Technique for Addressing Overload Contingency Due To Proposed RE-Grid Integration in Weak National Grid System of Pakistan

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Abstract – *Global warming and technological development has pushed Renewable Energy (R.E) to a higher penetration level in central grid systems. Higher levels of variable and intermittent R.E penetration in centralized grid system have posed serious threats to stability and security of grid system. Pakistan has also proposed integration of 9282 MW of wind and solar with its weak National Grid system by 2019/2020. Pakistan National grid needs to revamp its transmission system in south to accommodate such penetration of R.E in its National Grid system. Proper planning of transmission upgrade requires system studies such as contingencies and short circuit studies. The planning of transmission upgrades require setting of proper planning criteria based on Grid code and Economic assessment of developing transmission assets. The paper discusses various simple techniques to address overload contingencies due to RE Grid integration.*

KeyWords: **Renewable Energy (R.E), overload contingencies, RE-Grid integration, R.E curtailment, Intermittency, Energy not supplied (ENS), Intertripping Scheme.**

1. INTRODUCTION:

The recent thaw/development in high level penetration of Renewable energy with conventional grid system can be attributed to following reason.

1. Global Warming.
2. Carbon Taxes
3. Depletion of fossil fuels.
4. High cost of furnace oil & HSD.
5. Low tariff of RE plants.
6. Subsidies on RE plants machinery.

Wind and solar generation both experience intermittency; a combination of non controllable variability and partial unpredictability. This intermittency depends on natural resources that are location dependent. Following are direct challenges for grid system operators in integrating wind and solar generation. i.e. [1]

1. Non Controllable variability.
2. Partial unpredictability.
3. Location dependence.

Wind and sunlight are both temporarily and spatially outside human control, thus connecting wind and PV generation resources into electricity grid involves management and operations control of other controllable conventional power plant operations that may affect many other parts of the grid including conventional generation itself.

These operations and activities occur along different time scales from seconds to years and include:

1. Load (demand) management techniques.
2. New dispatch strategies for controllable and rampable generation.
3. Expansion of transmission capacity through investments in transmission assets.
4. Provision of ancillary services for frequency and voltage control.
5. Linking of grid load dispatch centres with weather and resource forecasting.
6. Utilization of energy storage technology.

wind power sector experienced huge growth in recent years as an example in EU by year 2015 one third of the newly installed generating capacity were wind turbine generators (WTGs) with cumulative wind Energy Capacity reaching 141.6GW [2] . It is forecasted that by year 2030 total installed wind power capacity in EU will be in order of 400 GW. In terms of energy market share it means that in 2030 wind energy would cover from 20.8% to 28.2% of European electricity demand [3].

India has recently projected to integrate 175GW of wind & solar energy with their national grid. Due to competitive bidding the Indian Electricity market has recently reached a lowest tariff of Rs.2.5/kwh for solar.

Indian Grid largely relies on coal fired thermal power plants which serve as base load as well as peak load plants.These plants can be retired in phases by providing the owners with incentives for switching to high efficiency thermal power plants or using environment friendly technologies such as regeneration of the flue gases.

[4] Has highlighted following challenges for integrating of 175GW of wind and solar power in Indian national grid.

The Indian power sector is set to face several challenges in near future as Indian govt has proposed addition of 175 GW of RE Capacity to be integrated with Indian National Grid by the year 2022. This will necessitate important and radical changes in the way conventional generation and grid operate. The following challenges are faced by National Grid,[4].

1. Low plant load factor of the thermal plants.

2. Requirement of flexible operation of the thermal power plants.

3. Ensuring adequate balancing capacity.

4. Meeting steep ramping requirement.

5. Forecasting of RES generation with acceptable degree of accuracy.

6. Ancillary services operation.

7. Construction of new transmission assets.

Implementation of new environmental policies including retirement of thermal units and phasing thereof is another issue which also pose serious challenges to the entire power sector.

The challenge also entails integration of additional RE Generation capacity of around 118GW into the National grid over the next 5 years. This will require strengthening of transmission and subtransmission networks which also require huge capital cost. Suitable interstate and intrastate transmission corridors need to be laid for evacuation of power from RE rich states to the load centers. The typical completion period of lying down a T/L (Transmission Line) varies from 3 to 4 years but the completion period for installation of RE based generation plant is typically around 12 to 18 months. This may lead to a situation of bottlenecking of power or RE Plant being forced to back down or paid capacity charges by the grid operator.

