CHAPTER 3

EGAT SYSTEM CHARACTERISTICS

3.1 System Tests to Determine Frequency Characteristics of Composite Load in Region II

Power system loads may be loosely categorized into heavy or light industry, commercial and residential. However, the composition of any one category, in terms of proportion of motor loads, heating, lighting, etc, is subject to speculation. Even residential loads may have significant but unknown proportion of rotating machinery in refrigeration, air-conditioners, furnaces and other appliances.[1] On the occurance of a sudden severe drop in frequency a short period of time must elapse before voltage regulators can act, after which generator and system voltage regulators will attempt to counteract the dropping voltage. However, regulators may soon run out of range and become inoperative.[2] The practical difficulty of establishing the frequency characteristics of a composite load is thus apparent. With these considerations in mind, it was possible to assume the following

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[1]D.H. Berry and others, "Underfrequency Protection of the Ontario Hydro System," <u>CIGRE</u>, 32-14, 1970 Session--24 August-2 September, 4.

[2]Charles F. Dalziel and Edward W. Steinback, "Underfrequency Protection of Power Systems for System Relief," <u>AIEE Transactions</u>, Pt. III - B, December, 1959, p. 1228 and p. 1237.

relationship[3] $$\Delta P = D.\Delta f + K_v.\Delta V$$

where ΔP = per unit overload on the remaining system

D = $\partial P/\partial f$ if the voltage is constant

Δf = per unit frequency change

K_v = $\partial P/\partial V$ if the frequency is constant

ΔV = per unit voltage change.

Two tests were performed on the region II of the EGAT system to obtain data on load characteristics. In each test, one hydraulic generator at the Sirindhorn Power Station was isolated to supply loads at Ubonrachathani, Mukdahan, Suvannakhet and Yasothorn transformer Stations. At each transformer station the load in megawatts and bus voltage were recorded, and total generation, transmission voltage and frequency were recorded at the power station. The supply frequency was varied between limits of 49.5 and 50.5 Hz over a period of approximately 15 min. The transmission voltage at the power station was maintained essentially constant during the opération.

The first of these tests was failed due to load increasing during test. The result of the second test are shown in Figure 3.1. The slope of the average curve, $D = \Delta P/\Delta f$ for $\Delta V = 0$, give the value of 0.79 % load reduction per one percent reduction in

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[3]Berry, loc. cit.

TIME	FREQ	MW	(%) DEMAND	KV
12.21	50.0	5.1	100.0	123
12.24	49.8	5.08	99.6	
12.26	49.5	5.06	99.2	
12.29	49.8	5.08	99.6	
12.31	50.0	5.1	100.0	
12.33	50.3	5.12	100.4	
12.34	50.5	5.14	100.78	
12.36	50.3	5.12	100.4	
12.38	50.0	5.1	100.0	

