POWER QUALITY ENHANCEMENT FOR COST REDUCTION IN PLASTIC INDUSTRY

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Abstract
In this paper we discuss poor power quality, the largest cost reduction opportunity in the plastics industry. Poor power quality is a bit like death and taxes it is inevitable. No matter what kind of business we have, or type of products manufactured. But many people don't even know that they have power quality problems and even if they suspect it, they don't know how to identify where the problems lie or how to diagnose the type and severity of the power quality issues.power quality issues cost the plastics industry approximately 9.6 billion dollars annually. The study also showed that eighty percent of power quality issues are created by conditions that are found inside of those industrial facilities. So those issues are diagnoseable and preventable but there's because these problems are frequently misunderstood and ignored. It's complicated and we may recognize a lot of these symptoms like burnt motor windings, or a transformer winding, blown capacitors and they may be in VFD drives or an electrical component.
Keywords: *Voltage sag, harmonic analyser, reactive power, voltage imbalance, current imbalance.*

1. Introduction:

Fig.1 shows the recognition of poor power quality symptoms.

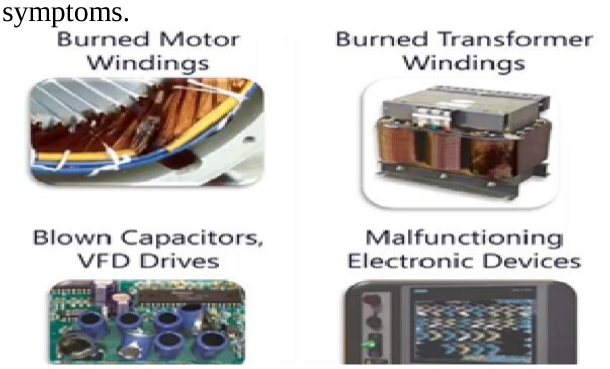

Fig.1 Recognition of poor power quality symptoms

In malfunctioning devices people believe that this is caused by part quality or faulty machine design. The reality is that there may be something they can't see that is causing these component failures if this is repeatedly occurring. This is a symptom of poor power quality.When we use terms like sags and swells voltage and current imbalances power factor etc we do get a lot of blank stares. So, we hope that the simplified analogies we've prepared will help the non-electrical engineers to understand the terminology and the key concepts that they need to know. The power terminology is shown in Fig.2.

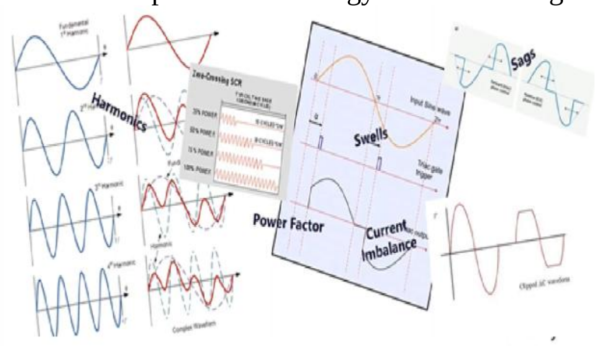

Fig.2 Power terminology

Voltage sag is a momentary decrease in voltage resulting in 10 to 90 percent of nominal voltage lasting from what half a cycle to 60 seconds. Causes of voltage sag are large motors starting, cycling of machinery. Basically any type of law that is starting consequences are the equipment might pull excessive current. loads which may lead to fuses or breakers tripping and again voltage sags that may also result in electronics. the opposite of a voltage sag is a voltage swell voltage swell is a momentary increase in voltage. In this case voltage is 110, 100 or 80 percent of nominal voltage lasting from half a cycle to 60 seconds in duration. Greater than a minute is called an over-voltage condition. This may be caused by high incoming voltage into our plant. for instance, we see close to 500 volts on our 460 volt 3-phase since we're right next to the main power grid.

Some consequences of voltage swells are a breakdown of power supply components, hardware failure due to overheating and electronics damage typically due to failing capacitors. Our analogy for voltage swell is water hammer. For example, we have a faucet fully open and we quickly close it we may hear knocking in our pipes. This is caused by high pressure in our water lines just like voltage swells and power lines. 87% voltage disturbances are caused by sags or swells dipicted in Fig.3.

