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IBR PRODUCT DEVELOPMENT AND MODELING ASPECTS

January 12, 2024
ERCOT IBRWG

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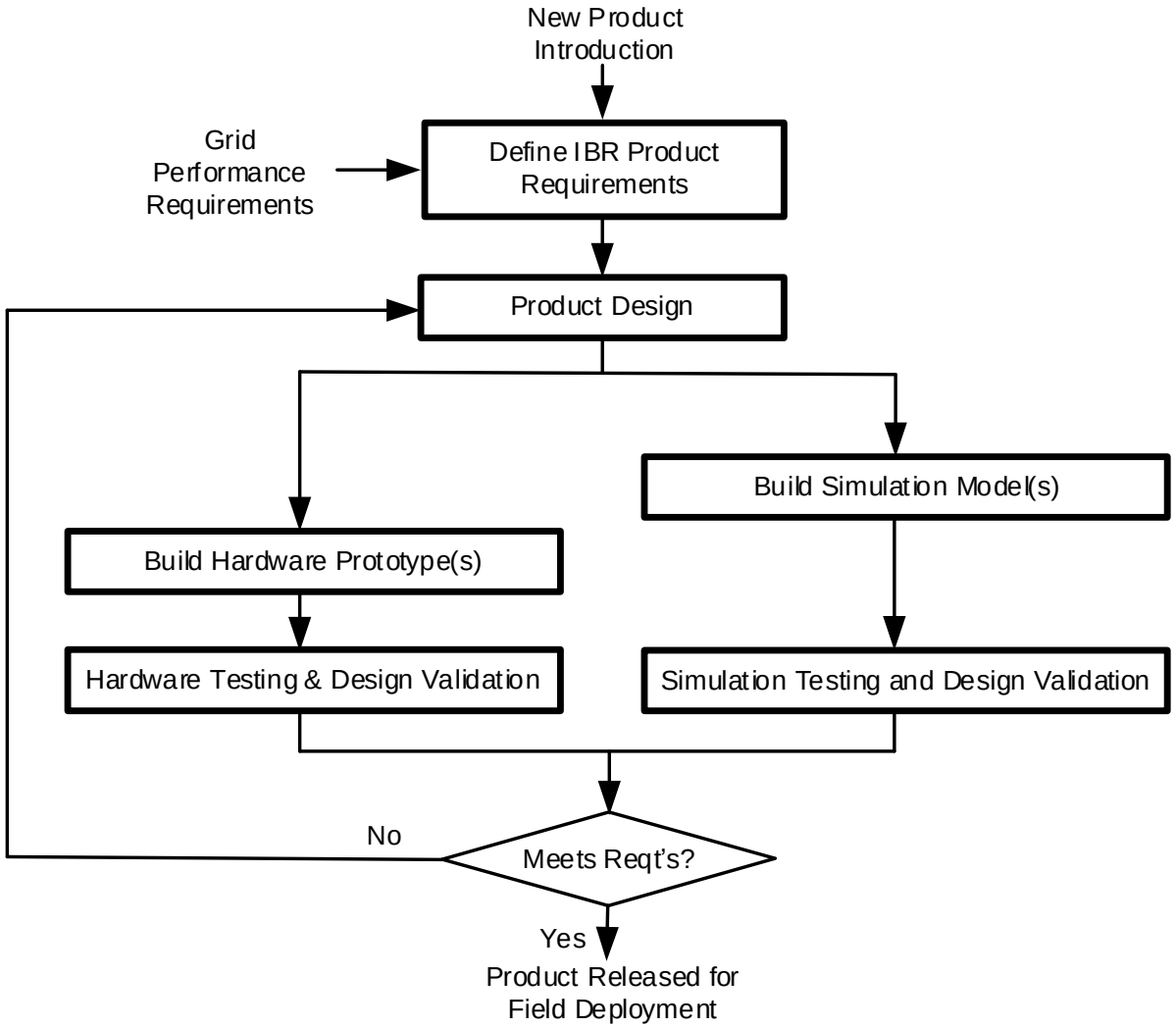
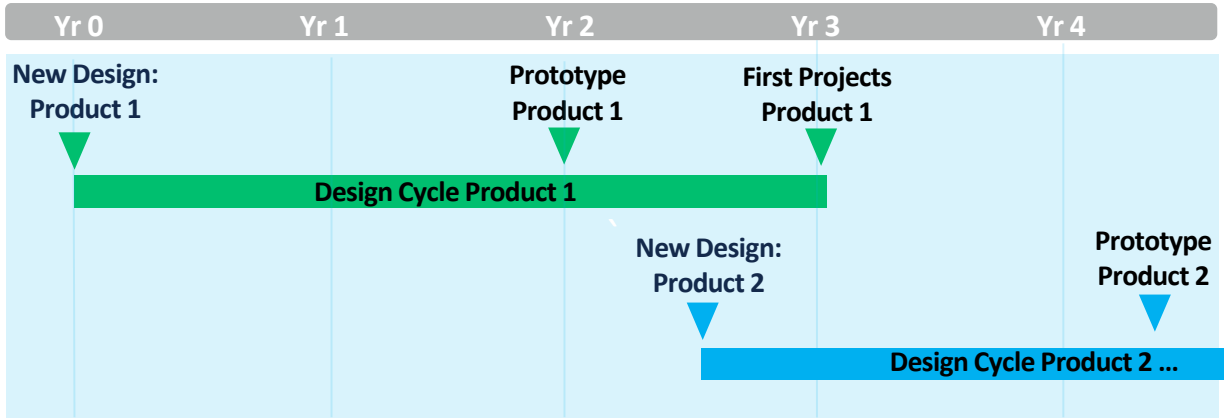
ERCOT IBRWG | PRODUCT DESIGN PROCESS

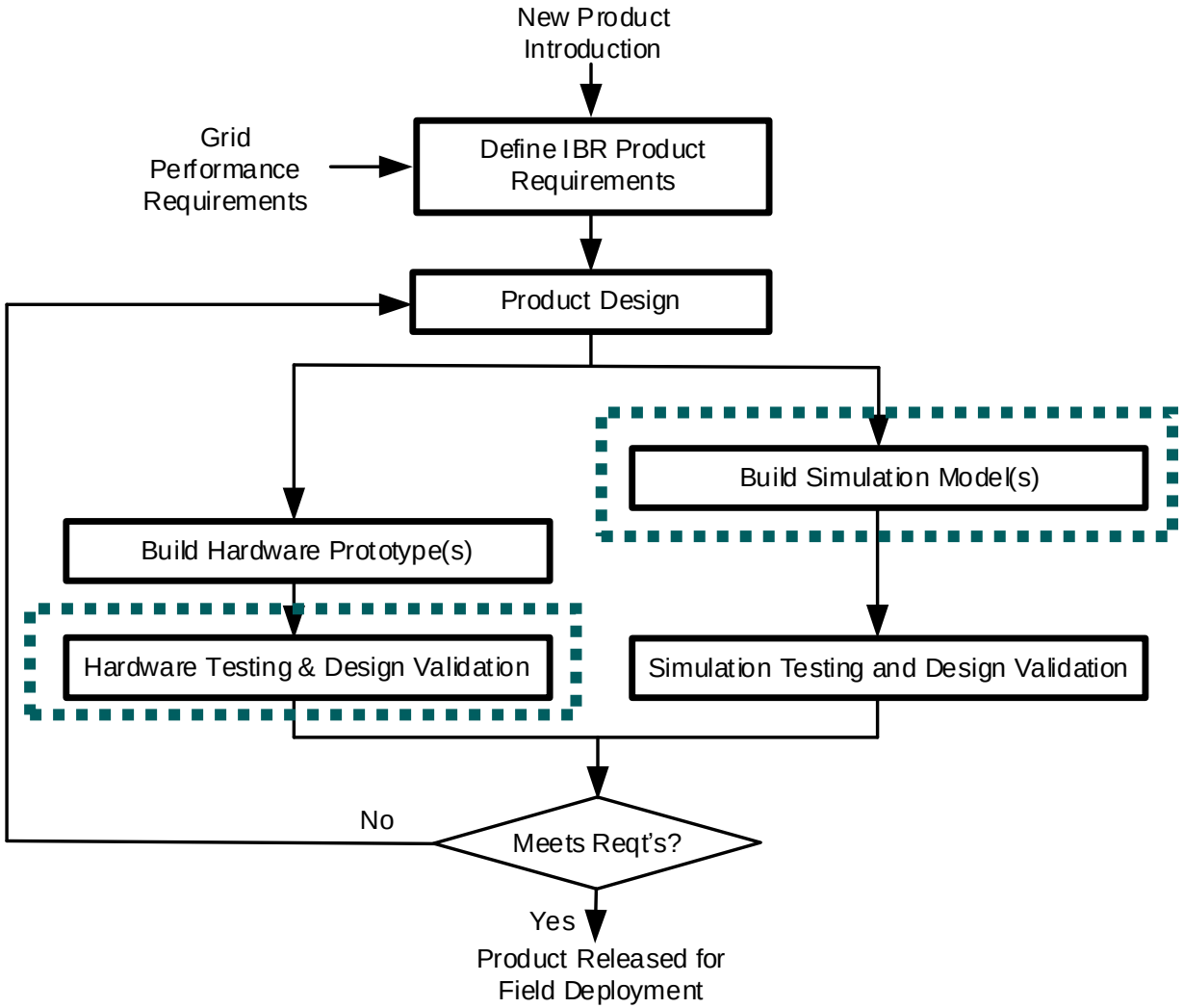


- New Product Designs initiated typically every ~2-3yrs (e.g. Wind Turbines), depending on market trends, with design cycle lasting multiple years per product
- It includes product requirements based on grid requirements and other aspects of targeted markets
- Grid requirements constantly evolving… may trigger product changes extending product design cycle
- Product design involves both hardware and control system design
- Design Validations carried out through extensive simulation and hardware testing



Product design process is usually independent of any specific project (for Wind, Solar, BESS) and follows wide-market trends

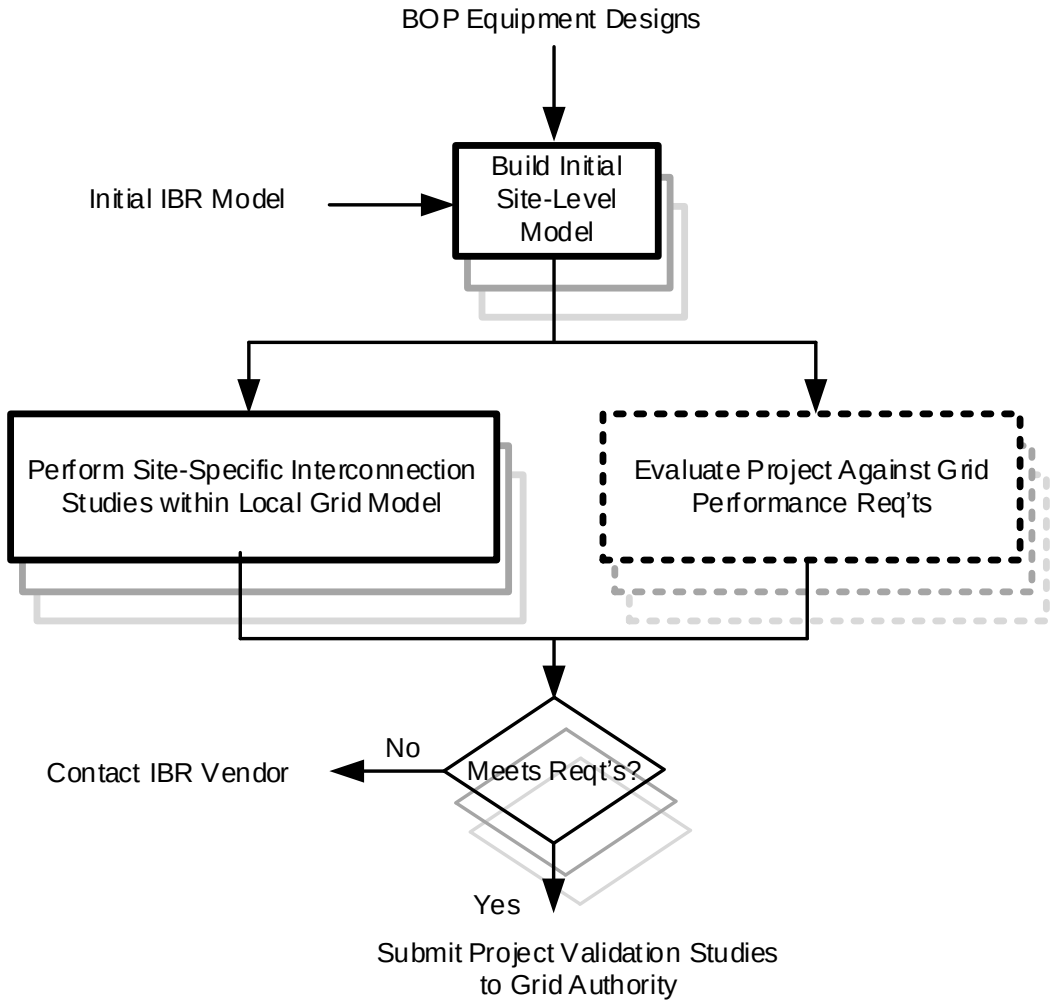
IBR MODEL DEVELOPMENT



- Initial IBR models typically required 1.5-2 years in advance of a particular project commissioning
- Model benchmarking carried out using initial simulation model and early hardware tests
- Initial IBR model released for a particular project is based on typical or default configuration of controls for high level application aspects (SCR, Series Compensation)

Initial IBR models typically released early in product development cycle (before full validation is complete) to meet interconnection process deliverables, usually with very little knowledge of grid interconnection details

PROJECT-SPECIFIC MODEL AND STUDY ASPECTS



- Generator owner (or their consultant) builds project-level model using initial IBR model and BOP equipment
- Project-level grid studies and/or evaluation of project against performance requirements is carried out
- If issues identified in studies that are related to IBR controls, IBR vendor is contacted. Potentially re-initiates product design process and model update.
- Site-specific model tuning requires grid characteristics which are not always available
- Tuning the model based on regional grid characteristics (such as general assumptions of weak grid in ERCOT), may not meet certain grid performance requirements (e.g. IEEE 2800 fast settling time)

Grid characteristics not clearly known upfront to tune initial model… meeting performance requirements in standards may conflict with optimal project tuning

GAPS IN MODEL DEVELOPMENT AND STUDIES

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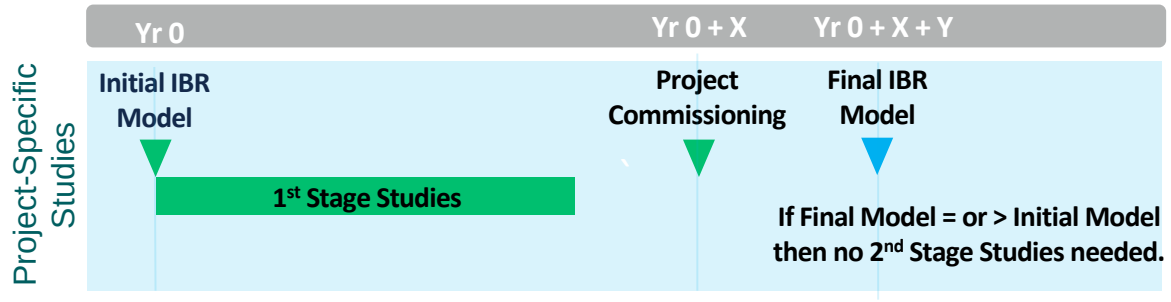
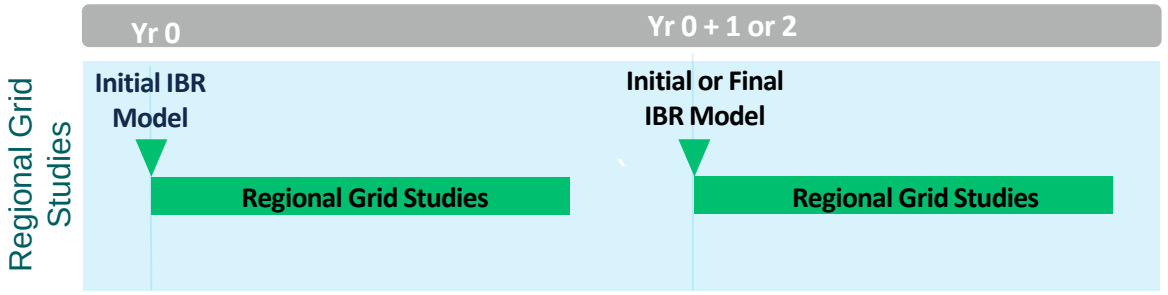
- Product development may be in early stages of performance validation when grid interconnection studies begin, requiring use of partially validated equipment models
- Generator owners + OEMs are incentivized to avoid changing models (and thus installed equipment) from initial submission to avoid interconnection delays triggered by repetition of interconnection studies, which could otherwise benefit from “latest and greatest” product
- Emerging items increasing likelihood/magnitude of model revision from initial model submission to “as commissioned” equipment:
  - Increasing complexity of grid (more IBRs, possibility for interactions)
  - Conflicts between certain grid performance requirements and requirements for stability
  - Changes/updates to grid performance requirements during product design cycle

ERCOT IBRWG | SUGGESTED MODELING/STUDY PROCESS IMPROVEMENTS

1. Have minimum 2 stages for project model submission – one initial model in early project stage and one final model after commissioning
2. Final models accompanied with an attestation by IBR vendors that model properly exhibits installed equipment behavior for intended types of grid events/phenomena being studied
3. Develop "standard" grid performance evaluation suite of simulation tests
   a. Simulation tests performed on both initial model and final model. If voltage/frequency stability performance in grid of final model is equal or greater than initial model, repetition of project-specific interconnection studies not required.
   b. Set of tests contain several simulation tests using realistic grid representation(s) and events likely to occur over the lifetime of the project.
   c. Set of tests may be updated over time as new gaps/issues are identified that weren't previously caught in prior versions of simulation tests.
4. Use regional grid studies to update standard grid performance evaluation suite based on results (if needed)



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