behavior of the generator in the network

المقـــــــــــــــــدمة

تُعد مسألة فهم السلوك الديناميكي لنظام القدرة الكهربائية على درجة بالغة من الأهمية خاصةً أن الهدف الأساسي لمشغلي نظم القدرة الكهربائية هو ضمان عمل النظام الكهربائي بصورة مستمرة مستقرة أمنة بعيداً عن الانقطاع في الحالات العابرة والاعطال الجسيمة بغض النظر عن السياسات الاقتصادية التي تعمل بها هذه النظم .

الهدف الاساسي التي تسعى اليه كل الانظمة الكهربائية هو الاستقرار . والاستقرار هو قدرة النظام على العودة الى شروط التشغيل الطبيعية بعد تعرضه لاضطراب ما دون ان يؤدي هذا الخلل الى فصل دوائر كثيرة او فصل وحدات توليد غير مسئولة عن العطل .

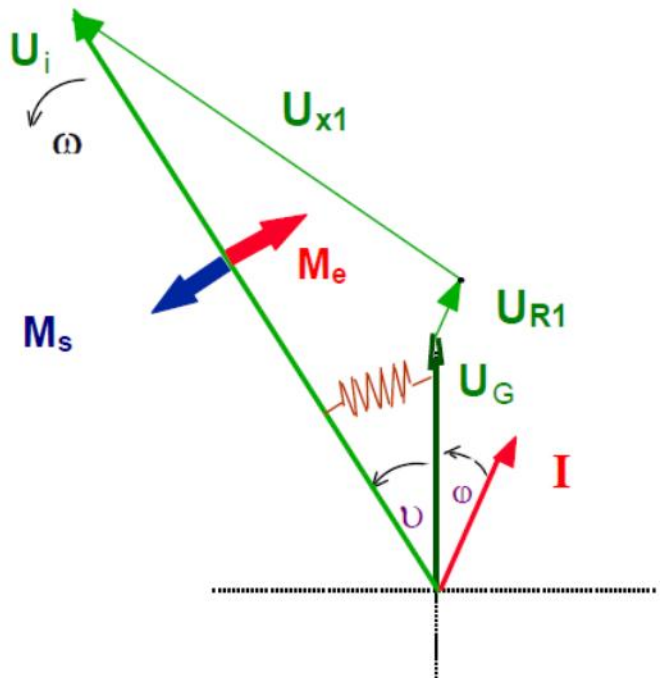
الاستقرار علميا هو استعادة التوازن بين العزم الكهربائي والعزم الديناميكي لمولدات التزامن المنتجة للقدرة بأسرع وقت ممكن دون دخول المولد في مراحل الخطر وفصله بوقايات الحماية .

استقرار النظام يعتمد على عوامل كثيرة أهما (نوع العطل / كفاءة وسرعة أجهزة الحماية / سلوك المولدات القريبة والبعيدة من العطل / حجم القدرة في الشبكة أثناء العطل / الخطة الدفاعية للشبكة .....ألخ) .

مفهوم عام لسلوك المولد (behavior of the generator)

المولد عبارة عن معدة مركبة من أجزاء ميكانيكية ومواد تأثر فيها القوانين الديناميكية والكهربائية والمغناطيسية وجميع هذه التأثيرات يجب أن تكون مقننة تحت السيطرة الدقيقة جداً بواسطة أجهزة ومعدات لكي نتحصل على طاقة وقدرة حسب المواصفات المطلوبة بالكميات المطلوبة وكل متغير غير مرغوب فيه من هذه التأثيرات يؤدي الى خلل في الانتاج غير مرغوب فيه مسببا أعطال تتابين خطورتها بحسب الكمية والنوع . ولعدم حدوث أعطال خطيرة هناك أجهزة مراقبة باستمرار للخرج والدخل لهذه المعدة وحماية لكل القيم المقننة ولكن هناك أعطال وظواهر طبيعية لابد من حدوثها تؤدي الى اضطراب قيم المخرجات وكما نعلم ان المولدات جميعها مشتركة في خطوط نقل للقدرة وكل متغير او طارئ تتأثر به المولدات المتصلة على التوازي في الشبكة ولكل عطل يحدث له ردة فعل على وحدة الانتاج (المولد + التوربينة) وهذه ردة الفعل تتفاوت على المعدة بحسب حجمها ومكانها من العطل ويكون ردة الفعل للمولد هو السلوك للمولد .

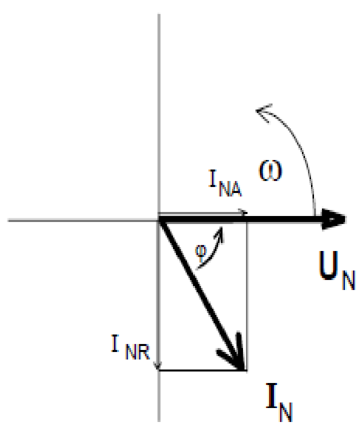
القدرة وتطبيقاتها :

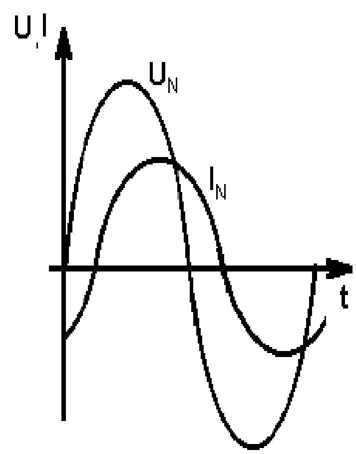


M_s electrical momentum
X_d synchronous reactance
U_G stator voltage
I_1 stator current
f_1 grid frequency
$\cos\varphi$ power factor

M_s mech momentum
U_1 armature voltage
U_i internal voltage
υ load angle

Apparent Power - Active Power - Power Factor



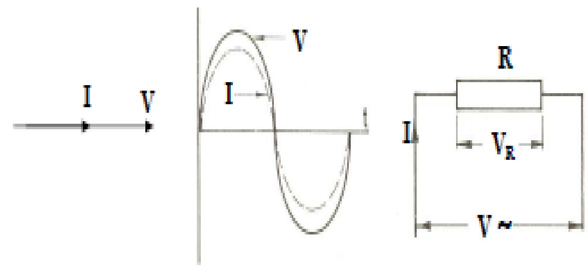


for a 3-phase power system

$$S_N = \sqrt{3} * U_N I_N$$
$$P_N = S_N * \cos\varphi$$

S_N Apparent Power
P_N Active Power
$\cos\varphi$ Power Factor
U_N Nominal Stator Line Voltage
I_N Nominal Apparent Stator Line Current
I_{NA} "Active" Stator Current Phasor
I_{NR} "Reactive" Stator Current Phasor

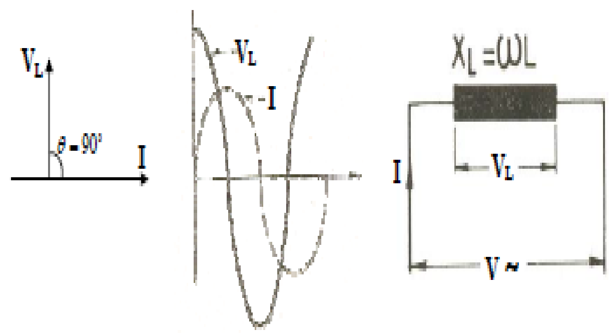
دائرة تحتوي على مقاومة R



وبتطبيق قانون أوم فإن $I = \frac{V}{R} amper$

ويكون الجهد على أطراف المقاومة V $V_R = I \cdot R$

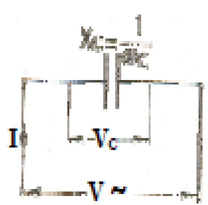
دائرة تحتوي على ملف (ممانعة حثية) XL



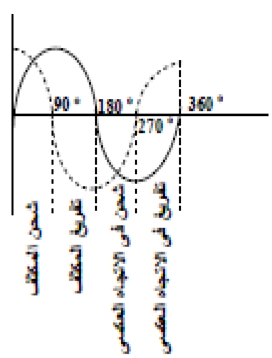
$$e.m.f = -L.\frac{di}{dt}$$

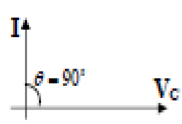
$$X_L = \omega L = 2\pi f L \quad \Omega$$

دائرة تحتوي على مكثف (ممانعة سعويه) Xc : C = Q/V



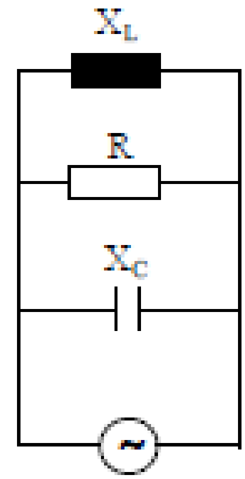
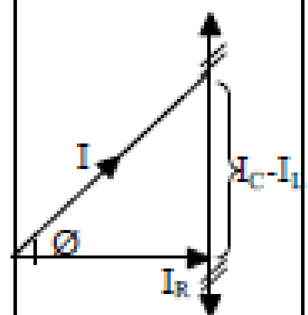
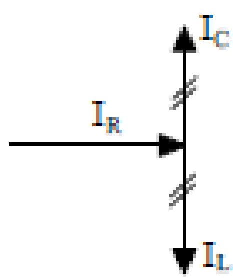
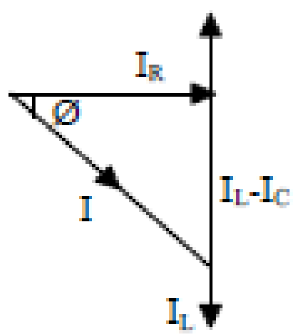
(أ) رسم الدائرة





