SELCUK UNIVERSITY
FACULTY OF TECHNOLOGY

ICENTE'22

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November 17-19, 2022

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Editor
Prof. Dr Sakir TASDEMIR

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6th International Conference, ICENTE
Konya, Turkey, November 17-19, 2022

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Editor
Sakir TASDEMIR

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Editör
Şakir TAŞDEMİR

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PREFACE

International Conference on Engineering Technologies (ICENTE'22) was organized in Konya, Turkey on 17-19 November 2022.

The main objective of ICENTE'22 is to present the latest research and results of scientists related to Biomedical, Computer, Electrics & Electronics, Mechanical, Mechatronics, Metallurgy & Materials and Civil Engineering fields. This conference provides opportunities for the delegates from different areas in order to exchange new ideas and application experiences, to establish business or research relations and to find global partners for future collaborations.

All paper submissions have been double blind and peer reviewed and evaluated based on originality, technical and/or research content/depth, correctness, relevance to conference, contributions, and readability. Selected papers presented in the conference that match with the topics of the journals will be published in the following journals:

- Artificial Intelligence Studies (AIS)
- Gazi Journal of Engineering Sciences (GJES)
- International Journal of Applied Mathematics, Electronics and Computers (IJAMEC)
- International Journal of Automotive Engineering and Technologies (IJAET)
- International Journal of Energy Applications and Technology (IJEAT)
- MANAS Journal of Engineering (MJEN)
- New Trends in Computer Sciences
- Open Journal of Nano (OJN)
- Selcuk University Journal of Engineering Sciences (SUJES)
- Intelligent Methods In Engineering Sciences (IMIENS)

At this conference, there are 260 paper submissions. Each paper proposal was evaluated by two reviewers. and finally, 215 papers were presented at the conference from 9 different countries (Turkey, Ukraine, Iraq, Macedonia, Algeria, Georgia, Tunisia, Romania, Albania) with 151 local and foreign universities and organizations participating,

In particular, we would like to thank Prof. Dr. Metin AKSOY, Rector of Selcuk University, conference scientific committee, session chairs, invited speakers, referees, technical team, participants, and all our colleagues who have contributed. They have made a crucial contribution to the success of this conference. Our thanks also go to our colleagues in our conference office.

Prof. Dr. Sakir TASDEMIR
Editor

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Abstract **- Thanks to the rapid development in technology, there is a remarkable increment in the amount of energy consumed all over the world. Especially in industrial facilities, the demand for energy has been developing day by day. With the increasing of energy consumption in the industry, some concepts such as efficient use of existing energy, energy saving and power quality gain importance. Power quality, which can be defined as the ability of power systems to transmit and distribute electricity to end users within predetermined reasonable limits, is of great importance in industrial facilities with continuous production. The fact that electrical energy goes beyond the determined limits will cause great problems for energy consumers. Today, many industrial establishments such as pharmaceutical, chemistry, paper, textile and semiconductor industries work 24 hours nonstop. Production stages of these systems form of extremely important and interrelated process stages. The corruption in power quality will affect the whole production. Devices, like variable frequency drives (VFDs), advanced microprocessors, programmable logic controllers (PLCs), relays, contactors and etc., used in all industrial sectors are easily affected by the variations in electrical power. In this study, the effect of "voltage sags" on the variable frequency drives are evaluated by measurements carried out. The obtained results have been evaluated by means of the MATLAB/SIMULINK program. When the simulation results were examined, it was determined that the DC bus voltage was kept within acceptable limits thanks to the battery-based solution that is installed and also, system connected to the variable frequency drive was not affected by voltage sag events.**

Keywords **- Power Quality (PQ), Voltage Sag, Variable Frequency Drive (VFD)**

I. INTRODUCTION

Variable frequency drives have a wide usage area in industrial facilities with their features such as high energy efficiency, energy saving capability and advanced process control. Despite these positive features, variable frequency drives are extremely vulnerable to events such as voltage sags, swells and other power quality problems where occur in the electrical power grid. Since variable frequency drives are used in very important and various processes in the industry, the effect of power quality problems on these devices is one of the most important reasons for downtime. The downtimes will occur in the facilities produce continuously could cause serious economic losses. In addition, since there is an extremely close relationship between the production stages, the downtime in one of these stages can affect the whole process. According to a report published in the USA, the annual total cost of these events is between 20-100 million $. [1]

II. EFFECTS OF PQ PROBLEMS TO THE INDUSTRIAL FACILITIES

Impacts of power quality problems are able to indicate their negative ways in many ways of industrial operations. These are loss of production, production interruption, loss of income, wasted energy, decreased equipment life, reduction in competitiveness and increased cost of labor. In the following, brief explanations are given that define these effects.

- **Loss of Production:** These are the losses that is caused by power quality problems that are not produced and naturally can not be sold when production is interrupted.
- **Production Interruption:** There are many closely related processes in continuous production systems. If any of these is affected by power quality problems, it will adversely affect the next process stage.
- **Loss of Income:** Power quality problem will directly affect the sales and cause disruptions in production plans.Naturally, income of the industrial facilities will decrease.
- **Wasted Energy:** Power quality problem where occur in the production process will cause serious energy wastage in the time that will pass until the entire process is restarted and the final product meets certain quality parameters. In fact, the energy in the time until the desired quality product is produced will be wasted.
- **Decreased Equipment Life:** Voltage sags-swells and short-term transients with high energy may cause high currents in electrical circuits. This situation can have serious adverse effects especially on electronic cards, controller unit and cause malfunctions.
- **Reduction in Competitiveness:** Encountered power quality problems may cause the poor quality specifications and this final products decrease the customer satisfaction.

- **Increased Cost of Labor:** Since it will take a certain time to eliminate the quality changes in the process conditions and to reproduce the desired quality product, extra personnel may be needed. This will result an increase in labor costs as it will result in overtime work. [2]-[3]

III. STRUCTURE OF VARIABLE FREQUENCY DRIVE

According to the latest researches, 70% of the electricity consumption of the industrial sector in the world is due to the consumption of electric motors.[4] Electric motors are served in a various implementation in the industrial facilities with different application and load characteristic such as fan, pumps, winders etc.

Different speed needs arise in different applications where electric motors are used. The speed of electric motors is proportional to the supply voltage frequency and also there is inverse relation to the number of poles. There are only two ways to change the speed of motors. These are; amendment the frequency of the voltage applied to the motor or changing the number of poles of the stator windings, respectively. Because it is practically not possible to change the number of poles of windings of motor, the speed of a motor is changed by using the relationship between the frequency of the supplied voltage and the supply voltage. Devices that is designed to meet the different speed need of motors are named as variable frequency drives. VFD's basically consist of four main units. These are AC/DC rectifier unit, DC bus and filter unit, DC/AC inverter unit, respectively. The following basic circuit diagram of the variable frequency drives and brief information about the components are given in the below.

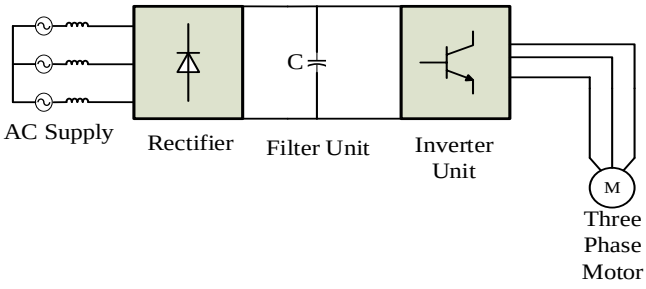


Figure 1: Basic Structure of VSD

Rectifier Unit: AC voltage is converted to the DC voltage and comprises of diodes or IGBT's.

DC Bus and Filter Unit: It eliminates ripples in DC voltage that occur as a result of AC-DC conversion in the rectifier unit and provides the energy to the inverter by means of capacitor it contains.

Inverter Unit: It is the part where the speed control of the motor is provided by converting the filtered DC voltage to AC voltage of adjustable magnitude and frequency. [5]- [6]

IV. POWER LINE DISTURBANCES

The main power quality problems that may cause disruption in the operation of adjustable speed drives used in continuous processes are given below.

Surges or Transients: can be defined as a short-term but high-energy electrical pulse that is induced on an electrical circuit or equipment. Short circuits, Lightning, bad weather conditions and loose connections are the primary reasons of this event.

Interruptions: It can be defined as an event that occurs when the supply voltage or load current drops below 0.1 pu for a period not exceeding one minute. Power system faults, equipment failures and control malfunctions are the main reasons of the interruptions.

Voltage Sags: A sag can be defined as a decrease in rms voltage between 0.1 pu and 0.9 pu for periods from 0.5 cycles to 1 minute. Some reasons of the voltage sags can be listed as weather conditions, switching of large loads and, commissioning of large asynchronous motors and power line failures, respectively. [7]

Although there are some other reasons why variable frequency drives are disabled, the most important thing to consider is undoubtedly the voltage sag events that occur in the electrical power grid. In the IEEE 1346 standard, the operations limits of the adjustable speed drives against the changes in the supply voltage are specified. According to the IEEE 1346 standards, variable frequency drives can operate up to a voltage sag of 15%. Means that, in 400 VAC system variable frequency drive can operate until 340 VAC.

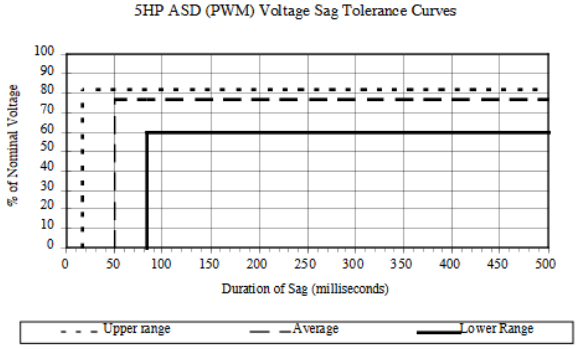


Figure 2: Voltage tolerance of VFD (IEEE 1346 standard)

As can be seen the above figure, out of the operation limits, variable frequency drive will fail. Voltage sag events occur in the AC mains supply of the drive will cause the voltage reduction in the DC bus of the VFD. If the DC bus voltage goes out of the predefined limits, inverter is not feeded and the speed of motor which the drive is connected will gradually decrease and related process may experience downtime. [8]

In 400 VAC, the DC bus voltage and the its lowest value at which the device can operate can be calculated using the formulas below.

$V_{DC} = 1.35 * V_{LL} = 540V$ (1) Where V_{LL}=400V

Adjustable speed drives trips when the value of DC bus is equal to 0.9 of its nominal value. In this case, the trip value of the DC bus voltage will be $V_{DC,trip}$ = 486 V.

The voltage of DC bus must remain within the specified operation limits, in order to maintain the proper variable

frequency drive operation that is used in extremely important process. To do this, there are various methods developed. Namely, these methods are divided into three subcategories, drive, hardware and energy storage based solutions. In this study, battery-based DC bus supply method, which is one of the energy storage-based solutions, will be evaluated with simulation results. [6]- [10-13]

V.BATTERY BASED SOLUTION

Besides acting as a filter, the DC bus section is the main energy source of the inverter unit thanks to the capacitors it contains. Voltage sag events where occur in the electrical power grid affects the DC bus voltage and causes a decrement on power supplied to the inverter unit, and as a result, the process in which the drive contains is affected by this situation.

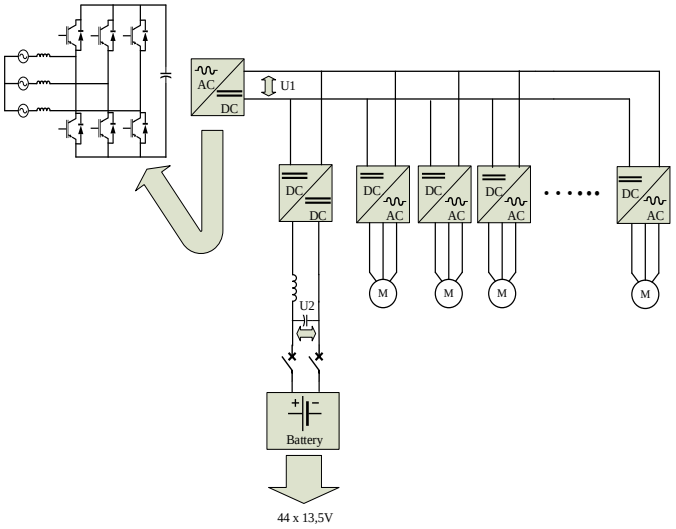


Figure 3: Modified Circuit of ASD by Adding a Battery Unit

To overcome this problem, battery-based solution is evaluated. The basic philosophy of the system is that when there is a voltage sag in the system supply voltage, this event also affects the DC bus voltage. When there is a voltage sag in the system, missing voltage of the DC bus will be provided by the battery units, and the effect of the event on the system will be reduced.

To obtain the required DC bus voltage, the batteries must be connected in series with each other. The current to be drawn from the batteries is directly proportional to the amount of the load. The modified drive circuit is shown in figure 3. Thanks to the active rectifier unit used in this study, DC bus voltage can be adjusted between 610-615 VDC and it feeds the inverter unit. The battery unit consists of 44 batteries with a voltage of 13.5 volts connected in series. DC bus voltage is continuously measured by voltage sensors. To prevent the DC bus voltage from falling below a certain value (554) when there is a voltage sag, the battery unit is activated as a discharge and feeds the DC bus unit its value reaches the 615V. Thus, the system is not affected by this voltage sag and remains within the operating limits. When the power grid returns to normal, the battery group is deactivated and charges itself with the system voltage.

In the below figures simulation results are shown. Figure 4 and figure 5 show the system supply voltage and DC bus voltage, respectively.

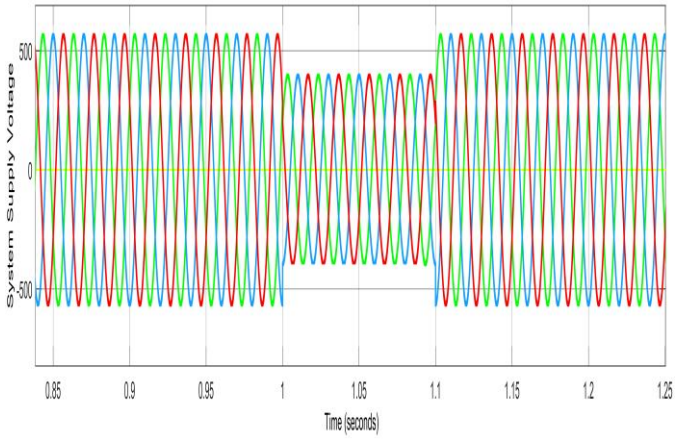


Figure 4: System Supply Voltage

In figure 4, a voltage sag between 1 and 1.1 seconds has occurred. During this period, the system supply voltage has decreased by 33%.

According to the obtained results, although the voltage sag caused the voltage drop on the DC bus for a very short time, value of DC bus voltage is within the acceptable limits. Simultaneously, battery unit sensed the voltage drop on the DC bus unit and activated to recover the DC bus voltage to the required value again.

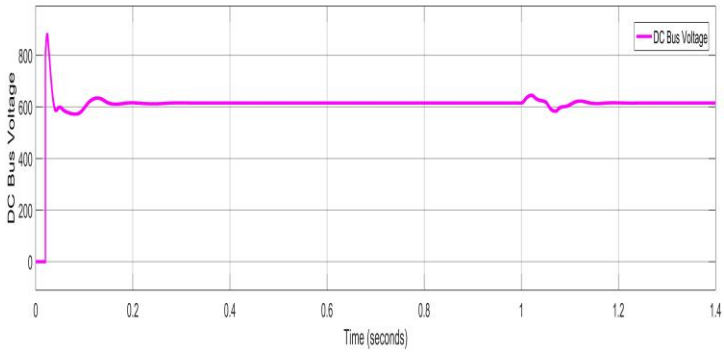


Figure 5: DC Bus Voltage

V. CONCLUSION

The concept of power quality is becoming an even more important issue in these last days, where the need for energy and its continuity are increasing. Since the majority of industrial facilities have the continues production feature, the concept of power quality has a special importance in these facilities. These facilities have production stages that are formed by the combination of production steps that are nested with each other. Variable frequency drives are the one of the most important components of these production steps and vulnerable to the power quality problems. A power quality problem in these critical processes can cause serious economic and technical problems. In this study, battery-based solutions carried out to increase the endurance of variable speed drives against the voltage sags, which have extremely important tasks

in critical processes, has been examined. According to the simulation results, thanks to the battery-based solution, the DC bus voltages of the adjustable speed drives remain within the acceptable limits during the voltage sag event and are not affected by the voltage sags.

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