NUMBER: EE 6633 Design Project-Based Learning Format

TITLE: DESIGN AND CONTROL OF LOW VOLTAGE (LV) ELECTRIC SYSTEMS

COURSE CREDIT: 3 credit hours

LEVEL: Graduate (Project Based Learning)
A number of assigned projects and simulation tutorials / presentations
Four (4) Projects and Two (2) Project Presentations each is 20% weighting
Two (2) assigned reading topics (20%)
One (1) Bonus Project (10%) – Extra

DESCRIPTION: The course deals with Electrical System Design concepts and techniques for low voltage distribution systems. Topics include power factor correction, voltage regulation feeder planning, stabilization methods, digital protection and power quality enhancement and economic techniques for loss reduction.

TEXT BOOK & REFERENCES:

1. Gonen "Distribution Systems"
2. IEEE Publications, published papers
3. Manufacturer's design manuals
4. Lou van der Sluis, "Introduction to Power System Transients", Wiley
5. El-Hawary, "Electrical Power Systems: Design and Analysis" IEEE Press
6. IEEE Standards Books and publications
7. Roger C. Dugan, et al, "Electrical Power Systems Quality", McGraw Hill
8. Glover & Sarma, "Power System Analysis and Design", PWS Publishing
9. Weedy & Cory, "Electric Power Systems 4th Edition", Wiley
10. Selected papers by Dr. Sharaf
11. Old Project Models / Templates

INSTRUCTOR: Dr. Adel Sharaf, Room GC117 Head/Gillin Hall (Sharaf@unb.ca)

NOTE: This course is structured in the project based learning (PBL) format with assigned design projects that is research oriented and requires the use of digital simulation tools such as Matlab / Simulink, EMTP, ATP/EMTDC, ESA, etc.

EE6633

Design & Control of L. V. Electric Systems
Project I

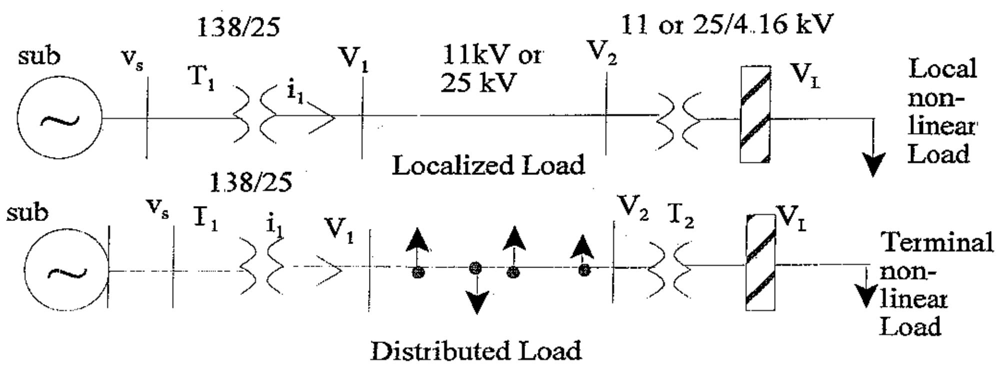
January 2007 **A.M. Sharaf** ***Due Feb 8, 2007***

(1) Discuss existing methods, mathematical tools & techniques used in the distribution grid system planning & design of Radial distribution feeders (LF, SC, Sizing, CAP-Compensation and PQ - issues & harmonic mitigation. (Below 25kV)

(2) For the L.V distribution feeder circuit below (Figure 1, 2) develop a MatLab/Simulink functional model to represent the feeder.

138kV S.C. level = 3-5 GVA

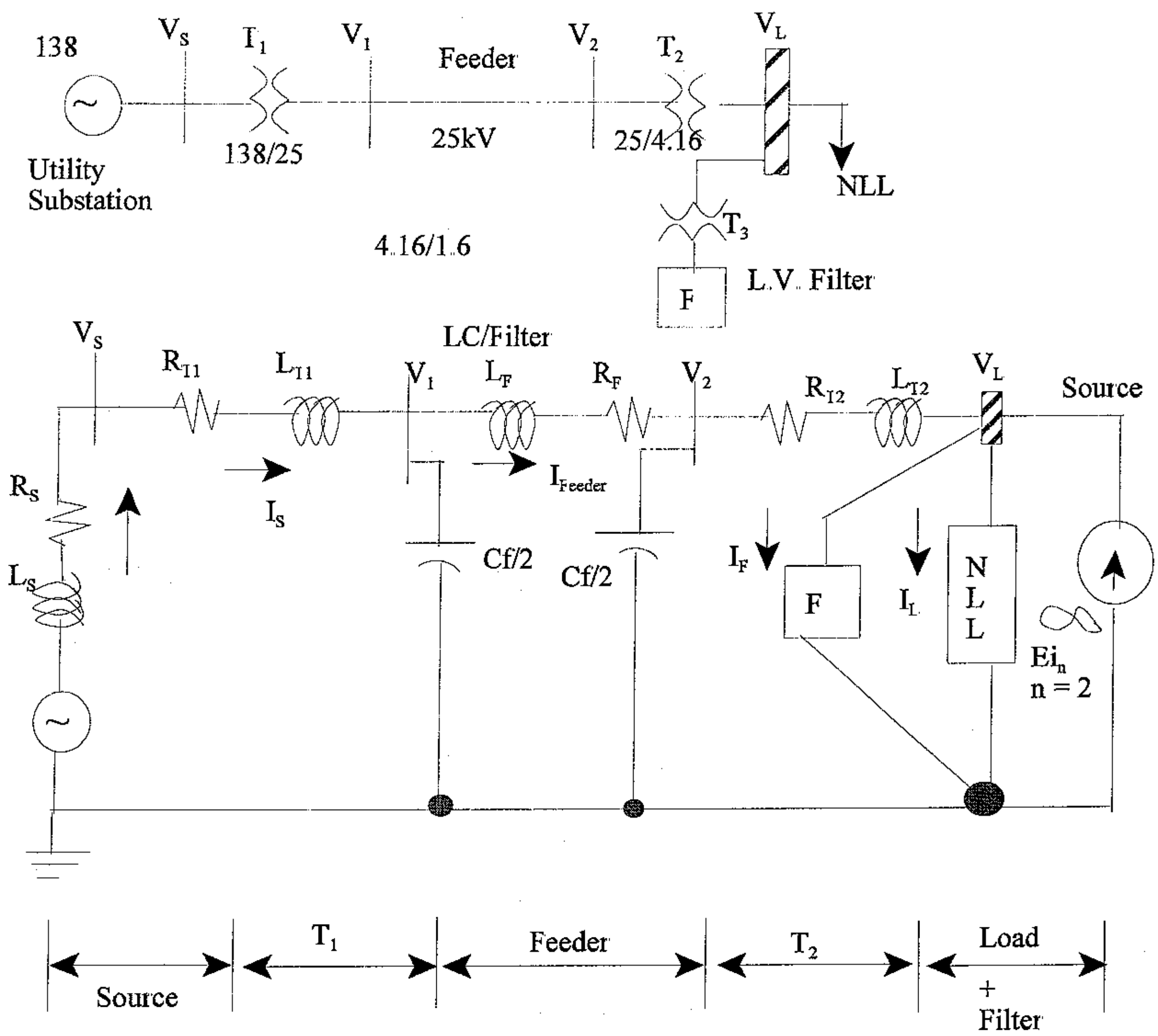
11kv or 25 kv
L-L
T: 138 / 11 or 25 kv
feeder size 5-10 MVA
length = 10-20 km



(3) Show how load flow can be performed for radial and distributed loads.

