Technical Issues and Solutions around Renewable Energy Integration

September 2017

Shintaro Komami

Preface

High Renewable Energy (RE) Integration has become true. More RE integration hereafter is not avoidable. Because, all developing countries around the world must consume as much energy as developed countries. Energy demand-supply balance will become tight. Especially in Japan, who imports very large part of energy sources, the problem is serious. However in Japan, progress of RE integration is slower than US, Europe, and even China. Since RE is not useful for self-consumption, most REs are integrated into power system and surplus energy is used by the other customers. Therefore, high RE penetration means high RE integration. In addition, Japan is an islanded country and having not so large power system, which is influenced by RE integration seriously. In spite of the circumstance, research around RE integration in Japan is behind the other countries. Under these circumstances, the author has studied around RE integration almost by his own.

These steps are needed to grasp the whole view of RE impact onto power system.

1) Exhaust unfavorable phenomena possible in power system.

2) List up those phenomena that go worse by RE integration.

3) Discover unknown phenomena possible by RE integration.

Since field of today's scientist has become narrow, 1) is difficult. Since penetration of simulation tool has made analysis ability poor, 2) is also difficult. Since gifted person has not chosen power engineering, 3) is also difficult. Thus the author, an already retired engineer, has personally challenged on those difficulty. This book is the fruit.

To grasp whole view is quite important especially consumers and political planners by these reasons.

a) Never be misled. Unfavorable information foe benders may be concealed.

b) Competition is noticed. Benders may conceal powerful rivals.

c) Multiple objects are noticed. Ugly true object may concealed behind beautiful false object.

d) Inconsistence is noticed. Harmful side effects by presented measure may be concealed.

It is fatally important for study to use models of existing power systems, and never use fictitious models. Also it is essential to model so as to the phenomenon in question is adequately reproduced. Past researches established some "standard models" by some "authorities", but adequacy of those models was scarcely demonstrated. In other words, past researches are at least quantitatively disappointing.

Countermeasures are needed for power system impact. There are these two extremes in countermeasures.

1] Aggressive solutions are progressive and not becoming old-fashioned, but is not proven.

2] Conservative solutions is not progressive and may become old-fashioned, but already proven.

Most scientists prefer aggressive solutions, because they have originality and favorable to gain research expense. However, system engineering teaches that conservative solutions must be presented by these reasons.

a] Standard for evaluating aggressive solutions.

b] Insurance when all aggressive solutions failure.

Occupational scientists do not study conservative solutions. Aggressive solutions such as smart grid and artificial intelligence are not verified but propagated by those people. Aggressive solutions have these three faults.

A) Risk that unconscious feedback loop goes to unstable.

B) Application software as brain is not established yet.

C) Who should responsible when disaster occurred in not clear.

The author pointed out these three issues in 2010. In 2016, an automobile accident to death occurred and those issues have become to be generally known.

Since occupational scientists do not study faults of aggressive solutions and application of conservative solutions, those works must be done by practicing engineers such as the author. Presenting various conservative solutions is a uniqueness of the book.

Thus, Table 0.1 that exhausts power system impacts by RE is established. There are many items. **Bald** items are not well known in society. ***Bald Italic*** items are qualitatively known but quantitative solution methods are not established. Underlined items are regarded as hopeful, but are not economical. There are many Bald, Italic Bald, and Underlined items. Society does not understand whole view of power system impacts by RE. The table is classified by geographical size as preventing miss method.

