Experiences with Small Hydro Driven Portable Generator Sets in Rural Areas

By

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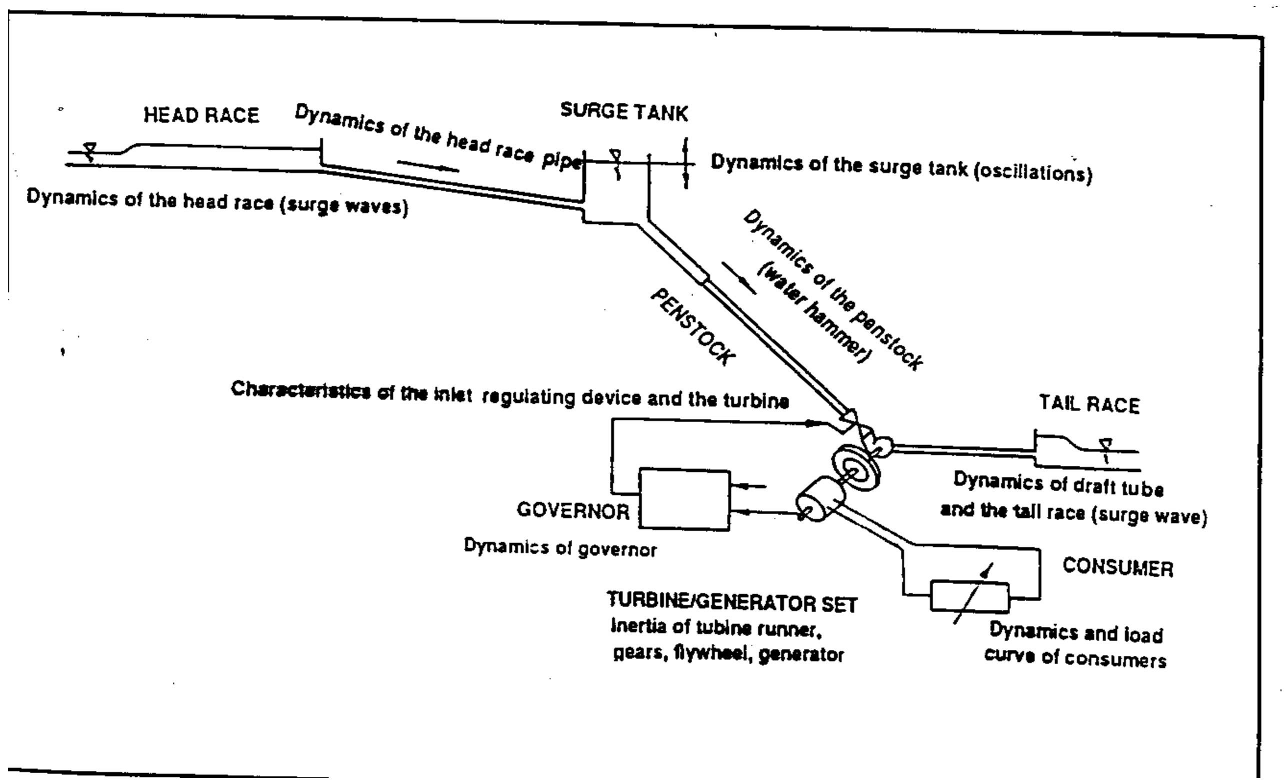
PORTABLE PILOT PROGRAMME ON PORTABLE MICRO HYDEL IN HILLY AREAS

- Scheme initiated by IREDA & MNES in 7 Himalayan Hilly state in 1996
- Total no Sites Identified 50

Layout of a Small Hydro station



Distribution of Portable sets

State	No of sets (Capacity)
1. UP (Uttarakhand)	1. 10 (10kW)
2.Himachal Pradesh	2. 5+10 (10kW & 15kW)
3.Arunachal Pradesh	3. 5 (5kW)
4.Meghalaya	4. 15 (5kW)
5 Bihar (JharKhand)	5. 10 (5kW)
6. West Bengal	6. 5(10kW)
7. Jammu & Kashmir	7. 5(5 kW)

Specifications for Equipment

Absence of discharge data

- **Non availability of spectrum of head**
- **Micro Pelton turbine with 4 nozzle in order to offer flexibility to the quantum of flow by closing 1 to 3 nozzle depending on site discharge(3 to 70 lps)**
- **Head range 30-70 M**
- **Rating Runner PCD Jet dia**
- **5/10kW 250 mm 20.0mm**
- **15 kW 315mm 30.4mm**

Sets were Designed for two Categories.