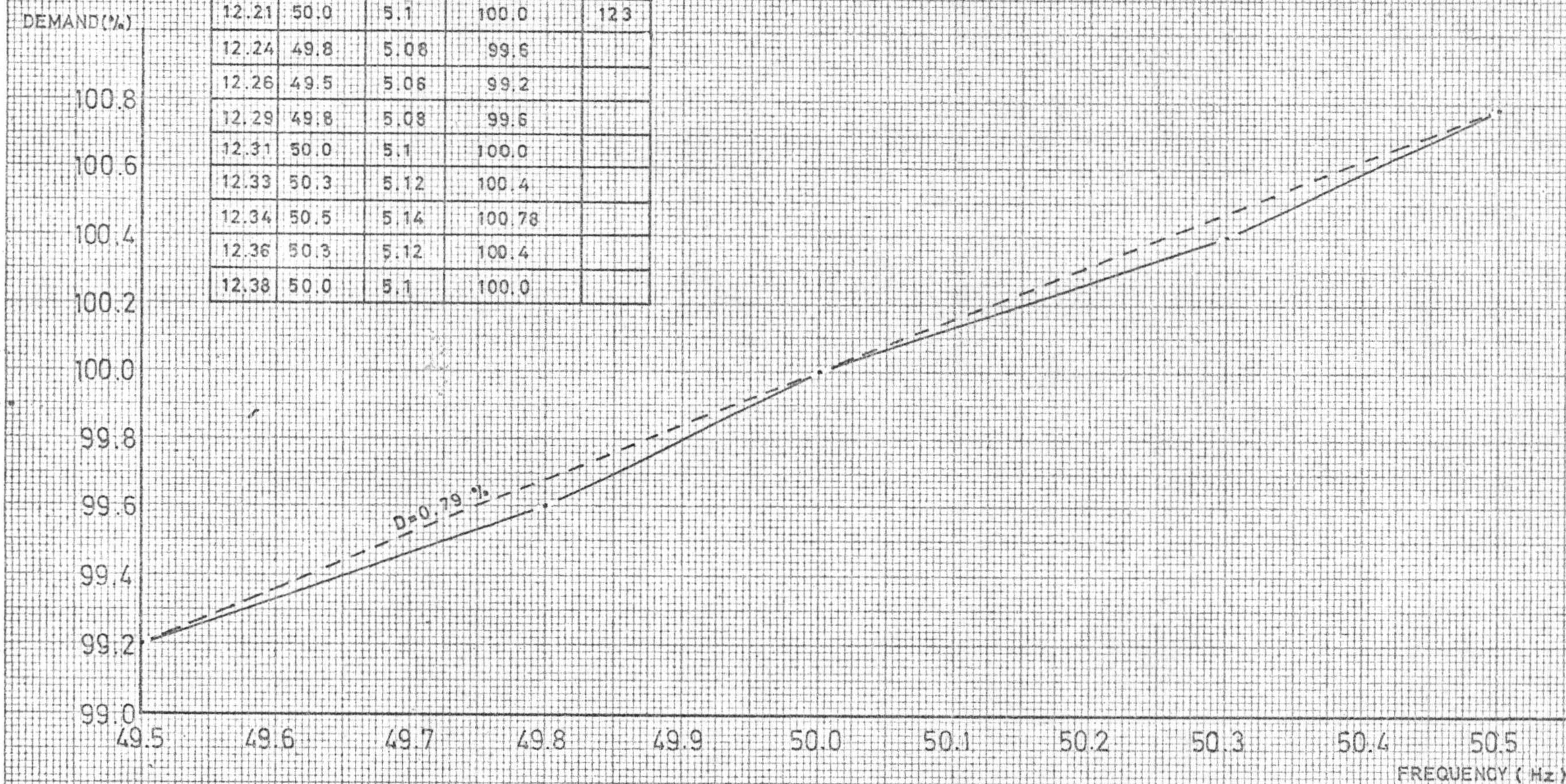

FIGURE 3:1. Demand plotted against frequency (constant voltage)

frequency. This value is on the average lower than might have been assumed without the test data. However, the limited amount of this value was reported by many references that it generally falls in the range of 0.5 to 2.0.[4] It is decided to use the value of D = 0.79 for loads on the Region II of EGAT system.

3.2 Selection of System Inertia Constants for Load Shedding Studies

The inertia of individual generators on the system is known accurately from manufacturer's data. However the inertia of the units in service at any particular time and left operating in an isolated area may vary over wide limits. The higher the system inertia constant, the lower is the rate of change of frequency and vice versa.[5]

The combination of all possible generating units remaining in service in Region II when one or both circuits of the tie-Line AT - NR-1 was tripped is shown in Table 3.1. As seen from the table, the lowest total inertia constant for maximum overload of the light load and peak load case were 1.0288 p-u and 2.2472 p-u respectively.

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[4]Ibid., p. 3

[5]J. Berdy, "Load Shedding-- Application Guide," General Electric Company, Trans. 1968, 4.

The p-u was based on 100 MVA. These values were 2.1 p-u and 2.53 p-u respectively when using the total remaining generation base. These values of inertia constant seemed reasonable for the application of a load shedding scheme.