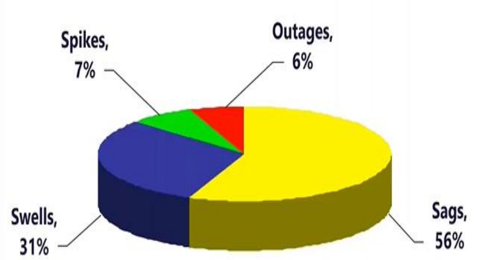

Fig.3. Survey of power quality disturbances

When we move from short-duration voltage issues to another problem voltage imbalance. This means the voltage values between the voltage phases are not equal. It's typically caused by unequally distributed single-phase loads and a facility's power distribution network will illustrate the problem with an example shown in Fig.4.

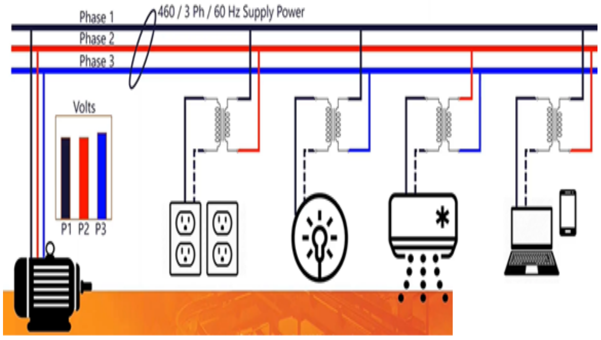

Fig.4 Single phase loads distributed among three phases

The graphic shows a 460 volt 3-phase supply voltage feeding a single motor and the voltage across all three phases is equal and it's so it's balanced. The voltage distribution changes when a single-phase load is added two phases 1 and 2. the 460 volts is transformed down to 120 volts single phase for the receptacle plugs. The extra current load on phases 1 and 2 reduces the voltage available to all devices. This is shown in the bar graph besides the motor and the result is a minor voltage imbalance at the motor. More single-phase loads are added, and they all are connected to phases 1 and 2. The increasing current loads reduce the available voltage for those phases even further the bar graph reflects a significant difference in voltage values and the result is a significant voltage imbalance at the motor.

To correct the imbalance the single-phase loads can be redistributed among all three phases. The current load on each phase is more balanced now. So, the voltage difference subsides, the bar graph now reflects similar values and the voltage imbalance at the motor is minimized. We've seen this uneven load distribution on three-phase lines causing voltage and balances and plantsand so many pieces of equipment andcomponent failures because of that. Some of the consequences of voltageimbalances are current and balanced VFD.

An electronics malfunction andtemperature rise and motors transformersand hot spots or uneven temperatures andheater banks what appears to be a small.A 5% voltage imbalance causes a very large50% increase in temperature rise and amotor for example this is significant tothe operation of a motor. This increasein temperature can cause insulation inthe windings to break down resulting ininternal shorts causing higher ampdrawls, more imbalance and higher tempsresulting in a snowball effect leadingultimately to a failed murder.

Sags or swells are equallyproblematic, but a swell is more likelyto damage our machinery component. A voltage sag can blowcapacitors and can have harmfuleffects because of the increase ofvoltages above the rated values of thecomponents where swells would typicallybe more passive and just create sometype of resetor system fault type of conditions. It's one of our moredifficult power quality terms that is harmonics.AC voltage or power supply is 60Hertz in US. That's 60 cycles per second voltage andcurrent waveforms have a 60 Hertz sinewave harmonic and a harmonic is aninteger multiple of the supply frequency. So as we mentioned in the US, we have60 Hertz that's the fundamentalfrequency. So, a second harmonic is 120Hertz. Linear loads such as simple motorsand incandescent lights have a constantimpedance or electrical resistance andconsume all supplied energy i.e. thevoltage and current waveforms looksimilar and cause no harmonic distortion. On the other hand, nonlinear loads that switch on and off faster than the fundamental frequency i.e loads that do not draw current during the entire waveform create distorted power users waveforms with unconsumed energy. This results in harmonic distortion.

Harmonic distortion dissipates as heat and surrounding electrical components. Inthis example heat builds up cycle aftercycle into the motor creating elevatedtemperatures. Another effect of harmonics is powerloss. The analogy we'll use here is sparkknock and a car engine. In normalcombustion the spark plug ignites thefuel resulting in a flame front thatreaches the piston near top dead centre. This results in full power transfer inpremature combustion. A hot spot in theengine's combustion chamber causes aflame front that pushes against thepiston before it reaches top dead centerreducing shaft rotation and reducingengine power. Like the normalcombustion example just described, thefundamental waveform delivers full powerto the motor. The devastating effects ofthe third harmonic is shown in theFig.5 below.

