RICE

# MVD Pump Save User Guide

## Advanced version

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# Abstract

This report is intended to be used as a user guide for developed software MVD Pump Save beta 3.2. The software tool has been developed in order to provide advanced comparison of operational and economical features under various operational conditions. It is able to compare a few currently in use control principles of pumps. All considered controls are compared with variable speed drive (VSD) with frequency converter.

The software offers advanced user interface tools enabling the user to define and modify in detail all necessary data of all components included in chain – motor, pump, system and control element/method. The detail data are then used in advanced computation core.

The software also includes basic economical evaluation features such as operational costs, payback period or lifetime savings calculations.

The software already includes default case study ready to be used for testing and learning purposes for pumps. However, the basic parameters can be modified by user according to particular application and data.



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# List of shortcuts

**VSD** ……. **V**ariable **S**peed **D**rive

**FC** …… **F**requency **C**onverter

**HC** …… **H**ydraulic **C**ouplings

**NPV** …….. **N**et **P**resent **V**alue

**CFC** …… **C**ompared **F**low **C**ontrol

**VFC** …….. **V**ariable-Speed **F**low **C**ontrol

**MVD** ……. **M**edium **V**oltage **D**rive

# 1 Introduction

This report has been written as a user guide for a software tool MVD Pump Save beta 3.2 which is an advanced version of previous release MVD Pump & Fan Save It introduces the software and provides user over the whole workflow.

MVD Pump Save tool has been developed in order to provide sophisticated comparison of operational and economical features (e.g. operational costs, payback period or lifetime savings calculations) under various operational conditions. It is able to compare a few currently employed control principles of pumps. All considered controls are compared with VSD with frequency converter.

## 1.1 System requirements

- Operating system
  - Microsoft Windows XP with Service Pack (SP 3), Windows Server 2003 with SP1, or later operating system running Microsoft Office 2010 and higher.
- Microsoft Excel 2010.

## 1.2 MS Excel settings

The application MV Pump Save is intended to be operated under the MS Excel 2010 software. Thus, following guide is demonstrated on this version.

First step - it is necessary to **enable macros immediately after application startup** according to Fig.1.

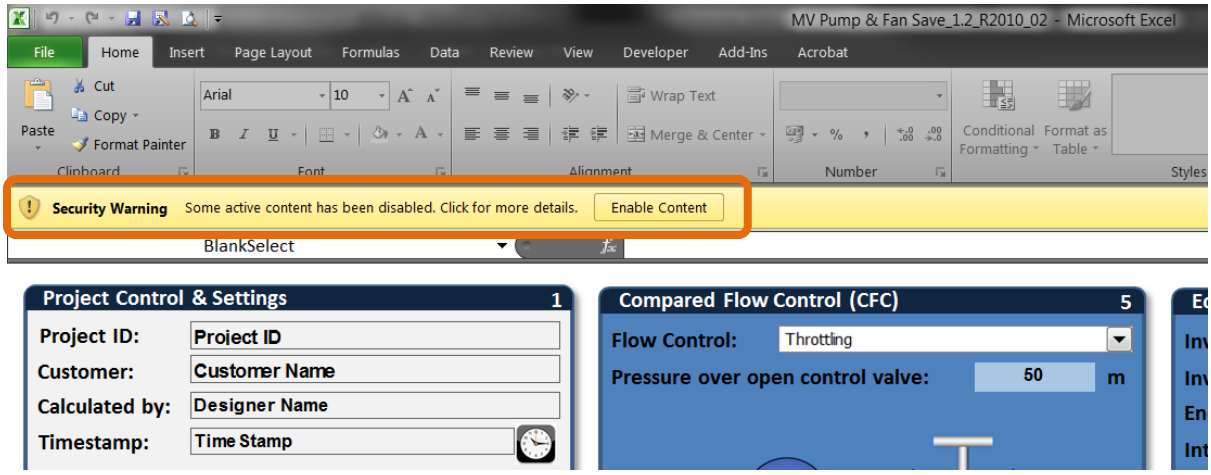



***Fig.1*** *MS Excel - Security Warning*

# 2 User Interface Description

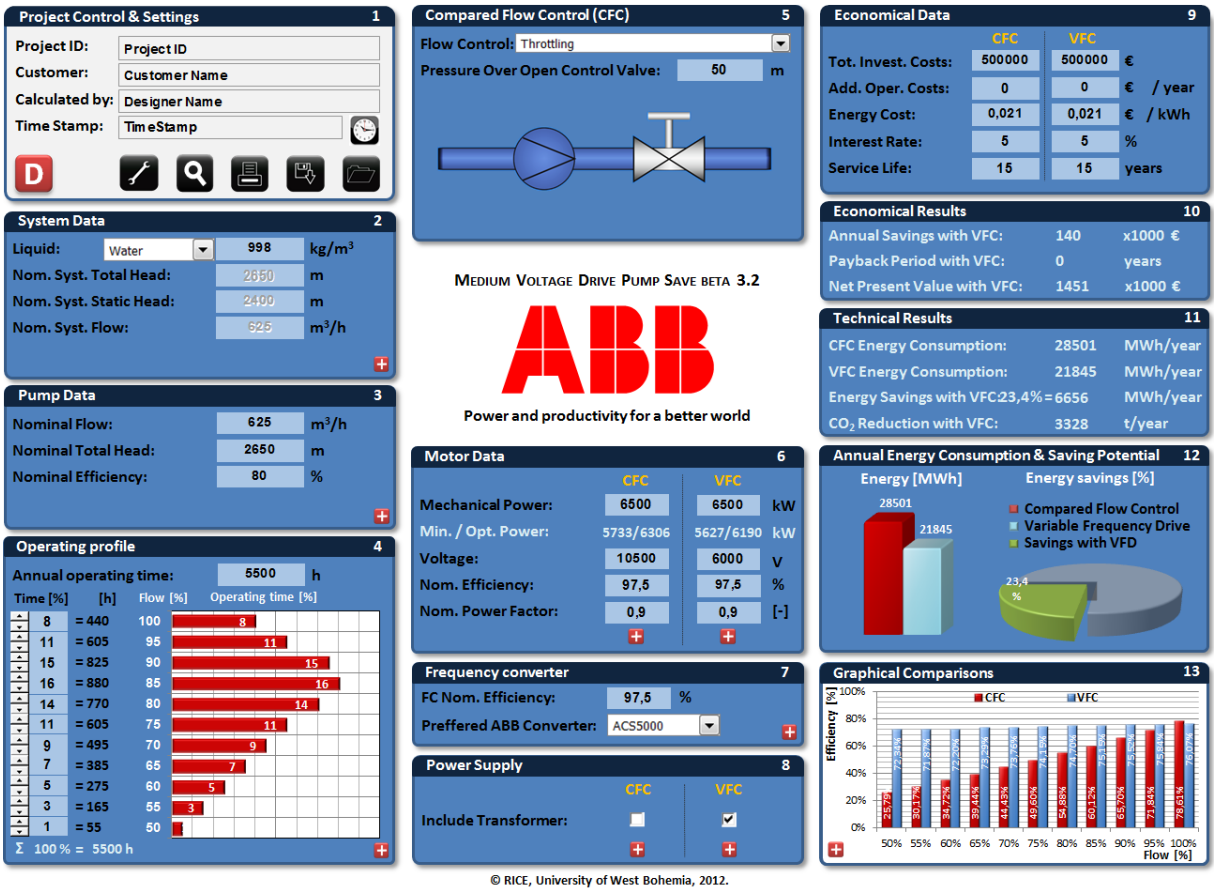



*Fig.2 User Interface Controls*

The user interface has two levels: Basic user interface and Enhanced user interface. Within the basic interface user can set up basic operating data of system, pump, operating profile and flow control to be compared with VSD with frequency converter. This part of interface is displayed in Fig.2. The enhanced user interface enables the user to define in detail parameters of the system, pump, operating profile, CFC, motor data, frequency converter and power supply. The advanced interface is activated by pressing the "plus" button placed in the bottom of the tabs (see Fig.2).

# 3 User workflow

In this chapter, all blocks will be described according to their numbers placed into the top right corner.

## 3.1 Project Control & Settings

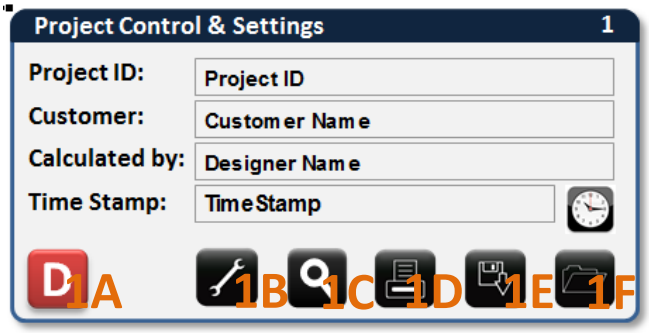



*Fig.3 Project control & setting entry*

In this entry, user can fill in following project data:

- Project ID
- Customer name
- Designer name (calculated by…)
- Date/time stamp – user defined
- Format or system time by pressing the clock button .

**1A.** *Default case study.* By pressing this button user can anytime reset all values into default values – all entries will be reset and all values recalculated.

**1B.** *Settings button.* Selection of metric/imperial system and currency (including current exchange ratio).Zoom button – auto adjusting the user screen according to current screen resolution.

**1C.** *Zoom button*. Auto adjusting the user screen according to current screen resolution.

**1D.** *Print*. Whole case study printing into the form of report.

**1E.** *Save button*. Save case study in unique format (*.vsd) into file able to be opened again with load button.

**1F.** *Load button*. Load a case study from *.vsd file.

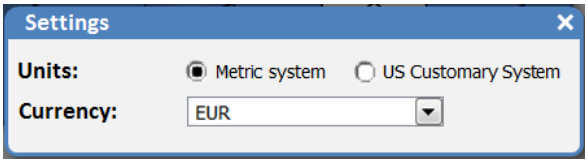



*Fig.4 Selection of units and currency system*

The *settings button* should be pointed out. After pressing this button, **Chyba! Nenalezen zdroj odkazů.** will appear where selection of metric/imperial system and currency (including current exchange) can be done. Default system is metric (SI), default currency is Euro.

