



Power generation

Energy efficiency assessment Improving fan system efficiency using Variable Speed Drives

Typical fan system configurations

The largest fans in power plants deliver air to the burners (force draft fan, FD) and extract flue gas from the boiler (induced-draft fan, ID). Plants with flue gas desulfurization may have additional booster fans.

Those large fans range from 1 to 18 MWeI and are usually built as axial fans. Their blades have an airfoil shape and the gas flow is controlled with variable pitch of the rotating blades. Axial fans have higher capital costs than centrifugal fans, and because of more numerous parts and complexity, they also require more maintenance (Black & Veatch, 1996).

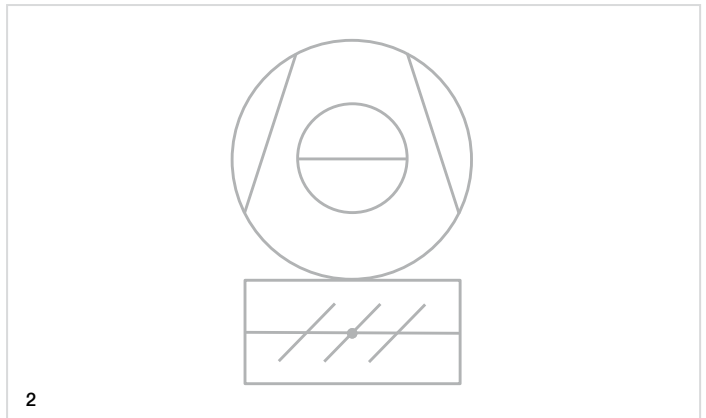
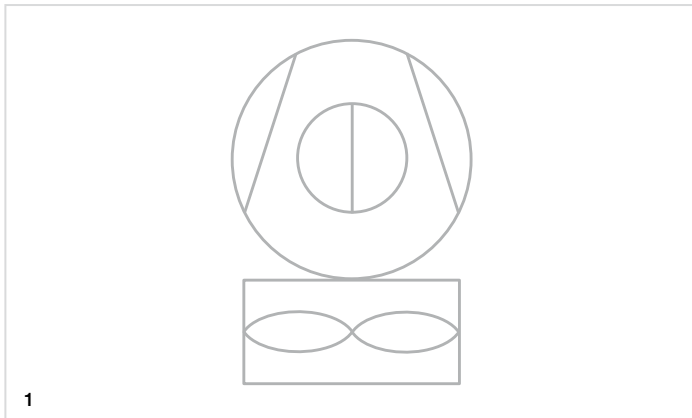
The efficiency of variable pitch axial fan control is similar to that of VFD speed control, but the increased number of moving parts and decreased motor efficiency at off-capacity loading make a VSD an attractive alternative, even on axial fans.

