Analysis of Turbophase® System Deployment on Natural Gas Generating Stations located in Florida Reliability Coordinating Council

- BY ENERGY EXEMPLAR

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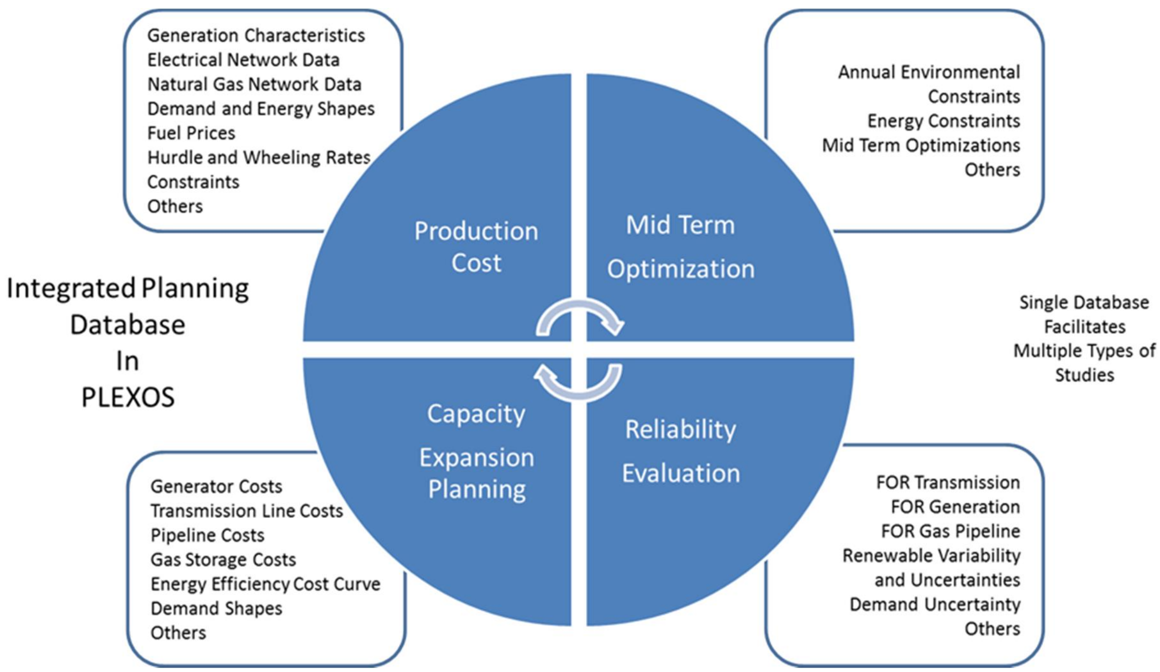
About Energy Exemplar and PLEXOS®

US Integrated Datasets for Power and Natural Gas Sector Challenges

The US is seeing resource change driven by environmental policy and public policy where many areas of the US have minimal load growth projections. Although many organizations, regulators, ISO's, federal departments, labs, consultants and others are engaged in a multitude of studies for the future grid designs in America. In the past few years there has been increased recognition that environmental policy and public policy in combination to the vast shale gas developments will lead to increased reliance of the power sector on natural gas generation. Thus the study process and the complexity of issues is driving the demand for integrated datasets and integrated models i.e. one software package that can handle all the complexities of planning and operations and market analysis in the short, medium and long term. The following diagram displays the integrated dataset for the PLEXOS® Integrated Energy Model.



Integrated datasets simulate the complexities of the energy markets and help to understand risks and rewards in a sector with many moving parts. The integrated database allows for co-optimization of ancillary services and energy market to study renewable integration and curtailments for sizing of transmission systems where traditional reliability tools are unable to size transmission optimally for public policy considerations. With the integrated datasets the system planner can switch on the fly from LOLE and LOLP studies to gas electric expansion to co-optimization of generation and transmission expansion and other planning analysis too. The integrated energy model assists in the assessment of winners and losers in asset evaluations and for public policy cost allocations and inter regional planning assessments. With the integrated datasets and integrated model frameworks the following table highlights some of the relevant modern applications of such tools.

Planning Objectives	PLEXOS Capability
Renewables Integration and System Flexibility Requirement Assessments	• Sub-Hourly Co-Optimization of Ancillary Services with Energy Market and Transmission Power Flows • Stochastic Optimization and Stochastic Renewables Models • PHEV, EE, DR, SG, Energy Storage Models
Least Cost Resource Change within and Across Regions	• Co-Optimization of Generation and Transmission Expansion • Generation Retirements and Environmental Retrofit Models • Reliability Evaluation
Minimizing production costs and consumer costs to electricity and natural gas rate payers	• Co-Optimization of Production cost of Electrical and Natural Gas Sectors • Electrical Network Contingencies and Natural Gas Network Contingencies
Sizing Natural Gas Network Components and Natural Gas Storage	• Co-Optimization of Natural Gas Network Expansion along with Electricity Sector Expansion • Electrical Network Contingencies and Natural Gas Network Contingencies
Environmental Policies	• Co-Optimization of Annual and Mid-Term constraints with short term optimizations • Energy Storage and
Integrated Reliability Evaluation	• Integrated Reliability Evaluation to Ensure LOLE and other Metrics Maintained with Co-Optimization of Electric and Gas Sector Expansion or True Monte Carlo

1. INTRODUCTION

The aim of this study is to valuate the benefits of deploying TurboPHASE modules on the Combined Cycle Gas turbines units in Florida Reliability Coordinating Council. For this purpose, Energy Exemplar's PLEXOS® FRCC dataset has been used to model and simulate a detailed a Nodal transmission model for the year 2015. The total capacity of Natural Gas fuelled generators in PLEXOS® FRCC database is 40297 MW and the total capacity of Combined Cycle units in FRCC currently being modelled in PLEXOS® is 24623 MW and total capacity of the Peakers is 9888 MW. TurboPHASE modules are placed on all the CCGT's and a 15% incremental MW is assumed which is 3693 MW. Gas fuel prices have been forecasted based on the historical Florida citygates fuel price.

In order to capture the flows on the inter-regional lines between FRCC and its neighboring regions, the study footprint has been expanded to include SOCO (Southern Company) balancing authority from SERC region. Simulations are run with and without TurboPHASE modules in hourly intervals optimizing over a day for the whole 2015 year where the generators are dispatched to hourly zonal load forecasts subject to operational constraints and flow constraints.

Below are the metrics that are analyzed to valuate the benefits of deploying TurboPHASE systems on CCGT's:

1) Production Cost Savings ($ millions) for 2015

2) Annual Gas Burn (GBTU) change

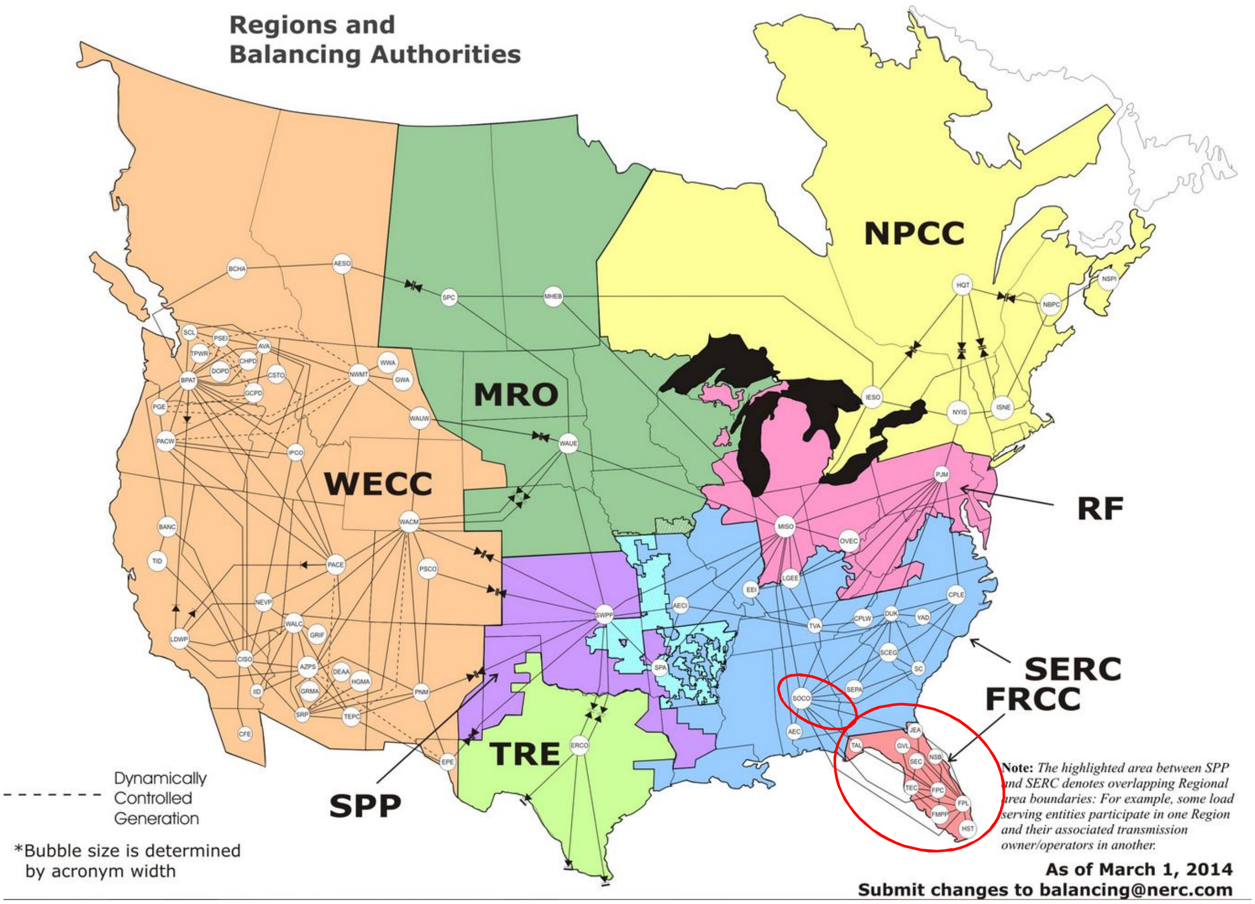
3) Annual Emission savings (tons)