TABLE 3.1

COMBINATION OF ALL POSSIBLE GENERATION UNITS FOR PEAK LOAD & LIGHT LOAD OF REGION II

Power Station	Peak Load Case (Total area load = 135 MW)								Light Load Case (Total area load = 72 MW)						
	Number of units running in the system								Number of units running in the system						
Num Pung	1	2	1	2	2	2	2	2	-	-	-	-	-	1	-
Sirindhorn	1	2	1	2	2	2	1	1	-	1	-	2	1	-	1
Ubol Ratana	2	2	2	3	3	2	2	1	2	-	-	-	1	1	2
Nam Ngum	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1
Chulabhorn	1	1	2	2	2	2	2	1	-	-	1	-	-	-	-
System inertia constant of Region II on 100 MVA base	2.3532	2.8966	3.0282	3.801	3.463	3.5716	3.1516	2.2472	1.1348	1.096	1.351	1.516	1.3254	1.0288	1.2168
Generation of Region II in MW	81	96	101	124	109	116	104	76	46	42	50	54	50	41	43
Import from Region I over both circuits of tie-line (MW)	54	39	34	11	44	19	31	59	26	30	22	18	22	31	29
% overload when both tie-lines were tripped	66.67	40.625	33.66	8.87	40.37	16.38	29.81	77.63	56.52	71.43	44.0	33.34	44.0	75.61	67.44

3.3 Load Shedding Program Requirements

Before a load shedding program can be developed, it is necessary to determine:-

1) The maximum overload level the program is to protect.
2) The maximum load to be shed.
3) The frequency level at which load shedding will be initiated.
4) The maximum permissible decay in frequency.
5) The minimum settle-out frequency.

3.3.1 <u>Maximum system overload</u> : Load shedding programs are usually designed to protect for some maximum overload condition.[6] For Region II of the EGAT system, a major portion of power required is imported from Region I over the double-circuit tie-line Angthong-Nakhon Ratchasima-1 and from Nam Ngum power station of Laos. From system load flow studies, it can be seen from Table 3.1, 3.2 and 3.3 that the maximum overload for Region II of EGAT system on peak load was about 90 % of remaining area generation or 64 MW. and about 80 % or 32 MW. on light load. The case of tie-line Nongkhai-Vientiane was tripped is not considered since the balance between generation and load can be achieved by importing more power from Region 1.

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[6] <u>Ibid</u>., p. 8

TABLE 3.2

GENERATION DEFICIENCY IN LIGHT LOAD CASE (TOTAL AREA LOAD = 72 MW)

Line Outage	Generation deficiency in MW	Over load in %	Load required to be shed in % of total area load	Load required to be shed in % of total area load when total load is of peak load
Both circuits of AT-NR1	32.0	80.00	44.44	24.0
One circuit of AT-NR1	16.0	28.57	22.22	11.9
Both circuits of SR2-NR1	-	-	-	-
Line NR1-PO	-	-	-	-
Line MK-NP	2.6	-	-	-

REMARK: NP plant was not running in the system during light load

TABLE 3.3

GENERATION DEFICIENCY IN PEAK LOAD CASE (TOTAL AREA LOAD = 135 MW)

Line Outage	Generation deficiency in MW	Over load in %	Load required to be shed in %
Both circuits of AT-NR1	64	90.14	47.4
One circuit of AT-NR1	32	31.06	23.7
Both circuits of SR2-NR1	24	21.62	17.8
Line NR1-PO	10	8.0	7.4
Line MK-NP	3	50.0	33.33

REMARK : When Line MK-NP was outage, total load of the area cover NP, SO, NN, NE, TH and THK was about 9 MW, so it was overload NP plant by 50 %

3.3.2 Maximum load to be shed : The amount of load shed should be sufficient to restore system frequency to normal (50 Hz) or close to normal. However, it would seem very much to be preferred to shed enough load so that the system will recover to 50 Hz.[7], since the situation that calls for load shedding should be so severe that it will always be much more important to be sure that enough load have been shed than to figure out exactly how little need be shed. To accomplish this, it would mean the load that is shed should nearly equal the amount of overload. For Region II of the EGAT system, the maximum load required to be shed for the case of peak load is about 48 % of the initial area load or 64 MW. and about 44 % of the initial area load or 32 MW. for the case of light load. The value of load required to be shed is shown in Table 3.4.

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[7] H. E. Lokay and V. Burtnyk, "Application of Underfrequency Relays for Automatic Load Shedding," IEEE Transactions, Vol. PAS - 87, No. 3, March, 1968, 783.

