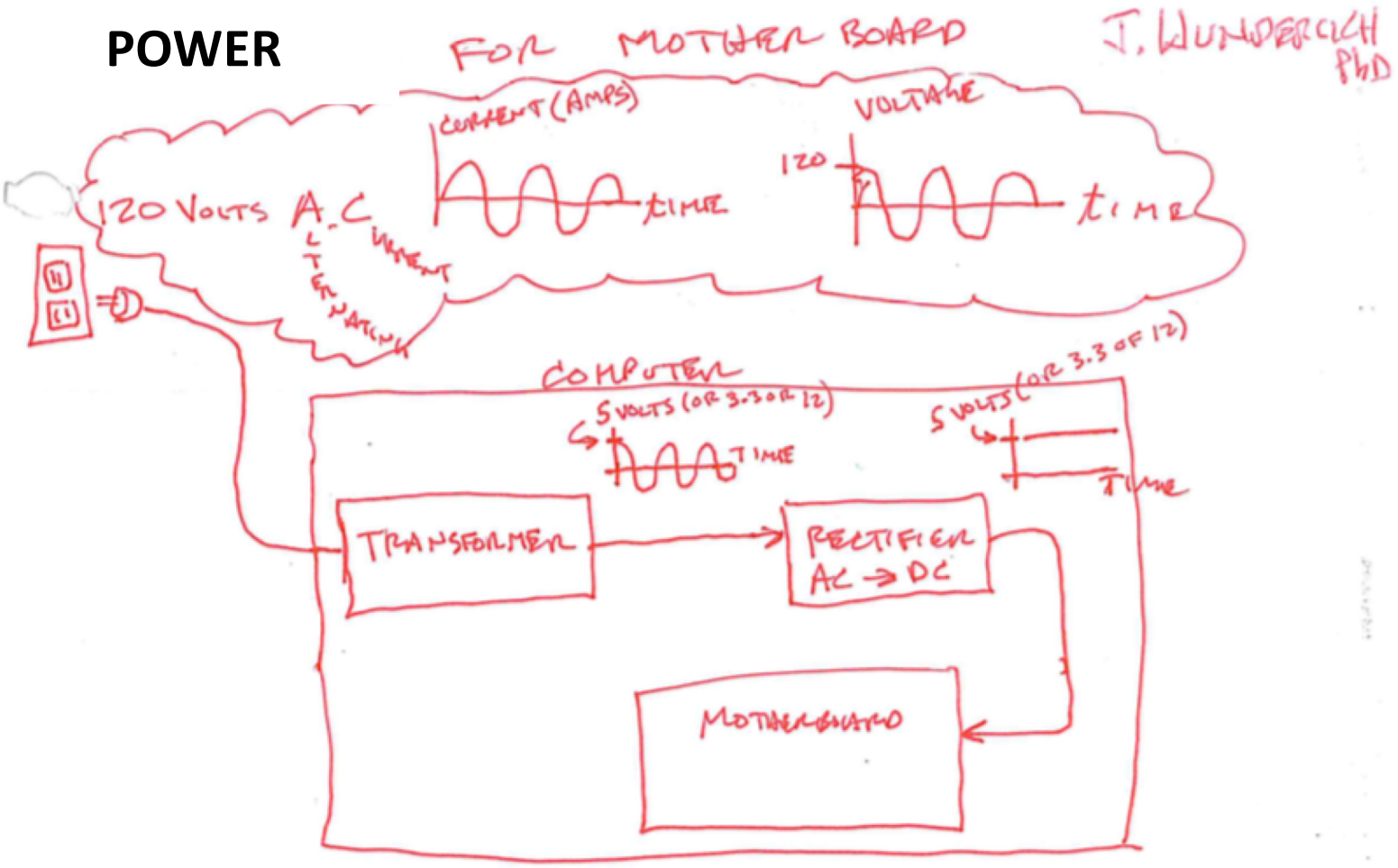
POWER



Purdue University standardized lecture notes established by a committee for the course when I was a Assistant Professor at Purdue:

POWER QUALITY

Customer expects: "Clean" sine voltage waveform with no outages
COMPUTERS NEED!

