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Modeling and Simulation of Novel Inverter Control Technique on HVDC Interconnection System to Improve System Stability and Power Factor

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Abstract: Generally the Power factor and Dynamic stability of a HVDC system plays vital role for maintaining the system stability and very effectively improves the system responses. The novel controller has demonstrated good responses with very weak inverter AC systems and widely changing AC parameters. In this paper it is studied that if it is possible to offer adequate replacement for synchronous condensers at weak HVDC-HVAC interconnection point. The actual HVDC system has excellent small signal responses with increased probability of commutation failure. To keep the same commutation failure probability, half of the synchronous condenser must be maintained in normal operation. Further synchronous condenser can also be disconnected, when the novel inverter control method is employed. However the nominal operating angle has to be somewhat increased. The financial benefits of the system are evident due to reduction of the synchronous condensers. The controller is designed with two primary objectives, one is the stability improvement of HVDC systems connected to very weak AC systems and the other is HVDC robustness with respect to the AC system parameter changes.

Key words: Advance angle · Delay angle · Extinction angle

INTRODUCTION

The HVDC-HVAC interconnection point at inverter side has been subject to numerous operating difficulties [1], where the high-magnitude AC voltage oscillations and the difficulty in recovery from disturbances are the main practical manifestations of concern [2, 3]. It is known that the majority of these problems are caused by weak inverter AC systems. In at least two actual HVDC systems, the stability problems are connected with low SCR AC system conditions [4, 5].

There has been lot of research focused on the use of HVDC control for enhancement of HVDC-HVAC system stability, here this paper addresses a Novel Inverter control technique implemented to maintain system stability. This paper offers the analysis of role of condenser at inverter HVDC side, where alternative options for each condenser function are discussed. This technique increases the strength and improves the stability of the system, which involves the controller tested for small signal disturbances, various fault scenarios and commutation failure probability [6].

For an Inverter: It may be necessary to determine the overlap angle □. At the rectifier, the following approximate expression can be applied when delay angle □, per-unit commutating reactance X_C and d.c. load current Id are known:

From HVDC system performance, steady state range of delay angle for a rectifier may be 10□< □ < 18□ and the lowest normal operating power factor will be when □ = 18□.

The converter bridge firing controls can be designed to increase the delay angle □ when an increase in d.c current is detected. This may be effective until the limit of the minimum allowable extinction angle □ is reached [7].

Voltage Control: With fast load variation, there can be an excess or deficiency of reactive power at the a.c commutating bus, which results in over and under voltages respectively. When the a.c system is weak, the changes in converter a.c bus voltage following a disturbance may be beyond permissible limits. In such cases, an a.c voltage controller is required for the following reasons [6]:

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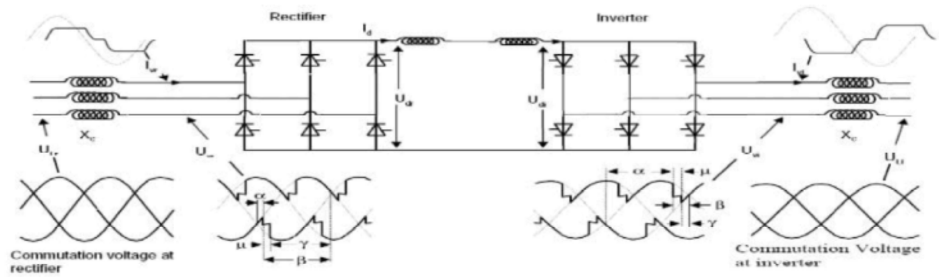

Fig. 1: Voltage And Current Wave Shapes Associated With D.C. Converter Bridges.

- To limit dynamic and transient over voltage to within permissible limits defined by substation equipment specifications and standards.
- To prevent a.c. voltage flicker and commutation failure due to a.c. voltage fluctuations when load and filter switching occur.
- To enhance HVDC transmission system recovery following severe a.c system disturbances.
- To avoid control system instability, particularly when operating in the extinction angle control mode at the inverter.