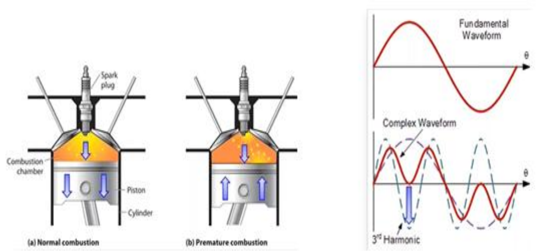

Fig.5 Effects of third harmonic

As the fundamental waveform in purple is reaching its peak, the third order harmonic and light blue is reaching its minimum value heavily distorting the waveform as shown in red and the resulting power delivered by the motor harmonics are caused by VFD drives laptops laser printers electronic ballasts fluorescent lighting and DC power supplies anything that converts AC to DC power. Lower harmonic frequencies are more damaging as they have more energy. Higher frequencies have less energy, but they tend to affect communications and control equipment. Total harmonic distortion or THD acceptable maximums are 5% for voltage and 10% for current. Now let's define power factor as thepercentage of electrical power doinguseful work that could be deliveringheat or mechanical energy in the case ofheat. In the lower left in Fig.6

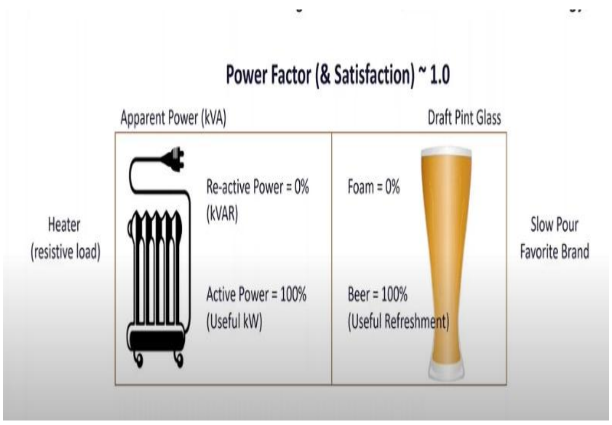

Fig.6 conversion of power to useful energy

Nearly all thepower used is converted to useful energythat's100% active power and the power factoris approximately 1. Comparing this to adraught pint glass carefully fell to thetop with our favourite beer the entireglass delivers 100% useful refreshmentand zero foam. So our satisfactionfactor is 1. Now we'll look at useful work done asmechanical energy when power factor doesvary when we have an inductive load likea motor. We have part of the power that'sused for active power which is turningthe motor and part of the power is usedfor reactive power which is used topower the magnetic windings. Those twocomponents of power add together tocreate apparent power that would beequivalent to a draught pint glass witha quicker pour where we have 70% of theglass filled with beer and 30% of theglass filled with foam.

The result iswe're less satisfied with our draft. With the motor the power factor isreduced.Our factor is important for acouple of reasons. In our example weonly drink the beer from the glass, butthe glass has to be big enough to holdthe beer and the foam otherwise thecapacity is exceeded. With the motor thepower company charges for active powerlike beer only. But must supplyservice for the complete apparent power. In our facility the motor performs workusing only active power, but our switchgear and wires must carry the fullapparent power to prevent overheating. Following up on power factor there aresome important facts to consider a powerfactor of 0.9 to 0.95 is consideredhealthy but typically in plastic plantswe see a power factor of 0.75 to 0.8.

Companies will typically penalize forlow power factor switch gear and wiremust carry extra load due to low powerfactor. Power factor can be corrected inthe case of motors using power factorcorrecting capacitors and for a facilitytypically done using autoadjusting capacitor banks. If we see why power quality isa growing problem in variable frequencydrives are more and more prevalent as wecontinue to try to optimize energy usageandour process and throughout our plants which creates significant potential forpower quality issues. The proliferationof electrons DC power supplies that areused to power up electronic devicescreate harmonics and add to powerquality issues. Memory digital logic andi/o boards used in. These devices arealso susceptible to power quality issues. Plant expansions and inadequateplanning often lead to unbalanced phaseloads in our power distribution network.Throughout our plant resulting inunbalanced phase voltages.

2. Role of VFD drives:

We know that more and moredevices in a production cell causeharmonic. Many of these are caused byenergy efficient devices or modernelectronics VFD drives for optimalconveying energy usage. VFT drives foroptimal drying and energy usage. Solidstate relays used for precise heatcontrol and DC power supplies used topower controls .at our injection mouldingmachine typically VFD drives are usedfor optimal process control and energyuses. Also, servo drives for speed andprecision typically used in robots.Solidstate relays for precise heat controland again DC power supplies for PC andPLC base controls as our productioncells expand in our facilities. We oftensee high harmonics and voltageimbalances in addition to drives heatersand controls.