***Important:* Change of units and/or currency will cause recalculation of actual values in the whole document!**

## 3.2 System Data

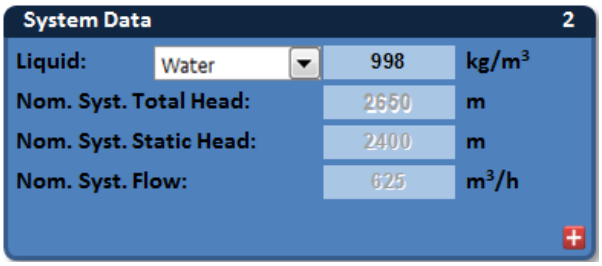



*Fig.5 Basic system data entry for Pump*

User can select type of liquid from the list of typical ones or to define his/her own liquid by entering desired liquid density (Fig.5).

By pressing the "plus" button, window Enhanced System Data appears (see Fig.6). The left hand side enables entering system parameters and define system curve. At the right hand side the system curves are plotted in relation to pump nominal curve (top) and sum of static and dynamics head. The default values correspond to default system values and are plotted also in Fig. 6. All pressure quantities are given in meters of current liquid.

**2A.** *Nominal Flow.* User can enter nominal flow value. Units used here are $m^3/h$.

**2B.** *Op. Limits of Nominal*. User can define operational control range of the pump.

**2C.** *Nom. Total/Dynamic*. Changing total head causes corresponding change in dynamic head only.

**2D.** *Nominal Static Head*. Nominal static head is given by nominal value in table **2I**.

**2E.** *Static Head Curve Type.* User can switch between constant static head curve and linear static head which increases linearly with respect to flow.

**2F.** *$CO_2$*. Entering weight of $CO_2$ emissions produced within 1 kW of pump output power.

**2G.** *Temperature*. Entering temperature of pumped liquid.

**2H.** *Real Nominal Operating Point Values (Calculated).* Real nominal operating point is calculated as an intersection of system curve and pump nominal curve. This block is useful especially in case when the user enters his/her system curve.

**2I.** *User System Curves – Input Data Source.* User can choose either the curve calculated from nominal values or the curve calculated from table entry. Choosing the table entry, areas **2D** and **2E** become inactive.

**2J.** *User System Curves – Table Entry.* User can define his/her own system curve which is given as a sum of dynamic $H_D$ and static part $H_S$. There are some restrictions on the system curve given by the table entry

- The system curve has to be increasing.

- The system curve has to lie in the operational area whose border are defined by dashed lines (Fig. 6, right, top – Pump VSD Flow Restriction)

If user crosses the restrictions, blocks 2 and 3 get red after closing the Enhanced System Data Window and user is forced to correct his/her data entry.

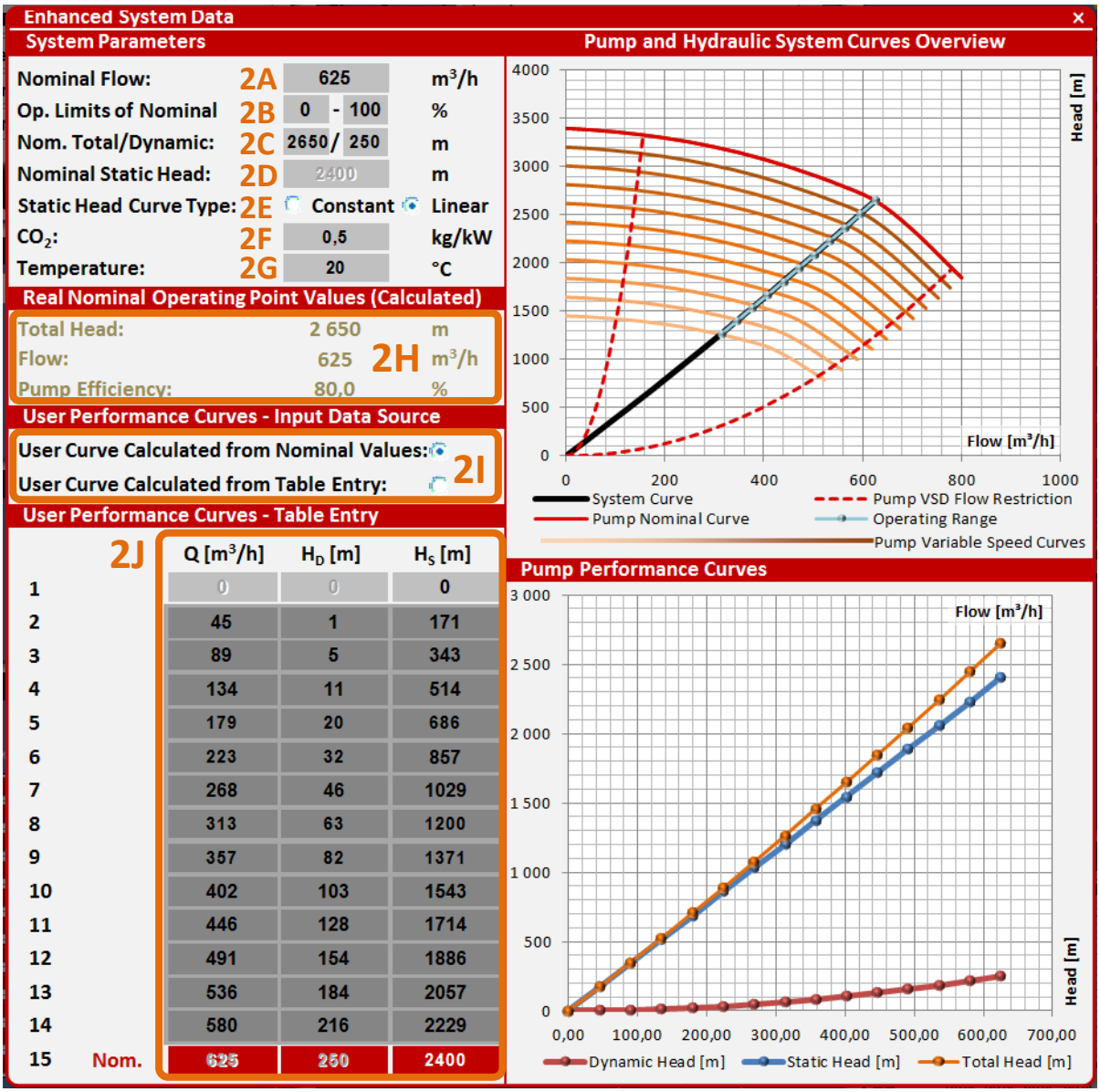



*Fig.6 Enhanced system data entry for System*

## 3.3 Pump Data

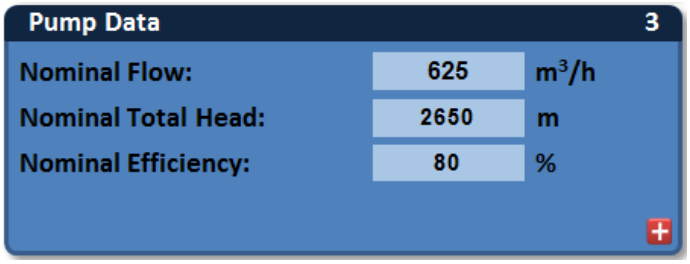



*Fig.7 Pump data entry*

This entry (Fig.7) serves for entering nominal pump values of flow, total head and efficiency.

Similarly to System data (chapter 3.2) by pressing the "plus" button, window Enhanced Pump Data appears (see Fig.8). The upper and left hand sides enable entering pump parameters and define pump performance and efficiency curve. At the right hand side the system curves are plotted in relation to pump nominal curve (top) and pump performance and efficiency curves (bottom). The default values correspond to default system and pump values and are plotted in Fig.8. All pressure quantities are given in meters of current liquid.

**3A.** *Nominal Flow.* User can enter nominal flow value. Units used here are $m^3/h$.

**3B.** *Op. Limits of Nominal Flow.* User can enter range of flow in percent with respect to the value of nominal flow. The operational range is indicated by dashed lines in the upper plot in Fig.1.

**3C.** *Nom. Total Head.* User can enter value of nominal total head of the pump.

**3D.** *Nominal Efficiency.* User can define nominal pump efficiency.

**3E.** *Nominal Speed.* Entering nominal pump speed.

**3F.** *Include Gearbox.* By ticking, user can select whether the gearbox is included into CFC and VFC. If the gearbox is selected, user can define *User Ratio* and *Efficiency* of the gearbox.

**3G.** *User ratio.* The value is the ratio of pump speed to motor speed.

**3H.** *Efficiency.* The value gives gearbox efficiency.

**3I.** *Real Nominal Operating Values (Calculated).* This block summarized final nominal operating values.

**3J.** *User Performance Curves – Input Data Sources.* User can choose either the curves are calculated from nominal values or the curves are calculated from table entry. Choosing the table entry, areas **3A**, **3C** and **3D** become inactive.

**3K.** *User Performance Curves – Table Entry.* User can define own pump performance and efficiency curves. Moreover, the nominal operating values can be changed by choosing one of the rows in the table entry by clicking proper radio button.