Runner PCD

- 5/10 kW
- 250mm

- 15kW
- 315mm

Jet dia

- 5/10kW
- 20mm

- 15kW
- 30.4mm

Type of the generating Equipment Purchased

- Pelton Turbine (with Four nozzle Gugler make)
- Synchronous Generator (4 Pole)
- Brushless Excitation System
- Electronic Load Controller (for speed Regulation)

Pilot Programme in Portable Sets

No	**State**	**5Kw**	**10kW**	**15kW**	**Total**
1	Uttarnchal			10	10
2	Himachal Pradesh		5	10	15
3	Arunachal Pradesh	5			5
4	Meghalaya			5	5
5	Bihar(JharkhanD)		5		5
6	West Bengal		5		5
7	Jammu Kashmir	5			5
	Total	**10**	**15**	**25**	**50**

Selection of Euipment

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Portable unit specifications

S.NO	Parameters	Unit	5/10kW	15 kW
	Type of turbine		Vertical Pelton	Vertical Pelton
	Rated Head	m	5-150	5-150
	Turbine speed	rpm	Depends on head	Depends on head
	Runaway speed	rmp	1.8 fold	1.8 fold
	efficiency		87	87
	Turbine generator connection		Belt driven	Belt driven
	Type of generator		synchronous	synchronous
	speed		1500	1500
	Dimension LXWXH	mm	15550x1450x400	15550x1450400
	Complete unit	Kg	300	3245
	Wt of Generator (5 pole 1500 rpm	Kg	120	142

Problems in Commissioning of a Plant

- Head available at site was different than the design head

- Supplied Pulley and belt system was discarded and redesigned to achieve the synchronous speed as per head (no of poles)available at the site.

Pulley Sizing Calculations

Annexure - 4

Head dependent Turbine Speed
Vis-a-Vis
Constant Generator Speed

Turbine Speed (rpm) = $n_1 = \dfrac{k\sqrt{2gH}}{\pi D / 60}$

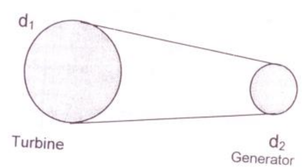
D - Diameter of turbine runner (m)
H - Head acting on turbine (m)
g - Acceleration due to gravity ($9.81\ m/sec^2$)

Since $\dfrac{\pi D n_1}{60} = k\sqrt{2gH}$

k		Head (m)
0.43	for Head	30 - 70 m
0.44	-do-	70 - 100 m
0.45	-do-	100 - 150 m

5/10 kW	D = 250 mm
15 kW	D = 315 mm

The speed derived from the above, for different heads would have to be synchronised with the constant Generator speed of 1500 rpm by providing pulleys of different diameters on the turbine & generator shafts to be operated through a common belt.



$$n_1 d_1 = n_2 d_2$$

where
n_2 = speed of generator i.e. 1500 rpm.
n_1 = speed of turbine
d_2 = pulley dia of generator
d_1 = pulley dia of turbine

Problem in Commissioning

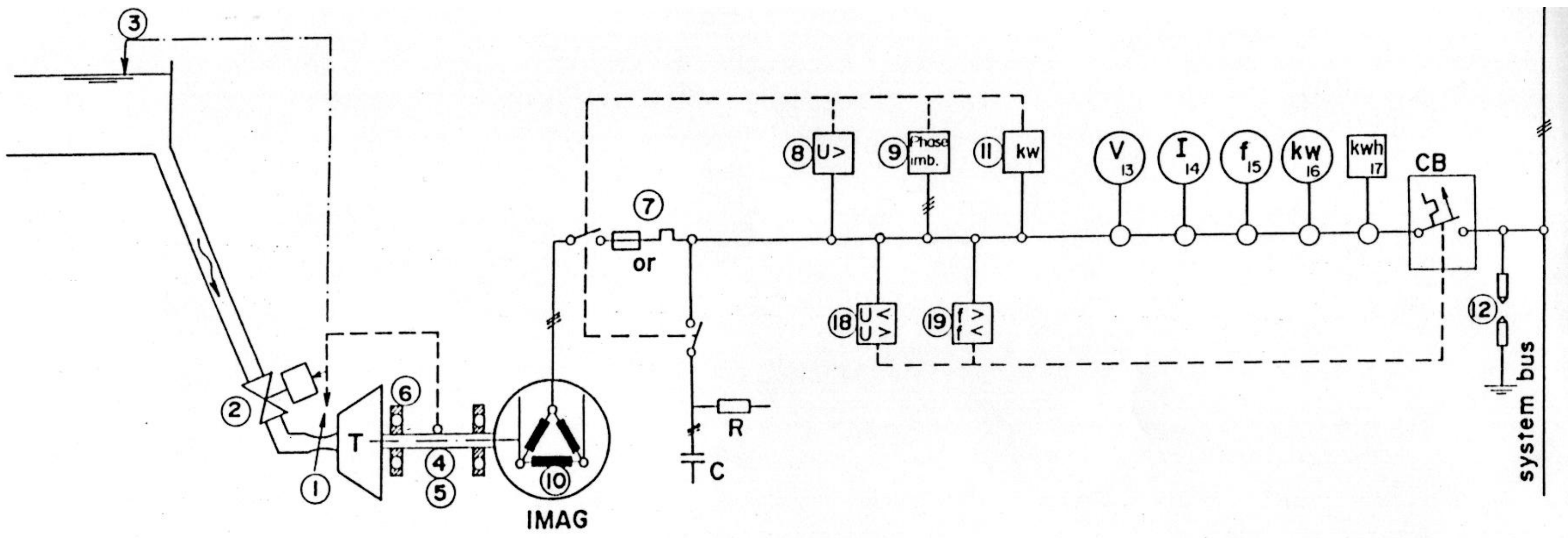
Generator pulley and belt drive were designed to get synchronous speed for a given head

