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BALANCING THE GRID: A PILOT ON SECONDARY RESERVES FOR HYDRO POWER PLANTS

GTG-RISE

Innovative, evidence-based approaches

The Greening the Grid-Renewable Integration and Sustainable Energy (GTG-RISE) program is a partnership between the United States Agency for International Development (USAID) and the Ministry of Power, Government of India, under the Asia - EDGE (Enhancing Development and Growth through Energy) initiative. GTG-RISE has conducted a series of prioritized innovation pilots and demonstrations to validate technologies and models to support large-scale integration of renewable energy into the Indian power grid. One of its pilots tested automatic generation control (AGC) at hydro plants in Southern India. GTG-RISE is implemented by Deloitte Consulting LLP.

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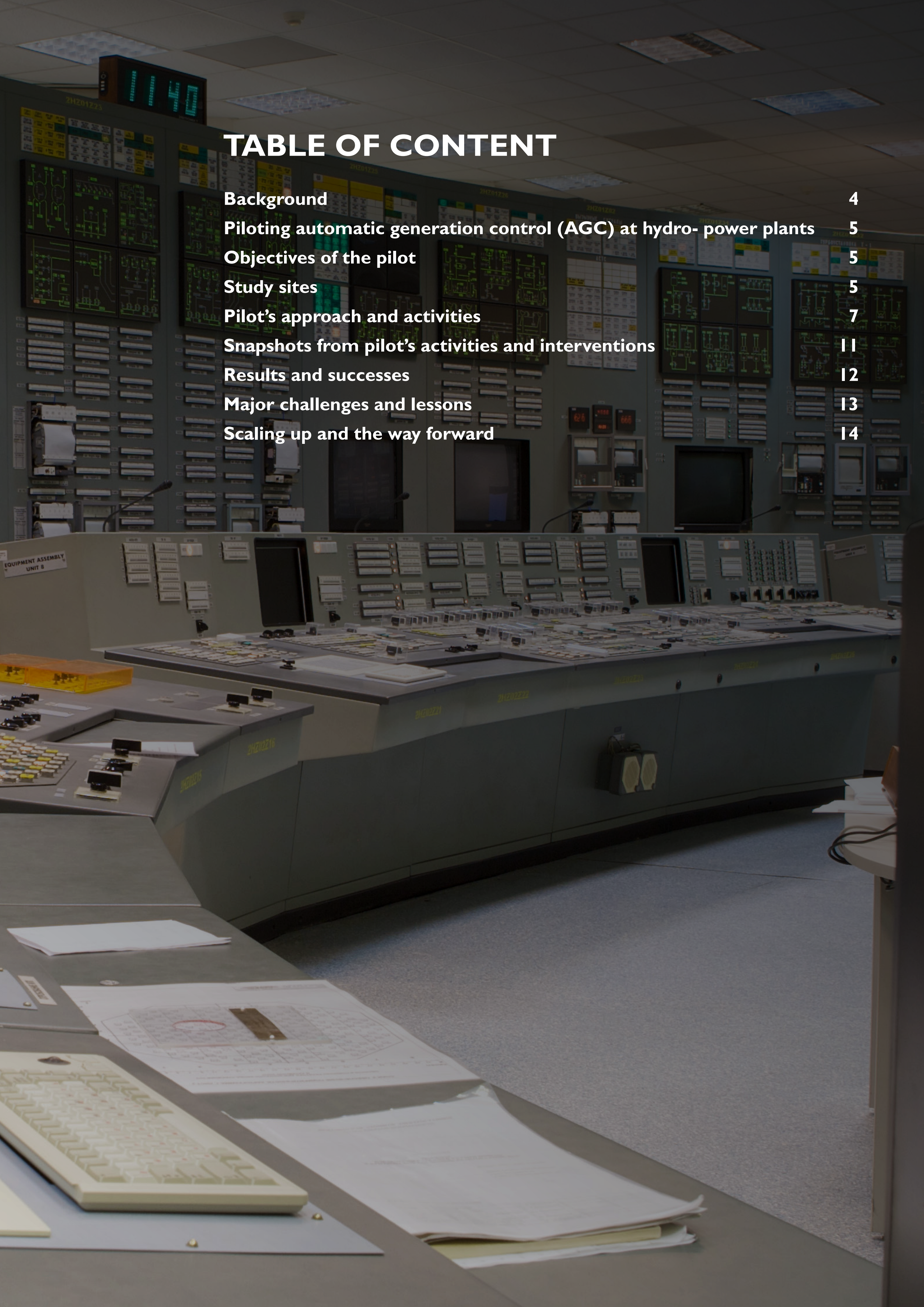

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BACKGROUND

WHY FOCUS ON GRID BALANCING ?

India is rapidly scaling-up its renewable energy (RE) capacity, with the goal of installing 450 gigawatt (GW) of RE by 2030. Integrating large amounts of variable RE RE generation into the power grid brings a degree of uncertainty that system operators must prepare for. Any mismatch in energy demand and supply in the grid causes a change in grid frequency, threatening the reliability of the overall power system. Real-time maintenance of load-generation balance is thus of vital significance. Large, complex grids such as India's require primary, secondary, and tertiary frequency controls to ensure grid reliability. In systems with significant RE penetration, additional ancillary services may be needed to manage the increased variability and uncertainty. Automatic generation control (AGC) — a major control function for adjusting the power output in response to changes in load — is an essential tool for providing secondary reserve support.

