VFD retrofit program for fixed speed electric motors (TopVFD)

Rolf Tieben, Impact Energy

Rita Werle

Conrad U. Brunner

Petar Klingel

Abstract

Topmotors is the national information and awareness raising program for efficient electric motor systems in Switzerland, supported by the Swiss Federal Office of Energy (SFOE) and operated by Impact Energy in Zurich. Between 2010 and 2014, Topmotors has analyzed a total of 4142 electric motor systems in detail as part of the financial incentive program "EASY" [1]. One finding of the investigation was, that only 19.5% of the electric motors were equipped with a variably frequency drive (VFD). Studies of Topmotors indicate, that a VFD would be useful in around 60% of all applications and could reduce energy consumption. For this reason, the financial incentive program "TopVFD" was launched in March 2019 to equip existing motors that are operated at constant speed with VFDs.

TopVFD is supported by the financial incentive program ProKilowatt within the framework of the competitive tenders [2] under the direction of the Swiss Federal Office of Energy (SFOE). TopVFD has a total budget of 1 million USD and a duration of 3 years.

The program targets electric motor systems in industry, large (public) buildings and infrastructure facilities.

Eligible for funding are motors which are

- larger than 7.5 kW output power
- younger than 6 years.

For motors older than 6 years, the upgrading to an IE4 motor (applied together with a VFD) is also eligible for financial support. The goal of TopVFD is to save 32.8 GWh of electric energy over the lifetime of the motors.

In addition to financial support for components, TopVFD also includes other services. Participants have access to a network of service companies that have been trained and can measure important parameters for understanding the entire motor system. These findings help the machine owner and the service companies to improve and operate the plant in the best possible way, from an energy efficiency point of view. The measurements and analyses can also be financed through the program. TopVFD provides not only financial support but also important technical expertise for the upgrading of fixed speed systems to speed controlled systems.

Background

During the financial incentive program EASY [1] 4 142 electric motor systems have been analyzed. A number of data such as age, output and operating hours were evaluated. The findings of the analyses have already been presented in an ACEE paper [3].

The 3 main findings of the investigation are:

1. motors are too old
2. motors are oversized
3. **only 19.8% of the motor systems already have a VFD**

Finding no. 3 as shown in Figure 1 was the impulse to propose the new financial incentive program TopVFD. Further investigations in other projects have shown that 50-60% of all motor systems can be operated successfully with a VFD and save a considerable amount of electricity.

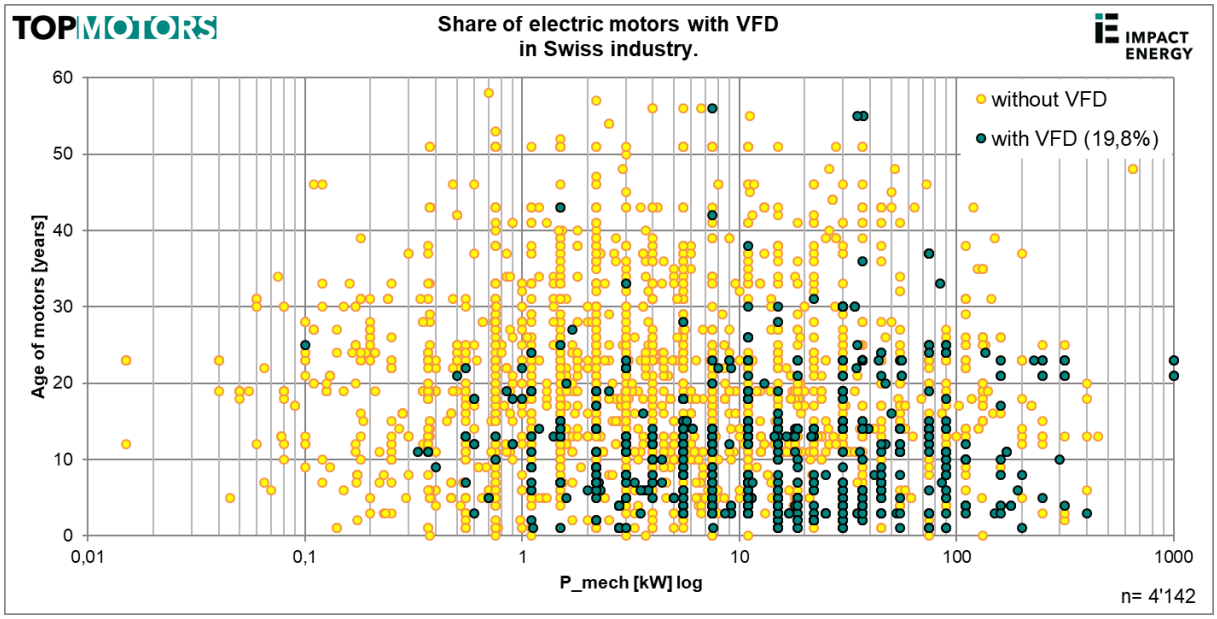

Figure 1 Share of electric motors with VFD in Swiss industry

There is a large reduction potential for almost every second uncontrolled motor system that can be saved with the useful retrofitting of a VFD. Therefore, Topmotors designed a new financial incentive program called TopVFD. The program has a duration of 3 years and is supported by the Swiss Federal Department of Energy with a total of USD 1 million. It has started on 01 March 2019 and will end on 01 March 2022.

