Using Medium Voltage Variable Frequency Drives Instead of Medium Voltage Switchgear in a Pump System

Adil ALAHMAD

***Abstract**: The rapidly accelerating pace of industrialization that is taking place in every region of the globe has resulted in a serious shortage of electrical energy. As a result, the already existing generating capacity must be increased to meet the growing demand. Yet, given the limited number of natural resources that are now accessible, the "Energy Saving" solution is the most critical response to the power constraint. More than eighty percent of the world's total energy consumption is accounted for by alternating current induction motors, which are used by the great majority of industrial sectors. To accomplish even more significant cuts in energy usage, existing Low-Tension Motors have Variable Frequency Drives (VFDs) placed in them. This is being done to save money. The maximum voltage that may be applied to these motors is 480 volts. Currently, which is a component of the industry, there is a need to preserve electricity in the High-Tension Motor sector, which includes ratings of 3.3, 6.6, and 11 KV. It is strongly suggested that any existing High Tension or High Voltage Motors be replaced with Low Tension Motors (with a rating of up to 400 kW, if at all feasible), since this makes the inclusion of VFDs considerably less complicated. This is since high-tension variable frequency drives (VFDs) have a complicated circuit, they are very costly, and they demand a lot of space. Using the continuous process chemical plants, this study discusses the modifications and requirements for retrofitting work. This report also devotes considerable attention to a discussion of the fruitful outcomes that were achieved.*

***Keywords:** Medium Voltage, Variable Frequency Drives (VFDs), Energy Savings, Switchgear.*

I. INTRODUCTION

Roughly eighty percent of industrial motors are coupled with three-phase induction motors [1]. Additionally, motors with a rating of up to 200 kW fall into the low-tension category (415 V), whereas those with a rating of more than 200 kW go into the high-tension category (3.3 kV, 6.6 KV or 11kV). The use of variable frequency drives for low-temperature motors is becoming more common as a means of achieving power reductions at a price that is both acceptable and accompanied by appropriate payback periods. When it comes to high tension Motors, on the other hand, industrial users do not use high tension VFDs because of the complexity, space required, and increased expense of these devices. The need for the process is being met with the use of valve throttling, which offers the possibility of an energy savings. In this case, we have the opportunity to switch out the current high-tension Motor with a low-tension Motor that is paired with a low-tension Variable Frequency Drive. This can be readily accomplished up to a rating of 400 kW without a significant amount of difficulty. Both the frequency of the supply and the number of poles influence the speed of an electric motor (1).

$$\text{Speed} = 120 \text{ x Frequency / Number of poles} \qquad (1)$$

Where N = 120 f / P

It is important to take notice of the fact that the variables determine speed are the frequency of supply and the motor poles number. Since the motor poles number cannot be change without change the motor itself, the only variable could be modified is the supply frequency going into the machine; this is the fundamental principle behind the working of a variable speed drive (VFD) [2].

A flow control valve gives us the ability to regulate the flow of any hydraulic system (FCV). The flow may be regulated to the appropriate value by opening or closing a valve located in the pump discharge line. However, this does not contribute in any way to the reduction of energy consumption [3]. This control technique operates the pump constantly. The standard pump curve is seen in Fig. 1 [4].

Case Studies of Pump Performance versus a Plotted Performance Curve: The flow rate is considered on an actual basis rather than a rated basis, minimum basis, or maximum basis throughout the Process. For the sake of comparison and taking appropriate action in accordance with the modelled curve, the minimal scenario assumes that the flow rate is at its lowest possible value (either because of an interruption in the process or anticipated future needs). The maximum diameter of the impeller is determined by the maximum flow rate.

The following are some examples of operational parameters and how they affect pump performance plots in a linear fashion like, the differential Head point, Flow or Capacity, Pump Efficiency, Net positive suction head required, Power Consumption, and Shut off Head, Impeller Size.

