A METHODOLOGY FOR THE REDESIGN OF FREQUENCY CONTROL IN MODERN POWER SYSTEMS IN PRESENCE OF RENEWABLE ENERGY RESOURCES

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ABSTRACT

The Ministry of Energy in Iran published a target to install 5GW Renewable energy resources to be connected to grids by 2015. However, as outputs from wind power generation fluctuate time to time and wind power resources are available only in specific areas, deterioration of the quality of utility's power supply has become an important issue

to be solved .this paper proposes a new algorithm to participate wind power generation in frequency control, with cooperation of DSO and TSO.

For above purpose, this paper also introduce a new concept, Bulk Virtual Power Plant.

INTRODUCTION

The power-frequency droop method is widely used in interconnected power systems. The droop concept enables sharing of the total load between the units proportionally. Also, since only the output parameters of the units are used, no communication between the units is necessary, but there are several issues that make this method inappropriate for future smart grid. In this method the units share real and reactive power according to pre-specified droop characteristics and there is always need for additional restoration control action[1-4].

On the other hand wind energy is not constant and windmill output is proportional to the cube of wind speed, which causes the generated power of wind turbine generator (WTG) to fluctuate. The generated output power fluctuation increases relative to the increase in installation capacity of the WTGs. There is a same problem of power fluctuation for other kinds of Renewable Energy Resources that make the Load Frequency Control (LFC) more complicated. There are ongoing researches to use battery storage system to limit the effect of variability of these kinds of generation on power system frequency[3-6].

For handling these two issues this paper presents a supervisory control strategy for load/frequency control problems with a new method for cooperation between TSO and DSO in a smart power system in presence of renewable energy resources and large scale energy storage. The aim here is finding supervising strategies able to reconfigure, whenever necessary in response to unexpected load or Renewable resource output generation changes, the nominal set-points on frequency and generated power to the generators of each area so that viable evolutions would arise for the overall power system and a new sustainable equilibrium is reached[7]. The focus is on the master/slaves scenario where the LFC master represents a supervisor in charge of taking decisions (TSO). At the remote sides, the LFC slave units are those parts of the strategy which require only local information (DSO). Some low capacity DERs may work under the control of DSO while high penetrated ones (including the related energy storage) may be supervised by the TSO. The master/slave scenario can be implemented in a power system with full observability and controllability which defines the future Smart grid. It must be noted that with this method there is no need for any further frequency restoration action like conventional frequency control system. Higher power frequency stability is another result of proposed method.

CURRENT FREQUENCY CONTROL METHOD IN IRAN GRID

Conventionally, Hydro power plants where responsible for frequency control in Iran grid. Initially there was just one unit in DEZ power plant (65 MW with D=0), which was regulating the frequency. Main issue of this method was shortcoming of power in comparison with bulk power plants and industrial loads for frequency control purpose. Besides, since only one unit is in charge for frequency control there is a very poor reliability[1].

For ensuring power stability and improving quality of frequency control, in 2008 , all generation unit were obligated to activate their governor's primary control loop and corporate in frequency control.

Acceptable frequency range is 50± 0.2 in Iranian grid code, thus with assumption of 40000MW for the peak load, even with a outage of 400MW generation unit, frequency must stay in 50± 0.2 limit. It is assumed that $R = 4\%$ or $R = 2\ Hz / pu.MW$ for all units and also load Damping factor D, is $D = 0.033\ pu.MW / Hz$.

With X as sum of generation of units participating in frequency control primary loop $R = 2\ Hz / pu.MW$ and Y , the ones which are not participating $R = \infty$, it can be written:

$$\frac{1}{R_{eq}} = \frac{\frac{X}{40000}}{2} + \frac{\frac{Y}{40000}}{\infty} = \frac{X}{60000}\ pu.MW / Hz \qquad (1)$$

Change in power is:

$$\Delta P_D = \frac{400}{40000} = 0.01\ pu.MW \qquad (2)$$

On the other hand:

$$\Delta f^{o} = -\frac{\Delta P_D}{D + \frac{1}{R}} \qquad (3)$$

As a result, $X = 2600$, this means that, for maintaining the frequency in prespecified limit in a contingency of outage of 400MW unit, at least 2600 MW must be participating in frequency control primary loop. It must be noted that usually maximum 5-10% of a generation unit may participate in frequency regulation service.
Figure 1 shows change of frequency in Iran grid during an outage of a 1000 MW generation Unit.

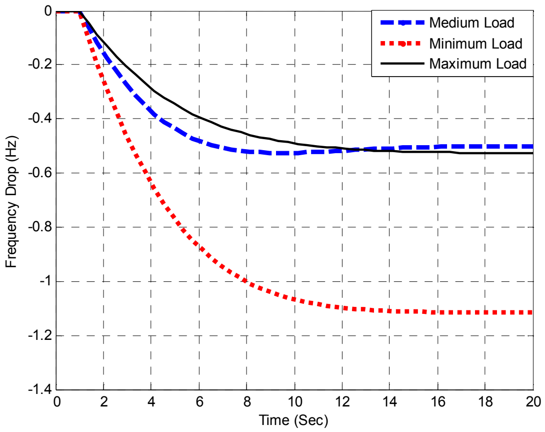

Figure (1): change of frequency trend in presence an outage of a 1000 MW generation Unit

As it shown in Fig.1, maximum frequency drop occurred in minimum load, which is about 1.1 Hz and caused the low frequency load shedding relays to operate.
As another example for current grid operation situation, Figure 2 shows the reaction of two gas generation units to the grid's frequency drop from 50 to 49.9 Hertz.

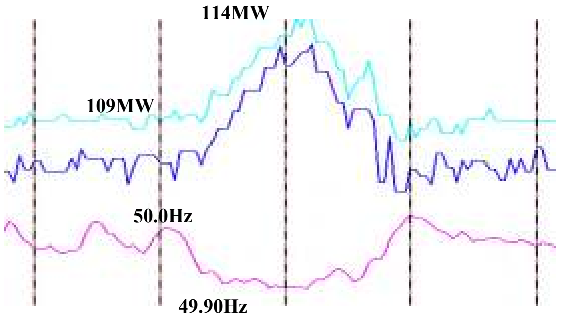

Figure (2): reaction of two gas generation Units to frequency drop

RENEWABLE ENERGY RESOURCES POTENTIALS AND FUTURE PROPOSED PILOT PROGRAMS

In recent years, Renewable Energy Sources (RES) attract huge attention in field of Electrical generation, mostly because of unstable and up growing costs of fossil fuel and Environmental issues of traditional fossil fuel power plants. Between all different RES, mostly accepted one is wind power and This paper focuses on this kind too.
The wind power development in Iran is still in its early stage. The scale of the wind power generation of Iran is still comparatively small. On one hand, in the investment of wind power generation, the expenditure for connecting with the power network and basic establishment still accounts for a large proportion. On the other hand, the supplies of wind power units are mainly dependent on import. Because of all the matters above, the construction of wind power generation charges a lot. The level of the cost in Iran is five times as much as that in Europe. The cost is 1200 US dollars per kW. So it will charge you 100~15.1 million US dollars for a wind power plant with the capacity of 100MW, while the fossil and water power plant costs cost much less as the same scale.
In Iran, the wind energy is difficult to compete with the conventional energy resources currently because of the difficulties caused by the techniques and the policies of the country. But it is predictable that this trend won't last long. Iran has rich resources in wind and solar energy because of its vast territory and the long coastline. By measuring the wind energy at the altitude of 8m, the theoretical wind energy reserves are 60GW. In addition, the wind energy on the sea is three times more than that on the land. Totally the exploitable wind energy reserve in Iran is 240GW.
There are several pilot projects with different dimension implementing in Iran grid regarding wind and solar power plants.
One of the main wind energy resources is located around Semnan. The interesting point for this region is that there is also a very high potential for solar energy too. Because of mentioned reasons, there is a plan for constructing bulk wind and solar power plant in the region. The wind power plant estimated to be around 500MW with DFIG turbines, and solar power plant is going to be of parabolic trough tracking type.

PROBLEM STATEMENT

As outputs from wind power generation fluctuate time to time and wind power resources are available only in specific areas, deterioration of the quality of utility's power supply has become an important issue to be solved [8].
Typical issues discussed recently are:

1. Tripping due to transmission system faults
2. Voltage fluctuation under varying wind conditions
3. Inability to control active power production
4. Lack of reactive power control and voltage regulation

This paper focuses on inability of wind power plant to dynamically participate in active power and frequency control.

Many variable speed wind turbine generator systems use a doubly fed induction generator (DFIG), where the rotor is connected to the grid through a back-to-back ac/dc/ac converter, which results in the decoupling of the rotor speed from the grid frequency. With the increase in the number of these asynchronous generators the overall system inertia is decreased, which leads to higher frequency fluctuations.

The latest wind turbines have robust designs for reliable performance and increased energy capture, as well as sophisticated control systems that support electric system requirements and enable cost-effective power system operation. But still corporation of these generations in frequency control needs sophisticated algorithms and controls in power grid.

Beside internal control (pitch control, output control…) there is also a need for change the supervisory control.

PROPOSED ALGORITHEM FOR FREQUENCY CONTROL IN PRESENCE OF RENEWABLE ENERGY RESOURCES

As mentioned before, future projects; large wind farms and solar power plants may cause serious frequency deviations and frequency control problems.

One of the major problems in controlling a large size wind farm from a central Dispatching is that rated power of each turbine is normally around 1-5 MW, this turbines are not placed close together (they may be connected to different lines and transformers), and also, they may even be connected to several distribution systems, which is usually the case for large wind power plants with rated power of 500 MW and above.

As discussed before, since droop control is not able to satisfy specified frequency margins in situation of high penetration of renewable energy resources, a novel algorithm is proposed in this paper to cope with mentioned problem.

Figure (3) shows the flowchart of proposed algorithm.

First of all, it must be decided that how much of the difference in power (regarding to a contingency or load increase) can be compensated through droop control of conventional power plants, if:

The difference power must be supplied from wind generation. To have a better controllability on a wind farm, it can be operated in hybrid with a solar power plant and also a large scale storage system (either Battery or flywheel). The combination of these three parts inherently reduces power fluctuation. With above mentioned information on such a power generation, this paper introduces the concept of Bulk Virtual Power Plant (BVPP). It is actually a development for Virtual Power Plant (VPP). VPP usually attributed to set of power generation with limited capacity connected to distribution system. But in the case of BVPP the assumption is a system of variant generation types (wind, solar, battery…)with large capacity connected to the grid through several points, either in transmission system or distribution system.

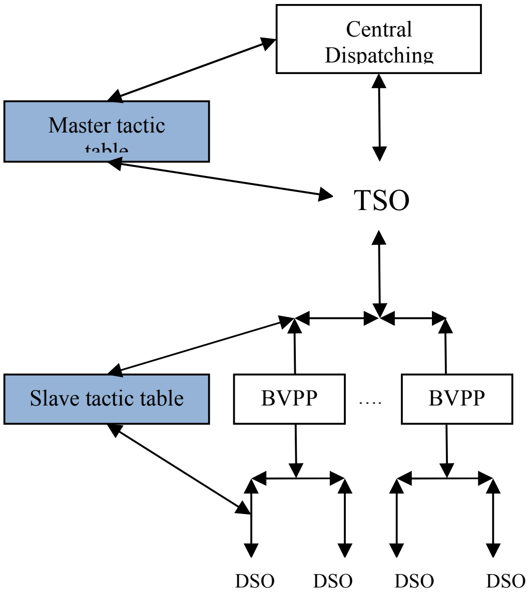

Figure (3): flowchart of proposed algorithm

$$P - P_{predicted} \rangle P_{specified} \quad (4)$$

As mentioned before it is not possible to control BVPP with traditional Droop control. So this paper proposes a new algorithm for P-Q injection method to solve this problem.

The flow chart of proposed algorithm is shown in Figure 3.

Usually, Control devices in more than two power plants or substations are connected by communication equipments to form a regional stability control or large-scale power systems. Proposed control method is composed of a master station, several slave stations and executive stations.

Frequency (stability) control strategy table is a logic control chart with detailed and predicted calculation and analysis. Both offline and online strategy tables can be provided.It must be noted that implementing this method needs a real-time communication infrastructure which is of course an important part of future smart grid.

With use of bilateral real-time communication structure, P-Q injection can be implemented in power system. As mentioned before stability strategy based on N-1 or even N-2 contingency are existed in master and slaves tactic tables. Thus, after a contingency this leads to a situation that needs a sudden change in power of BVPP, decision will be made in master tactic table and sent to the BVPP. The BVPP itself, based on the slave tactic table, will decide how to supply requested power. That means, based on real-time data, the situation of wind power plants, solar ones and batteries is clear, so correct decision can be made. Based on the decision of BVPP, DSO may regulate related generation units and batteries.

CONCLUSION

The problem stated in this paper is frequency control problem regarding future large pilot wind farms. As discussed, it is not possible to use droop control in this situation. This paper introduces a new concept for better operation of wind farms, BVPP.

With real-time monitoring and control basis, it is possible to implement a novel algorithm for frequency control. This algorithm works with cooperation of central control station, TSO, BVPP and DSO , based on P-Q injection method.

Control structure is master-slave type to improve decrease time and it is based on on-line and off-line tactic tables.

Finally it must be noted that such controls can't be run, unless in presence of real-time bilateral communication infrastructure provided by smart grid

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