Goal

TopVFD aims to increase the share of VFD controlled motor systems in the Swiss industry to reduce energy consumption through speed control. A VFD can reduce the input power of an electric motor system by the reduction of speed whenever the required load allows for reduced the flow. Especially in closed pump and fan systems, significant savings can be achieved. TopVFD is trying to increase the share of motors driven by a VFD, thus gathering measured data of real industry applications and generate best practice cases which can then be published to encourage other industry companies with comparable cases.

Within TopVFD, a total of 32.8 GWh electricity shall be saved during the lifetime of the optimized motor systems (15 - 25 years). This shall be achieved with the following three different measures:

measure	quantity	total financial support [USD]	creditable lifetime	Cumulative electricity savings [GWh]
retrofit VFD control	13	65 000	15	2.3
VFD + IE4 Motor < 20 kW	55	330 000	15	11.7
VFD + IE4 Motor ≥ 20 kW	40	280 000	25	18.8
Total	108	675 000		32.8

Table 1 Three main savings measures

Methodology

TopVFD is providing financial and technical support to owners of motor driven systems. All low voltage motor systems with a nominal output power >7.5 kW can profit in two cases:

- less than 6 years in service: upgrade with VFD
- more than 6 years in service: upgrade with VFD + new IE4 Motor

The economic parameters are defined by the SFOE in such a way that highly profitable projects with a calculated payback of < 4 years are not supported.

The calculation of the actual state, the target state and the electricity savings are based on a variety of data of former analyses and experiences. For the success of the program, it is imperative to give an early rough estimate of a potential electricity saving before any electric or mechanical measurements have been made on-site. With this estimate, also a first rough number of the potential subsidy can be estimated. During the course of the program sequential calculations based on detailed estimates and on-site measurements are made, also to finally check the success of the installed VFD and motor.

Thus, the calculation tool is based on a number of default values and assumptions. With the annual duration of operation (h/a), estimated by the owner, and a description of the motor (age, output power (kW), efficiency class) and the type of application (pump, fan, etc.), a first estimate of the electricity needed in the actual state is possible with a calculation based on a number of standard operation models (constant load, daily or weekly part load cycle, intermittent batch operation, seasonal temperature characteristics, etc.).

Participants of the TopVFD program have to deliver only a few basic information of their existing motor system to get a first estimate of the possible financial support. The following information is needed to calculate the financial support:

1. nominal output power of the motor (kW)
2. efficiency (existing motor: IE code)
    - IE1 (eff2)
    - IE2 (eff1)
    - IE3
3. operating hours per year (h/a)
4. application
    - pump, open system, < 20 kW

- pump, open system, > 20 kW
- pump, closed loop, < 20 kW
- pump, closed loop, > 20 kW
- ventilation fan
- conveyor
- other motor driven systems

Based on these inputs, the web-based software tool uses a database with several values to calculate the electricity savings. Every possible combination of output power, efficiency and application has individual default values like load profiles (actual & target), prices (motor, VFD, installation, measurements), efficiency (motors, VFD, motors driven with VFD), standby losses, etc. is taken into account. As a new feature, the calculation includes part load efficiencies of motors and VFDs.

The reduction of rotating speed of the motor causes a reduction of the electric input power whenever less than 100% output power is necessary. Depending on the application (pumps, fans, conveyor) different physical effects occur.

Figure 2 illustrates the energy savings potential of a closed loop systems with VFD compared to throttling the flow. A reduction of the rotating speed causes a reduction of the input power according to the affinity laws with the 3rd power. This means, reducing the flow Q (m^3/h) by 20% will save almost 50% of electric input power P (kW). In an open loop pump the savings are much less, because the reduced flow only induces a linear energy reduction.