2. FRCC Region Inputs & Modelling Assumptions

I. Footprint

FRCC zones (FMPP, FPC, FPL, GVL, JEA, SEC, TAL, TEC) and a Tier 1 zone SOCO (Southern Company) has been considered to model the interregional flows and simulate a 2015 Production Cost Model in PLEXOS® to calculate the Production Cost Savings & Carbon Emissions reduction with and without TurboPhase Modules on the Combined Cycle units. Below is the footprint considered for this study.

Figure 1: FRCC+Tier 1 footprint for 2015 simulation



II. Generators

The total capacity of Natural Gas fuelled generators in PLEXOS® FRCC database is 40297 MW and the total capacity of Combined Cycle units in FRCC currently being modelled in PLEXOS® is 24623 MW and total capacity of the Peakers is 9888 MW. TurboPHASE modules are placed on all the CCGT's and a 15% incremental MW is assumed which is 3693 MW.

III. Fuel

Florida Citygates daily Natural Gas fuel price forecast for 2015 are used for the simulation. Below is the 2015 hourly price forecast for Florida citygates.

Figure 2: 2015 Hourly fuel price forecast

IV. PLEXOS® Transmission Network model

The ERAG MMWG 2015_2013 series Transmission PSS/E model was imported to PLEXOS® for this study.

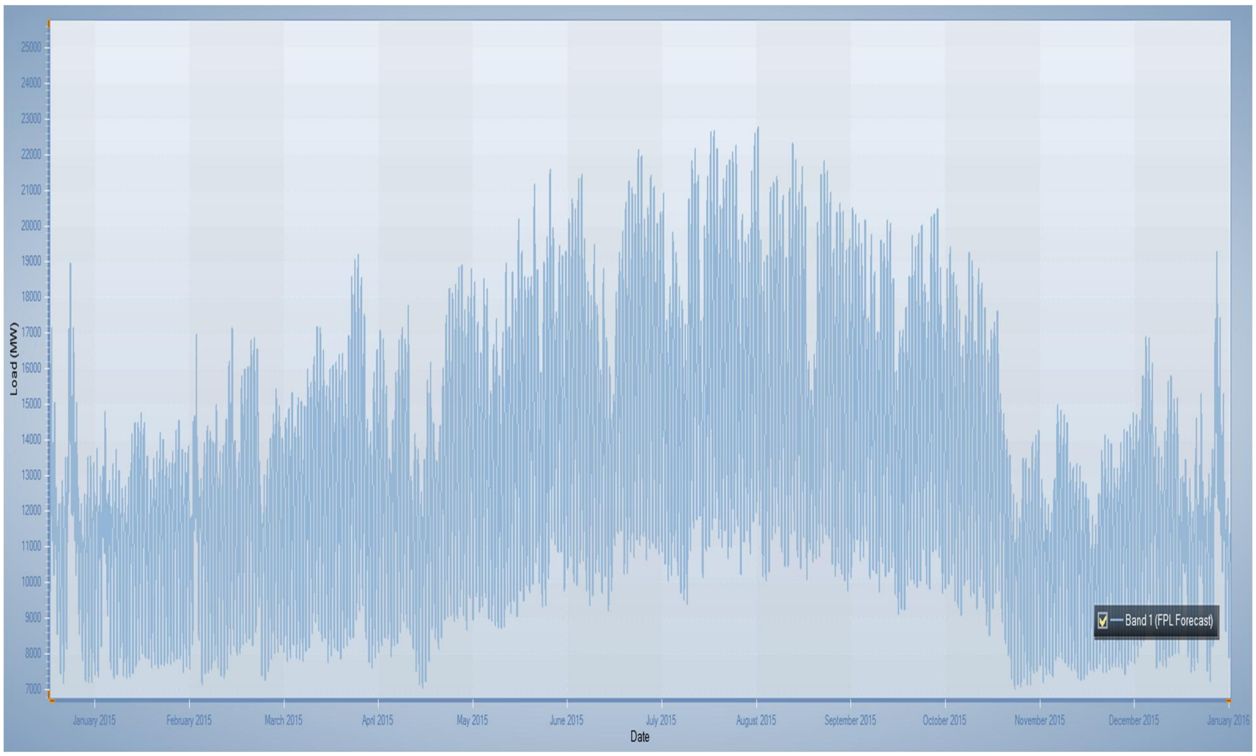
V. Emissions

Historical Emission Production Rates (lbs/MWh) for CO_2, SO_2 and NOx sourced from EPA's Continuous Emissions Monitoring (CEMS) Database are included for the all the thermal generators in the footprint under study.

VI. Demand

An hourly load profile for 2015 is used for all the FRCC zones and the generators are dispatched to this load with and without TurboPHASE modules on the CCGT's. Below the 2015 hourly demand forecast for FPL zone.

Figure 3: 2015 load for FPL at hourly resolution



VII. Ancillary Services

Currently, only CC's are allowed to provide a 10-min spinning reserve and contribute towards a 2.5% load risk on FRCC region.

3. PLEXOS Simulation Settings

Simulation Settings	Production Cost Model	Description
Horizon	1-Year; Interval Length: 1 hour (2015)	The Horizon the Model simulates over.
MT Schedule	Partial Chronology 20 Blocks per month	Annual decomposition of Constraints. Eg: Hydro, Emission, Fuel Supply
ST Schedule	Nodal	These settings control the Production Cost Modelling in the simulator and also the level of Transmission detail
Transmission	FS – OPF	Method for solving optimal power flow.
	PTDF Threshold – 0.04	Minimum absolute value of PTDF as coefficient in transmission flow constraints
	Enforce Transmission Line Limits above 230 kV	Voltage level at which thermal limits are modeled.
	Enforce Interface Line limits	Enforcement of interface limits
	Allow Node UnServed Energy – OFF [Own Implementation of Node USE]	Model Node [Unserved Energy] in the mathematical program.
	USE Threshold – 100 %	Formulates the [Unserved Energy] variables on the top x% nodes (highest load).
	Report Tx Solution – ON	Transmission reporting is enabled.
Production	Linear Relaxation	Unit commitment integerization scheme.
Performance	Relative Gap: 0.15% (if running MIP)	Declare the integer solution optimal when this gap is reached between the current integer solution and best-bound linear relaxation
Additional Settings	Only Spin Reserve ON	
	[Region]Transmission Voltage Threshold Setting:	Local Transmission Settings at Region level
	FRCC Region 230 kV	
	Tier 1 Region (SOCO) 230 kV	

4. 2015 Production Cost Simulation Results

I. Benefits Analysis with & without TurboPHASE

Initial simulations show a $ 96 million savings in generator production cost and a 4.78 million tons in Carbon emissions reduction. The Natural Gas Fuel Offtake increased by 30,189 GBTU. Also, the hours of operation and capacity factor of the Peakers reduced when TurboPHASE modules are installed on the CCGT's i.e. the CCGT's are displacing the peakers.

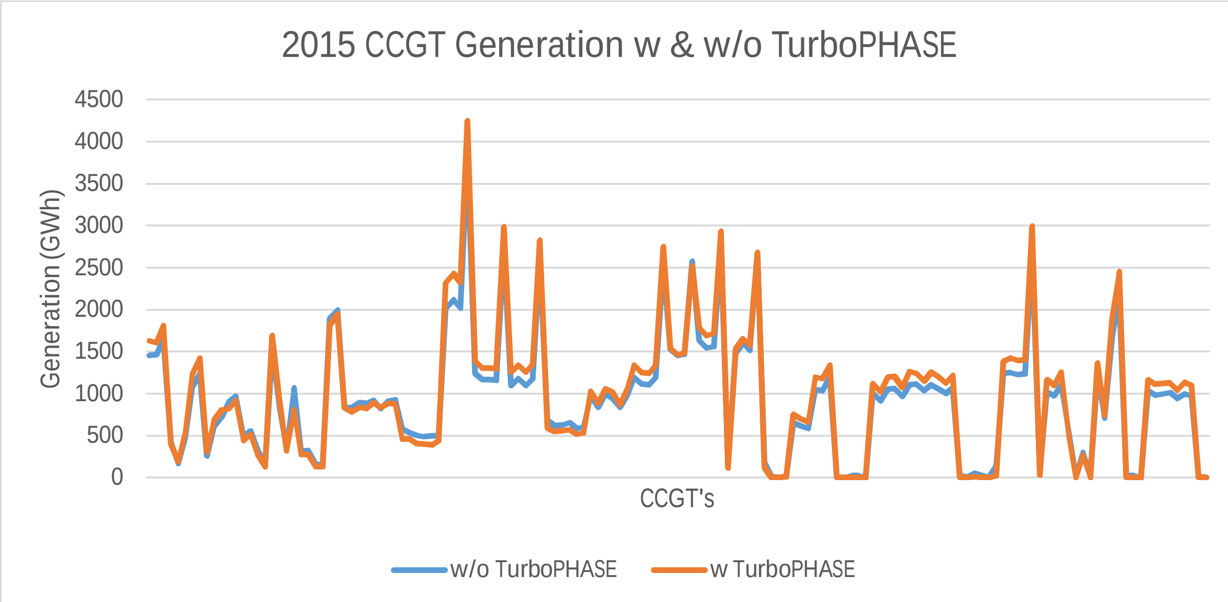
Table 1: High Level Metrics with & without TurboPhase

2015	FRCC Regions w/o TurboPHASE	FRCC Regions w/ TurboPHASE	DELTA
Production Cost Savings	$4,421,651,989	$4,325,586,191	$ 96,065,798
Annual Gas Burn	674433	704622	30,189
Annual Emissions			
CO2 (ton)	70,244,890	65,459,235	4,785,655
SO2 (ton)	52,387	38,148	14,239
NOx (ton)	40,334	32,510	7,824

II. 2015 CCGT Generation (GWh) with & without TurboPHASE

TurboPHASE modules are installed on the CCGT's in FRCC and the a 15% incremental MW increase in Max Capacity has been assumed. The total capacity of CCGT's in FRCC is 24623 MW which allows 3693 MW of TurboPHASE modules to be installed. The total generation with and without TurboPHASE for all the CCGT's in 2015 is 137,738 GWh and 146,545 GWh respectively. Below the figure showing the CCGT generation with & without TurboPHASE modules:

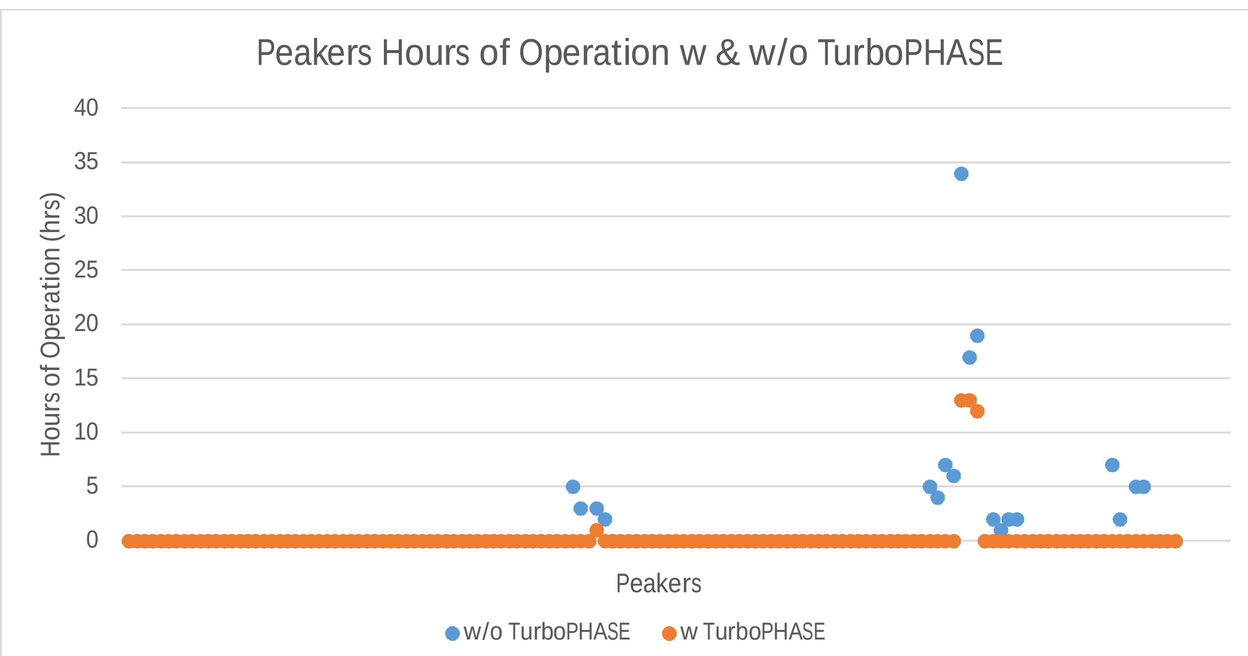
Figure 4: 2015 CCGT Generation w & w/o TurboPHASE



III. Peakers Hours of Operation w & w/o TurboPHASE

The peakers have been displaced by the use of TurboPHASE modules on CCGT's as the total hours of operation reduced to 39 hrs from 131 hours in 2015. Below the chart comparing the hours of operation for Peakers in 2015 w & w/o TurboPHASE:

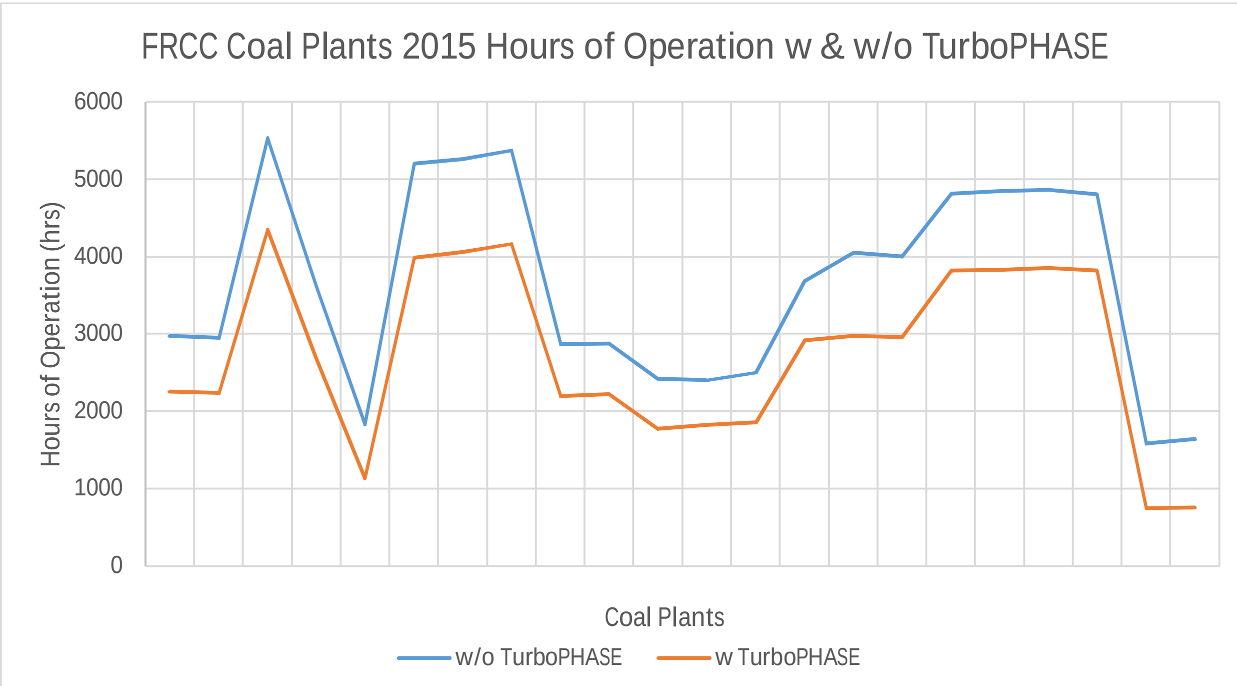
Figure 5: Peakers hours of operation w & w/o TurboPHASE



IV. FRCC Coal plants Hours of Operation w & w/o TurboPHASE

The coal plants have been displaced by the use of TurboPHASE modules on CCGT's as the total hours of operation reduced to 60411 hrs from 80097 hrs in 2015 i.e. approx. 25% decrease in the hours of operation of coal units with TurboPHASE modules on CCGT's . Below the chart comparing the hours of operation for coal plants in 2015 w & w/o TurboPHASE:

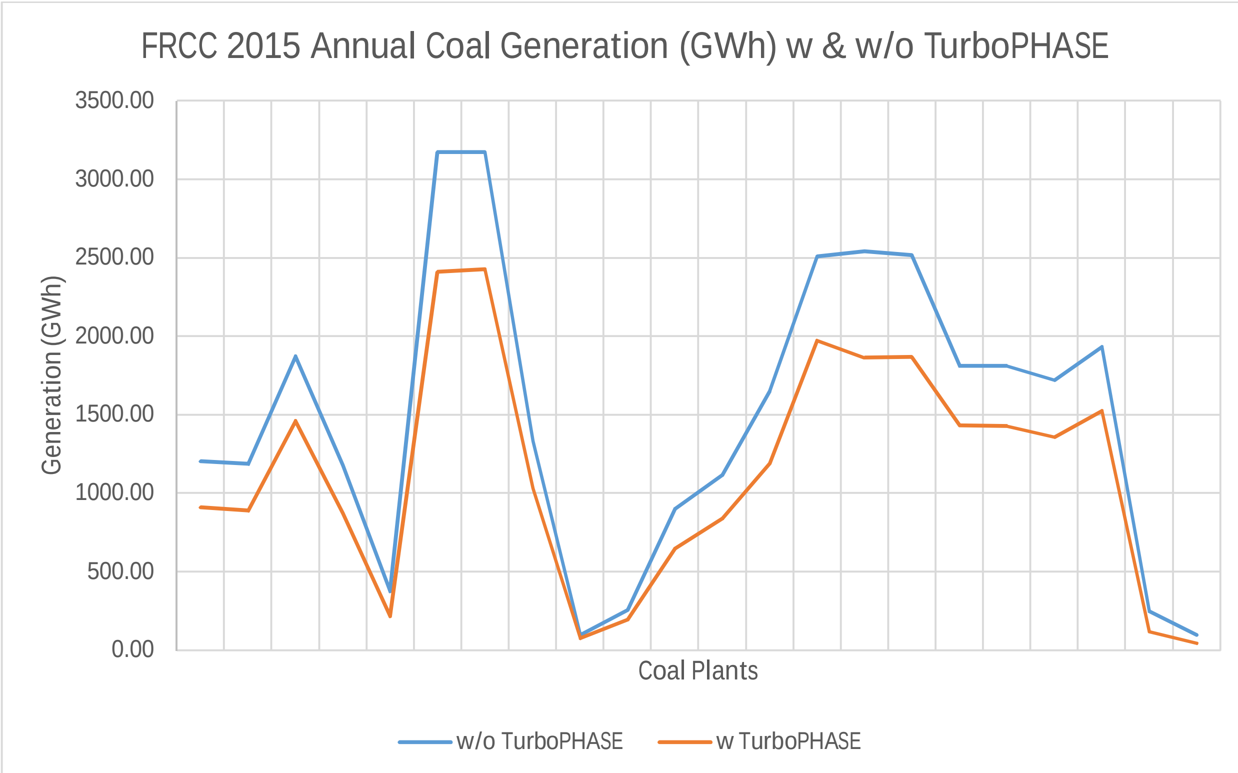
Figure 6: FRCC Coal plants hours of operation w & w/o TurboPHASE