Table 0.1 Whole view of REs' Impacts on Power System

Geographic size	Power system impacts	Causes (Mitigation factors)	Countermeasures (Regarded as most promising)	Social understanding
Large 1000km	RE output identification	Geographic diversity	**Transfer hypothesis***1	Insufficient
	Demand-supply imbalance ***Frequency deviation*** ***Shortage of regulation*** ***Shortage of reserve***	RE output fluctuation (***Mutual smoothing of RE***)*2 Surplus electricity	Addition of battery **Battery LFC***3 Curtailment of RE*4 Curtail of low carbon energy	
		Simultaneous trip of RE	FRT function of RE	
Medium 100km	**Voltage collapse***5 **Asynchronism***6 **Oscillation***7	(Partial load drop)*8 **Induction motor load***9 **Network path to load***10 ***Poor voltage support****11. ***Anti-islanding of RE****12	Addition of SMES ***Addition of SVC*** **FRT function of RE***13 **DVS function of RE***14 ***Fast & powerful exciter****15	Poor
	Frequency unstable*16	**Water Hammering***17 **DVS function of RE***18 **Anti-islanding of RE***19	**Δf-PSS***20 **Battery governor***21	
Small 10km	Voltage deviation	RE output fluctuation	Addition of SVC Curtailment of RE ***Leading power factor of RE****22 **Vector LDC of dist. Trans.***23	Insufficient
	Voltage Flickr*24	**RE's anti-islanding**	**Forced 3-phase grounding***25	
	Unintentional islanding	Demand-supply balance **Induction motor load***26 (**Induction motor load**) **DVS function of RE***27	Anti-islanding of RE Remote shutdown **Power line permit signal***28 **Forced 3-phase grounding**	

Explanation of technical terms

(*1) Use transfer hypothesis to account RE smoothing factor. Refer Chapter 1.

(*2) Fluctuation in total output of geographically diverse REs is much smaller than the sum of individual RE's fluctuation.

(*3) Assistance by battery in power system LFC that is mainly burdened by thermal generation makes it possible to shut down low output thermal generators and to increase power absorbing capacity.

(*4) In low demand period such as spring vacation in Japan, demand-supply balance can be maintained by curtailing a part of RE output. The method was introduced in METI study committee.

(*5) Load voltage abnormally drops and never recovers.

(*6) Voltage of some generators loses synchronism with the others. As the result plus voltage and minus voltage generators exist in a power system, and short circuit appears continually.

(*7) Swing of electric power flow increases by time and reaches to (*5) or (*6) at last.

(*8) Some loads drops by 20% depth voltage sag. Around 30% loads drop by very deep sag.

(*9) Half or more electric power is used by induction motors It is a matter of course that traditional simulation without modeling motors cannot represent unstable phenomena due to motor.

(*9) Traditional simulation ignoring secondary grid path (to load) cannot represent unstable phenomena due to secondary grid path impedance. It was introduced with (*9) in US IEEE General Meeting 2008.

(*11) Voltage support capability decreases if REs having poor voltage support capability replace thermal synchronous generators having rich voltage support capability.

(*12) Some active anti-islanding function of RE can make power flow oscillation worse.

(*13) Fault Ride-Through function makes RE possible to continue operation in spite of voltage sag.

(*14) Dynamic Voltage Support function makes RE possible to support system voltage recovery after sag.

(*15) To avoid asynchronism even in case of severe fault, some large synchronous generators of utilities employ fast and powerful excitation system, which is also effective to avoid voltage collapse.

(*16) Hydro dominant islanded systems sometimes show oscillation in frequency and collapse at last.

(*17) By inertia in water pipe, phases of valve mouth and turbine output can become opposite.

(*18) DVS of RE spoils frequency stabilizing effect of Δf type PSS.

(*19) Some active anti-islanding functions of RE make frequency instability worse.

(*20) A type of PSS that increases excitation during system frequency is increasing.

(*21) Fast battery governor can mitigate frequency instability due to slow hydro governor.

(*22) If generator decreases reactive power output Q when active power output P increases, system voltage slope become small. Q is like spirits. Rich Q makes voltage higher.

(*23) Line Voltage Drop Compensation estimates average load voltage using secondary voltage and current of distribution transformer, tap of which is controlled so that load voltage is kept as scheduled value.

(*24) 5 to 10 Hz voltage Flickr is observed in power network with rich RE

(*25) Forced 3-phease grounding of the objective line will result REs trip connecting to the line.

(*26) Even if load was isolated from power source, voltage does not fade out when load has much amount of induction motor. RE penetration makes the voltage fading out time longer.

(*27) Since DVS controls RE reactive power, inconsistency may appear with some active anti-islanding function that controls RE reactive power.

(*28) Usually permissive signal is sent by power line. The signal vanishes when the power line is disconnected.

Contents