Non-Synchronous Energy Electronics, LLC

A Novel Solution for an Energy Storage Driven Synchronous Condenser

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Introduction

This presentation describes a proposal from NSEE to add a synchronous condenser system in parallel with existing peaking gas turbines or Grid Following Battery Energy Storage System (BESS), which is driven by an Induction Motor fed by a BESS.

Such a system would allow the benefits of both bulk energy storage for balancing, along with grid forming capabilities that are now provided by synchronous generators, such as gas turbines.

Such systems will allow for a much higher penetration of Inverter Based Resources (IRBs), without the need for significant changes to the existing transmission grid's operation and protection & control schemes.

Many grid operators are now adding rate-based free-wheeling synchronous condensers, but those systems have significant limitations. As of now, there is no revenue model for generation or ES providers to get paid for grid stability, despite the tech research in grid forming inverters for instance. We believe a way can be found find revenue sources for such services, such that more expensive rate-based solutions are not required.

A solution for optimizing low-run peaking gas turbines with energy storage solutions

With the addition of significant amounts of solar power and energy storage to the bulk electric grid, and the subsequent shut down of spinning generators, grid stability and protection & control are becoming a growing concern.

While there is a move towards grid forming inverters to help solve this problem, inverters have limitations that make them unable to fully replace spinning generators.

Thus, many grid operators have taken to installing synchronous condensers, to aid with dampening grid oscillations, providing fault current, as well as VAR control for voltage stability. Since these assets don't generate real power, they have no revenue source to justify them, and thus are added to the rate base and their costs socialized.

NSEE has a Novel solution for an energy storage driven system that can provide real power control, like a standard BESS, but also the advantages of a synchronous condenser, along with primary frequency control and fast black start capabilities.

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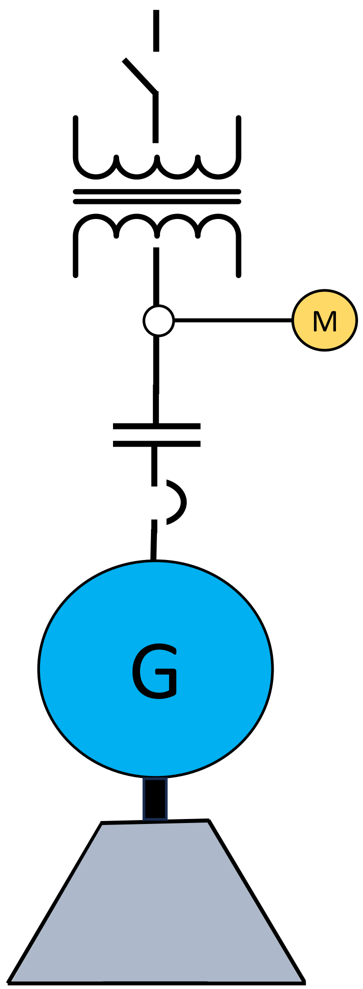
(Simplified Diagram) Existing Simple Cycle Gas Turbine Plant

Many Simple Cycle Gas Turbines are installed and available for fast ramp up and synchronization to the grid when called upon by the grid operator or when market conditions warrant.

Given the amount of solar and wind power installed, these turbines can sit cold for more than 90% of the time.

However, even when there is a surplus of net energy, grid operators often call upon gas turbines to run at low throttle in order to provide grid stability, power quality, inertia and fault capacity, which IBRs cannot provide.