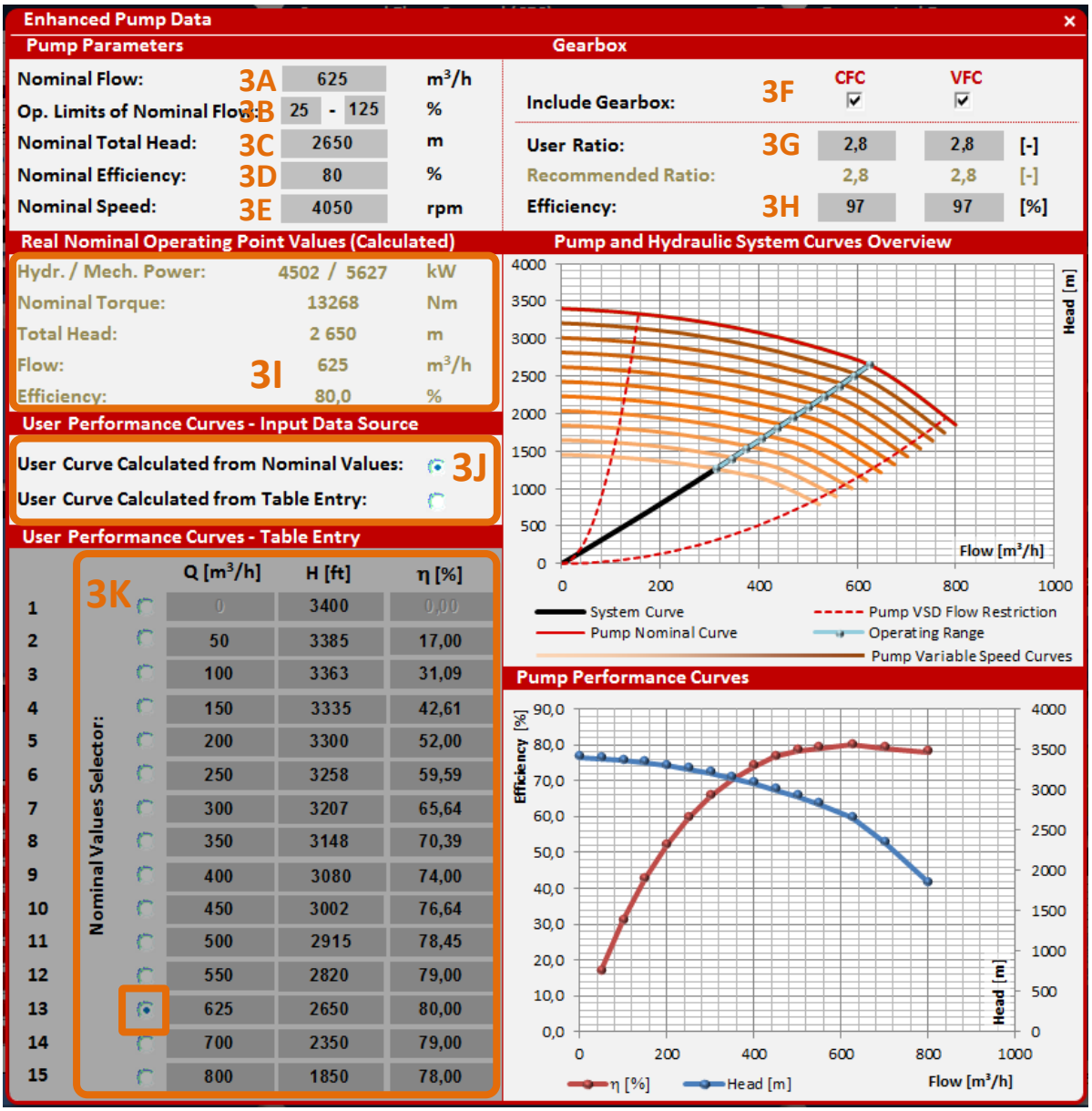



*Fig.8 Enhanced system data entry for Pump*

## 3.4 Operating Profile

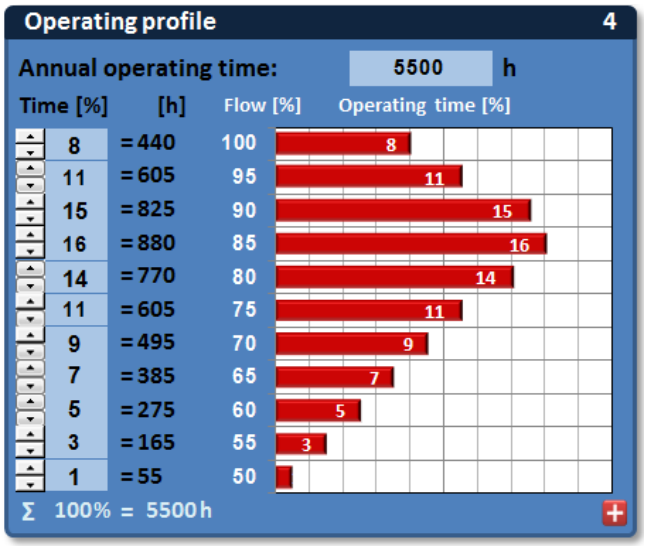



*Fig.9 Operating profile entry*

With this entry, user can set operating profile of the controlled drive with resolution of 10% of defined flow operating range (in Fig.9, there is the operating range defined from 50% to 100% of flow – i.e. the operating range from 0% to 49% is not used in this particular case). Sum of the entered values is continuously calculated in order to secure 100%. If the number is different, user will be warned. The important entry is also *Annual operating time* because it is used for economical calculations and, thus, should not be avoided.

By pressing the "plus" button, window Enhanced Pump Data appears (see Fig.10). Using the window, user can enter

**4A.** *Operating Range (Min-Max).* User can enter operating range of the operating profile.

**4B.** *Operating Limits (Min-Max).* This table summarizes basic pump and system parameters which are presented both in percent and in corresponding SI units.

- *System.*
- *Pump Fixed Speed.* The range of pump flow is indicated for fixed speed control.
- *Pump Variable Speed.* The range of pump flow is indicated for variable speed control.
- *Pump & System Curve.* The range defines maximum possible pump flow range by respecting the system curve.
- *Total Limits.* Minimum and maximum pump flows, which can be used for pump control, are introduced.

**4C.** The limits presented in **4B** are viewed graphically.

The value of 100% flow corresponds to real nominal system flow (intersection of pump and system curve).

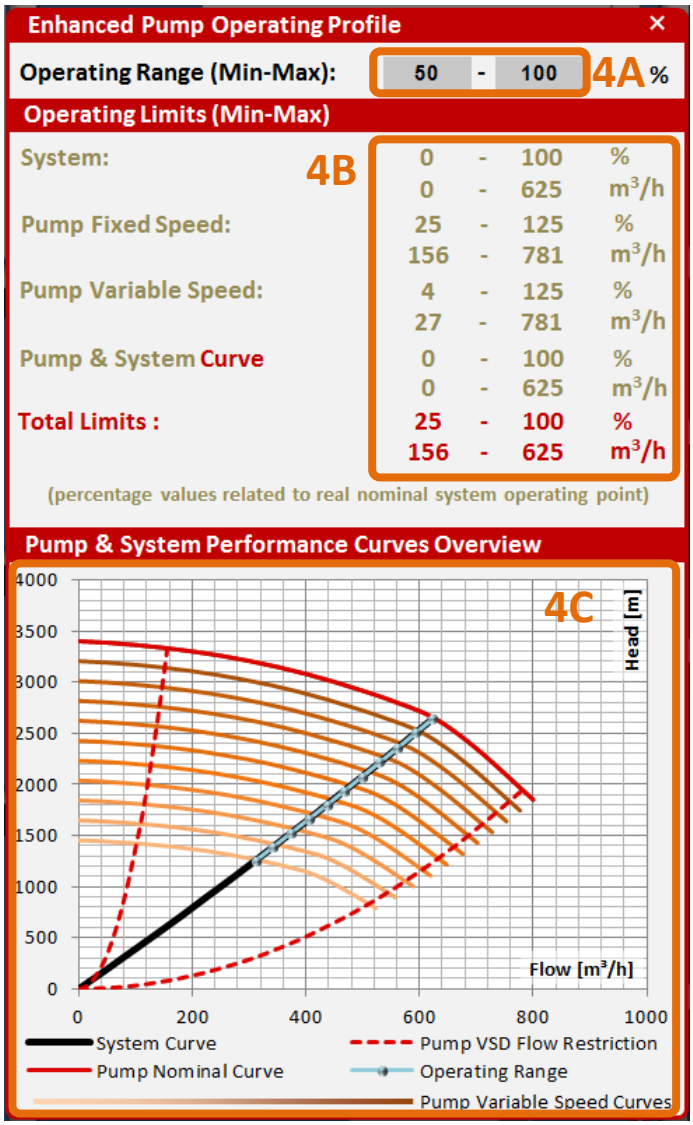



*Fig.10 Enhanced Pump Operating Profile entry*

## 3.5 Compared Flow Control (CFC)

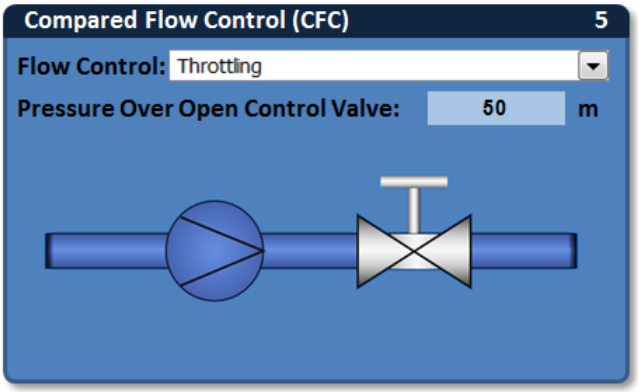



*Fig.11 Compared flow control entry (CFC)*

In this entry, user selects flow control to be compared with VFD. The list of compared flow control methods is following

- *Throtling.* User can moreover enter pressure drop over open control valve.
- *Bypass.*
- *Variable Speed Control – Hydrodynamic Coupling*
- *On – Off Control.*