(4) Design fixed LC power filter (TAF, C-type) compensators to improve power quality, reduce losses and enhance voltage regulation (refer to Dr. Sharaf's papers).

TIPS: Design of fixed structure LC compensators and power filters.



Define all Z_{filter}, Z_{load}, Z_{feeder}, Z_{T1}, Z_{T2}, Z_S

$Z = R + jw_nL$ $\qquad$ $wn = n \cdot w_1$

for a given dominant harmonic or a cluster of harmonics

n = (5, 7, 11, 13, ...)

The nonlinear load representation can affect LC compensator design based on optimizing penalty functional J_1, J_2 for a given harmonic order n or number of harmonics.

Use Matlab / Optim took box
Minimize J_1 or J_2 for a given harmonic order n.

$$J_1 = (\alpha_1 |I_{SN}|) + (\alpha_2 |V_{LN}|) + (\alpha_3 / 1^{I}{}_{Fn})$$

or

$$J_2 = \alpha_1 |I_{S_1}|^2 + \alpha_2 \left|\frac{P_S}{S_S}\right| + \alpha_3 |V_{Vn}|$$

J1 - Minimize load harmonic voltage, source harmonic current and maximize filter current for a given harmonic order n or range of n = (3-15).

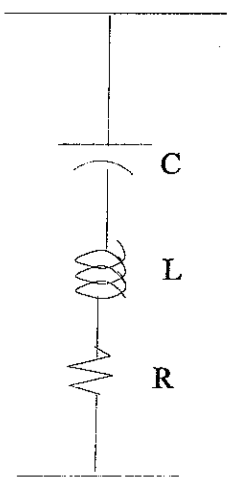
J2 - Minimize source losses at fundamental, maximize power factor and minimize load bus voltage.

Minimization is subject to constraints on values of L, C, Q, size, fundamental bus voltage limits of ± 5% - 1-% deviations.

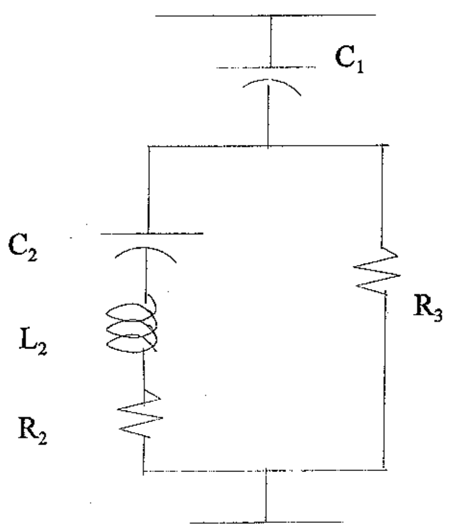
Other constraints imposed on nonlinear load operation, reactive levels of source Q_S.

$Q_F = W_1 C V_1^2$

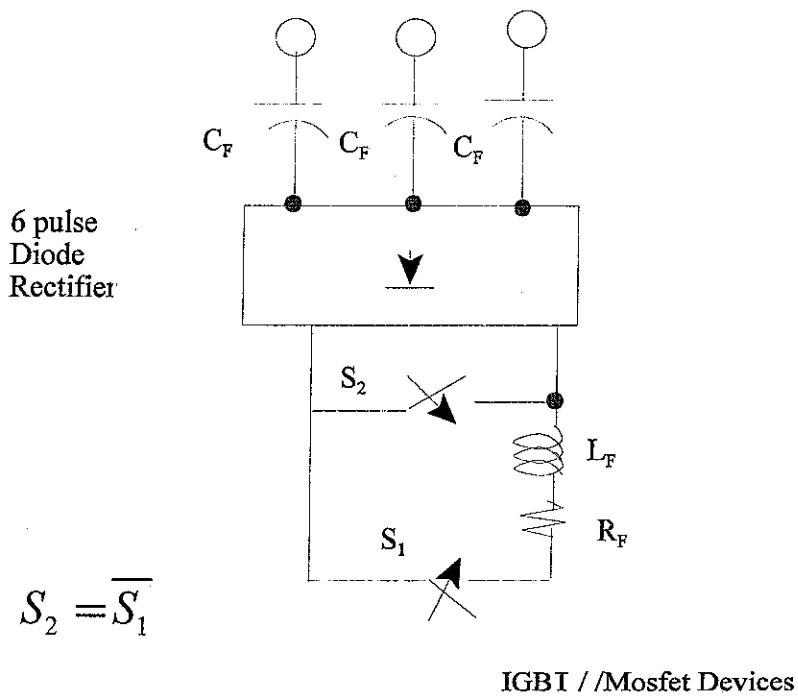
Select one scheme only



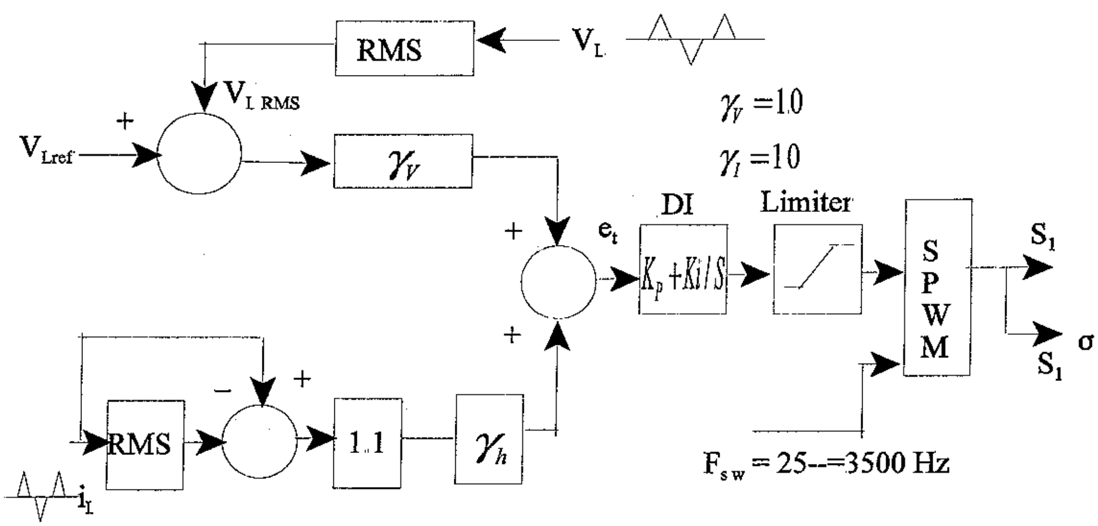
Scheme #1 Turned Arm Filter



Scheme #2 C-Type Filter



Scheme 2 Dynamic MPF-CC Filter Compensator



Dual loop dynamic controller for the MPF-CC filter/compensator

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Design of Voltage Stabilization Devises & Power Factor Correction Schemes
Project II - (PBL)

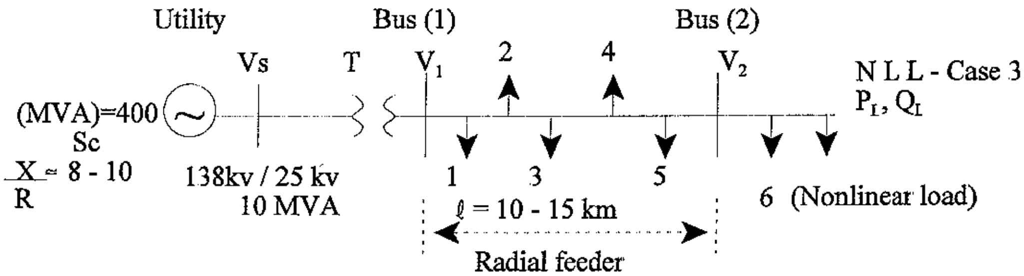
A.M. Sharaf ***Due Feb 22, 2007***

Project Objectives:

1. Study distribution feeder (11 kv or 25kv - Radial) power factor correction methods and voltage regulation/stabilization techniques.

