11. Strategy for High RE Penetration

Is Carbon Free Power System Possible?

Although it is true that most important condition of RE's high penetration is their economy, it is considerably important condition among the others is that RE can be integrated into existing system without problem or inconsistency. Low reliability is not acceptable even if economy is splendid. It seems wise to assess at the beginning whether carbon free power system with no thermal power stations is possible or not.

Thermal generators take two important roles. The first is reserve, which is classified from spinning reserve supplied by generators operating at partial output to stand by reserve supplied by stopped but warm generators, and energy reserve or kWh reserve is supplied only by thermal generators. If kWh reserve is supplied by batteries, cost may be gigantic. On the contrary, reserve can be economically prepared by good power system operation.

The second is system voltage support. Since thermal power stations can site near load center, they are the main body to support power system voltage. When they stop at all, even if REs have DVS, voltage support capability of whole system will considerably decrease. What may follow? And what are effective measures? Those are main theme of the chapter. If voltage support capability is short, much additional equipment such as SVC may be needed.

How serious is the voltage support problem? It may be effective to assess voltage support capability in condition that all thermal generators are stopped and that power shortage is fulfilled by nuclear power, RE, and battery so as to demand supply balance is maintained. As follows, four systems that seem to have voltage support problems are studied.

Carbon free power system 1 Its structure of is shown in Fig. 11.1. Coal fired generator G4 is scrapped. Nuclear generators G9 and G10 are newly built. Batteries B1 and B2 are added for maintaining balance. All REs and batteries are assumed as having DVS capability. So long as seeing power flow no reinforcement is needed. Generator G6 was mixture of large thermal generator and local hydro powers. The thermal power is scrapped, but generators are reused as rotary condensers (RC) for keeping voltage.

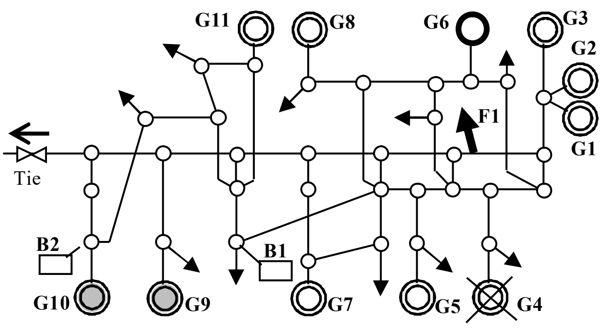

Fig. 11.1 Structure of carbon free system 1

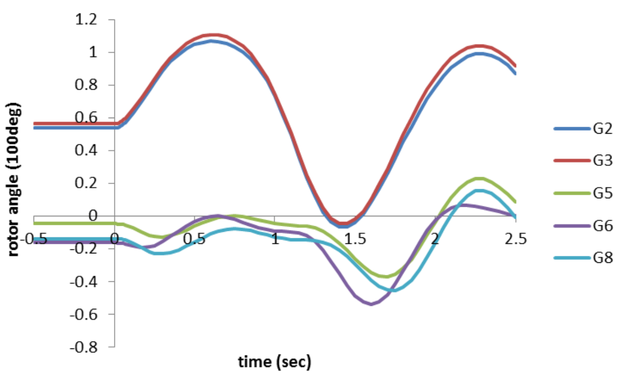

Fig. 11.2 Stability of carbon free system 1 (with RC)

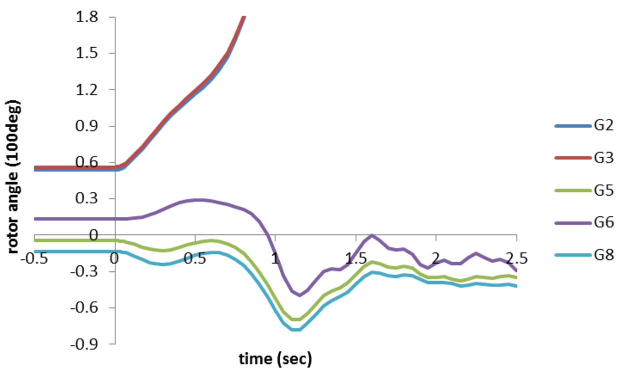

Fig. 11.3 Stability of carbon free system 1 (w/o RC)

6LG-O fault is assumed on 2-circuit 500kV transmission line at F1. Fault duration time is set as 0.07 sec. Heavy power flowing the 500kV line shifts to 275kV network. Since Transient synchronous stability is threatened, generator G1 is shed at 0.25 sec after fault occurrence.

Simulation results are shown in Fig. 9.2. The system maintains stability with RC. However, the RC is omitted, generators G2 and G3 go to asynchronism as shown in Fig. 9.3. Generator G6 has an importance role because only little power sources exist around it.

Carbon free power system 2 Its structure is shown in Fig. 11.4. Nuclear generators G1 and G2 are newly built, G3 and G4 are reinforced. 9 thermal generators are reused as RCs. The system has considerable amount of pumped storage, and no batteries are needed for demand supply balance. 500kV/275kV transformers are added in needs.

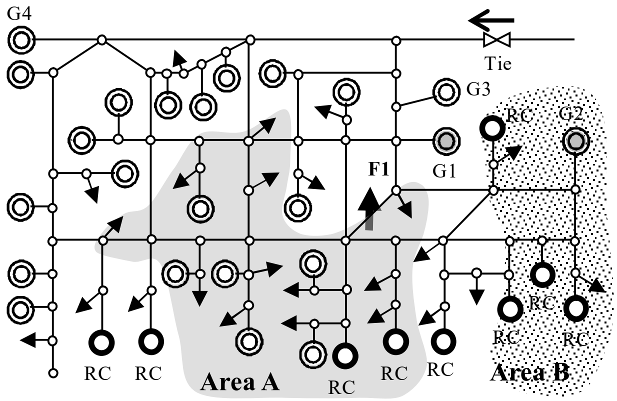

Fig. 11.4 Structure of carbon free system 2

3LG-O fault on 2-circuit 500kV transmission line is assumed at F1. Fault duration time is set as 0.07 sec. Deep voltage sag spreads to wide area and loads partially drop.

