CHAPTER 2

NEED OF UNDERFREQUENCY PROTECTION

2.1 The Hazards of Low Frequency

The frequency in an electric system is held, during normal operation, very close to the nominal value of 50 Hz. Daily load fluctuations have only very small influence on the frequency, due to the extensive inertia of the interconnected units, and quick acting regulating devices. Large decreases in system frequency can occur only when there is an excess of load over available generation.

For the sake of economy, electric steam generating units are not designed to operate at frequencies which are much different from synchronous. The amount of deviation permitted, although dependent on specific design, is usually not larger than about 3 percent of synchronous speed.

Mechanical damage, especially to the low pressure stage wheels because of axial and tangential vibrations, severely limits the magnitude of speed deviations and the time over which these may be tolerated. Resonant oscillations of steam turbine blades can occur when the turbine is operated at speed of the order of 10 % different from normal. Recent investigation on the subject also indicates that a 4 % drop in frequency for about 1 minute could result in blade fatigue failure.[1] Longer operating times are permitted for smaller frequency deviations. The damage suffered during each low frequency experience is cumulative. This suggests that low frequency conditions should be corrected as fast as possible.

Another serious complication is provided by the generating units auxiliaries. A thermal generating plant is quite sensitive to even a five percent reduction in frequency, while a hydro-electric plant is relatively unaffected by even a ten percent reduction. The power output of the thermal plant depends to a great extent on its motor-driven auxiliaries, such as boiler feedwater pumps, coal pulverizing and feeding equipment, and draft fans. As system frequency decreases, the power output of the auxiliaries begins to fall off rather rapidly, and this in turn futher reduces the energy input to the turbine-generator. The situation thus has a cascading effect, with a loss of frequency leading to a loss of power which can cause the frequency to deteriorate further to such an extent that the

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[1] D.H. Berry and others, "Underfrequency Protection of the Ontario Hydro System," CIGRE, 32-14, 1970 Session--24 August-2 September, 1; and B. Porretta and R.D. Brown, "Underfrequency Protection of Electrical Power System," (presented to Power System Planning and Operating Section of Spring Meeting Canadian Electrical Association, Toronto, Ontario, April, 1968), p.4.

generator may stall and be tripped out of the system.

The following inconveniences, risks and complications resulting from low frequencies are also expected:[2]

- Disturbances and inaccuracies may be noted in clocks, computers and frequency-sensitive machines.
- Motor shafts will rotate slowly, thus transferring less output to their coupled machines.
- Cause considerable damage to the customer's equipment, especially motors in refrigerators, home freezers, water systems, washing machines, and etc.
- Increase in the operating time of most induction relays, which may be significant in the system ultimate recovery.
- Products in process may be damaged. Also serious damage may result if the load involves materials which can jam a machine, promote stalling, or produce cobbles. (Often such industrial loads include ore crushers and rolling of hot materials, such as plate glass, iron products, etc)

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[2] Charles F. Dalziel and Edward W. Steinback, " Underfrequency Protection of Power Systems for System Relief, " AIEE Transactions, Pt. III-B, December, 1959, 1227; Porretta, loc. cit.; P.J. Squire, "Operation at Low Frequency in Great Britain, " AIEE Transactions (Power Apparatus and Systems), 73:1650, February, 1955; and J.O. Swanson and J.P. Jolliffe, "Load Shedding Program in the Pacific Northwest," AIEE Transactions (Power Apparatus and Systems), 73:1655, February, 1955.

As discuss above, operation at low frequency is dangerous in most instances. However, even if certain degrees of underfrequency could be tolerated in some areas, it is still very important that the speed be brought back to normal. This will permit interconnection integrity to be re-established with a minimum time loss after the removal of the original causes of disturbance.

Because of the limitations of spinning reserves, it is effective to use a properly co-ordinated load shedding schemes for adequate area protection in order to prevent the possibility of interconnection breakdown and the dangers of underfrequency operation. Although load shedding involves a deliberate service interruption, something which one is continually trying to avoid, it is invaluable to system security since it would become effective only when everything else has failed.

Before a load shedding program is developed, it is important to know the characteristics of load shedding.

2.2 Characteristics of Load Shedding

Certain conclusions about what should be the characteristics of load shedding can be summarized as follow:[3]-

1. Since, in general, it must act immediately (that is, in a matter of seconds) in order to be effective, it should be automatic.
2. Since it is to be called upon primarily in unpredicted situations, and must work regardless of where the system has split or whether or not communications are available, it should respond to the local frequency that is available on the spot.
3. For the same reasons as in (2), and to avoid the possible tripping of certain lines due to overloading caused by changes in the distribution of load, load shedding should be at widely and more or less uniformly distributed points in the network.
4. Further to assure uniformity, it should be in steps, so that in principle all line loadings will remain relatively the same at each step.

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[3] C. Concordia, "Panel on Load Shedding and Bail-Out Frequencies," <u>EEI System Planning Committee,</u> Feb. 13-14, 1969, pp.2-6.

5. In order to avoid unnecessary tripping on transient frequency swings at least three or four tenths of a second at the low frequency should generally be required before shedding is initiated. The exact value of time delay that should be used will depend upon circumstances, but a few tenths of a second will avoid most of the spurious responses.
6. Although sufficient time to avoid all spurious responses should be employed, it is brought out that the frequency steps must be spaced far enough apart (or the time delay must be small enough) so that if, for example, it is only necessary to shed the first load step, then the first step will trip before the next set point is reached so that unnecessary additional load shedding is avoided.
7. At least half of the system load should be on the automatic load shedding program.
8. The first step of load shedding should not be too close to normal because of possible severe frequency swings. Moreover, the proper values depend on the type of system.
9. Depending upon the exact nature of the initiating disturbance, the frequency may or may not return to normal after load shedding. However, the difference between the amount of load shedding required to restore to normal and that required just to arrest frequency decay is very small, and it is better to shed enough load to return to normal.

10. Even if the generation reserve were theoretically sufficient, it is practically impossible to see any effect of speed governor action within the first two seconds and can not afford to wait any longer before deciding to shed the load. Moreover, picking up the load by governor action will usually result in an intolerable frequency dip if reserve is distributed on the basis of economic loading. So, as a practical matter, it is beleived to accept an extremely small possibility of unnecessary load shedding. In order to assure the most effective utilization of the reserve, frequency drop could be reduced by applying under-frequency relays to the turbine control to boost power to maximum or using a nonlinear governor which has a regulation of, e.g., 5 % within a frequency band of ± 0.7 Hz, but a regulation of only 0.5 % outside of this band.