		R	1660						
		K	0.43						
		Head	Turbine pulley	turbine speed NT	Generator rpm NG	Speed ratio SR=NG/NT	**turbine pulley dia DT**	generator pulley dia GT=DT/SR	belt length
Pujrali	15	58	0.28	990	1500	1.52	350	231	2572
pandara	10	30	0.224	890	1500	1.69	224	133	2220
shoon	15	39	0.315	717	1500	2.09	350	167	2472
leo	15	39	0.315	717	1500	2.09	350	167	2472
saichu	15	39	0.315	717	1500	2.09	350	167	2472
sathari	15	39	0.315	717	1500	2.09	350	167	2472
chasak bhatari	15	39	0.315	717	1500	2.09	350	167	2472
chasak	15	39	0.315	717	1500	2.09	200	96	2124
udeen	10	42	0.25	943	1500	1.59	200	126	2171
hillutwan	10	42	0.25	943	1500	1.59	200	126	2171
sahali	10	45	0.25	977	1500	1.54	200	130	2178
sach bhatari	10	45	0.25	977	1500	1.54	200	130	2178

Operation & Maintenance Problems

- No water level sensing device was used at forebay.
- Due to varying flow frequency could not be maintained (Part load operation problem).
- No emergency shut down device was used
- Frequent failure of AVR and controller cards
- Frequent failure of civil works at intake

General layout of an MHP using an IMAG monitoring control and protection equipment



Turbine Control and Protection

1 Turbine gate (guide vane)

2 Emergency shutdown (valve, jet deflector)

3 Water level control

4 Tachometer

5 Overspeed trip

6 Bearing temperature

Generator Protection

7 Overload / short-circuit

8 Overvoltage

9 Phase imbalance

10 Winding temperature

11 Reverse-power relay

12 Lightning arrestor

Station Monitoring

13 Voltmeter

14 Ammmeter

15 Frequency-meter

16 Wattmeter

17 kWh-meter

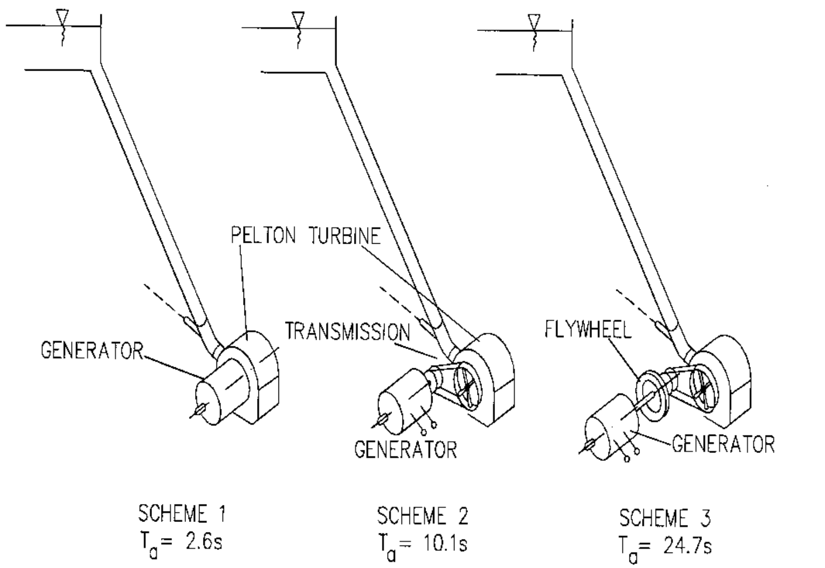
Grid Protection

18 Over- / undervoltage

19 Over- / underfrequency

OPTIMIZING THE PLANT LAYOUT FOR IMPROVING SELF REGULATION OF A SMALL HYDRO POWER PLANT

- DIRECT COUPLED GENERATOR
- DIRECT COUPLED GENERATOR WITH BELT DRIVE AND WITHOUT ANY FLY WHEEL
- DIRECT COUPLED GENERATOR WITH BELT DRIVE AND WITH FLY WHEEL