Simulation results are shown in Fig. 11.5. By contribution of the 9 RCs, load voltages recover even though slowly. However, when 9 RCs are omitted, load voltages cannot recover as shown in Fig. 11.6.

By the way, in spite of the 9 RCs, if FRT duration is 1 sec, many RE stop during voltage recovery and result voltage collapse. It may be considered that FRT duration is increased to 3 sec like US.

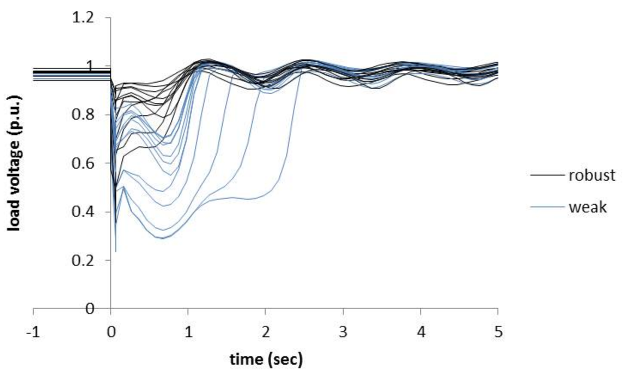

Fig. 11.5 Stability of carbon free system 2 (with 9 RCs)

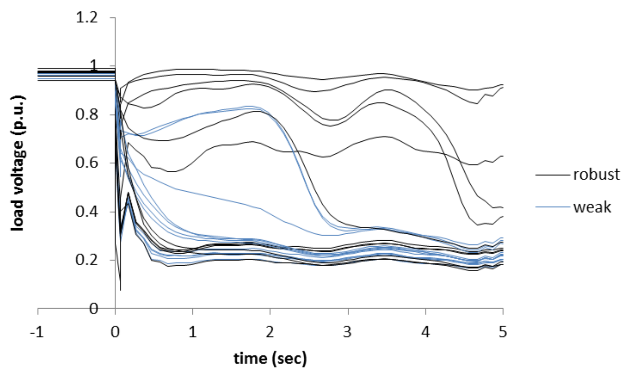

Fig. 11.6 Stability of carbon free system 2 (w/o 9 RCs)

By the way, power sources of area B were thermal only. If new nuclear G2 cannot site in the area and nuclear G1 is reinforced instead, area B suffers from power shortage, and goes to voltage instability in spite of the 9 RCs as shown in Fig. 11.7. It is understood that voltage stability cannot be maintained if area balance of power source is lost.

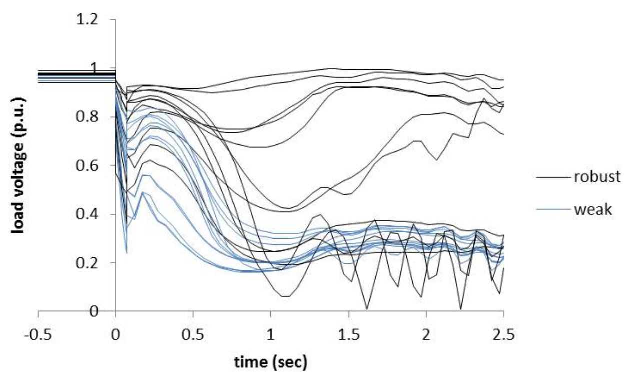

Fig. 11.7 Stability of carbon free system 2 (w/o G2)

It is favorable power source and load are well balanced with in an area. It is said that electricity should be generated locally and consumed locally. From viewpoint of electric engineering, their opinion is perfectly correct. In Japan, criteria of wide area electricity trade are not decided by natural laws made by gods but by social laws made by people. Some disasters must occur in near future because of neglecting natural law made by gods.

Carbon Free system 3 Its structure is shown in Fig. 11.8. Nuclear G1 is reinforced. Large thermal G2 at 275kV is rebuilt as nuclear. Large thermal G3 and G4 retire and local hydro only remains. Two thermal generators are reused as RCs. Since nuclear increase, 6 batteries are added for balancing.

As power source changed, power flow turn rightward to leftward. Some 500kV/275kV transformers are reinforced.

A 6LG-O fault on 500kV 2-circuit transmission line is assumed at F1. Fault duration time is set as 0.07 sec. End of the system (area A) that is shown in the figure as the right end with gray background and that was sending much power leftward has lost one of two routes and its stability is threatened. Simulation results are shown in Fig. 9.9. Generators and loads in area A are distinguished as gray lines. Load L5 outside of area A shows slow voltage recovery, because its nearby thermals are scrapped and voltage support became weaker.