TABLE 3.4

LOAD SHEDDING REQUIREMENT AND SETTLE FREQUENCY DUE TO OVERLOAD

Overload in % of remaining area generation	Generation deficiency in MW for peak load case	Load shed in % of initial area load	Load shed in MW for peak load case	Settle frequency in Hz	Generation deficiency in MW for light load case
0	0	0	0	50.00	0
10	12.27	9.091	12.272	46.66	6.545
20	22.50	16.667	22.500	43.88	12.000
30	31.15	23.077	31.153	41.52	16.615
40	38.57	28.571	38.570	39.51	20.570
50	45.00	33.333	45.000	37.76	24.000
60	50.62	37.500	50.625	36.23	27.000
10	55.58	41.176	55.588	34.88	29.650
80	60.00	44.440	60.000	33.68	32.000
90	63.94	47.368	63.947	33.21	34.105
90.14	64.00	47.407	64.000	32.59	34.133
100	67.50	50.000	67.500	31.64	36.000

3.3.3 **Initiation of load shedding - frequency level** : The frequency level at which load shedding is initiated depends on several factors. For one, the level should be below any frequency drop from which the system could recover or below any frequency at which the system could continue to operate. Another factor which must be considered is the frequency deviations which occur during system swings. For example, when the local generation swings with respect to the large system, there can be a large frequency variation in the system so that underfrequency relay operation can be prevented through the use of a lower frequency setting and/or some time delay.

For Region II of the EGAT system, the frequency level for initiating load shedding was selected at 49.0 Hz. One of the reasons to use this frequency level, besides considering the factors discussed above, was that it was the same initiating load shedding level as of the MEA in the Region I.

3.3.4 **Permissible frequency reduction** : The load shedding program must be coordinated with equipment operating limitations during low frequency operation. These limitations are usually associated with operation of power plant auxiliaries. The critical frequency of station auxiliaries was estimated at 42.5 to 45.0 Hz for the 50 Hz system.[8]

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[8]Dalziel and Stienback, op. cit., p. 1233.

For Region II of the EGAT system, the maximum permissible frequency of 44 Hz was selected.

3.3.5 Settle-out frequency : As stated in the section of maximum load required to be shed that the situation that called for load shedding should be so severe that it would seem to be preferred to shed enough load to recover the system to 50 Hz. In addition, since shedding a little more load will permit the system to recover from a settle-out frequency say 49.5 Hz to 50 Hz. So, a settle-out frequency of 50 Hz is selected for Region II of the EGAT system.

3.4 Frequency Characteristics and Load Shedding Requirements For Region II

Before considering the design of a load shedding scheme with underfrequency relays, the behavior of the system during an overload must be understood. The reduction in system frequency of Region II with time due to maximum overload in the case of peak and light load is shown in Fig. 3.2 where overload is defined:

$$\text{Overload (\%)} = \frac{\text{Load-Sum of Unit Loadings}}{\text{Sum of Unit Loadings}} \times 100$$

The two curves differ due to the amount of overload and the system inertia constant. Also, no change in input power to the turbines is assumed.