DIFFERENT LAYOUTS (SCHEME 1, 2 AND 3)

Solution of Allevi ‘s Chart to Compute Rise in Pressure in water column and to estimate the rise and drop in speed with rejection and Application of load

1. Wave propagation speed

2. Accelerating time water column (T_w). Or water starting time

3. Reflection time of pressure wave(T_r)

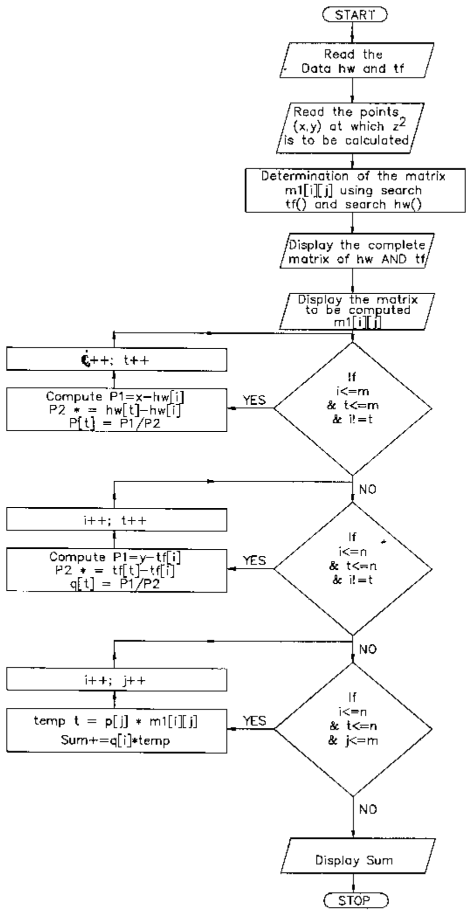
4. Closing time (${T_f}$)

5. $h_w = T_w / T_r$ (water acceleration time/ water reflection time Normally $T_w < T_r$)