2. PAKISTAN WEAK GRID SYSTEM AND PROPOSED R.E INTEGRATION:

Pakistan has also given incentives to private foreign investors for establishing wind and solar plants in the south of Pakistan by providing them with subsidies, wavier of custom duties and tariff attractiveness such as cost plus tariff or Levelized cost of Electricity.

The national grid of Pakistan run by state owned National Transmission and Despatch Company (NTDC) is projecting addition of 9282MW of wind and solar power by year 2019/2020. Such large amount of RE integration with weak National Grid of Pakistan can pose serious problems. Most of the Transmission network i.e. 500/220KV Lines and Transformers are overloaded in summers. 80% to 90% of 500/220KV and 220/132KV Power Transformers are overloaded in Pakistan in summers. This offers huge bottlenecks for evacuation of such large capacities of additional generation of R.E plants,[5]. The National Grid capacity of Pakistan is 2000MVA and its vulnerability is evident from two back to back blackouts of January 2015.

The following problems are faced by proposed grid integration of 9282MW of R.E addition with weak national grid system.

1. Transmission congestion.

2. Weak transmission network.

3. Post fault contingencies.

4. Voltage and transient stability.

3. GENERATION CURTAILMENT:

Energy curtailments can be defined as “when the dispatch order from the grid system operator to the renewable energy plant is to reduce or stop the generation, even though the RE resource is available.”

In India the RE curtailment has been caused by one of the following two reasons:

1. Technical curtailments.

2. Economic curtailments.

These are further discussed below:

2.1. Technical Curtailments: This is involuntary curtailment due to technical problems in transmission system due to which it can’t dispatch full RE capacity. There can be multiple reasons for this curtailment some of which are:

a. Transmission unavailability.

b. System operating requirements leading to curtailments.

c. Congestion management processes.

d. Power plants performance constraints.

e. Load amount and profile.

2. Economic Curtailments: This curtailment is due to availability of cheaper power compared to RE plants due to higher tariffs of REs. So the utilities sometimes refuse to purchase the power from RE plants. Such type of curtailment can be avoided by feed in tariffs in which utilities are bound to take the RE capacity.[6]

4. ECONOMIC AND TECHNICAL PLANNING CRITERIA

To plan a power system in consistent manner a clear cut and pre-defined planning criteria which can be applied to system as a whole, considering planned new generation. This planning criterion consists of:

1. Technical constraints- for system security
2. Economic constraints- for proper utilization of resources and avoiding over-investment.

The technical criteria has always upper hand due to system security considerations. After meeting the technical criteria it is then necessary to perform an economic assessment for those transformers and lines which are loaded above 100% after fault but are under the technical planning criteria. It is to be considered that technical planning criteria has always upper hand due to system security needs however the outcome of the economic criteria can be analyzed together with reasonable engineering judgment to avoid overspending for the purpose of achieving results having marginal effect. If however the cost of ENS (Energy not supplied) due to generation curtailment and outages due to fault is greater than cost of building new assets then grid reinforcements are suggested in these cases. For cases in which cost of grid reinforcement is greater than cost of ENS then instead of grid reinforcement appropriate inter-trip or automatic run back scheme is suggested.

For calculating the cost of ENS, data related to the service availability of T/Lines and transformers are collected from NEPRA (National Electric Power Regulatory Authority) performance standards. In the absence of any statistical data about the transmission system of NTDC Pakistan i.e. system performance report it is proposed to use the following data collected from NEPRA performance standards.

a. Transformer availability: 98% (outage probability: 2%).
b. 220/500kv T/Line availability: 99.8% per 100km.
c. 132KV T/Line availability: 99.5% fix independent of line length.[7]

Any overloading contingency will be assessed using the economic criteria. Overloading contingencies in existing transmission network can be resolved in one of two ways. Either the generation behind the constraint can be curtailed or the system can be reinforced by constructing new lines and grids. In order to analyze each option it is normal practice to have a simple and clear set of planning criteria. This ensures that each option is assessed equally to determine the most economical solution, while not compromising on system stability and security levels.