Manuscript received on 27 January 2023 | Revised Manuscript received on 05 February 2023 | Manuscript Accepted on 15 February 2023 | Manuscript published on 28 February 2023.

***Correspondence Author**
Adil ALAHMAD*, Department of Electrical and Electronics Engineering, Istanbul University-Cerrahpasa Istanbul, Turkey. Email: adil.alahmad@hotmail.com, ORCID ID: https://orcid.org/0000-0001-7384-5141

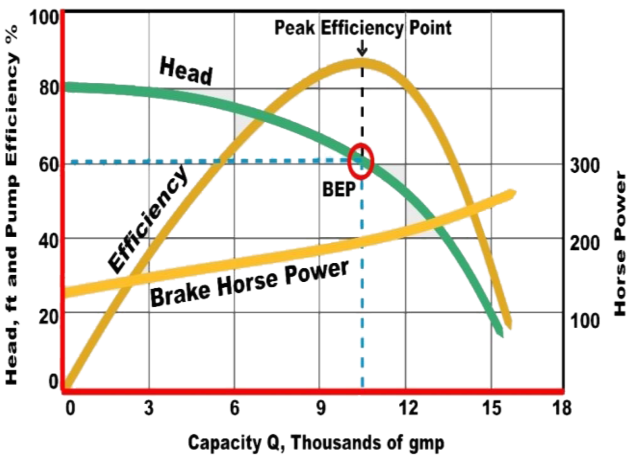

Fig 1. Curve of Pump

The affinity law for a centrifugal pump is a specification of the connection between the factors used in the pump (such as head, flow, and shaft speed) and the power. This rule is utilized in hydraulics [5].

So, modify the speed have to vary the frequency, which results in a significant reduction in power consumption when the motor is operating at low speeds. If the frequency is altered using a VFD rather than by throttling the valve, this is something that is doable. The speed, torque, and direction of an AC induction motor may all be controlled by a variable frequency drive (VFD), which also contains the converter and inverter. Control circuitry that is quite complicated is used to coordinate the switching of power devices. This is often accomplished via the use of a control board, which is responsible for dictating the firing of power components in the correct order. A microprocessor or digital signal processor is capable of fulfilling all of the criteria for the internal logic and decisions. Fig. 2 presents a diagrammatic representation of a variable frequency drive (VFD).

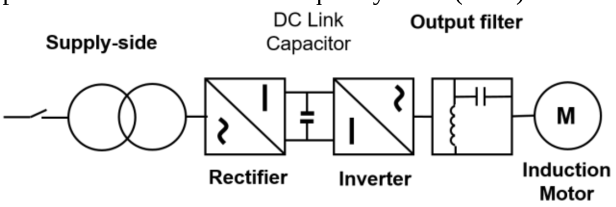

Fig. 2. Block diagram of variable frequency drive

II. LIMITATIONS

However, variable frequency drives (VFDs) do have a few drawbacks, such as the pumping of harmonics into the system, the need for space for air conditioning in the variable frequency drives room to ensure the smooth operation of variable frequency drives are specially designed, and so on. The bottlenecks for the planned retrofit may be broken down into the following categories:

- Alterations were made to the Motor base in order to install the low-tension Motor.
- Modifying the height of the low-tension motor so that it coincides with the frame of the pump.
- An appropriate half-coupling of the motor that is compatible with the half-coupling of the pump that is already installed.
- An appropriate low-tension motor to power the current pump, with particular attention paid to the motor's acceleration torque.
- Using low-voltage cable instead of medium-voltage cable.
- The installation of the distribution transformer, in conjunction with an appropriate low voltage panel to connect the new low-tension Motors [6].
- The initial investment for long-term assets such as distribution transformers, long-term motors, long-term panels, long-term cables, and long-term couplings, etc.
- The settings of the protective relays for the motor pump in substation feeders [7].
- Harmonics being pumped into the existing grid by variable frequency drives [8].
- The upkeep of complex variable frequency drives (VFDs).
- The need of having power electronics specialists on hand to deal with VFDs and the issues that they present.

