Electrical and Computer Engineering
Graduate Course

COURSE NUMBER: EE6643
TITLE: TRANSIENTS IN ELECTRIC SYSTEMS
COURSE CREDIT: 3 credit hours

INSTRUCTOR: Dr. Adel Sharaf, Office: Room GC117 (open door consultation)
Email: sharaf@unb.ca

LEVEL: **Graduate - (Project Based Learning)**
4 Assigned Projects and Digital Simulation, Tutorials (Groups of 2)
Plus 1 extra bonus project for grade enhancement (if needed)
(individual project - optional for grade improvement)

DESCRIPTION:

The course deals with Switching Transient Phenomena and Transient Recovery Voltage (TRV) on electric power systems, grounding, selection of switch gear and relaying schemes, digital protection, power quality issues, harmonic phenomena and voltage compensation methods, as well as interface problems and required compensation and filtering schemes, power filters and LC compensators and resonance conditions.

TEXT BOOK & REFERENCES:

1. A P Meliopolons "Power System Grounding & Transients
2. IEEE Publications & Reference papers
3. G T Hydt, "Electric Power Quality"
4. Lou Van Der Sluis "Introduction to Power Transients", Wiley
5. Arrillaga & Watson, "Computer Modelling of Electrical Power Systems", Wiley
6. MATLAB/ SimuLink & Power System Tool Boxes Manuals
7. "Digital Protection" by L.P. Singh - Wiley
8. "Power System Protection" by P.M. Anderson, IEEE Press.
9. IEEE Standards, Publications and standard books.
10. Refer to Dr. Sharaf's webpage http://www.ece.unb.ca/Sharaf

NOTE: ***The course is structured in the project based learning (PBL) format that is research oriented and requires the use of digital simulation software such as MATLAB/Simulink, EMTP, EMDC/ATP, ESA, Simplor, other CAD-CAE software packages.***

* Project Based Learning (PBL) - open consultation and interactions.

DEFERRED EXAMS

University regulations on deferred exams are described in Section B -V. Examination, Standing and Promotion, C. Deferred Examinations, of the Current Undergraduate Calendar. All deferred exams in courses offered by the Department of Electrical and Computer Engineering are scheduled to be written on the fourth or fifth day of classes in the following term. There are no exceptions.

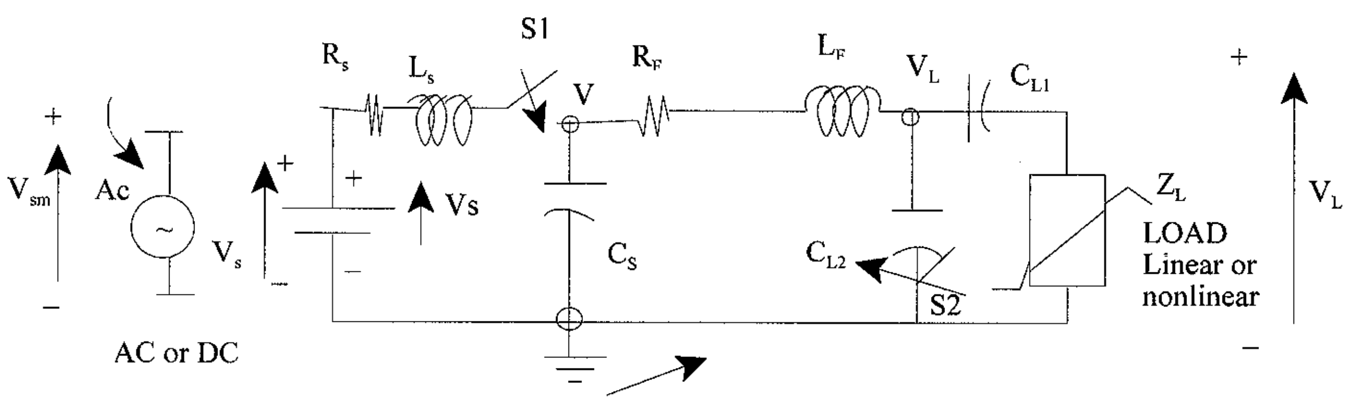
EE6643

Project 1 Transient Phenomena

A. M. Sharaf

Mark: 20 Marks **Due February 1, 2008**

Transients in Electric Systems



1. Discuss Transient Analysis Tools, Methods and Software Tools (D.E., Laplace, Fourier, etc...)

2. Study voltage and current transients for linear type loads and nonlinear type loads with solid state switch (1) closed, then suddenly opened, find the inductive & capacitive voltages across switches and load for DC and Ac sources (Vs, Vsm).

