PLUG&SHRED SOLUTION

Smart Power Technology for Recycling Process

DANIELI AUTOMATION

MEASUREMENT & ANALYSIS

Modern industrial activity requires flexibility and efficiency to ensure responsiveness to market demand, but that is not the case for the power drive systems traditionally applied to scrap shredders. Such systems - slip ring motor with Liquid Resistance Starter (LRS); direct starter at full or reduced voltage; hydraulic transfer coupling; and combined DC solution with motor and converter - are not optimizable according to scrap quality and density, operating conditions and wear parts, resulting in a static process with low productivity, high maintenance/production costs, and high energy consumption.
Danieli Automation and Danieli Centro Recycling have jointly designed and supplied Smart Power Technology with an innovative control strategy for energy saving, improved productivity, better use of wear components and reduced impact on the MV distribution network.

Measurement campaign target
The study presented here is intended to evaluate and demonstrate the benefits that can be obtained with a drive, in comparison to the existing LRS solution. The benefits regard production enhancement, energy saving, better utilization of wear components and reduced impact of the process on the MV distribution network.

Measurement points
The power measurement campaign was performed with:
> Power Quality Meter connected to the VTs and CTs of the MV motor switchboard;
> Recorder connected to the LRS, with voltage probes and current probes to measure and integrate the energy dissipated in the LRS.
Power Quality Measurement and analysis are based on and refer to EN50160.

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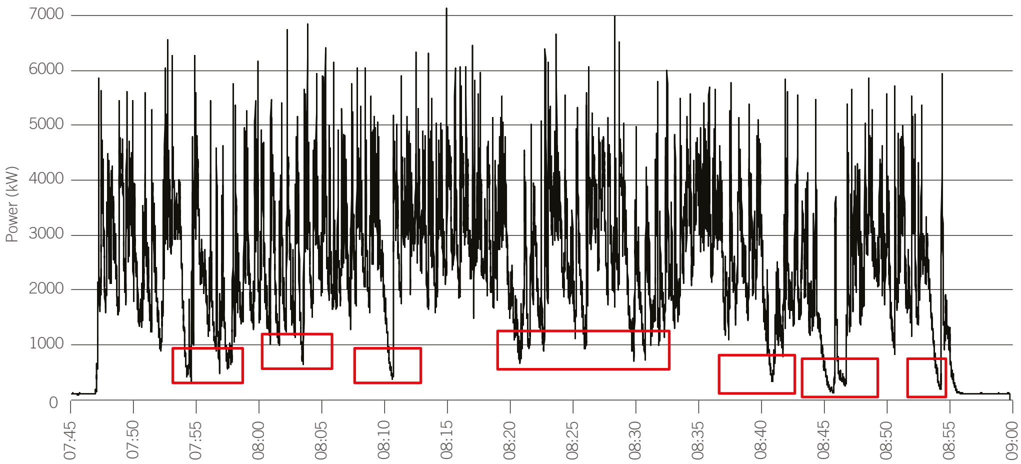
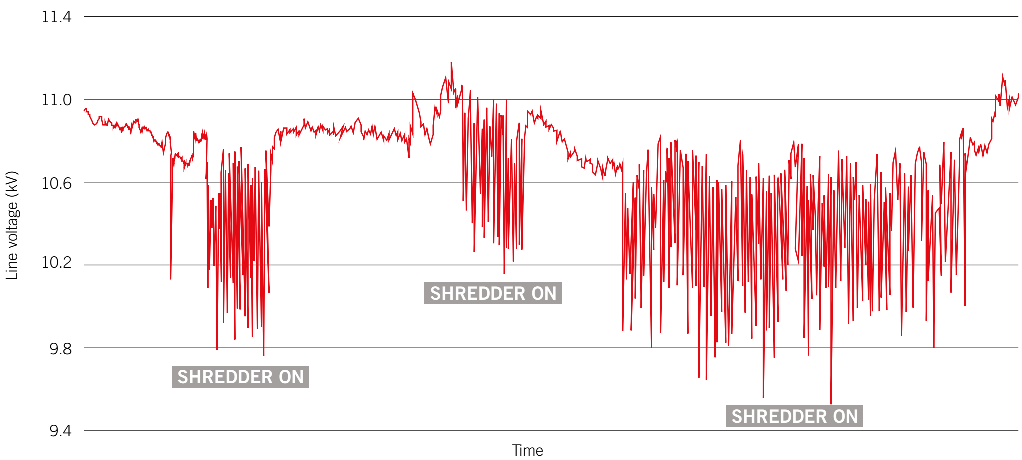