III. METHODOLOGY ADOPTED

A case study will be used later to illustrate this further. There are a total of eight different pumps in the chemical process plant that are powered by high-tension motors rated at 6.6 kilovolts. All of them are changed out by VFDs and 380V low tension motors of an energy efficiency [9]. Table I displays the technical data that was collected. Schematic illustrating how everything works, along with the power connection: According to the needs of the facility, only four of the eight pumps will be in operation at any one time, while the other four will be kept on standby. This strategy ensures that there is a backup for each piece of machinery, which is necessary for chemical plants that operate nonstop.

Table-I: Technical Data

Parameter	Existing Motor	New Motor
Power	200 kW	200 kW
Frequency	50 Hz	50 Hz
Phases	3	3
Voltage	6.6 kV	0.38 kV
Normal speed	1500 RPM	1500 RPM
VFD used	-	3-ph, 200 kW
Cable Voltage	6.6 kV	0.38 kV

IV. CURRENT METHOD OF ELECTRICITY DISTRIBUTION

Fig. 3 depicts the current plan for how power connections are to be made using HT switchgear. According to the needs of the plant, only four of the eight pumps will be operational at any one time, while the other four will stay in standby and rotate through operation every other week.

This ensures that there are always two pumps operating on each portion of the switchgear by running 1A, 2A, 3A, and 4A for one week and then 1S, 2S, 3S, and 4S for the following week.

Retrieval Number:100.1/ijsp.B1014053223
DOI: 10.54105/ijsp.B1014.023123
Journal Website: www.ijsp.latticescipub.com

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Moreover, this system makes it simple to do preventative maintenance on equipment while also providing for complete redundancy. This guarantees that there is always equipment available, which is necessary for the plant to run well.