3. Study the effect of the shunt power factor correction capacitor compensation scheme (sss switch 2) closed: © = 50 - 150 µF or 50% load reactive compensation.

4. Study the effect of any AC source voltage distortion and DC biasing in the supply voltage.

5. How the capacitor (C_O) can be switched on/off to reduce the nonlinear load voltage (V_L) distortion. Design a simple PWM-Switching Controller Co is P.F. Correction Capacitor.

TIPS

a. Use Matlab/Simulink/PS BLK set software, refer to already built-in system and load models in Power System ToolBox.

b. Select any nonlinear load model (I) - Temporal Form

e.g. $R=R_0+R_1 \sin {}^1\omega_{r1} t + R_2 \sin {}^2\omega_{r2} t$ $\omega_1 = \omega_2 = 15 - 25$ rad/sec

$L=L_0+L_1 \sin {}^1\omega_{r1} t + L_2 \sin {}^2\omega_{r2} t$

or nonlinear model (II) - Current Dependent Form

cr. $R = R_0 (1 + {}^{\alpha}{}_1 | i_L | {}^{\beta}{}_1)$ Range $\alpha = 0.5 - 0.7$ $\beta = 2 - 4$

$L = L_0 (1 + {}^{\alpha}{}_1 | i_L | {}^{\beta}{}_1)$

c. Select any RL, RC load parameters and the degree of load nonlinearity (α, β).

d. Use per unit system at all Simulations

e. Assume $V_{s,}$ V_{sdc} to be 1.0 per unit.

f. Select typical line or feeder line parameters (distribution or utilization feeder)

g. Select any motorized, Inrush-type-load as a nonlinear load if you wish.

h. Refer to Dr. Sharaf papers, on Power Quality for Modelling, and Pierre Kreidi MSCE Thesis 2003.

i. Use existing Matlab / Sim-Power models.

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Project 2 **Capacitive Series Compensation Switching** **A. M. Sharaf**

