulation on bothac and dc sides. Several design considerations are discussed in atwo-stage bidirectional ac–dc converter system for dc electronicdistribution system application and most results can be appliedto other applications, such as electric vehicle charger station,PV system, etc.

G. Gharehpetian, and A. Heidary described The first peak of the fault current amplitude has been controlled and system can work in the safe operation region. In the proposed BSSFCL, the switching overvoltages have been decreased. This topology can protect switches

3. EXISITING SYSTEM

The bridge-type fault current limiter (FCL) was proposed for using in the dc grid, due to merits including minor negative influence on dc grid normal operation, fast response to dc faults and efficient coordination with the dc circuit breaker (DCCB).In Existing system to apply the bridge-type FCL in the dc gird for replacing the dcreactor directly installed on the dc line. As we know, the bridgetype FCL was first invented for the ac system. When used in the MMC-based dc gird, it has a different working principle with the parameters redesigned.

4. PROPOSED SYSTEM

In this paper, in order to evaluate the performance of the existing coordinated operation of the fuzzy logic controlled bridge type fault current limiter and optimal reclosing in more detail, an alternative static nonlinear controller is proposed in this paper.The static nonlinear controller can be represented by a simple equation,

$$R_{sh} = R * (\text{TKED})^2$$

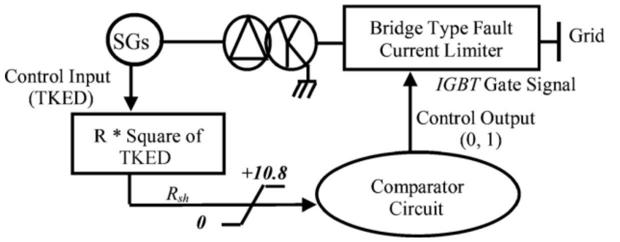
against overvoltages. After fault removal, only one reactor is used. This reactor causes fast recovery via changing the topology from the AC mode to the DC mode and results in fast recovery to the initial state. These characteristics of the proposed BSSFCL increase the reliability of the electrical network and the BSSFCL is suitable for higher voltage applications by considering the insulation coordination problems.

range, then the performance of BFCL changes rapidly. That range is given in the next paragraph. It is important to note that the same parameter is used throughout the simulations. Again, the comparator operation is designed in the same way as for the fuzzy logic controller. The IGBT switch will turn on only when the gate signal is 1. On the other hand, it remains off when the gate signal is less than 1.

For designing the nonlinear controller, the TKED square of the generators in the system is multiplied with a controller constant. The reason behind multiplying with R is, without any constant, the TKED variation will be very abrupt and out of control. Moreover, the square of TKED is chosen as it represents a very simple nonlinear controller. From our observation we came to a very important decision about choosing the valuefor R. We observed that has a range of value beyond which thesystem becomes unstable and out of control. In concrete form,the range of is

$$0.024 \leq R < 0.055 \text{(approximately)}$$

If we decrease the value of from higher to lower, then the system performance becomes better. On the other hand, beyond the lower limit, the system becomes unstable due to the over compensation of the controller. The controller constant R is used to limit the high variation of TKED in the controller. The lower the value of R will be, the less abrupt the TKED variation will be, as R is multiplied with the TKED square in the controller. Therefore, in this work, we observed that beyond the lower limit of the range of R, the variation of TKED becomes trivial and it has a steady response within the limit of the limiter in the next stage. Thus the nonlinear controller has a steady response and it degrades the BFCL operation if we choose a value of beyond the lower limit. Similarly, if we increase the value of



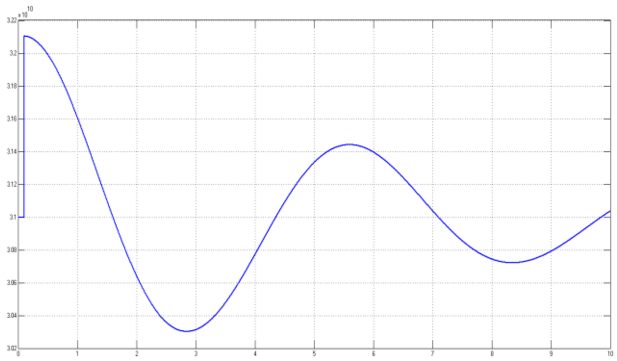
Static nonlinear controller connection scheme with bridge type FCL.

The block diagram of the static nonlinear controller. The optimal value of the controller parameter is 0.024. This optimal value is determined by trial and error method. As we used a simple nonlinear controller, the value of the controller constant has paramount effect on the operation of the nonlinear controller controlled BFCL. We noticed if the value of is beyond some

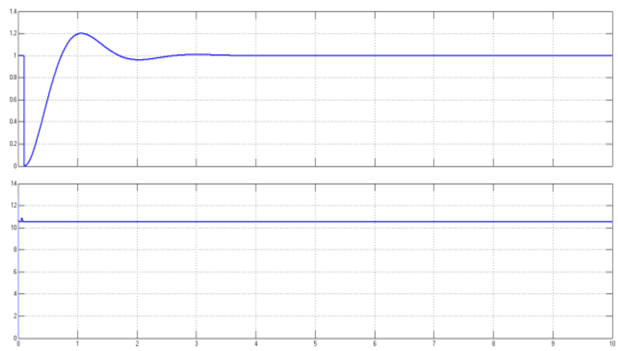
lower to higher, the performance of the BFCL degrades. If the value of R increases beyond the higher limit of the controller constant's range, then due to higher abruption of the TKED variation the BFCL's operation degrades and the whole system becomes unstable.

5. SIMULATION RESULT

Output for Total Kinetic energy response:

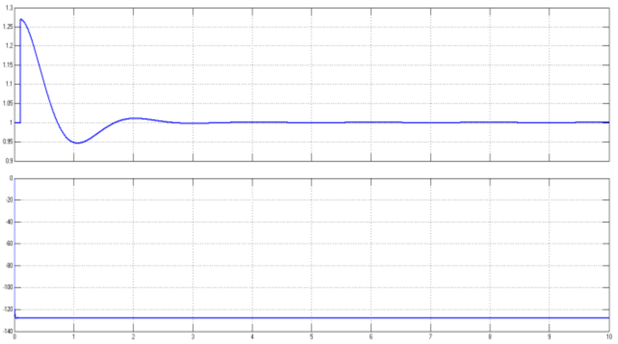


Magnitude and Phase voltage output



Magnitude and Phase current output

from



6. CONCLUSION

This paper proposes the application of static non-linear controlledbridge type FCL for improving the transient stability of multi-machine power systems. The performance of the static non-linearcontrolled bridge type FCL is compared with that of the Fuzzy Logic controlled bridge type FCL. From the simulation plotsand index values, the following conclusions can be drawn.

a) The proposed static non-linear controlled bridge type FCL canimprove the transient stability of the multi-machine powersystems.

b) The transient stability performance of the static non-linear controlled bridge type FCL is better than that of the fuzzy logic controlled bridge type FCL.

Therefore, the proposed static non-linear controlled bridge typeFCL can be considered as an effective means for transient stability enhancement in multi-machine power systems.In our future work we would like to address the communication delay problem and propose solutions to reduce the negativeeffect of delay. Moreover, we also would like to explore othertypes of fault current limiters for power system transient stability enhancement. Also, since the proposed controller will handle input and output signals, during signal transmission there might be possible cyber-attacks or hacking. Inthe future, possible cyber vulnerabilities of the static non-linear controller considering its cyber physical architecture and the solutions will be studied.

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