Energy-efficient lightingcauses harmonics and power qualityissues. There arebillions of dollars lost to powerquality issues in the plastics industry. Each year that's a staggering numberthat includes so many negative impactson both ouroperations and our end customers as well. Component equipment failures canrepresent large single expenses but evensmall, repeated costs add up quickly lost. Production time is the most frequentlymentioned headache for customers. We talkwith at least two cascading problemswith operations. cash flow and customersdownstream in the supply chain. Theseimpacts really do beg the question whatcan be done to avoid them spread before. About power quality problems beingtypical in the case of a plant expansionwe also mentioned injection mouldingmachines. Over the last five to tenyears there are a few cases. Of that nodoubt that getting away from thehydraulic machines and going to useall electrics really helped our process.And because of thatfact we are trying to bemore process orientated and try to reduce the rejection rates. Andwe have better quality. Somaintaining more constant pressures andspeedsand all electric machines aregreat for that but of course at the same time as mentioned a little bit with the variable frequency drives that are involved.

The other energy was being used from other utilities such as we know electrics or some pneumatics and certain equipment as well. Not as much in the case of injection molding machines but with going to more and more electric. That's putting more stress on the existing infrastructure. We have seen some issues with some older controls that were in the in an existing customers facility. And after making some upgrades they started experiencing some problems and so we were trying toknow what would has changed. Nothing's changed and we haven't doneanything and then after going on saythere are those type of things, we'vebeen able to troubleshoot that. That wasindeed the problems. Now we have a final case for powerquality diagnosis.

In plastic industry, most equipment ispowered by electricity and that may betrue in many industries. But in plasticslarge and expensive motor drives andheavy heat loads drive the cost ofelectricity to be a large part of theproduct cost often second only toraw material. So good power quality isvital to maximizing uptime and tominimizing product costs to improve thebottom-line power quality problemshappen in our own buildings. If youremember 80 percent of power qualityproblems are created inside our ownfactories. So we can manage thoseproblems before they manage and it'scritical to map key power grids justlike any other process in our business. Whether it's utility like water, anauxiliary process like material handlingproduction issues or logistics. None ofthem are successful by accident. Most ofthose are planned routinely and plannedvery carefully. It shouldn't be anydifferent with something as important aspower gym power quality diagnosiscertainly makes sense. But it hasn'talways been so easy.

3. Implementation of new tools:

Several tools arerequired such as an oscilloscope curtand voltage meters, a harmonic spectrumanalyser and an AC voltage tracer. Manyplants do not have all these tools andthe price for these items certainly addsup. Limitations of traditional diagnosticmethods typically the tools are on spotdevices handheld instrumentation thatsample at intervals while someone isoperating them it requires resources andtime to collect data. Typically, this isdone by a third-party vendor. Data iscaptured at a point in time, but processloads vary throughout the day or week oreventhroughout the year. So, the datacollected might not always catch hiddenissues in our plant. Typically, thisresults in a high investment cost. Over ten thousand dollars just tocollect the data. Once the data iscollected often this requires athird-party expertise to understand.Lastly, we must record or mainly uploaddata for future comparisons. This iscritical step in helping understandpower quality issues later.

Nowthere's a new way to diagnose themachine. Sense power analyser is like an MRI forour machines.It diagnoses poor powerquality issues and gives focus tocorrective action. Efforts unliketraditional hotspot tools it has a 24/7monitoring capability. This can be usedto spot trends that are based on timeintervals that may require longerperiods of time. In historical data tospot and to identify anomalies that maynot be seen with on spot tools due totiming off. When these events occur suchas on off our schedules it replaces several diagnostic tools and has adramatically reduced investment cost.Itis simple to use, and no specializedtraining is required to operate. Theyleverage the latest in the industrial.Internet of Things technology can beinstalled in about 30 minutes.

The power analyser productis our main control box which includescurrent towards for each phase of powerthat can easily be clamped on toexisting motor leads or other loads. Aninternal data hub is included for datacollection and communication usingtraditional rj45 Ethernet connections orvia Wi-Fi to a standard router whichconnects to the cloud. This is at theheart of where our analytics andDiagnostics are performed. Our visualization package can be viewedvia webpages using a standard webbrowser or an app form installed on aphone or tablet. The working of power network analyser is shown in Fig.7.

Fig.7 Working of Power network analyser.