Due FEBRUARY 29, 2008

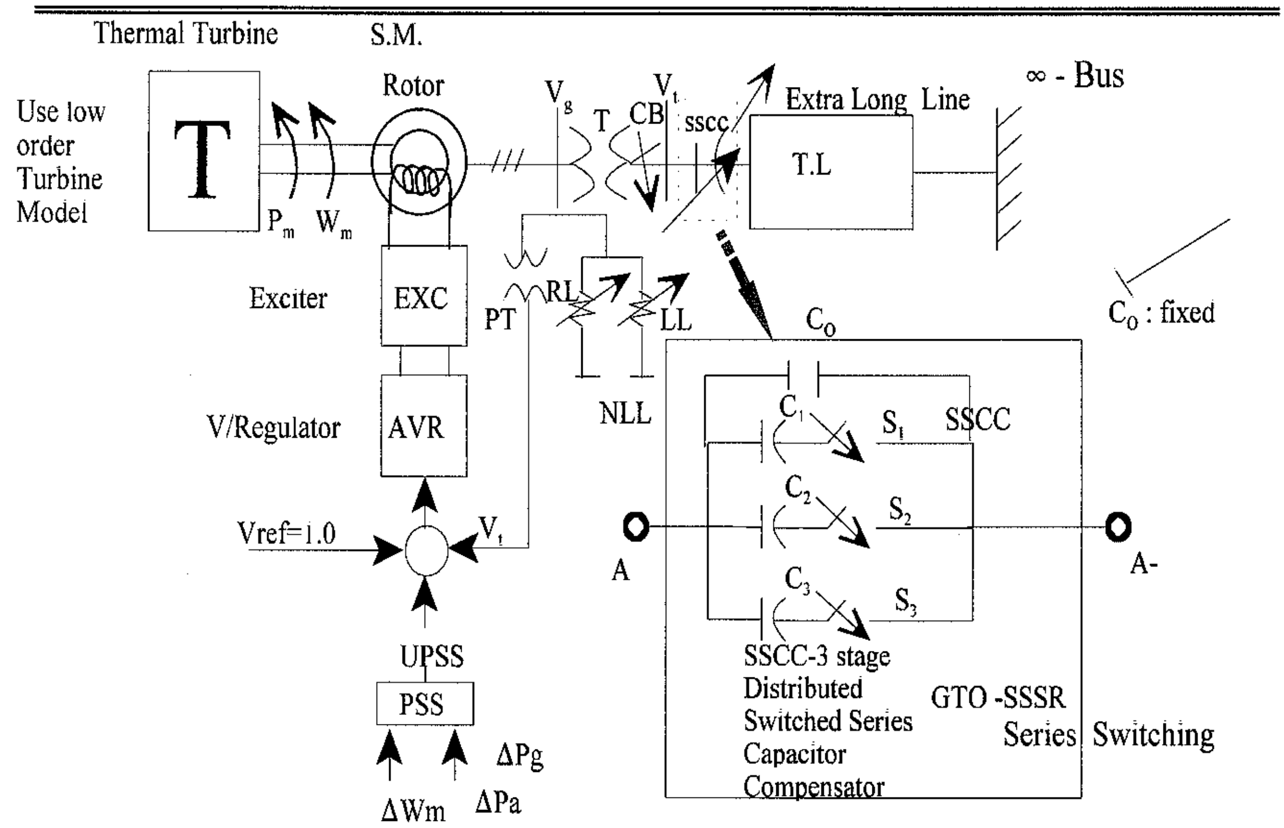

Figure 1: SMIB System

1. Discuss transient, voltage and harmonic stability issues and their broad classifications in Electric power and utility systems.

2. How voltage, current and power transients can be limited or mitigated on the power systems. What are the tools, devices and techniques.

3. Use Matlab/Simulink/P.S BLK Setto model the SMIB system shown in Figure 1, include all AC control and machine models and long transmission line

4. Discuss & examine the effect of nonlinear/dynamic type electric load on the transient voltage and electromechanical stability under any fault (3ϕ - short circuit fault at bus (V_t)

5. Examine how the series capacitor switched compensation can be used to enhance the tie line power transfer capacity

6. Develop a new coordinated machine & SSCCstabilization control - scheme for the combined action of power system stabilizer and switched series capacitor bank stages (the controller will regulate both Δ UPSS and value of $\Delta C = [c$, or $(C_1 + C_2)$ or $(C_1 + C_2 + C_3)]$

TIPS:
1) Refer to Dr. Sharaf FACTS Papers - (UPFC, SSSC - Facts) with M ElMoursi
2) Use a coordinated controller for combined (SSCC) and PSS Regulation
3) Use any typical per unit values
4) The series capacitor is divided into levels (0.15, 0.35, 0.65 pu)
5) Use built-in berified models of the Matlat/Simulink/Power system toolbox
6) Use simple models for speed control, turbine, exciter, voltage regulator, transmission line, transformer
7) Use Dr. Sharaf's built-in Matlab (nonlinear) static or dynamic models
8) Study excursions such as:
   (1) 3ϕ short circuit
   (2) Generation/nonlinear load prime power load/torque excursions