India's Central Electricity Regulatory Commission (CERC) outlined a roadmap in October 2015 for implementing reserves in a phased manner. AGC implementation for secondary control was a key requirement. Subsequently, the National Load Despatch Centre (NLDC) and Power System Operation Corporation Limited (POSOCO) outlined the need for AGC pilots across India's grid regions (covering all forms of generation — thermal, hydro, and RE) before regulations and procedures for nationwide launch could be framed. The National Thermal Power Corporation Ltd (NTPC) implemented India's first AGC pilot at its Dadri thermal power plant. However, AGC enablement for hydro and renewables remained untested. USAID's GTG-RISE initiative addressed this gap by piloting AGC at two hydro plants in India's Southern region.

"This is indeed an epochal moment for us. The AGC pilot at KPCL's hydro plant will showcase pathways to implement AGC and will give us critical data to inform rollout at national level. I thank USAID for their partnership in taking forward these important pilots under its GTG-RISE initiative."

Mritunjay Kumar Narayan
Joint Secretary (Transmission), Ministry of Power

PILOTING AUTOMATIC GENERATION CONTROL (AGC) AT HYDRO- POWER PLANTS

Ensuring the power system's reliability in the face of increased RE penetration is critical. The fluctuating nature of energy from renewables requires energy balancing in real time to keep supply and demand in sync. AGC can enable grid operators to easily adjust the power output of generators in response to changes in load and enable secondary control of ancillary services to balance energy supply and demand in real time. However, given the absence of a regulatory requirement for AGC, system operators in India have not operationalized or tested AGC in their energy management systems.

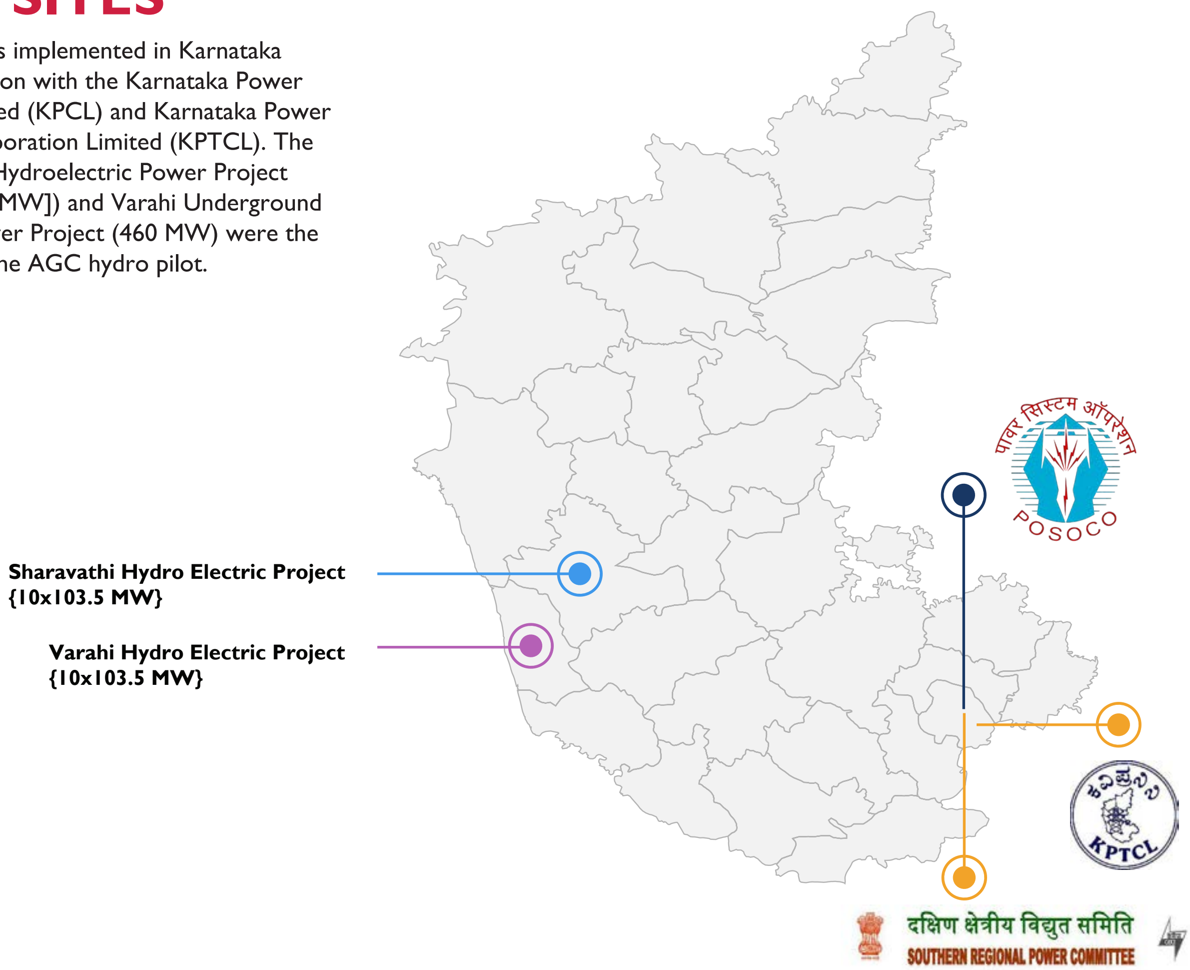
USAID's GTG-RISE initiative — committed to innovative, evidence-based grid solutions — implemented an AGC pilot at two hydro plants in the southern state of Karnataka to demonstrate AGC as a grid strengthening mechanism. Implemented in consultation with NLDC and POSOCO, the five-year (2017–2021) pilot not only provided much-needed data on AGC but also bolstered confidence ahead of its national rollout.

OBJECTIVES OF THE PILOT

The GTG-RISE pilot tested AGC operation at two hydro plants in Karnataka by enhancing the existing software and hardware systems at the two plants and corresponding enhancements at the State Load Despatch Center (SLDC). The pilot also sought to demonstrate the techno-economic benefits of AGC to aid policymakers and regulators in the development of a scalable roadmap for AGC adoption, including a compensation framework for enabling AGC support.

STUDY SITES

The AGC pilot was implemented in Karnataka in close collaboration with the Karnataka Power Corporation Limited (KPCL) and Karnataka Power Transmission Corporation Limited (KPTCL). The state's Sharavathi Hydroelectric Power Project (1,03.5 megawatt [MW]) and Varahi Underground Hydroelectric Power Project (460 MW) were the sites selected for the AGC hydro pilot.



The GTG-RISE pilot on AGC implementation at hydro plants supported the Ministry of Power's efforts to build a robust, resilient, self-reliant power sector in the country. Its insights will help address the issue of variability in RE generation, a critical achievement that will spur India's progress on its decarbonization journey.

Managing reserves to guarantee reliable grid operation

Large-scale integration of energy from variable, unpredictable renewable sources require system operations to be more flexible, with rapid response capabilities that balance and enhance the resilience of real-time grid operations. Ancillary services can help maintain the proper flow and direction of electricity, address imbalances between supply and demand, and assist the system in recovering after a power system event such as outage of generator or transmission line due to faults. The imbalance between energy demand and supply can be mitigated through various ancillary reserves. Reserve power is divided into primary reserves, secondary reserves, and tertiary reserves according to time it takes to activate the reserve and the duration of activation.

Primary reserves come from local automatic controls, which deliver reserve power in response to any frequency change. Secondary reserves come from centralized (at state/regional) automatic control and deliver reserve power to bring back the frequency and the interchange power flows to their target values. Tertiary reserves come from manual changes in dispatching and unit commitment to restore the secondary control reserve, manage eventual congestions, and bring back the frequency and interchange power flows to their target if the secondary control reserve is insufficient.

India has both primary and tertiary reserves readily available. The compensation market is available for tertiary reserves and primary reserves are socialized with no specific compensation mechanism. However, secondary reserves, or regulation reserves, are not sufficiently present. In other countries, such as the U.S. and European countries, system operators maintain secondary reserves in the range of 1% to 2% of total peak demand through AGC control. India needs such secondary reserves, made available through AGC, to manage variable RE. As India continues to add RE to the grid, the need for secondary reserves will grow. Adding AGC-enabled reserves will allow grid operators to operate the grid smoothly, thus facilitating RE additions into the grid.

PILOT'S APPROACH AND ACTIVITIES

The GTG-RISE pilot leveraged best practices and international experience to identify the technical interventions and operational changes needed to implement AGC at two hydro power plants in Karnataka. The pilot's interventions were conducted in a phased manner over a five-year period, starting in 2017.

AGC pilot at hydro power plants: Summary of stage-wise initiatives

Stage I

Conceptualization & Pilot Implementation

- Technical due diligence and pre feasibility assessment of AGC
- Selection of Implementing Agencies
- Demonstration of AGC pilot on Hydro and RE Plants in Southern India

Stage II

Compensation framework for AGC support

- Develop compensation framework for enabling AGC support from Hydro and Solar generation.
- Design, Modeling and implementation of economic evaluation

Stage III

Scale Up

- Pre-feasibility studies for scaling roll-out across all regional and national power plants
- Recommendation on regulation, policy and market framework

2017

- Pilot Conceptualization
- Stakeholder Discussions
- Site visit to Hydro and Solar facilities for AGC implementation

2018

- Site visits & technical assessment
- Stakeholder consultations
- Technical Feasibility Analysis
- Knowledge Dissemination Workshops

2019

- Development of Ancillary Service Roadmap for Hydro & Solar power plants
- Knowledge Dissemination Workshops

2020-21

- Demonstration of AGC functionality
- Scale Up at National Level
- State Level Handholding
- Knowledge Workshops

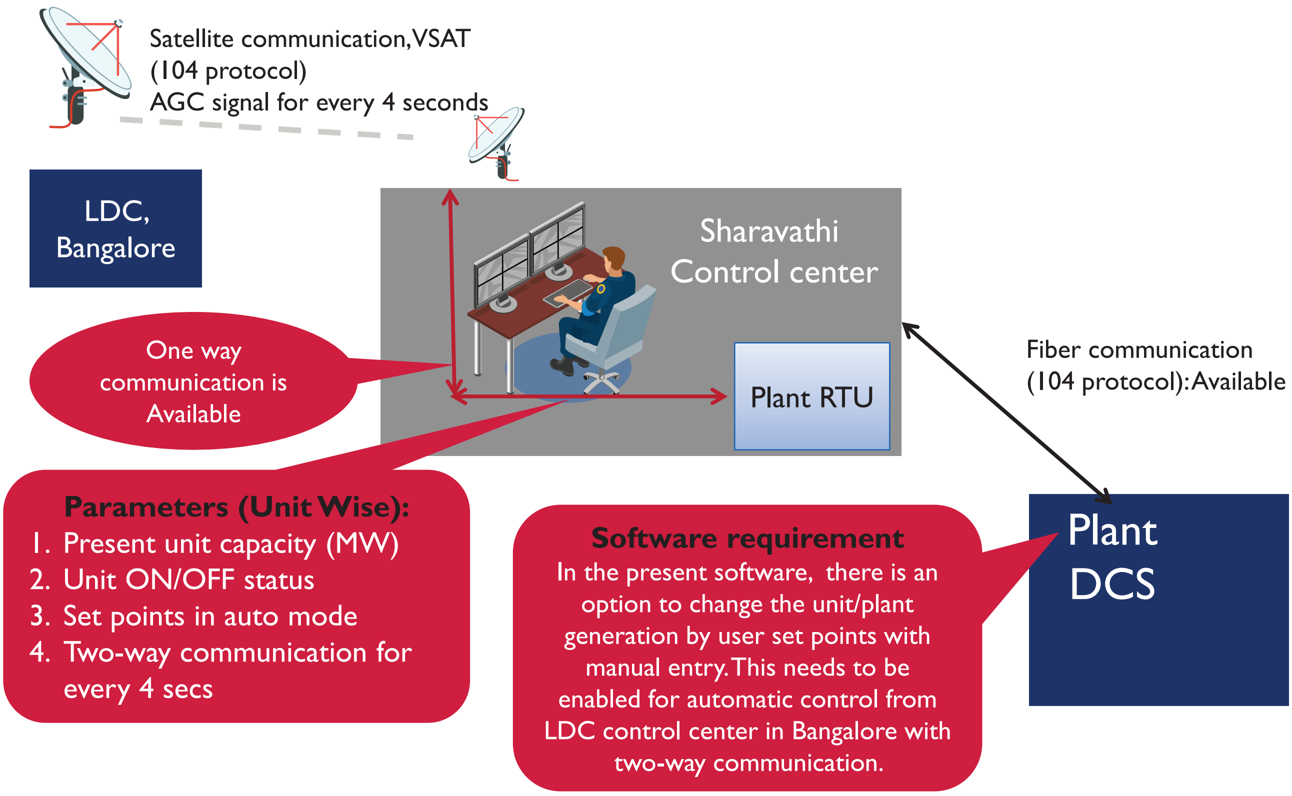
A) UNDERSTANDING THE REQUIREMENTS FOR AGC IMPLEMENTATION

The first phase of the pilot (2017–2018) focused on ascertaining the hydro plants' techno-commercial feasibility for implementing AGC. The GTG-RISE team conducted various site visits and carried out technical assessments to determine feasibility and to select hydro plants for the pilot. The key considerations included, but were not limited to, water availability, years of hydro plant operation, turbine technology, flexibility of the plant, and annual availability. Based on these considerations, two hydro plants (Sharavathi and Varahi) out of the three proposed were selected for the pilot.

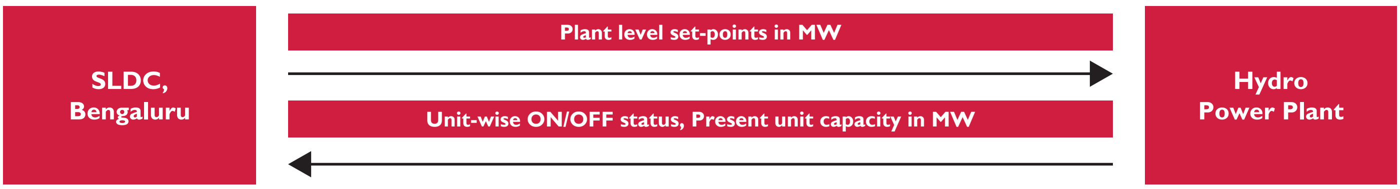
Before the AGC pilot was implemented, operators at the two hydro plants used to change their generator output set-points manually based on the information the SLDC in Bangalore gave them over the telephone. Some parameters of unit details, such as real-time generation output in MW, were communicated by KPTCL Remote Terminal Unit (RTU), which is placed at the hydro plant control center. Automation of generation output set-points from the SLDC needed to be facilitated through the SLDC's existing AGC module (software). As the two hydro plants are more than 10 years old and do not have any advanced control systems, how to enable AGC posed a challenge. In fact, most hydro plants in India use one-way communication to report real-time generation to the SLDC. The figures below show the pre-requisites for AGC implementation at the Sharavathi hydro plant; the requirements were similar for the Varahi hydro plant.

SHARAVATHI HYDRO POWER PLANT

Requirements for AGC implementation



Data communication between the plant and SLDC



After a detailed examination of various technical aspects at the pilot sites, the GTG-RISE team proposed the following interventions:

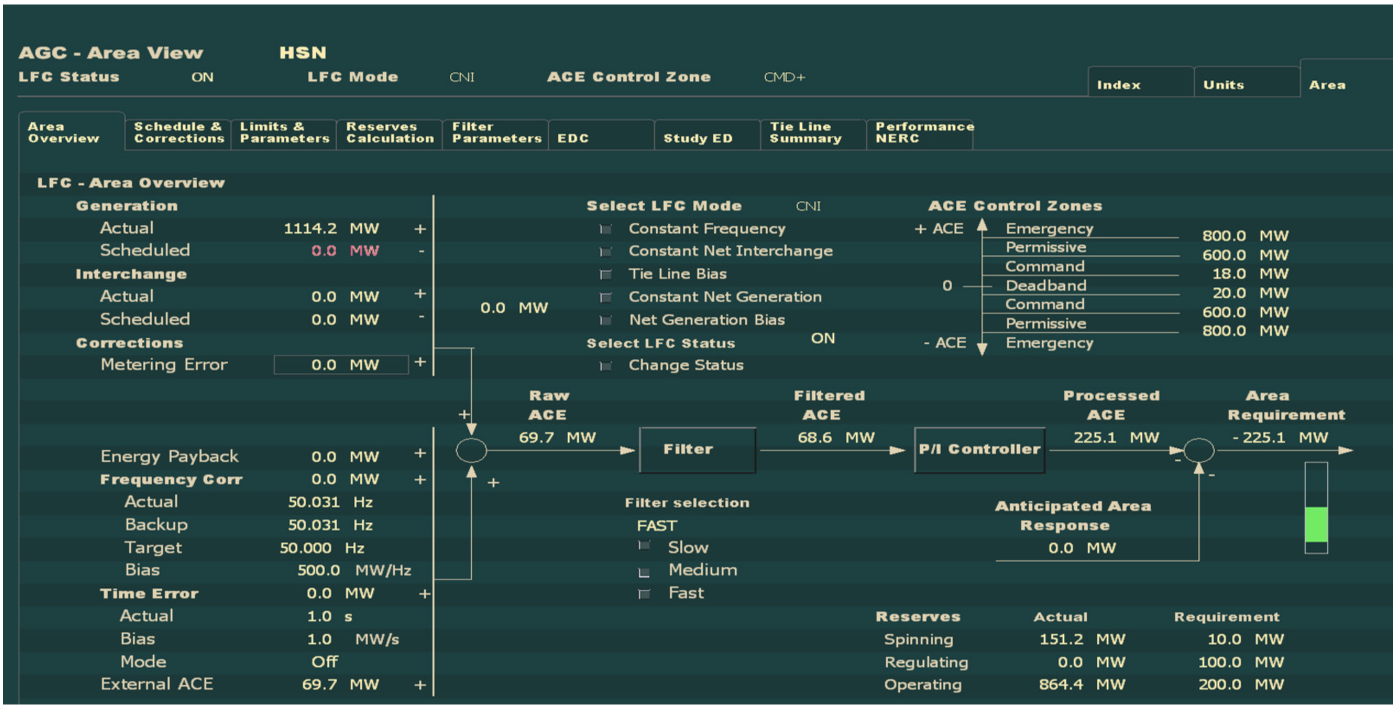
- AGC module configuration in the energy management system (EMS) at the SLDC in Bengaluru
- Hardware and software facilities at KPCL's Sharavathi and Varahi hydro power plants
- Two-way communication facilities between the hydro power plants and the SLDC
- AGC signal generation as per grid frequency and tie-line power flow

B) AGC IMPLEMENTATION AT PILOT SITES

The second phase (2019–2020) of the pilot saw a host of activity geared toward AGC rollout at the two hydro plants. The original equipment manufacturer (OEM) for the respective plants was identified to implement the needed hardware and software facilities at the hydro power plants and undertake the requisite engineering work at the SLDC. The OEM's scope of work for AGC implementation at both plants included setting up the software to function in response to the signals received from the SLDC and providing interface between the plant RTU and the KPTCL RTU within the required parameters. The pilot was implemented at a time refresh interval of 4 to 10 seconds. Ten units at Sharavathi and 3 units at Varahi were configured in the AGC module. The SLDC AGC module could enable and disable AGC operation; the specific units could do the same. However, the master control remained with hydro plant operators to enable AGC operation at the unit or plant based on unit performance and other constraints.

A high-profile virtual event on December 8, 2020, marked the go-live launch of AGC at Karnataka's two hydro plants. The event was attended by senior officials from the Ministry of Power, POSOCO, KPCL, KPTCL, GTG-RISE, SLDC, and the selected system integrators (ABB India Limited and Andritz Hydro Private Limited). The AGC pilot's go-live was completed in December 2020.

AGC pilot implementation at SLDC, Bengaluru

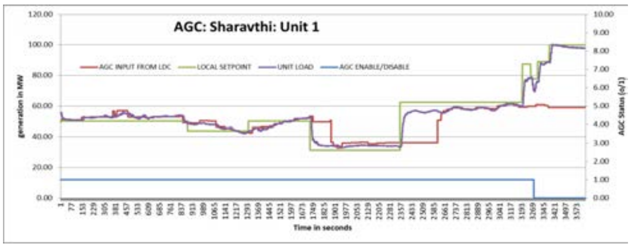


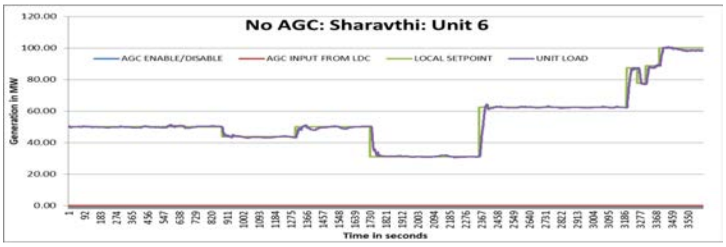
The pilot was executed for 3 months to generate use cases to evaluate the benefits of AGC operation for grid operation with high RE in the system. A number of use cases were tested and verified at the two pilot sites, including outgoing and incoming signals and AGC logic and limits for optimum response.

C) IMPROVED GRID MANAGEMENT THROUGH AGC

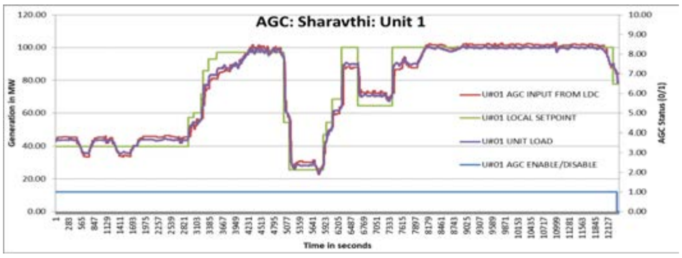
Data from the pilot's test runs was analyzed to arrive at comprehensive recommendations about AGC's technical benefits for grid operation and the compensation mechanism for participating hydro units. After AGC was enabled at the pilot sites, the GTG-RISE team tested the hydro plants for their response to AGC signals sent by the SLDC in almost real time. The units with AGC increased their generation when the Karnataka state grid needed to import power and decreased generation when the state was exporting power. The AGC module at the SLDC was able to generate AGC signals as per tie-line power flows and frequency response. The hydro units' response to AGC operation is presented in the figures below.

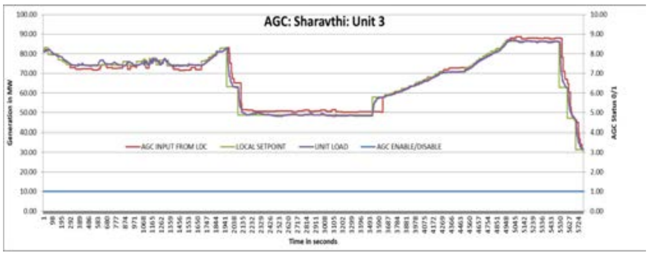
AGC response of Sharavathi hydro units with and without AGC operation





AGC response of Sharavathi hydro units with AGC operation





During the test runs, the hydro units responded to AGC signals from the SLDC in near real time, indicating the hydro unit's smooth operation. The hydro units' responses were within local boundary limits, set at +/- 10% of the scheduled value, and within global boundary limits, set at a technical minimum of 20 MW and maximum of 100 MW for the Sharavathi units and 15 MW minimum and 115 MW maximum for the Varahi units.

AGC response from the hydro units successfully compensated for variable RE up to 100 MW from Sharavathi and up to 36 MW from Varahi, demonstrating how the secondary reserves enabled through AGC facilitate smooth grid operation in the face of RE variation. The secondary reserves from AGC also helped the system operator to minimize the deviation settlement mechanism (DSM) charges linked with frequency. The reduction in DSM charges will help to avoid penalties to be paid to central pool and minimises cost to distribution companies.

> ***Karnataka is leading in terms of RE integration. KPCL is one the first entrants into AGC, and it is our privilege to be contributing to initiatives for energy security and environment.***
>
> **V Ponnuraj**
> Managing Director – Karnataka Power Corporation Limited (KPCL)

SNAPSHOTS FROM PILOT'S ACTIVITIES AND INTERVENTIONS

Photo GTG-RISE

Discussions between GTG-RISE team and the KPCL Managing Director (MD) on the AGC hydro pilot

Photo GTG-RISE

Visit to Varahi hydro power plant for technical assessment

Photo GTG-RISE

Visit to Sharavathi hydro power plant for technical assessment

Photo GTG-RISE

Discussions between GTG-RISE and KPTCL-SLDC on the AGC pilot

Photo GTG-RISE

Grantee award to Andritz for implementation of AGC at Varahi hydro power plant

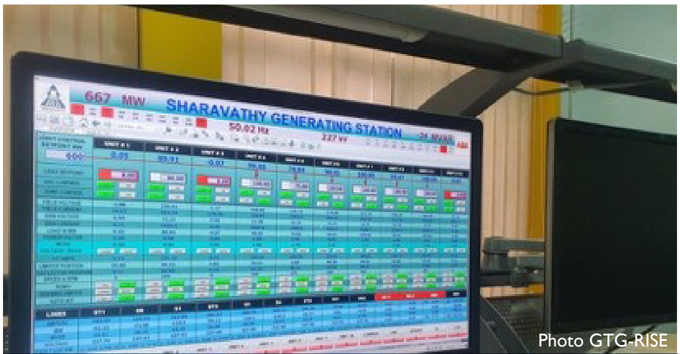


Photo GTG-RISE

AGC system implementation at Sharavathi hydro power plant

Photo GTG-RISE

Virtual event for the go-live launch of the AGC pilot at the Sharavathi hydro power plant

RESULTS AND SUCCESSES

The AGC pilot has generated evidence to inform the development and implementation of a long-term ancillary services roadmap for the county and boost integration of renewables. Its comprehensive set of recommendations can be the building blocks for a nationwide rollout of AGC at hydro power plants. In addition to supporting KPCL to enable AGC, the pilot's results and recommendations have been well received by POSOCO and the State Electricity Regulatory Commission (SERC). The Southern Regional Power Committee (SRPC) has recommended that all hydro units in the Southern region follow the GTG-RISE pilot for similar implementations at all hydro units in the region.

The pilot also resulted in capacity building of key plant personnel for AGC operations: more than 100 engineers were trained through operator trainings and knowledge dissemination workshops. Plant operators at both the Sharavathi and Varahi plants have been trained to operate AGC independently. SLDC members too are well equipped to operate AGC in accordance with grid requirements. In fact, the trained SLDC members can now configure any hydro unit or thermal unit at the SLDC with no support from the OEM and with no extra license cost to configure AGC at additional units.

GTG-RISE also conducted a techno-economic analysis of the incremental cost savings due to an AGC-enabled fast response by the hydro units. The analysis aimed to support regulatory framework guidelines for a compensation mechanism for secondary reserves (AGC). To this end, a report on technical outcomes and regulatory framework guidelines has been submitted to state and central regulators to help build an understanding of AGC's technical benefits and compensation for secondary reserves. The guidelines suggested sharing the benefits with AGC operation at system level to participated hydro units by looking into the Indian market prices as reference for regulation down and additional mark up prices for regulation up.

"The AGC pilot is a dream come true for all system operators. Integration of renewables is going to become more complex, and Karnataka is leading from the front by demonstrating the use of AGC in its hydro power plant. I congratulate everyone associated with this pilot."

