CHAPTER 4

DEVELOPMENT OF LOAD SHEDDING PROGRAM

4.1 Importance of Load Shedding

The operation of an electric system today requires the highest possible reliability of service to the customer consistent with economic justification of the costs of such service. Automatic load shedding programs can increase system reliability by preventing total system collapse from emergencies when load exceeds generation.[1]

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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; J. Berdy, "Load Shedding-- Application Guide, " General Electric Company, Trans. 1968, 1; Gardon D. Firedlander, "Prevention of Power Failures-- The FPC Report of 1967, " IEEE Spectrum, February ,1968, 61; Charles F. Dalziel and Edward W. Steinback, " Underfrequency Protection of Power Systems for System Relief, " AIEE Transactions, Pt. III-B, December, 1959, 1227; and H.E. Lokay and V. Burtnyk, " Application of Underfrequency Relays for Automatic Load Shedding, " IEEE Transactions, Vol. PAS-87, No.3, March, 1968, 776.

The application of underfrequency relays in substation throughout the load area, preset to drop specific percent magnitudes of loads at predetermined low system frequency values, provides the simplest automatic load shedding program.

4.2 Determination of Relay Setting

The determination of relay settings for a load shedding program is essentially a trial and error procedure. The purpose of this procedure is to determine the best combination of number and size of load shedding steps and corresponding relay settings which will shed the required load within the frequency limits specified for a maximum overload condition and yet which will shed a minimum amount of load for less severe conditions. The initial step in the procedure is the selection of the number of load shedding steps and the load to be shed per step as will be discussed in the next section.

4.3 Number and Size of Load Shedding Steps

The number of load shedding steps selected is usually related to the maximum load to be shed. The larger the total load to be shed, the larger the number of load shedding steps used. The minimum amount of load will be shed when the number of load shedding steps fall in the limit of 3 to 5 steps.[2]

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[2] Berdy, op. cit., p.11.

The load shed per step is not particularly critical. The amount of load shed on the initial step is usually related to the size of the largest generator or the pick-up capacity of the inter-connecting tie-lines. In each succeeding step, the amount of load shed is usually determined by arbitrarily allocating some portion of the remaining load to be shed to each step. In general, it is fall in the range of 7 to 10 percent of total connected load.[3]

It should be apparent that the selection of the number and size of load shedding steps is more or less arbitrary. In some instances, it will be possible to obtain coordinated load shedding within the specified frequency range with the initial selection. In others, it will be necessary to adjust both the number and size of steps in order to shed all of the load within the prescribed limits.

4.4 Procedure for Developing a Load Shedding

An initial combination of number and size of load-shedding steps is selected and checked for relay coordination. The unnecessary load shed is measured when emergency overload conditions are less than

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[3] IEEE Committee Report, " Survey of Underfrequency Relay Tripping of Load Under Emergency Conditions, " IEEE Transactions. Vol. PAS-87, No.5, May, 1968, 1362.

the maximum overload used for developing the complete load-shedding program. The result of this analysis will suggest better combinations to be studied. The procedure for developing a load-shedding program can be briefly summarized as follows:[4]

1) Determine the total load requirid to be shed. The amount is based on maximum overload the load shedding program is designed to protect and the desired leveling frequency for that overload.

2) Select the number of load-shedding steps and the amount of load to be shed per step. This selection is arbitrary, but the larger the overload to protect, the greater frequency spread required between successive relay settings. Also, the percent of load shed for the first steps should be less than for later steps. However, the number of load shedding steps and the load shed per step are frequently governed by substation and feeder arrangements and loading on the power system. For actual feeders or substations must be assigned to open for each load-shedding step. Also,

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[4] Lokey and Burtnyk, op.cit., p.778; H.E. Lokay and V. Burtnyk, " Developing Automatic Load-Shedding Programs with Under-frequency Relays," Westinghouse Engineer, Vol.28, No.2, March , 1968, 54.

the assigned feeders must maintain approximately the same percent load being shed regardless of the daily load conditions.

3) Select a trial group of relay frequency settings. A good initial approach is to divide the frequency spread between the accepted settle-out frequency and the highest relay setting available in the same proportion as the load of each shedding step is to the total load shed.

4) Check coordination between succeeding relay settings. Coordination is checked between adjacent relay settings to determine if more load steps than necessary are shed for lower overload conditions. Coordination of relay settings is required because system frequency will drop below the relay setting before the relay has actually operated. Thus, relay settings must be far enough apart to avoid shedding steps unnecessarily. The additional drop in frequency below the relay setting can be determined by including circuit breaker operating time, auxiliary relay time and any other additional time delays that occured in the calculation.

5) Check coordination between lowest frequency relay setting (last load shedding step) and the underfrequency relay settings used for organized system and plant shutdown. These additional backup underfrequency relays are generally used to protect the system for overloads beyond the load

shedding program. Coordination is required to ensure that the additional relays will not operate for overloads within the load shedding program.

6) Based on the results of steps (3) to (5), select a revised set of relay settings and repeat the calculations. Calculations from the first trial will generally indicate if and how improved settings can be obtained. An indicator that can be used for improving settings is the area between the appropriate load-shedding step curve and the curve of minimum load that must be shed to settle at settle out frequency. The minimum area that can be obtained while still achieving relay coordination is the best combination of relay settings to drop the minimum excess load for smaller values of overload than that of maximum protected overload.

7) Using other combinations of load shed per step and number of steps, repeat steps (2) through (6). The area for each combination can be compared to select an optimum combination for the load shedding program.