Role of Novel Inverter Control System: With inverter feedback the system responses are fast [7, 8]. Stability improvement of HVDC systems connected to very weak AC systems [9]. Eliminates the dominant oscillatory mode and system has satisfactory small signal responses even when SCR is low as SCR=1.0.Prevention of commutation failure by switching to gamma mode. From the economic point of view, the new controller introduces significant benefits [1]. The cost for fixed capacitors and their maintenance expenses are far below the corresponding cost for SC of same reactive power rating. The replacement of SC with the fixed capacitors in this new scheme provides the better financial benefits.

Novel Inverter Control Method:

RESULTS

The power system block set was designed to provide a modern design tool that will allow rapidly and easily build models that simulate power systems [10].

Power Factor Improvement: Fig 4. shows lagging in the current to voltage for the normal firing angle, In Fig. 5 it is evident that the power factor is improved with extinction angle control by varying the firing angle.

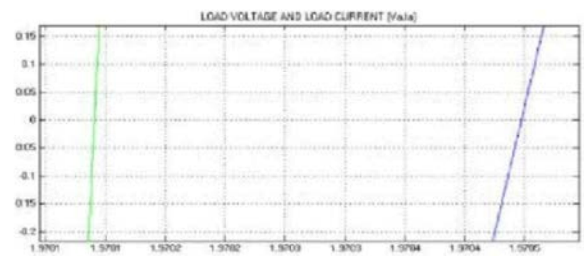

Fig. 4: Three Phase Inverter With Improvement InP.F With S.C=50uf (□=10°, γ=18°) Lag > 6.3°

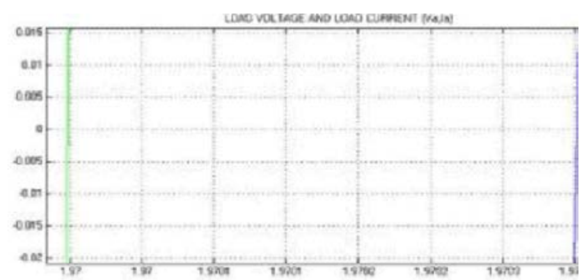

Fig. 5: Three Phase Inverter With Improvement InP.F With S.C=50uf (□=5°, γ =18°) Lag = 6.3°

Fig. 6: Three Phase Inverter With High ImpedanceSingle Phase Fault (□=5°, γ =0°)

Figs. 6 and 8 shows the analysis of high impedance single phase fault. Fig. 6 shows the system response for high impedance single phase fault duration from 1.1 sec to 1.3 sec. The inverter output voltage oscillates to maximum positive and negative from 1.18 sec to 1.2 sec for the firing angle 5°. It is evident from figs.7 and 9 the stability of the system is improved for the extinction angle of γ = 18°.

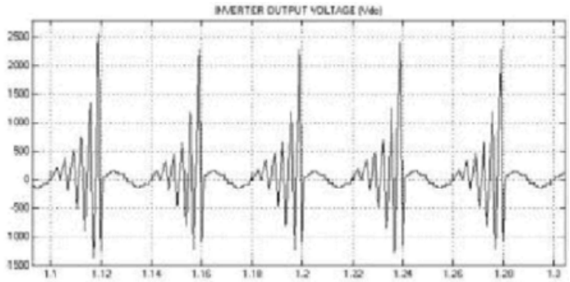

Fig .7: Three Phase Inverter With High ImpedanceSingle Phase Fault (□=5°, γ =18°)