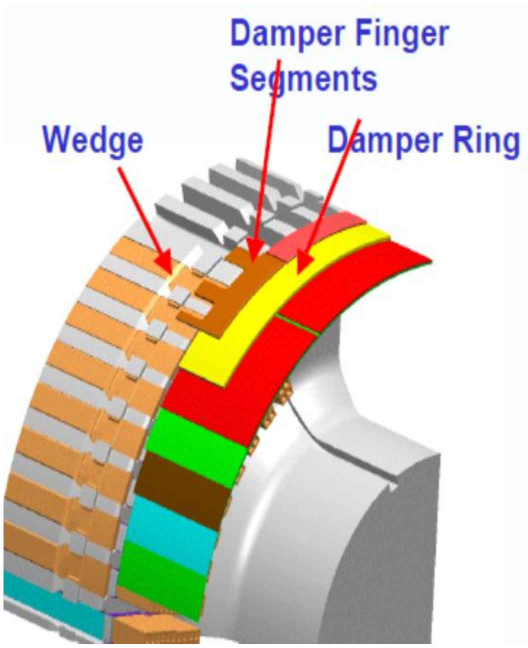
(جـ) رسم المتجهات

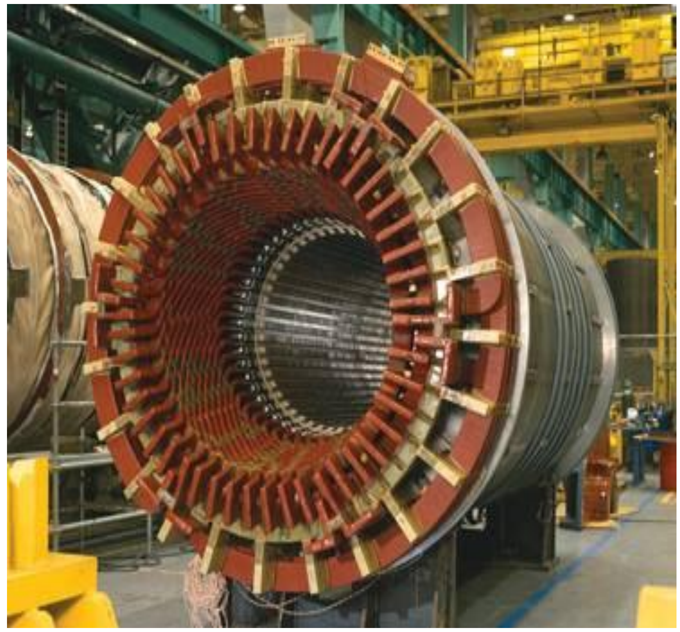
$$X_C = \frac{1}{\omega \cdot c} = \frac{1}{2\pi f c} \Omega$$

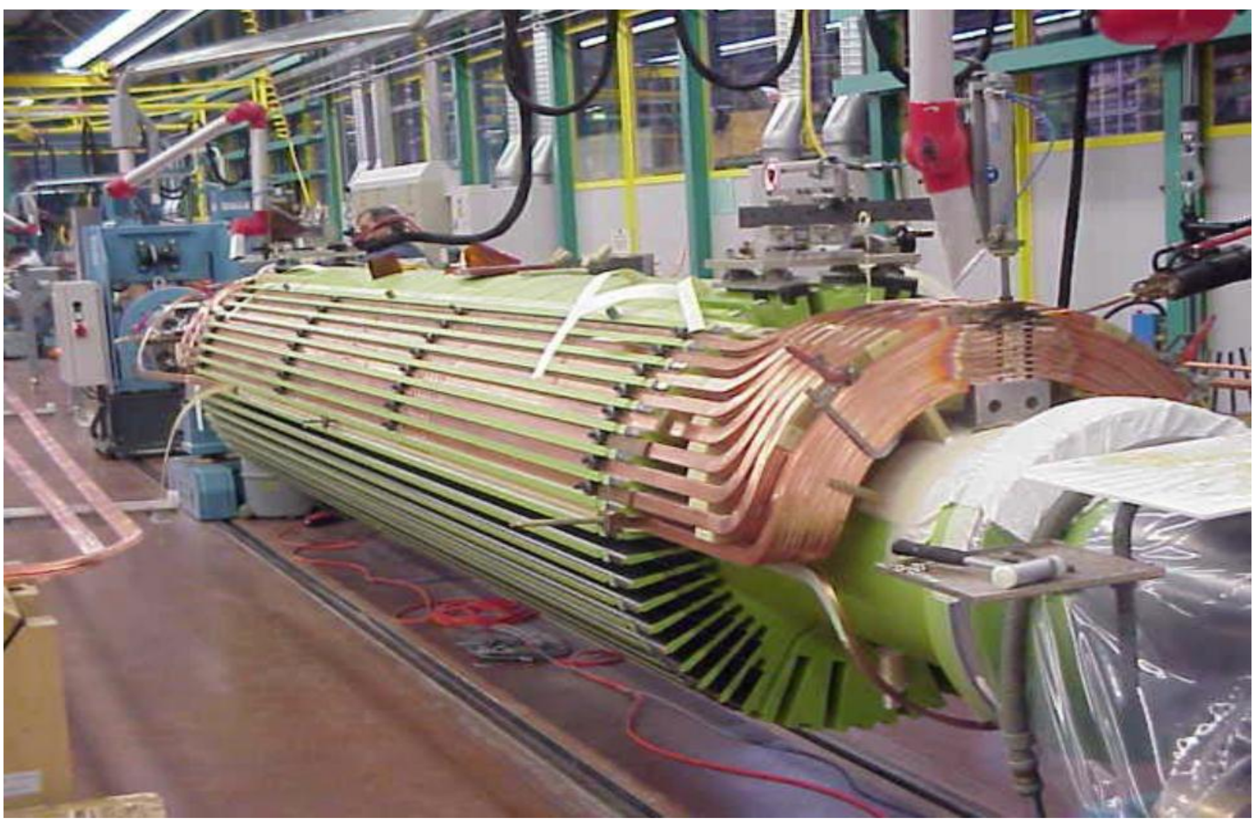
تركيب الدائرة	$X_L < X_C$	$X_L = X_C$	$X_L > X_C$
	التيار الكلي في الدائرة يسبق الجهد بزاوية أقل من 90^{5} وتعامل الدائرة كأنها دائرة سعوية 	التيار الكلي في الدائرة في نفس زاوية الوجه مع الجهد ويعامل الدائرة كأنها ذات دائرة مقاومة مادية فقط 	التيار الكلي في الدائرة متأخر عن الجهد بزاوية أقل من 90^{5} وتعامل الدائرة كأنها دائرة حثية 

$$Z = \sqrt{R^{2+\left(WL-\frac{I}{WC}\right)2}}$$

تركيب المولد والبيانات الفنية :



