Annexes

Electronics

Numbering of Elements in the Block diagram

1. Gas inlet
2. Valve
3. Electronic heater
4. Electrically controlled shut off valve
5. Electrically controlled valve
6. Controlling signal off the blower
7. High speed Turbine
8. Signal transmitter
9. Asynchronous generator
10. Oil mist lubrication
11. Compressor
12. Water cooling for generator
13. Throttle valve
14. a) Generator side converter
    b) Mains side converter
15. Breaking resistor
16. EMC filter and choke
17. Magnetic switch towards mains
18. Fuse
19. Relay
20. Fuse
21. Relay
22. Fuse
23. Relay
24. Fuse
25. Industrial Computer
26. Monitor

Inverter

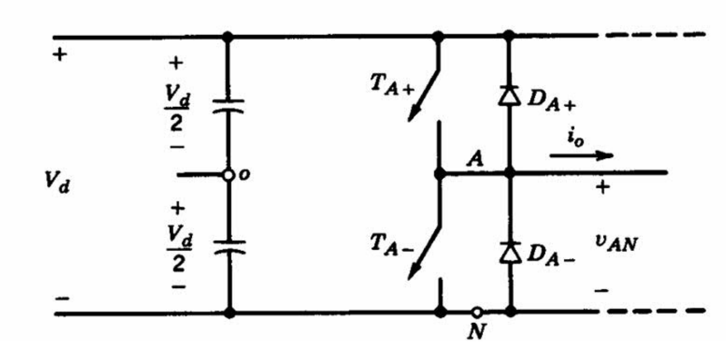

Figure 8-4 One-leg switch-mode inverter.

Switch controlling method based on the relation of the input controlling signals:

$$v_{control} > v_{tri} \quad T_{A+}\ is\ on, \quad v_{A0} = \frac{V_d}{2}$$

$$v_{control} < v_{tri} \quad T_{A-}\ is\ on, \quad v_{A0} = -\frac{V_d}{2}$$

The two switches can never be on at the same time.

Parameter File for the Simulation Inputs

```
%Parameter file

clc;
clear all;

%Carrier frequency in Hz
Vfreq=90;
Vper=1/(2*Vfreq);

%Carrier signal amplitude
Vamp=1;

%Reference Signal frequency in Hz
Sfreq=10;

%Reference signal frequency in rad/s
Srad=2*pi*Sfreq;

%Amplitude of Reference Signal
Samp=0.8;

%Frequency ratio
Ms=Vfreq/Sfreq

%Amlitude Ratio
Ma=Samp/Vamp
```

Fast Fourier Transfer Script for Calculation

```
figure(1);
Fs = 1e3;
T = 1/Fs;
x = ReT.signals.values;
NFFTx = 2^nextpow2(length(x));
X = fft(x,NFFTx)/(length(x));
frx = Fs/2*linspace(0,1,NFFTx/2);
plot(frx,2*abs(X(1:NFFTx/2)))
title('Amplitude Spectrum of Re')
xlabel('Harmonics of f1')
ylabel('|Re(Flux)|')
grid on
axis([0 20 0 0.007])
```

Fluid mechanics

APPENDIX

Error Calculation

1) According to variable p_0:

$$q_V = K_1 \cdot \frac{1}{\sqrt{p_0}}\text{, where } K_1 = \alpha \cdot \varepsilon \cdot \frac{d_{orifice}^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot \Delta p_{orifice} \cdot R \cdot T}$$

With this,

$$\frac{\partial q_V}{\partial p_0} = -\frac{1}{2} \cdot K_1 \cdot \frac{1}{\sqrt{p_0^3}} = -\frac{1}{2} \cdot \frac{K_1}{\sqrt{p_0}} \cdot \frac{1}{p_0} = -\frac{1}{2} \cdot q_V \cdot \frac{1}{p_0}$$

$$\left(\delta p_0 \cdot \frac{\partial q_V}{\partial p_0}\right)^2 = \delta p_0{}^2 \cdot \left(-\frac{1}{2} \cdot q_V \cdot \frac{1}{p_0}\right)^2 = q_V{}^2 \cdot \left(-\frac{1}{2} \cdot \frac{\delta p_0}{p_0}\right)^2$$

2) According to variable T:

$$q_V = K_2 \cdot \sqrt{T}\text{, where } K_2 = \alpha \cdot \varepsilon \cdot \frac{d_{orifice}^2 \cdot \pi}{4} \cdot \sqrt{\frac{2 \cdot \Delta p_{orifice} \cdot R}{p_0}}$$