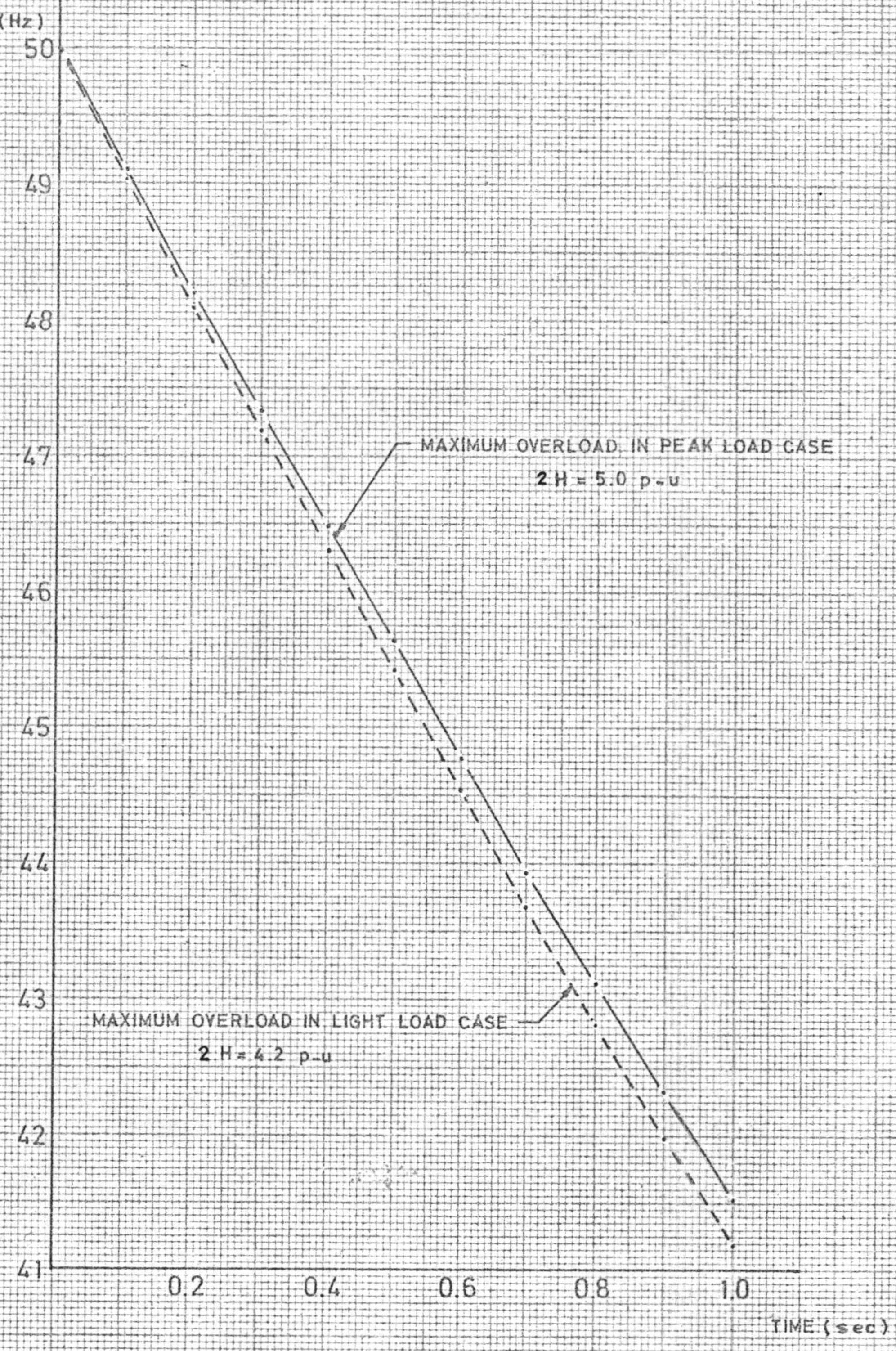


FIGURE 3:2. Frequency decay due to maximum overload for peak and light load case of the Region II