Reality: Studies have shown a typical installation can expect over 70 power disturbances per year

Customer's own equipment may cause problems within and external to the plant

E.g., Switched mode power supplies DELIVER POWER IN "GULPS"

Categories of Power Quality Problems

Voltage variations and interruptions — Transients — temporary effect

Harmonics — steady-state problem

Wiring/grounding problems

These are my review notes that I purchased for studying for the engineering licensing fundamentals exam that I passed in 1983; an all day exam which was closed book in the morning and open book in the afternoon

TABLE 1*

Through and Across-Variables for Physical Systems

System	Through-variable f	Integrated through-variable h	Across-variable v	Integrated across-variable x
Mechanical-translational	Force F	Translational momentum p	Velocity difference v_{21}	Displacement difference x_{21}
Mechanical-rotational	Torque T	Angular momentum h	Angular velocity difference Ω_{21}	Angular displacement difference Θ_{21}
Electrical	Current i	Charge q	Voltage difference v_{21}	Flux linkage λ_{21}
Fluid	Fluid flow Q	Volume V	Pressure difference P_{21}	Pressure-momentum Γ_{21}
Thermal	Heat flow q	Heat energy $\mathcal{H}$	Temperature difference θ_{21}	Not used in general

*Reference 4 (Table 4-1, p. 82)

ALSO,

P = POWER (IN WATTS)

R = RESISTANCE (IN OHMS)

$$V = iR$$

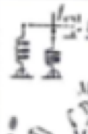
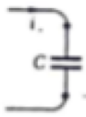
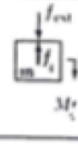
$$P = i^2R = iV$$

REVIEW NOTES FOR THE EIT EXAM

These are my review notes that I purchased for studying for the engineering licensing fundamentals exam that I passed in 1983; an all day exam which was closed book in the morning and open book in the afternoon

TABLE II*

A classification of relations for simple physical system models

CLASSIFICATION		PHYSICAL MEDIUM: *Electrical*	*Mechanical*	*Heat conduction*	*Fluid*
(1) Variables	Through variable	 Current i	 Force f (Moment M)	 Heat-flow rate q	 Flow rate w
	Across variable	Voltage drop v	Velocity u (Angular velocity Ω)	Temperature T	Pressure p or Liquid height h
		Note: arrow indicates direction of voltage *drop*.			
(2) Equilibrium relations (among through variables)		KCL: $\Sigma i_{\text{out}} = 0$	Force equilibrium (Newton's law, à la D'Alembert) $\Sigma f^* = 0$ $\Sigma M^* = 0$	First Law of Thermodynamics $C\frac{dT}{dt} = q_{\text{net in}}$, no work, no phase change	Continuity $w_{\text{net in}} = \frac{dm}{dt}$ Force equilibrium $\Sigma f^* = 0$
Compatibility relations (among across variables)		KVL: $\Sigma v_{\text{loop}} = 0$	$\Sigma u_{\text{loop}} = 0$ $\Sigma \Omega_{\text{loop}} = 0$	$\Sigma T_{\text{loop}} = 0$	$\Sigma p_{\text{loop}} = 0$
(3) Constitutive physical relations					
Passive energy-storage elements	"T-type" (storage via a through variable)	 Inductor $i = \frac{1}{L}\int v\,dt$	 Spring $f_{\text{spr}} = k\xi = k\int u\,dt$  $M_{\text{spr}} = k\psi = k\int \Omega\,dt$		
	"A-type" (storage via an across variable)	 Capacitor $i = C\dot{v}$	 Mass $f_i = m\dot{u}$ $M_i = J\dot{\Omega}$	 Heat capacity $q_{\text{net}} = C\dot{T}$ (derived from the First Law)	 Gas storage $w = C\dot{p}$ $w = C\dot{h}$ Liquid storage

*Reference 1 p. 131

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TABLE II (Continued)

