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산업용 전력계통의 안정도 유지를 위한 과전류계전기의 시간지연 한계

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Time Delay Limit of Over Current Relay for Maintaining Stability in Industrial Power Systems

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Abstract - The industrial power distribution system is a radial system and therefore usually protected with time delayed over current relays (OCR's). Proper time dial settings are provided at the OCR's. Meanwhile, the systems, where synchronous generator, or synchronous motors, or large induction motors are operating, can not be protected with only OCR's with time grading. This paper presents a technical limit and a suitable range of time delay in applying OCR's to clearing faults in the industrial power systems for maintaining stability. Dynamic simulations are made to show them employing a real power systems of a large petro-chemical complex.

1. GENERAL

The industrial power system is a distribution system containing synchronous generators, synchronous motors, induction motors, and static loads which are interconnected with a utility. The distribution system is radial and therefore usually protected with time delayed over current relays. Proper time dial settings are provided for the primary, secondary, and tertiary protection. Meanwhile, the systems, where synchronous generator, or synchronous motors, or large induction motors are operating, can not be protected with only OCR's with time grading. This paper presents a technical limit and a suitable range of time delay in applying OCR's to clearing faults for maintaining stability in the industrial power systems. Dynamic stability simulations are made to show them employing a real power systems of a large petro-chemical complex as an example. [1],[2],[3]

2. MODELING OF POWER SYSTEMS

2.1 Network system

The industrial distribution system selected for this study is a real petro-chemical plant system which contains 105 bus comprising 1 swing bus, 6 generator bus, and 98 load bus as well as 112 branches comprising 55 transformers, 10 reactors, and 47 cables. The plant power system includes 115kV utility connection and its down stream radial systems such as 13.8kV, 6.6kV, 4.16kV, 2.4kV, and 0.48kV systems. See figure 9.

3.2 Synchronous Machine

The transient model for a round rotor machine is used for generators. The same model for the salient rotor machine is used for synchronous motors. The model uses an internal voltage source behind a fictitious impedance.[4]

3.3. Excitation system

The excitation system of the generator TG-2,3,4,5, 6N,7N is a static type, the model of which is the potential source controlled rectifier exciter, IEEE Type ST1, The excitation system of the generator 2N and 3N is a brushless type, for which IEEE type 2 is employed.[5]

3.4. Steam turbine system

The Woodward 505 Steam Turbine and Governor is used to represent the prime mover of the TG-6N,7N, the model of which is well suited to represent the extraction and condensing turbine used in the petro-chemical plant. The IEEE type ST is employed to represent the prime movers of the other generators. [4],[6]

3.5 Load model

The loads in the plant are mainly induction motors and synchronous motors. Induction motors at each bus are lumped as an equivalent motor, which is represented by a circuit model.

3. CASE STUDIES AND SIMULATION RESULT

3.1 case studies

Dynamic simulation on 34 cases are performed to find the critical fault clearing times(CFCT's) at the 115kV, 13.8kV, 6.6kV, 4.16kV, 2.4kV, 0.48kV bus where 3 phase short circuits occurs. All the generators in the plant are considered to be in service initially. The fault clearing time for primary, secondary, tertiary are selected as 0.1s, 0.4s, 0.7s respectively. In the 13.8kV main distribution systems in the plant, the Is Limiter is installed in parallel with a current limiting reactor to reduce the short circuit currents. Is-Limiter is blown-up when a fault takes place at an adjacent bus. [2]

3.2 Check points during stability simulation

The check points from the stability simulation plots are frequency variation of generators: power angle deviation: voltage variation at the interested bus: speed, V, I, of representative synchronous motors: and slip, V, I, of induction motors. Figures 6,7, and 8 show comparison of simulation plots for 0.1s(stable), 0.22s(critical), and 0.24s(unstable).