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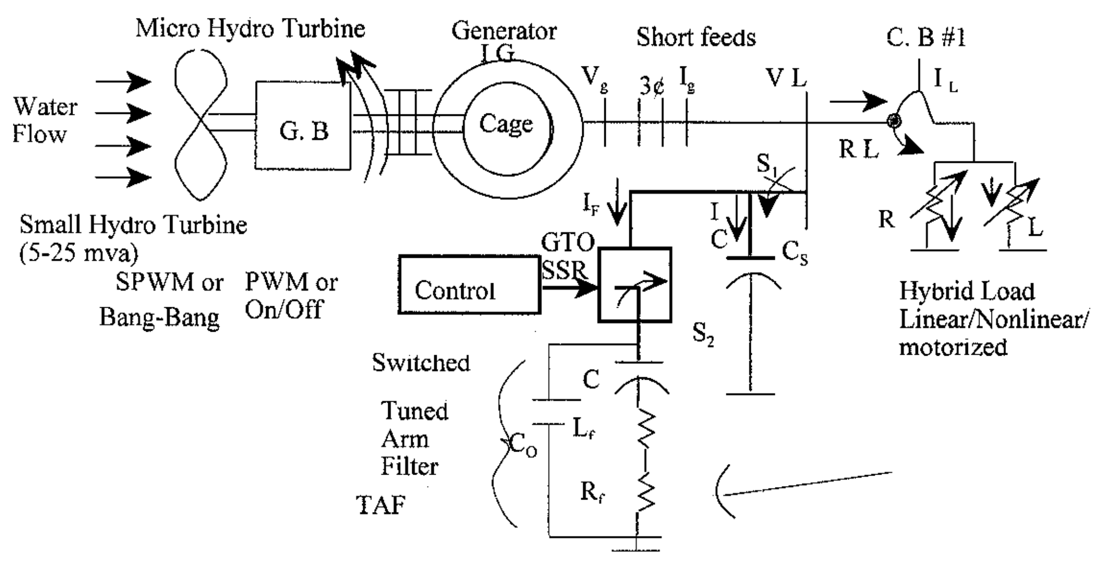
Project 3 — **A. M. Sharaf**

Mark: 20% — **Renewable Micro Hydro Energy Scheme & Interface Transients** — **Due: MARCH 28, 2008**

Models

(I.G. + Turbine + Load + Filter + C) [for ease use PS Blockset]



Typical Values:

Figure 1: Micro-Hydro Induction Generator

$C_s = 150 - 300\ \mu F$
$L_f = 10 - 50$ mH
$R_f = 0.5 - 1\ \Omega$

1. Review the switching - (energization and de-energization) phenomena in the Renewable Energy Conversion Scheme (RECS) and problems and protection requirements especially when using solid-state switches(S_1, S_2).

2. Develop a Matlab/Simulink / Power Sim Model of the Micro-Hydro-Induction generator System - Shown in Figure 1 with a standalone sq. cage. Induction generator (size 500-5000 KVA)(use existing Matlab BS blockset - customize per unit values)

3. Select the value for self-excitation capacitor (Cs) to establish full rated voltage at no load (voltage buildup). Try fixed valve (150-450 µF/phase)

4. Propose a main loop Voltage - Stabilization V-Control (PID) control Strategy based on either (ON/OFF) or (PWM) switching of the Smart Power Filter (Tuned-Arm Filter - Modulated Yc Control), or a bank of Zero-Voltage switched capacitors/TSC. Add minor PQ-Harmonic reduction control loop.

5. Check voltage and current transients due to any load excursions (variations) faults and capacitive switching (on/off) Use load excursions (DR, DL)

6. Evaluate the general effect of switching on the supply of waveforms and the power quality PQ with either synchronous or a synchronous switching, (CB_1, S_1, S_2 open & close at any given time)

Tip:
- i Select typical machine parameters in P.U.
- ii Use matlab/simulink/PSB *
- iii Use built in blocks if available
- iv Use controlled-switched/time-switched models to evaluate CB - Circuit Breaker On/Off scenarios.

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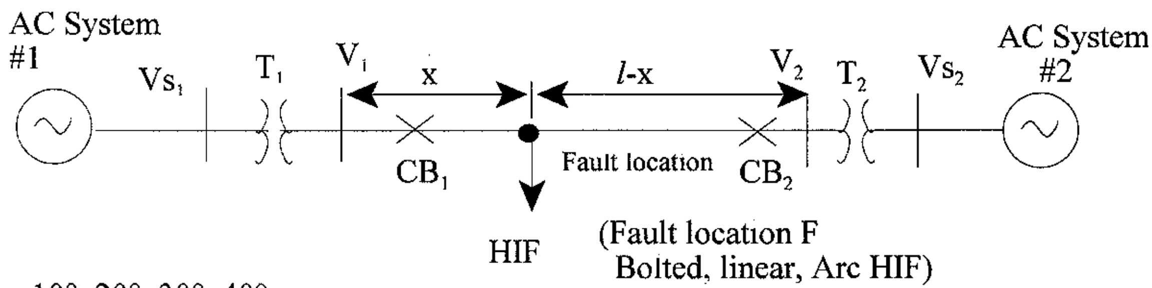
Project 4 | **HIF Faults** | A. M. Sharaf

Mark: 20% | **Due: APRIL 24, 2008**



$\delta = 10°, 20°, 30°, 40°$
$V_{s1} = \sqrt{2}V_1 \, Sin(wt + \delta)$
$V_{s2} = \sqrt{2}V_2 \, Sin(wt)$

Figure 1: Interconnected EHV
EHV Transmission Line (long line)
(Length l = 100 -500 km - total length)
Fault Distance X = (0.1, 0.2, ..., 1.0) l

Smart relays R_1, R_2 at located at bus (1) and (2) using (υ, i) and possible (ϕ = υ, I) signals.