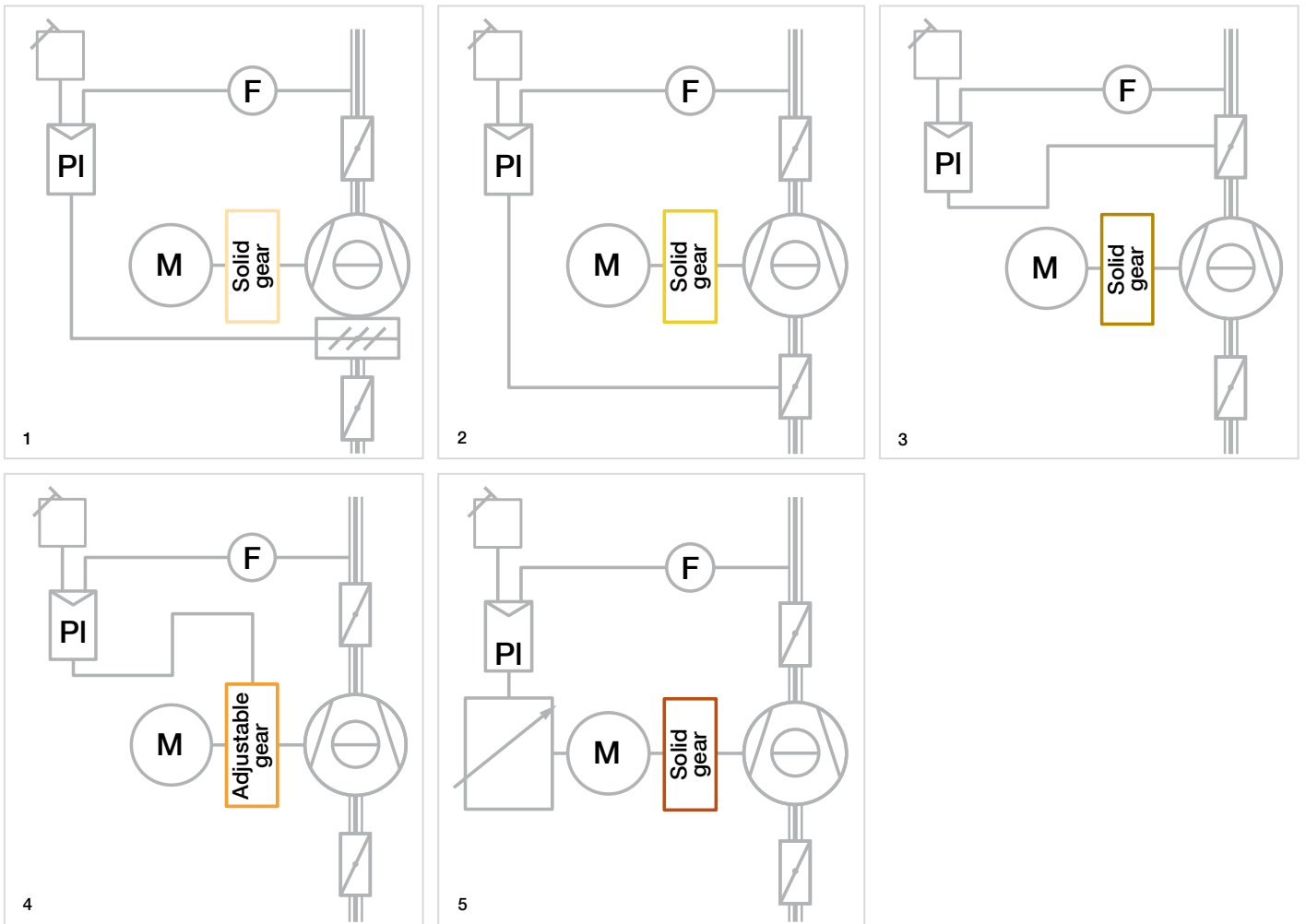
All other fans in power plants are usually smaller, and built as radial fans, also called centrifugal fans.

The pressure and flow characteristics of radial fans are dependent on the orientation and shape of the fan blades, like backward-curved blades, straight 'radial' design, forward-curved blades.

An additional blade design factor is the cross-sectional shape of the blade, which may be flat, curved or airfoil shapes.

1 P&ID symbol for axial fan including rotating blade pitch adjustment | 2 P&ID symbol for radial or centrifugal fan including inlet guide vane | 3 Axial fan example: 324 MWeI coal plant flue gas booster fan | 4 Radial fan example: 441 MWeI coal plant primary air fan





1 Inlet guide vane control | 2 Inlet damper control | 3 Outlet damper control | 4 Adjustable gear control | 5 VSD control

Inlet guide vane control

Motor and fan run with fixed speed. A solid gear may be used, since fan speed may be lower than motor speed. Flow is adjusted with the inlet guide vane position. The guide vane directs the gas into the same direction of rotation as the fan impeller, which reduces the fan flow. Inlet guide vane control is more efficient than inlet dampers due to reduced friction in creating the pre-swirl movement.

Inlet damper control

Motor and fan run with fixed speed. Flow is adjusted with the inlet damper position. The inlet damper directs the gas into the same direction of rotation as the fan impeller, which reduces the fan flow. Inlet damper control is less efficient than an inlet guide vane due to increased friction in creating the pre-swirl movement.

Outlet damper control

Motor and fan run at a fixed speed. The flow is adjusted with the outlet damper position. Outlet dampers are least efficient of all methods. They throttle the airflow to remove power supplied by the fan. As outlet dampers close, the system curve becomes steeper, intersecting the fan curve at the required lower flow rate, and at a point below the fan's best efficiency point.