Analysis of the effects on the process
The graph shown in figure 1, part of a complete measurement, represents the total power required by the motor during normal production and operation. The measurement appears on the MV switchboard and includes:
> Mechanical power transferred to the shredder shaft
> Motor electrical losses
> Power dissipated in the LRS

Analyzing the measurement in detail:
> Many intervals with no load or reduced load, typical of an “Auto Pilot”, with control logic based on the motor current or speed feedback only.
> Slow response of the feeder rolls. The red boxes show several cases where the motor is at reduced load, waiting for the impact of the scrap on the rotor.
> Average power is low compared to nominal motor power, below 65%, which indicates that the motor is underutilized, resulting in lost production.
> Repetitive uncontrolled power peaks up to 250-300% of the motor power and above maximum motor overload. These power peaks are partially transferred to the motor shaft, but a considerable part is lost/wasted in the motor and for LRS water cooling. In addition, these uncontrolled overloads/ peaks, if not properly attenuated, will impact the lifetime of the mechanical cardan-shaft.
> The motor is subjected to a load condition that is inconsistent with the motor’s nominal performance, continuously stressed by torque/power peaks even if the real service factor is drastically low.
> Slow response of the LRS to tune and adapt rotor resistance to the load condition.
> Even if the average power (calculated on the entire production shift) is lower than the nominal motor power, power fluctuations are considerable, which indicates that the process is characterized by low energy efficiency and discontinuous and inefficient shredder feeding.



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> The power measured on the motor stator and LRS highlights that considerable energy – up to 10% - is wasted in heat.

Impact of the process on the network
Power Quality Measurement and associated analysis lead to other aspects and effects on the distribution network, in particular:
> the measurement highlights that the line voltage is characterized by rapid voltage change due to shredder load variation. The voltage fluctuation influences the behavior and response of the other motors/loads too, with additional transient currents on the network (see figure 2).

At each load peak voltage drops with amplitude depending on the load, and probably on the configuration and operating condition of the MV distribution network.

In support of the above arguments, in three hours of production the Power Quality Meter detected:
> 45 swell events, consisting in fast voltage variation due to sudden load decrease
> 167 low voltage events generated by voltage drops during overload
> Flicker Pst events (Flicker Short Term) on motor ramp-up and heavy overload, with maximum of 1.35
> Flicker Plt (Long Term) with maximum values of 0.95

Flicker (Pst and Plt) is evaluated during a one-week measurement campaign.
The above affects are consequences of the process and the source of network disturbances impacting power quality, starting from the Power Common Coupling (PCC) between the Recycling Plant distribution system and MV network.

SOLUTION PROPOSED

To summarize, the effects/issues mentioned above can be grouped in two different types:
> Process (motor underutilization, kinematic chain stress, low efficiency, etc.…)
> Network (power peak demand, swells, flickers etc.)
In both cases, a Plug&Shred solution will ensure better production performance and a damping effect against the sources of network disturbance. The Plug&Shred solution combined with a dedicated Firmware and a Smart Adaptive Auto Pilot represents the state of the art of the Shredder Drive System, making the conventional solutions (LRS, Hydraulic Transfer Coupling, DOL, DC system) obsolete in terms of technology and performance. In comparison with a combined DC system, motor and thyristor rectifier, the Plug&Shred solution also eliminates the typical problems of an obsolete DC drive solution:
> Low efficiency
> High cost of DC motor maintenance (brushes and collector)
> Low and limited overload capability, network disturbances (harmonics and low power factor)
> Sensitive and inadequate solution for weak network, etc.