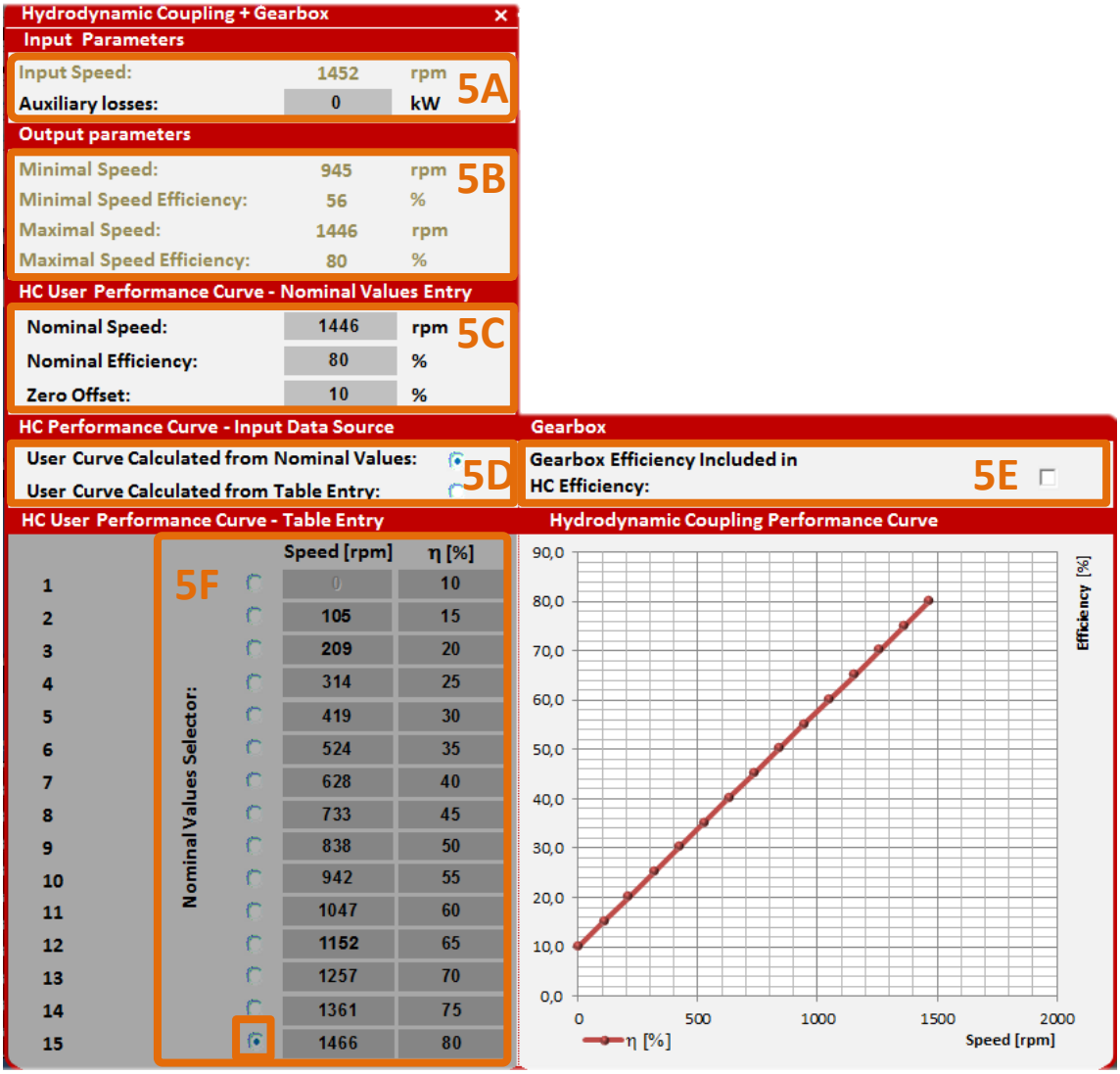



*Fig.12 Enhanced Hydrodynamic Coupling + Gearbox entry*

In case of *Variable Speed Control – Hydrodynamic Coupling* user can specify Hydrodynamic Coupling and Gearbox enhanced data by clicking the "plus" button. Within the enhanced Hydrodynamic Coupling + Gearbox window, following data can be controlled

**5A.** *Input Parameters.*

- *Input Speed.* Input speed of hydrodynamic coupling is listed.
- *Auxiliary losses.* Some additional losses arising during hydrodynamic coupling operation can be added in the form of lost power.

**5B.** *Output Parameters.* Minimal and maximal speed and corresponding efficiencies are summarized. Minimal and maximal speed is given by pump operating profile (see chapter Fig.8).

**5C.** *HC User Performance Curve – Nominal Values Entry.*

- *Nominal Speed.* User can enter nominal speed of hydrodynamic coupling.
- *Nominal Efficiency.* User can define efficiency corresponding to nominal speed.
- *Zero offset.* This value determines shifting of first point of hydrodynamic coupling performance curve which corresponds to zero speed.

**5D.** *HC User Performance Curves – Input Data Sources.* User can choose either the curves are calculated from nominal values or the curves are calculated from table entry. Choosing the table entry, area **5C** becomes inactive.

**5E.** *Gearbox.* By ticking, user specifies whether gearbox efficiency is included in HC efficiency curve.

**5F.** *User Performance Curves – Table Entry.* User can define his/her own hydrodynamic coupling performance curve. Moreover, the nominal operating values can be changed by choosing one of the rows in the table entry by clicking proper radio button.

## 3.6 Motor Data

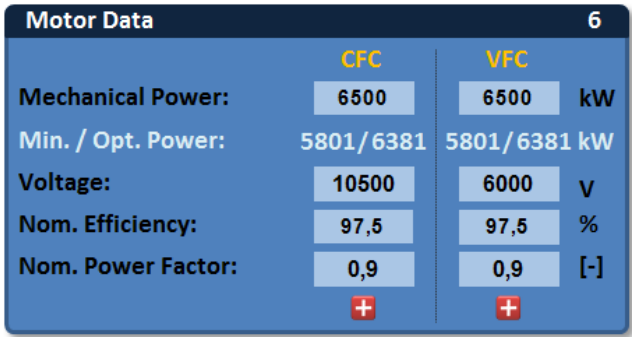



*Fig.13 Motor data entry*

Electrical motor data entry – user can set own values of motor power, voltage, nominal efficiency and nominal power factor for both compared flow controlled drive and variable flow controlled drive. This window also offers precalculated value of power – minimum/optimal calculated from preset system and pump data. Minimum value is minimum motor power able to run the system, optimal value is minimum value increased with 10% of security reserve. If user put in lower value than minimum, it will be automatically corrected by software into the minimum one.

There are two "plus" buttons in Fig.13 who enable to modify motor data for compared flow controlled drive and variable controlled flow drive, respectively. Using the first one, i.e. for compared flow controlled drive, screen displayed in Fig.1 appears. User can specify following values

**6A.** *Nominal Mechanical Power.* User can enter motor mechanical output power corresponding to nominal operating point.

**6B.** *Nominal Voltage.* User specifies nominal voltage of the motor.

**6C.** *Nominal Frequency.* User can specify the frequency corresponding to nominal operating point.

**6D.** *Nominal Speed.* Nominal speed of the motor can be defined.

**6E.** *Number of Poles.* Number of poles of the motor can be defined.

**6F.** *Nominal Efficiency.* Nominal efficiency of the motor can be specified.

**6G.** *Nominal Power Factor.* Nominal power factor is defined by this field.

**6H.** *Auxiliary Losses.* Moreover, user can enter power which corresponds to auxiliary losses given by motor operation.

**6I.** *User Performance Curves – Input Data Source.* User can choose either the curves are calculated from nominal values or the curves are calculated from table entry. Choosing the table entry, areas **6A**, **6F**, **6G** and **6H** become inactive together with fields corresponding to CFC in Fig.13.

**6J.** *User Performance Curves – Table Entry.* User can define his/her own motor performance and efficiency curves. Moreover, the nominal operating values can be changed by choosing one of the rows in the table entry by clicking proper radio button.

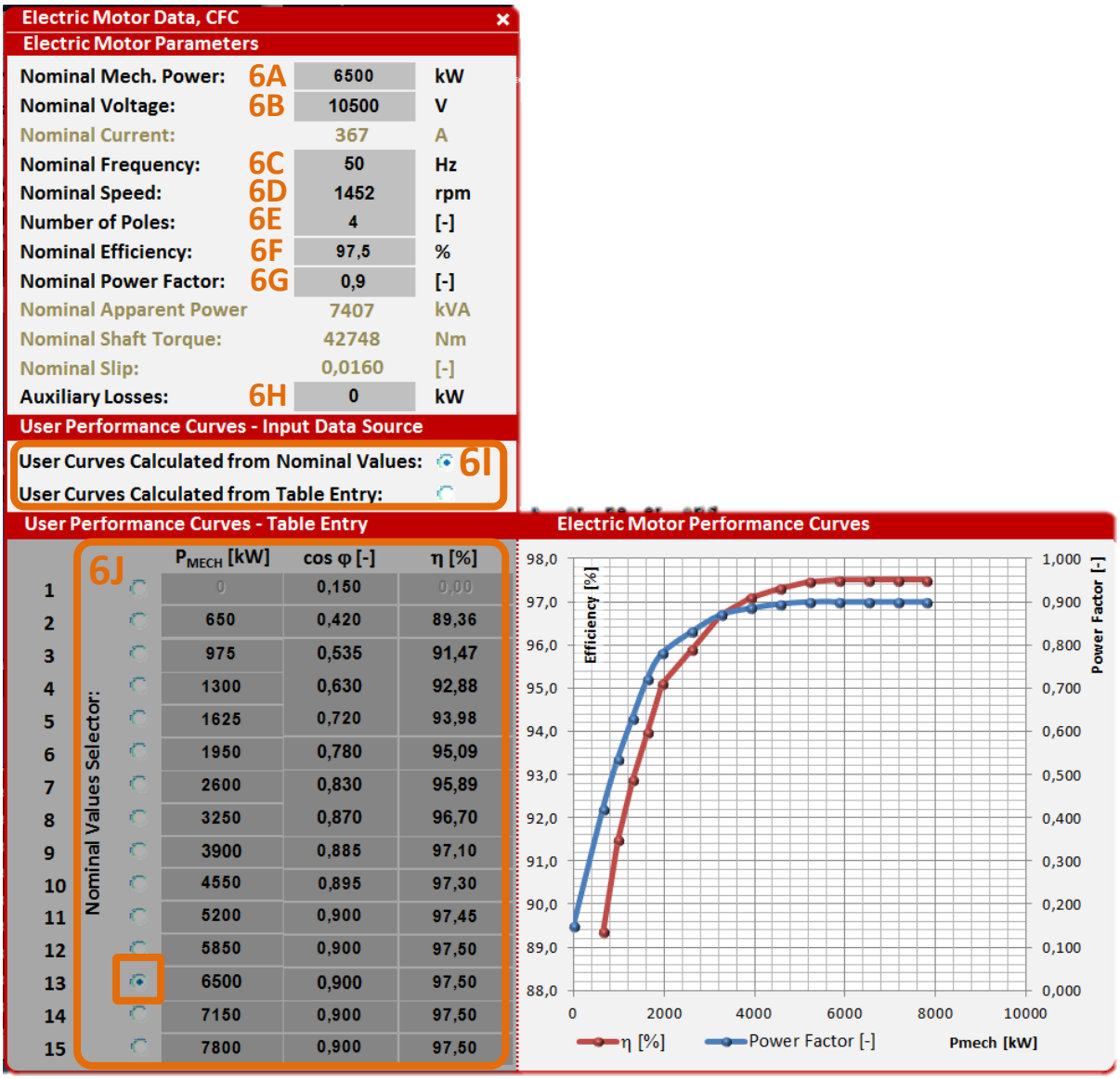



*Fig.14 Motor data entry*

The right bottom side of Fig.1 displays electric motor efficiency curve and power factor in dependence on motor mechanical power.