4.5 Develop a Load Shedding Program for EGAT

With the system parameters summarized in Table 4.1, System characteristic curves and relay characteristic described in chapter 3, a load shedding program can be designed according to the calculating procedures described in section 4.4. Sample of calculation is shown in detail in Appendix E. A computer program is also developed to fulfil all the calculation. The computer input consists of all system parameters, the number and size of load shedding step, and the operating time of the breakers and their associated relays. The computer output are the relay settings, final rate of change of frequency after shedding each step load, actual time and frequency when breaker opened at each load shedding step and the area between the load shedding step curve and the minimum load shed curve. The results obtained from computer are used to determine the optimum combination for the load shedding.

TABLE 4.1

SUMMARY OF REGION II OF EGAT SYSTEM CHARACTERISTICS

	PEAK LOAD	LIGHT LOAD
Load reduction (d)	0.79 %	0.79 %
System inertia constants (M = 2H)	5.0 p-u	4.2 p-u
Maximum system overload in (%) of remaining area generation	90 %	80 %
Maximum load required to be shed in (%) of initial area load	48 %	44 %
Initiation of load shedding	49 Hz	49 Hz
Maximum permissible frequency	44 Hz	44 Hz
Settle out frequency	50 Hz	50 Hz

Over one hundred combinations of number and size of load shedding steps has been studied. Some of them are listed in Table E.1 of Appendix E. The following table shows the optimum combination determined from the studies.

TABLE 4.2

OPTIMUM LOAD SHEDDING

Step	Frequency Setting (Hz)	Load Shed (p-u of initial load)
1	49.0	0.08
2	48.2	0.08
3	47.3	0.08
4	46.7	0.12
5	45.1	0.12

This five-step load shedding program for the protection of the maximum overload of region II is also illustrated in Fig. 4.1.

STEP	RELAY SETTING	LOAD SHED
1	49.0 Hz	8 %
2	48.2 Hz	8 %
3	47.3 Hz	8 %
4	46.7 Hz	12 %
5	45.1 Hz	12 %

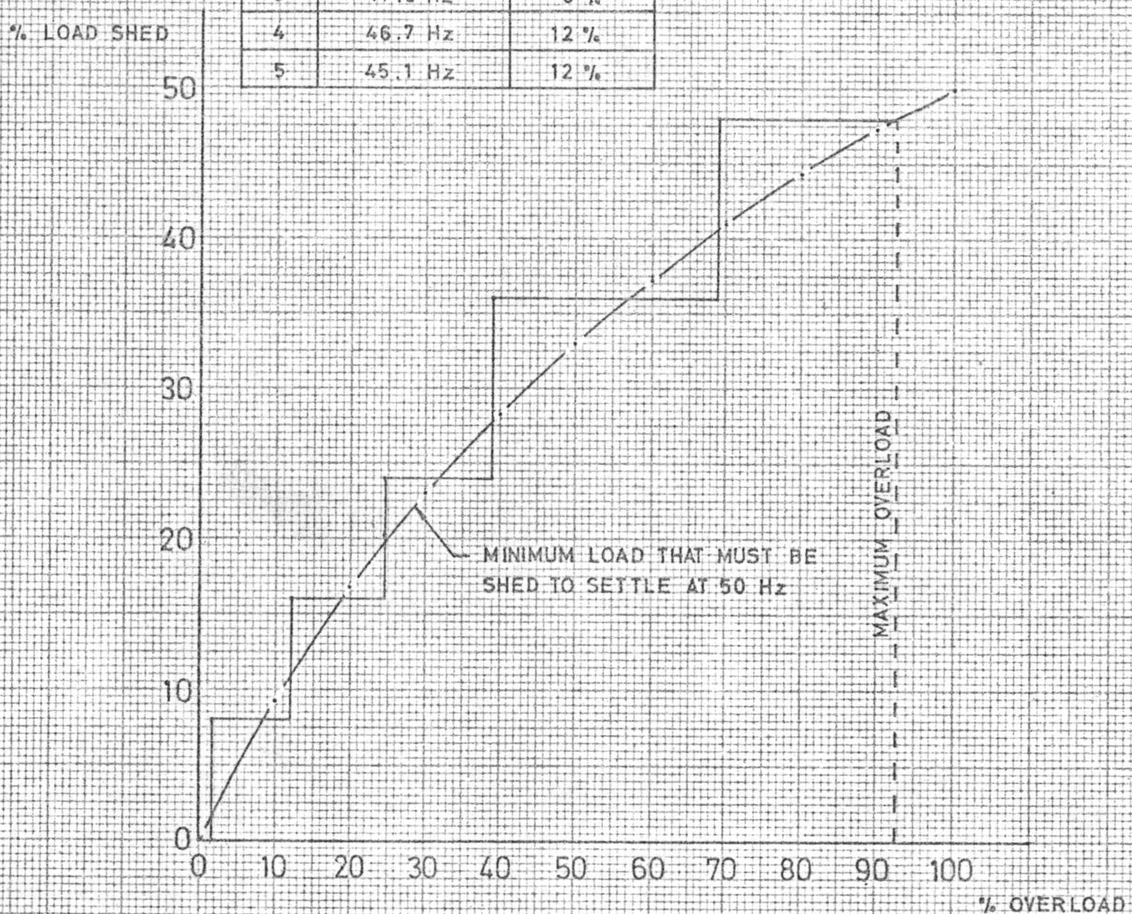

FIGURE 4.1. Five-step load shedding program to protect maximum overload of Region II