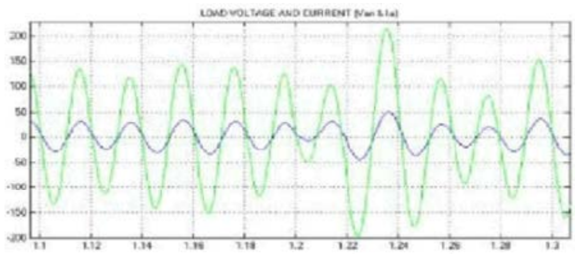

Fig. 8: Three Phase Inverter With High Impedance Single Phase FaultSingle Phase Fault (□=5°, γ=0°)

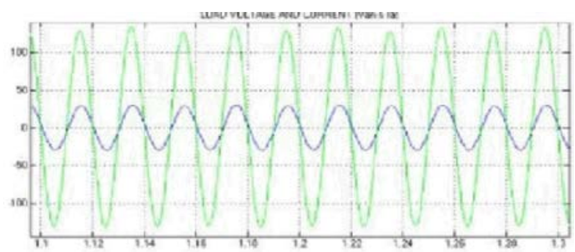

Fig. 9: Three Phase Inverter With HighImpedance Single Phase Fault (□=5°, γ =18°)

Ground Fault:

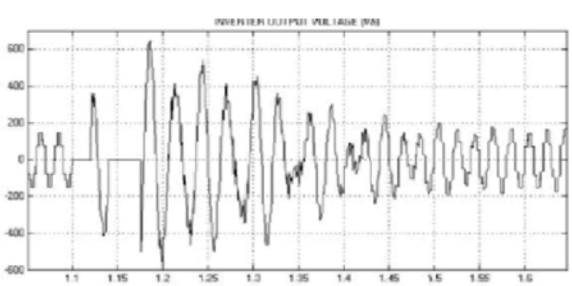

Fig. 10: Three Phase Inverter With Ground Fault (□=5°, γ=0°) S.C – 500uf

Figs. 10,12,14 and 16 shows the system response with ground fault. This ground fault has been studied without extinction angle i.e. normal angle control. The inverter output voltage oscillates to maximum positive and negative and post fault condition performance is not good. Figs. 11,13,15 and 17 with extinction angle of γ = 15°, with slight reduction in condenser the voltage oscillation is reduced and the post fault performance is good.