Using the second "plus" button (i.e. for variable controlled flow drive), the same screen as in Fig.1 appears but it enables to enter the same motor data for VFC.

## 3.7 Preferred ABB Drive

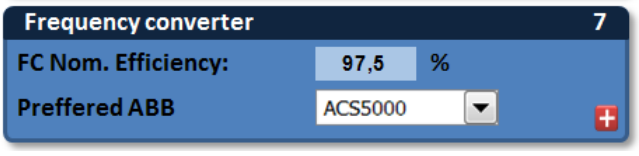



*Fig.15 Selection of preselected ABB drive entry*

According to the motor data (chapter 3.6), the software offers the list of suitable ABB drives sufficient for entered power and voltage range.

Selection of the drive has only informative character and it is also listed in the final report. Using enhanced button, user can specify more parameters on the frequency converter by entries displayed in Fig.16

**7A.** *FC Input Voltage.* User can define FC input voltage.

**7B.** *Power Supply Frequency.* User can enter power supply frequency of the frequency converter.

**7C.** *Nominal Efficiency.* Nominal efficiency of the frequency converter can be specified.

**7D.** *Nominal Power Factor.* User can enter nominal power factor of the frequency converter.

**7E.** *Auxiliary Losses.* Moreover, user can enter power which corresponds to auxiliary losses given by frequency converter operation.

**7F.** *Nominal Cont. Apparent Power.* User can specify nominal cont. apparent power of the frequency converter.

**7G.** *Output Frequency Range.* User can specify the frequency range of the frequency converter.

**7H.** *User Performance Curves – Input Data Source.* User can choose either the curves are calculated from nominal values or the curves are calculated from table entry. Choosing the table entry, areas **7C**, **7D** and **7F** become inactive together with the field corresponding to FC Nom. Efficiency in Fig.15.

**7I.** *User Performance Curves – Table Entry.* User can define his/her own frequency converter curves. Moreover, the nominal operating values can be changed by choosing one of the rows in the table entry by clicking proper radio button.

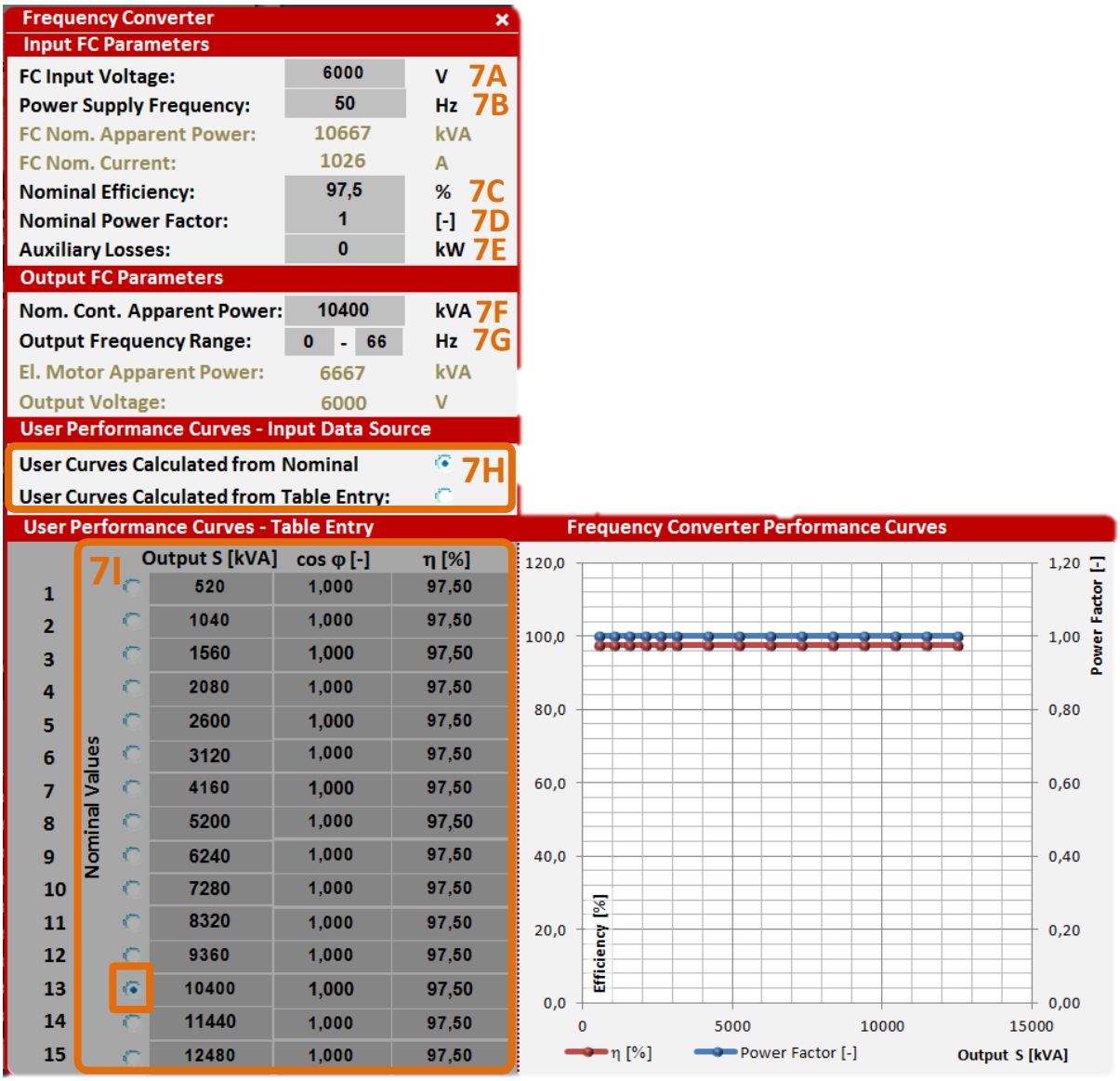



*Fig.16 Frequency converter data entry*

## 3.8 Power Supply

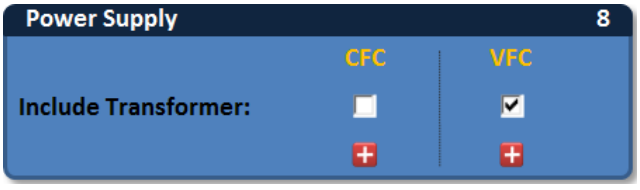



*Fig.17 Transformer/no transformer selection*

Selection of the field "*Include transformer*" affects only the overall efficiency calculation. The transformer can be included for both drives separately. Using "plus" buttons, the transformers parameters can be specified according to Fig.17 in following order (i.e. for CFC Transformer)

**8A.** *Nominal Apparent Power.* User can enter nominal apparent power of the transformer.

**8B.** *Primary Voltage.* Primary voltage of the transformer can be defined.

**8C.** *Short Circuit Voltage.* User can enter short circuit voltage of the transformer.

**8D.** *No Load Current.* User can enter no load current of the transformer.

**8E.** *No Load Losses.* User can enter no load losses of the transformer.

**8F.** *Load Losses.* User can enter load losses of the transformer.

**8G.** *Calc. Efficiency from No-Load and Load Losses.* If this field is checked, user can inter his/her own Nominal Efficiency (see **8H**).

**8H.** *Nominal Efficiency.* User can enter nominal efficiency of the transformer.

**8I.** *Nominal Power Factor.* User can enter nominal power factor of the transformer.

**8J.** *Auxiliary Losses.* Here, user can enter power which corresponds to auxiliary losses given by tranformer operation.

**8K.** *User Performance Curves – Input Data Source.* User can choose either the curves are calculated from nominal values or the curves are calculated from table entry. Choosing the table entry, areas **8A**, **8E**, **8F** and **8H** become.

**8L.** *User Performance Curves – Table Entry.* User can define his/her own transformer performance curves. Moreover, the nominal operating values can be changed by choosing one of the rows in the table entry by clicking proper radio button.