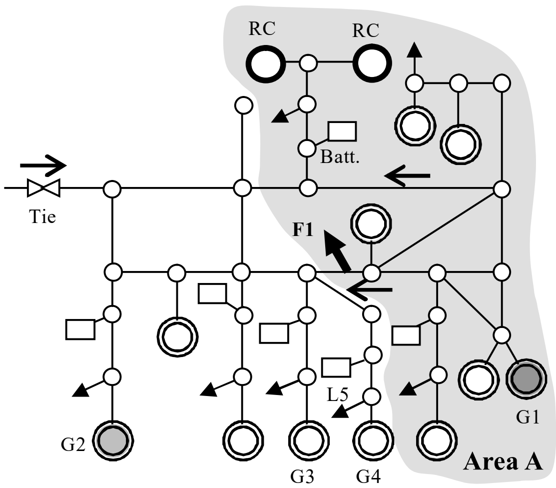

Fig. 11.8 Structure of carbon free system 3

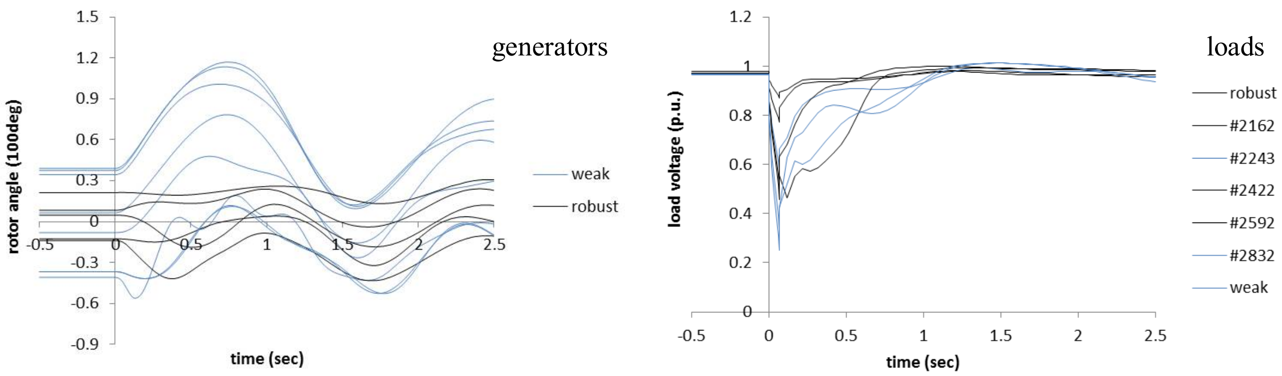

Fig. 11.9 Stability of carbon free system 3 (with 2 RCs)

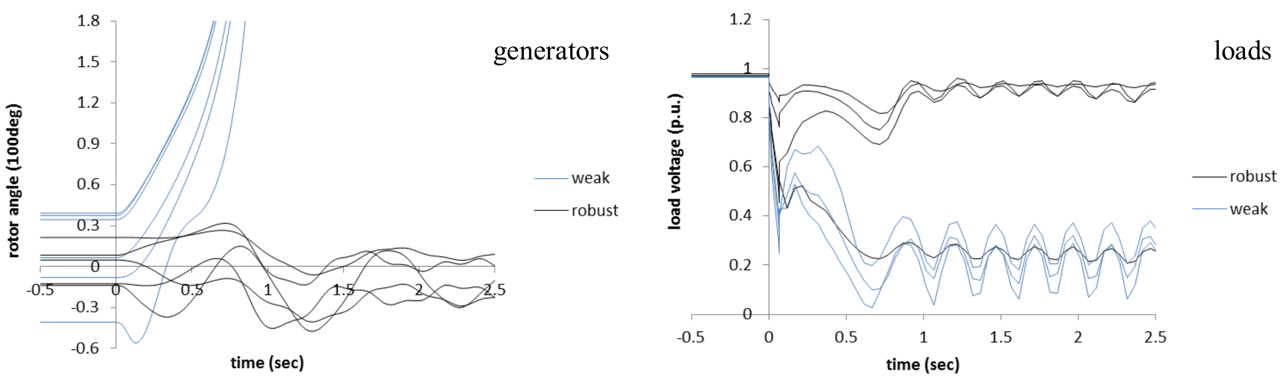

Fig. 11.10 Stability of carbon free system 3 (w/o 2 RCs)

2 RCs bear an important role to support voltage at the midway of long and thin system created by the fault.

Simulation result without the important 2 RCs are shown in Fig. 11.10 All generators in area A go to asynchronism, all load in area A go to voltage collapse, and in addition, load LF outside of area A goes to voltage collapse.

Carbon Free System 4 Its structure is shown in Fig. 11.11. Thermal G1 and G2 is scrapped. Generators in G1 and G2 are also scrapped. Thermal generators in G5 and G6 is reused as RCs. Nuclear G7 is newly built. 3 batteries are added in trunk system for balance. Some 500kV/275kV transformers are added for increased downward power flow.

Power supply in Area A is insufficient. Area A receives much power from outside. Area A had much thermal power sources in G2, G5, and G6. However, G2 is scrapped, and Generators in G5 and G6 only remain as RC. By batteries having 10% capacity of load, power supply shortage is somewhat mitigated.

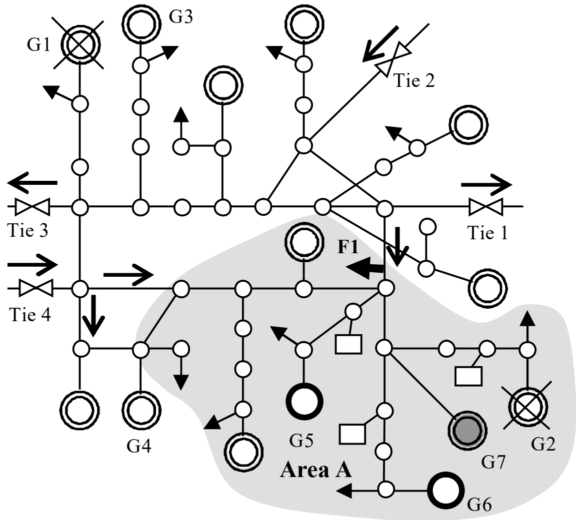

Fig. 11.11 Structure of carbon free system 4

A 2-circuit 6LG-O fault is assumed on a 2-circuit 500kV transmission line at F1. Fault duration tine is set as 0.07 sec. One route for receiving power from outside is lost and stability of area A is threatened.

Simulation results are shown in Fig. 11.12. Synchronous and voltage stabilities are maintained. Voltage recovery delay is a little slow but better than very slow recovery of "Carbon Free System 2".

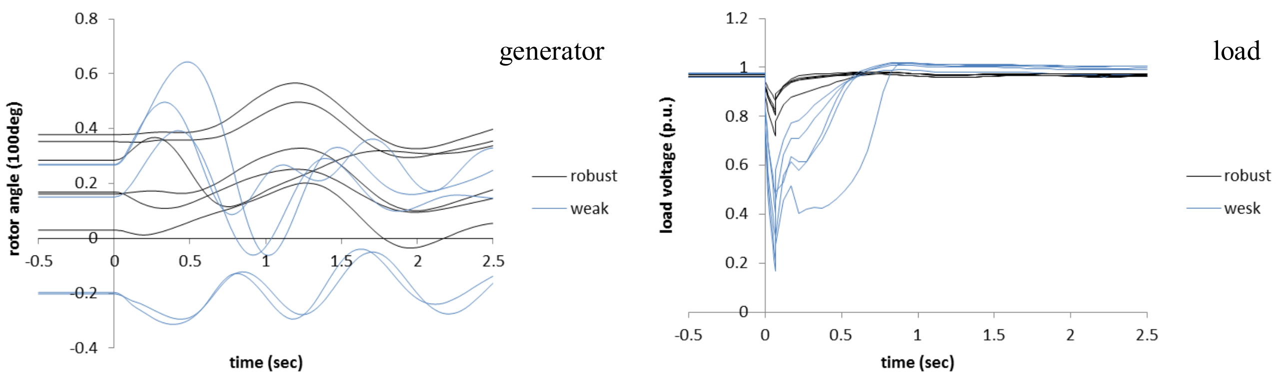

Fig. 11.12 Stability of carbon free system 4 (with 2 RCs)