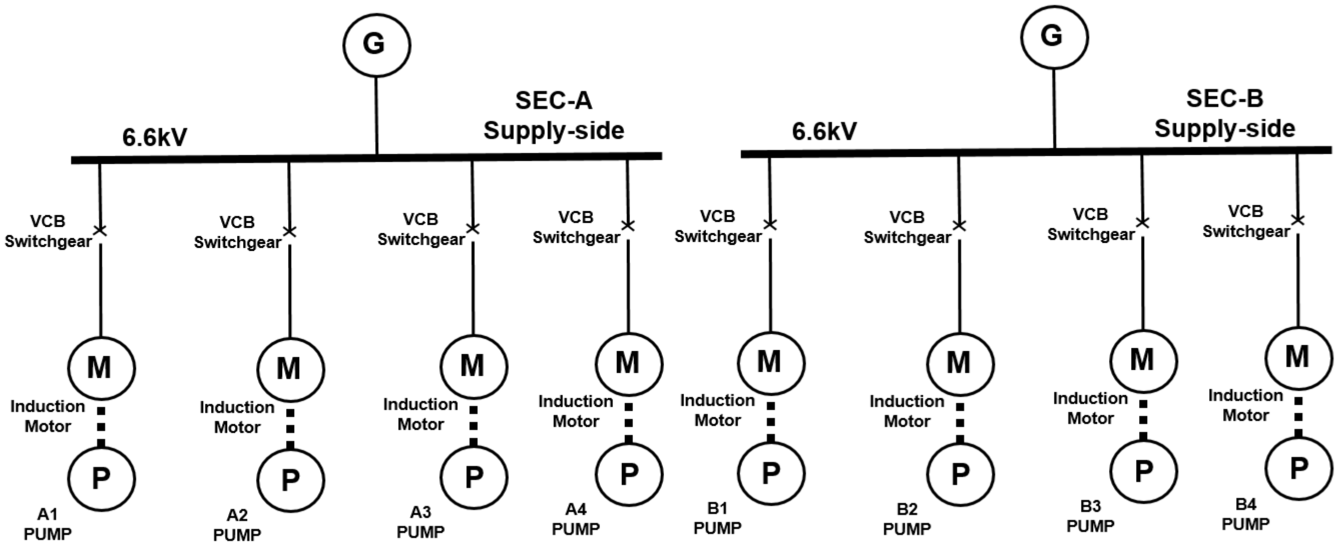

Fig. 3. Current method of electricity distribution

V. SUGGESTING METHOD OF ELECTRICITY DISTRIBUTION

Fig. 4 depicts the updated plan for the project. With the removal of motors, a total of eight numbers of 6.6 kV feeders on 6.6 kV switchgear became available; as a result, two of these feeders were used to connect a total of two new transformers.

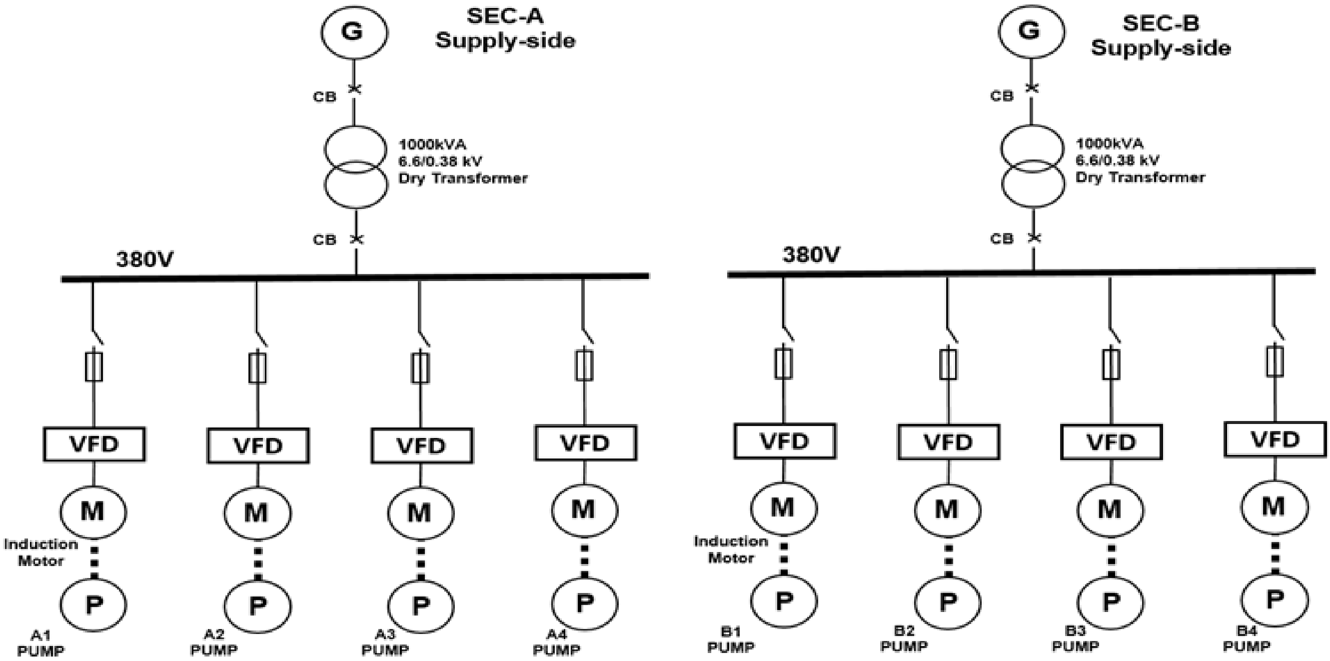

Fig. 4. Suggesting method of electricity distribution

Using Switch Fuse units, these transformers are first connected to a 380 V Motor Control Center (MCC), and then they are linked to newly install low voltage motors with greater efficiency ratings. When the previous high voltage cables have been removed, the low voltage cables may be placed and linked to the motor. The control cords and start/stop push buttons that were already in place will not be changed. Since there is no change in the KW rating of the pump motors, the protective relays that are already installed and the settings they are currently using are not altered. Built-in safeguards in the variable frequency drive (VFD) will take care of the negative point of protection at lower loads.

