Context

The objective of this EMC investigation was to determine if possible interrupts to the control system operation may have been due to possible excess EMC conditions.

This investigation has been carried out on a finalized installation. Results shown in this report are based on the installation status during a maintenance shutdown.

Per the original intervention scope based on the given plant maintenance schedule, an analysis was done on the control system installations for quick investigations, visual and non-interfering measurements.
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APPENDIX

1. Measuring Devices Used
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1. Executive Summary

1.1 Summary

The likelihood to record an erratic EMC perturbation at the point in time where measurements are conducted being extremely low, a particular attention was brought to determine weaknesses that could allow a perturbation to reach the products.

1.2 Inspections Performed

- electric and magnetic field measurements
- groundings common mode currents
- power supplies voltages and isolation
- earthing DC ohmic values vs PE
- analysis of cabinets installation and wirings
- UPS structure analysis (interview)
- Field cables trays
- MV/LV transformer room -> earthing system
1.3 Global Conclusion:

- no CPU managed exception happened during the intervention
- UPS power supply architecture is relevant.
- no electromagnetic incoming threat detected during our measurements in the given process conditions (This doesn’t mean than no erratic perturbation ever strikes)
- inadequate earth distribution (multiple nails/ star structure) to the cabinets of the control rooms
- cabinets construction weaknesses (not compliant with High Frequency behavior) detected, corrective actions need to be conducted to reinforce the installation.
- cabinet cabling management not fully compliant with EMC rules
- good cable trays construction but lack of earthings along the paths
- corroded earthing connections at field sensors and actuators.
- some safety inputs and outputs are directly wired from PLC safety I/O Modules to the remote field sensors and actuators (long and exposed path)
- the Digi-one Ethernet/serial interface is suspect due to its direct noise injection to the CPU and the fact that it cannot be grounded.
1.4 Recommended Actions

**High Level Recommended Actions:**

<table>
<thead>
<tr>
<th>Non conformity</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Unshielded communication cables</td>
<td>Use SFTP (STP minimum) Cat 5 (Cat 6 preferred) with metallic connectors</td>
</tr>
<tr>
<td>2 Bonding of cabinets</td>
<td>Use large copper braids L/W &lt;10 (5 best)</td>
</tr>
<tr>
<td>3 No shielding connection</td>
<td>Connect armor of big IO cable to the dedicated bar with metallic clamps</td>
</tr>
<tr>
<td>4 Different grounding on RIO</td>
<td>Remove RIO tap grounding from ISE and tie as short as possible to the CPU backplane</td>
</tr>
<tr>
<td>5 Unshielded windows</td>
<td>Install RFI shielding mesh (grid) on the cabinet window</td>
</tr>
<tr>
<td>6 Loops</td>
<td>Remove loops in remaining of cables, if not possible flatten it in 8 shape on grounded metallic plates (frame of the enclosure)</td>
</tr>
<tr>
<td>7 Shielding clamps</td>
<td>Use clamps with communication cables connected to ungrounded devices</td>
</tr>
<tr>
<td>8 Segregation</td>
<td>Provide a separation between power supply (120Vac) with control from analog, 24Vdc and communication</td>
</tr>
<tr>
<td>9 Digi One</td>
<td>Replace Digi one by a grounded module</td>
</tr>
<tr>
<td>10 Power supplies</td>
<td>Check and fix isolation faults</td>
</tr>
</tbody>
</table>

**Medium Level Recommended Actions:**

<table>
<thead>
<tr>
<th>Non conformity</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cable trays</td>
<td>Improve the grounding: parallel earth conductor</td>
</tr>
<tr>
<td>2 Raised floor</td>
<td>Improve the grounding: meshing</td>
</tr>
<tr>
<td>3 Corroded earthings connections at field sensors and actuators</td>
<td>Refurbish periodically for good earthing continuity</td>
</tr>
<tr>
<td>4 Groundings</td>
<td>Grounding should be as short as possible (20cm max, use terminal blocks if needed)</td>
</tr>
<tr>
<td>5 No shielding connection</td>
<td>Connect Ethernet cable shields to PE at both sides</td>
</tr>
</tbody>
</table>

Several points have been raised showing non-conformities with Schneider Electric recommendations. Corrective actions have been listed.
2. Customer site

2.1 Description of site

Each control room consists in 2 parts, the DCS room and the Control room itself where the 5 investigated cabinets are located.