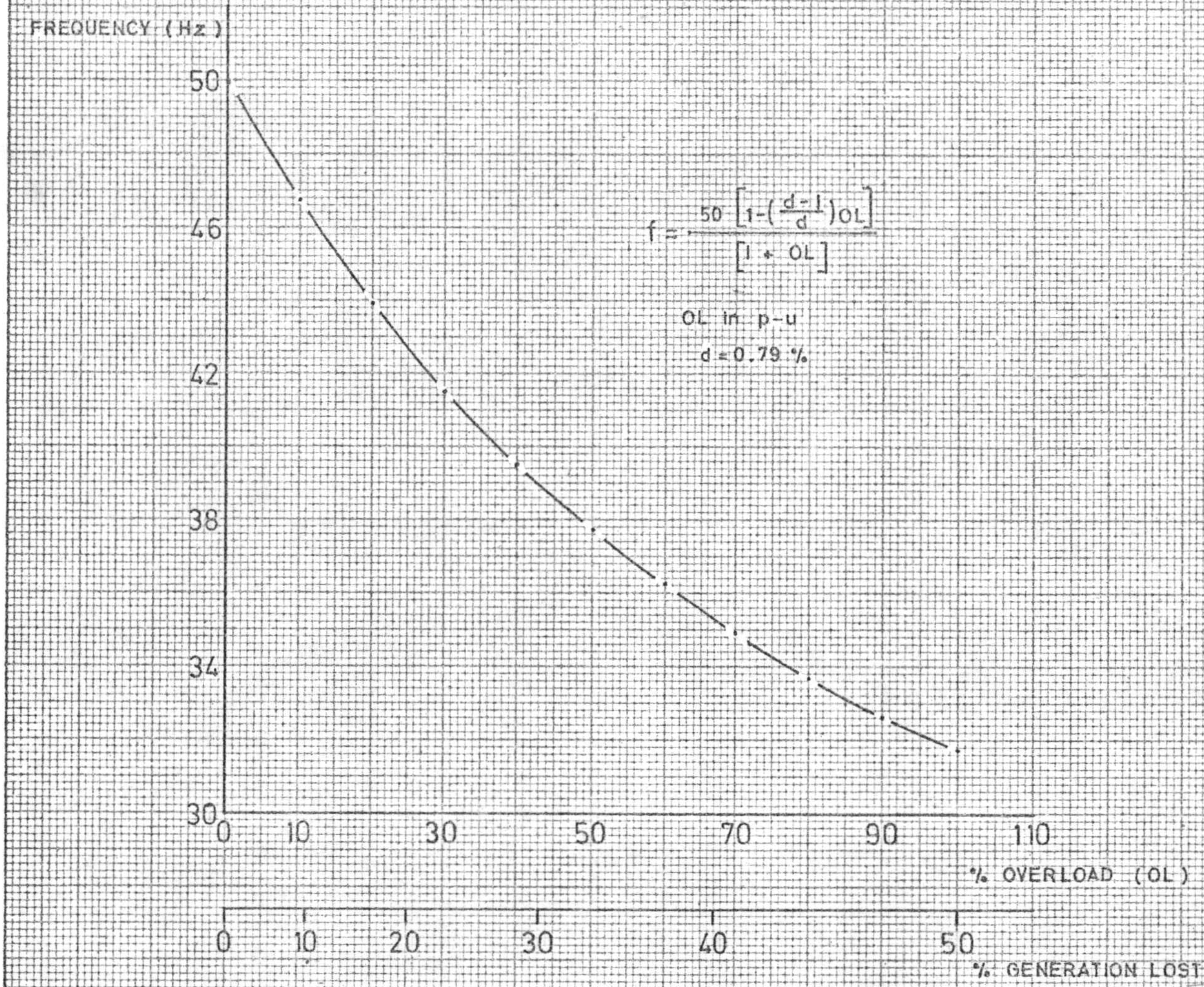
The frequency at which the system stabilizes for overloads of 0 to 100 percent is shown in Fig. 3.3. To use this curve, a minimum desired settle-out frequency is selected, and the overload that the system can withstand without having to shed load is then determined.

The amount by which the system overload exceeds the limit indicated in Fig. 3.3 is the amount of load that must be shed. This excess load is shown in Fig. 3.4 for system settling at 50 Hz. Similar families of curves can be developed for other values of minimum desired settle out frequency. The load required to be shed is in percent of initial total system load in the affected area and the overload is in percent based on the remaining area generation as defined previously.

Curves of Fig. 3.2 through Fig. 3.4 were calculated using the equations as derived in Appendix A, B and C respectively.

3.5 Underfrequency Relay Characteristics.

The English Electric 50 cycle 110/240 volt underfrequency relay type FTG is used in Region II of the EGAT system. It is continuously adjustable over a frequency range of 47.0 - 50.5 Hz and its setting will be accurate within $\pm$ 0.1 Hz of the desired set point. The pickup of the FTG will vary slightly with variations in voltage and temperature. The variation in pickup over the variation in input voltage of $\pm$ 25 % is less than 0.1 Hz with the pickup frequency decreasing with decreasing voltage. With the relay continuously energized, its frequency pickup will vary



$$f = \frac{50\left[1-\left(\frac{d-1}{d}\right)OL\right]}{\left[1+OL\right]}$$

FIGURE 3.3. Final frequency versus system overload for the Region II of EGAT system