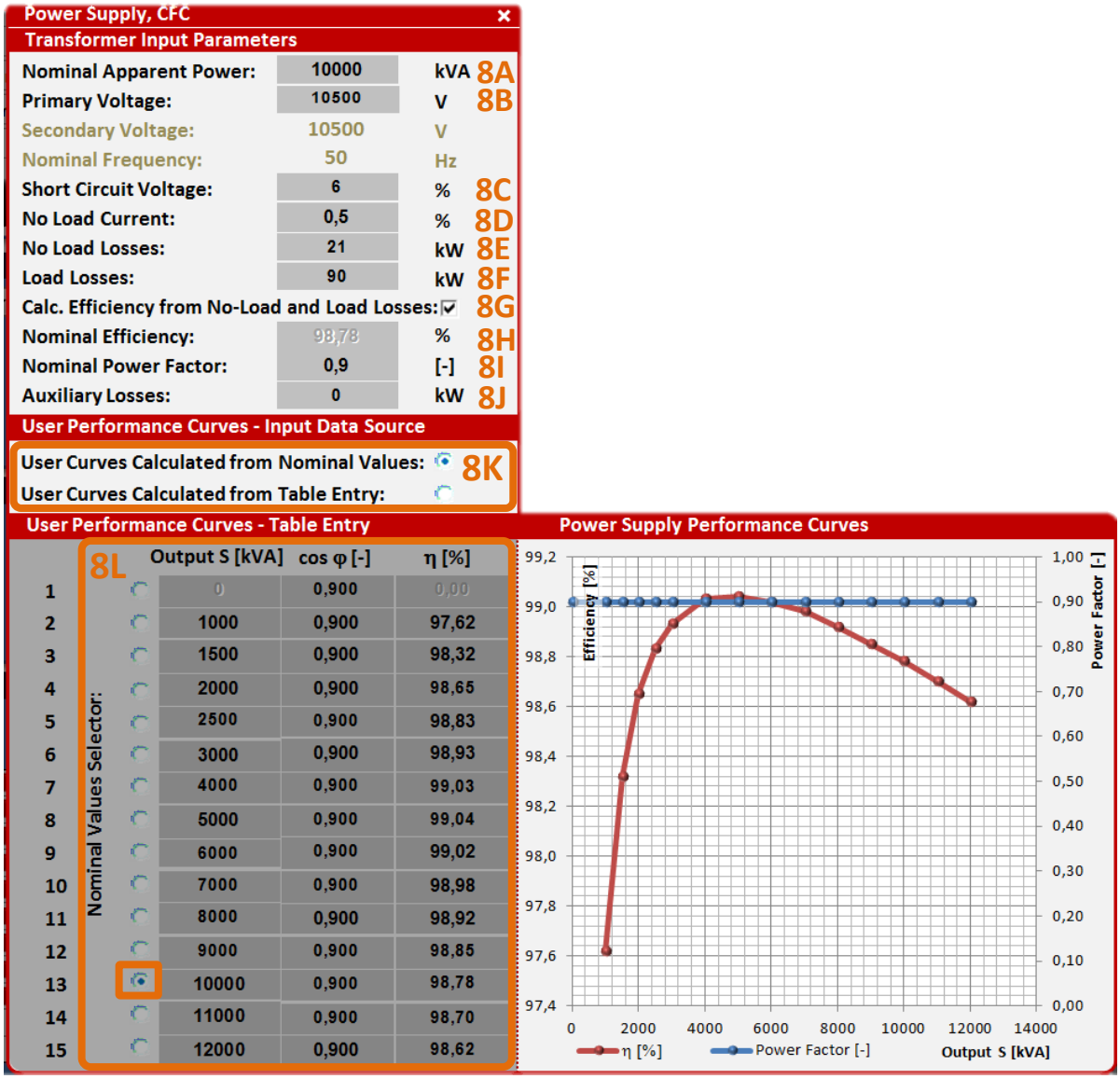
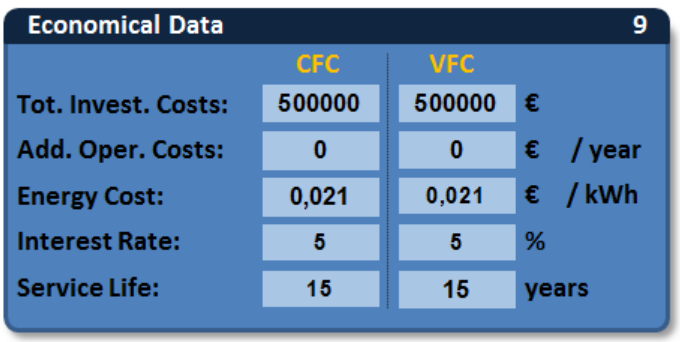



*Fig.18 Transformer data entry*

## 3.9 Economic Data




In this entry, user can set basic economic and operational data needed for final economical results provided in windows 10 and 12.

*Fig.19 Economic data comparison*

## 3.10 Results

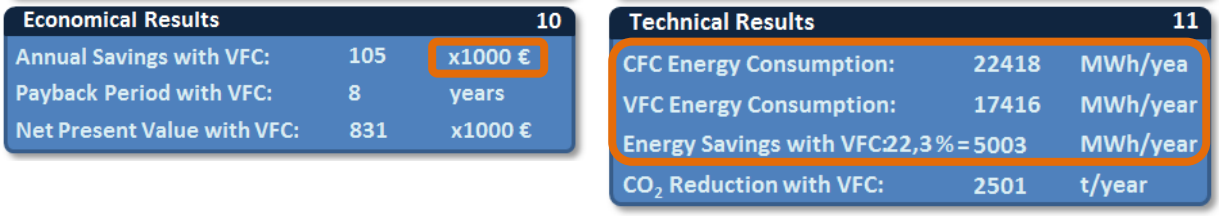



*Fig.20 List of a) economic results, b) technical results*

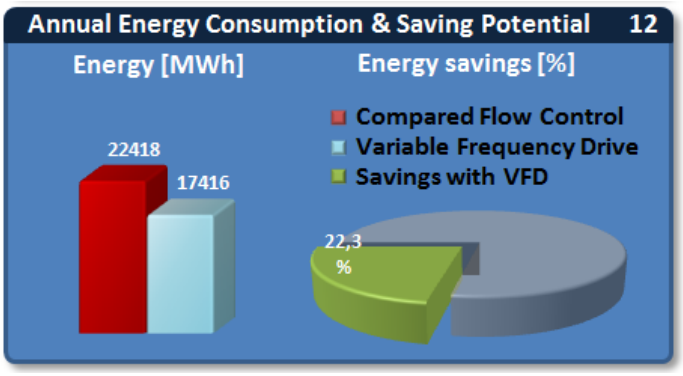



*Fig.21 Annual energy consumption & saving potential comparison*

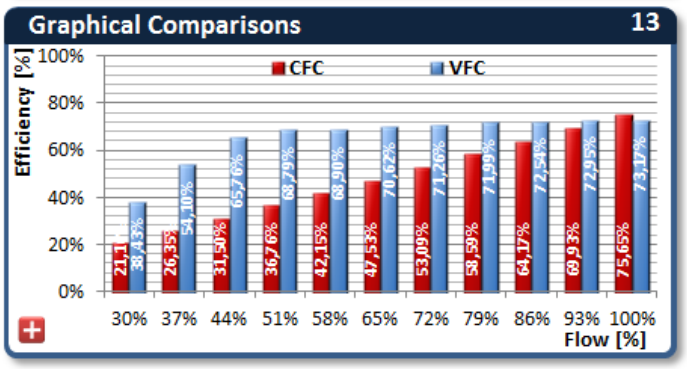



*Fig.22 Efficiency comparison*

In these four windows, final economic and technical results are provided according to defined system parameters and operating profile.

In Fig.20a), economic evaluation is provided – user can discover, what annual savings, payback period and net present value are going to be with VFD in comparison to selected CFC. In the highlighted frame, there is a multiplier of corresponding value in the line. This system has been employed due to various values of currencies.

In Fig.20b), comparison of energy consumptions of VFD solution (improved energy consumption) with an original one (present energy consumption) is provided. Energy savings are also considered for the solutions with VFD – how much energy will be saved with VFD in comparison to CFC. The highlighted part is also graphically displayed in Fig.21 in the same meaning.

The last Fig.22 introduces calculations of VFD and CFC efficiencies for the whole power range with resolution of 10% of defined flow range. The calculations are based on mathematical models of each type of employed control and include efficiencies of the whole drive chain, e.g. *"pump-gearbox-electrical motor-frequency converter-transformer"* for VFD.

Clicking on the "plus" button, Enhanced Graphical Comparison Tab appears (see Fig.23).

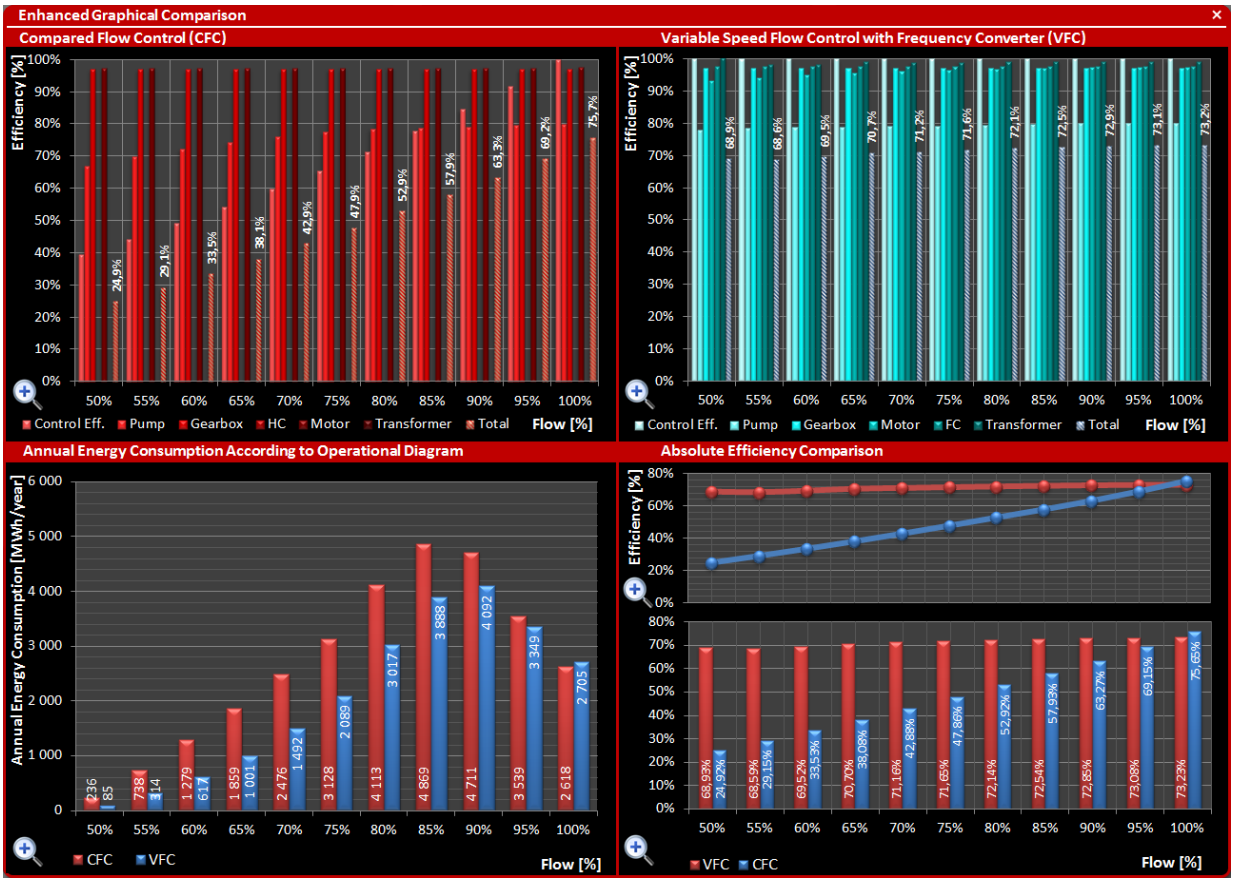
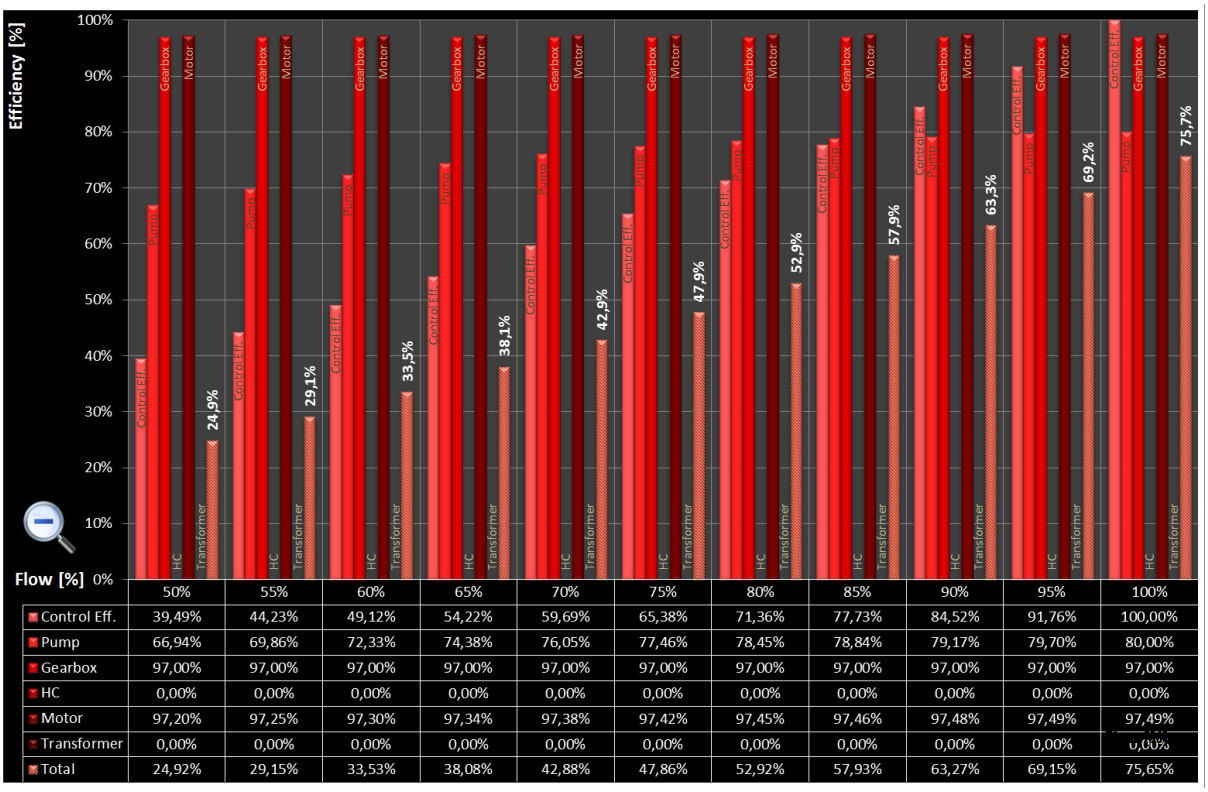