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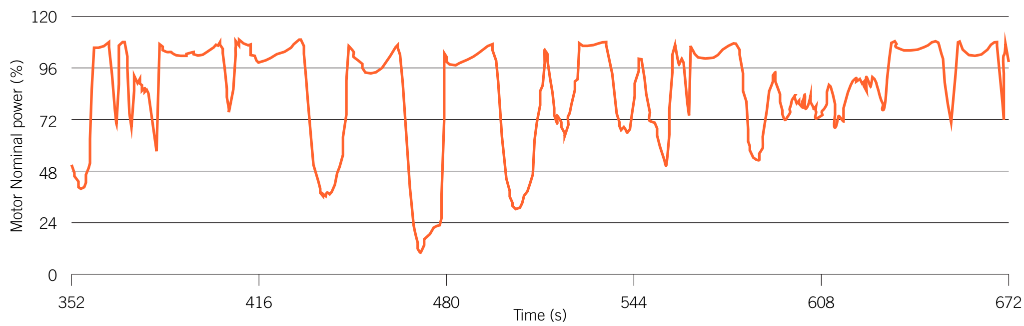


In detail, and starting from the process issues, a drive will provide the following benefits:

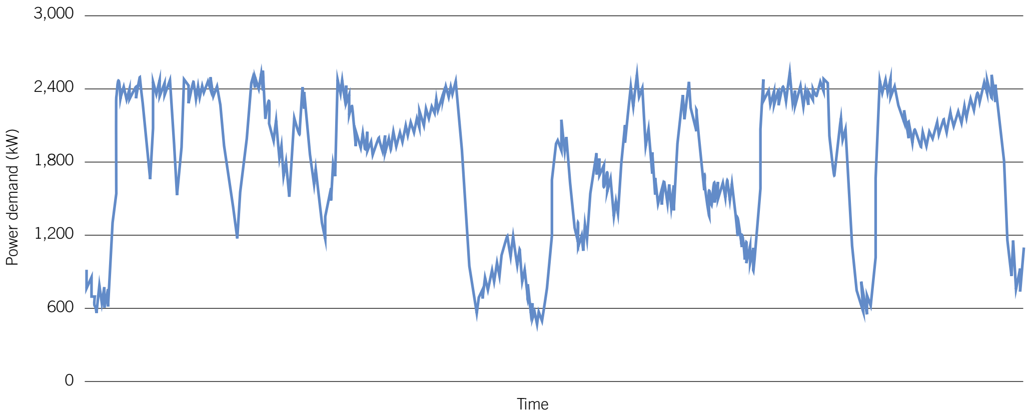
<u>Control of power peaks and demand</u>
To limit power peaks, and instantaneously control the power required by the process during production. As an example, the graph in figure 3 (sample time of 10msec) indicates the behavior of the power control function applied to a shredder driven by a 3000hp motor.
During production, power doesn't exceed 110% of nominal motor power, regardless of operating and overload conditions. Drive reaction and correction are immediate, responding in a few msec, versus 2-3 seconds typical of an LRS.
The influence of the power and control cut off is evident. Power limits can be set in the HMI, according to the energy supply contract and the contractual power limits available in different time slots, thus avoiding any penalties for power excesses.

<u>Dynamic torque limits as a function of motor thermal image</u>
Motor utilization will be thermally optimized using variable torque limits as a function of winding temperature. Optimization of production using the maximum motor thermal capability without risk of overheating the motor, kinematic chain and converter. This function ensures maximum motor torque to recover rotor speed, for a short recovery time after a massive or heavy load.

<u>Vector Control firmware</u>
The drive controls and manages motor torque in real time with an accuracy of 3% (in sensorless mode), avoiding any mechanical stress for the cardan shaft in case of overload. In addition, motor response is much faster than the same motor connected to the network with LRS, something that is unachievable for a traditional system. Encoder or speed feedback sensors aren't required, making this a more simple and reliable solution.

<u>Energy saving</u>
Estimated saving of around 8%-10% also considering the drive losses, or up to 15-20% depending on operational decisions.

<u>Better use of wear parts</u>
Decreasing motor speed for different types of scrap reduces hammer wear by about 10-15%.



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Better motor utilization
Thanks to the drive firmware designed for shredder applications and an Adaptive Auto Pilot, the motor will be better utilized, achieving a higher service factor without affecting motor and kinematic chain lifetime. The response of the feed rolls will be faster thus compensating system delays.
The start/stop/speed commands will be managed, taking into account the drive feedback (torque, speed, acceleration and deceleration of actual motor speed) and scrap density. This will result in a higher utilization factor of the shredder without power excesses, something that is impossible to achieve with an LRS.