With this,

$$\frac{\partial q_V}{\partial T} = \frac{1}{2} \cdot K_2 \cdot \frac{1}{\sqrt{T}} = \frac{1}{2} \cdot K_2 \cdot \sqrt{T} \cdot \frac{1}{T} = \frac{1}{2} \cdot q_V \cdot \frac{1}{T}$$

$$\left(\delta T \cdot \frac{\partial q_V}{\partial T}\right)^2 = \delta T^2 \cdot \left(\frac{1}{2} \cdot q_V \cdot \frac{1}{T}\right)^2 = q_V{}^2 \cdot \left(\frac{1}{2} \cdot \frac{\delta T}{T}\right)^2$$

3) According to variable Δp:

$$q_V = K_3 \cdot \sqrt{\Delta p}\text{, where } K_3 = \alpha \cdot \varepsilon \cdot \frac{d_{orifice}^2 \cdot \pi}{4} \cdot \sqrt{\frac{2 \cdot R \cdot T}{p_0}}$$

With this,

$$\frac{\partial q_V}{\partial \Delta p} = \frac{1}{2} \cdot K_3 \cdot \frac{1}{\sqrt{\Delta p}} = \frac{1}{2} \cdot K_3 \cdot \sqrt{\Delta p} \cdot \frac{1}{\Delta p} = \frac{1}{2} \cdot q_V \cdot \frac{1}{\Delta p}$$

$$\left(\delta \Delta p \cdot \frac{\partial q_V}{\partial \Delta p}\right)^2 = \delta \Delta p^2 \cdot \left(\frac{1}{2} \cdot q_V \cdot \frac{1}{\Delta p}\right)^2 = q_V{}^2 \cdot \left(\frac{1}{2} \cdot \frac{\delta \Delta p}{\Delta p}\right)^2$$

4) According to variable d:

$$q_V = K_4 \cdot d^2\text{, where } K_4 = \alpha \cdot \varepsilon \cdot \frac{\pi}{4} \cdot \sqrt{\frac{2 \cdot \Delta p_{orifice} \cdot R \cdot T}{p_0}}$$

With this,

$$\frac{\partial q_V}{\partial d} = 2 \cdot K_4 \cdot d = 2 \cdot K_4 \cdot d^2 \cdot \frac{1}{d} = 2 \cdot q_V \cdot \frac{1}{d}$$

$$\left(\delta d \cdot \frac{\partial q_V}{\partial d}\right)^2 = \delta d^2 \cdot \left(2 \cdot q_V \cdot \frac{1}{d}\right)^2 = q_V^{\ 2} \cdot \left(2 \cdot \frac{\delta d}{d}\right)^2$$

Taking the above equations into consideration the error of the flow rate is the fallowing:

$$\delta q_V = \sqrt{q_V^{\ 2} \cdot \left(-\frac{1}{2} \cdot \frac{\delta p_0}{p_0}\right)^2 + q_V^{\ 2} \cdot \left(\frac{1}{2} \cdot \frac{\delta T}{T}\right)^2 + q_V^{\ 2} \cdot \left(\frac{1}{2} \cdot \frac{\delta \Delta p}{\Delta p}\right)^2 + q_V^{\ 2} \cdot \left(2 \cdot \frac{\delta d}{d}\right)^2}$$

If we divide both sides of the equation with the flow rate q_V then we get the relative error of the flow rate:

$$\frac{\delta q_V}{q_V} = \sqrt{\left(-\frac{1}{2} \cdot \frac{\delta p_0}{p_0}\right)^2 + \left(\frac{1}{2} \cdot \frac{\delta T}{T}\right)^2 + \left(\frac{1}{2} \cdot \frac{\delta \Delta p}{\Delta p}\right)^2 + \left(2 \cdot \frac{\delta d}{d}\right)^2}$$

Estimation of Air Flow Rate

To estimate the flow rate of the air we need to have some information about the engine the Air Flow Meter is used with. The necessary information are: the volume of the combustion chamber, the rotation speed of the crank shaft (rpm), and the construction (2 of 4 stroke engine). We have estimated that the AFM would be for a four stroke four cylinder engine, and the speed range would be 850-6250 rpm. The considered volumes are: 1600, 1800, 2000 and 2500 cc. The used equation is simple, we only need to take into account that the air intake happens for every second revolution of the crank shaft, and we suppose the air is non compressible.

$$q_V = V_{engine} \cdot \frac{n_{engine}}{2 \cdot 60}$$

We can see that the relation between the flow rate and the rotation speed is linear. And for a given engine the volume is constant.

The different colors represent different engine volumes. Yellow stands for 1600cc, Purple is 1800cc, Blue is 2000cc and orange is 2500cc.