1. Select Parameters in per unit for a long EHV / UHV (345 kv - 765 kv) - say 500 kV (L-L)

2. Investigate fault transients for the linear Bolted fault, (Fixed Rf and Arc HIF faults)

3. Use Arc HIF fault resistance nonlinear models (refer to Dr. Sharaf's Publications)

4. Device a time based transient pattern recognition relaying-detection & protection scheme using either (V_1, i_1) at Bus (1) or (V_2, i_2) at Bus (2) or both. Use (FFT, Nonlinear mapping, Wavelets, ANN expert system or statical Pattern recognition tools - Auto/Cross v, ι.spectra.

5. How does the fault location distance affects fault dynamics and smart relay accuracy & detection.

6. Select appropriate circuit (CB_1, CB_2) Breakers (Type and Size)

7. Study the effects of supply voltage phase shift (δ) between area Bus (1), (2) on fault.

TIPS: Compare (no fault, bolted, HIF Arc)

a) Use Dr. Sharaf's Fault SLD equivalent circuit shown in Fig 2.
Use MATLAB.Simulink/PS BLKSet.
b) Select T. L. parameters: (R = r/Km, L = mH/Km, C = µF/Km)
c) Select equivalent AC system plus transformer Thevenin's impedance $\left(\frac{XTn}{RTn} \leq 10 - 20\right)$
d) Plot all (V_{1s}, i_s) as well as (V_f, i_f), (V_1, i_1), (V_2, i_2) phase portraits.

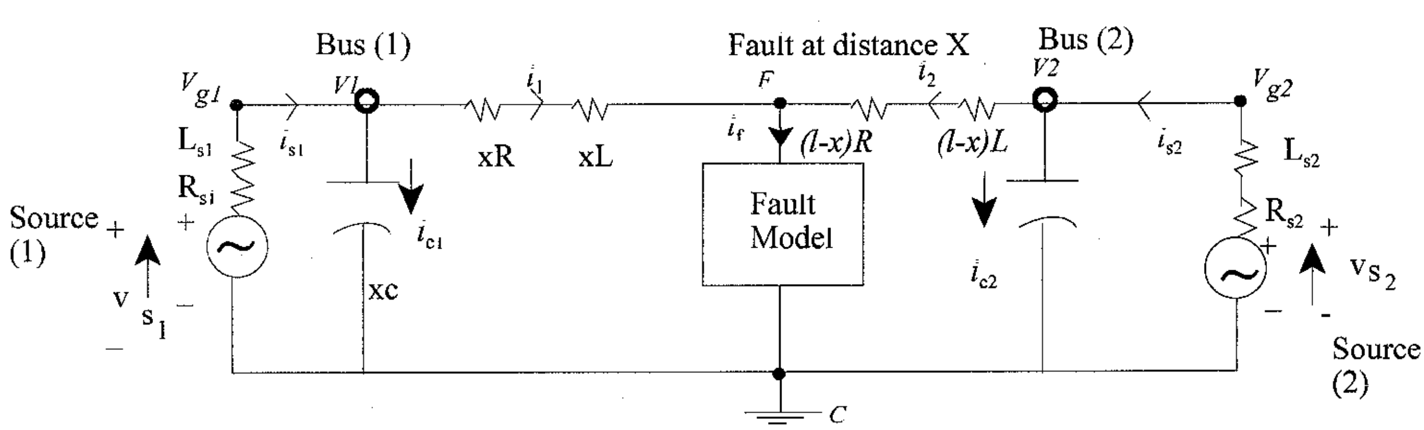


Fig 2: SLD - Per phase Equivalent Circuit with (Fault Nonlinear Arc Model) V_f - V_S - i_F

See: Proposed Smart Relay in Figure 3

X: Distance to fault form Bus (1)

R, L, C. are parameters of T - L per kilometer

Fault Model: (i) Bolted ($R_f = 0$, $L_f = 0$)

(ii) Linear Fixed $\begin{cases} Rf = 20 - 100\Omega \\ Lf = 1 - 5mH \end{cases}$

(iii) Nonlinear - Temporal or Current Dependent.