VI. INCORPORATION AND ASSOCIATION

The frame refit and alignment is the most difficult challenge, so they will take a backload of retrofit assignments. It is good knowledge that misalignment is directly responsible for up to fifty percent of the damage to spinning equipment [10].

Retrieval Number:100.1/ijsp.B1014053223
DOI: 10.54105/ijsp.B1014.023123
Journal Website: www.ijsp.latticescipub.com

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When machines are installed in an improper alignment, they might face various problems, including pump-motor vibration, damage to bearings [11], premature seal wear, and damage to couplings, to name a few. In addition, misaligned pumps are known to use up to 15% more energy than their aligned counterparts [12]. In Fig. 5, respectively, one can see an illustration of proper alignment and the alignment process. The height of the motor base frame has been raised with the assistance of C-channels to make it comparable to that of the pump. The regional market is scoured for the purchase of new connections. The task was completed extremely quickly and without any difficulties. The alignment measurements were spot-on in both the axial and radial directions.

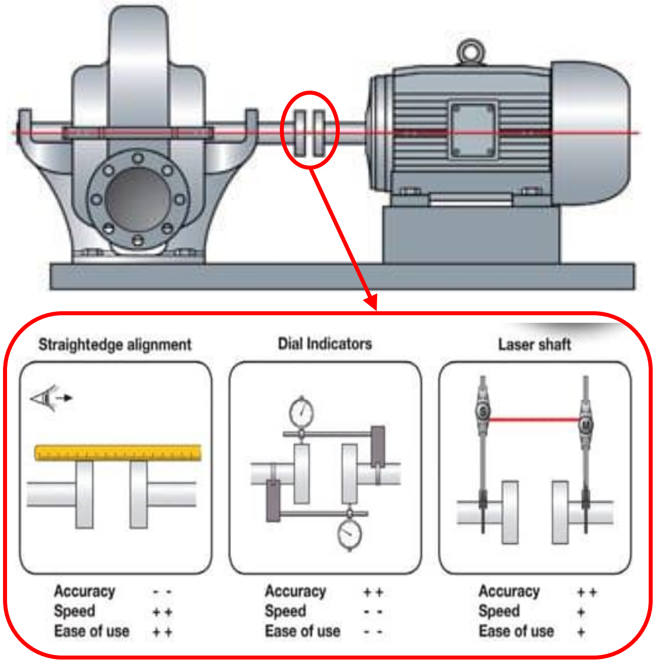

Figure 5. Motor - Pump aligned shaft

VII. CONCLUSION

As it is anticipated that the demand for VFDs would increase at a compound annual growth rate of 5.94% in the years to come, the current trend is leaning in the direction of more recent VFDs to accommodate the period of the fourth industrial revolution. It is feasible to refit high-torque (HT) motors (up to a rating of 400 kW) with low-torque (LT) motors and VFDs, where there is a scope for flow control and hence an opportunity to save energy. This is because the usage of high-voltage VFDs is restricted. This may be accomplished by making some significant alterations to the motor base and the cabling, as well as by spending more money on capital expenditures. This strategy, on the other hand, has significant advantages such as short payback periods, enhanced performance of equipment,

less reactive power consumption, and a gentle start for motors, all of which contribute to an improvement in the estimated lifespan of motors and pumps. Moreover, their upkeep, when performed with the assistance of emerging technologies like as the Internet of Things, on-line problem detection and repair, and modular spare replacement, has the potential to make them more user-friendly in the not-too-distant future.

DECLARATION

Funding/ Grants/ Financial Support	No, I did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	I am only the sole author of the article.