DCS room

Contains a set of cabinets (not analyzed) among which we find power distribution cabinets and earthing cabinets, below are represented the metallic trays (under the soil) holding the power and earthing cables routed to the control room cabinets.

Earths

According to the information retrieved, there are 5 concurrent interconnected earth nails (seen in the DCS earthing distribution cabinet):

- Reference earth = PE
- I/A system earth = FE1
- Non I/A system earth = FE2
- IS earth = ISE (intrinsically safe earth)
- Plant earth = (usage not identified)
Routing

The drawing below shows only what we understand is implemented, (information couldn’t be retrieved), but is just here to illustrate the very different paths and distances of the earth and power distribution depending on the PLC.

Control Room power and earth distribution
Fire Safety PLC Cabinet view (Plant 1 & 3)

Comparing Plant 1 and 3 on one side, Plant 2 on the other side, the PLC are organized in a different manner.
In Plant 1 and 3, a local rack contains the CPU, and a RIO Rack contains the I/O modules
Plant 2 has a single 16 slot rack for CPU and I/O modules.

Inside the cabinets, the following different earths are present:
- FE1 functional earth 1
- FE2 functional earth 2
- PE protective earth -> quantum racks
- ISE intrinsically safe earth -> RIO (plants 1 & 3)
3. Earthing System and Earth Construction

3.1 Recommended Earthing System

Earthing system is TT with the neutral connected to earth through a low value resistor (10-15 Ohms). TT is conditionally suitable for EMC purpose (as specified in standards IEC 60643-4-41, IEC 60643-4-44, EN 50174-2, EN50310) if the earth construction is well managed. European and International standardization (IEC 60643-4-44, EN 50174-2, EN50310), recommends using TN-S earthing system for EMC as specified in Schneider Electric Grounding and Electromagnetic Compatibility of PLC Systems Basic Principles and Measures User Manual:

<table>
<thead>
<tr>
<th>System</th>
<th>EMC performance</th>
<th>Guidelines for use</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT</td>
<td>Conditionally suitable Between the ground connection of the primary distribution network and the leakage current from the electrical system, that are caused by ground faults within the system. As with transient currents, potential difference occurs due to the leakage current from devices. These transient currents can lead to faulty couplings or even faults within the system. A corrective measure here is an equipotential bonding conductor between the devices connected directly to earth. These measures basically convert the TT system into a TN-S system.</td>
<td>- ELCB for personnel safety is required  - Surge arresters should be installed (distributed over power transmission lines)  - This type of network requires corresponding measures for devices with high leakage current potential that are located behind the ELCB in the outgoing direction</td>
</tr>
<tr>
<td>TN-C</td>
<td>Bad</td>
<td>- Ensure an unobstructed path for the PEN conductor when expanding the system!  - Because of the high current in the PEN conductor this system is not permitted in areas of particularly dangerous sources.  - If devices with high total harmonic distortion are operated in a system, this type of system is not recommended.</td>
</tr>
<tr>
<td>TN-C-S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TN-S</td>
<td>Very good The TN-S system is the best solution from an EMC point of view. The PE conductors have no power in normal operation.</td>
<td>- Ensure an unobstructed path for the PE conductor when expanding the system!  - A 500 mA ELCB must be installed for protection against fire.  - Corresponding measures are required for devices with high leakage current potential that are located behind the ELCB in the outgoing direction.</td>
</tr>
<tr>
<td>IT</td>
<td>Bad Note: The IT system is recommended as intrinsically safe for safety matters since no electric arcs can occur.</td>
<td>- Ensure an unobstructed path for the PE conductor when expanding the system!  - Filters for asymmetric interference currents cannot be installed.  - Good EMC is only provided within systems (buildings) where all devices are connected to the same grounding device.  - If circumstances dictate that the system must be divided to limit the cable lengths and leakage currents</td>
</tr>
</tbody>
</table>

Recommended earthing system in Schneider Electric documentation
3.2 Observation on Site:

Earth construction is star.

Each piece of equipment is connected to the earth terminal by its own Protective Earth conductor (PE). In the case where the equipment are interconnected, and if the PE conductors are long, or the equipment are far away from each other, there is a high common mode impedance between equipment, large ground loops, and a poor equipotential state particularly at high frequencies.