6 $Z^2 = (H_{max}/H_r)$

7 Calculate max Rise and drop in speed (± 1.15 to .8 t0 .99)

Coordination of water conductor, turbine & generator time constants

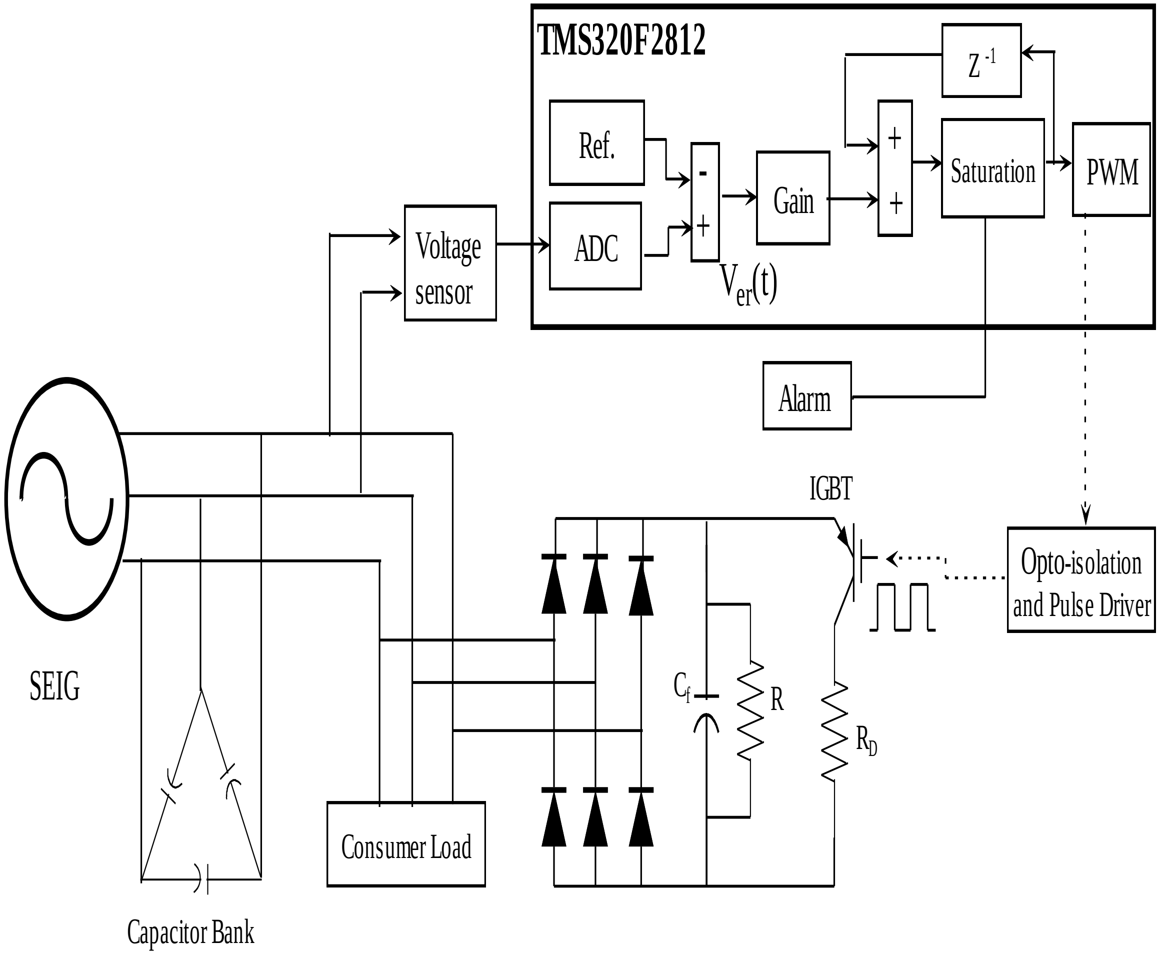


DEVELOMENT OF DSP BASED LOAD COTROLLER FOR THREE-PHASE SEIG

- ***DC controllable load***

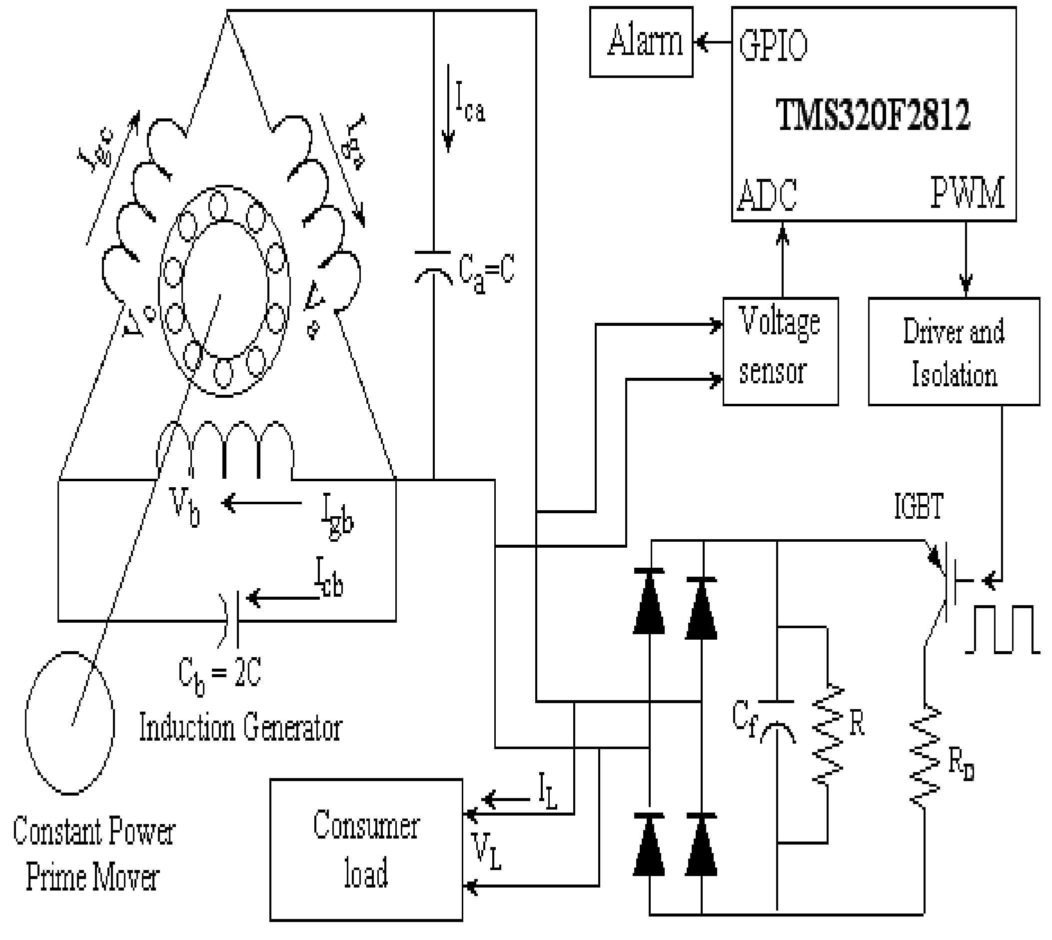
- ***Component required***
- ***Voltage sensor 1***
- ***3 ph rectifier***
- ***DC chopper (1 IGBT)***
- ***DSP and supply***