Adjustable gear control

The motor runs at a fixed speed. The hydraulic gear or eddy-current clutch changes the speed of the fan. The flow is adjusted with the fan speed.

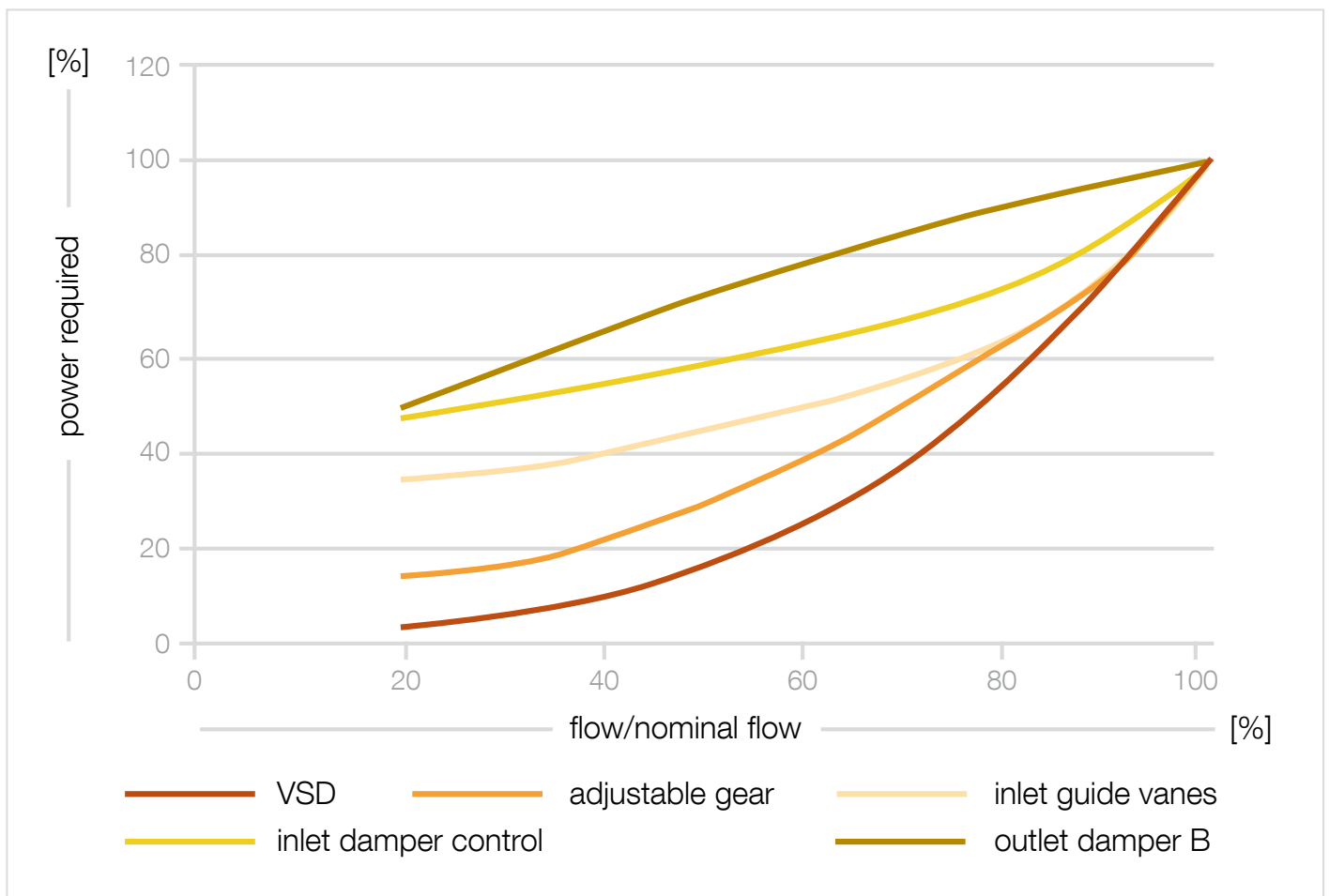
The hydraulic gear includes significant hydraulic friction which can be observed as waste heat at the hydraulic oil cooler. Hydraulic friction has its lowest value at full load (5%) and increases as the load goes down (>20%).