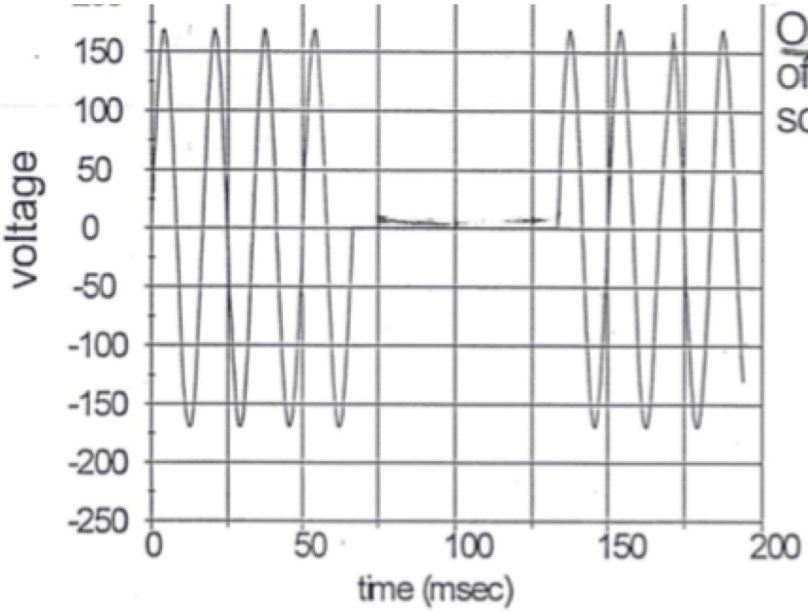
CLASSIFICATION		PHYSICAL MEDIUM			
		Electrical	*Mechanical*	*Heat conduction*	*Fluid*
(3) Constitutive physical relations (continued) Passive energy-dissipation elements		Resistor $i = \frac{1}{R} v$	Damper $f_f = bu$ $M_f = b\Omega$	Heat resistance $q = \frac{1}{R}(T_1 - T_2)$	Fluid resistance $w = \frac{1}{R}(p_1 - p_2)^{1/n}$
Sources	"T-type" (Constraining a through variable)	$i = i(t)$ prescribed Current source	$f = f(t)$ prescribed Force source	$q = q(t)$ prescribed Heat-flow source	$w = w(t)$ prescribed Mass-flow source
	"A-type" (Constraining an across variable)	$v = v(t)$ prescribed Voltage source	$u = u(t)$ prescribed Velocity source	$T = T(t)$ prescribed Temperature source	$p = p(t)$ prescribed Pressure source
Isolators		$v_2 = Kv_1$ (independent of load) Amplifier			$\dot{y} = cx$ (independent of load) Hydraulic integrating amplifier

TABLE II (Continued)

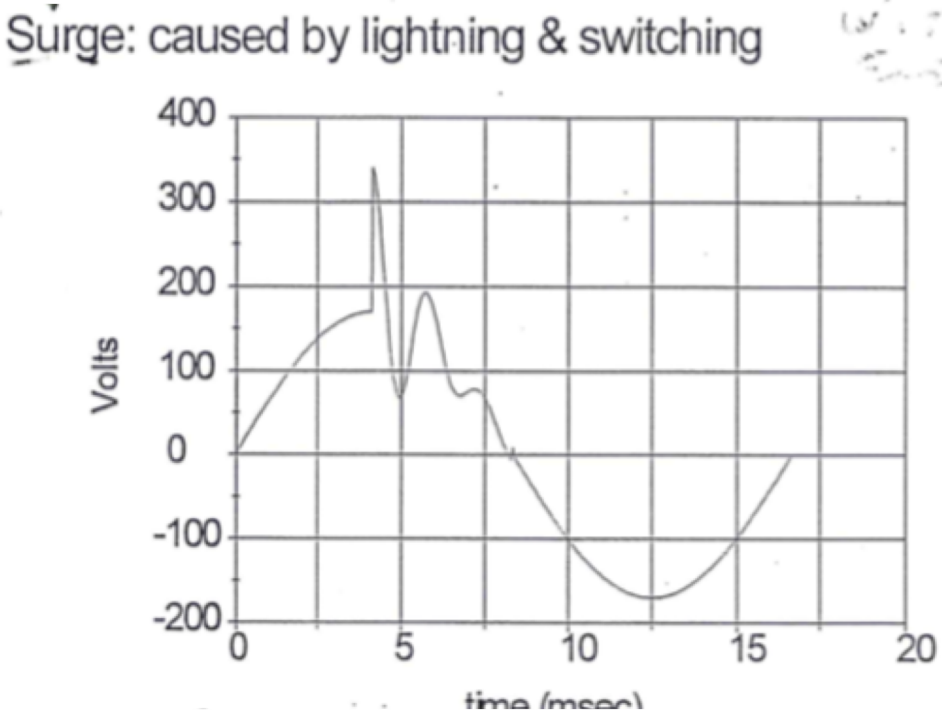
CLASSIFICATION	PHYSICAL MEDIUM		
	Electrical-electrical	*Electrical-mechanical*	*Mechanical-mechanical*
Energy-conversion elements	$v_2 = Nv_1$ $i_2 = \frac{1}{N} i_1$ (N is the turns ratio) Transformer	$v = K\Omega$ $M = Ki$ Motor or generator	$\Omega_2 = \frac{1}{N}\Omega_1$ $M_2 = NM_1$ (N is the ratio of radii: $N \triangleq \frac{r_2}{r_1}$) Gear train