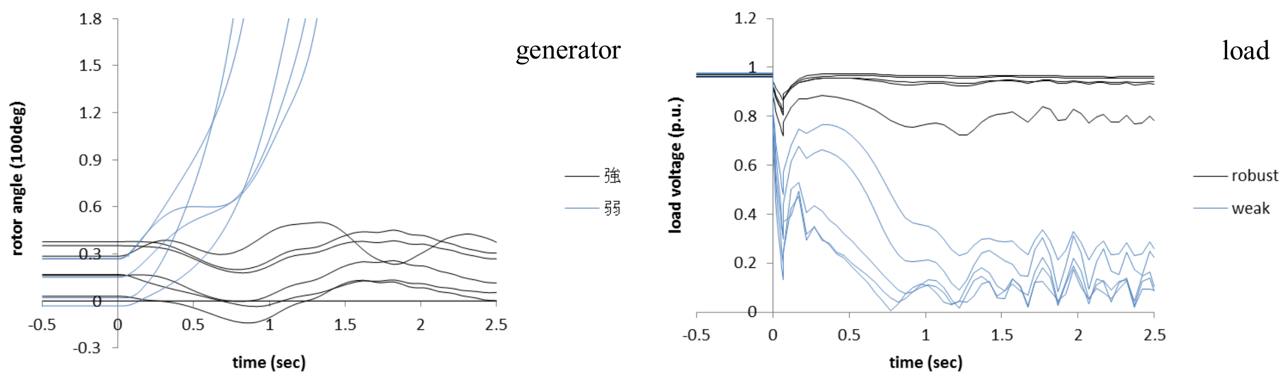

Fig. 11.13 Stability of carbon free system (w/o 2 RCs)

Since RCs in G5 and G6 bear important role to support voltage of area A, stability is lost if those RCs are scrapped. Simulation results are shown in Fig. 9.13. All generators in area A (weak) go to asynchronism and all loads in area A (weak) go to voltage collapse.

How readers think about the four examples? Carbon free power system may seem to be a fiction, and newest pessimistic knowledge such as IM load and network impedance to load terminal may deny the reality. However, carbon free system in not impossible for today's science and technology. Readers may rely on science and technology themselves more. It may be indispensable to purge and rebuild leaders and education stuffs in electric power engineering field, to invite excellent juniors to our field, and to make a restart. However, damage by 3.11 is so hard that to make nuclear play as considerable power source is desperate. As result, synchronous generator decrease more, RE must play more role of synchronous generator.

Imaginary synchronous generator

Inverter operates in two extreme mode now as follows.

1) CVCF Operates at constant voltage and frequency without assuming integration. Used as back-up power source in blackout. Since inverter operates as voltage source, if fault occurs in the circuit it feeds, large fault current appears and it may destroy the inverter.

2) PLL Outputs active and reactive power obeying system voltage and frequency. Load's voltage support is burdened to system. By decrease of voltage support capability due to high RE integration, many problems on stability appears. The origin of problems and criticism "RE is parasite" exists in PLL.

Presently, inverter switches these two extreme operation. Inverter operates usually in 2) PLL mode, but switched to 1) CVCF mode during power system outage. However, the switching cannot be finished by instant, but load must experience some short time outage, because it must be confirmed that inverter is certainly isolated from power system.

Such a strategy to switch extreme operation mode has poor expandability. So, some scientists aim "imaginary synchronous generator", which is a inverter controlled as if it behaves as synchronous generator. Of course, over current endurance of inverter is much poorer, so some invention is indispensable.

To say the truth, technology for imaginary synchronous generator is almost established. Fig. 11.14 is structure of hydro power training simulator[(1)(2)] developed in 1996 by the author. As hydro power section is so poor that it cannot buy training simulator by full turn-key like thermal and nuclear power sections. Therefore, core software was developed by the author and the other software was developed by local bender.

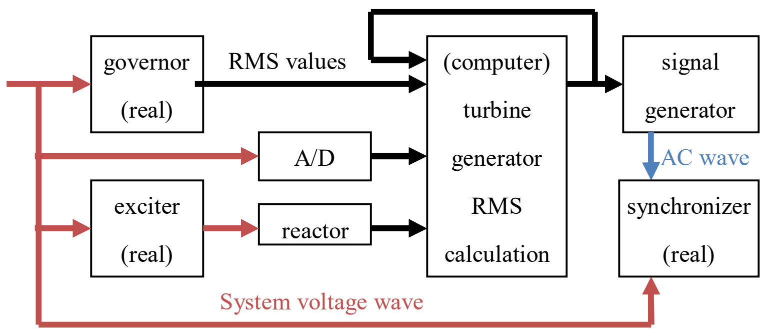

Fig. 11.14 Structure of hydro power simulator

Here appeared an issue how make generator voltage wave for operating real synchronizer. In the system it was made by signal generator from RMS values of voltage magnitude and phase in computer. Then, if the signal generator is replaced by inverter, not only driving synchronizer but also interconnection becomes possible. Therefore, imaginary synchronous generator is accomplished half or more. However, it is not wise to simulate synchronous generator honestly, because synchronous generator has defects. Fast response and smaller overcurrent will be favorable.

Super DVS on RE

Thus, if all REs have DVS capability, and if some thermal generators are reused as rotary condensers, carbon free power system is possible. DVS function used here is similar to SVC, and the function can be reinforced like SVG, and amount of RCs can be reduced. A utility in Japan is studying more powerful super DVS that supplies short circuit current during fault. For the purpose, more robust element than now used IGBT becomes needed. Increased short circuit current in distribution network must be considered. The author regards supplementary voltage support devices such as RC are conservatively hopeful. However, technology around power system may be changed in those days when RE really penetrates much, therefore, prejudice must be forbidden.