Random harmonics generated due unsymmetrical control



THREE-PHASE IM AS SINGLE PHASE SEIG WITH LOAD CONTROLLER

- *DC controllable load (Random Harmonics generated)*
- *Component required*
- *Voltage sensor 1*
- *1 ph rectifier*
- *DC chopper (1 IGBT)*
- *DSP and supply*

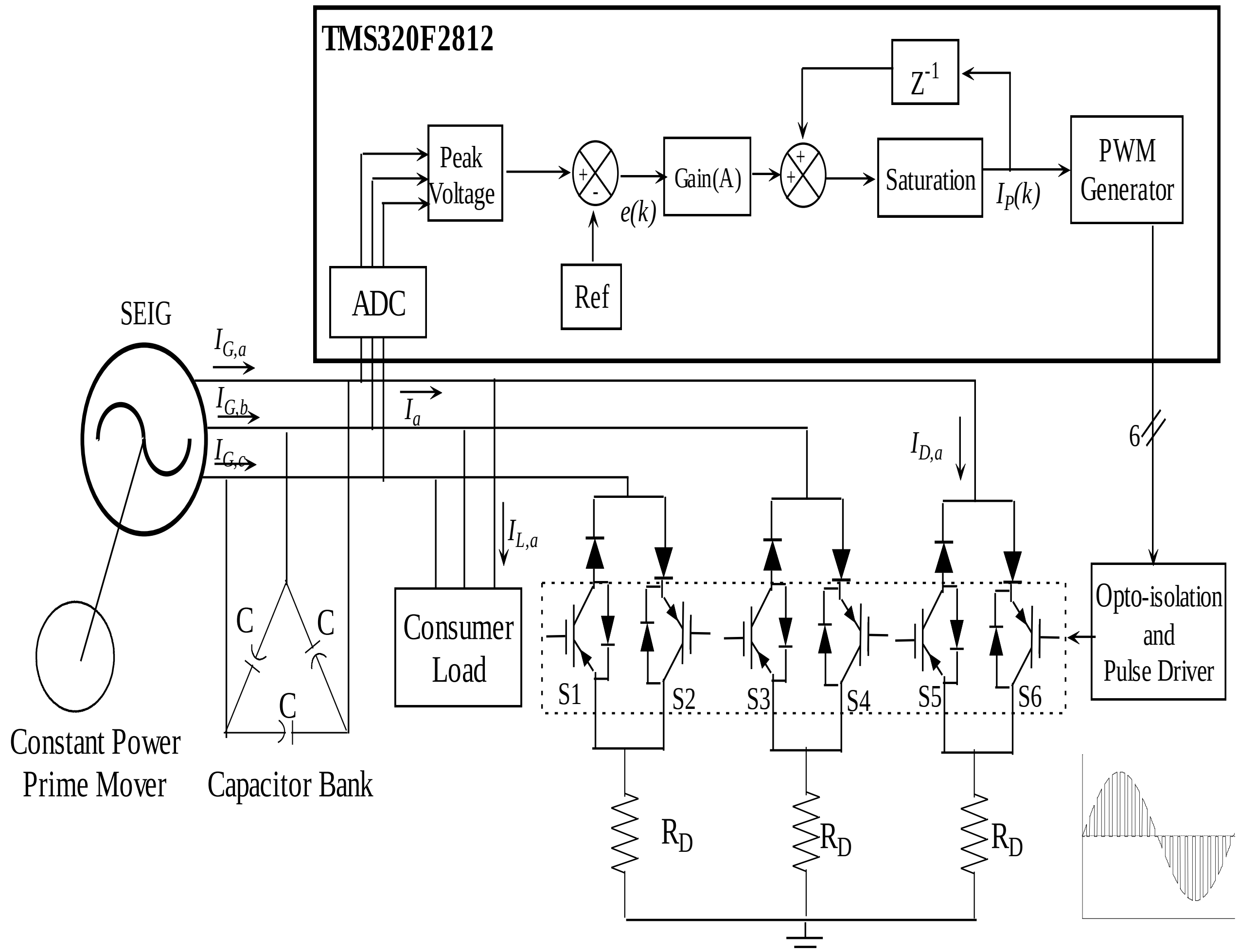


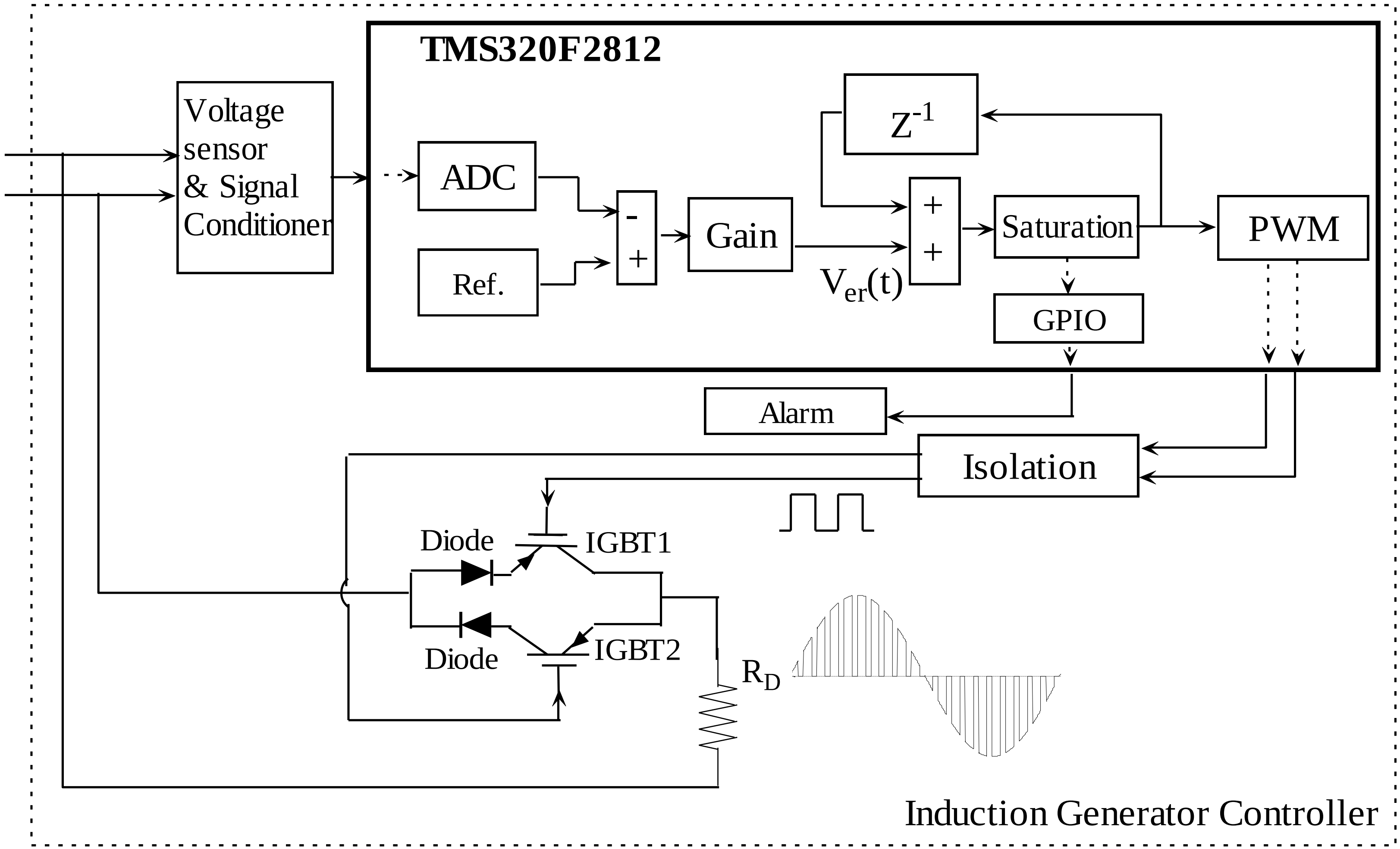
SEIG WITH ETRC AC CHOPPER CONTROL (Symmetric Control)

Component Required

- *AC controllable load (side band Harmonics generated)*
- *Component required*
- *Voltage sensor 1*
- *1 ph rectifier*
- *AC chopper (6 IGBT)*
- *DSP and supply*
- *ETRC and Sinusoidal PWM AC chopper control used*
- *Odd Harmonics appear as side band & integral multiple of switching frequency*