5. OVERLOAD CONTINGENCIES

After fault has happened external to RE plants some lines in vicinity can get overloaded due to tripping of faulted line. This subtopic discusses various techniques used in power industry to mitigate the post fault system overloads. These methods are used in European grid and particularly in U.K. the National grid operator in Pakistan and RE Plant owners can review these methods and perform their cost benefit analysis as per grid code of Pakistan to choose the best method in order to maximize the grid usage without spending lot of money on construction of new T/Lines or other equipment. The following methods/actions are discussed below:

6. TECHNIQUES FOR MITIGATING SYSTEM OVERLOADS:

6.1. Transmission Line Uprating Or Construction Of New Lines: When after performing contingency analysis for fault simulation, the results shows that overloads are present post fault , then as a solution either overloaded T/L(Transmission Line) can be uprated by Re-stringing of conductor or new T/Line can be constructed. Both options are expensive as particularly considering that the overloads may only be possible for a few hours per year due to system configuration, loading or high output of R.E Generation. Therefore cost benefit analysis should be performed to calculate cost of energy not supplied in case of overloaded contingency and the cost of new T/Line to see which cost is greater.

6.2. Pre-Emptive Manual Pre-Fault Action: In this method contingency analysis is performed based on worst case scenario during planning timescales or based on the real time state of the power system during operational timescales. Then in case of any overloaded contingency the output of specific generator or group of generator is reduced to mitigate the overloading after fault. This is very simple manual method which doesn't require any new equipment however the power system is not operated in optimal way where low cost generation is curtailed and expensive generation is the only option to replace it. This is particularly the case if there is only renewable generation with "free fuel" behind the overload.

6.3. Manual Post-Fault Action: In this method the overloaded T/line is operated in overloaded manner taking advantage of long thermal time constant of T/Line. But the grid operator should be aware of protection setting of T/Line so that it is not exceeded. The system operator should be aware of such overloaded contingencies and he should take quick actions. The benefit of this method is that the power system is operated in economical way without energy curtailment and action is to be taken only in case of known contingency. However the operator should have overcurrent protection setting data of T/lines to avoid any unnecessary tripping of line and possible cascade tripping due to this.

6.4. Intertripping: This is a special protection scheme which is fully automatic. In this scheme the generators in a power plant are tripped owing to an overload contingency post fault caused by the Power plant in whose vicinity the overloading is happening. This scheme can be implemented in new power plants where the cost of a line upgrade or construction of a new line could make the construction of the power station un-economic. The power plant may therefore accept an agreement requiring intertripping rather than pay the cost of a construction of T/Line.

This scheme operates in following fashion; once the protection scheme detects a fault on a line which is causing an overload contingency then special protection scheme of intertripping comes into action at once. The scheme sends signal to the specific generator to be intertripped. This scheme requires good communication links between specific contingency location and the generator. The signal is directly send to the circuit breaker of the generator to be tripped. This scheme is also helpful in avoiding stability problem caused by the specific contingency as the scheme acts very fast and automatic.

There is one problem in this scheme as sudden tripping of generator is not good for the life of a generator due to sudden load rejection therefore to reduce these tripping a tripping order is maintained so that one generator doesn't trip all the time. This scheme should only be armed if contingency analysis indicates overloads after fault otherwise it is not operational. It is also taken care of that loss of a single generator or a power plant will not cause large frequency deviation due to limit on allowed single loss of generation or overloading on tie lines.

6.5. Fast Runback Scheme: This scheme is used where main constraint is thermal overload instead of stability and it is used in modern convertor controlled RE Plants which can relieve or are direct cause of the overload. The scheme takes advantage of fast convertor control of RE Plants to quickly ramp down the output of RE plant to zero. The signal is received by the central controller of the RE plant which then quickly ramps down the output power. This ramping action is completed in 10 sec time otherwise the automatic trip of RE plant breaker is initiated for backup purpose. This scheme has been tested and is in operation at multiple wind farms in U.K in order to avoid costly system upgrades such as building new T/Lines. It is applied to the plant which is certain to relieve the overloading and also long distances are avoided for communication links. This scheme has advantage of fast ramping of power compared to sudden load rejection of intertriping scheme. Also the power plant can still contribute its MVARs to manage post contingency voltages in the area. The RE plant should be compensated for operation of this scheme due to inconvenience of not being able to produce full available output.

7. CONCLUSIONS

Overloading contingencies in existing transmission network can be resolved in one of two ways. Either the generation behind the constraint can be curtailed or the system can be reinforced by constructing new lines and grids. In order to analyze each option it is normal practice to have a simple and clear set of planning criteria. This ensures that each option is assessed equally to determine the most economical solution, while not compromising on system stability and security levels.

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