Table 1. Time delay of over current relay

voltage of bus kV	bus location from generator	critical fault clearing time	protection applicable
115	Up stream from gen. via tr.	0.2 sec.	1ry
13.8	On gen. bus or close to gen.	0.14 -0.24 sec.	1ry
13.8	Remote from gen. via reactor	more than 0.5 sec.	1ry and 2ry
6.6	On same bus or close to gen.	0.18-0.2 sec.	1ry
4.16 2.4 0.48	Down stream load bus through tr.	more than 0.7 sec.	1ry, 2ry, and 3ry

3.3 Simulation Result

The CFCT's have been determined whether or not any one generator in the plant runs out of synchronism. When any short circuit faults on the utility 110kV networks are cleared by the primary protection with a fault clearing time of 0.1seconds, the industrial systems remain stable. The CFCT at the 110kV bus is 0.2 seconds.

The CFCT's on the bus at every voltage level in the plant are obtained from the dynamic simulation as shown in the table 1. As realized in this table, the power systems are stable with the primary protection time (0.1 seconds). But in the most fault cases except the 4.16kV, 2.4kV, 0.48kV, it is less than the available secondary protection time of 0.4 seconds. In the case of the fault being cleared critically, some of synchronous motors run out of synchronism. In this regards, any fault occurred at 13.8kV or 6.6kV systems close to generators shall be cleared by the primary protection.

The transient stability simulation is also performed to confirm the satisfactory recovery of the 4.16kV, 2.4 kV, and 0.48kV systems following the clearance of three phase faults at selected locations on the power systems. The main protection time of 0.1 seconds, the back-up protection time of 0.4 seconds for the secondary protection and 0.7 seconds for the tertiary protection are all applicable.

4. CONCLUSION

The stability simulation on the industrial power systems are carried out to investigate time delays applicable to the over current relays.

The primary protection such as instantaneous OCR or bus differential relay or pilot wire differential relay shall be designed for the bus of impedance-close to generator at the same voltage as generator voltage. The secondary protection may be allowed for the bus of impedance-remote from generator even if the voltage of bus is as same as generator voltage.

The primary, secondary, and tertiary protection are allowed for the down stream load bus without generators.