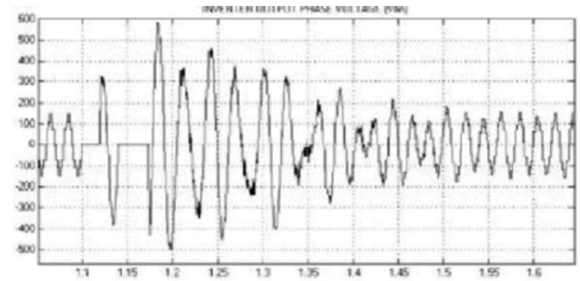

Fig. 11: Three Phase Inverter With Ground Fault *(□=5°, γ =15°) S.C = 500uf*

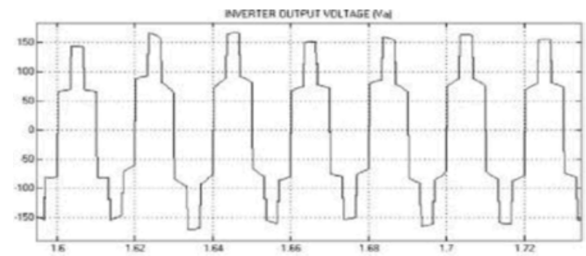

Fig. 12: Three Phase Inverter With Ground Fault (□=5°, γ =0°) S.C – 500uf

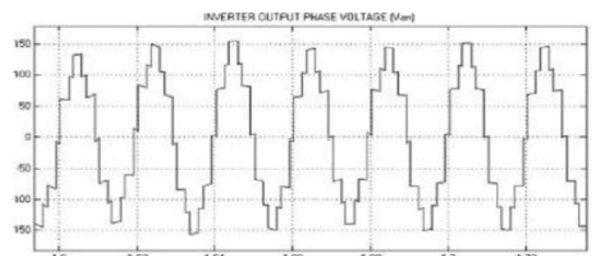

Fig. 13: Three Phase Inverter With Ground Fault (□=5°, γ =15°) S.C = 500uf

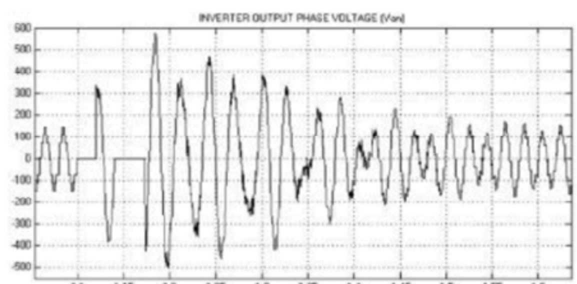

Fig. 14: Three Phase Inverter With Ground Fault *(□=5°, γ =15°) S.C – 400uf*

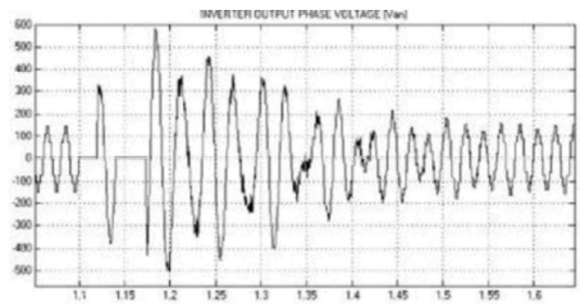

Fig. 15: Three Phase Inverter With Ground Fault *(□=5°, γ =15°) S.C –500uf*

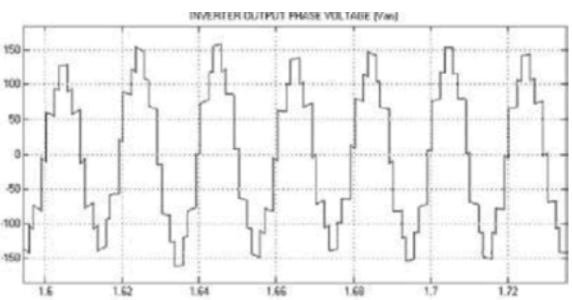

Fig. 16: Three Phase Inverter With Ground Fault (□=5°, γ =15°) S.C – 400uf

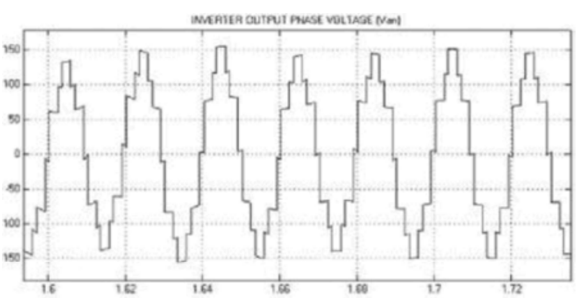

Fig. 17: Three Phase Inverter With Ground Fault (□=5°, γ =15°) S.C – 500uf

Future Scope: In this paper from the simulation result and real system it is evident that the Novel inverter control gives better improvement in power factor and stability. Here only the extinction angle alone taken for the analysis. In future the paper can be studied in detail by considering harmonics, filters etc. By filtering and reducing harmonics the system stability can be improved in a better way [10-15].

CONCLUSION

In this paper from the economic point of view the novel controller introduces significant benefits in the case of HVDC system. The simulation responses presented in this paper shows that it is possible to reduce the number of condensers that are traditionally assumed necessary at inverter side HVDC-HVAC interconnection point. The novel controller very effectively improves the system responses to various fault conditions and post fault recovery. The transient responses are evidently reduced and it is better than in case with large number of condenser in operation. It is concluded that the system reliability will be improved, compared to the original system, enhances the system stability without relying on the telecommunication link between the terminals and the novel control concepts introduces apparent benefits in the case of new HVDC system.

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