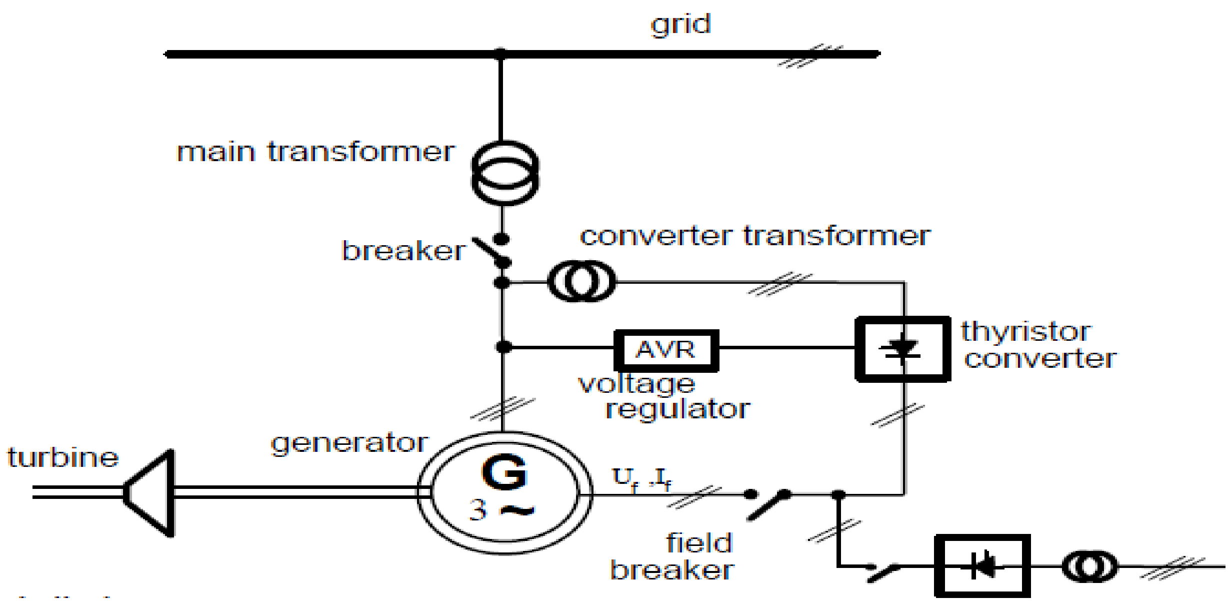


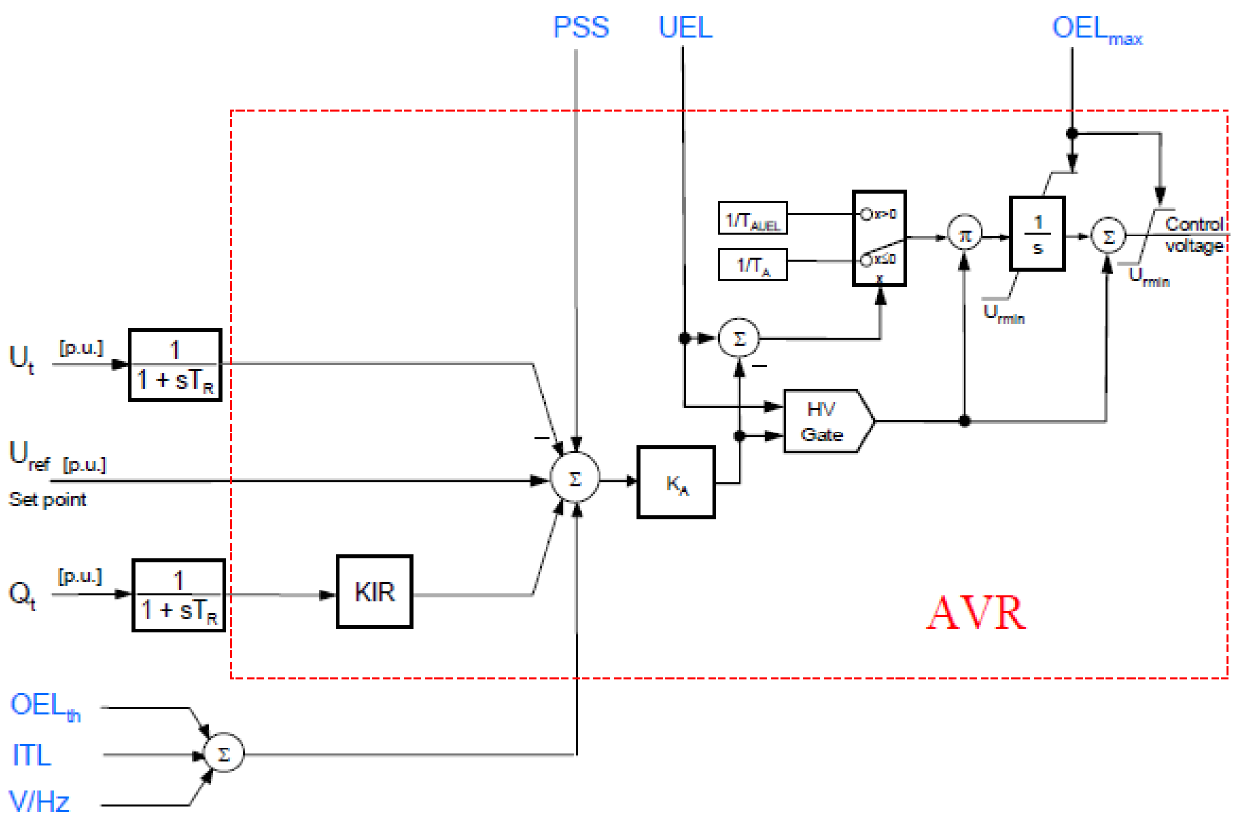


1.	Generator main data	Sym.	CL. B	Dim.
1.1	Standards		IEC	
1.2	Rated Output	S_n	210	MVA
1.3	Rated Output	P_n	168	MW
1.4	Rated terminal voltage (± 7.5%)	U_n	15750	V
1.5	Rated phase current	I_n	7698	A
1.6	Rated power factor	$\cos\varphi_n$	0.80	-----
1.7	Frequency	f_n	50	Hz
1.8	Nominal speed	n_n	3000	rpm
1.9	Air inlet temperature	T_{cg}	40	°C
1.10	Altitude	h	0	m
1.11	Generator field current at no load and rated terminal voltage	If_o	478	A
1.12	Generator field voltage at no load and rated terminal voltage	Uf_o	73	V
1.13	Generator field current at rated output	If_n	1545	A
1.14	Generator field voltage at rated output	Uf_n	302	V
1.15	Ceiling factor	f_{pl}	1.6	-----
1.16	Short-circuit ratio	Kc	0.46	-----

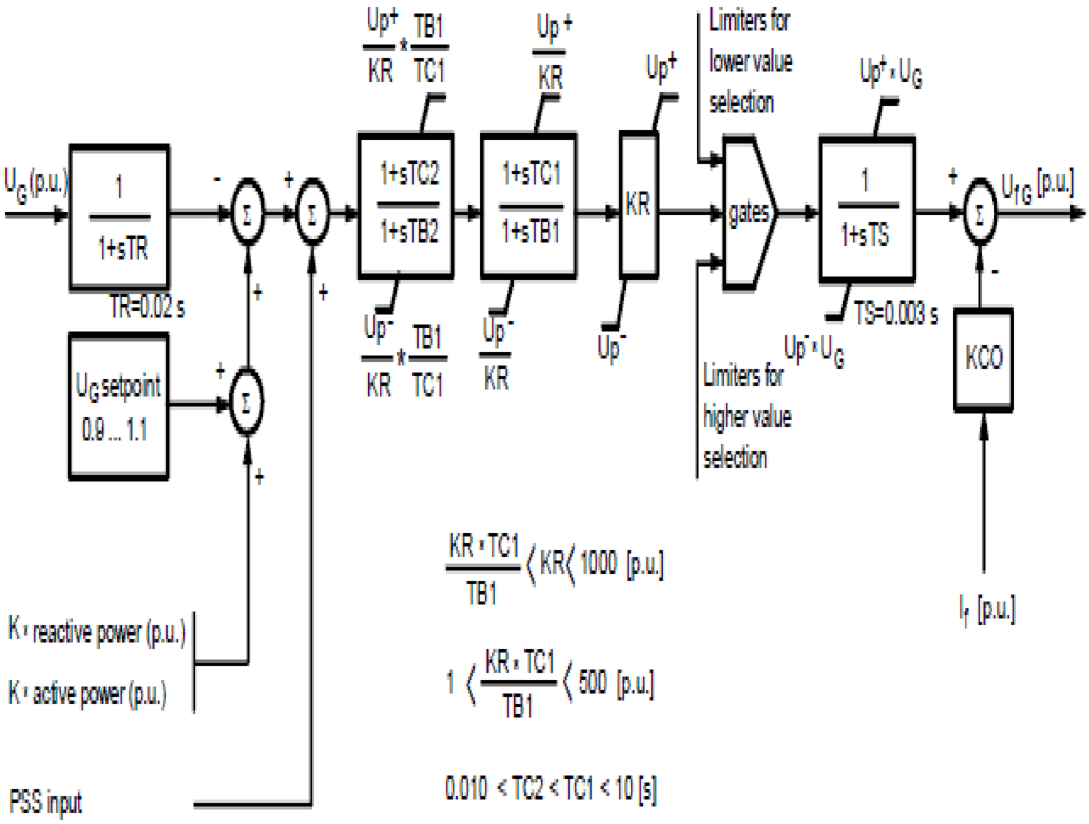
2.	Generator reactances and resistances	Sym.	CL. B	Dim.
2.1	Rated impedance	Z_n	1.181	Ω
2.2	Direct-axis synchronous reactance (unsaturated)	x_d	2.53	p.u.
2.3	Direct-axis transient reactance (unsaturated) ±10%	x'_d	0.248	p.u.
2.4	Direct-axis subtransient reactance (unsaturated) ±10%	x''_d	0.187	p.u.
2.5	Direct-axis transient reactance (saturated) ±10%	x'_{dv}	0.229	p.u.
2.6	Direct-axis subtransient reactance (saturated) ±10%	x''_{dv}	0.140	p.u.
2.7	Quadrature-axis synchronous reactance (unsaturated)	x_q	2.36	p.u.
2.8	Quadrature-axis transient reactance (unsaturated)	x'_q	0.40	p.u.
2.9	Quadrature-axis subtransient reactance (unsaturated)	x''_q	0.20	p.u.
2.10	Negative-sequence reactance (unsaturated)	x_2	0.19	p.u.
2.11	Zero-sequence reactance (unsaturated)	x_o	0.086	p.u.
2.12	Negative-sequence reactance (saturated)	x_{2v}	0.15	p.u.
2.13	Zero-sequence reactance (saturated)	x_{ov}	0.064	p.u.
2.14	Potier reactance	x_P	0.25	p.u.
2.15	Leakage reactance (stator)	x_σ	0.17	p.u.
2.16	Positive-sequence resistance	r_1	0.0026	p.u.
2.17	Negative-sequence resistance at 75°C	r_2	0.015	p.u.
2.18	Zero-sequence resistance at 75°C	R_o	0.0010	p.u.
2.19	Stator resistance per phase at 95°C	R_a	1.291	mΩ
2.20	Rotor resistance at 95°C	R_f	0.188	Ω

منظومة التحريض + pss





Transfer Function AVR



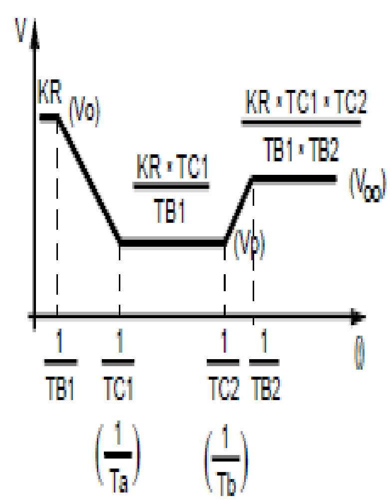
$\frac{KR \cdot TC1}{TB1} < KR < 1000$ [p.u.]

$1 < \frac{KR \cdot TC1}{TB1} < 500$ [p.u.]