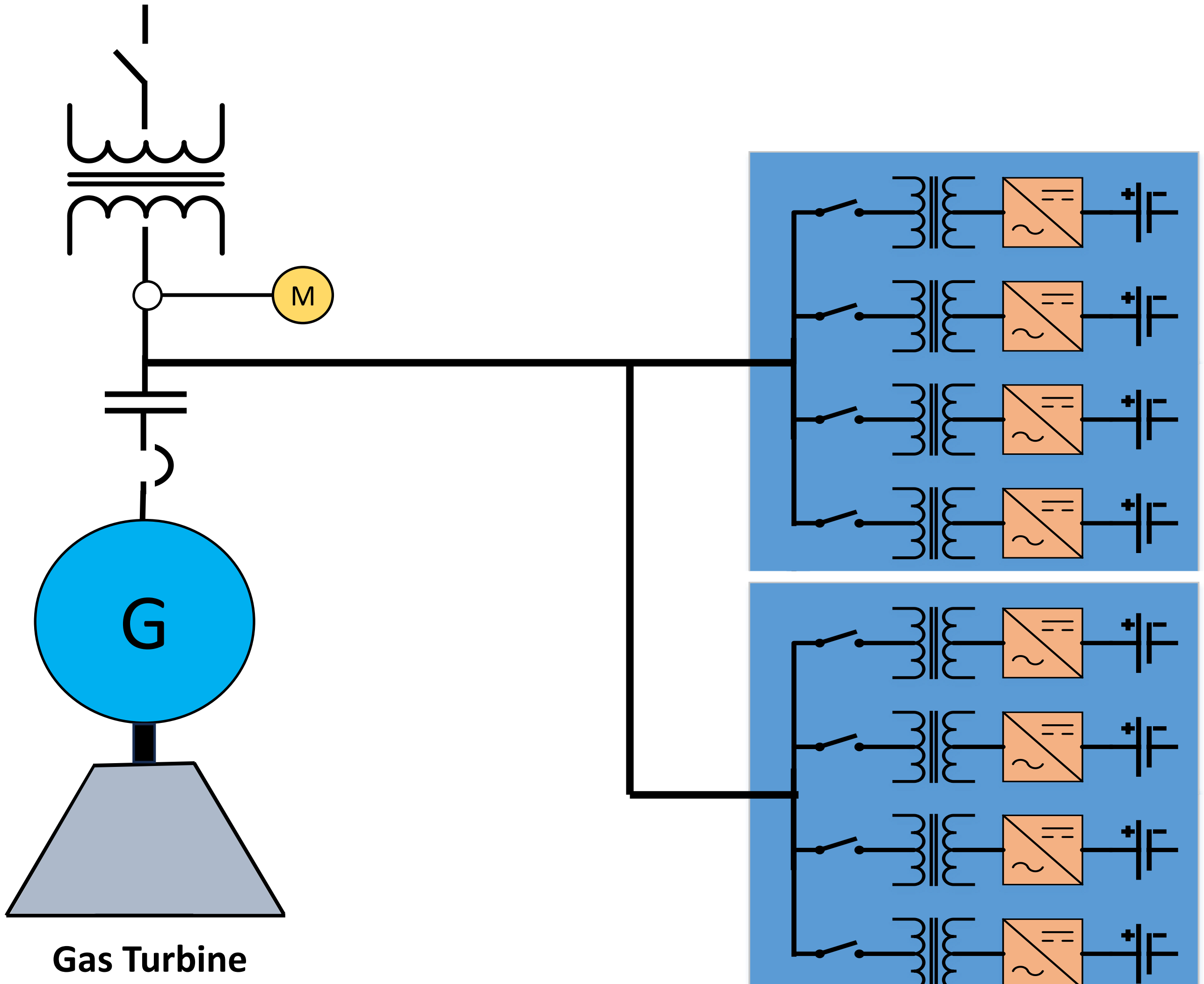
Gas Turbine

Adding BESS to these Plants

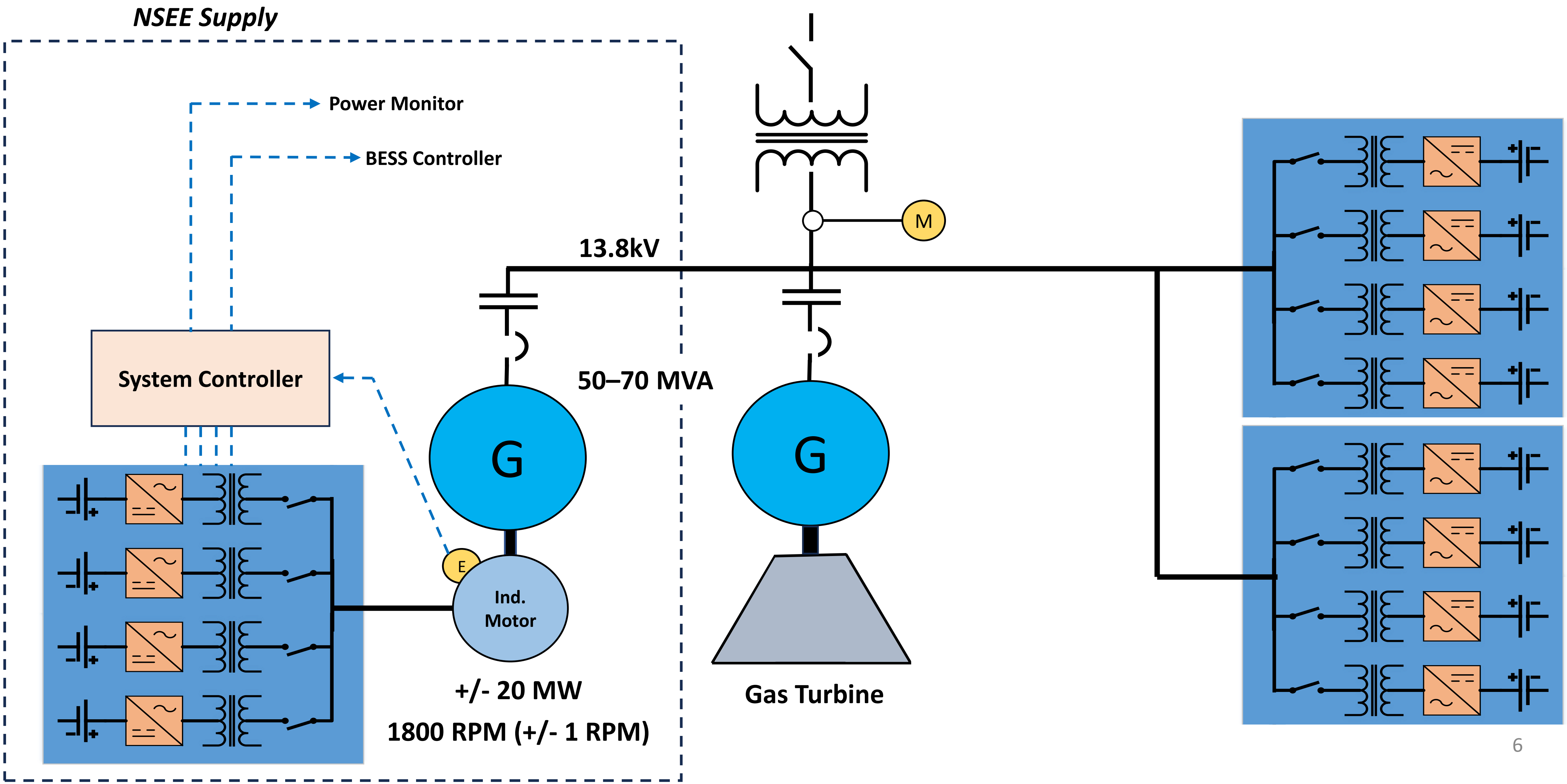
Given the value of the existing grid interconnections and the fact that the turbines are not running most of the time, may plants have added grid following Battery Energy Storage Systems.

This allows the plant owner to earn revenue with the BESS in the market, without having to wait for an interconnection to the grid.

These systems do not provide the full compliment of services to the grid that a synchronized gas turbine does, such as inertia, fault current contribution, grid forming, black start etc.



Added Energy Storage Driven Sync Condenser



By adding an energy storage driven synchronous condenser, the system can be optimized when the gas turbine isn't running

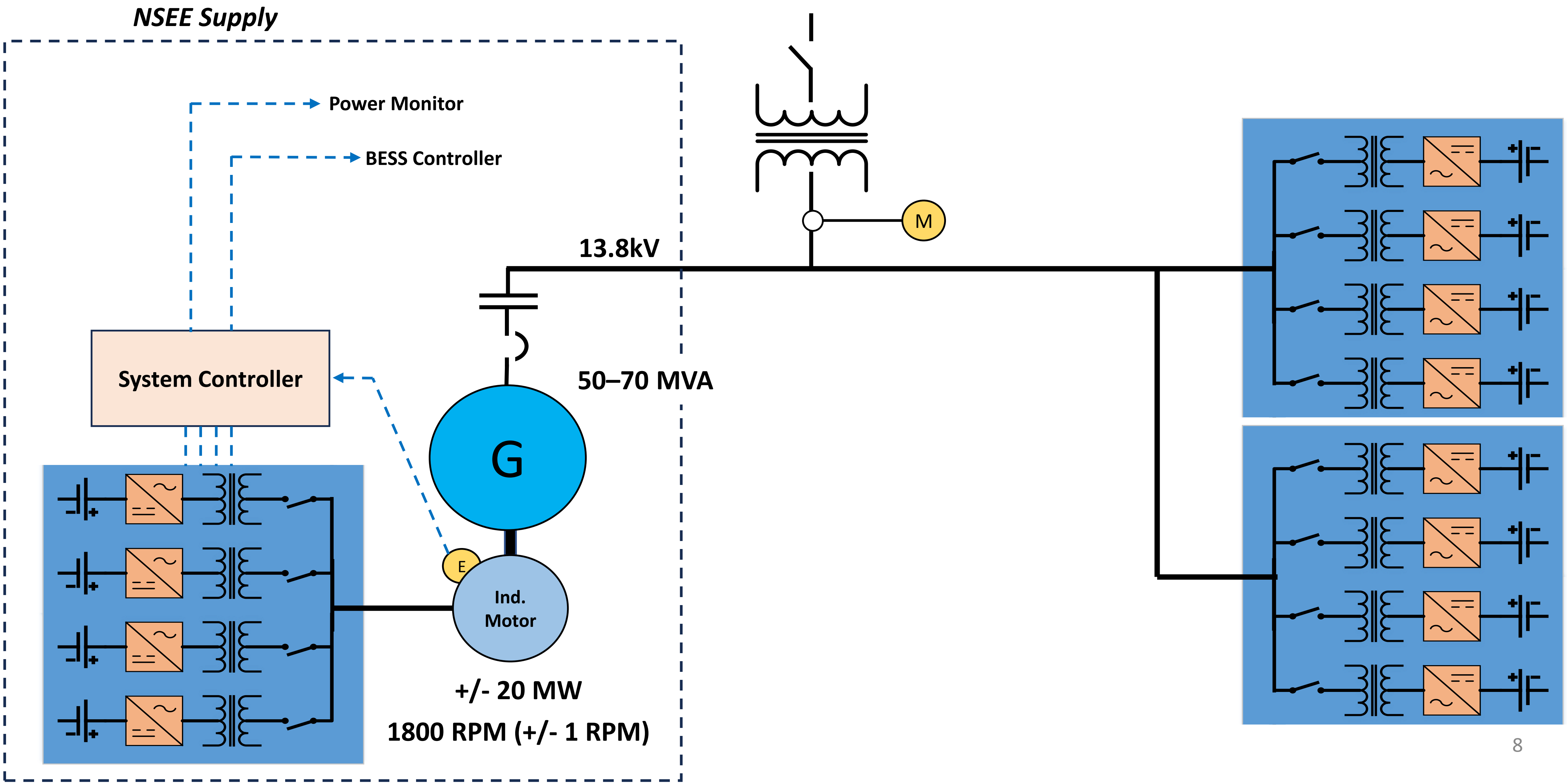
The addition of a parallel ES driven Sync Cond. provides the grid with the services and stability of the gas turbine, with tighter frequency control and load following capabilities, such as power flow control from the BESS system.

By matching the condenser to the gas turbine alternator, the interconnection studies and approvals will be vastly simplified, while keeping the expected system performance the grid operators are familiar with.

A key part of the design is to use existing gas turbine market mechanisms for revenue recovery. Currently, this is a big gap, as the market mechanisms for gas turbines are not fulfilled by the BESS additions.

NSEE believes that once such an EDSYC system is installed, the grid operators would have it online for all of the hours that the gas turbines are off, and that the gas turbine run times would be even more reduced than they are now.

Run the Energy Storage Driven Sync Condenser In Parallel with a Grid Following BESS



Adding an energy storage driven synchronous condenser to an existing grid flowing BESS

The addition of a parallel ES driven Sync Condenser to an existing BESS would give the whole system the ability to provide grid services similar to a synchronous generator plant, along wit the ability to absorb power and bulk load shift, but without the need for fuel to be burnt.

Again, many gas turbines are run at low throttle to provide grid forming, grid stability, fault current and fast reserve power. Standard BESS plants cannot provide all of these services, but if they were coupled with and ES driven sync condenser they could, at least for much more fo the time that gas turbines are run now.

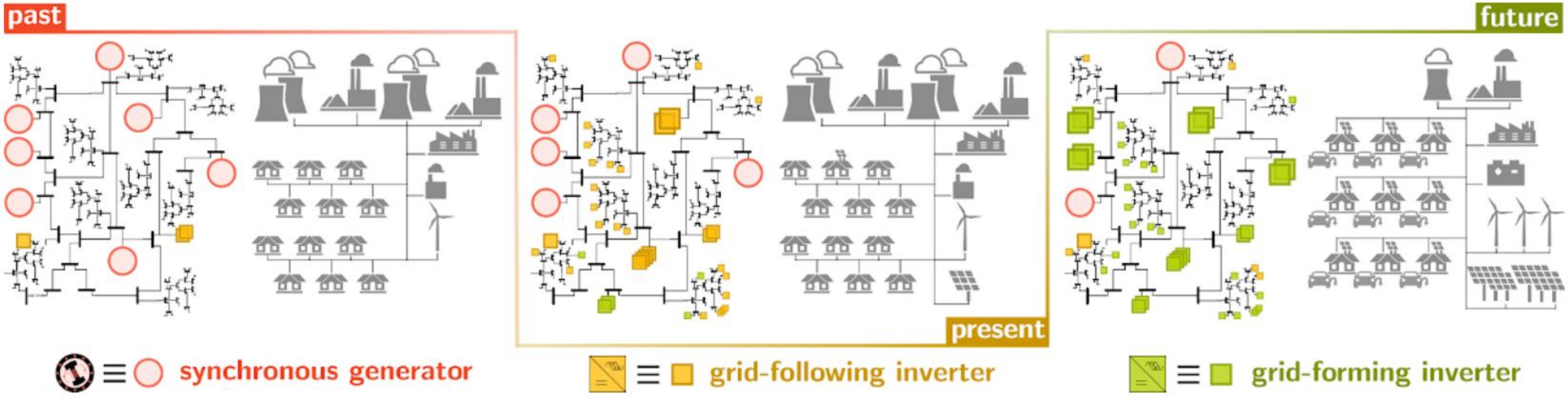
This would allow BESS plants to replace gas turbines when the energy production of IBRs is adequate for the load, and not need to use gas turbines as much when the power is not required. This includes times when IBRs are curtailed and gas turbines run in order to provide grid forming and stability.

Many organizations are working to overcome the limitations of Inverter Based Resources (IBRs)

what?

the **un**iversal **i**nteroperability for grid-**f**orming **i**nverters (**unifi**) Consortium is a U. S. Department of Energy funded effort to advance grid-forming (GFM) inverter technology • we are led by the National Renewable Energy Laboratory (NREL) with Ben Kroposki serving as our Organizational Director • **unifi**'s mission includes:

- fostering an ecosystem to enable researchers, industry partners, and other stakeholders collaboratively pursue advances in GFM tech
- defining system-level guidelines and unit-level functions to prove vendor-agnostic interoperability of GFM tech



Grid Forming Inverter Limitations

The previous slide from NREL shows a future of how to operate a large scale grid using grid forming inverters instead of synchronous generators, noting that with grid following inverters, the penetration depth of IBRs is limited, thus the need for grid forming inverters.

NSEE offers grid forming inverter solutions, but believes that both during transition and in the longer term, spinning synchronous machines provide value over grid forming inverters, and should be a part of the mix.

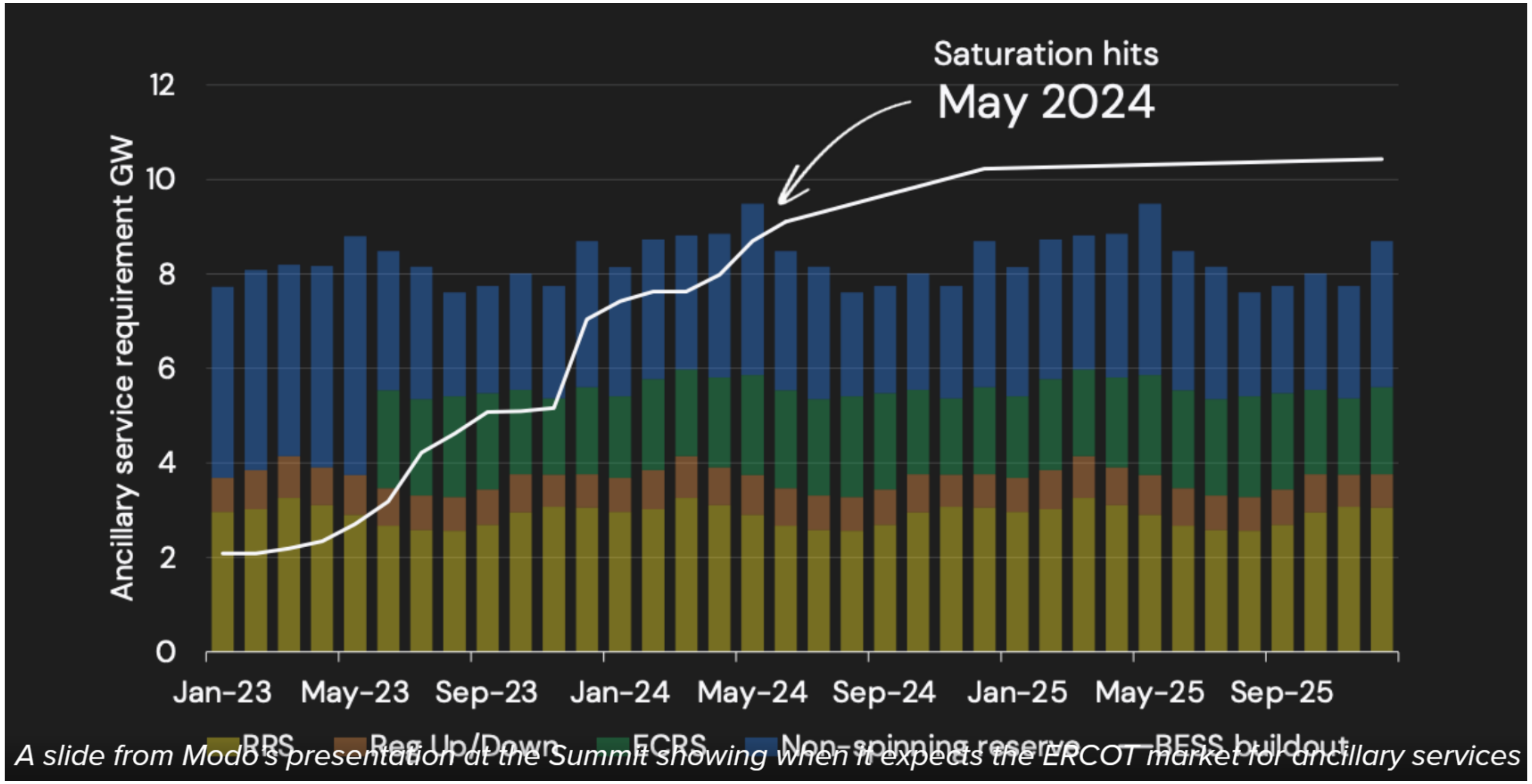
Many grid operators are installing simple synchronous condensers, which are rate based and provide no economic value that can be bid into the market. These machines provide damping to the grid, and fault current contribution to replace that which is lost from synchronous generators, but not frequency control or black start capability.