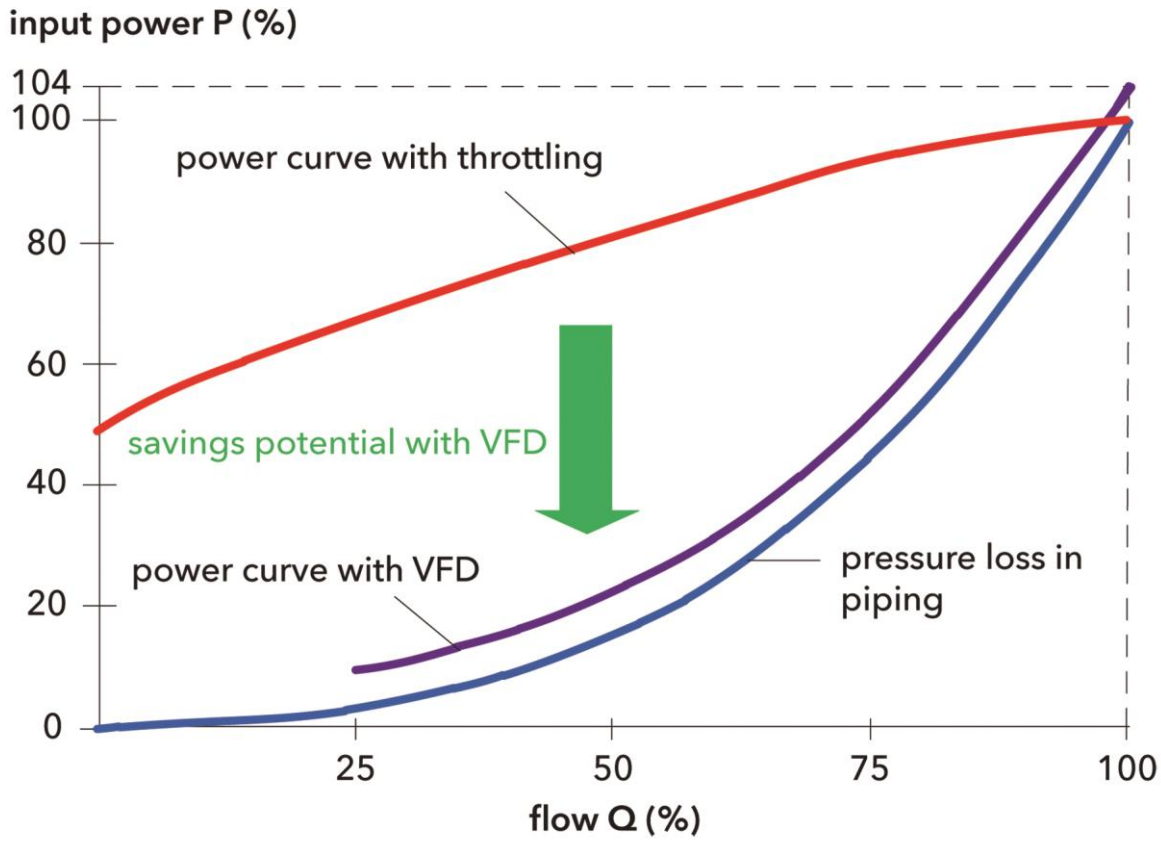

Figure 2 Savings potential of a VFD by speed reduction in a closed loop system

This effect generates a big energy savings potential with all ventilation and closed pump systems.

VFD efficiency

TopVFD has to consider for the estimate of the energy savings the change in efficiency from an existing fixed speed system to a load-controlled system. The fixed speed system involves only the motor efficiency at nominal and partial load and the efficiency of the application (pump, fan, etc.). In the improved system, the estimate has to include the efficiency of the VFD in full and partial load and changes of the partial load situation for the motor and the application.

The VFD losses have been published for the reference converter at IE1 efficiency level for nominal and partial load (speed and torque) situations in IEC 61800-92, edition 1, 2017 [4] .