2. Validate a novel design for a DRV/MPF/SCC compensator (developed by Dr. Sharaf) as a voltage correction/power factor enhancement device for radial 25kv (L-L) distribution feeder (see figure (1)). Study operation with nonlinear temporal load.

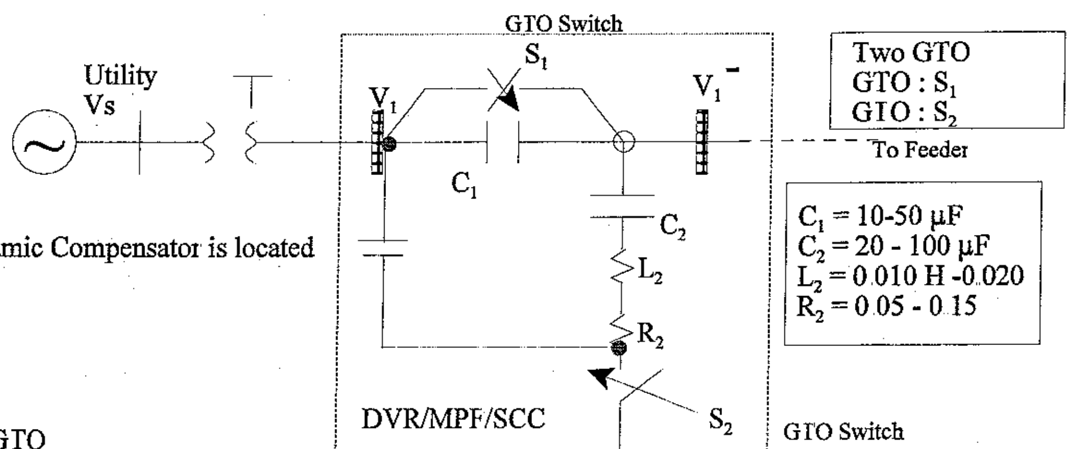
Figure (1) Sample study system.



Select loads
* Use (P, Q) or (S_1, PF) linear loads in case (1)
* Use distributed loads maximum does not exceed 10 MVA (allow for 20% overload of transformer)

Figure 1: Sample Radial Distribution feeder
Requirements:
1) Investigate distribution feeder operation without any reactive compensation devices
2) Repeat case (1) with fixed or switched capacitor bank located at feeder bus (1) or bus (2) or Midway. Select optimal size and location (Qc - Fixed, Qc or Switched)
3) If the novel dynamic DVR/MPF/SCC compensator device shown in Figure 2 is used, compare with cases (1), (2) above for a nonlinear temporal load arc furnace or inrush type motorized load.

Figure (2) DVR/MPF/SCC Scheme



Novel Dynamic Compensator is located at Bus (1)

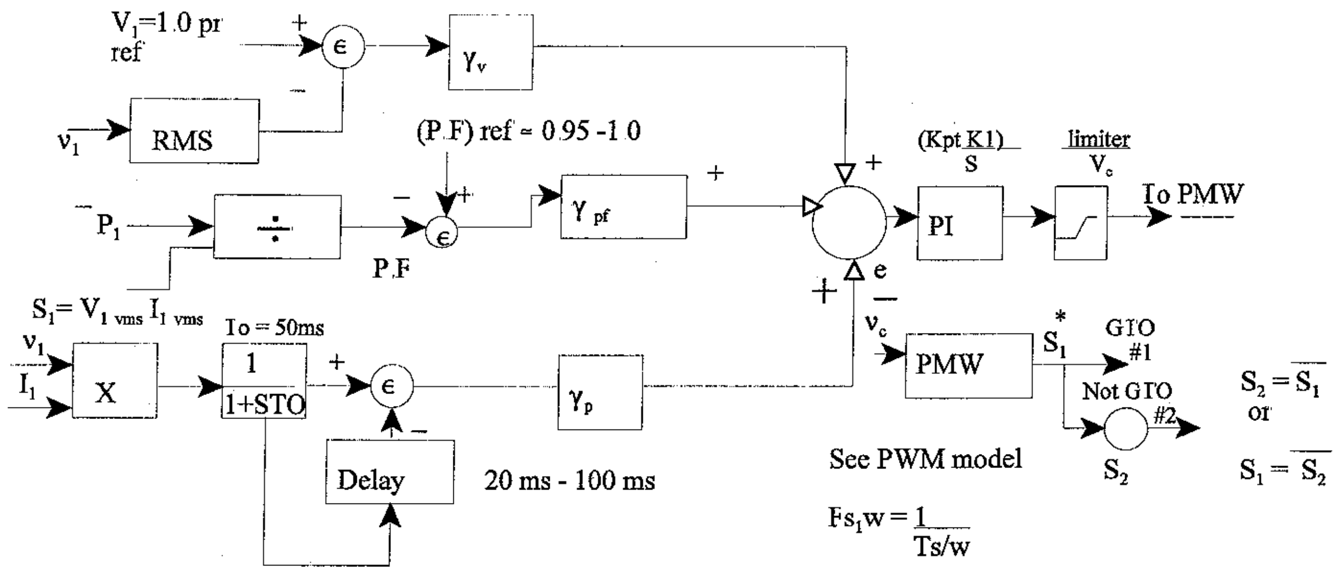
see figure 3

S_1, S_2 Are GTO Switches

Compare all three cases and discuss all (1), (2), (3) in terms of:

1. Voltage profile - regulation issues along the feeder
2. Power factor at substation or feeder bus
3. Active and Reactive losses along the feeder
4. Effect of dynamic DVR/MPF/SCC controller on feeder performance in case of combined linear and nonlinear terminal load at bus (2) (Temporal)
   $R = R_0 + R_1 \sin Wr_1 t + R_2$
   $L = L_0 + L_1 \sin Wr_1 t + L_2 \sin^2 Wr_2 t$
   * (Refer to Dr. Sharaf P Q - papers) * Select all values

Figure (3): Novel Tri=loop dynamic controller (Dr. Sharaf's)



* Use a simple PWM - model $F_{s/w}$ = 300 - 1000 Hz in PS - Tool box or use model in Dr. Sharaf's papers
* Select ($\gamma_v, \gamma_{pf}, \gamma_p$) $\simeq$ all equal to 1.0 as an initial choice then optimize selection
* PI control $\frac{vc}{e} = (kp + ki / s)$ Kp = 5-100; ki - 0.5,10

Tips: Use all values in <u>per unit</u>, Select Base
PBase - 10 mva V Base = 25 kv (Base) L - L

1. Use Mat lab / Simulink / PS - Blk set availavle built-in function
2. Use proposed controller shown in figure (3) or modify if need be
3. Refer to nonlinear load models in Dr. Sharaf's papers
4. Size Capacitors Qc $\geq$ 50% of total load Q_L (fixed & switched or combined)
5. Assume a distributed (P,Q), (S, PF) linear loads first
6. Use controller (Tri-loop shown in figure (3)
7. Assume & justify any parameter
8. Assume one nonlinear temporal load for case (3) only.

