Seismic Adequacy of VVER-Type Equipment - Review of Experience

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ABSTRACT

The purpose of this paper is to describe the modified GIP procedure titled as GIP-VVER, which has been created and is used to verify seismic adequacy of safety-related mechanical and electrical equipment of VVER-type NPPs (Soviet-type PWR). It is anticipated that this modified procedure will become a more or less standard tool for these purposes.

INTRODUCTION

Earthquake experience data was recognized in the U.S. as an efficient tool for a simplified and indirect seismic verification procedure of mechanical and electrical NPP's equipment components by the Seismic Qualification Utility Group (SQUG) more than 15 years ago. SQUG collected data available from past earthquakes and seismic tests and reviewed them in detail. This review was then used to develop and establish the formal procedure titled as the Generic Implementation Procedure (GIP) [1,2] that is used to verify seismic adequacy of safe shutdown equipment of western NPPs.

The purpose of this paper is to describe the modified GIP titled as GIP-VVER which has been created and can be used to verify seismic adequacy of the safety-related mechanical and electrical equipment components and also distribution systems of VVER-type NPPs, namely VVER-440/213 and 1000 type NPPs. The procedure GIP-VVER has been prepared using the following background:

- public available information contained in SSRAP, GIP, U.S. DOE, LLNL and MCEER documents [3,4,5,6],
- information extracted from the documents prepared in a frame of the IAEA Benchmark Study for the Seismic Analysis and Testing of WWER-Type Nuclear Power Plants [7,8,9,10,11,12],
- information extracted form the results of available seismic tests performed mostly in Czech Republic during the last about 15 ears and collected systematically and studied by S&A-CZ,
- experience taken from various many seismic walkdowns, evaluations and analyses of VVER-type NPPs equipment performed by S&A-CZ during the last ten years for these NPPs in Czech, Slovakia and Hungary,
- information extracted from other related papers and documents [13,14,15,16,17,18,19,20].

The scope of equipment covered by the current version of the GIP-VVER procedure includes, similarly as the original GIP, the following twenty classes of mechanical and electrical equipment [21,22]:

(1)	Motor Control Centers	(11)	Chillers
(2)	Low Voltage Switchgears	(12)	Air Compressors
(3)	Medium Voltage Switchgears	(13)	Motor Generators
(4)	Transformers	(14)	Engine Generators
(5)	Horizontal Pumps	(15)	Distribution Panels
(6)	Vertical Pumps	(16)	Batteries on Racks
(7)	Fluid-Operated Valves	(17)	Battery Chargers and Inverters
(8)	Motor and Solenoid-Operated Valves	(18)	Instruments on Racks
(9)	Fans (ventilators)	(19)	Temperature Sensors
(10)	Air Handlers	(20)	I&C Panels and Cabinets

European and particularly VVER-type relays, switches, transmitters and electric penetrations are significantly different from those included into the original GIP databases. These two classes of equipment are not included into the GIP-VVER procedure and their seismic verification shall be based on testing. In addition to twenty classes lusted above, the GIP-VVER procedure also includes guidelines for simplified analytical seismic evaluation of the following classes of equipment:

(23) Cable Supporting Structures (based mainly on the EPRI methodology [23]) ,
(24) Tanks, Heat Exchanger, Filters (based mainly on the documents [24,25]).
(25) Pipelines and HVAC Ducts (including tubing, based on the public available documents [26,27,28].

GIP-VVER also includes special guidelines to verify adequacy of anchorage [29] and seismic adequacy of non-bearing masonry walls

GENERAL DESCRIPTION OF GIP-VVER IN RELATION TO TWENTY MAIN EQUIPMENT CLASSES

As the original GIP, also the GIP-VVER approach is primarily a screening and walkdown procedure. However, if an equipment item is classified as an outlier, rigorous approaches as testing on shaking table, deep study of input data, sophisticated analysis etc. may be used to verify its seismic adequacy. Generally, four major steps of this GIP-VVER procedure when applied to twenty main classes of equipment are as follows:

- selection of Seismic Review Team (SRT),
- identification of safe shutdown equipment,
- screening verification and walkdowns,
- outlier identification and resolution.

An engineering judgment is the major tool used by SRT during the screening verification and walkdowns to evaluate seismic adequacy of the equipment. The SRT includes the system engineers, plant operation personnel, experienced and professionally trained seismic capacity engineers, and also personnel to identify and evaluate essential relays (if necessary). The basic criteria to verify seismic adequacy of an equipment item during the screening walkdown are:

- seismic capacity greater than seismic demand (by comparison of the corresponding $ISRS_{SSE}$ or GRS_{SSE} to Bounding Spectrum
- similarity to the equipment in the seismic experience data bases (checking of caveats, based on walkdown and information available from documentation),
- adequate anchorage of equipment (calculations or engineering judgment, based on walkdown and documentation),
- potential seismic interactions evaluated (based on walkdown).

The GIP-VVER procedure uses two bounding spectra (BS):

(a) BS attached to PGA = 0.33 g (the same as introduced by SSRAP and used by GIP),
(b) BS attached to PGA = 0.50 g (1.5 times SSRAP BS) for VVER equipment classes, which are evidently robust and rugged.

The following sheets are used for seismic verification and walkdowns:

- Screening Verification Data Sheet (SVDS) in which an each equipment component or distribution line to be evaluated is identified simply by a single line item,
- Seismic Evaluation Work Sheet (SEWS) for detail seismic verification of equipment component items or distribution lines,
- Seismic Walkdown Sheet (SWS) for equipment component items and distribution lines verified by analysis to check their proper performance in accordance with documentation, their anchorage adequacy, absence of potential seismic interactions and other aspects of their seismic resistance.

SIMILARITY OF VVER-TYPE EQUIPMENT TO EQUIPMENT INCLUDED IN THE SQUG DATABASES

Similarity of VVER-type equipment to equipment included in the SQUG databases [30] is the most important keystone of practical application of the GIP-VVER procedure. Generally, the principal of similarity is based upon comparison of equipment dynamic and the most important physical characteristics [31].

The specific terms are as follows:

critical device	a safety-related device whose malfunction produces the lowest possible fragility level of excitation for an equipment item,
device	a secondary component attached to a primary equipment structure,
physically similar equipment	different equipment items whose dynamic response and functional (operational) characteristics are approximately equal within a specific frequency range, or equipment whose fragility functions are nearly equal in the most sensitive frequency domain,
critical frequency	frequency at which the peak value of the primary equipment structural response related directly to the malfunction of the equipment occurs,
critical mode	mode for which the peak value of the primary equipment structural response related directly to the malfunction of the equipment occurs,
critical equipment damping	damping ratio for critical mode of equipment item.

The procedure for establishing similarity within an each equipment class includes comparison of the following:

- most probable modes of malfunction (based on recognized behavior of all equipment critical devices) ,
- predominant resonant and critical frequencies and mode shapes,
- critical damping,
- most important physical equipment characteristics

  -- equipment size, mass and position (vertical, horizontal, inclined etc.),
  -- general making, quality of making, age of equipment,
  -- location of the center of gravity, presence and location of cantilevered parts,
  -- implementation of heavy and / or moving internal parts,
  -- implementation of supports and anchorage,
  -- implementation of attached lines, substructures, devices etc.
  -- presence of devices (mechanical or electrical) sensitive to vibrations and shocks.

Class 1 Motor Control Centers (MCC)

The VVER-type motor controllers are mounted in a sheet metal drawers or cubicles typically assembled into stacks lined up side-by-side and bolted together inside the MCC cabinets. Motor controllers include the circuit breakers or disconnect switches, magnetic contactors, relays, control transformers, fuses, and push buttons. They provide control and electrical fault protection for motors powered at 400 volts and less. The MCCs represented by this class contain all attached devices. However, the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks and are attached to the MCC shall be identified and their seismic adequacy shall be verified separately. On the other hand, this equipment class covers explicitly such non-sensitive attachments as connected junction boxes, cables, fuses, rigidly attached small control transformers etc. The GIP-VVER caveats for this class are slightly modified in comparison to the SQUG-GIP caveats. One important caveat was stiffened up, which means that that the first conservatively estimated natural frequency of a fully equipped MCC cabinet must be higher than 12 Hz (not 8 Hz as requested by SQUG-GIP).

Class 2 Low Voltage Switchgears (LVS)

The VVER-type low-voltage circuit breakers are mostly the drawer-type. They are mounted on a rail support system. While in operation, the circuit breaker clamps to bus bars in the rear of the assembly. This class is associated with circuits of 0,4 kV or less. The LVSs represented by this GIP-VVER equipment class contain all attached devices. However, the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks attached to the LVS shall be identified and their seismic adequacy shall be verified separately. On the other hand, this equipment class covers explicitly such non-sensitive attachments as connected junction boxes, cables, fuses, rigidly attached circuit breakers, small control transformers etc. The GIP-VVER caveats for this class are slightly modified in comparison to the SQUG-GIP caveats. There is one important additional requirement that the first conservatively estimated natural frequency of such a fully equipped LVS cabinet must be higher than 12 Hz.

Class 3 Medium Voltage Switchgears (MVS)

The VVER-type medium-voltage circuit breakers are air-magnetic and drawer-type. They are mounted on rollers to allow them to be wheeled in and out of their cabinets. The VVER-type air-magnetic medium-voltage circuit breakers typically include spring-actuated contacts, tripping devices, switches, and fuses. There may be also the stationary load interrupter switches. This class is associated with circuits of 6,0 kV. The safety-related relays are mounted inside the metering compartment. Relays are usually inserted through cutouts in the internal door. The metering compartment may also contain devices as ammeters, voltmeters, hand switches, signal instruments and small control transformers. The MVSs represented by this class contain all attached devices. However, the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks attached to the MVS shall be identified and their seismic adequacy must be verified separately. Nevertheless, this equipment class covers such non-sensitive attachments as connected junction boxes, cables, fuses, rigidly attached small control transformers etc. The GIP-VVER caveats for this class are slightly modified in comparison to the SQUG-GIP caveats.

Class 4 Transformers (TRN)

The VVER-type transformers included in this equipment class are typically the substation type (6,0/0,4 kV) and the distribution type (0,4/0,22 or 0,4/0,11 kV). The VVER-type substation TRNs are freestanding and air-cooled dry-type. The TRN coils are mounted in a ventilated steel cabinet on rollers and they are fixed in operating position usually by rubber isolators. The VVER-type distribution TRNs are air-cooled. This equipment class includes not only internal parts, but also TRN cabinets and connecting cables. The typical seismic issue is seismic resistance of rubber isolators subjected by the heavy transformer internals. Special restraints are added in many cases to fix them against movement in both horizontal directions. The GIP-VVER caveats for this class are slightly modified in comparison to the SQUG-GIP caveats. There is only one additional request that the base isolators under the TRN internals must be checked against seismic inertia effects.

Class 5 Horizontal Pumps (HP)

This class includes horizontal pumps and also blowers, both driven by electrical motors only. The peripheral components such as attached cables, local instrumentation, and also suction and discharge pipes up to their first support are included in this equipment class. The VVER-type HPs are represented in a variety of performances. Two specific features should be mentioned:

- nozzles may be critical namely when the size of the attached pipelines is reduced, or when the nozzle is flange type,
- anchorage may also be critical when extremely short grouted anchor bolts are used (typical issue on all VVER-type NPPs).

The VVER-type HPs are similar to those included in the SQUG database. The GIP-VVER caveats for this class are only slightly modified in comparison to the SQUG-GIP caveats. It is usually necessary with these HPs to provide a separate verification of seismic adequacy of nozzles, namely when they are flange-type, or if the size of the attached line is reduced just near the nozzle.

Class 6 Vertical Pumps (VP)

This includes pumps with the impeller drive shaft mounted in a vertical direction and powered by an electric motor mounted at the top of the frame that is anchored to a concrete base pad. There are two general types of VPs: centrifugal pumps and deep-well pumps. This equipment class includes the pump, drive motor, associated local I&C devices attached to the pump (if any), cables, and also attached piping up to their first support. VVER-type VPs are represented in a variety of performance. Nozzle loads are usually not such a critical issue as with HPs. The VVER-type VPs are similar to those included in the SQUG database. The GIP-VVER caveats for this class are only slightly modified in comparison to the SQUG-GIP caveats.

Class 7 Fluid-Operated Valves (FOV)

This class includes valves that are actuated by fluid. There are the following VVER types of FOVs: diaphragm-operated (mainly spring-opposed), piston-operated, and pressure relief valves. This class includes the valve, the operator, the inlet and outlet pipelines up to the first support, and also all peripheral attachments (air lines, pneumatic relays or control solenoids, connected power and I&C cables, and also local pressure air tanks (if any). Two specific features should be noted:

- valves manufactured in former socialist countries have been designed, performed, tested, and installed during the last about 15 years in accordance with requirements of so called "General Technical Conditions for Nuclear Valves" OTT-82 and OTT-87 [32] which provide requirements for to verification of seismic adequacy of valves by testing and by analysis,
- it is typical for almost all VVER-type NPPs that fluid operated valves are manipulated by air from nearby local pressure air tanks the capacity of which is enough at least for 5-10 open-close operations.

The VVER-type FOVs are similar to those included in the SQUG database. The GIP-VVER caveats for this class are only slightly modified in comparison to the SQUG-GIP caveats. One caveat related to nearby local air tanks was added.

Class 8 Motor-Operated Valves (MOV) and Solenoid-Operated Valves (SOV)

This class includes valves that are actuated by electrical motors (MOV) or by passing an electrical current through a coil creating a magnetic field that opens or closes the valve (SOV). Components of MOVs include valve bodies, motor operators with control boxes, gear boxes, and drive motors. This equipment class includes the valve, operator, the inlet and outlet pipelines up to the first support, and also all peripheral attachments as connected power and I&C cables. Three specific features should be noted:

- valves manufactured in former socialist countries have been designed, performed, tested, and installed during the last about 15 years in accordance with requirements of so already mentioned documents OTT-82 and OTT-87 [32], which provide requirements for verification of seismic adequacy of valves by testing on a shaking table and by analysis,
- it is typical for all VVER-type NPPs that there are also MOVs with remotely located operators and more or less complicated and sensitive to different seismic movements between the valve and its remotely located operator gear mechanisms,
- it was also recognized that some of VVER-type MOVs are equipped by actuating relays or limit switches which are relatively sensitive to vibrations and shocks and, therefore, it is necessary to identify them and verify their seismic adequacy by testing.

This class includes also MOVs installed on HVAC ducts. The caveats for this class are slightly modified in comparison to the SQUG-GIP caveats. Two caveats for MOVs with remotely located operators and presence of sensitive actuating relays are added.

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Class 9 Fans (FAN)

This class includes both freestanding and duct-mounted fans. Fans that are components of other equipment components as air handlers are covered by the respective equipment classes. There are two basic VVER-type fans: axial and centrifugal. This equipment class includes the fan impeller and its enclosure, the drive motor, attached ducts, cables, mounted louvers, compensating devices, and instrumentation lines. FANs installed on VVER-type NPPs are usually supported by springs. These springs are completed by lateral restraints to avoid excessive displacements of base-isolated FANs during an earthquake. The GIP-VVER caveats are only slightly modified in comparison to the original SQUG-GIP caveats.

Class 10 Air Handlers (AH)

This class includes sheet metal enclosures containing a fan and a heat exchanger. Air handlers are used for cooling and distributing air. The basic components of AHs are fans and cooling coils. Fans are normally centrifugal and produce air flow across the coils, which act as heat exchangers. Additional components such as filters, air-mixing boxes, and dampers may be included in more sophisticated air handlers. AH enclosures consist of sheet metal welded or bolted to a framework of steel angles or other profiles. There are also cooling water pipes, electrical cables and instrumentation lines. Self-contained air conditioning units are a variation of air handlers in which the sheet metal enclosure includes a small refrigeration unit. AH configurations vary from floor-mounted units to small units suspended on rod hangers from ceiling or attached to the wall. This class includes sheet metal enclosures, fans and motors, cooling coils, air filters, mixing boxes, dampers, attached ducts, instrument lines, and also attached cables. The caveats for this class are slightly modified in comparison to the SQUG-GIP caveats.

Class 11 Chillers (CHL)

This class includes skid-mounted units consisting of components such as compressors, condensers, evaporators and I&C local panels. Investigation of similarity for this class of equipment is not finished yet.

Class 12 Air Compressors (AC)

This class includes freestanding air compressors together with attached components such as air intakes, air receiver tanks, local instrumentation panels, cable and discharge lines etc. Investigation of similarity for this class of equipment is not finished yet.

Class 13 Motor Generators (MG)

The VVER-type MGs are composed of motors and generators that are coupled into a motor-generator set. Both the motor and generator are mounted to a common drive shaft and bolted to a steel skid that may be spring supported. The skid or the MG block also supports peripheral attachments such as cables, piping, small pumps and local I&C panels. MGs represented by this class contain all devices directly attached to the MG or its skid. However, the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks attached to the MGs, if any, shall be identified and their seismic adequacy must be verified separately. The GIP-VVER caveats for this class are only formally modified in comparison to the SQUG-GIP caveats.

Class 14 Distribution Panels (DP)

The VVER-type DPs are composed of vertical sections, which normally contain stacks of circuit breakers or fusible switches, associated with control, relays, instrumentation, small control transformers, and distribution buses mounted in sheet metal frame-type cabinets. The function of DPs is to distribute low voltage AC or DC power from a main circuit to branch circuits, and to provide overcurrent protection. The VVER DPs typically serve AC power systems up to 0,4 kV and DC power systems up to 220 V. There are two types of DPs on the VVER-type NPPs: floor-mounted switchboards and wall-mounted panelboards. This class includes the circuit breakers, fusible switches, metering compartments, housing cabinets and attached cable lines. However, the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks attached to the DPs, if any, shall be identified and their seismic adequacy must be verified separately. There is one additional requirement that the first conservatively estimated natural frequency of a fully equipped switchboard cabinet must be higher than 12 Hz.

Class 15 Batteries on Racks (BAT)

This VVER-type equipment class includes both batteries and their supporting racks. The VVER-type batteries consist of lead-acid storage battery units mounted in series in steel-frame racks. Batteries are used to supply a steady source of DC power for circuits in I&C systems, to power DC start motors for engine-generators, and to provide DC power to inverters for UPS. This equipment class includes batteries, supporting racks, electrical connections between batteries, and attached cables. The old Soviet or other batteries having no positive lateral restraints and almost no anchorage are replaced by VARTA-type or similar well-designed batteries. The GIP-VVER caveats almost the same as the original SQUG-GIP caveats.

Class 16 Battery Chargers and Inverters (BCI)

The VVER-type BCIs are grouped into a single equipment class since they perform similar functions, contain similar components, and are located in the same or similar cabinets. Battery-chargers are assemblies whose function is to convert AC input into DC output, while inverters are assemblies whose function is to convert DC input into AC output. The most common applications for both battery chargers and inverters are as components of an UPS. Typical UPS consist of a battery charger, inverter, a set of batteries and an automatic transfer switch. The primary components of battery chargers used on the VVER-type NPPs include small transformers, capacitors, resistors, solid-state diodes, control relays, small circuit breakers and fuses. The front panel of the cabinet (the door) contains ammeters, voltmeters, switches, and alarms. The inverters used on the VVER-type NPPs use solid state components similar to those located in battery chargers. BCIs represented by this class contain all internal components, junction boxes, cables etc. with an exception of the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks, which shall be identified and their seismic adequacy shall be verified separately. The caveats for this class are only slightly modified in comparison to the SQUG-GIP caveats. There is only one additional requirement that the first conservatively estimated natural frequency of such a fully equipped BCI cabinet must be higher than 12 Hz.

Class 17 Engine Generators (EG)

The VVER-type EGs consists of generators driven by piston engines. Turbine-generators are not used in VVER-type NPPs. EGs are emergency power sources that provide AC power in the event of loss of off-site power. Generators typically range up to 6.3 MW, electric output is normally 6 kV. Reciprocating piston engines are diesel-fueled. Generators and engines are located on a common steel skid that may be rigidly anchored to the concrete foundation or supported by spring base isolators resting on a similar concrete foundation. The skid or the engine block also supports peripheral attachments such as cables, piping, small pumps and local I&C panels. EGs represented by this class contain all devices directly attached to the EG or its skid. However, the safety-related relays, switches and instrumentation sensitive to vibration and shocks attached to the EGs, if any, shall be identified and their seismic adequacy must be verified separately. The VVER-type EGs are generally similar to those included in the SQUG database. The GIP-VVER caveats for this class are only slightly modified in comparison to the original SQUG-GIP caveats.

Class 18 Instruments on Racks (IR)

The VVER-type IRs consists of steel frames or steel panels supporting local controls and instrumentation as signal transmitters to remote control panels. Instrument racks typically consolidate transducer or control signals from equipment items in their vicinity. Instrument racks usually consist of steel profile bolted or welded together into a floor or wall supported frame. Components are attached either directly to the rack members or to metal panels that are welded or bolted to the rack. Typical components supported on instrument racks include pressure switches, transmitters, pressure gauges, recorders, hand switches, various small size valves and pneumatic system components. Attachment to instrument racks include steel tubing, cables and junction boxes. Both pneumatic and electronic components, as well as associated tubing, cables, and junction boxes are included in this equipment class. Some of VVER-type IRs consist of special thin-wall profiles bolted together that are relatively flexible, not adequately restrained and anchored. It is also often that the instrument components are not properly attached to the rack. The caveats for this class are modified in comparison to the SQUG-GIP caveats. One caveat was upgraded, which means that that the first conservatively estimated natural frequency of a fully equipped IR must be higher than 12 Hz. Pneumatic and electronic components need to be tested in many cases.

Class 19 Temperature Sensors (TS)

The VVER-type of this equipment class consists of thermocouples and resistance temperature detectors that measure fluid temperature and are mounted on piping or tanks using threaded joints. Temperature sensors are typically linked to transmitters mounted on nearby instrument racks, which amplify the electronic signal generated by the sensors and transmit the signal to a remote I&C system. The electronics associated with VVER-type TSs is solid state. The VVER-type TSs are similar to those included in the SQUG database. The GIP-VVER caveats for this equipment class are practically the same in comparison to those as given in the SQUG-GIP.

Class 20 I&C Panels and Cabinets (I&C)

The VVER-type of this equipment class includes a variety of I&C panels and cabinets. These panels and cabinets generally consist of a steel frame supporting sheet metal panels to which I&C devices are bolted or clamped. Panel and cabinet structures range from a single panel, braced against or built into a wall, to a freestanding panels or cabinets. I&Cs represented by this GIP-VVER equipment class contain all attached devices attached to sheet metal panels or within sheet metal cabinets with an exception of the safety-related relays, switches and instrumentation devices sensitive to vibration and shocks which shall be identified and their seismic adequacy must be verified separately. Nevertheless, this equipment class covers such non-sensitive attachments as connected cables, rigidly attached small control transformers, gauges, meters, controllers, solid-state circuit boards, tubing etc. Flexible

attachments of I&C components inside the panels and cabinets represent a significant problem. The VVER-type I&Cs are similar to those included in the SQUG database. The GIP-VVER caveats are slightly modified in comparison to the original SQUG-GIP caveats. There is one additional requirement that the first conservatively estimated natural frequency of such a fully equipped I&C cabinet or panel must be higher than 12 Hz.

SEISMIC INTERACTIONS

Examples of seismic interactions that are typical for VVER-type NPPs include:

- unreinforced masonry walls adjacent to safety-related equipment may fall and impact safety-related equipment,
- fire extinguishers may fall and impact or roll into safety-related equipment,
- inadequately anchored equipment components may overturn, slide and impact the adjacent safety-related equipment,
- equipment carts, chains, air bottles, welding equipment etc. may roll into, slide, overturn, or impact the safety-related items,
- storage cabinets, office cabinets, files, bookcases etc. may fall and impact adjacent safety-related equipment,
- too flexible piping, cable trays, conduits, and HVAC ducts may deflect and impact the adjacent safety-related equipment,
- anchor movement may cause breaks in nearby piping, cable trays, conduits, HVAC ducts etc. that may fall or deflect and impact the adjacent safety-related equipment,
- emergency lights and lower ceiling panels can fall down and damage the safety-related equipment,
- free crane hooks by bang safety-related equipment in their vicinity.

CONCLUSION

Based on experience from great number of seismic inspections performed during the last about nine years on the VVER-type NPPs, it may be concluded that the main problems related to seismic adequacy of their mechanical and electrical equipment are:

- missing or non-proper anchorage of components, missing anchor bolts, non-proper tightening of anchor bolts,
- large seismic nozzle loads due to long unsupported attached pipes,
- large valve operator cantilever length (special investigation requested) and motor operated valves with drivers in remote locations (cardan-type connection must be evaluated),
- missing or non-properly performed pipe and duct supports and additional pipe restraints (for instance, application of viscous dampers for large hot pipe systems),
- replacement of brittle elements (for instance, glass level indicators etc.),
- inadequate base isolation,
- large and high vertical flat-bottom tanks without any positive anchorage and large flat-bottom tanks free standing on the special supporting grid and liner (no anchorage),
- concrete pedestals under large horizontal tanks and heat exchanger (no information available about their reinforcement),
- missing or non-proper anchorage of components, missing bolts, nuts and screws, non-proper tightening of anchor bolts,
- seismic functionality of relays, switches and similar items must be verified by seismic tests,
- determination of in-cabinet seismic response spectra necessary for separate verification of internal items,
- fixation of internal drawers, relays, switches, sensors and similar items to the cabinet or panel is often too weak,
- old accumulator batteries must be replaced (aging),
- overloaded and not-properly anchored cable structures,
- potential seismic interaction.

The GIP-VVER screening criteria should be used with caution. The seismic capability engineers must exercise sound engineering judgment during the screening walkdown and verification. It also remarkable, that specifically active mechanical and electrical equipment components installed on VVER-type NPPs, at least in Czech, Slovakia and Hungary, are systematically updated and replaced by components designed and qualified in accordance to the internationally recognized standard requirements [33,34].

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