Purdue University standardized lecture notes established by a committee for the course when I was an Assistant Professor at Purdue:

IEEE terminology: “INTERUPTION’ or ‘DROPOUT”

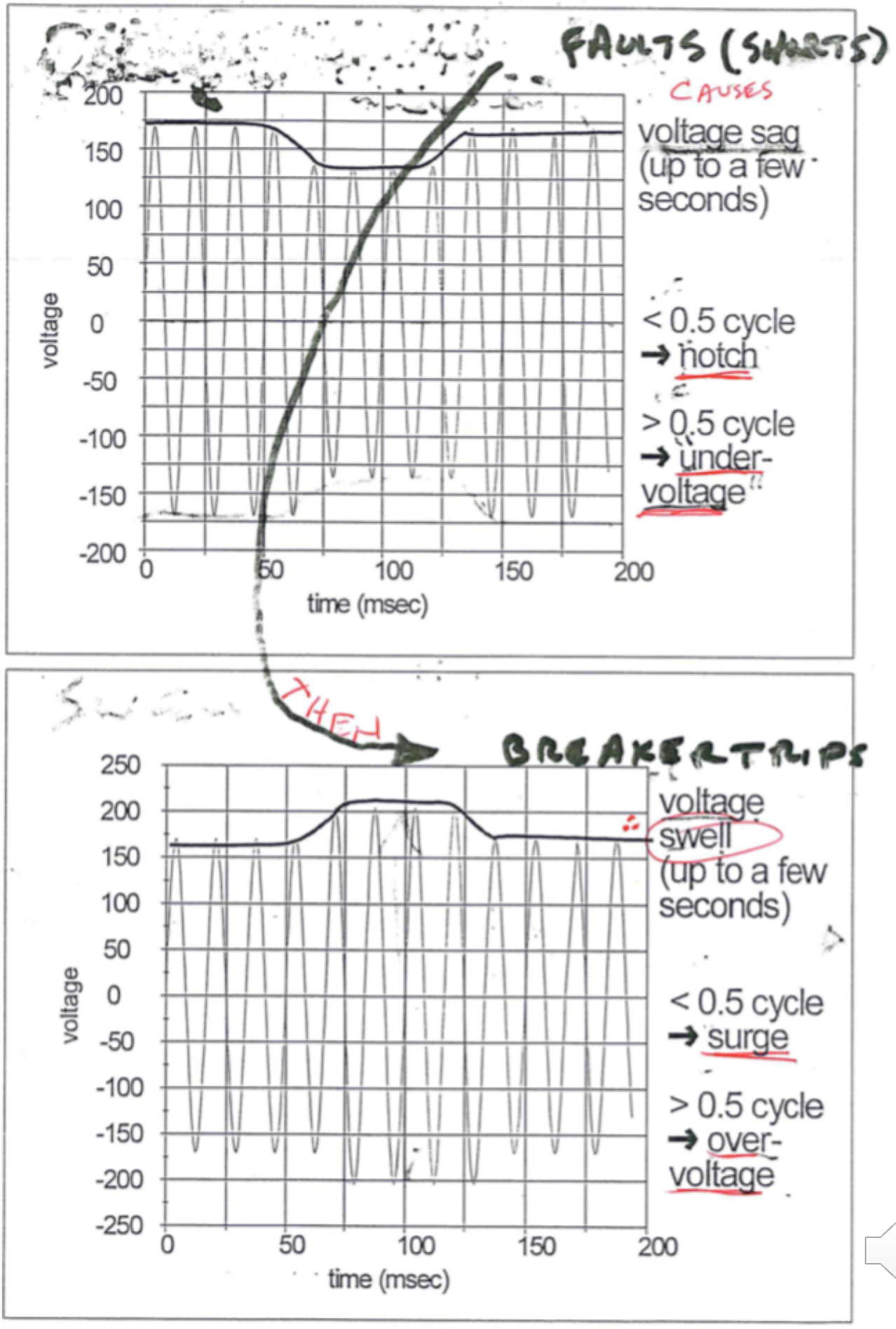


‘TRANSIENT’ (i.e., a temporary start-up thing)