Model 1

$i_f = i_{fo} (1 + \propto V^{\beta}_f)$
Select ($\propto$, $\beta = 2 - 4$)
$L_f = 1 - 5$ mH

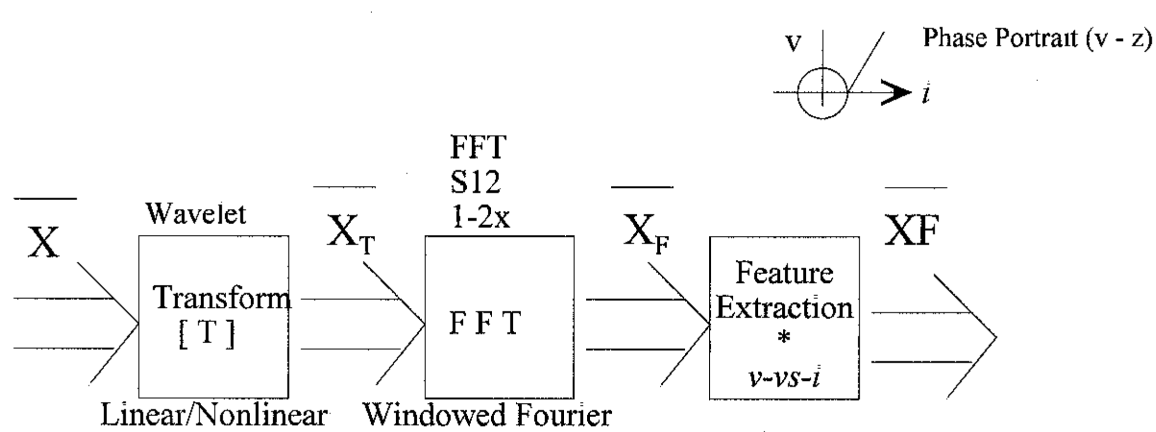
Model 2

$R_f = R_{fc} (1 + \propto Sin^2 w_r t)$
$R_{fo} = 10 - 50\ \Omega$
$\propto = 0.3 - 0.7$
wr = 10 - 20 rad/dec

Model 3

Any Arc - Type Model or Saturation - Type

Figure 3: Smart - Pattern Recognition
HIF - Fault Detection Scheme

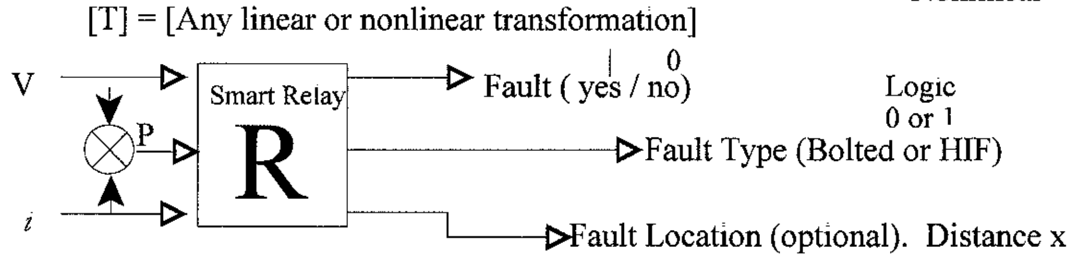


$\overline{X} = [v_1, \dot{i}_1, P_1, v_2, \dot{i}_2, P_2]$

— OR —
* Wavelets
* GA Tabu
* Linear discriminant
* Nonlinear - ANN

$P_1 = v_1, \dot{i}_1, \quad P_2 = v_2, \dot{i}_2$

[T] = [Any linear or nonlinear transformation]



$P = v_1$

Tip: Refer to Dr. Sharaf HIF papers with Guosheng Wang and Atif Saleem.as we;; as Facts papers with M. ElMoursı