$0.010 < TC2 < TC1 < 10$ [s]

$\frac{KR \cdot TC1}{TB1} \cdot \frac{TC2}{1000} < 0.2 \cdot TC2 < TB2 < TC2$ [s]

Up^{+} = Up / U_{fG}
Up^{-} = $0.85 \cdot Up^{+}$
Up = Excitation system ceiling volta
U_{fG} = No-load air gap field voltage
U_G = Generator terminal voltage
I_f = Field current
KCO = Voltage drop due to thyristors commutation
V = Frequency dep. amplification
ω = Angular frequency



$$Pm - Pe = Pa \qquad (2a)$$

or

$$Pm - Pe = 2 \cdot H \cdot \frac{\partial \omega}{\partial t} \qquad (2b)$$

where:

Pe	=	electrical power [p.u.]
Pm	=	driving power applied to the shaft [p.u.]
Pa	=	acceleration power [p.u]
ω	=	rotor angular speed [p.u.]
H	=	inertia time constant [s]

The electrical power and torque can be also expressed as :

$$Pe(fo) = Te(fo) = \frac{Uf \cdot U\infty_{bus}}{Xd(fo) + Xe} \cdot \sin\delta + \frac{U\infty_{bus} \cdot [Xd(fo) - Xq(fo)]}{2 \cdot [Xd(fo) + Xe] \cdot [Xq(fo) + Xe]} \cdot \sin(2 \cdot \delta) \qquad (3)$$

where

Uf	=	field voltage [p.u.]
$U\infty_{bus}$	=	voltage at the infinite bus [p.u.]
Xd(fo)	=	direct axis synchronous reactance [p.u.]
Xq(fo)	=	quadrature axis synchronous reactance [p.u.]
Xe	=	external reactance [p.u.] (e.g. unit trans. react. + grid)
δ	=	load angle [deg]
fo	=	oscillation frequency [Hz]

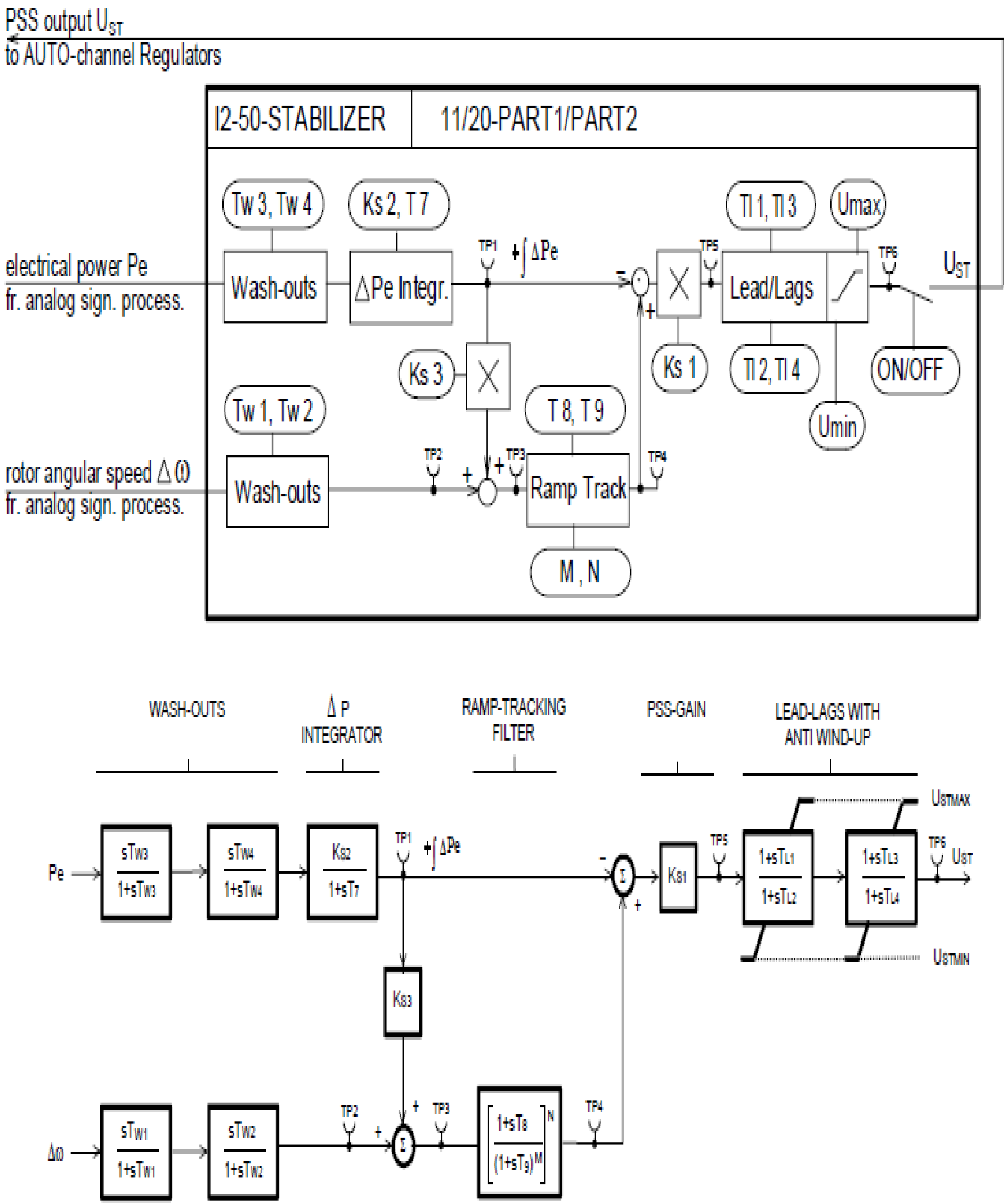
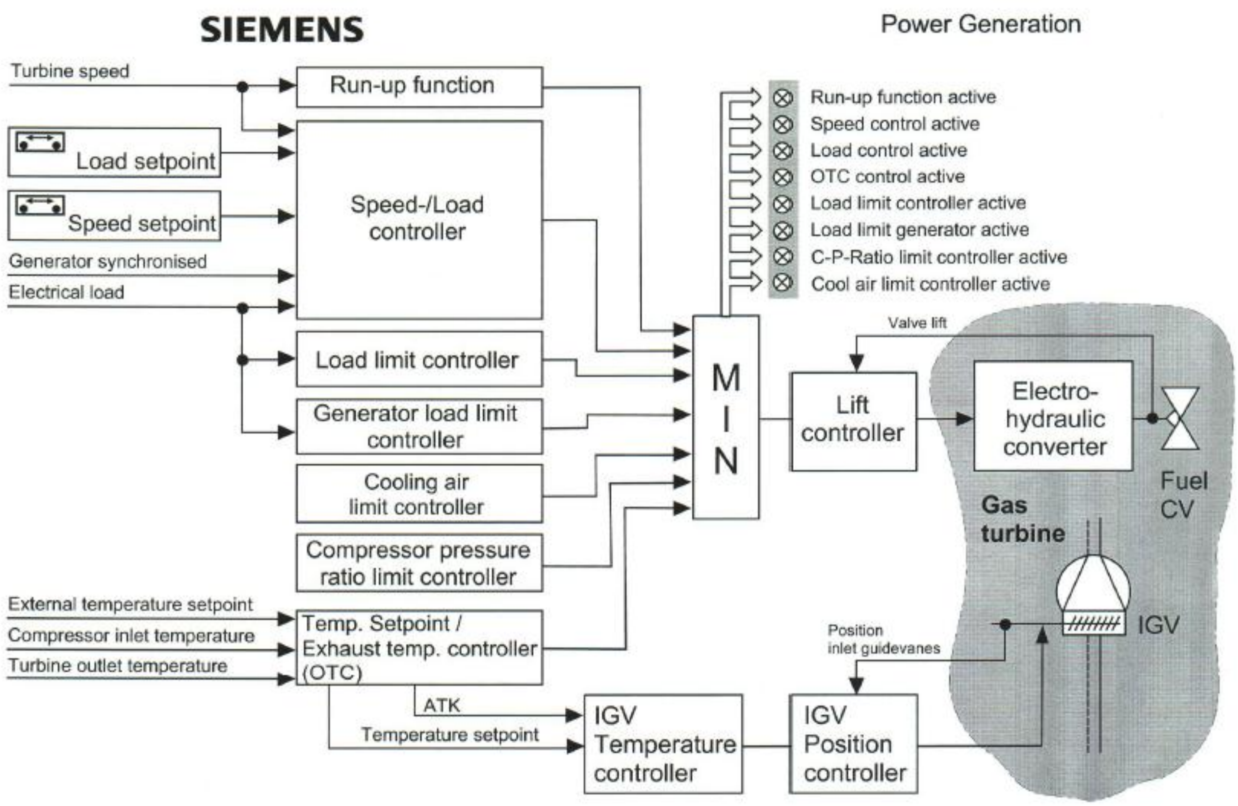


Fig. 5 Transfer function PSS "IEEE Std.421.5-1992"

Parameter		Unit
T_R	Measuring device time constant	s
KIR	Reactive power compensation factor	p.u.
K_A	AVR gain	p.u.
T_A	AVR time constant	s
U_{rmax}	Maximum output of regulator	p.u.
U_{rmin}	Minimum output of regulator	p.u.