A cable can be seen as a resistance and inductance. As a rule of thumb a one meter long cable at 1MHz has impedance around 5 Ohms.
Frequency behavior of a conductor

The length of the green/yellow (PE) conductors (L > 1 to 2 m) is such that they:

- Effectively contribute towards LF (50 Hz - 60 Hz) equipotential bonding of the site and therefore to the safety of persons and property (standard IEC 60364).
- Play practically no role in HF equipotential bonding.

The task of the earthing system is to be a path to the soil for currents, while maintaining voltage differences between any two points of an installation (touch and step voltages) as low as possible. Generally, national regulations specify maximum voltage values for personnel safety including provision for protective earth (PE) conductor practices. However, these PE conductors alone are generally not sufficient to fulfill the EMC requirements. In case of long PE conductors, the system can face issue with high common impedance and large loop able to catch noise of electromagnetic fields emitted by walkie talkies, smartphones, antenna and lamps. The electronic equipment will be directly impacted in case of fault, lightning surge, transients or electromagnetic field source nearby.
3.3 Adding a Bonding Conductor (Recommended Action)

Adding a bonding conductor between equipment improves the EMC as shown below:

Improvement of the EMC regarding a bad earthing management

It is recommended to improve the bonding and earthing of the installed solution. Here below are presented star earthing networks classed by efficiency:
3.4 Cable trays

The cable trays where earthing cables are routed and the raised floor can be used to create a meshed common bonding network.

To minimize EMC issues, all cable trays with equipment should be earthed and bonded together with short connections. The cable tray can be used as a parallel earth conductor (PEC). The role of such PEC is to reduce the common mode currents in the cables by using the stray capacitances between the cables and the PEC (here the cable tray). Additional earth connections are recommended between the PEC and the earthing system at irregular intervals between the apparatuses. These connections should be done at the outside of the cable tray (inside part is preserved for the shielding behavior provided by U-Shape).
3.5 Raised floor

Regarding the raised floor, some measurements carried out during the visit have shown that the contact between the supports is not always guaranteed. It is necessary to add a frame ground grid. The ideal solution is to bond each of the uprights. As a compromise, it is possible to only bond one out of two or three in each direction. A grid size of 2m per bond is enough in most cases. The recommended copper section is 10 mm$^2$ or more.
4. Earthing and Bonding of Cabinets

4.1 Bonding (Mandatory Action)

Bonding all exposed metallic parts of an installation and connecting them to the earthing network is a way for meeting safety requirements (touch and step voltages). This connection can be implemented in a manner that will not only satisfy safety requirements, but also enhance the EMC performance of the installation.

Wide and short bonding straps are suitable. The grid itself should be connected to the PE collector using copper braids. Such connections improve HF behavior because of low impedance.

The copper braid dimensions must be such as:

Length/Width < 10 (<5 is the best)

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Cross section (mm²)</th>
<th>Hole dia. (mm)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>17</td>
<td>10</td>
<td>6.5</td>
<td>NSVE815010D6</td>
</tr>
<tr>
<td>155</td>
<td>17</td>
<td>16</td>
<td>6.5</td>
<td>NSVE815016D6</td>
</tr>
<tr>
<td>200</td>
<td>27</td>
<td>25</td>
<td>6.5</td>
<td>NSVE820025D6</td>
</tr>
<tr>
<td>200</td>
<td>33</td>
<td>50</td>
<td>6.5</td>
<td>NSVE820050D6</td>
</tr>
</tbody>
</table>

Copper braid with Schneider Electric references

For a correct faraday cage behavior, the cabinet doors should be bound to the cabinet equipotential.
Panel assembly

The side plates should be interconnected with short copper braids as illustrated below:

Straps to be installed to improve the bonding
4.2 Grounding (Mandatory Action)

PE cables of power supplies must be limited to 20cm. Quantum backplanes mounting accessories (140XCP40100) are mechanically mounted on the cabinet.

Recommended solution is to use the frame to connect PE cables and have as short as possible ground connection between apparatuses and the frame.

Per IEC 61439-2 standard, ground equipotential of the cabinet must be guarantee with a value of 0.1 Ohms maximum between the PE collector and all the metallic parts of the assembly. If so, the frame can be used to ground apparatuses. This is not true for current transformers, surge protective devices, incomer and feeder (power) where the ground must be done by connecting the PE cable to the PE collector.

Use a short connection with a ground terminal DIN rail mounted.

Example of recommended ground connection
It is recommended to improve the bonding and earthing of the installed solution.