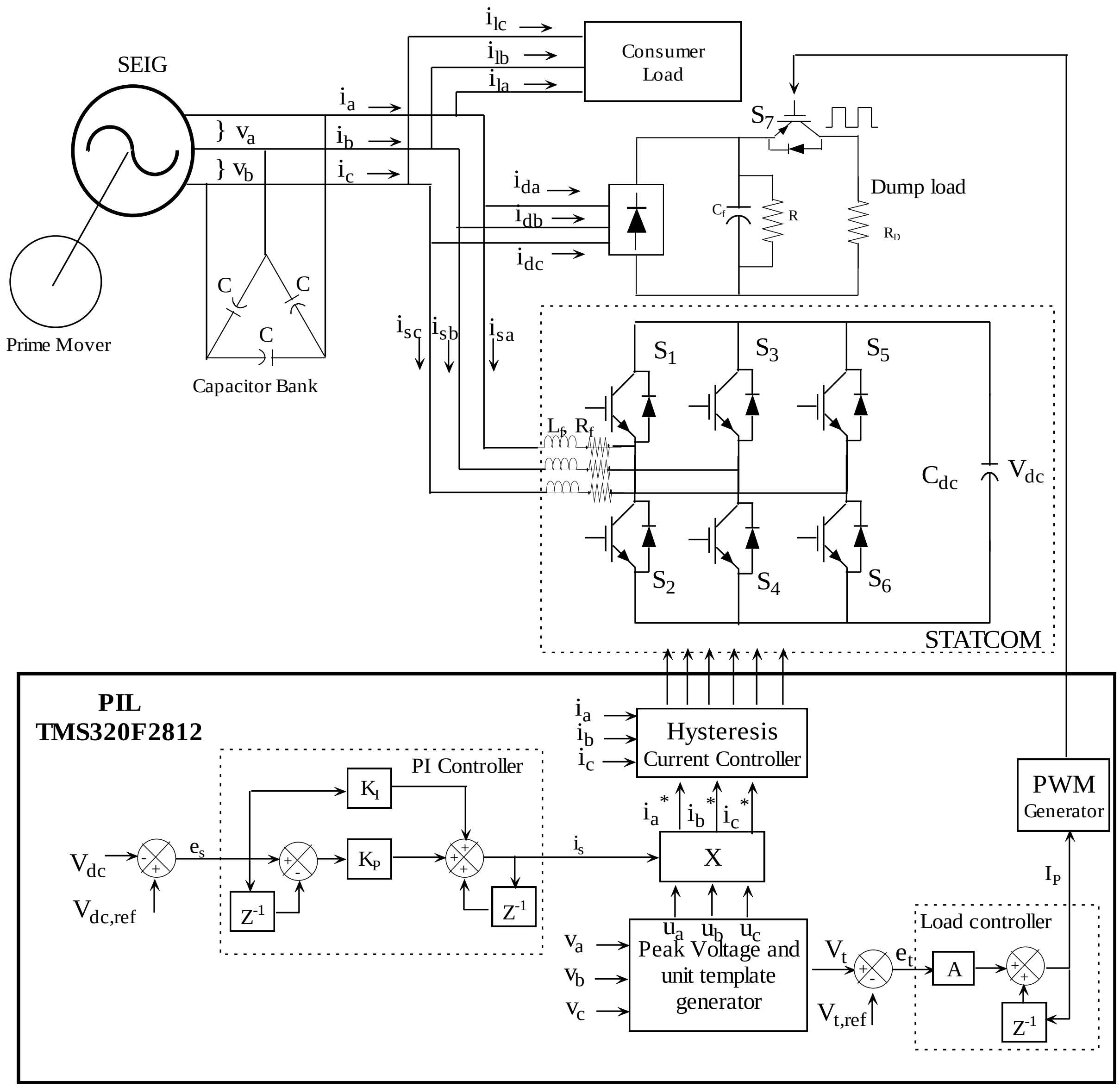
Power & Control Circuit





Schematic diagram DSP based induction generator controller for single phase SEIG.

DSP STATCOM BASED VOLTAGE AND FREQUENCY REGULATION



Schematic diagram of three phase SEIG-STATCOM system.

Controllers for Constant Speed Application

- Development of DSP based load control and protection scheme for stand alone synchronous generator
- Excitation System for synchronous generator
- Control system for parallel operation of synchronous and induction generator

Variable Speed Application

- Variable speed Stand alone Induction generator Cage machine
- Variable speed generators (wound rotor machine to optimize the plant output under varying head conditions(Turbine best efficiency point changes with change in the head conditions subsequently the speed)

Design Softwares Developed

- 1. Sizing of installed capacity of the stand alone power station
- Feasibility Study of SHP
- Energy pricing and Financial analysis (cash flow) for the power scheme with subsidy and without subsidy (computation of IRR, NPV, Unit cost, Debt Service Coverage Ratio etc. (as per Govt. norms)
- Design of Earthing system for SHP
- Design of distribution system

Thanks for Kind Attention