*Fig.23 Enhanced Graphical Comparison*

The tab is divided into four parts. The parts reveal detail data on efficiencies and energy consumption of compared flow controls. Every part can be zoomed by clicking on the zoom button  . By zooming the first part titled as *Compared Flow Control (CFC)*, screen displayed in Fig.1 appears.




| | 50% | 55% | 60% | 65% | 70% | 75% | 80% | 85% | 90% | 95% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control Eff. | 39,49% | 44,23% | 49,12% | 54,22% | 59,69% | 65,38% | 71,36% | 77,73% | 84,52% | 91,76% | 100,00% |
| Pump | 66,94% | 69,86% | 72,33% | 74,38% | 76,05% | 77,46% | 78,45% | 78,84% | 79,17% | 79,70% | 80,00% |
| Gearbox | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% | 97,00% |
| HC | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| Motor | 97,20% | 97,25% | 97,30% | 97,34% | 97,38% | 97,42% | 97,45% | 97,46% | 97,48% | 97,49% | 97,49% |
| Transformer | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| Total | 24,92% | 29,15% | 33,53% | 38,08% | 42,88% | 47,86% | 52,92% | 57,93% | 63,27% | 69,15% | 75,65% |

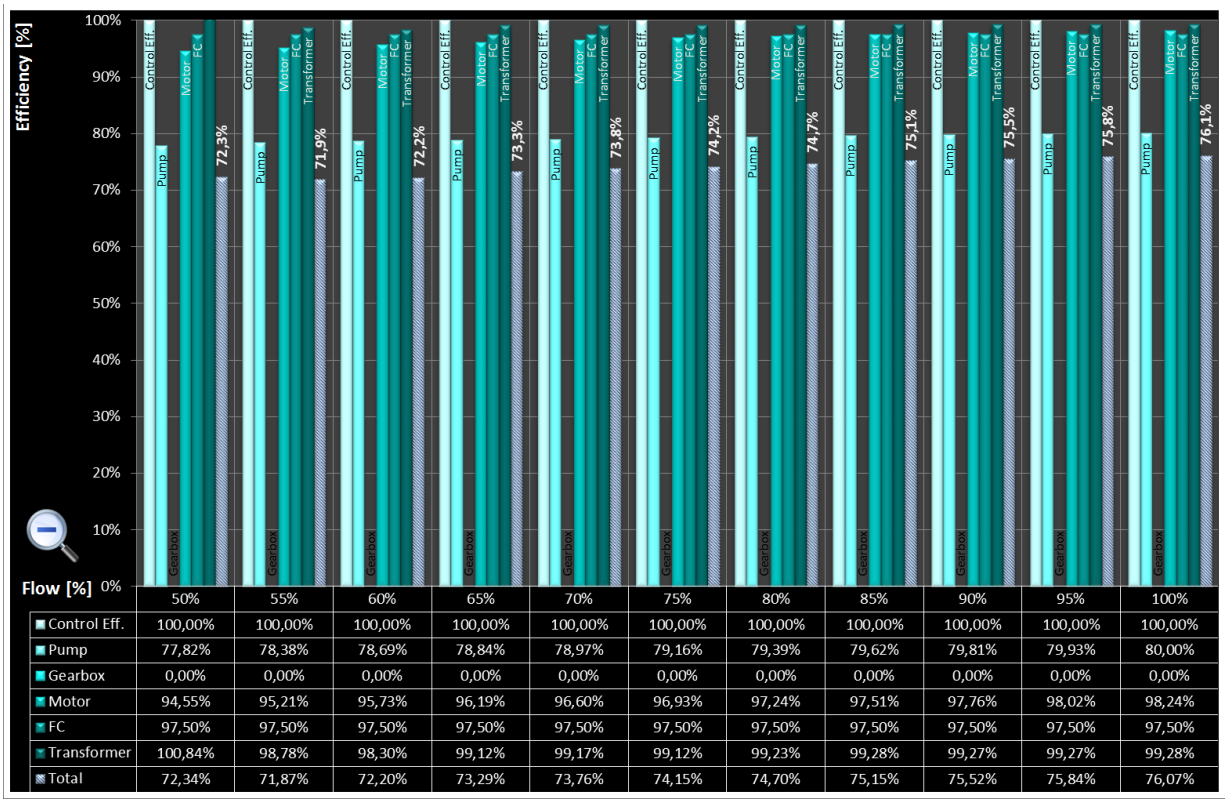
*Fig.24 Enhanced Graphical Comparison - Compared Flow Control (CFC)*

The CFC zoomed tab displays in detail efficiencies of all elements in the drive-pump control chain in dependence on flow for defined operational range (e.g. from 50% to 100% of flow). For every given flow, following efficiency data are displayed both in values and bar graphs

- *Control Efficiency* – efficiency of following control methods: throttling, bypass and on/off control is given. If hydrodynamic coupling (HC) is chosen to be compared, then Control Efficiency is set up to be 100% and efficiency of HC appears in the middle row titled HC.
- *Pump* – pump efficiency is stated.
- *Gearbox* – gearbox efficiency is stated. If there is zero efficiency, the gearbox is not included in the drive-control chain.
- *HC* – efficiency of hydrodynamic coupling is stated in case, when HC control method is to be compared. If the HC control is not employed, the efficiency is set to be zero and its efficiency is not included in the calculation.
- *Motor* – motor efficiency is stated.
- *Transformer* – transformer efficiency is stated. If there is zero efficiency, the transformer is not included in the drive-control chain.

- *Total* – total efficiency is stated as a product of all non-zero efficiencies within each column.

The second part placed in right bottom corner titles as *Variable Speed Control with Frequency Converter (VFC)* gives detail efficiency overview of control using frequency converter (see Fig.1).




| Flow [%] | 50% | 55% | 60% | 65% | 70% | 75% | 80% | 85% | 90% | 95% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control Eff. | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| Pump | 77,82% | 78,38% | 78,69% | 78,84% | 78,97% | 79,16% | 79,39% | 79,62% | 79,81% | 79,93% | 80,00% |
| Gearbox | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| Motor | 94,55% | 95,21% | 95,73% | 96,19% | 96,60% | 96,93% | 97,24% | 97,51% | 97,76% | 98,02% | 98,24% |
| FC | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% | 97,50% |
| Transformer | 100,84% | 98,78% | 98,30% | 99,12% | 99,17% | 99,12% | 99,23% | 99,28% | 99,27% | 99,27% | 99,28% |
| Total | 72,34% | 71,87% | 72,20% | 73,29% | 73,76% | 74,15% | 74,70% | 75,15% | 75,52% | 75,84% | 76,07% |

*Fig.25 Enhanced Graphical Comparison - Variable Speed Control with Frequency Converter (VFC)*

The data in Fig.1 are organized in the same manner like in Fig.1.

Annual energy consumption is given for VFC and CFC in detail in the third part (bottom left corner). It compares used energy in dependence on flow (see Fig.26).