Good Luck

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Design of Low Voltage AC Systems
Project III - (PBL) 25% + 5% Bonus

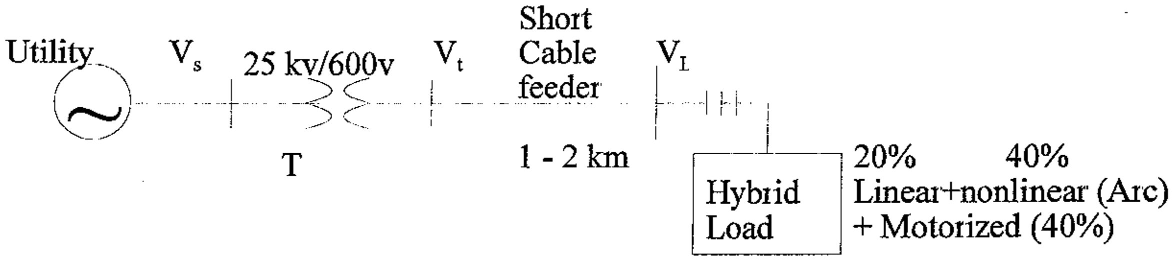
A.M. Sharaf — ***Due: March 16, 2007***

PBL-Project Objectives:

1. Study the operation of Low Voltage (L.V) distribution /Utilization (3ϕ, - 4 wire) systems under both balanced /unbalanced, normal/ and Fault conditions (short circuits, open circuits).

2. Discuss special techniques select the compensation devices to improve power quality PQ, power factor PF, utilization of power / energy.

3. Discuss existing mnethods for High Impedance Faults (HIF) - Arc detection / Relaying and select the appropriate scheme to detect elusive HIF-Arc type faults



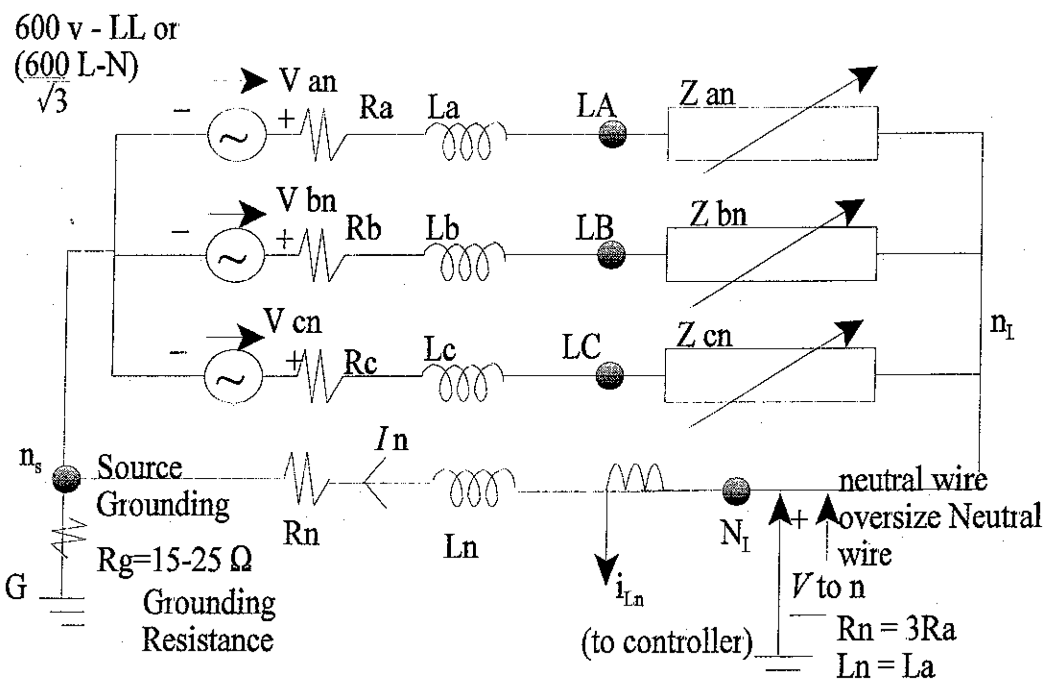


Figure 2: (3ϕ - 4w) utilization load - system sample

* Z an, Z bn, Z cn loads can be either balanced or unbalanced, normal passive or active nonlinear type loads.

$$* \; Z\,an = Ro\left(1 + \propto \left(\frac{Va}{V_b}\right)^{B}\right) + jw\,L_0 \;\; \underline{(\text{non-linear})} \quad , \quad Vb = \text{base voltage (Rms)}$$

Z_{bn}, Z_{cn} can be same or with ± a typical 25% imbalance in magnitudes

* The neutral-wire is usually sized 2 - 3 times the conductor size for safe operation.

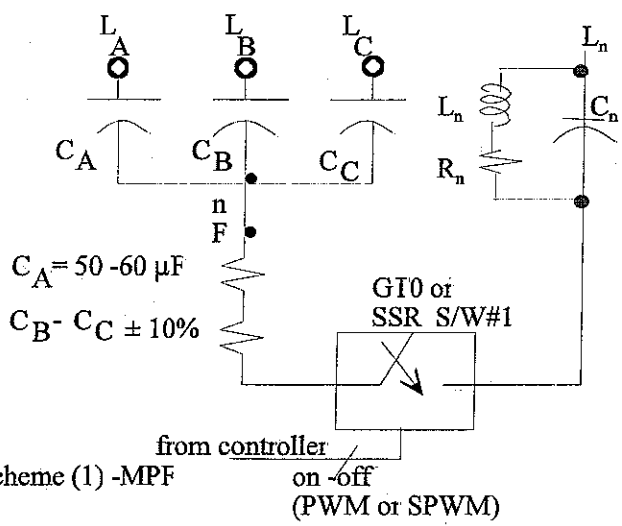
Project Requirement: Select α, β ⇒ $\left\{ \begin{array}{l} \alpha = 0.30 - 0.70 \\ \beta = 2 - 4(nonlinearity) \end{array} \right\}$

i) Develop a Matlab/Simulink/ PS BLK set Model (refer to Dr. Sharaf's papers)

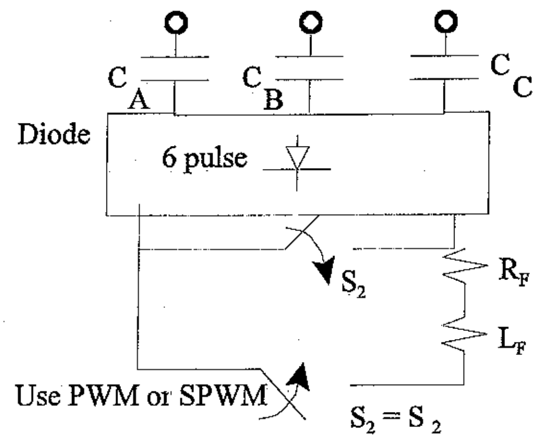
ii) Study the operation for balanced as well as unbalanced operation β = 0 of load

iii) Study operation for HIF - Arc type faults with β order = 2 or 3

iv) Study operation for 3 ϕ unbalanced load case with the novel simple (MPF) modulated power filter located at the load terminals and developed by Dr. Sharaf.