1 - Painted sheet metal
2 - Masking - removal of paint
3 - Ensure adequate tightening by means of a nut and bolt system with washers
4 - Ensure high-quality contact is maintained over time

N.B: apply paint or grease to protect against corrosion after tightening.

Dedicated washers should be used to crush the paint.
4.3 Observation on site

Plate on painted part

A contact should be surface on surface, metal on metal.

Gaps between the plate and the lugs

In Plant 1 and 3, RIO reference (ISE) is different from the CRP reference (PE). This must be corrected by connecting as short as possible the tap screw to the CPU backplane.

Straps to be installed to improve bonding
5. Radio frequency transmitters

5.1 Disturbances with Radio Frequency Transmitters

Radio frequency transmitters such as mobile phones and walkie talkies can disturb PLCs. Some measurements have shown that electromagnetic field emitted by Motorola MTP 850 EX can reach 98 V/m. Electromagnetic field emitted by mobile phones can reach 35 V/m.

5.2 Safety Distances and Shielding

Prevention is to keep a safety distance of 70cm away from cabinets to use RF transmitters or provide protection inside the cabinet: the doors with big openings for PLC LED view could be equipped with metallic grids in order to prevent from any radio interference.

Correct Door Bonding and mask the windows with grids

RFI shielding meshes can be found on the market with good shielding attenuations (100 to 30 dB between 1MHz and 2.5GHz).
6. Cable management system

6.1 Cable Trays

Cable trays are metallic. The construction is well managed with bolted plates providing the shape continuity between the different parts. However, the earth is not connected to all different parts to guarantee good ground continuity all along the path. Metal conduits shall be connected at both ends and for long distances additional connections at irregular intervals are recommended to avoid resonances.

Cable trays constructions
6.2 Observation on site

Some parts are corroded &/or full of dust which could be a source of problem in case the connection is lost.

Very dusty earth connection

Corroded tray
6.3 Cable Management (Recommended Action)

Check from time to time the earth connection on site.

Cable management can provide an efficient reduction of disturbances. The enclosing shapes give the best reducing effect.

Examples of cable trays with associated EMC performances

Poor EMC metal conduits can be used when electromagnetic interferences environment is low and power, IO, IT and analog signals are separated using dedicated cable trays.

Segregation of signals

It is recommended to install the cables on the inner corner where magnetic field is low or on the middle side but not on the edge. The magnetic field is here maximum.

Placement of cables in cable trays
6.4 Observation on site

All the signals are mixed. There is no segregation provided.

In plant 2 current measurement in grounds and cabling managements have been correlated.

Current in PE 602 (Plant 2)  Current in PE 6011 (Plant 2)

High frequency noise has been captured in PE cable connected to 602. Signal in PE cable connected to 601 is regular with current spikes from switching. The cabling management is much more mixed in 602 than 601.
6.5 Signal Separation (Recommended Action)

Separate sensitive signals (analog and communication) from control and power supply (20cm).
7. Electromagnetic environment

7.1 Description of Environment

Electric and magnetic fields have been measured around PLCs with the process ON and OFF.

Sources of noise have been identified in the cabinets:

- **Plant 1**

<table>
<thead>
<tr>
<th>Device</th>
<th>Relay</th>
<th>Fans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field (µT)</td>
<td>30</td>
<td>47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device</th>
<th>24Vdc Power supply (Left)</th>
<th>24Vdc Power supply (Right)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric field (V/m)</td>
<td>30</td>
<td>47</td>
</tr>
</tbody>
</table>

- **Plant 2**

<table>
<thead>
<tr>
<th>Device</th>
<th>Relay</th>
<th>Fans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field (µT)</td>
<td>52.5</td>
<td>51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device</th>
<th>24Vdc Power supply (Left)</th>
<th>24Vdc Power supply (Right)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric field (V/m)</td>
<td>193</td>
<td>96</td>
</tr>
</tbody>
</table>
Cables shall not be installed on the side of 140CPS modules. A high electric field to cable coupling occurs. Moreover, these coupled cables are routed in the same duct than unshielded communication cables.

![Image of signal cables installed on CPS module]

Signal cables installed on CPS module
7.2 Cable Reinstallation (Strong Action)

These cables shall be installed under the backplane.