V. 2015 FRCC Annual Coal Generation (GWh) w & w/o TurboPHASE

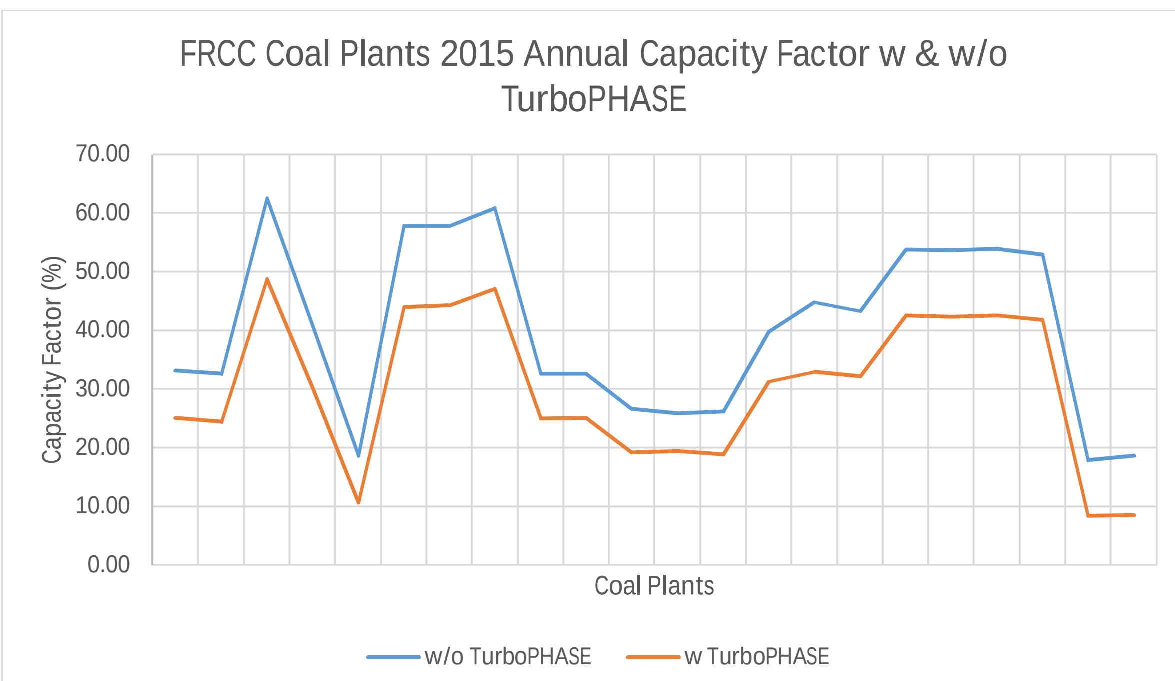
The annual coal generation in FRCC decreased by 24 % with the addition of TurboPHASE modules on CCGT. Below is the chart comparing the annual generation of FRCC coal plants with and without TurboPHASE modules.

Figure 7: FRCC 2015 Annual Coal Generation (GWh) w & w/o TurboPHASE



VI. FRCC Coal units 2015 Annual Capacity Factor w & w/o TurboPHASE

Figure 8: FRCC Coal 2015 Annual Capacity Factor (%) w & w/o TurboPHASE



VII. FRCC Coal units 2015 CO2 Production (Tons) w & w/o TurboPHASE

The annual coal CO2 production in FRCC decreased from 26.7 Million Tons to 20.2 Million Tons i.e. a 24 % decrease with the addition of TurboPHASE modules on CCGT. Below is the chart comparing the annual CO2 production (tons) of FRCC coal plants with and without TurboPHASE modules.

Figure 9: FRCC Coal 2015 CO2 Production (Tons) w & w/o TurboPHASE