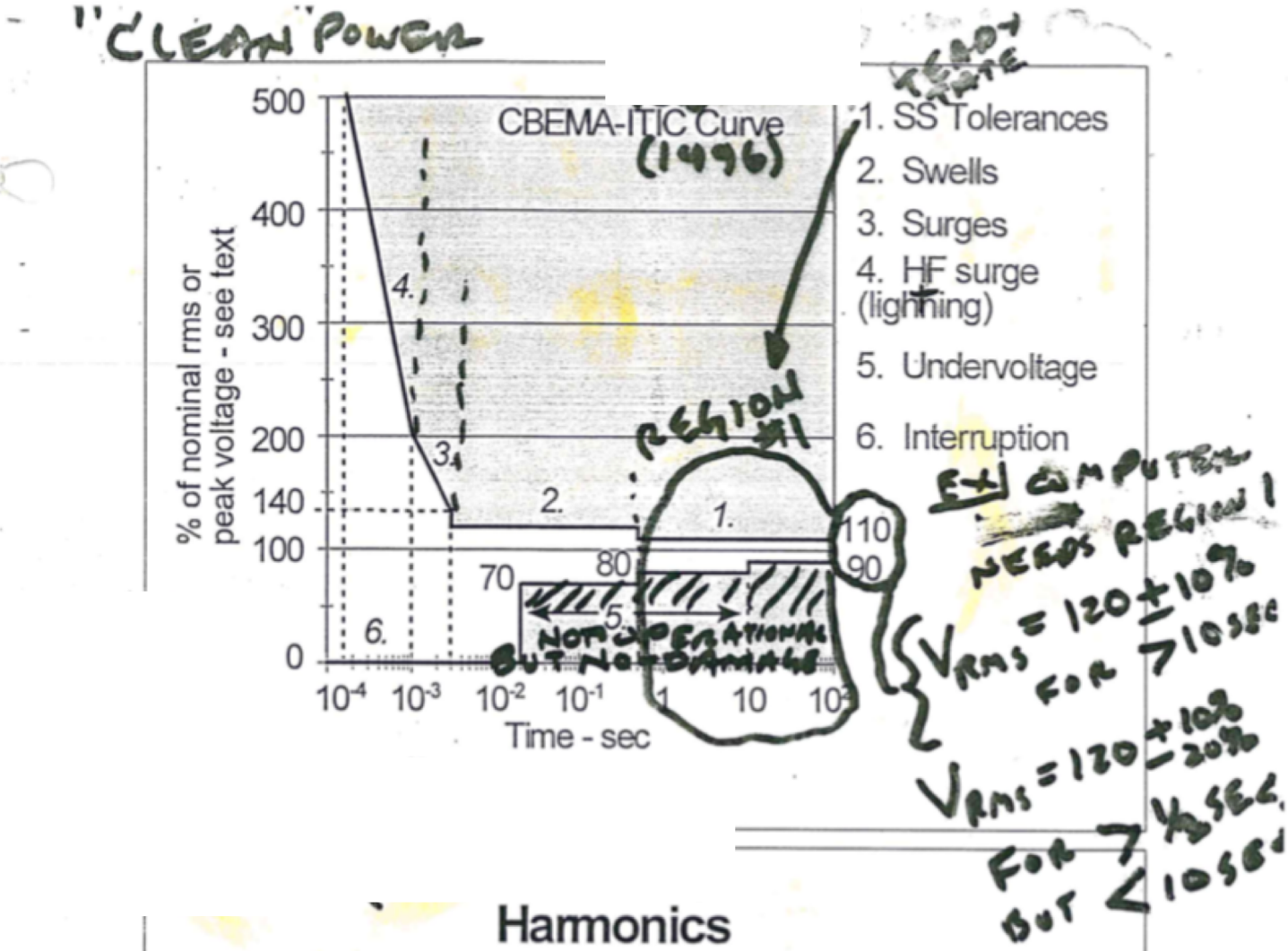


EXAMPLE CAUSES: 1) initial energizing of power factor correction capacitors
2) switching on transmission lines

Purdue University standardized lecture notes established by a committee for the course when I was an Assistant Professor at Purdue:



Purdue University standardized lecture notes established by a committee for the course when I was a Assistant Professor at Purdue:



Harmonics

What are harmonics?

Fourier Components of current or voltage

FUNDAMENTAL FREQUENCIES

WHERE $f_{harmonic} = n f_{powersystem}$; n = 1, 2, 3, ...

Where do harmonics come from?

Nonlinear loads!

Curve from the Information Technology Industry (IIT) counsel standards: