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Power Systems
Engineering Center

Prevention of Unintentional Islands in Power Systems with Distributed Resources

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Presentation Outline

- Review of DER Terms & Sources
- Unintentional Island Detection & Protection
- Review of Screening of Unintentional Islanding Possibility/Risk
- UI Laboratory Testing Efforts
- Proposed Items for Discussion
- References

Terms

- **Area EPS** – Area Electric Power System
- **Local EPS** – Local Electric Power System
- **PCC** – Point of Common Coupling
- **DR** – Distributed Resource (e.g. distributed generation (DG), distributed energy resource (DER))
- **DER** – Distributed Energy Resource (The IEEE 1547 Working Group voted and decided to change DR to DER in the next version. DER will NOT include Demand Response as it does in some countries)
- **Anti-islanding** (non-islanding protection) – The use of relays or controls to prevent the continued existence of an unintentional island

DER Sources

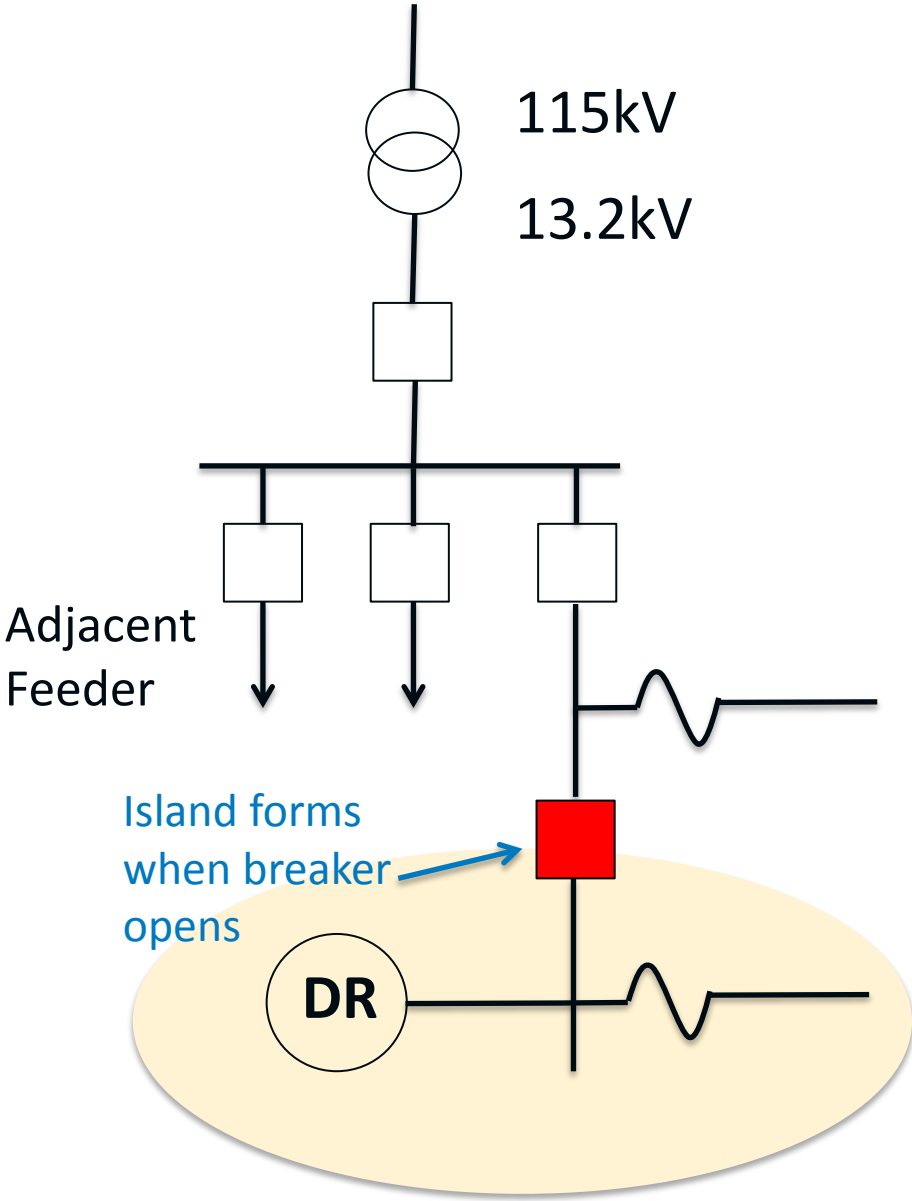
- **Synchronous generators**
  - voltage source devices that can support islanded grid operations
  - typical in diesel or natural gas powered engine-generators
- **Induction generators**
  - found in some engine-gen sets and wind turbines
  - usually will not be able to support an island but will instead cease to produce current because of the loss of reactive power, (necessary to support a rotating magnetic field within the generator)
  - under certain conditions, may be necessary to provide for direct detection of faults in a manner similar to that of synchronous generators.[4]
- **Inverter-Based DR**
  - found in PV systems, wind turbines, microturbines, fuel cells, and battery energy storage.
  - typically current-source devices that require a voltage-source (typically the utility grid) to synchronize to.
  - voltage-source (e.g. grid forming) inverters do have the ability to support islanded operation.

References [4]

Island Definition

Island: A condition in which a portion of an Area EPS is energized solely by one or more Local EPSs through the associated PCCs while that portion of the Area EPS is electrically separated from the rest of the Area EPS.[1]

- Intentional (Planned)
- **Unintentional (unplanned)**



Unintentional Island Detection & Protection

IEEE 1547: Unintentional Islanding Requirement

IEEE 1547-2003: 4.4.1 Unintentional Islanding Requirement

For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and ***cease to energize the Area EPS within two seconds*** *of the formation of an island.* [1]

IEEE 1547-2003: Unintentional Islanding Requirement

Footnote to IEEE 1547 Requirement[1]

Some examples by which this requirement may be met are:

- **The DR aggregate capacity is less than one-third of the minimum load of the Local EPS.**
  - If the aggregate DR capacity is less than one-third of the local EPS load, it is generally agreed that, should an unintentional island form, the DR will be unable to continue to energize the load connected within the local EPS and maintain acceptable voltage and frequency. [4]
- **The DR installation contains reverse or minimum power flow protection**
  - sensed between the Point of DR Connection and the PCC, which will disconnect or isolate the DR if power flow from the Area EPS to the Local EPS reverses or falls below a set threshold.
- **The DR is certified to pass an applicable non-islanding test.**
- **The DR contains other non-islanding means**
  - such as a) forced frequency or voltage shifting, b) transfer trip, or c) governor and excitation controls that maintain constant power and constant power factor.

Methods of protecting against unintentional islands

- Direct Transfer Trip (DTT)(communication-based)
- Other Communication-Based Anti-Islanding
  - Power line carrier (PLC)
  - Impedance Insertion
  - Phasor-based (tested, under development)
- Reverse/Minimum Import/Export Relays
- Passive Anti-islanding
- Active Anti-islanding
  - e.g. instability induced voltage or frequency drift and/or system impedance measurement coupled with relay functions
- Grounding Reclosers (i.e. alternative protection techniques)

References [10]-[37]

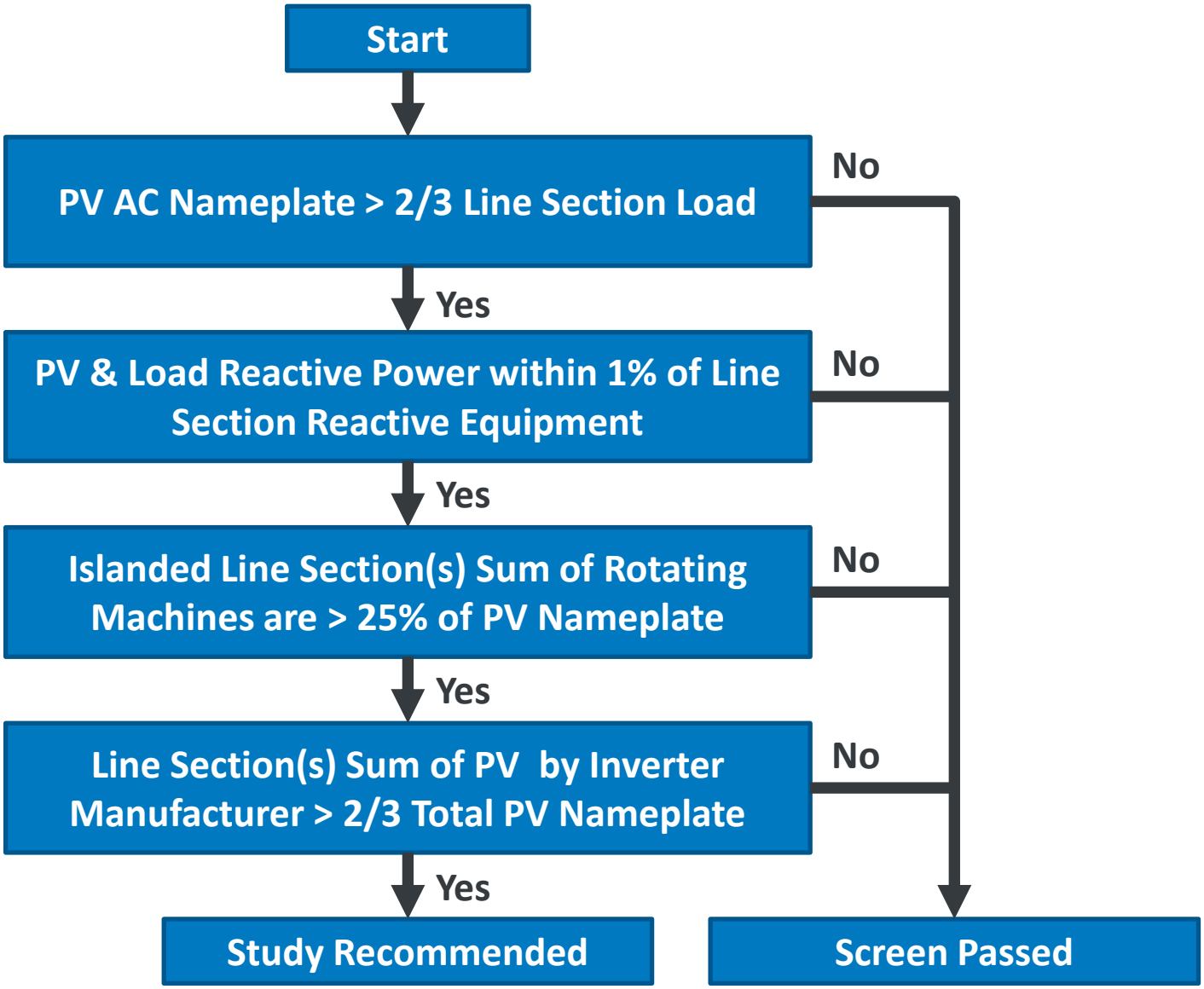
Assessment of Risk for Creation of Unintentional Islands

Guidelines for Assessment of DG Unintentional Islanding Risk

Suggested Guidelines for Assessment of DG Unintentional Islanding Risk – Sandia Report [49]

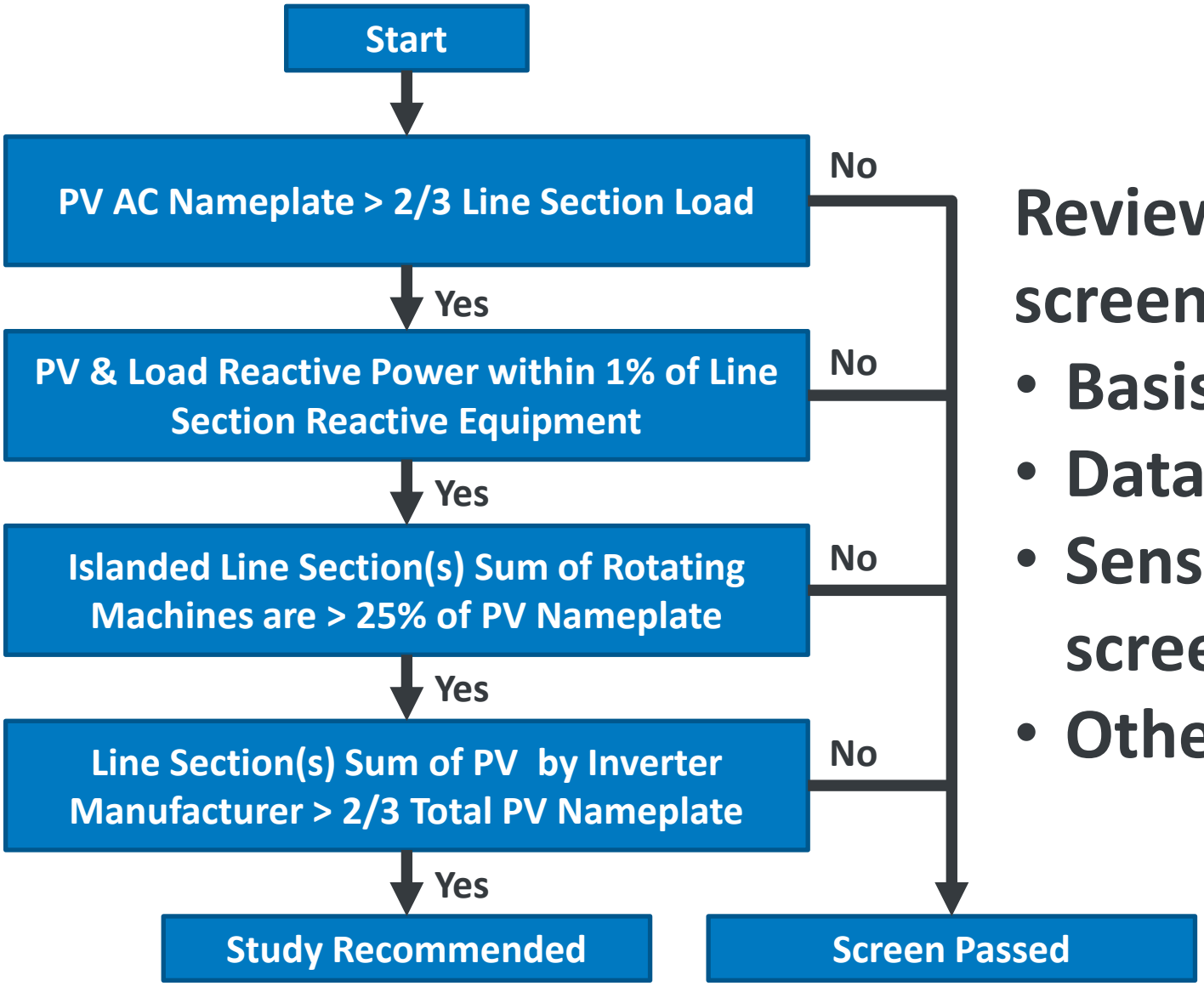
- **Cases in Which Unintentional Islanding can be Ruled Out**
  - Aggregated AC rating of all DG within the potential island is less than some fraction of the minimum real power load within the potential island
  - Not possible to balance reactive power supply and demand within the potential island.
  - DTT/PLCP is used
- **Cases in Which Additional Study May Be Considered**
  - Potential island contains large capacitors, and is tuned such that the power factor within a potential island is very close to 1.0
  - Very large numbers of inverters
  - Inverters from several different manufacturers
  - Include both inverters and rotating generators

Review of Sandia Suggested Guidelines of AI Screening



See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening

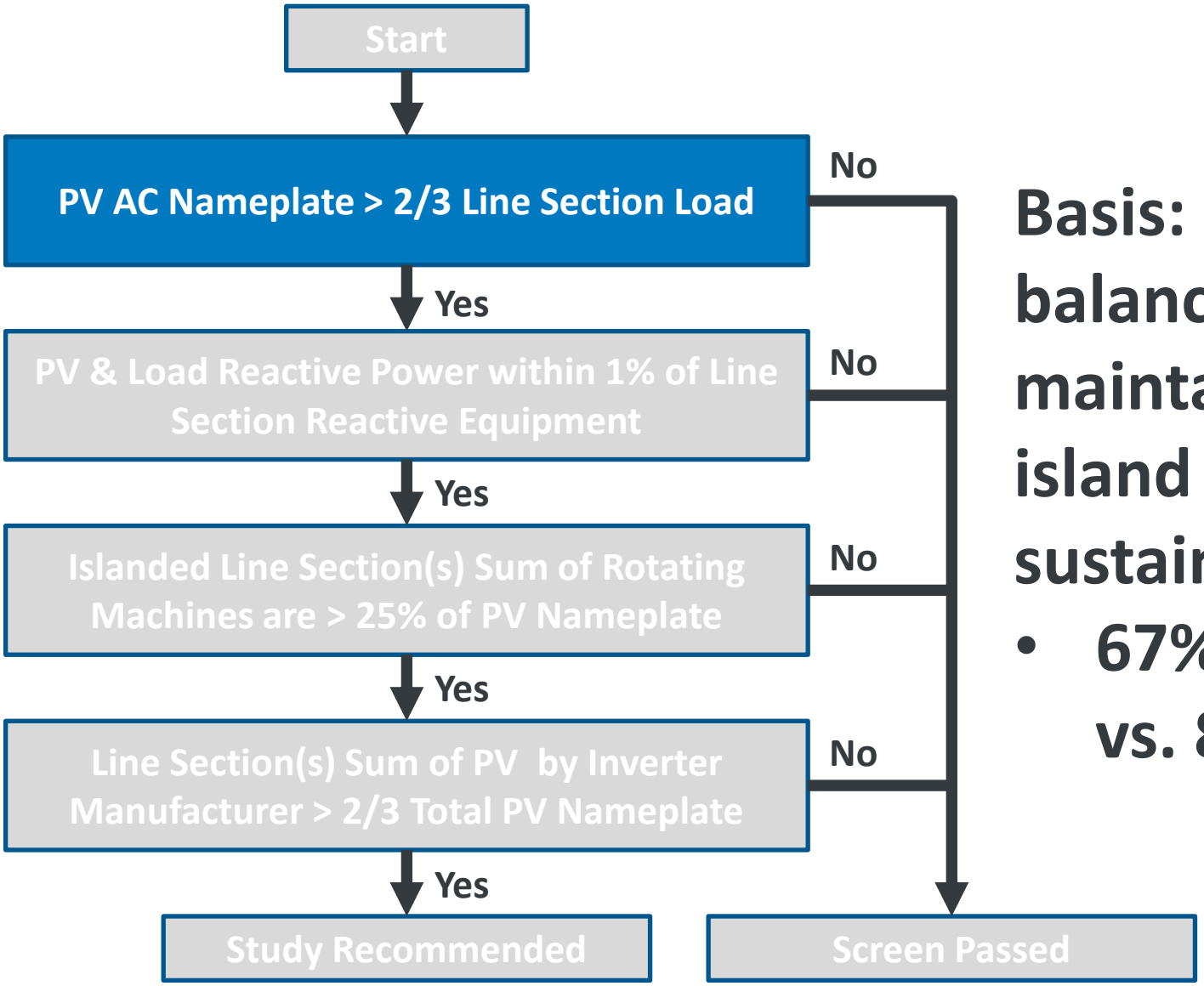


Review each screen element

- **Basis for screen**
- **Data needed**
- **Sensitivity of screen**
- **Other options**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening

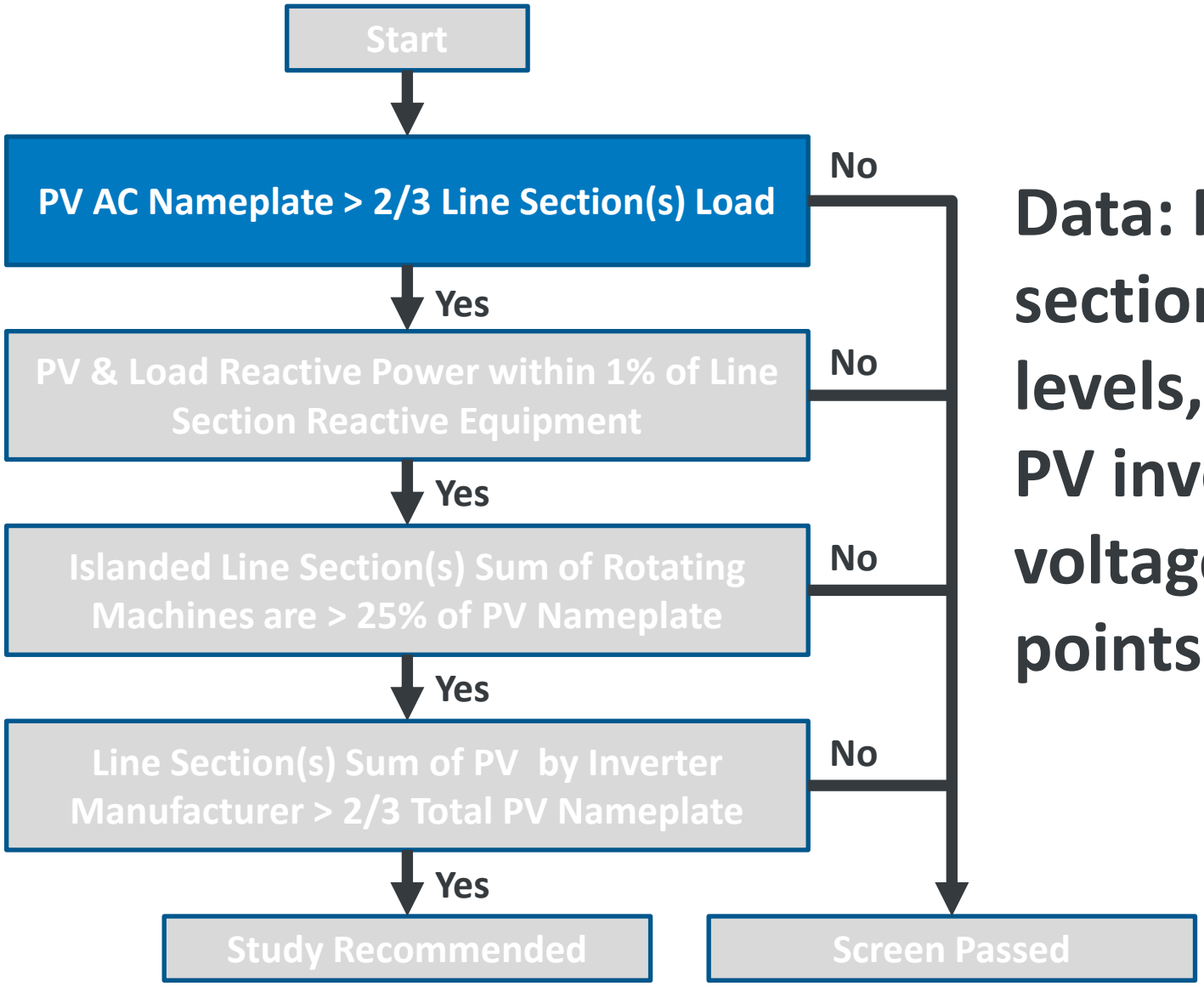


Basis: Real power balance must be maintained for island to be sustained

- **67% vs. 77% vs. 88%**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

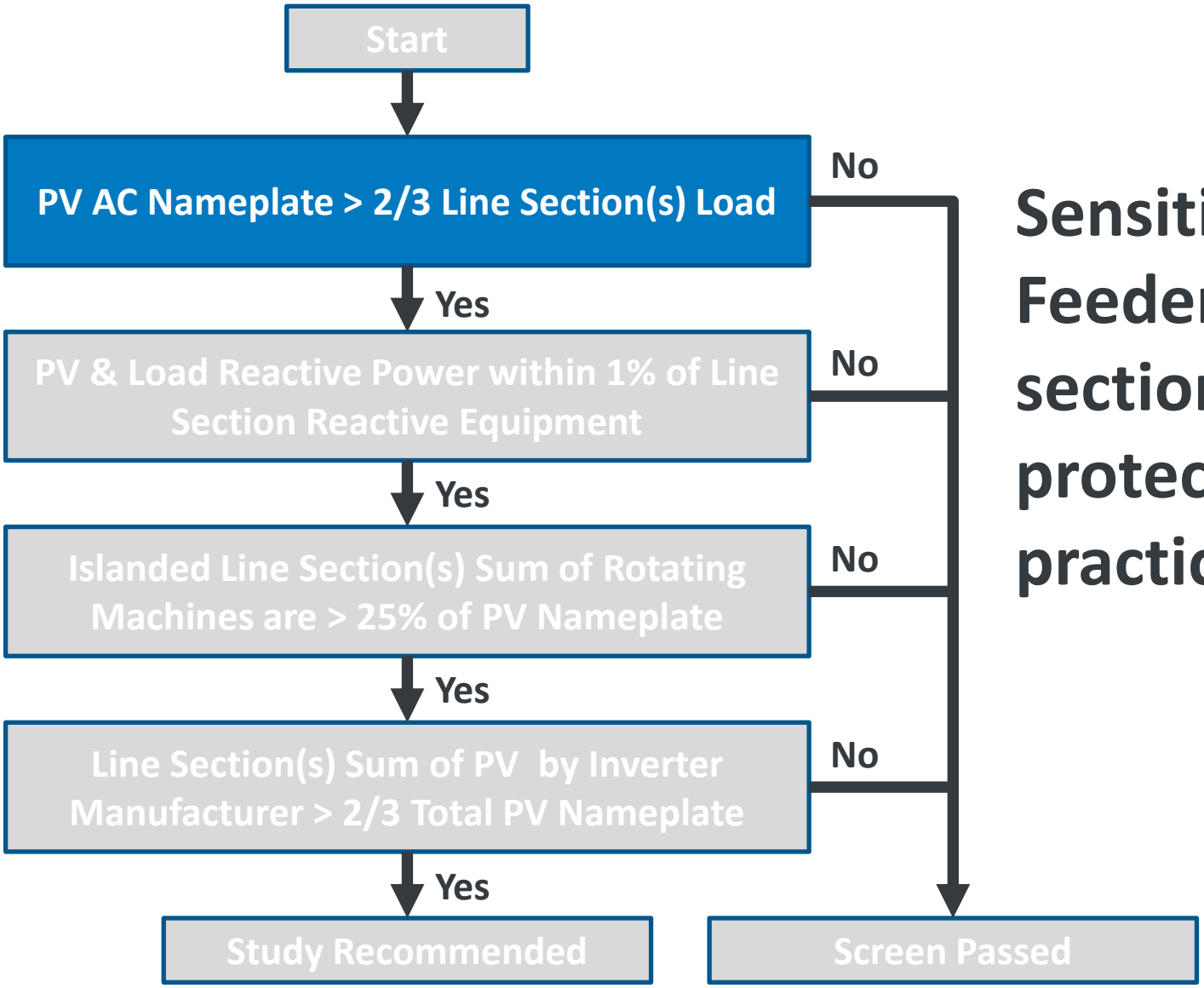
Review of Sandia Suggested Guidelines of AI Screening



Data: Need line section(s) load levels, potentially PV inverter voltage trip points

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening



Sensitivity: Feeder/line section loading, protection practices

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

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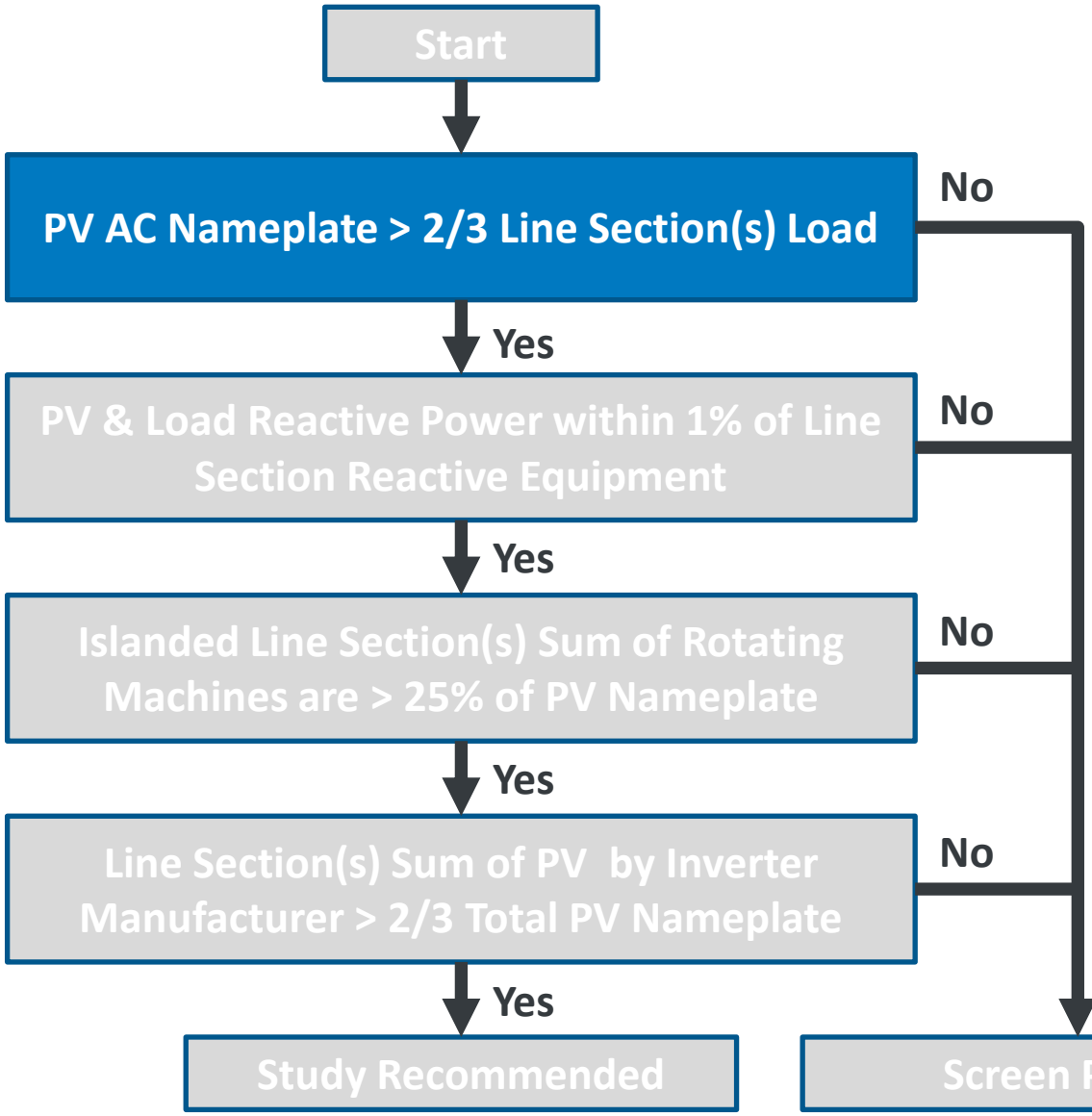
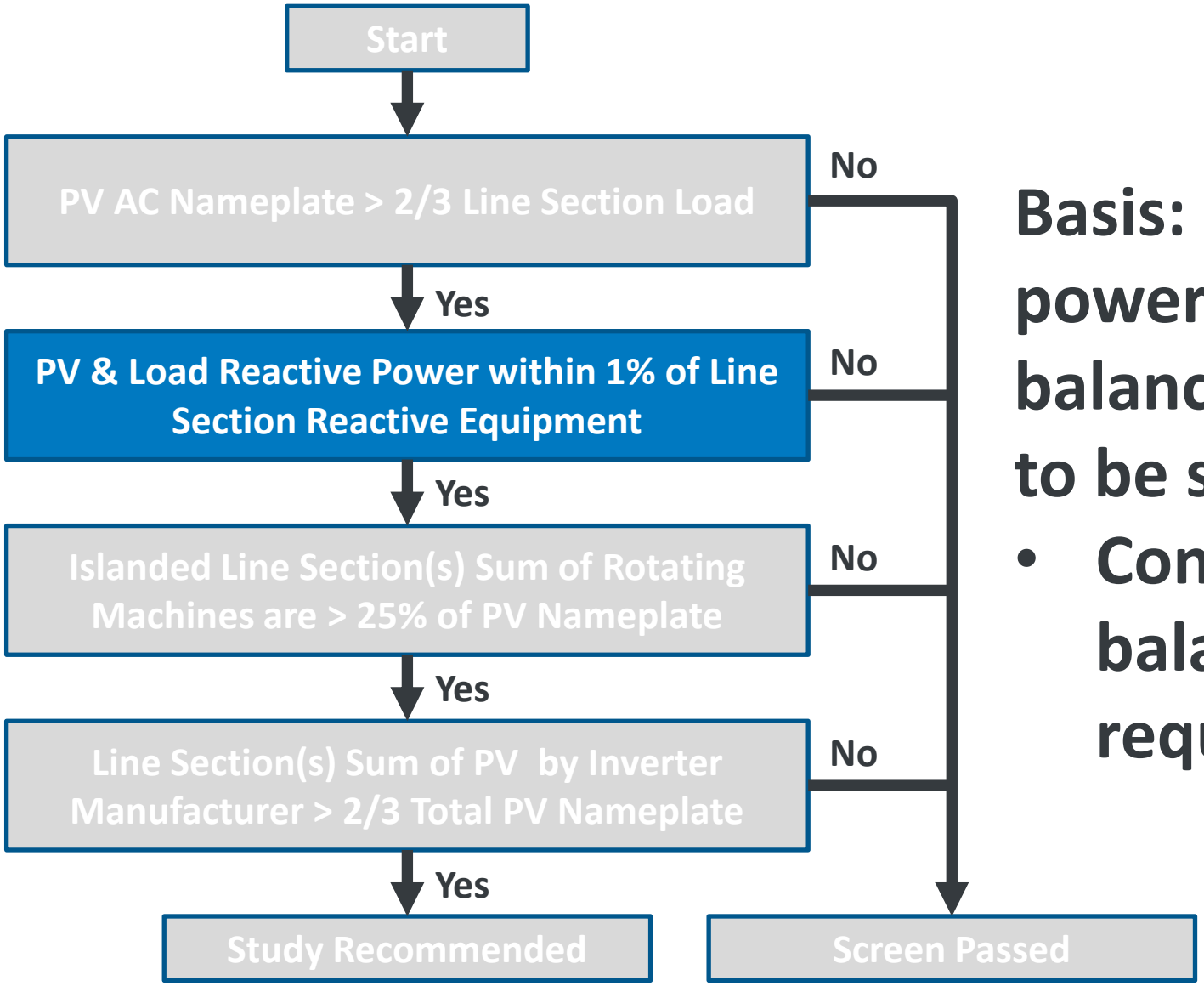


Options:

- Screen level
- set required voltage trip settings
- rework screen based on power imbalance

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening



Basis: Reactive power must balance for island to be sustained

- **Conservative balance required - 1%**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

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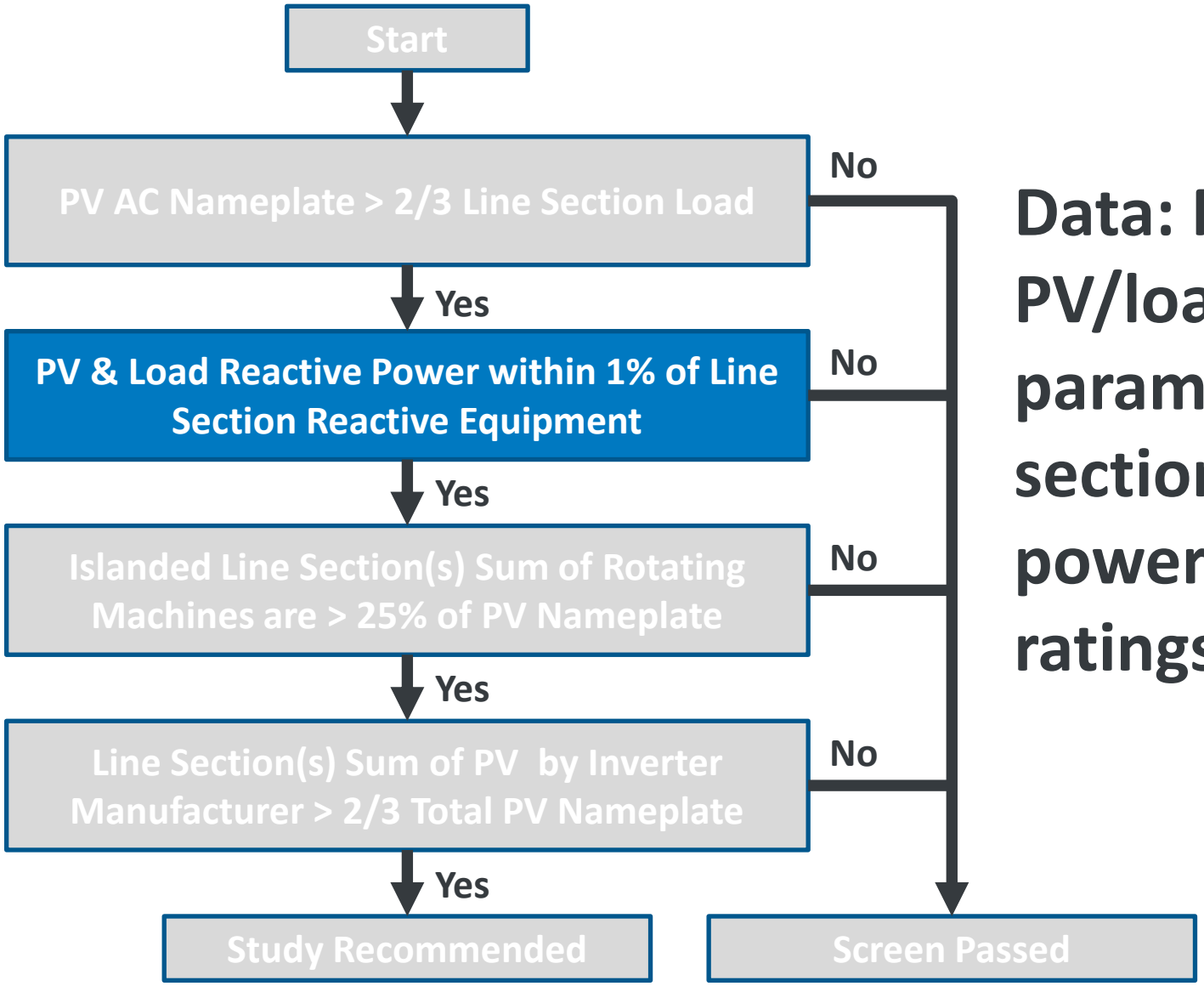
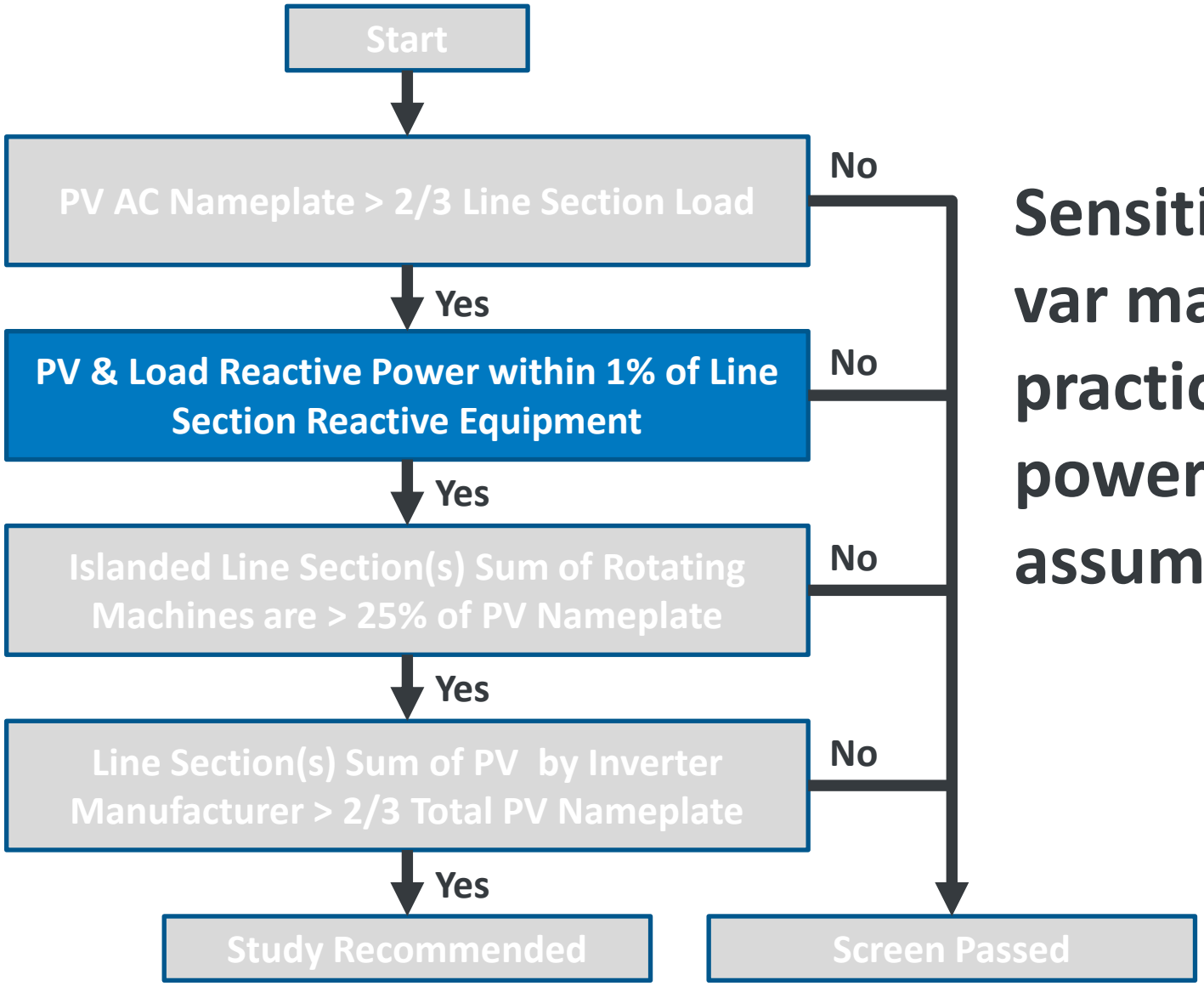


Data: Need PV/load operating parameters, line section reactive power devices ratings

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

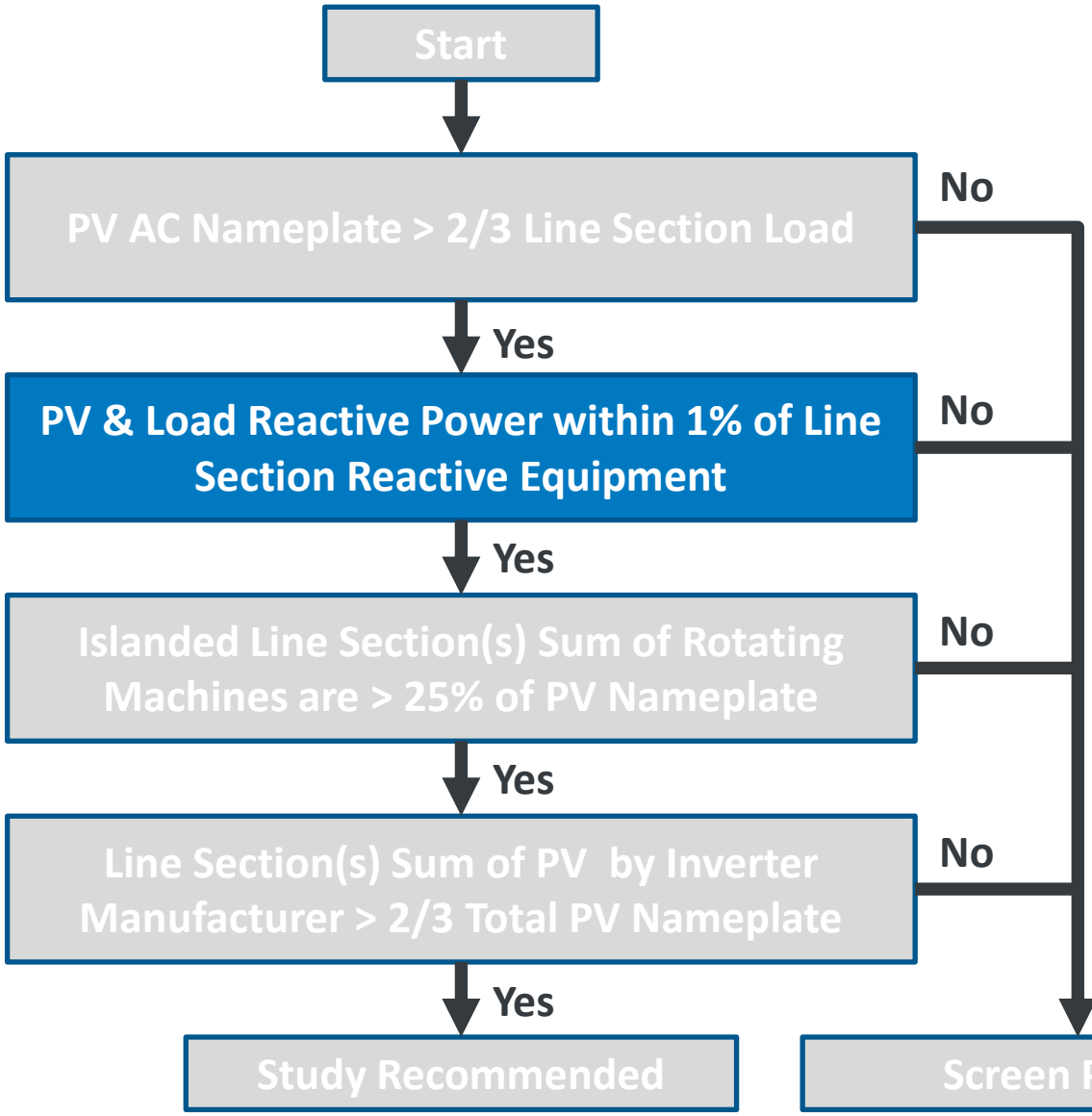
Review of Sandia Suggested Guidelines of AI Screening



Sensitivity: Utility var management practices, load power factor assumptions

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening

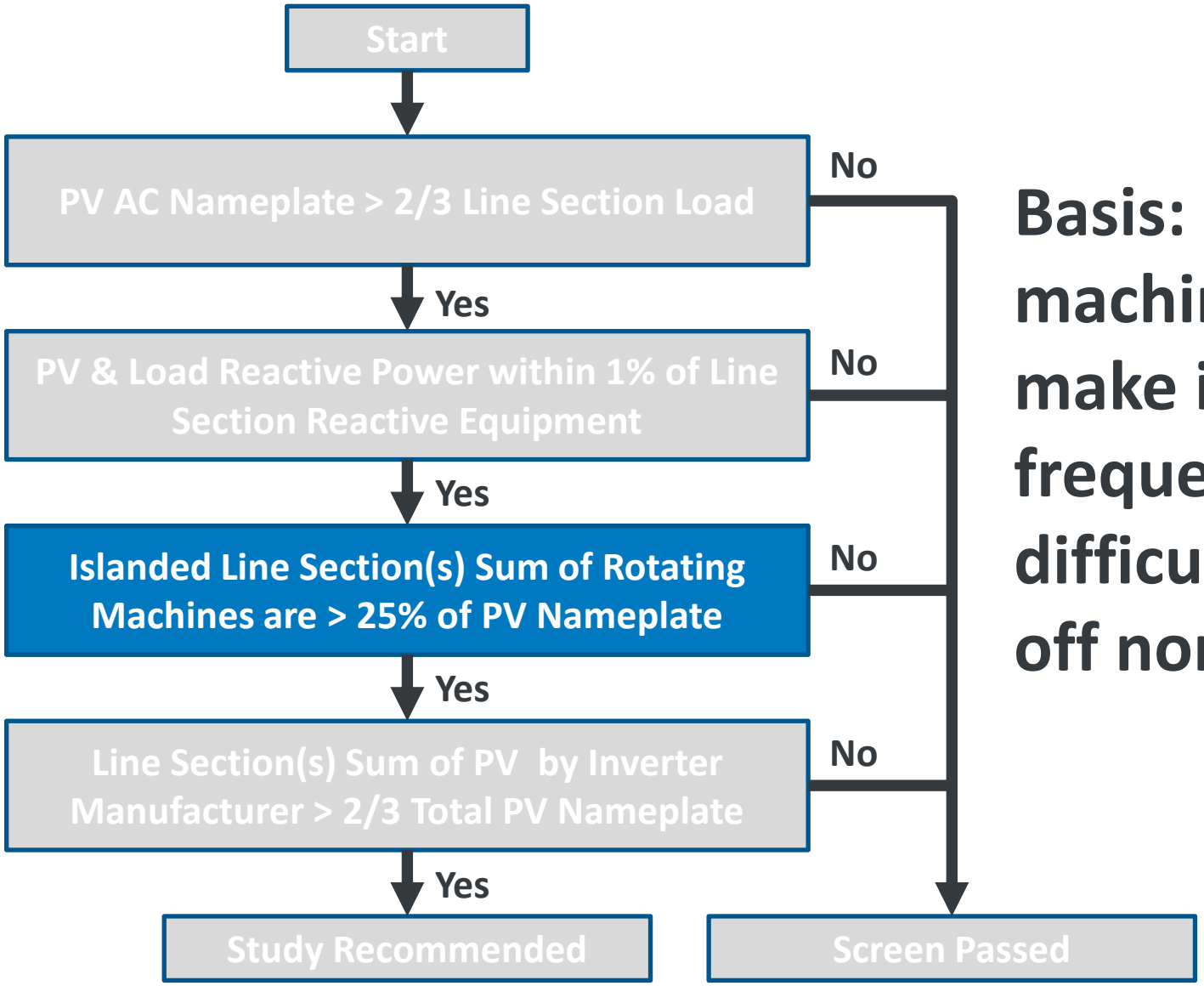


Options:

- **Screen level**
- **Specify PV var requirements**
- **Move caps to nearby line sections**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

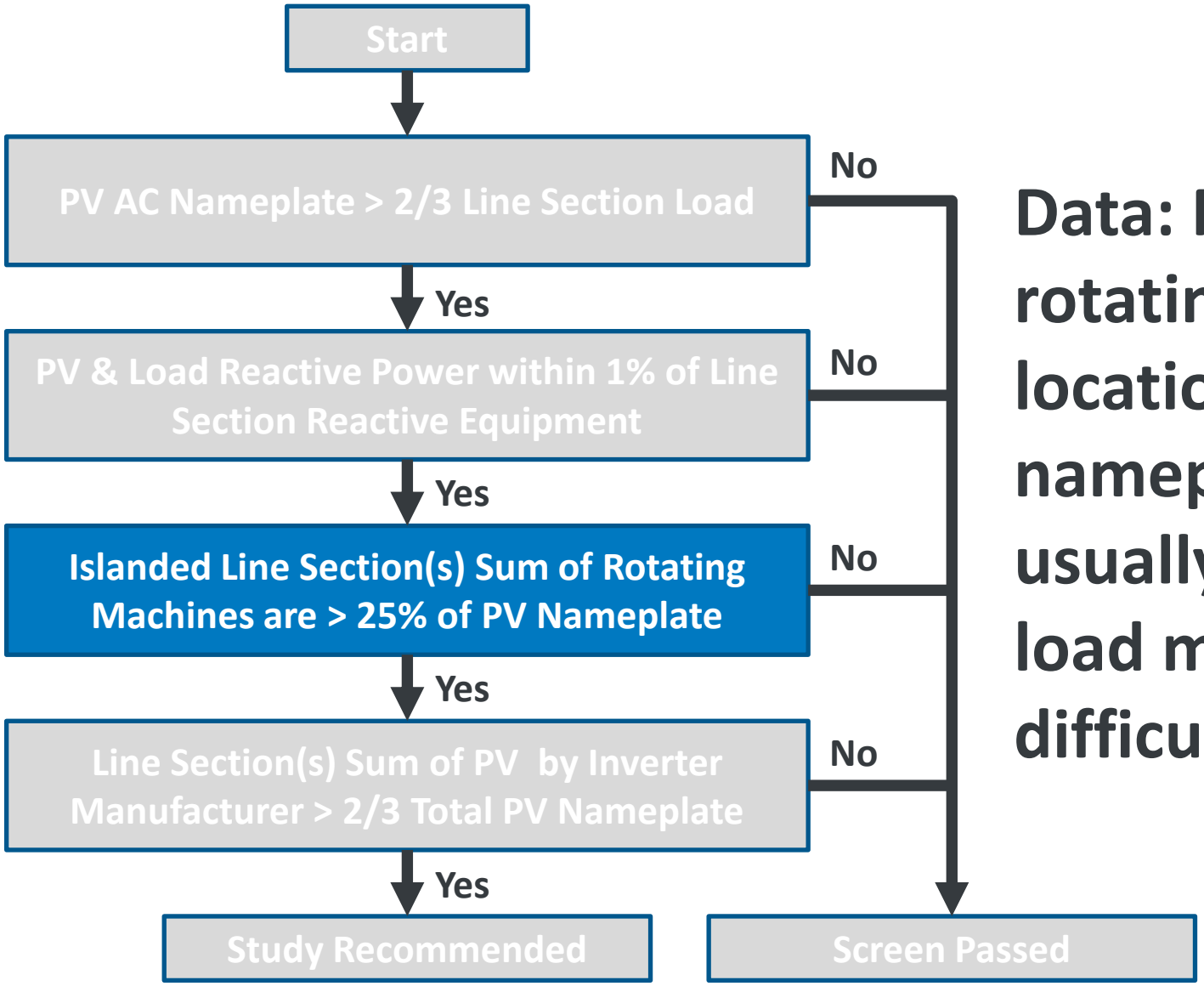
Review of Sandia Suggested Guidelines of AI Screening



Basis: Rotating machines can make island frequency difficult to "push" off nominal

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

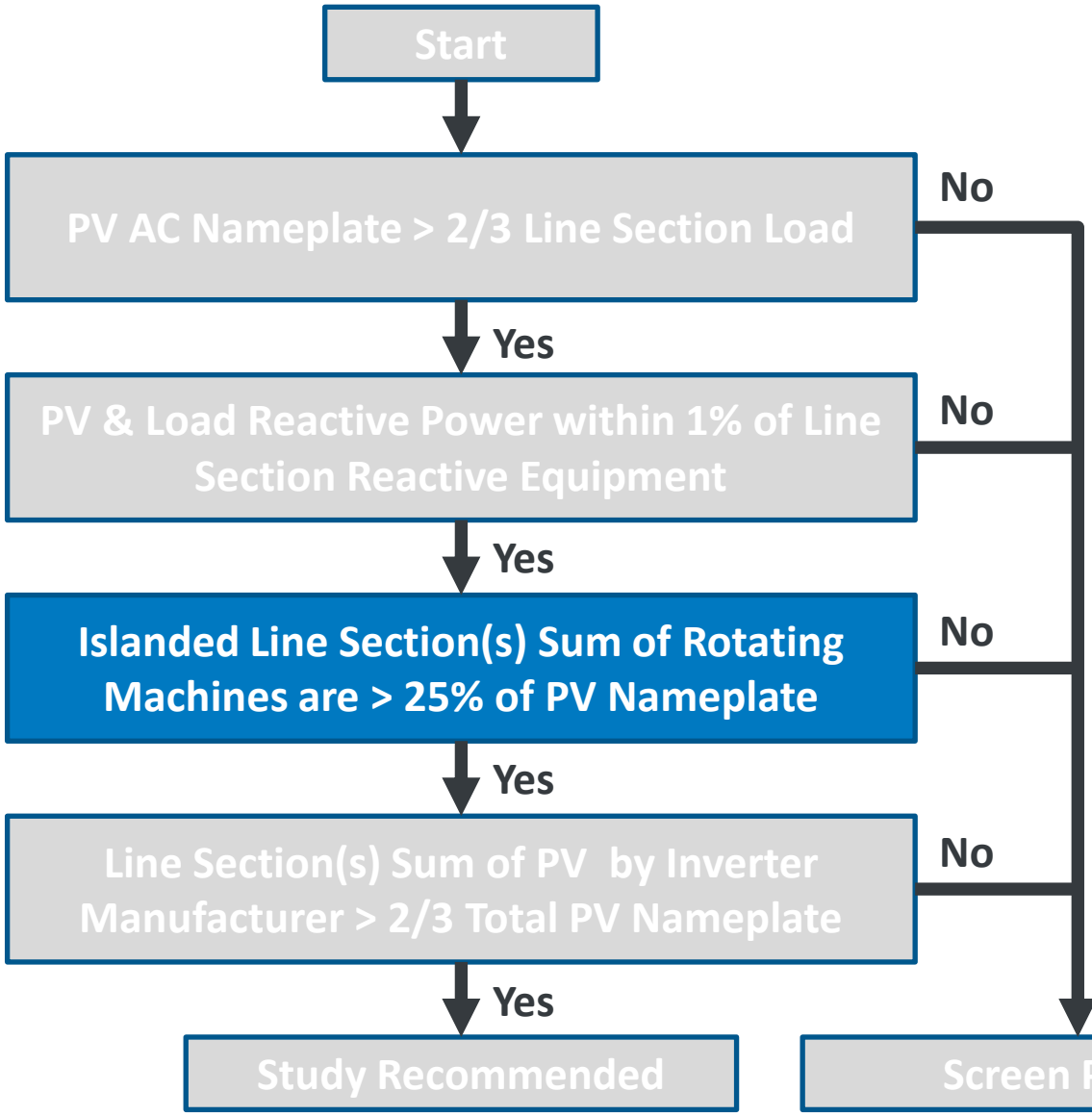
Review of Sandia Suggested Guidelines of AI Screening



Data: Need rotating machine location and nameplate (DG usually known, load much more difficult.

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening



Sensitivity:

- **Amount of existing rotating DG/load**
- **Doesn't consider rotating machine islanding func.**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

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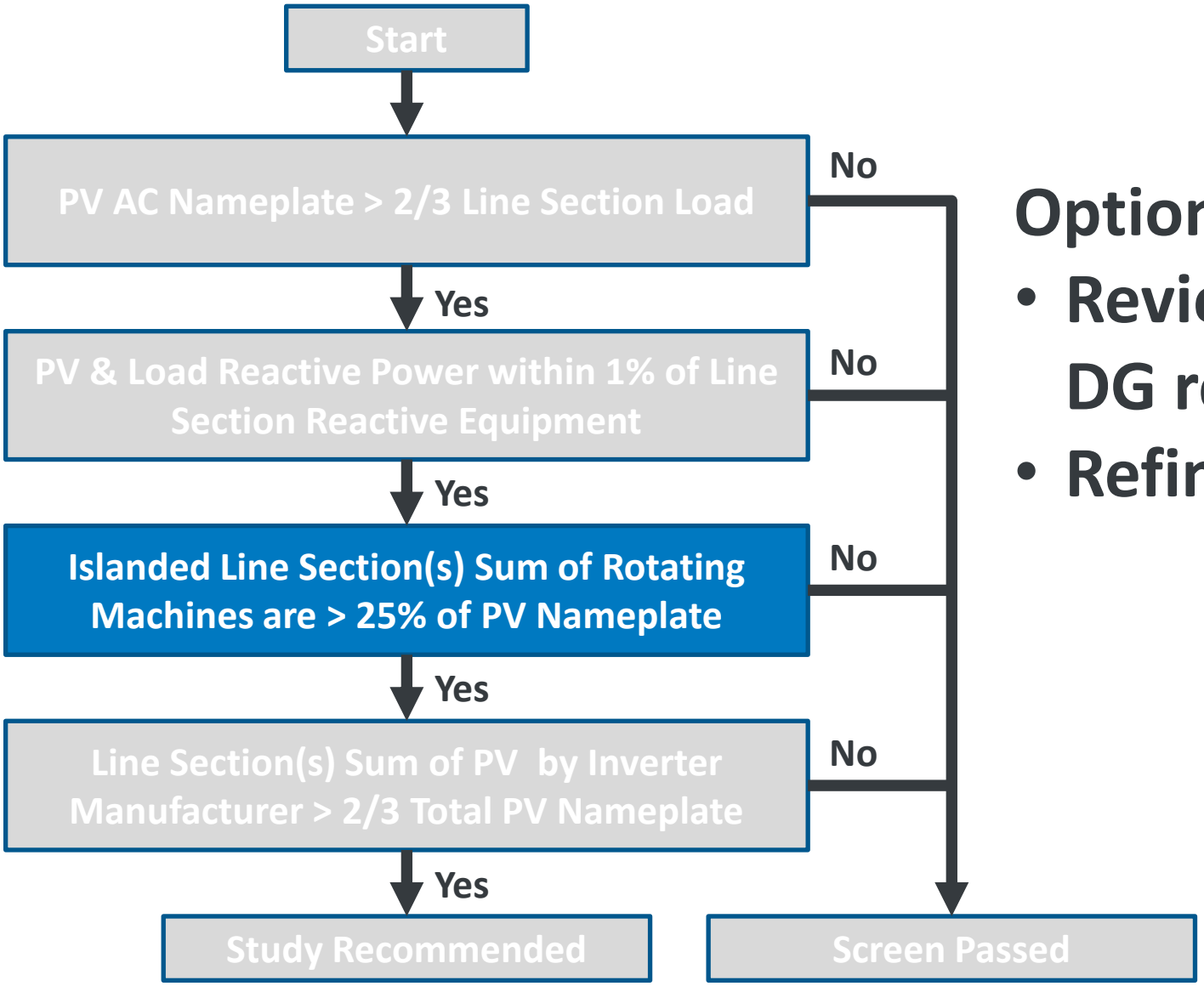
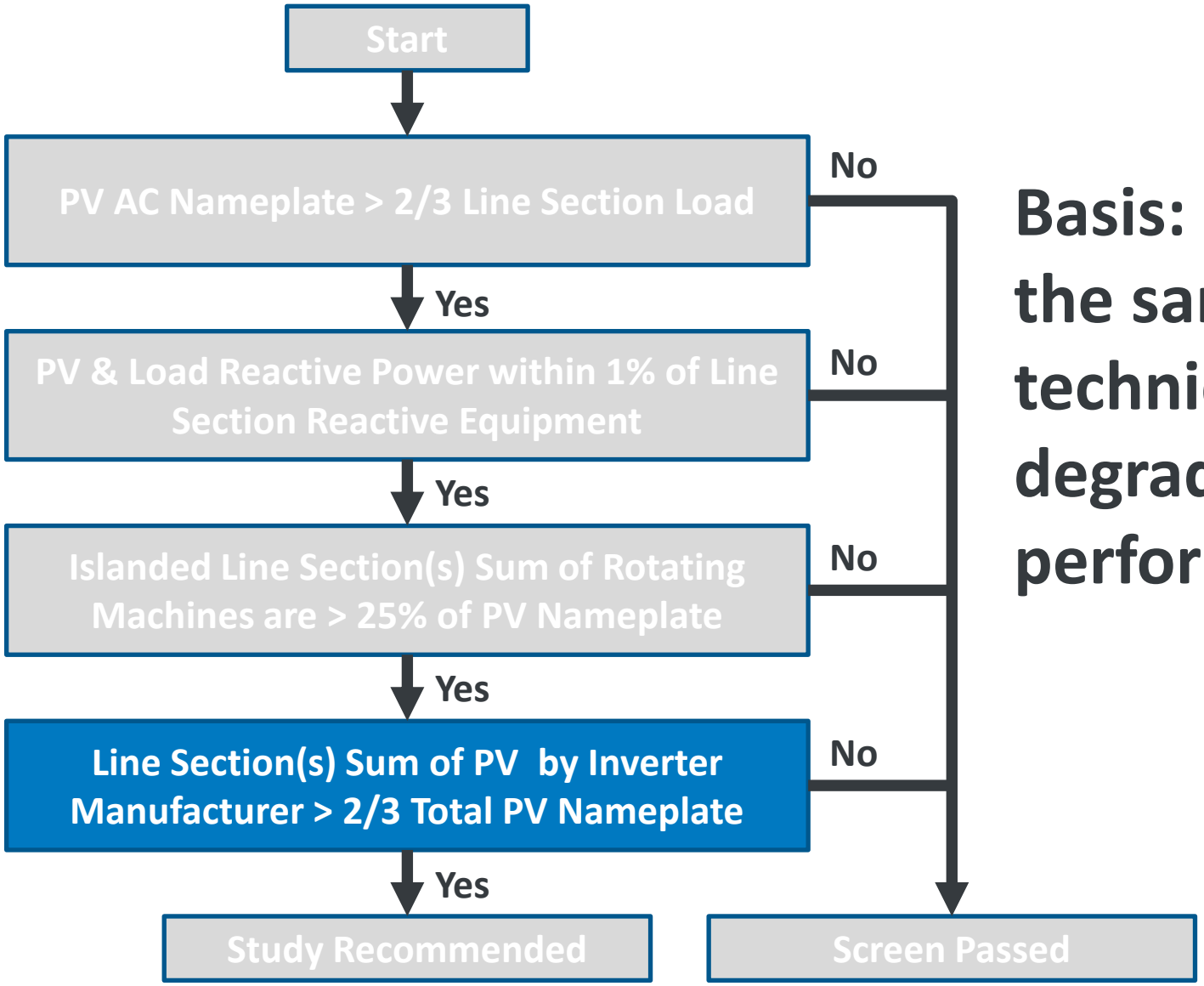


Options:

- **Review rotating DG requirement**
- **Refine level**

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

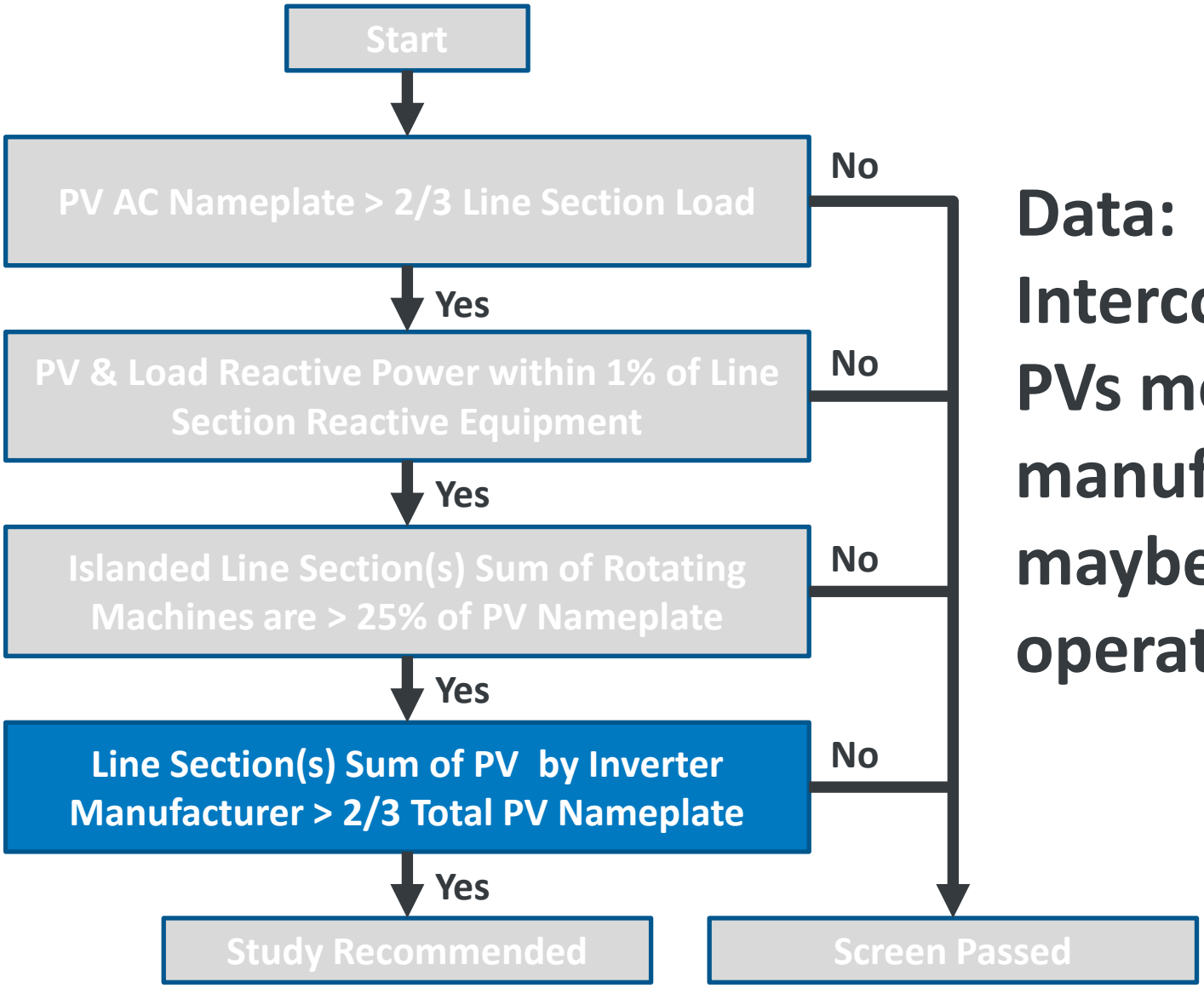
Review of Sandia Suggested Guidelines of AI Screening



Basis: PV using the same AI technique can degrade performance

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

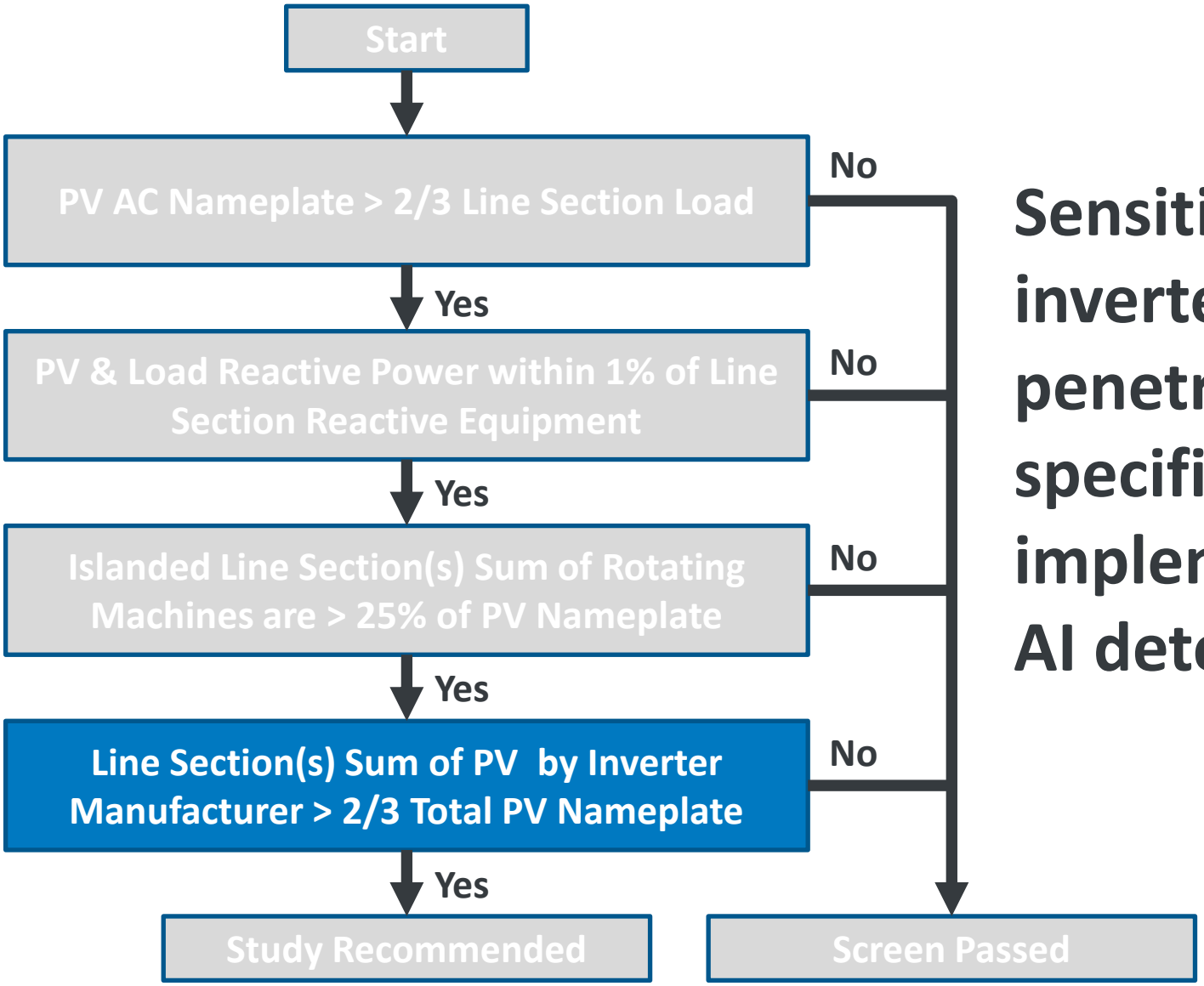
Review of Sandia Suggested Guidelines of AI Screening



Data: Interconnected PVs model / manufacturer, maybe even operating mode

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

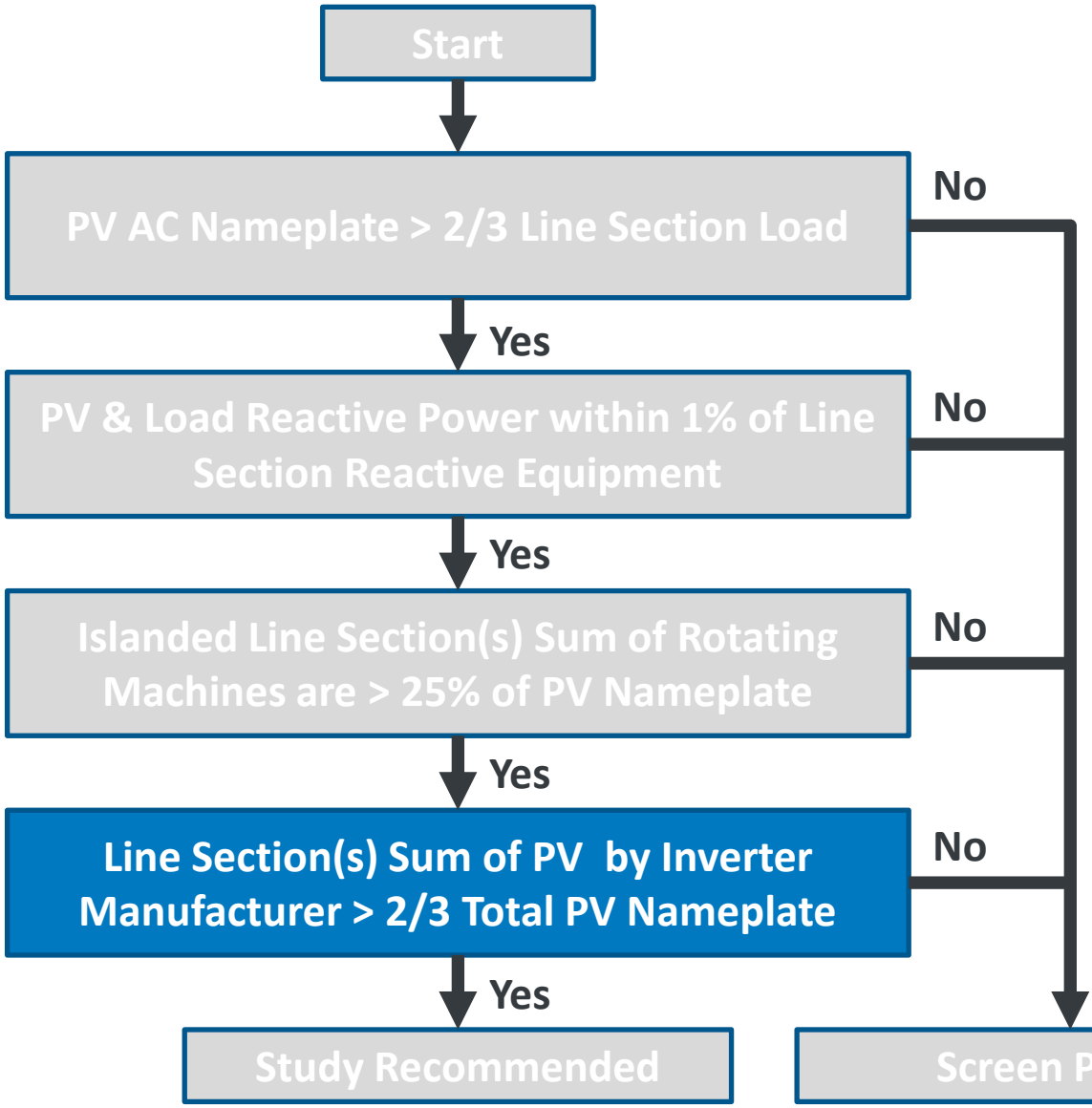
Review of Sandia Suggested Guidelines of AI Screening



Sensitivity: PV inverter market penetration, what specifically is implemented for AI detection

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Review of Sandia Suggested Guidelines of AI Screening



Options:

- Specify AI technique to be used
- Test PV inverters for multiple connections
- Remove screen altogether

See: Ropp and Ellis, "Suggested Guidelines for Assessment of DG Unintentional Islanding Risk," SNL Report SAND 2012-1365, March 2013. – Some liberties taken.

Lab Testing Results to Date

References (> 2013)

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Multiple Inverter Testing

- Sandia Testing [44] – examined 4 inverters/single PCC (demonstrated that multiple inverters still meet 2 sec requirement.

- NREL Testing [45] - examined 1) the impacts of both grid support functions and 2) multi-inverter(3)/multi PCC islands on anti-islanding effectiveness.
  - Showed that with grid support functions (volt/var and frequency/watt) enabled, the 2 sec requirement is still met.
  - Showed that multiple PCCs did not cause trip times beyond 2 seconds (regardless of system topology)

Items for Discussion

Unintentional Islanding Concerns

- **Personnel Safety**
  Unintentional islands can cause hazards for utility workers if they assume downed lines are not energized during restoration
- **Reconnection out of phase**
  This can result in large transient torques applied to motors connected to the islanded area EPS and their mechanical systems (e.g., shafts, blowers, and pumps), which could result in damage or failure.
- **Power Quality**
  Unplanned island area EPS may not have suitable power quality for loads
- **Protection/Overvoltages**
  Unintentional islands may not provide sufficient fault current to operate fuses or overcurrent relay protection devices inside island, if an adequate ground source is not present in the island, a ground fault can result in voltages that exceed 173% on the unfaulted phases.
- **Single-phase/3 phase inverters**
  Some testing to date only done on single phase inverters
- **Single DGs Vs. multi on circuit**
  requirements in UL1741 only specified for single inverters
- **At each PCC, multi vs single model / manufacturer (anti-islanding detection methods)**
  some multi-inverter testing to date only done with single model inverters
- **Other Concerns?**

References [4]-[7]

The Future of Anti-islanding Protection

- Passive islanding often has a NDZ, but it is hard for power systems to maintain a generation/load balance for extended periods of time (beyond 10s)[50]
- Active anti-islanding techniques are fast and work best on “stiff” grids. Most techniques work when a significant change in system characteristics occur because of island formation.
- New integration requirements are opening up voltage and frequency trip points to enable grid stability at high DR penetrations
- Multiples of active anti-islanding techniques may or may not work against each other.
- Future power systems may not be as stiff with reduced use of synchronous generators.

Probability of Islanding

- To create an electrical island, the real and reactive power flows between DR and loads must be exactly matched
- What is the probability of this happening?

- IEA PVPS Task 5 – Study [46]
  - The "benchmark" risk that already exists for network operators and customers is of the order of 10^{-6} per year for an individual person
  - The risk of electric shock associated with islanding of PV systems under worst-case PV penetration scenarios to both network operators and customers is typically $<10^{-9}$ per year
  - Thus, the additional risk presented by islanding does not materially increase the risk that already exists as long as the risk is managed properly
  - Balanced conditions occur very rarely for low, medium and high penetration levels of PV-systems.
- The probability that balanced conditions are present in the power network and that the power network is disconnected at that exact time is virtually zero.[47][48]

Items for Discussion

- 2s requirement – Is this the right number?
  - Too slow for instantaneous/fast reclosing
  - Too fast for some communications based AI methods
  - Need active AI to achieve this with matched load

- Active Anti-islanding – Is it needed?
  - What happens when you have thousands of different techniques and deployed DR?
  - Should there be 1 method that everyone must use? (tried before, but patents got in the way)
  - Will active AI work against maintaining grid stability at high penetration levels?

NREL … Providing Solutions to Grid Integration Challenges

Thank You!

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[1] 1547™-2003 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

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[10] Kobayashi, H. Takigawa, K, Hashimoto, E., Kitamura, A., Matsuda, H., "Method for Preventing Islanding Phenomenon in Utility Grid with a Number of Small Scale PV Systems", IEEE Photovoltaic Specialists Conference, pp. 695-700, 1991 IEEE

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