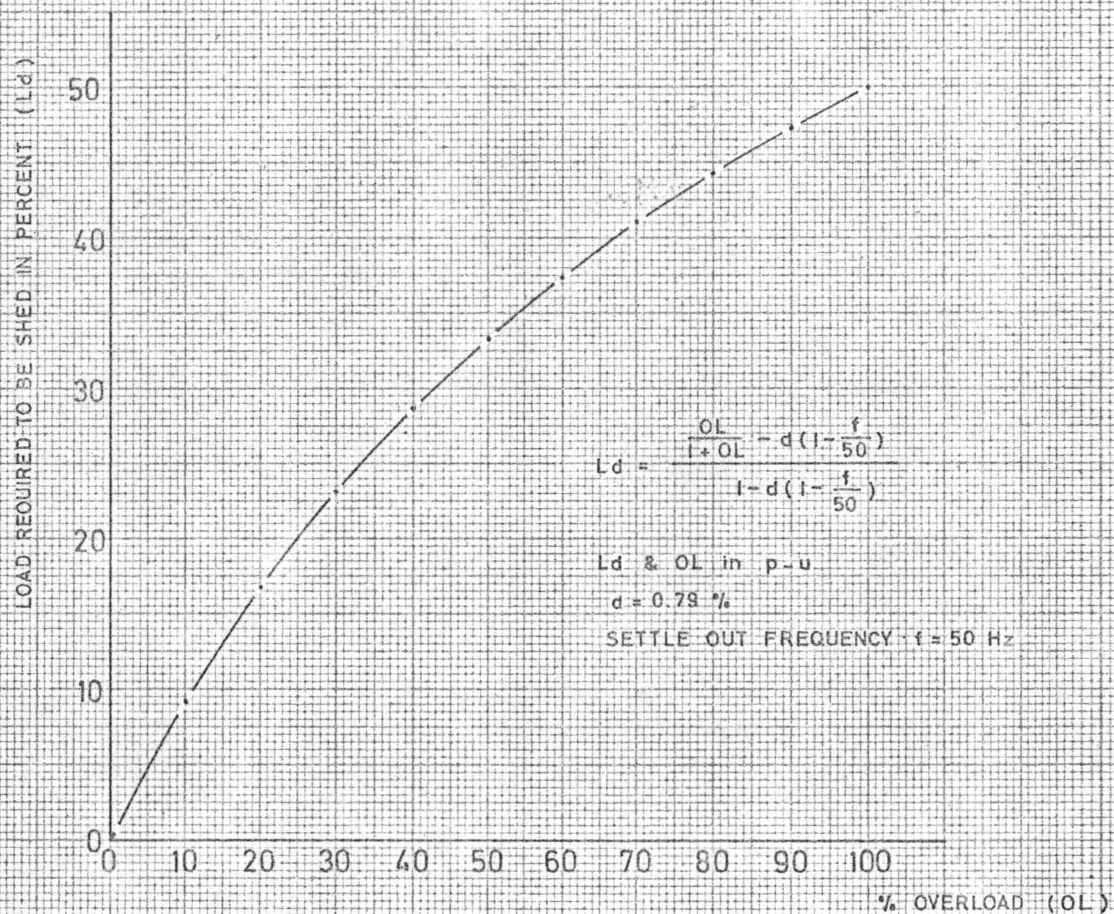


FIGURE 3:4. Load shedding requirements versus system overload

less than 0.1 Hz over an ambient temperature range of $-5^{\circ}C$ to $+40^{\circ}C$. The FTG has an operating time of less than 300 milli-seconds or 0.3 sec. at rated voltage and independent of rate of change of frequency.

The English Electric time delay unit type VTT 11 is also used to delay pickup of the relay. The timing is started by closing an initiating contact and the output relay is energized at the end of the set time. The unit resets when the initiating contact is re-opened. The timer provides a continuously variable time delay on pickup and reset over the range of 0.5 - 5.0 seconds. It has an accuracy of 0.01 seconds at nominal voltage and an ambient temperature range of $10^{\circ}C$ to $30^{\circ}C$ and 0.025 seconds for supply voltage variation of 30 %.