

# Issues and Solutions around Renewable Energy Integration

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## Preface

After Fukushima nuclear disaster at 11 March 2011 (3.11), no one will dare to oppose economical and smooth penetration of renewable energies (RE). RE has become not only a method for realization of low carbon society but also a considerable power supply source through serious electric power/energy shortage due to following shut-down of nuclear power stations caused by a kind of anti-nuclear mass-hysteria that is not suitable in such a civilized country. However, RE's ability itself has not increased by 3.11. To be economical, cost down technique of RE produce is indispensable, but the author is not a specialist of the field. For smooth penetration of RE, negative impact of RE to power system must be thoroughly listed up and analyzed, economical combination of impact-mitigation methods must be found, and the field is specialty of the author. In academic field, new and sensational countermeasures such as "Smart Grid" are praised, but most such measures are poorly validated in economy and reliability. On the contrary, experienced and reliable countermeasures seem trivial, therefore, are not sufficiently considered in academic field. Perhaps, reliable electric power supply cannot be achieved by academic field only.

Today, there are many people who argue policy about future energy supply including much RE penetration although any reasonable RE penetration process do not become clear. They do not show any interesting ideas but loudly speak out their desire and ideology again and again. 10 years future is blind in engineering field. A genius may appear and make something beyond anticipation. The author thinks so, because he had failed to evaluate future engineering about insulated high voltage wire after long perplexity in his younger days. Decisions for future issues had better be decided by future people. It seems be arrogant that today's people decide future issues. Most important duty for those who live today is to find solutions for present issues (and/or still remained issues) even if they consider prosperity of future generation. However, making sensation may be much attractive for today's loud speakers than taking responsibility to future generation.

The reason why present issues have been not solved seems for the author that concerning people do not have effective ideas or gifts for creating those ideas. Since it is certainly too much demanding that those who have social responsibility also should have those gifts, picking up excellent ideas from wide fields seems a good idea. However, present lack in excellent ideas tells that the picking up has not been working well. Ideas proposed from obscures are hardly respected even if the ideas are quite excellent. Certainly economical ideas are also hardly respected because those ideas will not bring large business opportunity. Committees consists of those who are regarded experienced have not been able to pick up excellent ideas proposed from obscures. By those circumstances that are especially significant in Japan among highly civilized countries, many excellent but obscure scientists regretfully may turn to hermits.

Considering those circumstances, the author decided a principle that fruits from researches are published as papers with peer review. Assertion without verification or assertion based on ideology is no more than pseudo-science, and perhaps those assertions will be hardly published as papers with peer review. To avoid peer review, pseudo-science rather tends to make up a new party and make one side sending of large amount of their convenient information. Therefore, publishing as papers with peer review seems to be able to certificate that our researches are not pseudo-science. In addition, published papers are preserved long

with their authors' name (if not having classic value). A fact that the research had been made by the persons in past is never erased. A fact that someone had warned is also never erased. Threshold of peer review is in principle equal to experienced and obscure. By publishing, plagiarism may be effectively prevented.

Societies with those ill circumstances appeared not only recently but also in ancient. For an example in China the Analects of Confucius had said that you had better appear when society is ethical, but you had better be a hermit when society is not ethical. To have a high ideal is not bad but you have no duty to become a martyr. It is more important to preserve tradition from ancestors. You had better hide and wait ethical society. If ethical society do not realize in your lifetime, you had better continue to be a hermit till you die. A similar thought can be read in letters from Epicurus in ancient Greece. Epicurus persuaded that being a hermit and living quietly is clever way of life, opposing to Seneca who had highly evaluated activity in political field. Epicurus was not a mere Epicurean. It is an evidence for demonstrating thought of hermit had been supported by many people through long history that words of Confucius and letters from Epicurus had been maintained beyond two thousand years.

Although many papers already have been published based on the book, effect of papers is limited. Since volume of a paper is around 10 pages or less, whole view of RE's power system impacts and their mitigation methods cannot be proposed in one paper, which can propose only a partial view. However, it is quite important to have a whole view. An undesirable phenomenon may be caused by duplex causes. Usually there exist competitive multiple solutions for an issue. A solution is sometimes effective to solve another issue, or also sometimes makes worse another undesirable phenomenon. Regretfully there are many swindlers who speak loudly only their convenient parts using the fact that common people cannot have whole view. They may be innocent and simply know the parts only. Usually one speaks what he wants to inform. But although what was informed may be useful for loud speakers but that may be sometimes harmful for society. Careful attention must be needed.

