1. OVERALL

(1) Environment destruction due to the ozone layer destruction and earth warmth phenomena becomes more serious in these days, while energy demanding increases. To save our earth from such situation, ISO14000 series was established and went into operation.

(2) To protect against earth warmth phenomena, it is necessary to decrease CO_2 which were born by energy consumption, which leads to energy saving.

(3) Present condition of energy consumption.

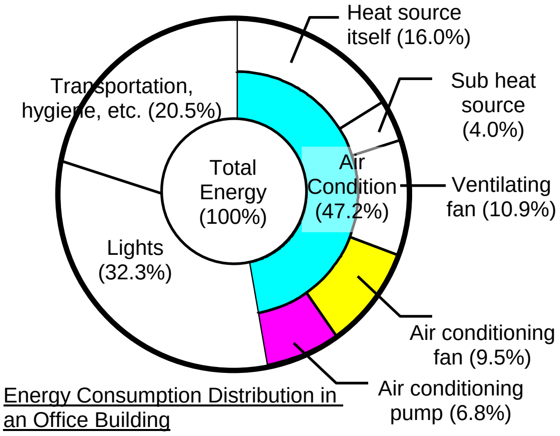
Right figure shows the distribution of energy consumption of a building.

Approximately 50% of the total consuming energy is for the air conditioning. And half of that 50% is used for driving fan and pump system.

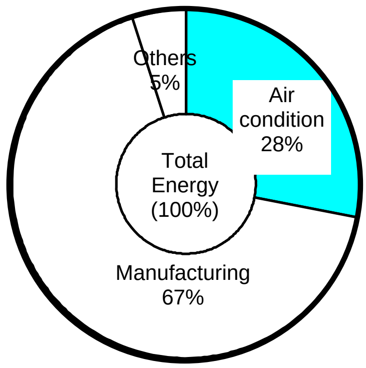
Other than air conditioning, there is a water feeding pump, which means the requirements for driving such fan and pump application is quite big.

Also from the energy consumption of the factory, 30% is for air conditioning.

In this sense the energy saving on fan and pump application is one of the best solution.



Energy Consumption Distribution in an Office Building
(From Architectural design material)



Energy Consumption Distribution in a Car Manufacturing Factory
(G.M.PUBLIC INTEREST REPORT 1979)

Energy Saving Procedure on fan and pump with Inverter

Controlling the speed of fan and/or pump is reducing the required power.

→We recommend to use inverters to control the speed to get energy saving.

< Equipment examples which can achieve energy saving by using inverter >

Pump : Water feeding pump, Air conditioning pump, Pressure pump for factory, waste water pump, Pressure pump for boiler, etc.

Fan : Ventilation fan, Cooling fan for cooling tower, Air conditioning fan (feeding & exhausting), etc.