DVS function assumed in chapter 4, 5, and 6 is designed like SVC, and assumed to have reactive power-voltage characteristics like parallel composite of capacitor and saturated reactor. The type of DVS is called as “impedance type” hereafter. For avoiding over current of interconnection equipment, active power is assumed to be controlled as proportional to square voltage. Characters stated above are expressed by equations as follows.

$$P = P_0 (V/V_0)^2$$
$$Q = W_0 [(V/V_0)^2 – V/V_0)^B]$$
$$B > 2$$

Since existing RE’s power conditioner system (PCS, interconnection equipment) is built by IGBT, more powerful voltage support PCS named “current type” can be realized. The characteristics are expressed by equations as follows.

$$P = P_0 (V/V_0)^2$$
$$Q = W_0 [(V/V_0)^1 – V/V_0)^C]$$
$$C > 2$$

Characters of impedance type with B = 9.5 and that of current type with C = 4.5 are compared in Fig. 11.14. Peak value of reactive power is almost same, but current type can supply more reactive power at lower voltage region. At low voltage region, PCS current becomes smaller in case of impedance type, but does not decrease in case of current type. Current type uses PCS capacity more thoroughly and usefully than impedance type. When voltage is 1 or more, PCS current exceeds 1. This is caused limitation of simulation tool. Of course in real PCS, such overcurrent is avoided by control. However, stability problems occur when voltage is lower. Such slight incorrect modeling can be ignored.

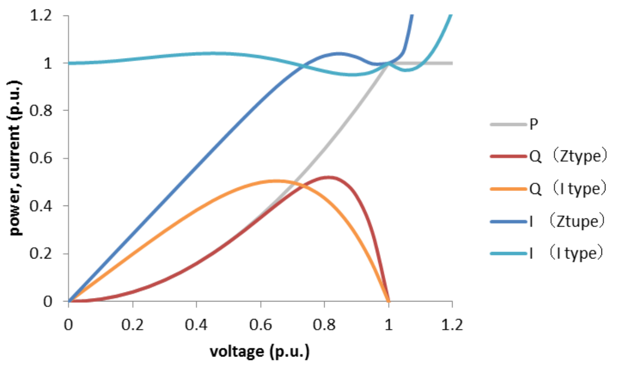

Fig. 11.14 Characters of impedance type and current type

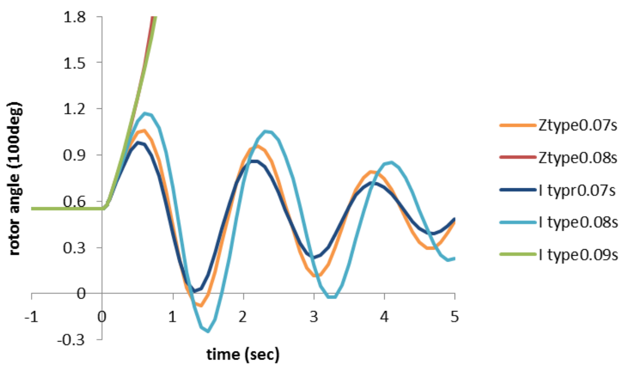

Fig. 11.15 Stability with impedance & current type (send)

Synchronous Stability in Power Sending System In the power sending system introduced in chapter 5, synchronous stability with impedance (Z) or current (I) type DVS is examined, and the results are shown in Fig. 9.15. Fault duration time is taken as parameter. Current type and 0.08 sec clear case is more stable than impedance type and 0.08 sec clear case, but less stable than impedance type and 0.07 sec clear case. That is, current type shows better stability than impedance type, but the difference is smaller than 0.01 sec of fault duration time.

Synchronous Stability in Power Receiving System In the power receiving system introduced in chapter 5, synchronous stability with impedance (Z) or current (I) type DVS is examined, and the results are shown in Fig. 9.16. Fault duration time is taken as parameter. Current type and 0.08 sec clear case shows almost same stability as impedance type and 0.07 sec clear case. Current type and 0.09 sec clear case is more stable than impedance type and 0.08 sec clear case. That is, current type shows better stability than impedance type, and the difference is larger than 0.01 sec of fault duration time.

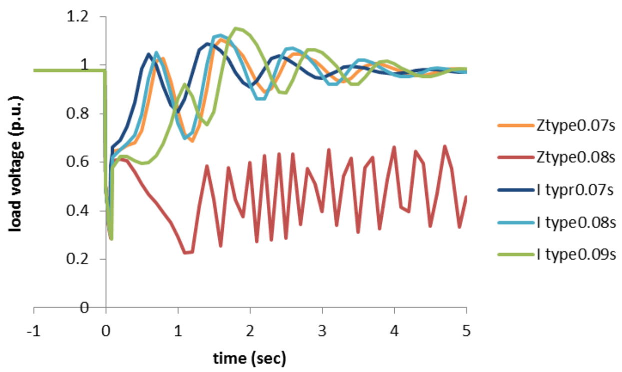

Fig. 11.15 Stability with impedance & current type (receive)

As shown above, DVS used in former chapters operates in light duty, and can be more effective for improving system stability if PCS capacity is fully used. In addition, current supply during fault is not adopted here, but the current supply can mitigate voltage drop during fault and slightly improve stability.

Measures for Frequency Deviation

Issues in large geographic area such as interconnection are demand supply balancing and frequency deviation. Measures as follows seem effective by studies above.

Regulation Battery Regulation function in LFC can be sufficiently achieved. An idea is shown in Fig. 11.17. 500MW class thermal generator can LFC at 150MW output or more. At Minimum output 100MW LFC is impossible. Now suppose operates in LFC at 200MW. By taken LFC on battery, generator output can be reduce to 100MW or 0MW (stop), and negative reserve is generated.