Scheme (1) -MPF



Scheme (2) -MPF

Select (either scheme (1) or Scheme (2)

{L_n = 5 - 10 mH
{ C_n = 10 - 50 μF
{ R_n = 0.5 - 3 ohms

Figure 3: MPF Novel Switched/Modulated Filter Scheme (Developed by Dr. Sharaf) - Select only one scheme

The MPF filters PWM or SPWM switched either to reduce haromics in the neutral current or enhance electric utilization or improve power factor, Select $F_{s/w}$= 300 - 10090 Hz)

Select any control scheme based on Dr. Sharaf's paper or using the following tri-loop dynamic controller shown in Figure 4.
Show all dynamic response wave forms, especially i_{Ln}, v_{Ln}, , ϕ_{Ln} and then 2-d, 3-d phase portraits ($V_L n$ - $i_L n$) $V_L n$ - $i_L n$ - $\phi_L n$

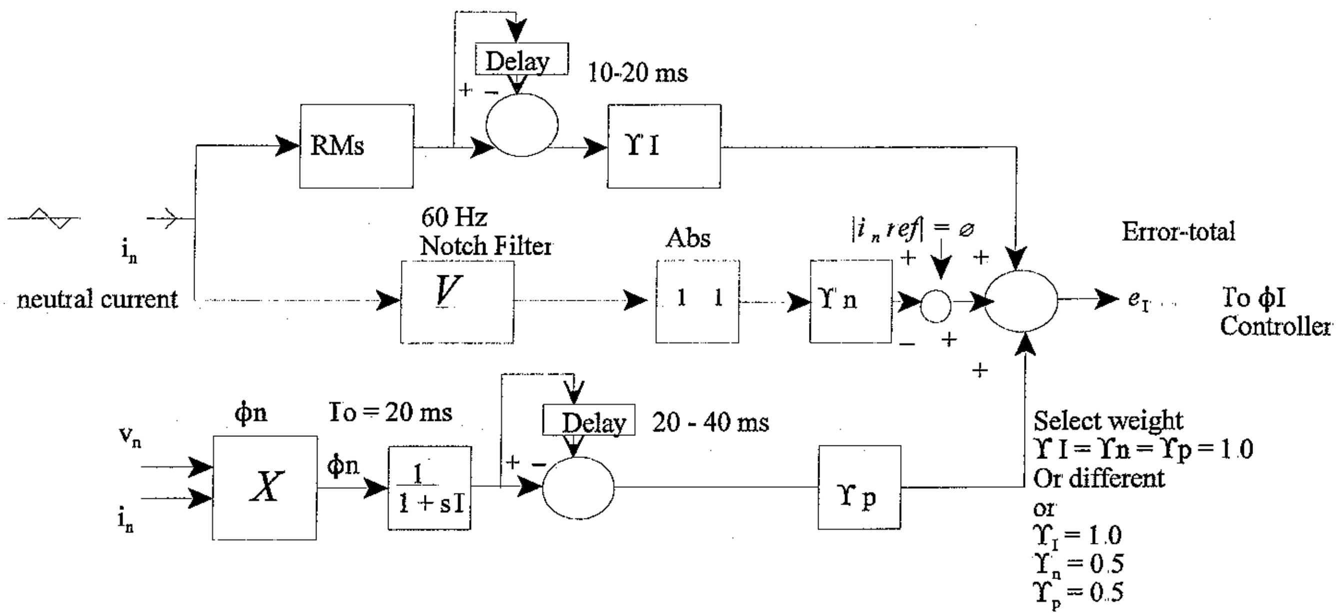


Figure 4A : Tri loop controller

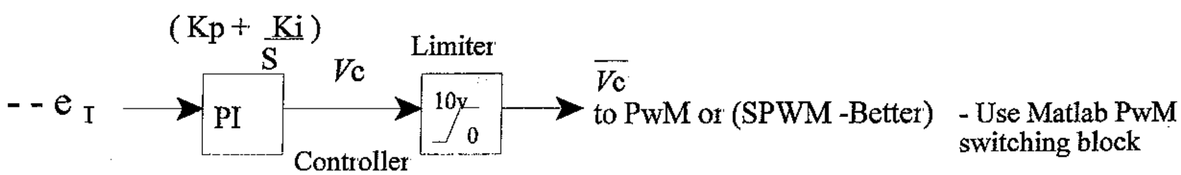


Figure 4B: PI Controller Activation

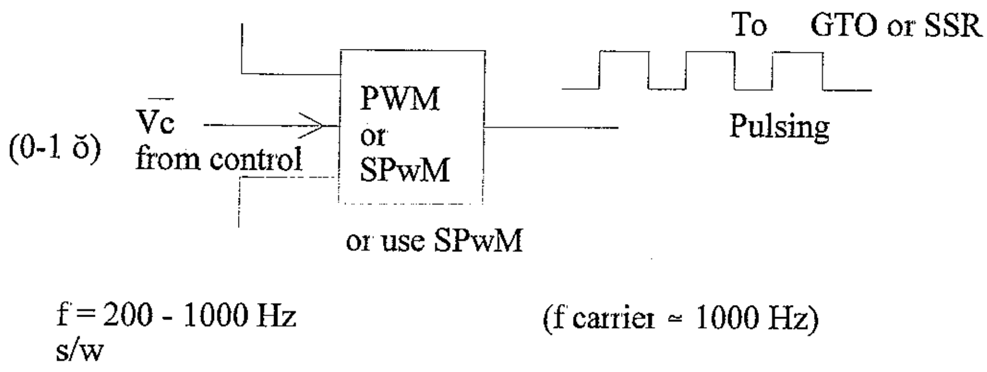
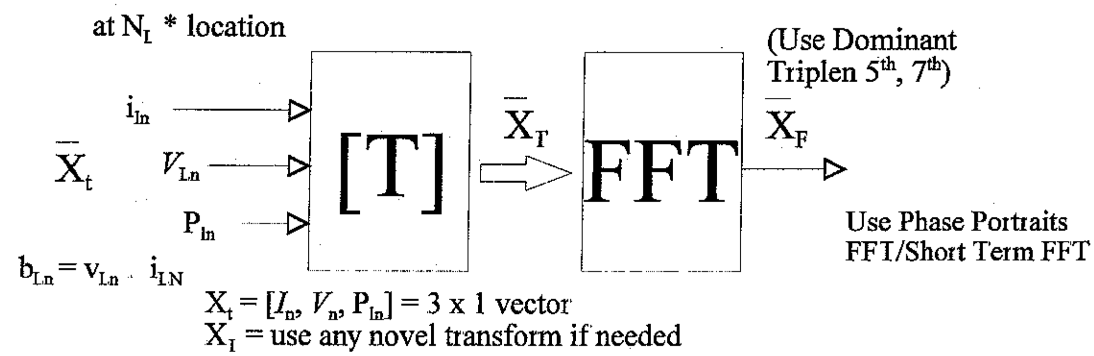


Figure 4C: Pulse width Block use PWM or (Better use m - 0 - 1.0 - Modulation Index SPWM ...)

Bonus 5% Extra

**V) Develop a simple harmonic relay pattern detection scheme based on v_n, i_n electric signature analysis refer to Dr. Sharaf's papers on HIF detection)



* Plot all dynamic response of all v, I, control, switching signals
* Plot all relay signatures
* Plot 2 - d phase portrait (v_n - i_n)
* Plot 3 - d phase portrait (v_n - i_n - P_{In})
T: Any nonlinear Transformation (wavelets, Walsh, ...)
** Compare no fault, bolted, linear and nonlinear faults - Refer to Dr. Sharaf's papers on HIF - Arc Detection.

Good Luck

Please Note:

☞ This project has many novel ideas for Research topics and M. Eng Report selection - so put a good effort.

☞ I hope one or two students can publish a good paper out of the novel MPF - concept as was done last year!

EE6633

Design of Low Voltage Electric Systems
Project IV - (PBL) 10%

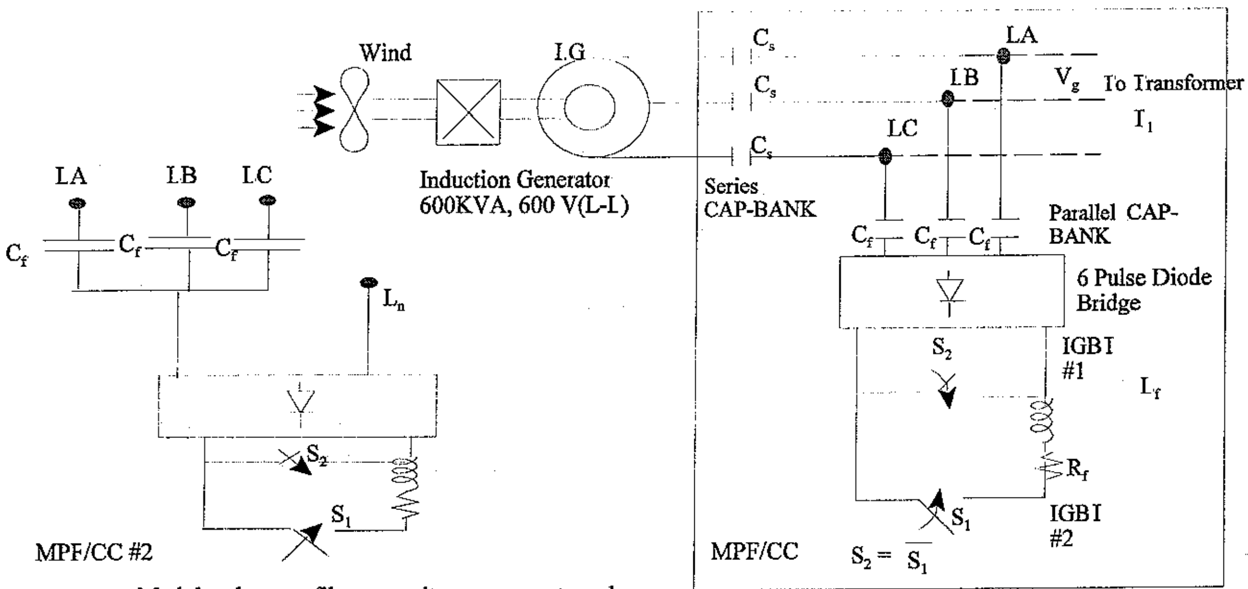
A.M. Sharaf ***Due: April 05, 2007***

Project Objectives: *(Best Project will be published and presented to ECE Graduate Students)

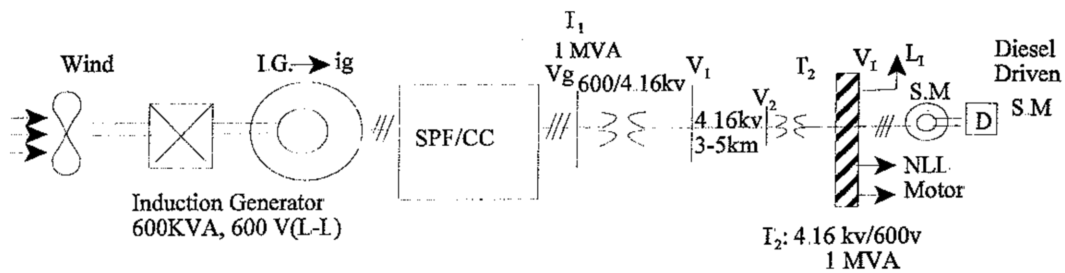
i) Design a novel switched power filter and capacitor compensator SPF/CC scheme for wind-diesel local dispersed energy system.

ii) Study the voltage stabilization and regulation issues and control strategies for dispersed WIND-DIESEL Renewable Energy Systems.
** Assume and justify selected/missing parameters

TIP: Use Matlab/Simulink/Sim-power models and existing wind-diesel models



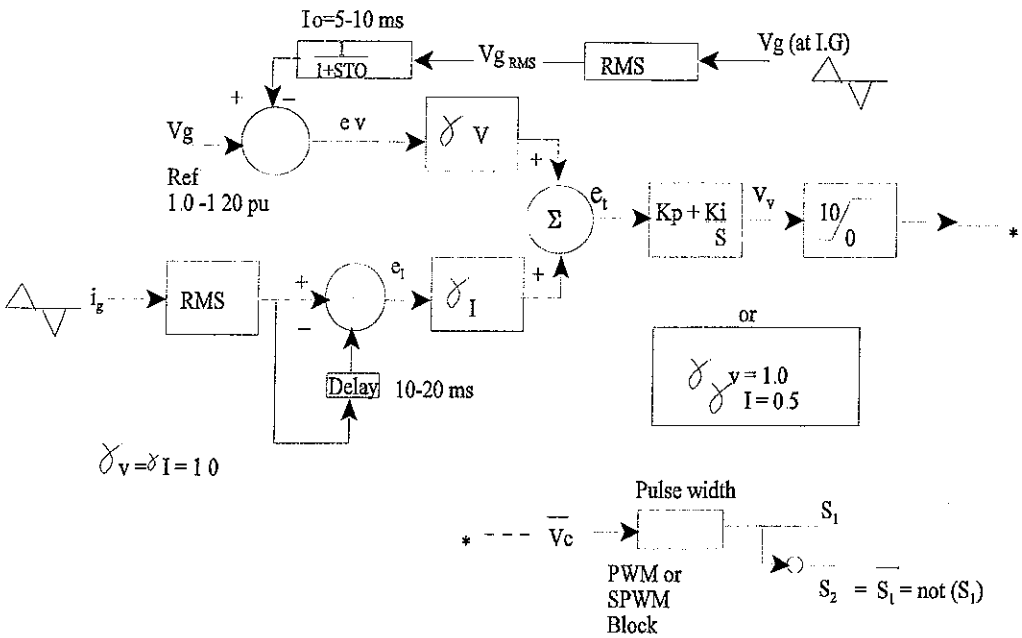
Modulated power filter-capacitor compensator scheme



T1, T2 are transformers rated at 1 MVA 06/216kv
Figure 1 SLD of local wind - diesel scheme

The diesel driven synchronous generator (SM) is rated at 600kva at 600 v (L-L)
The novel SPF/CC filter compensator in controlled by a dual loop stabilization controller as shown in Figure 2 (Dr. A. M. Sharaf)

Figure 2



F i g u
re 2: Proposed dual loop novel error driven controller for (PWM) or SPWM) switching

$C_s = 10 - 25\ \mu F$
$C_f = 100 - 250\ \mu F$
$L_f = 5 - 15\ mH$
$R_f = 0.15 - 0.25\ \Omega$

	Hybrid Load	Nonlinear Linear	40% 20%	Motor 40%
Short Collection Feeder 4.16 kv(LL)	$R = 0.35 \Omega / Km$ $X = 0.25 - 0.35\ \Omega/km$ 3 - 5 Km Length			
Diesel - SM	600 v (L-L), 600 KvA Synchronous Generator with Field or permanent Magnet excitation system Diesel - Engine (locomotives type)			
Controller	PID	$Kp = 5 - 100$ $Ki = 0.5 - 10$ $K_D = 0.15 - 2.5$ (optional)		

PWM or SPWM can be used
for $f_{s/w}$ = 600 - 1200 Hz up to 5000Hz for IGBT switches S_1, S_2
carrier $S_2 = \bar{S}_1$ (IGBT - switching)

Required

(1) Plot dynamic response to electrical load, wind, diesel engine prime mover excursions (all v, all i) as well as short-circuit (3¢ - g) for 50 - 100 ms near induction generator or load bus.

(2) Plot the control system parameters (ev - vs - ei), (ev, ei, et) versus time. Vc, Vc (limited)

(3) Plot V_I - Vs - i_L versus time

(4) Plot P feeder, Q feeder, I short feeder

(5) Compare dynamic response without and with all excursions.

(6) Discuss phase portraits (V_L - V_S - I_L), (VLg - V_S - I_g), (e_v - v_I - i_L)

Key Design: To minimize Diesel start-stop
Ensure diesel engine is running at 25-100% of rated value depending or wind regime conditions

GOOD LUCK

EE6633

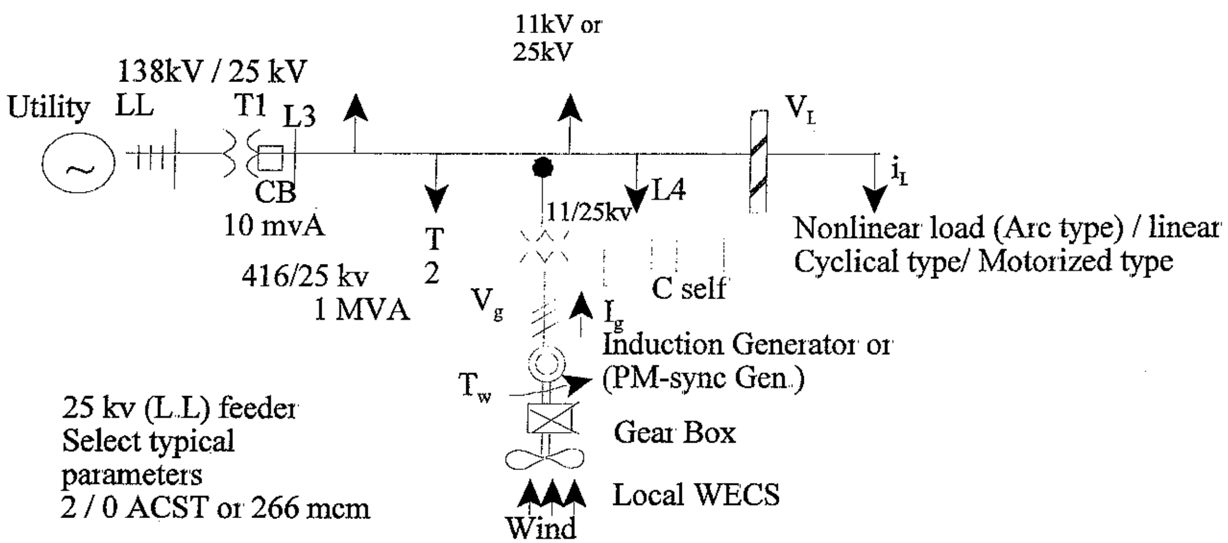
Design of Low Voltage Electric Systems
Bonus
- (PBL) 10%

A.M. Sharaf ***Due:*** April 05, 2007

Project Objectives:

i) To study the operation of the low voltage distribution feeder (11kV or 25kV) under localized /dispersed wind interface scheme(use the simple Quasi-static wind turbine torque model) - refer to Dr. Sharaf's papers.

ii) Design & size an effective dynamic voltage stabilization and modulated/switched power filter device (DVS / MPF) to ensure power quality PQ and Minimum Hartmonics (Min^m - Grid Impact) as well as voltage stabilization. *Refer to Dr. Sharaf's papers & MatLab models.



* Select best x - distance to wind location for interface!

Figure 1: Distribution feeder with proposed WECS -Interface at distance X
(25kv - 20 - 40 kilometer feeder)

Requirements:

1) Study the operation of the distribution feeder of figure 1 without and with the wind energy interface conversion dispersed generation for normal and wind / energy excursions. (Use either PM - Synchronous or Induction machine as a wind-generator)
2) Discuss the impact of this WECS on fuse / relay/ C.B. protection coordination at different laterals | Taps and at substation C.B.
3) Design a MPF / SCC / DVS interface scheme based on Dr. Sharaf Design shown in Figure 2 and controlled by the dynamic tri-loop Min^m - impact controller of figure 3
4) Plot the dynamic response of all key voltage, current and compensator / controller variables.
5) Use DVS/MPF or VSI - 6 pulse statcom compensator.

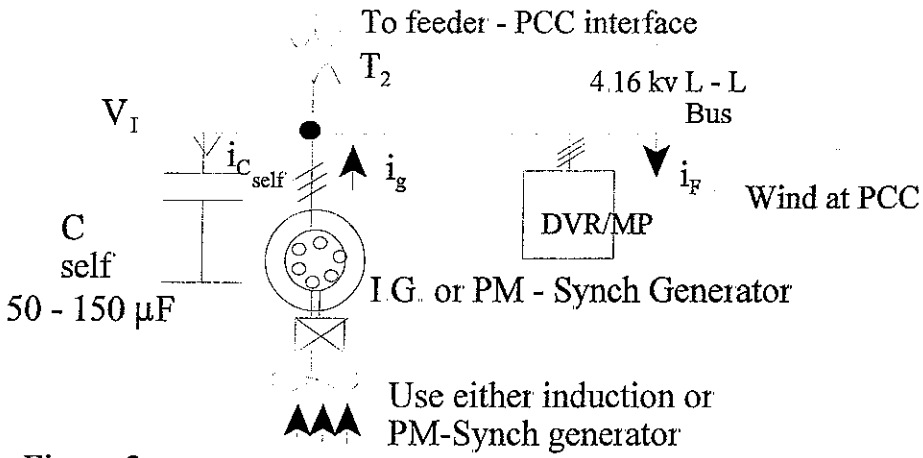
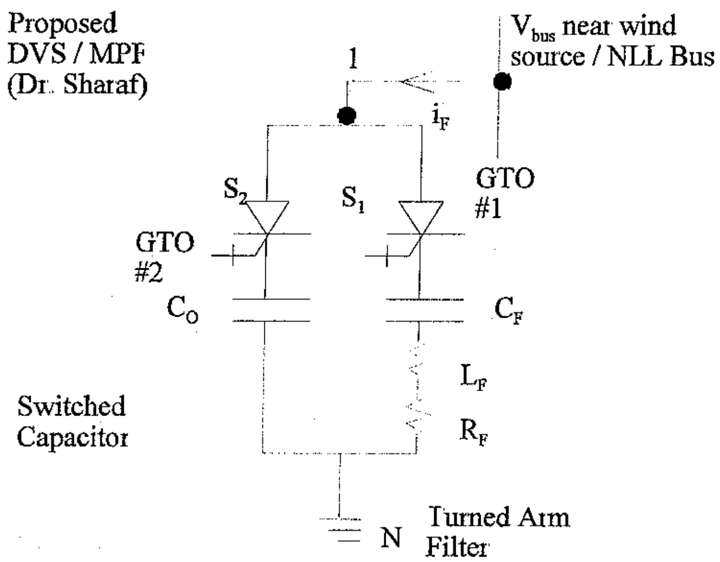