K.V.S. Baba
Chairman and Managing Director, POSOCO

MAJOR CHALLENGES

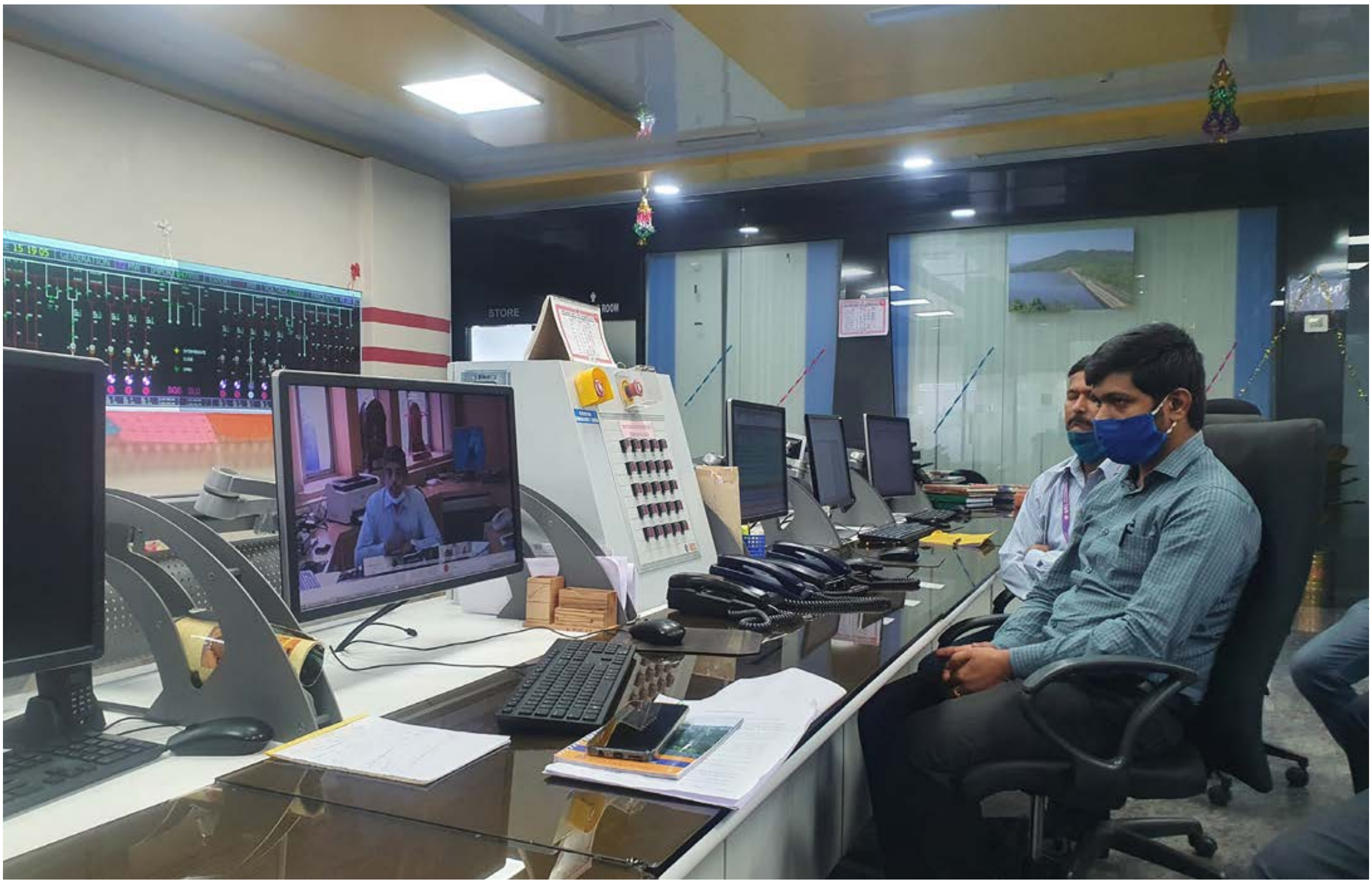
Technical challenges to AGC operation in India come from multiple fronts. First, most power plants do not have the communication facilities needed to send and receive signals in real time. Because AGC operation requires the closed loop operation between the hydro generator and SLDC at time intervals of 4 seconds to 10 seconds, the pilot implemented a two-way communication facility. The signal communication protocol between the hydro plant DCS (Digital Control System) and RTU at the respective grid substation is configured on IEC60870-5-104 protocol.

Second, most hydro facilities lack the necessary software for AGC control at hydro power plants. The new controller was deployed and connected with DCS to handle the AGC signal monitoring and processing with time refresh intervals of around 2 seconds.

Third, plant operators and SLDC staff need to be trained on using AGC software. This challenge can be overcome by continuing to train operators at hydro power plants from the design to the implementation stage on how to use, enable and operate AGC operation.

Other challenges include the lack of an advanced 'human machine interface' (HMI) to interact with plant controls; most generators in India still operate without HMI facilities. This challenge arose at one of the hydro plants (Varahi hydro power plant) where the AGC logic implementation and operation was implemented with back-end processing. Even though these processes will run AGC at the plant, they do not monitor AGC performance at the plant control center comprehensively.