The last part (right bottom corner) of the tab contains two graphs. The upper one summarizes total efficiency of VFC and compared flow control (see Fig.1). The lower one provides the same data displayed in bar graph (see Fig.28).

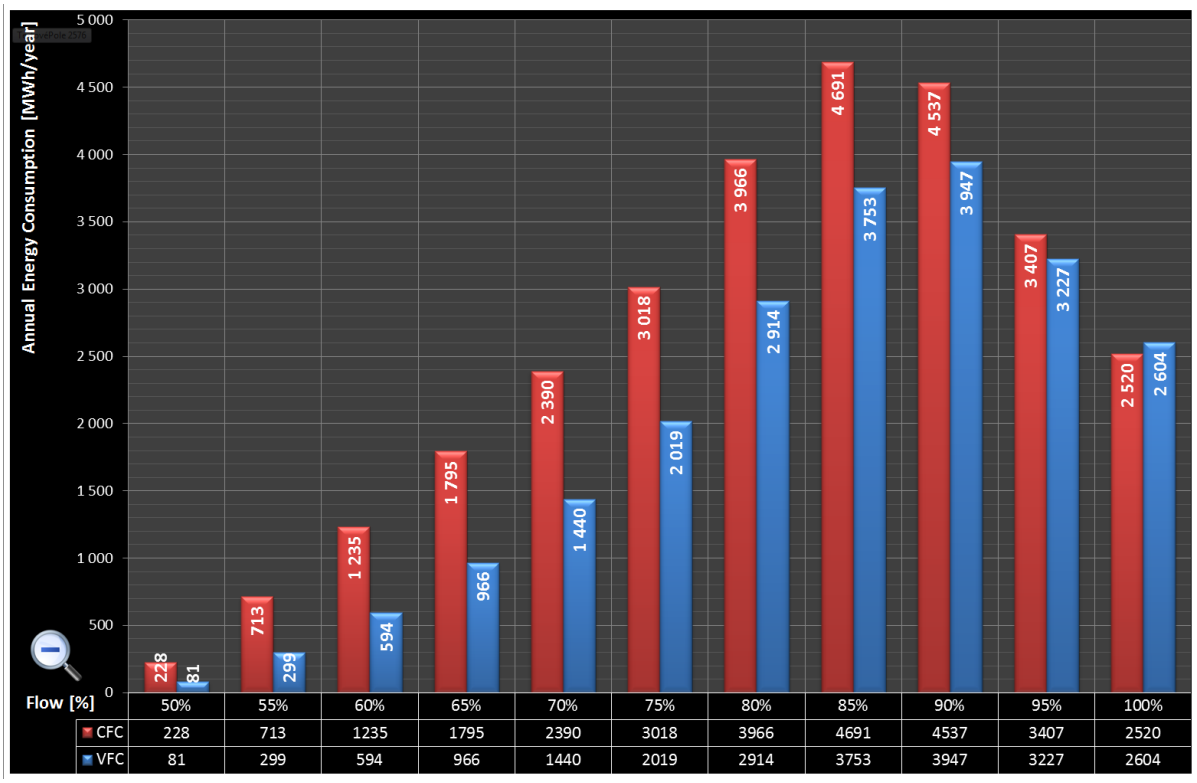



*Fig.26 Enhanced Graphical Comparison – Annual Energy Consumption*

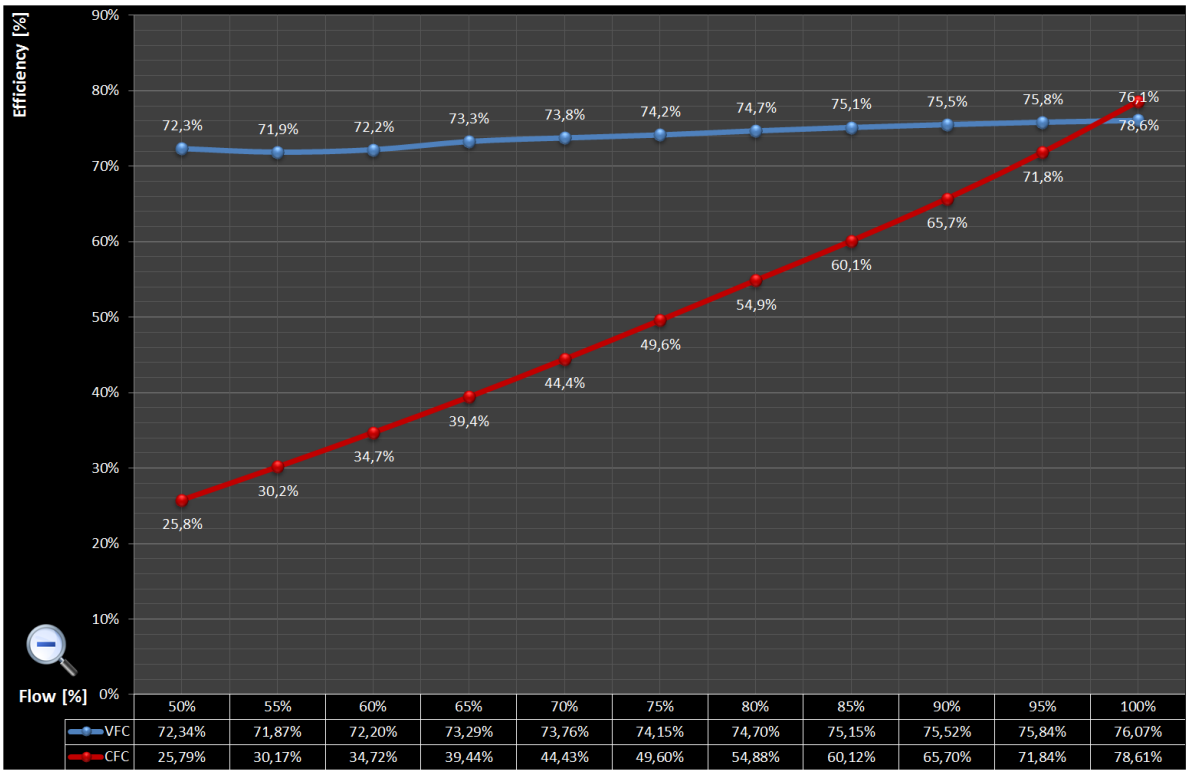



*Fig.27 Enhanced Graphical Comparison – Absolute Efficiency Comparison (line graph)*

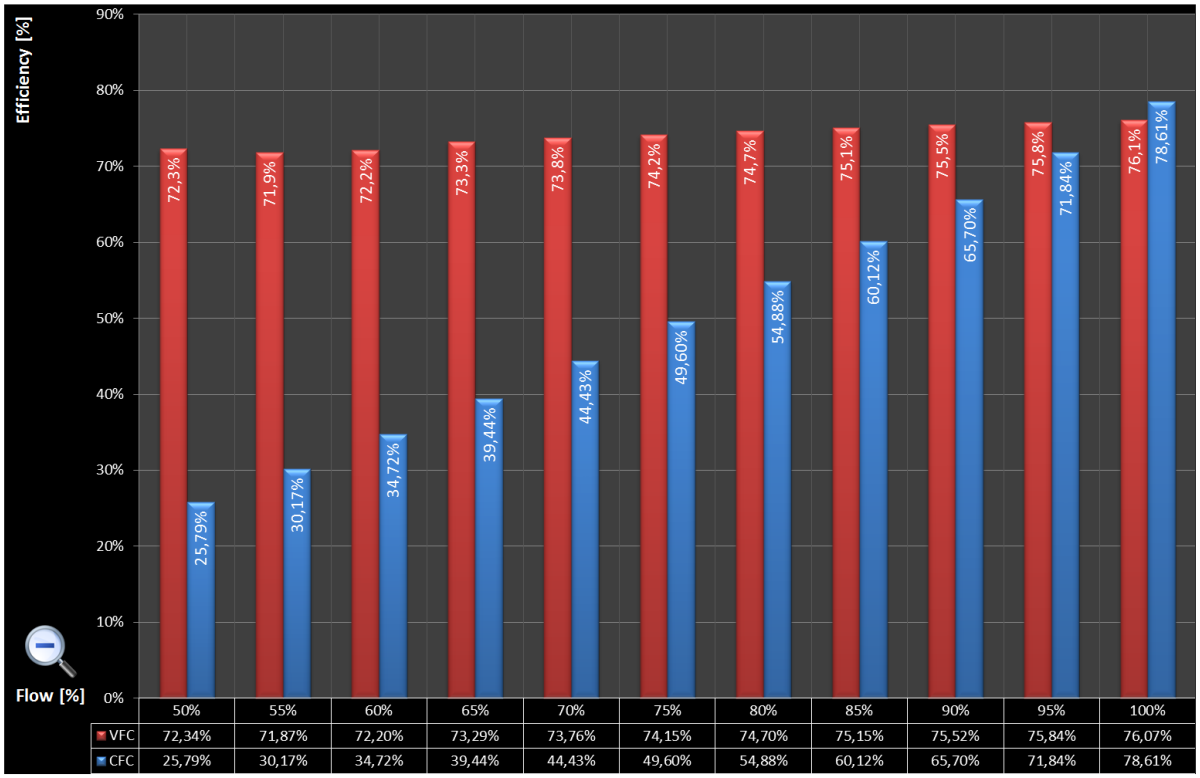



*Fig.28 Enhanced Graphical Comparison – Absolute Efficiency Comparison (bar graph)*

# 4 Conclusion

This document is intended to be used as a user guide for developed software MVD Pump Save beta 3.2 enhanced version. It introduces the software and guides the user over the whole workflow.

MVD Pump Save beta 3.2 tool has been developed in order to provide comparison of operational and economical features (e.g. operational costs, payback period or lifetime savings calculations) under various operational conditions. Presented tool offers enhanced data entering and enhanced efficiency calculation. It is able to compare a few currently employed control principles pumps. All considered controls are compared with VFD.

The software already includes default case study ready to be used for testing and learning purposes for both pumps and fans. However, the basic parameters can be modified by user according to particular application and data.

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# List of Figures

# Revision History

| Rev. | Chapter | Description | Date<br>Name / Dept. |
|---|---|---|---|
| 1 | All | Document release | May 26, 2012<br>MB, JM, MS / RICE |