It is easyto install a machine to sense poweranalyser. Around power supply lines theysimply clamp over the power lines to bemonitored. Then install voltage leads atsupply terminals. They are color-codedred, blue and black for easy phaseidentification and finally connect poweranalyser to a voltage supply. It runs off24-volt DC 115 volt or 230-volt ACsingle-phase. Once the unit'sinstalled it's just as easy to use witha brad browser. Simply navigate to themachine sense crystal ball online portal. Register the power analyser and we'llhave access to the power analyserdashboard. The first gages will noticeour diagnostic analytics. They useintuitive icons to illustrate thecondition being diagnosed from the poweranalyser data. Status is easy to seethrough green, yellow, and red backgroundcolours.

Standard power diagnosis gaugesinclude current and voltage imbalance. Voltage sag and swell plus a machineutilization gauge that indicates machineon time and operation under load formotors predictive analyticcages are also available. They interpretthe power data and tends to provide anindication of the electrical component. Health for motors bearing condition andstator winding condition is predicted. Based on advanced scientifically provenalgorithms for multi element heaterbanks individual element failure ispredicted along with the electricalphase supplying power to that element.

Finally, there are traditional powermonitor dashboard gauges that displayupdated power data parameters tracked.include voltage and current RMS valuespower factor and active Power Plusvoltage and current total harmonicdistortion values. 24-hour minimum andmaximum values are also shown for quickdirectional feedback on recent powerquality conditions.Prophecy's cloud servers keep historicaldata up to six months. This allows forbuilt-in trend reports that allow us toidentify power quality patterns oranomalies over time. That can assist rootcause analysis of unexplained downtimeor malfunctions energy consumption isalso tracked. So, we can manage peakusage for large assets or compare usagebetween assets and similar processes. All account users canelect to receive power analyzer alertsvia email or SMS text.This information isalso contained in MRO reports availablethrough the crystal ball web portal.

About actual machinesense poweranalyser customers and how they're ableto easily diagnose their power qualityissues. First, we'll see about anextrusion film facility which wasexperiencing supply power shortages. Symptoms every night the customer wasexperiencing what appeared to be regularrepeatable power shortages causingunexpected water-cooling unit shutdownsin. Extrusion lines to slow downresulting in reduced output capacity. Thediagnosis using a machine sense poweranalyser already installed on theirextruder. Each day thespecialist cure the local power companywas contacted and shown the data fromthe power analyser. They were able toidentify a nearby industrial facility onthe customer's same supply line who hadrecently installed a very large inductive load i.e low power factor machine. Each day the power company increased ampservice to the extrusion facility andthe nearby industrial facility, and theproblem was solved. In the first casestudy we found that the power suppliedfrom the power company was causingproduction issues in their facility. Inthis second case we find that theirtroubles are caused by problemsinside of their own building. They set upa five-story office building with testslab equipment.

The poweranalyser found excessive total harmonicdistortion and current imbalance. Anengineer can review the wiring diagramsand identify that the majority ofsingle-phase loads were tied to one oftheir three-phase power supply lines. Therecommendation a balanced single-phaseload configuration across all threesupply phases in addition total harmonicdistortion from laptop power suppliesand lighting circuits were found. Theywere mitigated with THD filters thatwere installed. We were able to confirm thatthe signs of unbalanced shaft loadingcaused by their electrical issues weremitigated after the recommended fixeswere installed. In this last example wesee how the power analysers advancedanalytics can be used to diagnose anequipment's power related problem. Thesetup a PEP sheet extrusion line with adedicated dryer and hopper.

The dryer maintainstemperature, but other elements areoverworked eventually. Additionalelements fail and temperature reducesand proper setpoint can no longer bemaintained. Material stays wet obviously. Product is scrapped unplanned downtime. To repair the dryer is required. Additional spare parts cost is incurred. As a result, this type of scenario is commonoutcome with diagnosis. Courtesy of the machine sense power analyser through advanced heater analytics. We candetect element failure,and which phases they affect scheduleddowntime to repair the dryer can be madewithout the chaos of a down process lineavoiding an unplanned downtime scrap andcosts associated with equipment andprocess failure. Themachine sense power analyser comes in two different models. Two basic modelsthere is a 100-amp current towards fourfor smaller machines. Some peoplemay call smaller machines but 100 ampand then 300-amp model for larger. The100-amp unit is 1195 and the 300 and is1295 and that will come with theproducts that we showed earlier.

4.Conclusion:

Power quality monitoring is used tomonitor the quality of voltage andcurrent produced by a power plant.Here we should match the system performance correctly with theneeds of customers. Whereas the nation is monitoring to cater specific problems. Here it performs short-term monitoringat its specific customer siteswhereas the next one is monitoring as apart of enhanced power quality servicewhich means here installing equipmentwithin the customer's premises. But then action is monitoring as a partof predictive maintenance. Equipment maintenance can be quickly ordered toavoid failures likecatastrophic failures.

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