Production enhancement
An average power increment means better motor utilization and production enhancement. This is the result of a smart new “Adaptive Auto Pilot” in combination with the drive, essential to manage the motor in overload condition.

Reduced maintenance
With the drive, LRS maintenance (electrodes, electrolytic solution, mechanical alignment etc..) will be just a memory. Even the LRS cooling system will be eliminated, with additional savings in terms of maintenance and annual budget.

Through the drive, the shredder’s impact on the network will be corrected to acceptable levels by means of real-time power control and smoothing of sudden load variations, which are the source of swells and dips, and therefore flicker disturbances. The graph in figure 4 shows the power demand of a shredder with a motor limited to 2400kW, on the network side, showing that the maximum demand is limited to 2400kW, with limited power fluctuation and smoothed load variations, thus eliminating voltage flicker. The conclusion is that the impact of a shredder on a weak network will be drastically reduced, and the shredder will furthermore become an adaptable/tunable process according to the time and power limits imposed by the Energy Supply Contract.

SHREDDER MOTOR RESPONSE WITH & WITHOUT MV/LV DRIVE

Simulation and comparison of motor power with and without drive

In order to highlight the benefits and differences in terms of network impact with and without drive, here below is the simulation study without and with the drive applied to the shredder.

In the graph in figure 5, the first clear evidence is the reduced power peaks and the reduced power required by the process in overload cases, limited to 4MW and configurable on HMI.

The simulation doesn't include the effects of an Adaptative Auto Pilot.

The graph in figure 6 magnifies the limiting and smoothing effect that can be obtained on motor power demand. The smoothing effect can be optimized according to the process and network system.

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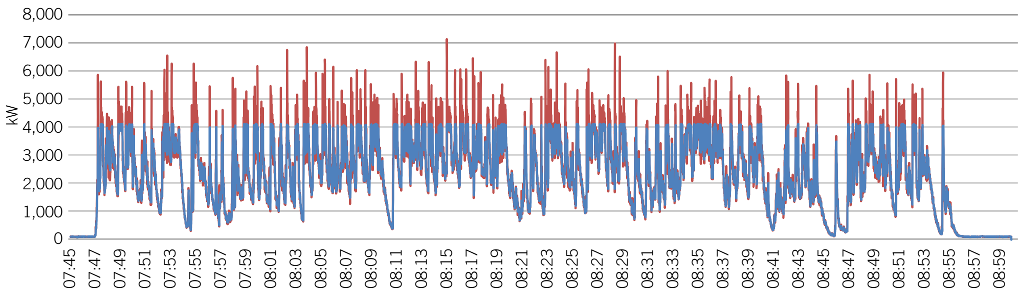

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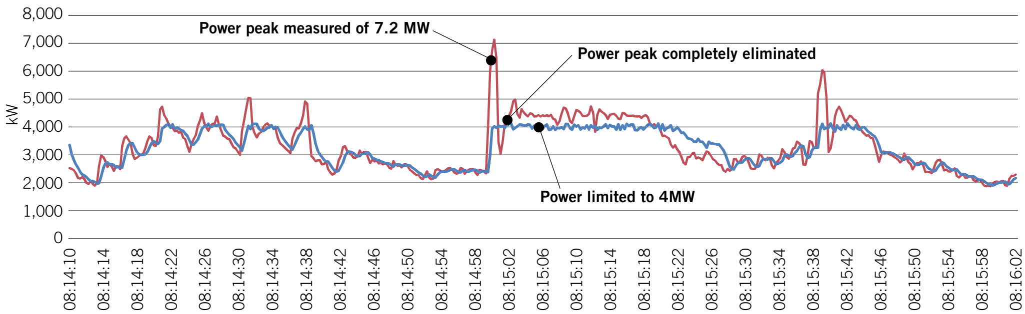

Motor Power Demand

- Without drive
- With drive

PLUG&SHRED DRIVE SECTION SOLUTION

- LV drive up to 690V and up to 3000kW

- MV drive up to 11kV and up to 10MW

> Air or water cooled
> Ultra-low harmonic solution
> High overload capability
> Regenerative
> Power configuration and firmware
for weak network

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