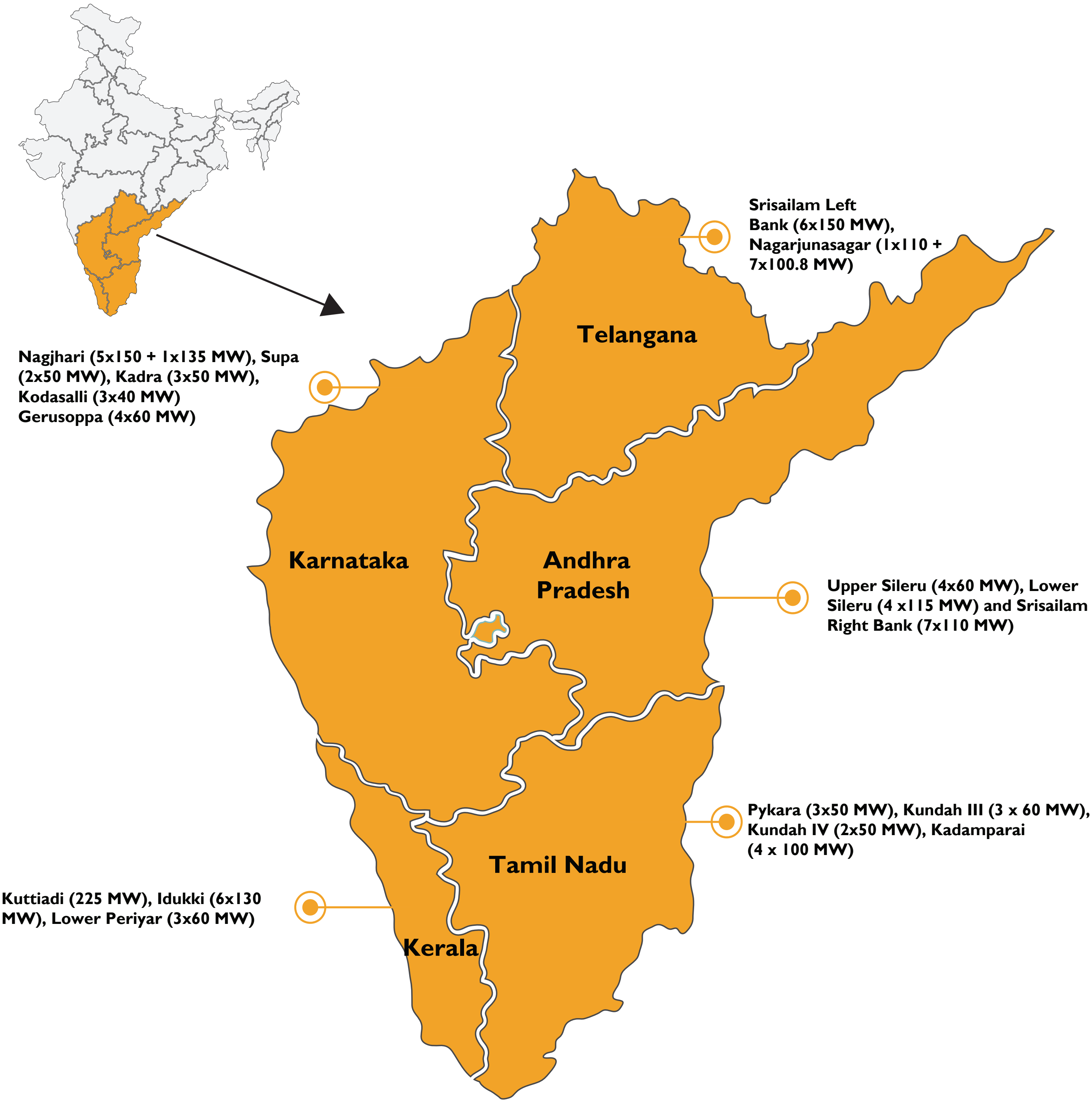
Importantly, SLDCs in India lack AGC modules. Most SLDCs have functioning supervisory control and data acquisition(SCADA) systems, but they do not have active energy management systems (EMS). Clearly, before SLDCs can move ahead to procure and install the necessary software and train their staff, the SLDC management needs to understand how enabling AGC will facilitate power grid operations. Also, OEMs, vendors, and system operators need to learn how to configure and operate AGC in real time. The Karnataka SLDC had an EMS, although that EMS' software was not configured for AGC. The pilot configured the AGC module, with support from the OEM, and provided capacity building for system operators during pilot implementation. Implementing AGC functionality at SLDCs that do not have an EMS with the potential for an AGC module will make AGC implementation more complicated. But it can be done with additional investments in dedicated hardware, software, and integration activities.



SCALING UP AND THE WAY FORWARD

State utilities managing hydro power plants, Independent Power Producers (IPPs), and SLDCs can all benefit from AGC implementation. Overall AGC benefits for the state come from reduced RE curtailment and reduced penalty charges under the deviation settlement mechanism, as well as the ability to add more low-cost renewables into the grid. Grid operators can benefit from maintaining tie-line flows as per schedule, managing frequency near 50 Hz, and releasing primary reserves for scheduling. Enabling AGC for conventional units is what will make it possible to add RE to the grid.

As secondary reserves from hydro units have an extremely fast response, they can support the grid operator deal with variations in RE generation. AGC can be enabled at most hydro units in India by defining the proper compensation for AGC participation under the secondary reserve markets. The potential is big: India's hydro generation stands at around 46,000 MW. Of the total hydro capacity, 40% to 50% is based on reservoir storage, either large storage or balancing storage capacity. These are the potential hydro plants where AGC can be scaled-up. Southern India represents a huge opportunity, since it has so many hydro units where AGC can be implemented, as highlighted in the map below.



> ***Renewable energy deployment in South Asia is essential to enhance energy security and lower the carbon footprint, which is a key mandate of the U.S. government's Asia Enhancing Development and Growth through Energy initiative, or Asia EDGE initiative. This pilot will help realize this goal by enabling large-scale RE deployment.***
>
> **Julia Kennedy**
> Deputy Indo-Pacific Coordinator, USAID/India

**** Details about the pilot, its methodology, results, and recommendations are contained in a report that can be made available upon request.***

Kindly write to mhazra@usaid.gov for a copy of the report.

Disclaimer

August 2021