REFERENCES

1. Data from the web portal “electrical-engineering- portal.com/lt-medium- ht-vfd-part-2, “LT / medium / HT VFD used in the industry”. [2] IEC 60034 (Part 30), “Electrical machinery, single speed, three phase cage-induction motors”.
2. Ö. F. Farsakoğlu, N. Aksoy, H. Y. Hasirci and A. Alahmad, "Design and application of solar dish-gamma type stirling system," 2018 5th International Conference on Electrical and Electronic Engineering (ICEEE), Istanbul, Turkey, 2018, pp. 242-246, doi: 10.1109/ICEEE2.2018.8391339. [CrossRef]
3. W. Leonhard, “Control of electrical drives”, Springer, 2001. [4] G. D. Anderson, “Variable frequency drives: Installation & Troubleshooting (Practical guides for the industrial technician), 2013.
4. A. Alahmad and F. Kaçar, "Simulation of Induction Motor Driving by Bridge Inverter at 120°, 150°, and 180° Operation," 2021 8th International Conference on Electrical and Electronics Engineering (ICEEE), Antalya, Turkey, 2021, pp. 121-125, doi: 10.1109/ICEEE52452.2021.9415930. [CrossRef]
5. B. K. Reddy, and B. SreeBindu, "Recent Challenges in Electrical Engineering and the Solution with IT”, International Journal of Recent Technology and Engineering (IJRTE), Volume-8, Issue-2S11, September 2019. [CrossRef]
6. O.F. Farsakoglu, A. Alahmad, Comprehensive Design of Stirling Engine Based Solar Dish Power Plant with Solar Tracking System. J. Electr. Electron. Syst. 2018, 7, 1–5. [CrossRef]
7. A. Alahmad and F. Kaçar, "Medium-Voltage (MV) Motor Drives Topologies and Applications," 2022 International Conference on Electrical, Computer and Energy Technologies (ICECET), Prague, Czech Republic, 2022, pp. 1-5, doi: 10.1109/ICECET55527.2022.9872584. [CrossRef]
8. H.A. Abd el Ghany et al. A faulted side identification scheme-based integrated distance protection for series-compensated transmission lines Int J Electrical Power Energy Syst (2019). [CrossRef]
9. A. Alahmad, F. Kaçar, Ö. F. Farsakoğlu and C. P. Uzunoğlu, "Medium-Voltage Drives (MVD) - Pulse Width Modulation (PWM) Techniques," 2023 Second International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2023, pp. 91-94, doi: 10.1109/ICEARS56392.2023.10084995. [CrossRef]
10. S. Fabian, T. Krenicky, “Operation and Diagnostics of Machines and Production Systems Operational State II”, Trans Tech Publications, Switzerland, pp. 27, 2014.
11. A. Kayal and A. Alahmad, "Controlled Islanding Solution for Blackout Prevention in Transmission Systems," 2023 Second International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2023, pp. 119-123, doi: 10.1109/ICEARS56392.2023.10085170. [CrossRef]
12. O.F. Farsakoglu, A. Alahmad, 2018. Design and Testing of Solar Dish-Stirling System with Solar Tracking System. Gazi Mühendislik Bilimleri Dergisi, 4(1), pp.1-8. [CrossRef]

Retrieval Number:100.1/ijsp.B1014053223
DOI: 10.54105/ijsp.B1014.023123
Journal Website: www.ijsp.latticescipub.com

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AUTHORS PROFILE

Adil ALAHMAD obtained his Bachelor's in Electrical, and Electronics Engineering from Tishreen University, Master's degree, Electrical, and Electronics Engineering from Kilis 7 Aralık University (Partner with Kahramanmaras Sutcu Imam University). Ph.D. candidate at the Department of Electrical, and Electronics Engineering, Istanbul University- Cerrahpasa. His research interests include Smart grids, Converters, Motor drives, Power Electronics, and Distribution systems. He has published many research papers in peer reviews journals and conferences.