2. STRUCTURE OF THE INVERTER

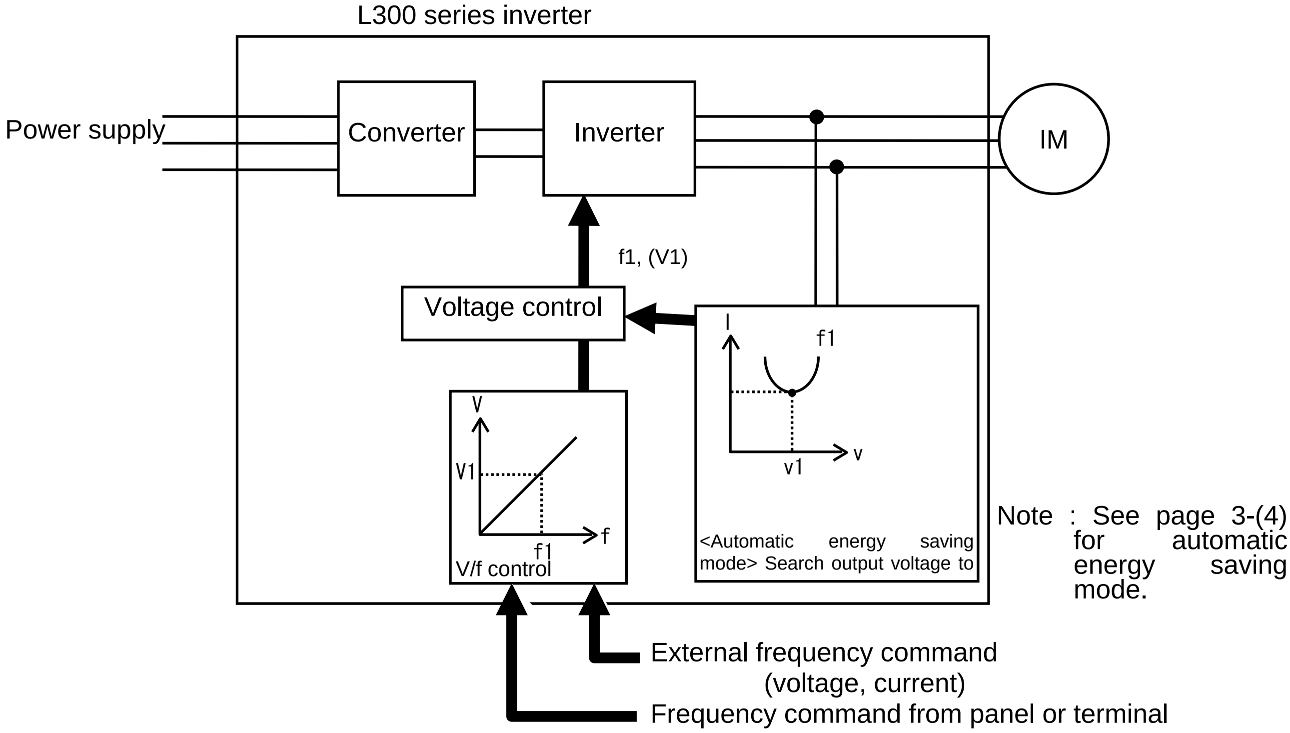


Fig 2-1. Inverter Structure

Inverter changes the supplied AC voltage to DC at converter portion. And change again to a required AC voltage (frequency) at inverter portion. The frequency command is given by external signal (voltage or current) or by integrated panel or from the terminal, and controls the speed of the motor.

In case of fan and pump performance, lower speed gives them the lower power. Therefore if inverter is used, we can achieve energy saving based on this theory.

Moreover, J300 and L300 series have “Automatic energy saving function”, which can achieve more energy saving than normal V/f control.

3. THEORY OF ENERGY SAVING

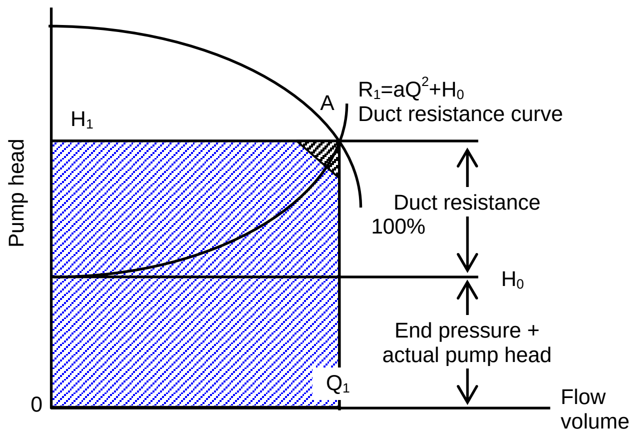
3-(1) Energy saving effect on a pump application

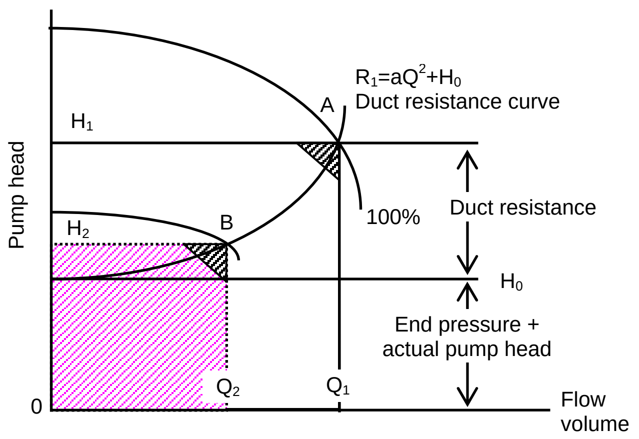
In general, pump performance has the following characteristics.

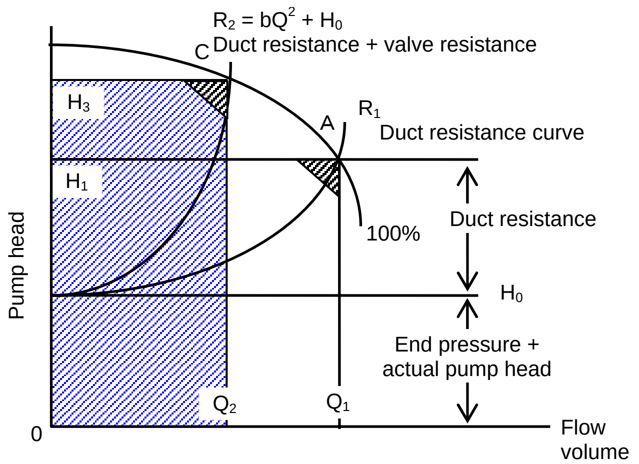
P (required power) $\propto$ Q (flow volume) $\cdot$ H (pump head)

Based on this characteristics, we can get table 3-1, a comparison of the required power between using with commercial supply driving, inverter driving and flow control with valve control.

Table 3-1. Required power comparison

<table>
<tr><th colspan="2"><Commercial Supply (flow volume 100%)></th></tr>
<tr><td>
(1) Frequency : frequency of power source
f_1 = 50Hz
(2) Operation point : A node (A) of pump characteristic curve and duct resistance curve.
(3) Flow volume : Q_1
(4) Pump head : H_1
(5) Required power : $P_1 = K (Q_1 * H_1)$
(Hatching portion of the graph.)
</td><td>


</td></tr>
<tr><th colspan="2"><Inverter Control (controls the flow volume to 60%)></th></tr>
<tr><td>
(1) Frequency : <u>Flow volume is in proportion to the output frequency of the inverter.</u>
$f_2 = 0.6 * f_1$ ($f_2 / f_1 = 0.6$)
(2) Operation point : When changing the flow volume to 60%, the pump characteristic curve comes down as shown in the right figure. And the operation point changes to the point B.
(3) Flow volume : $Q_2 = 0.6 * Q_1 = f_2 / f_1 Q_1$
(4) Pump head : Pump head decreases in proportion to Q^2 (= f^2).
$H_2 = aQ_2^2 + H_0$
$= a(f_2 / f_1 * Q_1)^2 + H_0$
$= a(f_2 / f_1)^2 Q1^2 + H_0$
(5) Required power : $P_2 = K(Q_2 * H_2)$
$= K[f_2 / f_1 Q_1 * \{a(f_2 / f_1)^2 * Q_1^2 + H_0\}]$
$= K[\{a(f_2 / f_1)^3 Q_1^3 + f_2 / f_1 Q_1 H_0\}]$
Required power (= K f^3 ; hatching portion of the figure) decreases.
</td><td>


</td></tr>
<tr><th colspan="2"><Commercial Supply (controls the flow volume to 60% by valve)></th></tr>
<tr><td>
(1) Frequency : f_2 = 50Hz
(2) Operation point : In case of controlling flow volume by valve, valve resistance is added to the duct resistance, and the curve becomes like R2. And operation point comes to a point C.
(3) Flow volume : $Q_2 = 0.6 * Q_1$
(4) Pump head : $H_3 = bQ_2^2 + H_0$
(5) Required power : $P_3 = K (Q_2 * H_3)$
$= K [0.6Q_1 * (b(0.6)^2 Q_1^2 + H_0)]$
$= K [b(0.6)^3 Q_1^3 + 0.6Q_1H_0]$
From this b>a, valve control required more power than inverter driving under same flow volume.
</td><td>


</td></tr>
</table>

From table 3-1.,

> Controlling the flow volume by inverter, required power changes in proportion to the flow (pump rotation) cube.
>
> **P (required power) $\propto$ N^3 (rotation^3)**

For example you decrease the output frequency from 50Hz to 40Hz (80% of the pump rotation), required power becomes approximately half, which you can see in table 3-2..

Table 3-2. power comparison at 80% of rotation

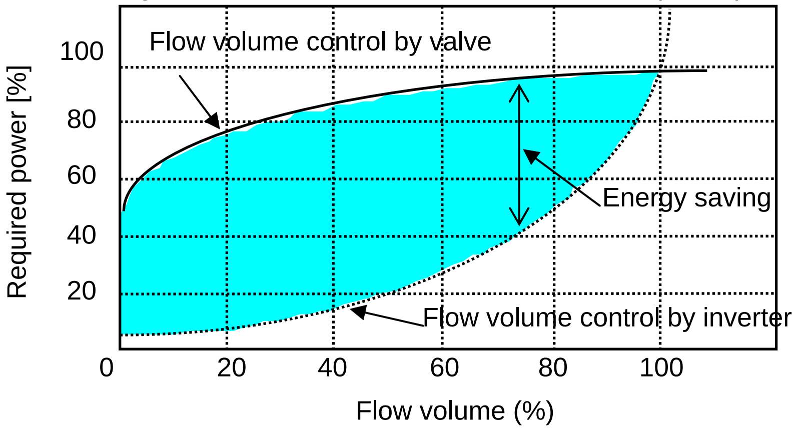
Output frequency Of the inverter	50Hz	40Hz
Flow volume	100%	80%
Power	P_1 (100%)	$P_2 = P_1 * (0.8)^3$ $= 0.51 * P_1$ (51%)

In case of valve control, flow volume decreases. On the other hand the pump head increases. Therefore the power does not decrease so much.

Fig 3-1. Shows the required power for each inverter control and valve control.

With inverter control, you can achieve the energy saving as following hatching portion.

Fig 3-1. Relation between flow volume & required power



3-(2) Energy saving effect on a fan application

Fan performance has the similar characteristics as pump performance.

P (required power) $\propto$ Q (air volume) · H (pressure)

Q $\propto$ N (rotation)

H $\propto$ N^2 (rotation^2)

> Thus, controlling the air volume by inverter, required power changes in proportion to the flow (pump rotation) cube.
>
> **P (required power) $\propto$ N^3 (rotation^3)**

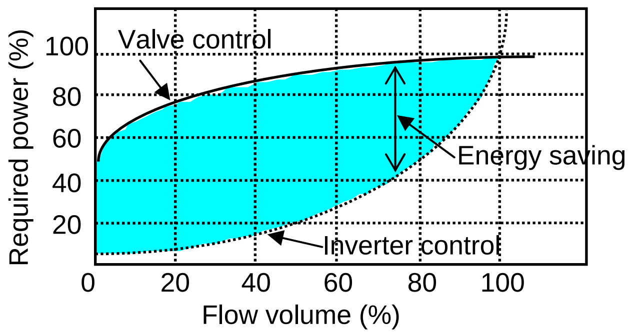
Using inverter on fan & pump control, you can achieve energy saving compared to damper or valve control.

3-(3) Comparison between inverter control & valve control

There are several difference other than required power, shown in table 3-3.

Table 3-3.Comparison between inverter control & valve control

	Valve control	Inverter control
Control range of flow	35 – 100%	10 – 100%
Response	++	+++
Maintenance	+++	+++
Accuracy	+	+++
Installation cost	+++	+
Noise	+	+++
Required power	Almost no difference when controlling flow	Reduce when controlling flow

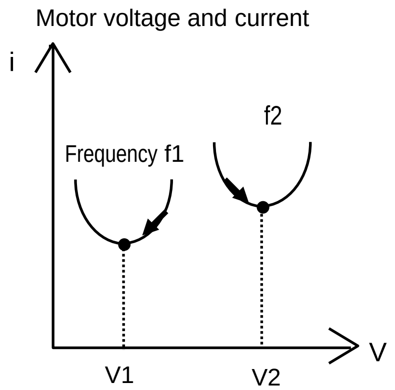


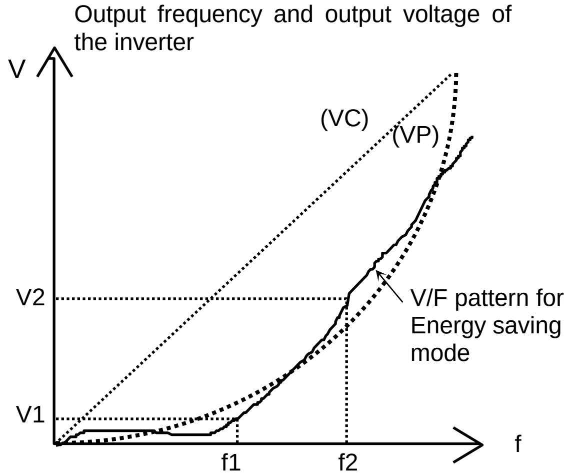
3-(4) Automatic Energy Saving Function

Using inverter for fan & pump application gives you energy saving compared to commercial supply driving. This is because the required power reduces when you use inverter. Additionally, automatic energy saving function gives you more energy saving compared to V/f control. This function is to control (compensate) the output voltage under the same output frequency, so that the motor current becomes minimum.

Automatic Energy Saving Function   Available on J300, L300, SJ300, L300P series.

Inverter controls the output voltage under the same output frequency, according to the change of the load, so that the motor current becomes minimum (= power consumption becomes minimum).





4. ACTUAL DATA ON INVERTER CONTROL

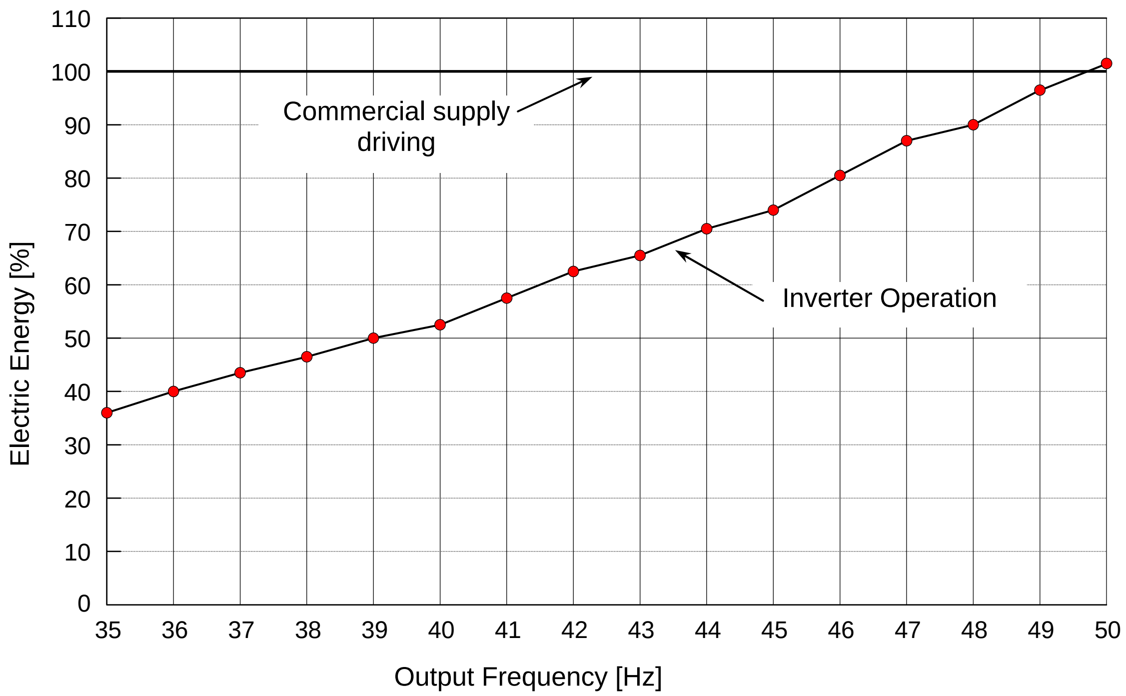
You can find here below two example data of electric energy with fan and pump application with using inverter. (Electric energy = required energy / efficiency)