Figure 2

Nonlinear load Use inrush motor Arc furnace or temporal / switched loads

* Turbine 2 - 3 MVA @ 4.16 Kv



Suggested Parameters

$C_O = 20 - 100\ \mu F$
$C_F = 60 - 150\ \mu F$
$L_F = 10 - 50\ mH$
$R_F = 0.15 - 0.2\ \Omega$

Feel free to vary these parameters

Figure 2A: Novel Dynamic voltage regulator DVR / MPF stabilization scheme (see figure 3 for controller) located near wind source or nonlinear load

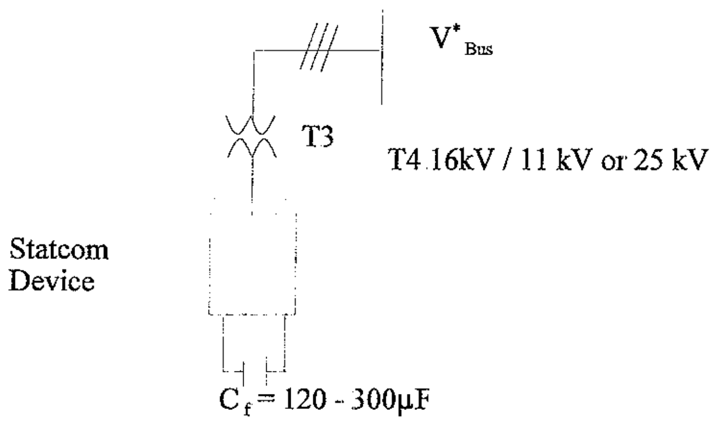


Figure 2B: Statcom

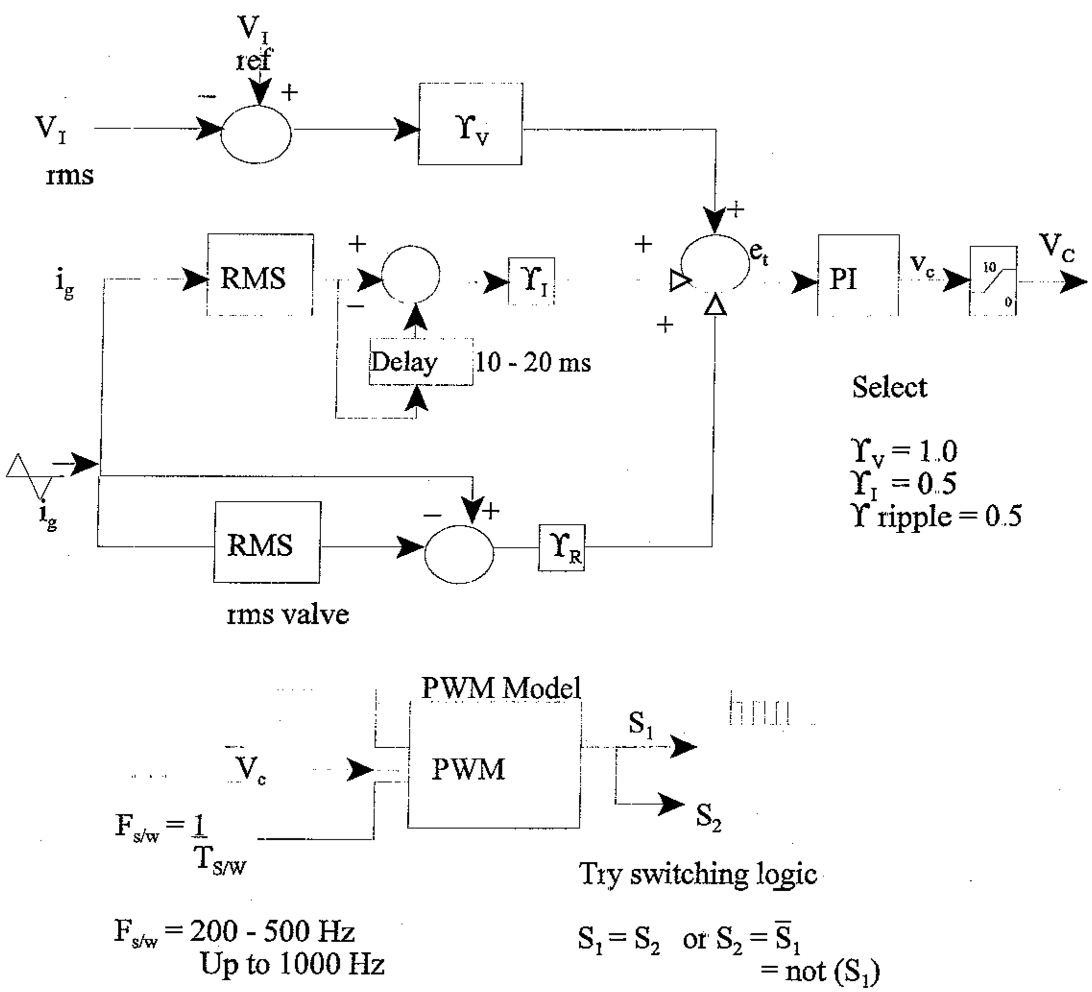


Figure 3: Novel Tri-loop Dynamic error driver controller (Dr.-Sharaf)

TIPS:
Suggest/modify any parametric change or selection
* Refer to Dr. Sharaf's papers

1) Use Matlab / Simulink / is BLKSet
Build in models for generators, Wind Turbine.

2) Modify MPF / Capacitor Shunt parameters to ensure full $| V_T |$ lies within (0.90 - 1.10 pu)
Assume and justify any new parameteric additions or controller structure changes.

3) Plot the phase portraits - volt ampere
* $(_g - V_s - i_g)$
* $(V_g - V_s)$, where $t_g = v_g i_g$ for the wind - generator
* plot all controller key signals e_t, v_c, v_c, S_1, S_2, G_{TO} - switching patterns.

4) Study operation under combined excursions in wind and load up to ± 20 - 50%