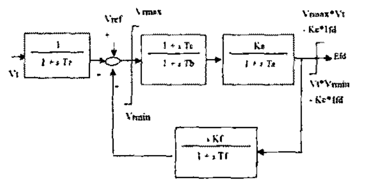

Figure 1. IEEE Exciter Type ST1 Potential source controlled rectifier system

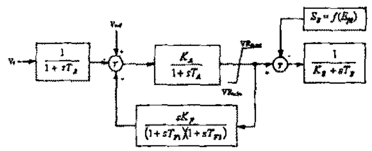

Figure 2. IEEE Exciter Type 2 Rotating rectifier system

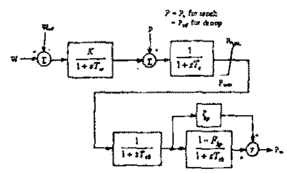

Figure 3. Steam turbine and governor system Type ST

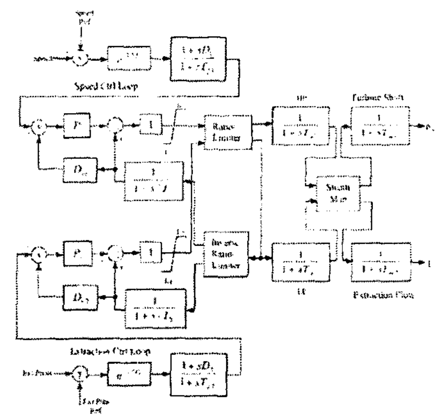

Figure 4. Steam turbine and governor system Woodward 505

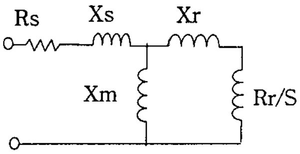

Figure 5. Circuit model for induction motor

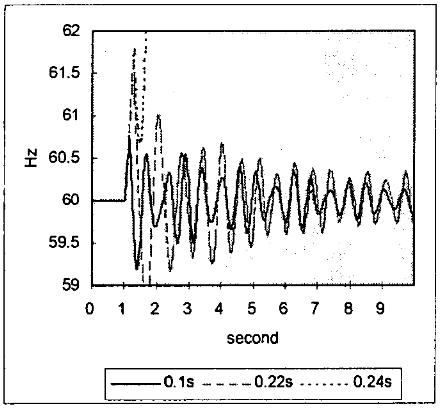

Figure 6. Comparison of generator frequency

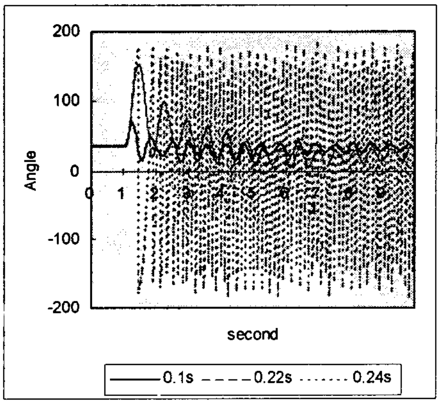

Figure 7. Comparison of generator angle

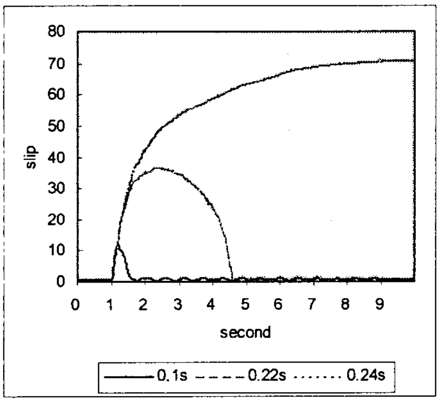

Figure 8. Comparison of induction motor slip

〔REFERENCE〕

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〔6〕IEEE Committee Report, "Dynamic Models for Steam and Hydro-Turbines in Power System Studies", IEEE Trans. PAS, Nov/Dec, 1968.

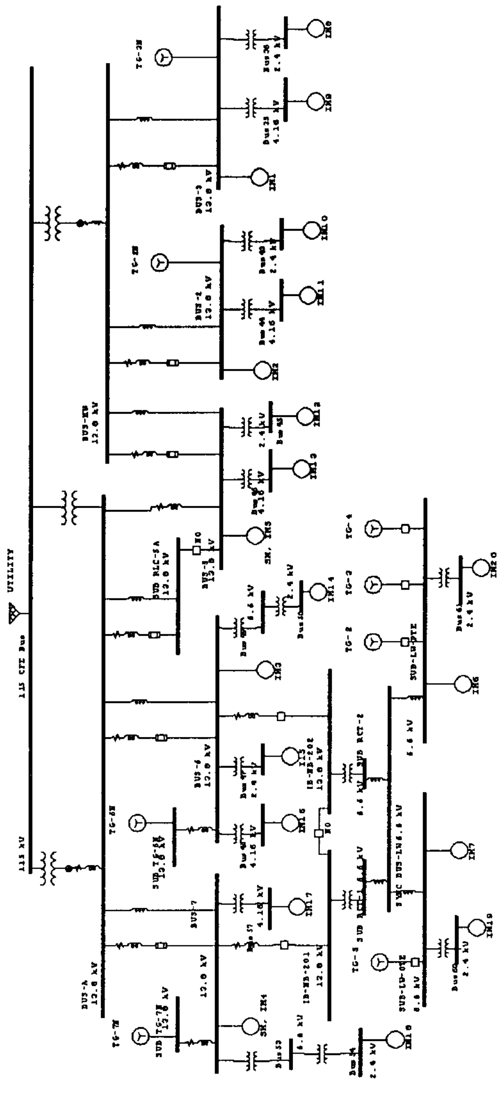

Figure 9. Simplified single line diagram of the industrial power systems