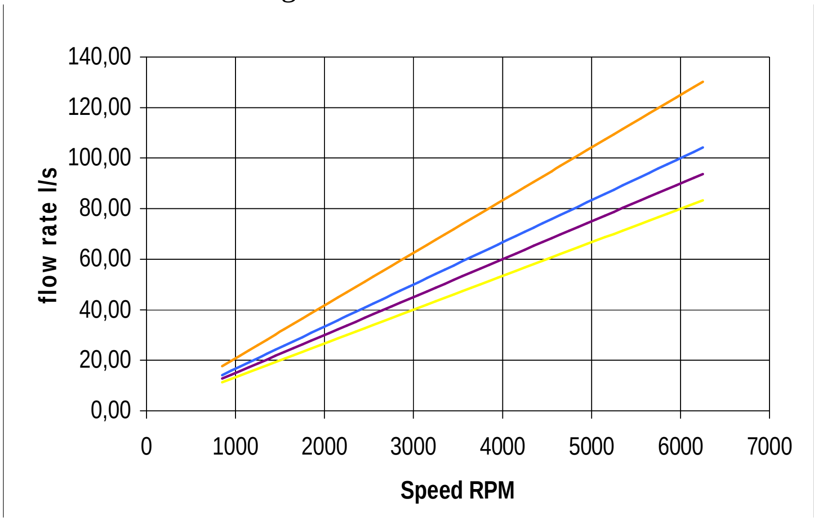

Figure 1, Estimated Flow Rate for Engine

Calculation of Orifice Diameter

Once we know the flow rate we want to measure it is necessary to select a proper orifice diameter for the calibration section of the system. For this purpose I created a Table in Excel. This table contains the pressure difference on the orifice for different orifice diameters. The goal was to have a maximum pressure difference of 5000 Pa. This was a limitation because of the accuracy of the measuring device. And we needed to know for this selection the volume of the engine.

flow rate:	α	ε	ρ air
	0,6	1	1,2

$$q_v = \alpha \cdot \varepsilon \cdot \frac{d^2 \pi}{4} \cdot \sqrt{\frac{2 \Delta p_{MP}}{\rho_{lev}}}$$

$$\Delta p_{MP} = 8 \cdot \rho_{lev} \cdot \frac{q_v^2}{\alpha^2 \cdot \varepsilon^2 \cdot \pi^2 \cdot d^4}$$

orifice diameter d [mm]	Pressure difference on the orifice plate Δp MP [Pa] — q v [m3/s]: 0,001	0,05	0,1	0,13
0,02	16,89	42217,16	168868,64	285388,00
0,025	6,92	17292,15	69168,59	116894,93
0,03	3,34	8339,19	33356,77	56372,94
0,035	1,80	4501,29	18005,15	30428,71
0,04	1,06	2638,57	10554,29	17836,75
0,045	0,66	1647,25	6588,99	11135,40
0,05	0,43	1080,76	4323,04	7305,93
0,055	0,30	738,17	2952,69	4990,05
0,06	0,21	521,20	2084,80	3523,31
0,065	0,15	378,40	1513,62	2558,01
0,07	0,11	281,33	1125,32	1901,79
0,075	0,09	213,48	853,93	1443,15

The standard prescribed also the diameter ratio for the pipe and the orifice plate, this was in the range of 0,2 to 0,75 $(0,2 \leq \beta \leq 0,75)$. The AFM had an output diameter of about 60mm. This means the orifice diameter is limited to 12-45mm. The actual diameters that were manufactured for this measurement are 35-40-45mm. The measurements were made with the 40mm plate.

Measuring Arrangement Details

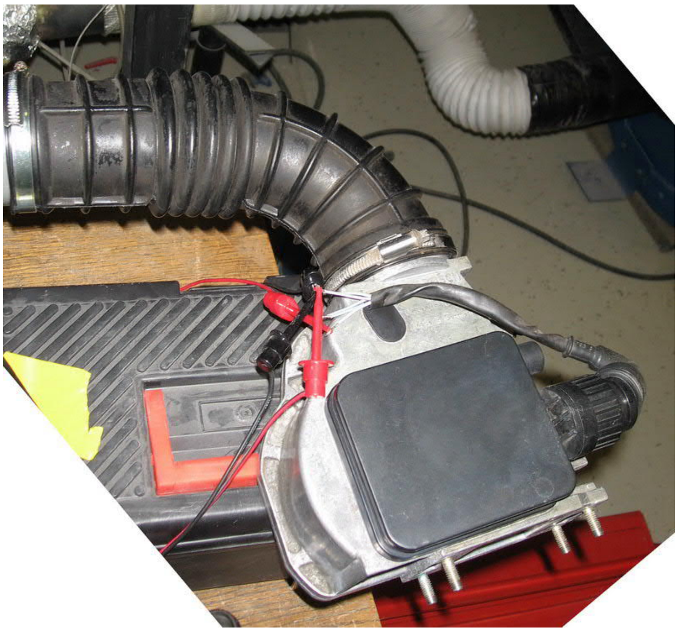

Figure 2, AFM with electrodes applied

Figure 3, Manometer, Voltage Source and Digital Multimeter