A magnetic field has been measured (7µT, when few nT were measured in correctly routed cabinets) on IO signals due to the mix with 120 VAC power supply in 606 (Plant 2). The power supply cable should be routed on the left (as per other cabinets). The measured value itself is not risky, but the demonstrated coupling here is a clear weakness that could allow an erratic perturbation to strike the equipment inside the cabinet.
8. Power supply

8.1 Description of Architecture

The power supply architecture is redundant, one source is provided from one UPS, one from distribution room and a bypass mode is available in case of failure. Neutral of UPS is grounded at the secondary of an isolation transformer. A filter is added for the power supply delivered by distribution.
8.2 Grounded Positive Potentials

The following measurement values are provided here only for reference, the detected inconsistencies are highlighted in red and the necessary actions are also highlighted in red.

Some of the 24 VDC power supplies have grounded positive potentials. This issue comes from the process side as measurements shown that the default disappeared after disconnecting all the control.

Example:

<table>
<thead>
<tr>
<th>Plant 3: 603</th>
<th>Right 120VAC/24VDC Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line/Neutral</td>
<td>Line/ Ground</td>
</tr>
<tr>
<td>118.3 VAC</td>
<td>119.1 VAC</td>
</tr>
<tr>
<td>+/-</td>
<td>+/Ground</td>
</tr>
<tr>
<td>24.16 VDC</td>
<td>0.301 VDC</td>
</tr>
<tr>
<td></td>
<td>23.86 VDC</td>
</tr>
</tbody>
</table>

In this example, the power supplies are shown to have grounded positive potentials, allowing much of the DC voltage to be found from neutral to ground instead of line to ground. The proper configuration yields results than can be similar to the following example.

Example:

<table>
<thead>
<tr>
<th>Plant 1: 602</th>
<th>Right 120VAC/24VDC Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line/Neutral</td>
<td>Line/ Ground</td>
</tr>
<tr>
<td>117.3 VAC</td>
<td>117.9 VAC</td>
</tr>
<tr>
<td>+/-</td>
<td>+/Ground</td>
</tr>
<tr>
<td>24.16 VDC</td>
<td>19.06 VDC</td>
</tr>
<tr>
<td></td>
<td>3.33 VDC</td>
</tr>
</tbody>
</table>
8.3 120 VAC Reversed Potentials

The following measurement values are provided here only for reference, the detected inconsistencies are highlighted in red and the necessary actions are also highlighted in red.

In plant 2, some 120 VAC potentials are reversed. This could be a safety an issue during maintenance.

Example:

<table>
<thead>
<tr>
<th>Plant 2: 604</th>
<th>Left 140CPS 120VAC Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line/Neutral</td>
<td>Line/Ground</td>
</tr>
<tr>
<td>117.3 VAC</td>
<td>1.1 VAC</td>
</tr>
<tr>
<td></td>
<td>118.1 VAC</td>
</tr>
</tbody>
</table>

In plant 2, the 120 VAC potentials are reversed. The following is an example of the correct configuration.

Example:

<table>
<thead>
<tr>
<th>Plant 2: 604</th>
<th>Right 140CPS 120VAC Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line/Neutral</td>
<td>Line/Ground</td>
</tr>
<tr>
<td>117.8 VAC</td>
<td>118.4 VAC</td>
</tr>
<tr>
<td></td>
<td>0.79 VAC</td>
</tr>
</tbody>
</table>
9. Communication cables

9.1 Cable Type

We noticed that communication cables used in cabinets are not the cables recommended by Schneider Electric. For industrial environments, it is recommended to use SFTP cables.

**Observation on site:**

- Ethernet red UTP cable between cabinets
- White serial UTP cable to Digi One serial server
- Ethernet Cat 5 UTP cables are routed between cabinets

UTP cables are **not** efficient to prevent low and high frequency radiated disturbances to impact the signal.
9.2 Cable Change (Mandatory Action)

Use SFTP cables. UTP cables can be used in tertiary industries but for heavy industries with high levels of disturbances SFTP or at least STP is a must have. Schneider Electric validates all the products using STP cables (ref. 490 NTW 000 XX).