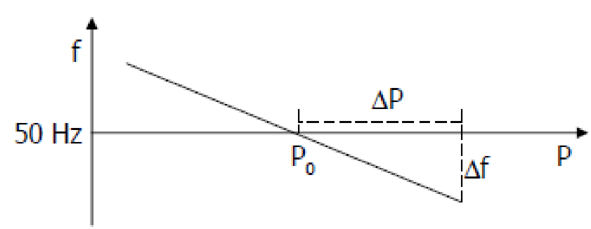
Parameter		Unit
T_R	Measuring device time constant	s
T_{AP}	Input filter time constant	s
$Q_{tref}(P_t)$	Set point for minimum reactive power $Q_{tref}(0.00)$ $Q_{tref}(0.25)$ $Q_{tref}(0.50)$ $Q_{tref}(0.75)$ $Q_{tref}(1.00)$	 p.u. p.u. p.u. p.u. p.u.
K_{QB}	Max. reactive power for no load operation	p.u.
T_{BUEL}	Time constant for UEL transient gain	s
T_{CUEL}	Time constant for UEL transient gain	s
K_{AUEL}	UEL gain	p.u.
T_{AUEL}	UEL time constant	s
I_{fmax}	Setpoint for ceiling field current	p.u.
K_{Ifmax}	OEL_{max} gain	p.u.
T_{Amax}	OEL_{max} time constant	s
U_{rmax}	Maximum output of regulator	p.u.
U_{rmin}	Minimum output of regulator	p.u.
VHz_{max}	Maximum voltage to frequency ratio	p.u.
K_{VHZ}	VHz gain	p.u.
T_{VHZ}	VHz time constant	s
$I_{fth}(T_{CG})$	Setpoint for maximum continuous field current $I_{fth}(11°C)$ $I_{fth}(47°C)$ $I_{fth}(60°C)$	p.u.
T_{Ath}	OEL_{th} time constant	s
OEL_{max}	OEL maximum output of integrator	-
$I_{tth}(T_{CG})$	Setpoint for max. continuous generator current $I_{tth}(11°C)$ $I_{tth}(47°C)$ $I_{tth}(60°C)$	p.u.
Q_{min}	ITL minimum reactive power	p.u.
T_{Alt}	ITL time constant	s
ITL_{max}	ITL maximum output of integrator	-

منظومة التحكم في القدرة (التردد):



The power frequency characteristic of a turbine governor is determined by its frequency **droop**. Each governor increases or decreases its power according to its droop δ when the frequency of the system deviates from the rated value. The droop describes the connection between the change in power and a given change in the frequency:

$$\delta = \frac{\dfrac{\Delta f}{f_N}}{\dfrac{\Delta P}{P_N}} \times 100\%$$



Droop / power-frequency ch.:

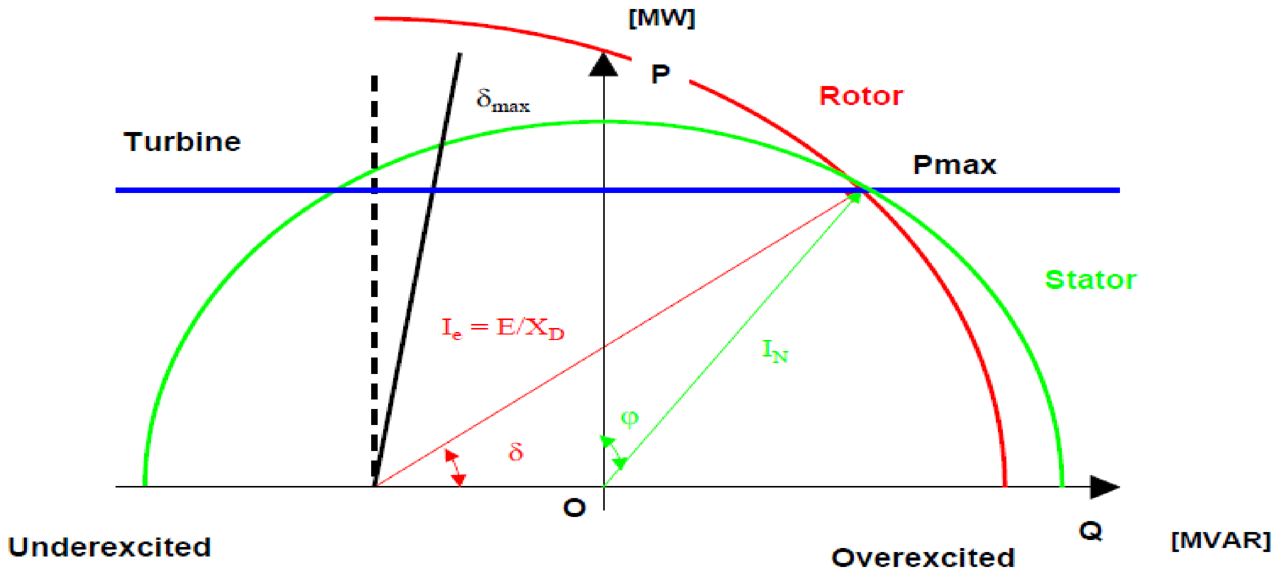
$$K_G = \frac{\Delta P}{\Delta f} = \frac{\Delta P}{\dfrac{\delta}{100} \times \dfrac{\Delta P}{P_N} \times \underbrace{f_N}_{50}} = \frac{2 \times P_N}{\delta} \frac{MW}{Hz}$$

The smaller the change in frequency for a given load change, the stiffer the system (the smaller the droop, the greater the power-frequency ch.)

Normally, droop δ of the magnitude of 6%

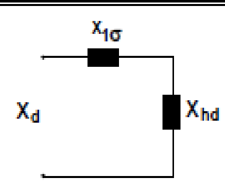
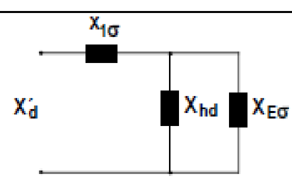
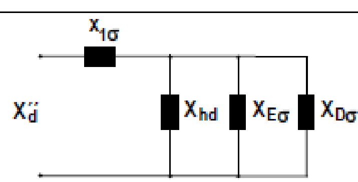
المنطقة التشغيلية للمولد (power chart):

Power chart



Reactances

- are the added "imaginary" resistances of the coil arrangements in a generator
- give information about the geometry of the coils, the behaviour of a generator at incidents and the relation between alternating voltage and current
- in case of a short circuit the reactances of the rotor winding and the damper winding also affect the behaviour of the machine
- three time areas are defined : continuous, transient and subtransient

simple equivalent circuit	value range of react. / time areas	ohmic law
	$1{,}2 < xdges < 2{,}0$ $T » 2{,}0$ s	continuous $I_k = \frac{U_N}{X_d}$
	$0{,}16 < x'd < 0{,}26$ $0{,}55s < T' < 2{,}0$ s	transient $I'_k = \frac{U_N}{X'_d}$
	$0{,}10 < x''d < 0{,}15$ $0{,}05$ s $< T'' < 0{,}10$ s	subtransient $I''_k = \frac{U_N}{X''_d}$

xhd	main reactance direct axis	UN	rated stator voltage
x1σ	leakage reactance	T	time area
xd	synchronous reactance	Ik	continuous 3phase sc-current
x´d	transient reactance	I´k	transient sc-current
x´´d	subtransient reactance	I´´k	subtransient sc-current
xEσ	field reactance		
xDσ	damper reactance		

الاعطال العابرة واستجابة المولد:

□ Insulation breakdown due to heat, humidity or a corrosive environment

■ Location (inside or outside a machine or an electrical switchboard)

Short-circuits can be:

■ Phase-to-earth (80% of faults)

■ Phase-to-phase (15% of faults). This type of fault often degenerates into a three phase fault

■ Three-phase (only 5% of initial faults)

These different short-circuit currents are presented in **Figure 5** .

Consequences of short-circuits

The consequences are variable depending on the type and the duration of the fault, the point in the installation where the fault occurs and the short-circuit power. Consequences include:

■ At the fault location, the presence of electrical arcs, resulting in

□ Damage to insulation

□ Welding of conductors

□ Fire and danger to life

■ On the faulty circuit

□ Electrodynamic forces, resulting in

- Deformation of the busbars
- Disconnection of cables

□ Excessive temperature rise due to an increase in Joule losses, with the risk of damage to insulation

■ On other circuits in the network or in near-by networks

□ Voltage dips during the time required to clear the fault, ranging from a few milliseconds to a few hundred milliseconds

□ Shutdown of a part of the network, the extent of that part depending on the design of the network and the discrimination levels offered by the protection devices

□ Dynamic instability and/or the loss of machine synchronisation

□ Disturbances in control / monitoring circuits

□ etc.

A simplified network comprises a source of constant AC power, a switch, an impedance Zsc that represents all the impedances upstream of the switch, and a load impedance Zs (see **Fig. 6**).

In a real network, the source impedance is made up of everything upstream of the short-circuit including the various networks with different voltages (HV, LV) and the series-connected wiring systems with different cross-sectional areas (A) and lengths.
In Figure 6, when the switch is closed and no fault is present, the design current Is flows through the network.

When a fault occurs between A and B, the negligible impedance between these points results in a very high short-circuit current Isc that is limited only be impedance Zsc.
The current Isc develops under transient conditions depending on the reactances X and the resistances R that make up impedance Zsc:

$$Zsc = \sqrt{R^2 + X^2}$$

In power distribution networks, reactance X = L φ is normally much greater than resistance R and

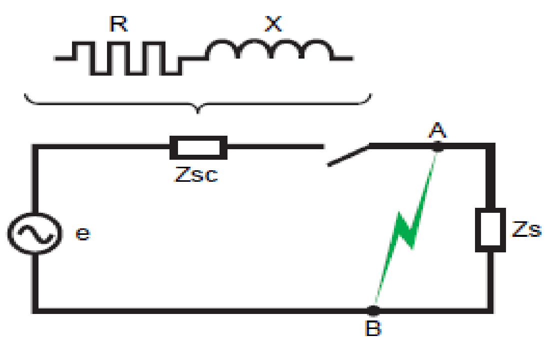


Fig. 6 : Simplified network diagram.

the R / X ratio is between 0.1 and 0.3. The ratio is virtually equals cos φ for low values:

$$\cos\varphi = \frac{R}{\sqrt{R^2 + X^2}}$$

However, the transient conditions prevailing while the short-circuit current develops differ depending on the distance between the fault location and the generator. This distance is not necessarily physical, but means that the generator impedances are less than the impedance of the elements between the generator and the fault location.