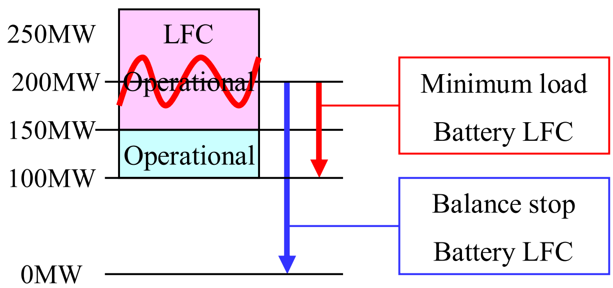

Fig.11.17 Idea of battery LFC and thermal operational range

The idea was once proposed to NEDO by the author. However, Hokuriku region has rich reservoir hydro and never suffers from shortage of negative reserve. Thus, the idea did not realize, but now realized in Hokkaido and Tohoku regions.

Its cost can be calculated as follows. Daily maximum demand in light demand period is almost 120GW in Japan. For regulation ±1% capacity of peak demand as follows will be needed.

$$120\text{GW} * 0.01 = 1.2\text{GW}$$

Since regulation compensates fast fluctuation, 0.2 hr duration of battery will be sufficient. That is,

$$1.2\text{GW} * 0.2\text{hy} = 0.24\text{GWh}$$

For fast charge and discharge, not NaS battery but Lithium ion battery is suitable. Unit price of converter is assumed as 30k¥/kW, and that of battery is assumed as 200k¥/kWh. Then, total price becomes as follows.

1.2GW * 30k¥/kW + 0.24GWh * 200k¥/kWh = 84G¥

The price is quite lower than the price that was thought as needed until today for another approach “reserve battery”

“Reserve battery” approach assumes that output of thermal generator 30% to 40% of rated power for keeping negative reserve, and excessive energy is stored in battery. Supposing 20% of 120GW peak demand is borne by thermal generators and storage is needed 5 hr in a day, necessary amount of battery is calculated as follows.

120GW * 20% * (40% – 30%) = 2.4GW

2.4GW * 5hr = 12GWh

Unit price of converter is assumed as same of the former case, 30k¥/kW. As battery, economical NaS battery is available. Its unit price is assumed as 40k|/kWh. Then, total price is calculated as follows.

2.4GW * 30k¥/kW + 12GWh * 40k¥/kWh = 5520G¥

Thus, new idea “regulation battery” is more economical than old idea “reserve battery”. However, it must be remembered that “reserve battery” has not only regulation but also a certain load following capabilities. “Regulation battery” depends load following on reservoir and pumped hydro power stations. In addition, both batteries cannot absorb power/energy in some periods with low demand and excessive supply. In such a scene, not only thermal power but also low carbon power must be curtailed.

Since RE and the other low carbon power sources have the same priority as “low carbon”, they should be curtailed evenly. From viewpoint of public safety, curtailment in hydro power becomes problem. Water flown in waterway turns to flow in the river, where human may be working (such as fishing). That is risky. As natural power, wind and solar power can be curtailed more safely. Nuclear power can also curtail although its ramp rate is limited. From viewpoint of control cost, curtailment of small and many solar powers is not economical. Control cost of remote-controlled hydro power, wind power, and megasolar or human controlled nuclear power will be lower.

Wisely thinking, curtailment of nuclear power seems attractive. However, utility must buy the curtailed amount of energy from solar or wind power with extraordinary high price. Is it fair? RE price must be reduced to adequate level when utility owned low carbon power source is curtailed. If the price is such level that compensates control cost increase when control object is changed from utility owned generators to REs, it may be acceptable. To pursuit total optimal, making adjustment such as adequate price is the role of regime and law, so the author thinks.

RE Output Prediction Demand prediction is indispensable for good load following. By experience of author at central dispatching office, RMS error in next day demand prediction is around 2% of peak demand. If annual peak demand is 5000MW, absolute RMS error is calculated as follows.

5000MW * 0.02 = 100MW

RE assumed to penetrates by 30% of peak demand. If RMS absolute next day prediction error of RE output is equal to that of demand, relative error in next day RE output prediction becomes as follows.

0.02/0.3 = 0.067 = 6.7%

The RMS error is not on point RE output prediction but on area total RE output prediction. Generally, latter error is considerably smaller than former error. For minute assessment more studies are needed, but roughly saying, such accuracy seems critically possible for today’s technology.

Today’s RE output prediction methods are based on weather forecasting information. Some heuristics are added for good accuracy. However, prediction accuracy much depends on accuracy of weather forecasting. By using today’s methods, RE output prediction error becomes more troublesome than demand prediction error, as RE penetrates. Before such scene becomes true, some accuracy improvement in weather forecasting becomes needed. It seems a wise way and to indicate the time of necessity is a role of system operators.

Flexible Operation of Thermal Generator In low carbon era, main role of thermal generator will become regulation and reserve, even in case of coal fired thermal generator, which has been recognized as base power supply because of its low fuel cost. Until today, restarted thermal generator must experience full power operation during several hours if it restarted cold condition. Thermal generation sector engineers say that the purpose of the full power operation is certifying that full power operation is possible. However, lasted full power brings shortage of negative reserve. In addition, what measure exists if it is found that the generator cannot operate at full power? These inflexible thermal generator operations must be overcome in low carbon era when RE highly penetrates.

In thermal generators output bands change, auxiliary machines start or stop. When ordered output change crosses band boundary, considerably long constant power operation is forced. In addition, full power test run is held when new coal is used. These numerous restraints in thermal power generation strongly hinder smooth system operation. The author proposes that thermal generation sector should begin research for flexible operation. But they refuse.

Battery speed governor By analysis in chapter 7, two causes exist in frequency instability of hydro power. The first: anti-islanding by RE active power's positive frequency sensitivity can be forbidden, because other measures exist. The second: reduction of Δf type PSS's merit due to RE's DVS function is troublesome. However, some battery must be introduced for the other purpose. On to the batteries, speed governing function with very small time lag can be added. Here, the delay is assumed as 1 sec time constant. Such time constant is realized very easily.

Frequency response of total speed governor, which is mix of 70% very unstable hydro speed governor with 2 sec water hammering Tw and 30% battery speed governor with very small time delay (1 sec time constant), is shown in Fig. 11.18. Phase delay is so drastically reduced that islanded hydro system never causes frequency instability. The question is whether battery locates within hydro islanded system.