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Conduction (LF: 0 - 50 Hz)</th>
<th>Common Mode</th>
<th>Interference Level</th>
<th>Application Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-wire cable</td>
<td>Average¹, Acceptable², Inadequate³</td>
<td>Bad, Bad</td>
<td>Good</td>
<td>Non-sensitive equipment only, low-frequency applications, 50 Hz-60 Hz</td>
</tr>
<tr>
<td>2-wire parallel</td>
<td>Average, Acceptable, Inadequate</td>
<td>Good, Bad, Bad</td>
<td>Equipment causing slight interference</td>
<td>Tertiary industry, slightly noisy industrial environments</td>
</tr>
<tr>
<td>2-wire twisted parallel</td>
<td>Good², Good up to 100 MHz, Passable²</td>
<td>Bad, Good, Bad</td>
<td>Excellent, Good</td>
<td>Low man-made interference, Tertiary industry, slightly noisy industrial environments, signals &lt; 10 MHz</td>
</tr>
<tr>
<td>Shielded twisted pair</td>
<td>Good, Good, Average</td>
<td>Good, Excellent, Excellent</td>
<td>Good</td>
<td>Low man-made interference (radio transmitters, fluorescent lighting), Slightly noisy industrial premises, local area networks, Tertiary data processing hardware</td>
</tr>
<tr>
<td>Aluminium tape shielding</td>
<td>Average, Passable, Inadequate</td>
<td>Average</td>
<td>Good</td>
<td>Typical man-made interference, Typical industrial sector (data processing, measuring, control)</td>
</tr>
<tr>
<td>Braid</td>
<td>Excellent, Excellent, Good</td>
<td>Good, Good, Excellent</td>
<td>Good</td>
<td>High man-made interference (heavy industry), Very sensitive products in a highly noisy environment</td>
</tr>
<tr>
<td>Shielding + braid</td>
<td>Excellent, Excellent, Excellent</td>
<td>Good, Good, Excellent</td>
<td>Good</td>
<td>High man-made interference (heavy industry), Very sensitive products in a highly noisy environment</td>
</tr>
</tbody>
</table>

Recommendation for communication cables
Here is presented a curve showing the impact of communication cable type on transfer impedance.

Transfer impedance represents the shielding effectiveness and can be considered as an image of how the communication signal can be affected by a noisy environment. The more the impedance is high, the less low voltage signal is protected.

9.3 Schneider Electric Range of Ethernet cables

Schneider Electric is introducing a new range of the Connexium Ethernet cables which are designed to be used in the same harsh industrial environment our Automation system. These cables feature an Industrial grade Ethernet physical media, that are more robust than standard off-the-shelf Ethernet cables and is fully shielded for reliable communications in high noise environments. These cables also feature a rugged RJ45 connector with a metal housing and is designed to simplifies the removal of the connector from devices in location with limited clearance.

See Appendix 2 for further details.
9.4 RJ45 Connector

RJ45 connectors shall be metallic. Otherwise the ground continuity is broken at RJ45 connector side and stray currents are not rejected to the ground but transmitted to the electronics.

Because of the proximity between the door and the CPU in Plants 1 and 3 and to avoid mechanical stress on cables, it is recommended to use references with rotating metallic RJ45.

3M Volition Cat 6 metallic RJ45 connector
9.5 Observation on site

Serial cable plastic connector  Ethernet cable plastic connector

RJ45 connectors are plastic. Noise has been captured in serial communication cable.

![Noise in serial line](image)

Because no shielding is provided (UTP cable with a plastic plug), this noise is directly injected inside the CPU. Dedicated EMC clamps must be used to connect shields before ungrounded Digi One serial server (CPU metallic RJ45 is provided). Replacement of Digi One product by grounded serial server is recommended.

SKDZ M4 reference from Industrial Solutions  SK reference from Industrial Solutions

Brass material should be used.
10. Ground continuity of shielding

10.1 Observation on Site

Cables coming from the process are shielded. Shielding has to be clamped at the entry of cabinets.

Some clamps are not made properly:

- no connection of the shield (picture taken in plant 1 shows a plastic strap to mechanically maintain the cable)
- a plastic clamp is used (picture taken in plant 2).

10.2 Shielding Clamps (Mandatory Action)

For analog signals it is recommended to clamp the shielding at only one end. Low frequency stray currents could flow in the shield otherwise and disturb the signal.

<table>
<thead>
<tr>
<th>Connection</th>
<th>Non-shielded</th>
<th>Shielded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>End connected to frame earth:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Digital sensors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10 V analogue output probes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-20 mA analogue output probes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication bus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable speed drive/Motor link</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Connections of shielded cables according to the type of signal
The shielding effectiveness regarding the frequency range depends on the number of connections.

Influence of connections on the shielding effectiveness

For long cables the shield should be clamped every 10-15 meters.

Influence of connections on the shielding effectiveness

All clamps should be checked as shield connection must be carefully done to be efficient in high frequency.