4-(1) Filter pump for swimming pool (200V, 7.5kW)

Measured data

	Output Frequency [Hz]	Motor output [kW]	Input power Measurement [kW]	Input current Measurement [A]	Motor current [A]	**Electric energy [%]**
Commercial driving	**50**		**6.1**	**19.5**	**19.5**	**100**
Inverter control	50	4.5	6.2	24.5	18.5	**101.6**
	49	4.2	5.9	24.0	18.0	**96.7**
	48	4.0	5.5	22.0	17.5	**90.2**
	47	3.7	5.3	21.5	16.7	**86.9**
	46	3.5	4.9	20.0	16.2	**80.3**
	45	3.3	4.5	19.0	15.6	**73.8**
	44	3.1	4.3	18.0	15.0	**70.5**
	43	2.9	4.0	17.0	14.7	**65.6**
	42	2.7	3.8	16.0	14.0	**62.3**
	41	2.5	3.5	15.0	13.4	**57.4**
	40	2.3	3.2	14.0	12.8	**52.5**
	39	2.1	3.0	13.0	12.2	**49.8**
	38	2.0	2.8	12.0	11.9	**46.4**
	37	1.8	2.7	11.5	11.3	**43.4**
	36	1.7	2.4	11.0	10.6	**39.8**
	35	1.5	2.2	10.2	10.4	**36.1**

Electric Energy Comparison



4-(2) Air feeding fan(200V,22kW)

Measured data

	Output Frequency [Hz]	Supply Voltage Measurement [V]	Input current Measurement [A]	Input power Measurement [kW]	Motor current [A]	**Electric energy [%]**
Commercial driving	**50**	**202.4**	**71.0**	**20.1**	**71.0**	**100.0**
Inverter control	50	203.6	86.2	21.0	70.5	**104.8**
	49	203.7	82.4	20.0	70.3	**99.6**
	48	203.8	78.3	18.8	68.4	**93.8**
	47	203.8	74.4	17.8	67.2	**88.4**
	46	203.8	70.5	16.7	65.6	**83.1**
	45	204.0	66.6	15.7	64.5	**78.1**
	44	204.0	63.3	14.8	63.0	**73.5**
	43	204.1	59.7	13.8	61.5	**68.7**
	42	203.9	56.6	12.9	60.2	**64.3**
	41	203.9	53.5	12.1	59.0	**60.1**
	40	203.5	50.6	11.3	58.5	**56.2**
	39	204.1	48.0	10.6	57.0	**52.7**
	38	204.0	45.0	9.8	56.0	**48.7**
	37	203.9	42.3	9.1	54.3	**45.2**
	36	204.1	39.9	8.4	53.5	**42.0**
	35	203.1	37.3	7.8	52.8	**38.9**

Electric Energy Comparison