Fault far from the generator

This is the most frequent situation. The transient conditions are those resulting from the application of a voltage to a reactor-resistance circuit. This voltage is:

$$e = E\sqrt{2}\sin(\omega t + \alpha)$$

Current i is then the sum of the two components:

$$i = i_{ac} + i_{dc}$$

- The first (i_{ac}) is alternating and sinusoidal

$$i_{ac} = I\sqrt{2}\ \sin(\omega t + \alpha - \varphi)$$

where $I = \frac{E}{Zsc}$,

α = angle characterising the difference between the initiation of the fault and zero voltage.

- The second (i_{dc}) is an aperiodic component

$i_{dc} = -I\sqrt{2}\sin(\alpha - \varphi)\ e^{-\frac{R}{L}t}$. Its initial value depends on a and its decay rate is proportional to R / L.
At the initiation of the short-circuit, i is equal to zero by definition (the design current Is is negligible), hence:

$i = i_{ac} + i_{dc} = 0$

Figure 7 shows the graphical composition of i as the algebraic sum of its two components i_{ac} and i_{dc}

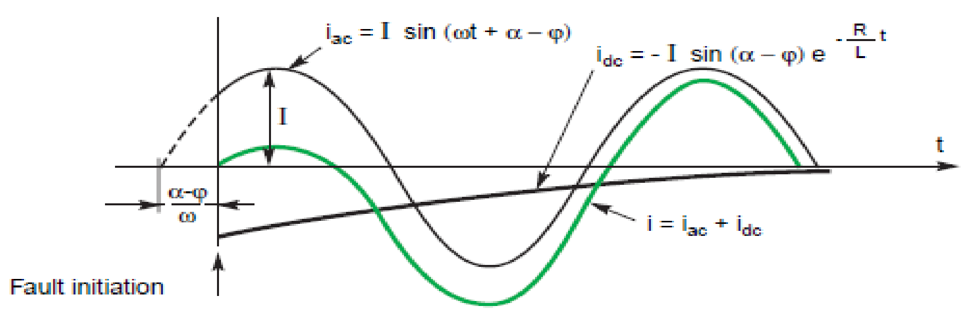
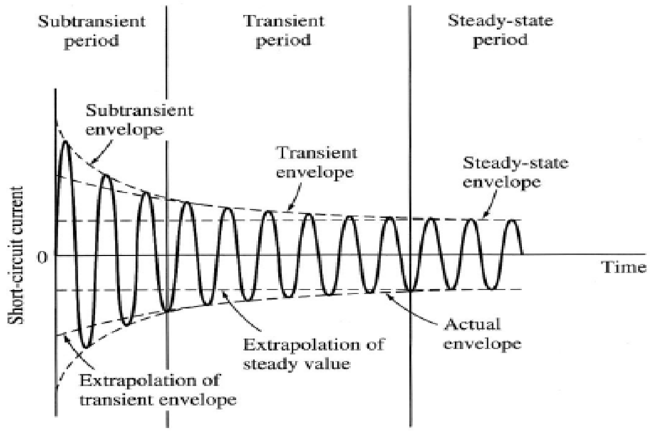


Fig. 7 : Graphical presentation and decomposition of a short-circuit current occuring far from the generator.

Type of fault	Abbreviation	Type
Single line-to-ground	SLG	Unsymmetrical
Line-to-line	LL	Unsymmetrical
Double line-to-ground	LLG	Unsymmetrical
Symmetrical three-phase	3P	Symmetrical

- When the fault occurs, the AC component of current jumps to a very large value, but the total current cannot change instantly since the series inductance of the machine will prevent this from happening.
- The transient DC component of current is just large enough such that the sum of the AC and DC components just ***after*** the fault equals the AC current just ***before*** the fault.
- Since the instantaneous values of current at the moment of the fault are different in each phase, the magnitude of DC components will be different in different phases.
- These DC components decay fairly quickly, but they initially average about 50 - 60% of the AC current flow the instant after the fault occurs. The total initial current is therefore typically 1.5 or 1.6 times the AC component alone.



- There are three periods of time:
  - Sub-transient period: first cycle or so after the fault – AC current is very large and falls rapidly;
  - Transient period: current falls at a slower rate;
  - Steady-state period: current reaches its steady value.
- It is possible to determine the time constants for the sub-transient and transient periods .

- The AC current flowing in the generator during the sub-transient period is called the sub-transient current and is denoted by I''. The time constant of the sub-transient current is denoted by T'' and it can be determined from the slope. This current can be as much as 10 times the steady-state fault current.
- The AC current flowing in the generator during the transient period is called the transient current and is denoted by I'. The time constant of the transient current is denoted by T'. This current is often as much as 5 times the steady-state fault current.
- After the transient period, the fault current reaches a steady-state condition $I_{ss.}$ This current is obtained by dividing the induced voltage by the synchronous reactance:

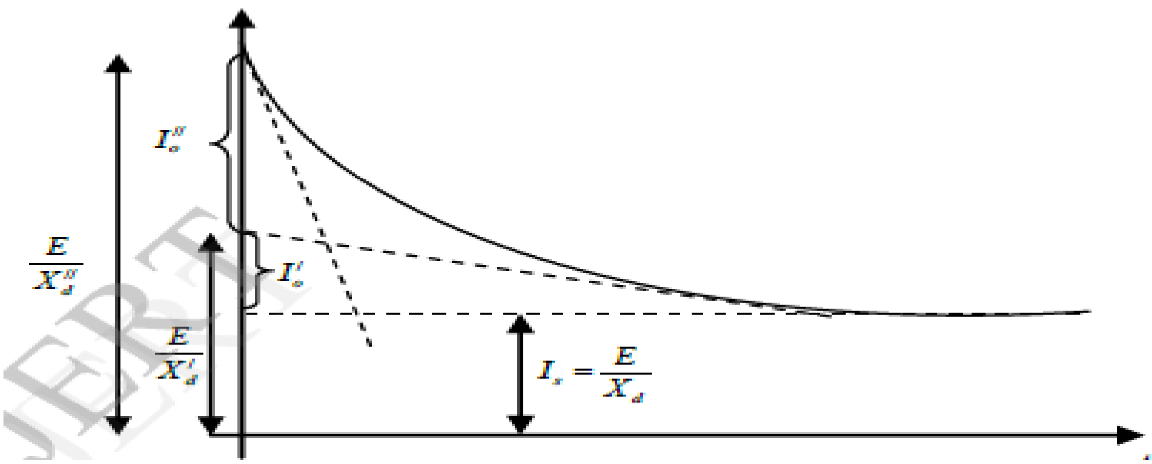
$$I_{ss} = \frac{E_A}{X_s}$$

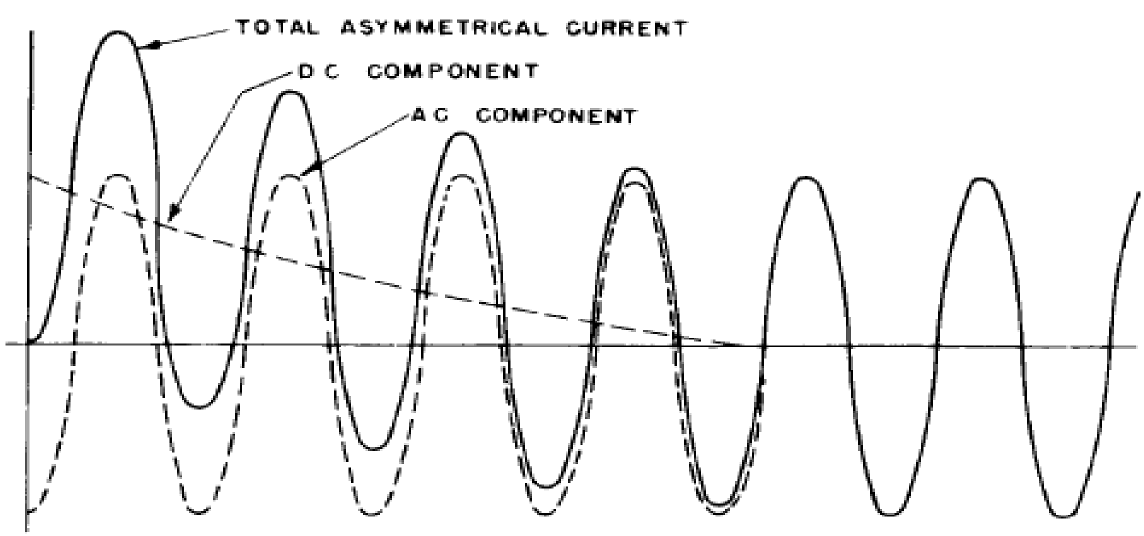
- The rms value of the AC fault current in a synchronous generator varies over time as

$$I(t) = (I'' - I')e^{-t/T''} + (I' - I_{ss})e^{-t/T'} + I_{ss}$$

- The sub-transient and transient reactances are defined as the ratio of the internal generated voltage to the sub-transient and transient current components:

$$X'' = \frac{E_A}{I''} \qquad X' = \frac{E_A}{I'}$$





لكل مولد ثلاث ملفات أنتاج بينها 120 درجة وأثناء القصر او الحالة العابرة تتكون مركبة تيار مستمر تعتمد على قيمة الجهد في الفيزا أثناء حدوث القصر وقيمته كما يلي

$$I_{dc-a} = \frac{E_o x\sqrt{2}}{X_d^{//}}(\sin\delta)e^{-\frac{t}{\tau_a}}$$

وقيمة تيار العطل هو جمع مركبة التيار المستمر مع المتغير

$$I_{dc} = E_o x\sqrt{2}\left[\left(\frac{1}{X_d^{//}} - \frac{1}{X_d^{/}}\right)\right]e^{-\frac{t}{\tau_d^{//}}}[\sin(\omega t+\delta)] + E_o x\sqrt{2}\left[\left(\frac{1}{X_d^{/}} - \frac{1}{X_d}\right)\right]e^{-\frac{t}{\tau_d^{/}}}[\sin(\omega t+\delta)] + E_o x\sqrt{2}\left[\frac{1}{X_d}\right][\sin(\omega t+\delta)]$$