Shielding clamp at 360° or at least 180°
Pig tails should be avoided and removed. Transfer impedance with pigtails is very high compared to a good connection using clamp at 360°.

Clamp material should be chosen per the environment to avoid corrosion. As shield is usually tined copper, brass material.
Material to be used to avoid corrosion

Clamp diameter shall be adapted to the cable screen diameter.

Galvanic couples (in mV) for some common metals (electrolyte: water + 2% NaCl)

Values in the shaded zone indicate compatible metal couples; however, this should not be construed as being devoid of galvanic action. Compatible couples represent a low galvanic effect.
11. Loops

11.1 Field to Loop Coupling

Field to loop coupling is a common source of problem in installations.

Medium frequency induced currents are permanent and must be avoided.

11.2 Loop Management (Mandatory Action)

Flatten the loops on the metallic frame of the enclosure and reduce the surface with 8 shape or if the cable is compliant (not shielded cables), twist it.

Mitigation to reduce field to loops couple
APPENDIX

1. Measuring Devices Used

- Oscilloscope Tektronix TDS 3054C, 500MHz, 5GS/s 4CH
- Current measurement system Tektronix TCPA300
- Current probe (30A) Tektronix TCPA312
- Current probe (150A) Tektronix TCPA303
- Multi-meter Metrix 3293 DMM
- Differential probe Lecroy AP031
- Isotropic Electric field probe, Microrad, 01E
- Field analyzer, Microrad, NHT 310
- Isotropic Electric and Magnetic Field analyzer, Maschek, ESM-100
- Handscope 2x40MHz OX5042-CK
- Clamp meter Fluke 376
2. Schneider Electric Range of Ethernet cables

Description

Product data sheet

The ConneXium Ethernet cable assemblies are specifically designed for use in harsh industrial environments combining specifically designed Cat 5E Ethernet cable with rugged RJ 45 connectors. The cable has 4 twisted pair conductors and is fully shielded for reliable communications in high noise environments. The RJ 45 male connectors have a rugged die cast zinc housing, a robust locking latch with extended actuator, and a built-in strain relief, providing secure and reliable connection.
Features

- Cat 5E Cable
- 4 Twisted Pair, 24 AWG Conductors
- Fully shielded cable
- Version with jacket material that meets CE
- Version with jacket material that meets UL
- Rugged RJ45 Connectors with metal shell
- Extended locking latch on connector
- Operating temperature range -20° to +70° C

Rugged 8 position / 8 contact modular plugs with metal housing and extended actuator for the locking latch.

Overview

The Connexium Ethernet cables are an Industrial grade Ethernet physical media, that are more robust than standard off-the-shelf Ethernet cables. These cables are designed to be used in the same harsh industrial environment as the Schneider Automation systems, using a specially designed Cat 5E cable combined with a rugged RJ45 connector that ensures communication reliability, flexibility and noise immunity.

The connectors feature a low profile design that allows their use in devices with multiple rows of connections in a back to back configuration, on devices such as Switches. These connectors include an extended locking latch that simplifies the removal of the connector from devices in location with limited clearance, a built-in strain relief.

These cables are for use in an electrical equipment cabinet or in cable raceway that are located within the plant. The RJ45 male connectors are compatible with Schneider Electric’s Ethernet enabled Automation products and systems and connecting to device such as hubs, switch, or HMI/Workstations.
These cables assemblies are more robust that the typical generic or office grade Ethernet cable that are lower cost but have the potential for allowing electrical noise to disrupt time critical communication such as I/O data in a Schneider PSx Automation system. These low-cost cables are traditionally supplied with plastic RJ 45 connectors, which is the same grade of connector used in office applications, include a plastic locking latch that is susceptible to breakage.

The Connexium cable assemblies are fully shielded for use in high noise environments, that is traditionally found in industrial automaton applications. The connectors that are included on the Connexium cables include a metal shell, an extended locking latch for ease of use, and a 360° shield connection for enhanced noise immunity.