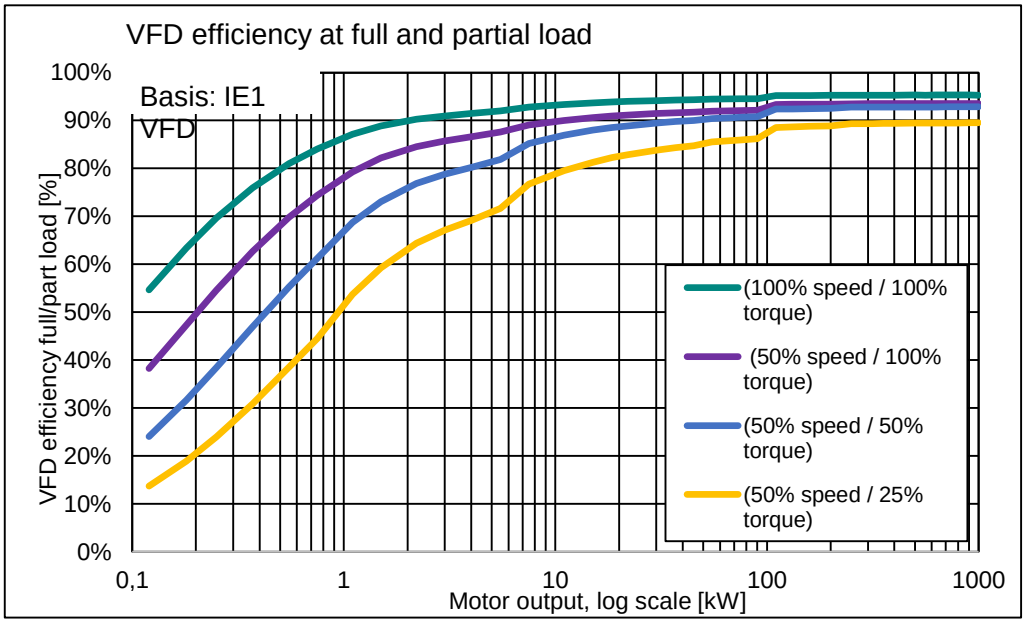

Figure 3 **VFD IE1 efficiency at full and partial load (source: IEC 61800-9-2, edition 1, 2017, [4])**

Figure 3 shows two important elements of the VFD IE1 efficiency:

- The VFD efficiency is heavily dependent on the output size: below 2 kW output the efficiencies at nominal output decrease from 90 % down to 0.12 kW with 55 %. Above 20 kW to 1000 kW the nominal VFD efficiency is practically constant at around 94 % to 95 %

- The VFD efficiency at partial load decreases heavily. At 50 % speed and 25 % torque (equivalent to 12.5 % load) in the yellow curve, the efficiency drops above 110 kW by 3 %, at 22 kW by 11%, at 11 kW by 14 % and at 1.1 kW by 34 %.

This means, oversized systems have a problem with the efficiency gain from VFDs. Only properly sized that eventually also operate during a considerable time in the upper part between 50 % and 100 % of the nominal output have a good chance to reap high efficiency gains.

For the calculation of the savings the estimate of the eventual optimum load profile is the crucial default value. This load profile cannot be calculated ex ante but only measured ex post after a successful installation of a VFD. Theoretically, a test run with a mobile VFD can be used in the actual situation to check on rotating sped and torque variations that are applicable in a given system.

The calculation model therefore refers to conservative estimates of improvement of load profiles due to VFD operations and respective efficiency gains. Clients tend to be happy if a lower estimate of the savings at the beginning turn out higher at the end than the other way around.

Expert network

To promote the TopVFD program, a network of around 15 service companies and manufacturers has been established in Switzerland.

The service companies have been exposed to the TopVFD program, its scope, its tools and its goals. The key engineers have been assembled in a full day training course also to learn to operate the respective software tools and to exchange experiences with electric measurements and their interpretation.

They benefit from the program as preliminary investigations (measurements) can be financially supported and the customer receives up to 30% of the project costs as a contribution from TopVFD. This significantly increases the probability that a customer will decide to implement the project. There is also a chance that the client will implement more and/or use better components.

These companies have routinely contacts with their customers, who are our main target group. The task of the members of the expert network is to consult their customers and to inform them about the funding opportunities.

The companies are not financially compensated for their support through the program. However, they benefit from the sales and when special services such as measurements or the implementation of the optimization itself are ordered by the customer.

The service companies routinely change motors and add VFDs. But they do not use sophisticated calculation tools to estimate the prospective energy savings. TopVFD tries to improve the predictability of the eventual savings.

Current state of TopVFD

The program has been developed in the first 2 quarters of 2019. The website including the calculation model and all information like "General Terms of Conditions" and marketing material are currently under development. At the same time, the expert network will be expanded and a training of the participants will be staged. The first advertising campaigns have been made in the summer of 2019 and are designed to make the promotional program known to the industry. Interested parties can register for participation since May 2019.

Outlook

The program is fully operational since summer 2019 and will support projects throughout Switzerland until spring 2022.

Within TopVFD, a total of 32.8 GWh shall be saved during the lifetime of the optimized motor systems (15 - 25 years).

References

[1] EASY - Efficient Motor Systems in Industry, Financial incentive program, 2010 - 2014, Impact Energy, Zurich

[2] ProKilowatt, National incentive program for electricity savings, Switzerland, www.prokw.ch

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[4] IEC 61800-9-2, edition 1: Adjustable speed electrical power drive systems - Part 9-2: Ecodesign for power drive systems, motor starters, power electronics and their driven applications - Energy efficiency indicators for power drive systems and motor starters, Geneva, Switzerland, 2017