Example (1) : GT14 210 MVA , 15.75 KV, Y-connected 3phase 50 Hz syn. Gen. is operated at the rated voltage and no load when a 3 phase fault occurs at its terminals . Its reactance per unit to the machines own base are

Xd =2.53 Xd'=0.248 Xd''= 0.187

And the time constant are T'=1.06 s T''=0.017 s

The initial DC component in this machine averages 50% of the initial AC component.

a) What is the AC component of current in this generator the instant after the fault?

b) What is the total current (AC + DC) in the generator right after the fault occurs

c) What will the AC component of the current be after 2 cycles? After 5 s?

The base current of the generator can be comuted as

$$I_{base} = \frac{S}{\sqrt{3V}} = \frac{210000000}{\sqrt{3}\times 15.750} = 7698 \text{ A}$$

The subtransient, transient , and stady –state currents are (per-unit and Amp)

$$I'' = E/X'' = \frac{1.0}{0.187} = 5.347 \text{ pu} \rightarrow 41161 \text{ A}$$

$$I' = E/X' = \frac{1.0}{0.248} = 4.032 \text{ pu} \rightarrow 31038 \text{ A}$$

$$I_{ss} = E/X_s = \frac{1.O}{2.53} = 0.395 \text{ pu} \rightarrow 3040 \text{ A}$$

A) The initial AC component of current is I''= 41161 A

B) The total current (AC & DC) at the beginning of the fault is

I_{tot} = 1.5 I''= 61741 A

C) The AC component of current as a function of time is

$$I(t) = (I'' - I')\, e^{-\frac{t}{T''}} + (I' - I_{ss})\, e^{-\frac{t}{T'}} + I_{ss}$$

$$= 10123\, e^{\frac{t}{0.017}} + 27998\, e^{\frac{t}{1.06}} + 3040$$

After 2 cycles t = 1/25 s and the total AC current is

|[1/25]= 961+26981+ 3040 = 30982 A

At 5 s , the current reduces to → |[5]= 0+1.802+ 3040 = 3041 A.

RMS for Fault Current

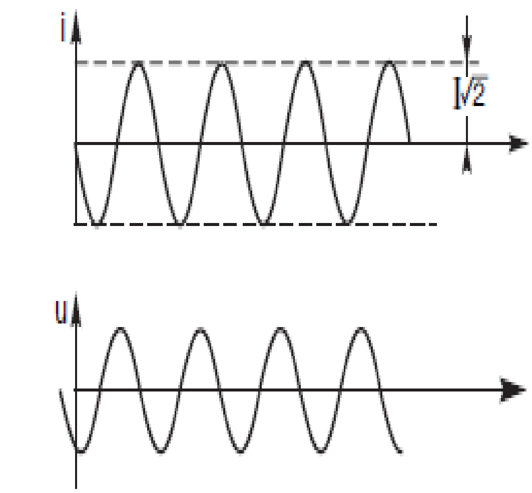
$$I_{RMS} = \sqrt{I_{ac}^2 + I_{dc}^2},$$

$$\text{where } I_{ac} = \frac{V}{Z}, I_{dc} = \frac{\sqrt{2}V}{Z} e^{-t/T} = \sqrt{2} I_{ac} e^{-t/T},$$

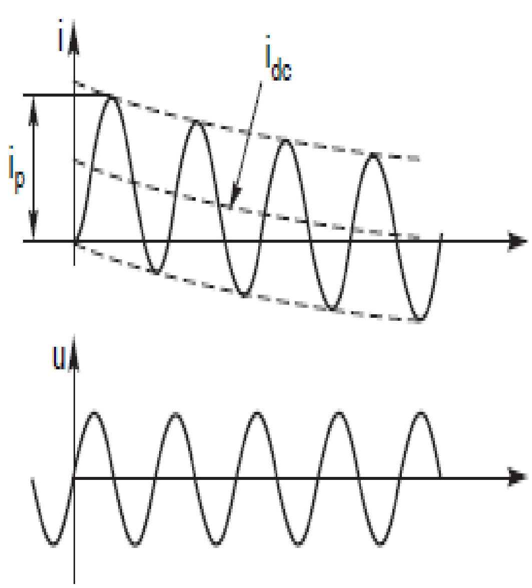
$$= \sqrt{I_{ac}^2 + 2 I_{ac}^2 e^{-2t/T}}$$

This function has a maximum value of $\sqrt{3}\, I_{ac}$. Therefore the worst case effect of the dc component is included simply by multiplying the ac fault currents by $\sqrt{3}$.

a) Symmetrical



b) Asymmetrical



The moment the fault occurs or the moment of closing, with respect to the network voltage, is characterised by its closing angle a (occurrence of the fault). The voltage can therefore be expressed as: $u = E\sqrt{2} \,.\, \sin(\omega t + \alpha)$.

The current therefore develops as follows:

$$i = \frac{E\sqrt{2}}{Z}\left[\sin(\omega t + \alpha - \varphi) - \sin(\alpha - \varphi)\, e^{-\frac{R}{L}t}\right]$$

with its two components, one being alternating with a shift equal to φ with respect to the voltage and the second aperiodic and decaying to zero as t tends to infinity.

Hence the two extreme cases defined by:

- $\alpha = \varphi = \pi / 2$, said to be symmetrical (or balanced) (see Fig. a)

The fault current can be defined by: $i = \frac{E\sqrt{2}}{Z} \sin \omega t$

which, from the initiation, has the same shape as for steady state conditions with a peak value E / Z.

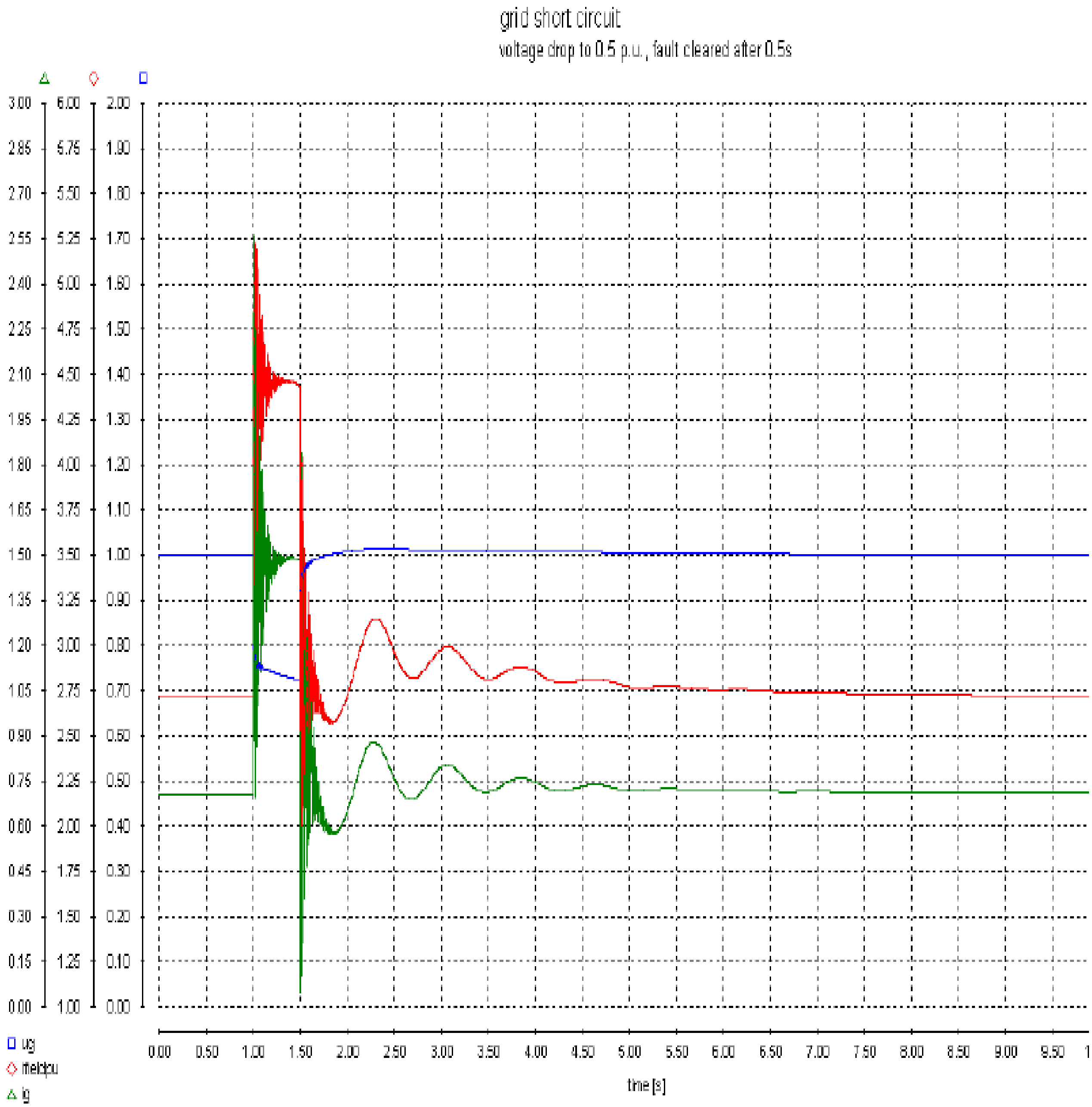
- $\alpha = 0$, said to be asymmetrical (or unbalanced) (see Fig. b)