When the amount of energy available from IBRs is sufficient, but grid stability is required, an ES driven sync condenser would offer the best solution.

Market saturation will eventually be reached for non-grid forming energy storage

This was from a study by Modo Energy for the ERCOT market

Basically, there needs to be a significant amount of large spinning generation present, and the energy storage market will only be able a percentage of that amount, unless it is grid forming and can replace the need for spinning generation.



A slide from Modo's presentation at the Summit showing when it expects the ERCOT market for ancillary services

Bulk Grid System Protection Issues

As mentioned previously, many grid operators are installing (or planning to) free-wheeling synchronous condensers to help with grid stability and protection.

The electro-mechanical lock of a synchronous machine rotor to the grid provides for much faster change measurements and response times than a control system that relies upon feedback measurement and then software analysis of an event.

This includes the amount of fault current produced, and speed with which it is produced, given that the existing bulk grid is generally designed around synchronous generators and requires significant fault currents in order to quickly operator appropriate breakers and fuses in the system. Changing from synchronous generators to IBRs can require significant changes to the existing protection schemes.

Such changes are expensive and complicated and can therefore lead to problems in a critical area where no problems existed before the change. Thus, the easiest solution to add rate based sync condensers, despite the high costs, which must be passed along to consumers.

Further in the presentation we will discuss how our solution can defer these costs.

Frequency Stability and Black Start

The accuracy of the induction motor speed control with encoder feedback can be within 1RPM, or 33mHz (1800RPM), much faster and more accurate than an inverter based system making or measuring a 60Hz grid.

With a synchronous machine rotor lock, even very small changes in frequency can be detected quickly and acted upon. This gives the Induction motor driven synchronous condenser the ability to provide very fast and accurate grid forming primary frequency control. This includes being the “first one on” in a black start situation.

Once grid operators are given access to the stability enhancements available from such systems, they will find them very useful as the build out of more solar power and other IBRs come on-line. This will be a work in progress, especially if there are many of these controllable ES driven machines. It is NSEE’s plan to work collaboratively with grid operators to optimize these advantages.

Commercial, Legal, Regulatory Issues

We realize that the most complicated part of getting such systems installed are the commercial aspects of using new solutions.

NSEE's belief is that such systems can be added to existing gas turbine plants, where the turbines now rarely run, and use the same market mechanisms to earn a sufficient ROI.

These systems would replace the need for rate-based synchronous condensers, which weren't needed when the grid was fed by synchronous generators instead of IBRs. They would also work in parallel with grid following BESS projects, of which there are many now installed and many more under construction and planning.

As grid operators incentivize a transition away from fuel burning power production, keep in mind the monetary value of grid stability that came inherent in large spinning power plants as they got compensated for the power sold. Those services now need to be valued separately.

For more info or to discuss specifics, please contact Alan McDonnell or Kevin McDonnell

We would much appreciate an opportunity to discuss further with you any opportunities you have, and answer any questions you have. For more information, please contact;

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