The book intends to prepare renewable integration techniques that may become needed in near future when renewables really penetrate much. Although certainly the book treats about future, it does not decide future policy arrogantly but does prepare tools for future use as kindness. Of course the author does not think that all items are listed up. Ordinary but in practice ignored items are included. Items making up to date those techniques that have become already out-of-date are also included. Although those items may be unpleasant for occupational power system scientists and engineers, someone must open them to public. In 2011 IEEJ annual meeting on power and energy, the author joined as a speaker to "Devils in Virtual Reality" panel discussion, and introduced some part of the book. The panel discussion seemed to be received quite favorably, and the contents were published in IEEJ journal in December 2012.

As stated above, having whole view is important. There are many undesirable phenomena in electric power system. The author examined whether high RE penetration will make those phenomena worse or not. The results are listed up in Table 0.1. Readers may be astonished by the large number of relating items; power system impacts, causes (or mitigation factors), and countermeasures. Items written in bold are not recognized widely yet. Items written in bold Italic are recognized qualitatively but are not analyzed quantitatively yet. Items with underline are regarded as hopeful countermeasures but the author thinks they are too expensive. The fact that many items are written in bold character tells that society does not

understand renewable integration sufficiently. There may be items that the author does not notice, but the other engineers will fulfill. The reason why items are classified by geographic size is a technique for listing up relating items thoroughly.

Table 0.1 Thoroughly Listing up 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	<b>Transfer hypothesis</b> * <sup>1</sup>	Insufficient
	Demand-supply imbalance <i>Frequency deviation</i> <i>Shortage of regulation</i> <i>Shortage of reserve</i>	RE output fluctuation <i>(Mutual smoothing of RE)</i> * <sup>2</sup> Surplus electricity	<u>Addition of battery</u> <b>Battery LFC</b> * <sup>3</sup> Curtailment of RE* <sup>4</sup> Curtail of low carbon energy	
		Simultaneous trip of RE	FRT function of RE	
Medium 100km	<b>Voltage collapse</b> * <sup>5</sup> <b>Asynchronism</b> * <sup>6</sup> <b>Oscillation</b> * <sup>7</sup>	(Partial load drop)* <sup>8</sup> <b>Induction motor load</b> * <sup>9</sup> <b>Network path to load</b> * <sup>10</sup> <i>Poor voltage support</i> * <sup>11</sup> . <i>Anti-islanding of RE</i> * <sup>12</sup>	<u>Addition of SMES</u> <i>Addition of SVC</i> <b>FRT function of RE</b> * <sup>13</sup> <b>DVS function of RE</b> * <sup>14</sup> <i>Fast &amp; powerful exciter</i> * <sup>15</sup>	Poor
	<b>Frequency unstable</b> * <sup>16</sup>	<b>Water Hammering</b> * <sup>17</sup> <b>DVS function of RE</b> * <sup>18</sup> <b>Anti-islanding of RE</b> * <sup>19</sup>	$\Delta f$ -PSS* <sup>20</sup> <b>Battery governor</b> * <sup>21</sup>	
Small 10km	Voltage deviation	RE output fluctuation	<u>Addition of SVC</u> Curtailment of RE <i>Leading power factor of RE</i> * <sup>22</sup> <b>Vector LDC of dist. Trans.</b> * <sup>23</sup>	Insufficient
	Unintentional islanding	Demand-supply balance <b>Induction motor load</b> * <sup>24</sup> <b>(Induction motor load)</b> <b>DVS function of RE</b> * <sup>25</sup>	<u>Anti-islanding of RE</u> Remote shutdown <b>Power line permit signal</b> * <sup>26</sup> <b>Forced 3-phase grounding</b> * <sup>27</sup>	

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  $\Delta f$  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) 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.
- (\*25) Since DVS controls RE reactive power, inconsistency may appear with some active anti-islanding function that controls RE reactive power.
- (\*26) Usually permissive signal is sent by power line. The signal vanishes when the power line is disconnected.
- (\*27) Forced 3-phase grounding of the objective line will result REs trip connecting to the line.

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