The fault current can be defined by:

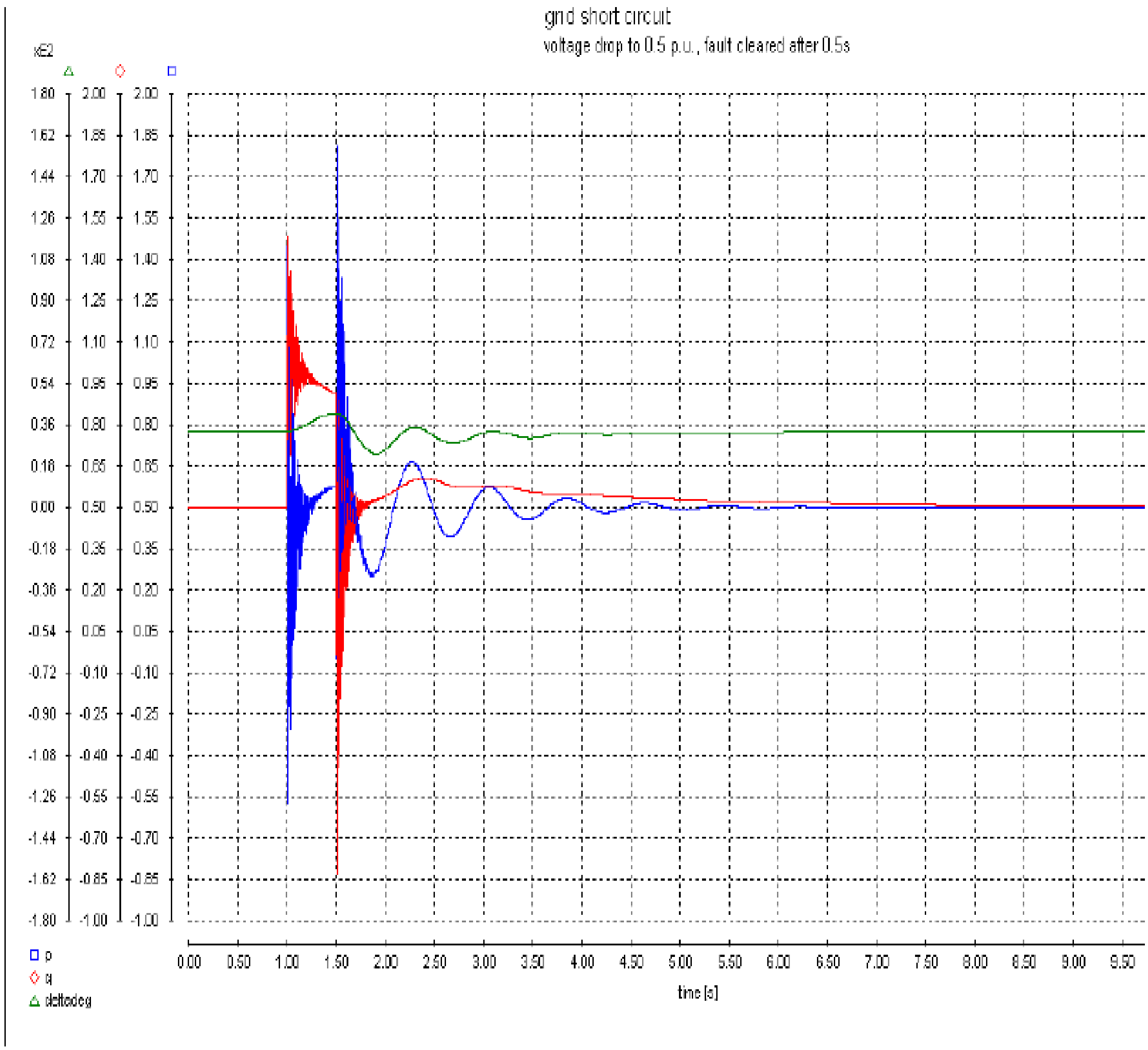
$$i = \frac{E\sqrt{2}}{Z}\left[\sin(\omega t - \varphi) + \sin\varphi \;\; e^{-\frac{R}{L}t}\right]$$

Its initial peak value i_p therefore depends on φ on the R / X ≈ cos φ ratio of the circuit.

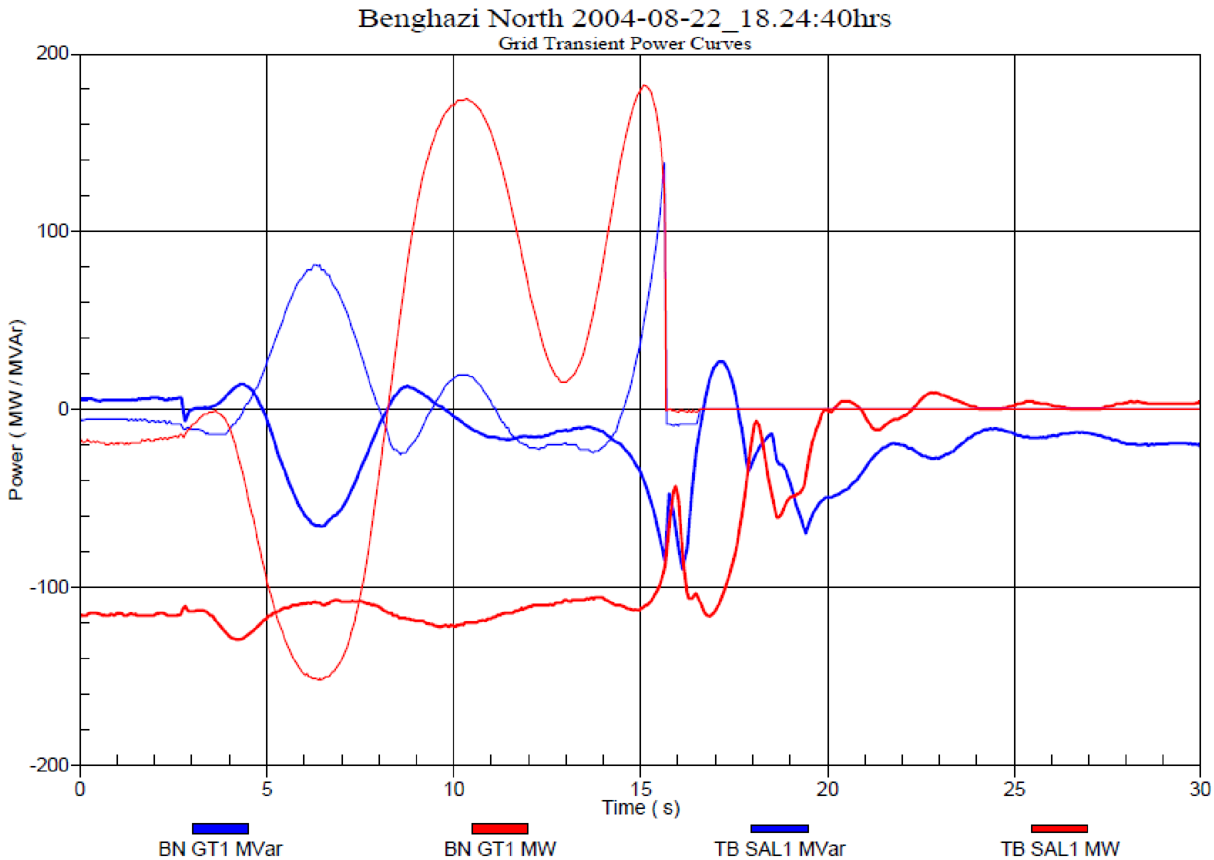
Records



grid short circuit
voltage drop to 0.5 p.u., fault cleared after 0.5s
ug
ifieldpu
ig
time [s]



grid short circuit
voltage drop to 0.5 p.u., fault cleared after 0.5s
xE2
time [s]
p
q
deltadeg



متطلبات استقرار الشبكة الكهربائية :

- كفاءة مشغلين وحدات التوليد (التحكم) ومشغلين تحكم الشبكة .
- وضع القيم الصحيحة والمدروسة (droop load setting) داخل منظومة تحكم التوربينة ومراعاة حجم وكفاءة وحدة التوليد .
- وضع القيم الصحيحة المدروسة لمنظومة (power system stabilizer) في وحدات التوليد مع التجديد كلما زادت القدرة بالشبكة .
- تحديث الخطة الدفاعية للشبكة لتكون متوافقة مع وحدات التوليد .
- التحليل السليم العلمي للأعطال العابرة وغيرها وفصل الوحدات وحل المشكلة فعليا لكي لا يتكرر الخطاء .
- التدريب المتواصل الحديث لعناصر التحكم .

م.عبدالعاطي العقيب

2013/11/11