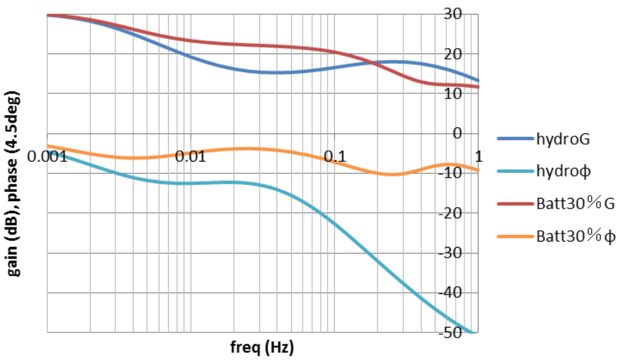

Fig. 11.18 Effect of battery speed governor mixture

Smart Grid

Definition of the words is not clear, but the words certainly has the meaning that intends positive effect by combining REs such as wind and solar and demand equipments such as heat pump and EV with power system using two way communication. In Japan smart grid (SG) is very often referred especially hoping to solve power system impacts due to high RE penetration. On the contrary, problems of SG are rarely referred except such crimes as communication or privacy invasion.

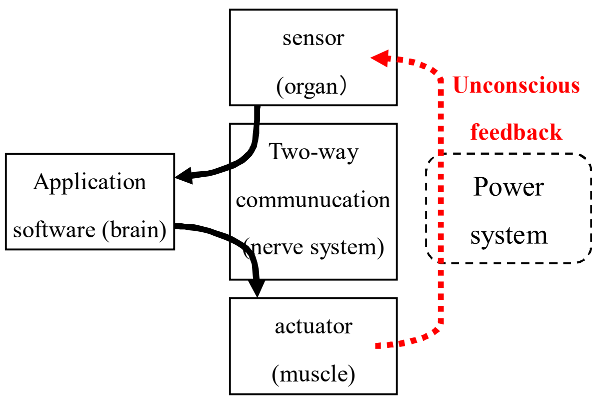

Fig. 11.19 Structure of smart grid as a metaphor of human body

Are there no other problems really? As a hint, SG is sometimes expressed like a human body as a metaphor as Fig. 11.19. By the metaphor three issues are thought of .

From the structure, issue 1 and are 2 immediately thought of.

Issue 1 It is added part by dashed line in the figure. If actuator moves, power system certainly somewhat affected. It is quite possible that the result is detected by sensor. Then, the unconscious feedback loop is formed. By the way, some time delay is needed for work by two way communication and application software. Much time delay is needed for high level work. Much time delay exists in feedback loop. Such loop becomes very unstable, which means not only that work becomes impossible but also that control result cannot be forecasted. When SG is realized, stable feedback loop with large time delay is also realized.

Issue 2 Technologies of sensor, two way communication, and actuator are nearly completed. However, application software (brain) is not built. Number of the objects that the brain deals is tremendously large. Perhaps, the brain will be highly sophisticated artificial intelligence (AI) having learning ability. It is true that many engineers in SG field once worked in AI field in the past. Terminals also become smart and will be a kind of sensor actuator complex. When SG is realized, it can be said that human at first create complex large artificial intelligence.

Issue 3 Another problem exists though unconscious from the figure. SG is sometimes called as “the second internet”. The reason that internet succeeded is very roughly saying that what exists beyond terminal is human. Human has common sense, do correct decision, and bears responsibility. However when SG is used in power system control, what exists beyond terminal is mare machine. By gigantic number of combination, to examine all functions of SG is impossible. If disaster occurs, who takes the responsibility? When SG is realized, problems on resultant responsibility reversion are solved.

The author also certainly feels excitation to join a human great challenge as SG. However, what were proposed till today were no more than sales of auxiliary equipments except brain. In is also too risky to wholly depend on an uncompleted technology such as SG, even if hope to SG is extremely high. Intermediate solution that half of problems are solved by SG technology can exists. To reduce burden on SG technology, and as safety net, problems by high RE penetration must be solved as many as possible by economic and reliable methods.

It was 2010 when the author pointed out the three issues(3), inspired by a scientific fiction novel(4). As to issue 3, a human accident to death occurred in 2016 caused by AI driven automobile. The responsibility was decided to exist in driver. Under such responsibility allocation, users such as electric utilities will not adopt SG and AI.

System Engineering

It may be surplus for readers but the author intends to a little minutely introduce. In “system engineering” that the author learned in university teaches that three types of solution must be prepared. The three kinds are as follows.

Solution A Aggressive “solution A” is advanced, sometimes adopts unrealized technology, and hardly become old-fashioned. Therefore, life as system is long and life time cost is low. However, it may not be completed by time limit.

Solution B Balance oriented “solution B”. Intermediate between A and C.

Solution C Conservative “solution C”. It consists of only now available technologies, is surely completed by time limit, but soon become old-fashioned and life time cost may be high. It must be prepared for the case that all ambitious trials are found to be failures. In addition, it is the base for evaluating more aggressive solutions.

SG is certainly an aggressive "solution A". System impact mitigation measures introduced in the book are perhaps conservative "solution C". System engineering teaches that both "solution A" and "solution C" are important and indispensable. Between them, numerous "solution Bs" can exist. To decide what solution is the best, it is helpful to employ the four indices; Usefulness, Economy, Reliability and Compatibility, so system engineering teaches.

Among the indices, Compatibility is unfamiliar word and needs some explanation. Any system starts as a part of supersystem. If the system stands alone in supersystem, the system is said to not have compatibility. If the system is welcomed by supersystem, the system is said to have compatibility. Typical example with rich usefulness and poor compatibility is the Shinkansen. Relationship with supersystem is sometimes called as "Backward Compatibility".

As the dual concept, "Forward Compatibility" exists. If the system extends to future but never limited, new system is needless. Such system has long historical life and economical in long term, and called as extendable. Typical example is parallel connected alternate current (AC) electric power system designed by Tesla. When electric power was first realized, series connected direct current (DC) power system was used by Edison. Parallel connection can be more easily extended than series connection. Alternate current is more useful than direct current. Thus, after Tesla, AC power system is showing very long life even in today.

How do the readers feel? System engineering is useful, isn't it? However, it has a flaw. Much kind of parts are included in a system. Knowledge on such parts is needed. To obtain such knowledge, long training period is needed. Even doctor course is not sufficient at all. Fruits cannot be harvested in a short period. Naturally such field is kept respectful distance by engineers. If no one cares the situation, such an important knowledge will be lost. So, electric power utilities and electric equipment venders collaborated to build up so called "Power Academy", and started co-working with universities in electric power system, system engineering, and the other electric power engineering fields. Such activity will be quite necessary and it is also one of corporate social responsibilities.

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Postscript

The author has been astonished, because results by extended classic analysis methods based on simply aggregated power system model has given almost same results by modern simulation tool on detailed power system model. Predecessors who could not use modern simulation tools were forced to develop and use classic analysis methods, which are proved quite adequate if correctly used. Those classic and extended classic analysis methods can give engineers insights, which modern simulation tools cannot. Further saying, only those who use classic analyses methods have qualification for performing simulation, because simulation without physical insights always has risk for mistaking and overlooking the mistake. However, in spite of its importance, classic theories are going to lose their initiators. *Buddhism* had predicted such a condition of itself as *Mappo*, which means decline of the doctrines, dieing out of initiators, and only remaining of the *Scriptures*. *Buddhism* had also predicted that *Mappo* would go worse to *Meppo*, which means complete ruin of the doctrines and the *Scriptures*. The author has published the book as a *Scripture*, and hopes that it will survive as long as possible in *Mappo* era of electric power system engineering.

By the way, why such an important technology is going to ruin? One reason is thought that accomplishment of simulation tools has reduced importance of classic theories. Since everybody will believe simulation result, engineers do not necessarily have to know theories and physical meanings, only if simulation runs to the end. By *Confucian* criticism, simulation technology has ruined engineers who developed it. Thus, simulation is in all its glory today. But let us think a little while. Simulation tools does not run and give answer if users do not put in numerical data. Users are not always expert engineers, but only masters of TV game named simulation and inhabitants of virtual reality of simulation. It is quite possible that users cannot examine the adequacy of model and data to be put into the tools. In such a condition, who can rely on the answers given by such simulations? Those who trust upon them might be sleeping on volcano mouth.

Electric power system is metamorphosing. Today's adequate model and data cannot always be adequate in tomorrow. The author think that now is the metamorphosing period. Two main incidents are progressing. One is retirement of aged thermal generation. Another is penetration of distributed generation. Both of the two will reduce load's voltage stability, and as the results, reduce transient, dynamic, and frequency stability of interconnection. Traditional model and method have been proved not to tell the truth but to overlook and mislead. As the countermeasure, the author has introduced new model and method. The results were astonishing. Besides, although everybody understands that high penetration of RE whose output fluctuates by time will threaten voltage and frequency regulation in power system, quantitatively analyses seems to stagnate, therefore, the author by himself clarified. The contents were published as paper and introduced in the book.

It is "Science of Philosophy" that understand why natural science has achieves such fine success. Science has its unique and brilliant method. To do along with scientific way is very likely to complete account responsibility. However in recent Japan, those who are regarded as scientists sometimes tell what are not scientific. Instant decision as active fault in nuclear plant by "Nuclear Regulation Committee" is typical, and members seem not to complete account responsibility for utilities and self-governing bodies. But the criticism can be also applied to utilities. Have utilities taken scientific approach and completed account responsibility for an example in problems on RE integration? Among utilities, the author has continued to be scientific. Research fruits have been published as paper with peer review. Peer review is a strong proof that distinguishes those papers from pseudo-science. Announcement by private publishing or technical report without peer review is not validated and sometimes brings useless misleading. Therefore, paper with strong impact must be published as paper with peer review. Although utilities are mainly not sender but receiver of information, they should know the difference between papers (with peer review) and private publishing or technical reports.

Contents dealt in the book are not in high level and not difficult. Ordinary scientists must reach the destinations. Then, why numerous employed scientists cannot reach the destinations before the author? It has been a question for the author long. However recently, it was recognized as possible as follows. That is, employed scientists do not like that now going research theme finishes. More epoch-making the research is, the research becomes higher “destructive creation”, which makes past efforts including outskirts nothing. By “destructive creation”, now going research come to its end and scientists must transfer another theme to live. Considerable effort will be needed. Treatment of employed scientists became worse than ever. Employment with period became ordinary. If the theme finished, extension of employing period may vanish. Therefore, the sense that available time of the theme should be made as long as possible can be understood. But it is national loss. They are non-employed scientists who break such sabotage by employed scientists. Of course, employed scientists oppose to new theories and so on. Contents of the book were also opposed. In Japan, the book may be burned like *Giordano Bruno*. Therefore, this English version is made. In near future, when the country will be in need, these technologies can be reverse-imported. That is *Kurofune* operation. Thus now, the book is uploaded in the author’s site.

3.11 Fukushima 1 nuclear meltdown and JR west Fukuchiyama line derailment brought much poison to society. Even if organization brought artificial disaster for profit-making, nobody is punished. Such punishment operates as deterrent, which is not hoped today. Under such condition it cannot believed that most people support reoperation of nuclear power generation. For people’s support, something such as “organizational disaster punishment law” must be established. In case of 3.11, Higashidori, Onagawa, Hukushima 2, and Tokai 2 nuclear power stations could escape from the tsunami disaster, because they had made various improvements before the disaster. Some reason must exist why only Fukushima 1 went to meltdown. The reason is not explained by organization nor the utility, and all nuclear power station is equally dealt, thus people deny all nuclear power station equally. The author thinks that unique sin of Fukushima 1 must be clarified.

The book is *Cassandra*’s prediction. Prediction never works if the two conditions are not fulfilled. The first is to realize. The second is to be believed. *Cassandra*’s prediction lacked the second condition. Thus, *Troy* lost out to *Greece* and became a ruin. However, even *Cassandra*’s prediction may be believed outside of *Troy*. And ruin of *Troy* may be discovered by *Schliemann*. Really, the *Cassandra*’s prediction is already spreading in the world as US as the first. In near future, it will become new standard of electric power system engineering. Then, for honor of Japanese engineers, the author intends to leave some evidence that these studies ware performed in the past, although the fruits were executed by fire or buried underground. That is a small hope of the author.

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An obscure electric engineer

Shintaro Komami