The eddy-current clutch transmits the motor torque and allows slower speed of the fan. The lower the fan speed, the higher the losses.

VSD control

The VSD changes the speed of the motor. Motor and fan are connected directly or via a solid gear.

In applications requiring variable flow and pressure, VFDs are the most efficient method of control. Varying the speed of the fan adjusts the flow rate to the system requirements without the need of additional mechanical devices, and at high efficiency. The VSD has a very high efficiency of around 98 percent over the full operating range.



Percent of design input power over percentage of capacity (Source: "Flow Control" a Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121)

As a summary of the above, fan efficiency at full load (which should be the fans design point) is usually acceptable. The more often a plant is operated at part load, the higher will be the benefit of a VSD. Quite often the fan is oversized, so the fan system runs in part load (=low efficiency) also, even when the plant runs at full load.

A small reduction in speed can make a big reduction in the energy consumption. A pump or a fan running at half speed may consume as little as one-eighth of the energy compared to one running at full speed.

By employing variable speed drives on centrifugal fans, instead of throttling or damping, the energy bill can be reduced by as much as 50 percent. Consequently, electric variable speed drives also help to reduce NO_x and CO₂ emissions.

Besides the electrical savings with VSDs customers achieve further benefits:

- Small flow variations can be corrected more rapidly by a VSD than by other control modes, which improves process control performance.
- Soft starting and reduction in speed reduces fan wear, particularly in bearings and seals. This results in reduced maintenance costs.
- Fan capacity may be a real bottleneck for some plants. VSD over speed may provide the additional capacity needed.

References

The ID fans at a UK power plant (200 kW + 150 kW) were running at full speed with flow control by dampers, but as the boiler ran at low loads for long periods, management believed that energy could be saved with variable speed control. When variable speed VSD drives were installed for flow control, and dampers locked in open position, these benefits were noted:

- Energy saving: 1,000,000 kWh/year
- Reduction in CO₂ emissions: 500,000 kg/year
- Faster response to load changes (Immonen, 2003)
- Noise level reduced from 89 dBA to 77 dBA
- Payback period of just 16 months

A Finnish pulp mill's industrial power plant compared hydraulic coupling to a VSD drive (1,370 kW) for its power plant ID (Induced Draft) fan. The power plant is running continuously and the flue gas flow varies from 50 % to 90 % of the maximum capacity. With VSD drive:

- Energy saving: 376,000 kWh/year
- Reduction in CO₂ emissions: 188,000 kg/year
- Better pressure control
- Less maintenance by soft starting
- Fan critical speeds can be avoided

An industrial power plant compared inlet guide vanes to VSD drives (110 kW each) for its FD (Forced Draft) fan. The power plant is running continuously and the fresh air flow varies from 50 % to 90 % of the maximum capacity.

With VSD drives:

- Power plant FD fan
- VSD drive instead of inlet guide vanes,
- Power plant booster fan
- VSD drive instead of inlet guide vanes
- Energy saving: 482,000 kWh/year
- Reduction in CO₂ emissions: 241,000 kg/year
- Better pressure control with varying loads
- Less maintenance by soft starting
- Efficient combustion

In a drive to reduce the plant's operational costs, Abbott Power Plant engineers selected ABB's ACS1000 standard medium-voltage (MV) drive to control a 1000 hp fixed-speed scrubber booster fan that was previously regulated by inlet vanes, and thereby improved the overall efficiency with reduced maintenance outlay.

- Energy savings of USD \$63,000 per year, an improvement of 25 % on inlet vanes
- Reduced maintenance and hardware savings: USD \$10,000 per year
- Payback on investment period was 24 months
- Additional benefits of the variable speed drives include:
 - no motor start-up problems
 - total process controllability

Typical fields of implementation in power plants:

- Primary air fans (PA)
- Secondary air fans
- Over-fire air fans
- Purge-air blower
- Cooling-air blower
- Mill fans
- Gas recirculation fans (GR)
- Stack blower
- FGD air fans

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