**Technical Specifications**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable</strong></td>
<td>4 Twisted Pairs</td>
</tr>
<tr>
<td><strong>Wire Gauge</strong></td>
<td>24 AWG solid conductor</td>
</tr>
<tr>
<td><strong>Impedance</strong></td>
<td>100 Ohms</td>
</tr>
<tr>
<td><strong>Minimum Frequency</strong></td>
<td>100MHz</td>
</tr>
<tr>
<td><strong>Compliance</strong></td>
<td>TIA/EIA-568 category 5E standard IEC 11801 / EN 50173 class D</td>
</tr>
<tr>
<td><strong>Shielding</strong></td>
<td>Fully shielded with aluminum foil Tined copper braid with a minimum of 65% optical coverage</td>
</tr>
<tr>
<td><strong>Bend Radius</strong></td>
<td>Minimum bend radius of 4 cm or less</td>
</tr>
<tr>
<td><strong>Cable Jacket Color</strong></td>
<td>RAL 6018 Green</td>
</tr>
<tr>
<td><strong>Connections</strong></td>
<td>Straight through connection in compliance with TIA/EIA-568A(T568) for pin number, pair number and color coding</td>
</tr>
</tbody>
</table>
The cables are wired as defined in the table below:

<table>
<thead>
<tr>
<th>A connector</th>
<th>B connector</th>
</tr>
</thead>
<tbody>
<tr>
<td>pin 4</td>
<td>Blue (White)</td>
</tr>
<tr>
<td>pin 5</td>
<td>White - Blue</td>
</tr>
<tr>
<td>pin 3</td>
<td>White - Orange</td>
</tr>
<tr>
<td>pin 6</td>
<td>Orange (White)</td>
</tr>
<tr>
<td>pin 1</td>
<td>White - Green</td>
</tr>
<tr>
<td>pin 2</td>
<td>Green (White)</td>
</tr>
<tr>
<td>pin 7</td>
<td>White - Brown</td>
</tr>
<tr>
<td>pin 8</td>
<td>Brown (White)</td>
</tr>
</tbody>
</table>

Cable Jacket - CE Compliant
Material: PUR (Polyurethane)
Compliance: Low Smoke Zero Halogen according to HD.624-7
Flame-retardant according to NFC32 070 N°1 (C2) and IEC 332/1

Cable Jacket - UL Compliant
Material: PVC (Polyvinyl Chloride)
Compliance: UL444 & -CM FT4 or CMG flame rating for cable UL recognized marking on the cable

Connector
Type: Male RJ45 connector
Construction: Die Cast Zinc Housing
Locking Latch: Flexile extended locking latch
Strain relief: Built-in strain relief
Shield connection: 360° optical coverage at cable to connector interface
# Environmental Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature</td>
<td>-20 to 70° C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>-40 to 85° C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>95% non-condensing per IEC/EN60060-2-30Db</td>
</tr>
<tr>
<td>Protection</td>
<td>IP 20</td>
</tr>
<tr>
<td>Altitude</td>
<td>2000 m</td>
</tr>
<tr>
<td>Pull Force</td>
<td>25N force applied parallel to the connector’s primary axis.</td>
</tr>
<tr>
<td>Vibration</td>
<td>Operates with devices in environment with sinusoidal vibration level of 5 Hz – 18.8 Hz with ± 3.5 mm constant displacement, 18.8 – 150 Hz with 5 g constant acceleration in accordance with the IEC 60068-2-6,</td>
</tr>
<tr>
<td>Conformance</td>
<td>RoHS Directive, WEEE</td>
</tr>
<tr>
<td>MTBF</td>
<td>Greater than 1,000,000 hours at 30°C Ground Benign.</td>
</tr>
</tbody>
</table>
Cable Models

The ConneXium Ethernet Cables that are CE compliant includes the following models:

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCSECE3M3M1S4</td>
<td>Ethernet Cable 1M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECE3M3M2S4</td>
<td>Ethernet Cable 2M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECE3M3M3S4</td>
<td>Ethernet Cable 3M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECE3M3M5S4</td>
<td>Ethernet Cable 5M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECE3M3M10S4</td>
<td>Ethernet Cable 10M Cat 5E w/RJ45</td>
</tr>
</tbody>
</table>

The ConneXium Ethernet Cables that are UL compliant includes the following models:

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCSECU3M3M1S4</td>
<td>Ethernet Cable 1M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECU3M3M2S4</td>
<td>Ethernet Cable 2M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECU3M3M3S4</td>
<td>Ethernet Cable 3M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECU3M3M5S4</td>
<td>Ethernet Cable 5M Cat 5E w/RJ45</td>
</tr>
<tr>
<td>TCSECU3M3M10S4</td>
<td>Ethernet Cable 10M Cat 5E w/RJ45</td>
</tr>
</tbody>
</table>