Energy transition considering power sector reform and RE integration into the grid: Issues, challenges and way forward

Reliable, uninterrupted and quality power supply is the key factors for economic growth of any country and become the government's priority. To meet this requirement, the power sector has grown tremendously over last two decades in the areas of generation, transmission, distribution sector. With a total installed capacity of 395 GW(as on 31st January, 2022), India has transformed from a power deficit (peak) -12.7% in FY 2009-10 to -1.2% in FY 2021-22. Every country throughout the globe has been trying to shift towards the renewable energy (RE) from conventional energy in order to meet the net zero emission target by 2070 in compliance with COP-26 held at Glasgow. In this context, India has set a target of 500 GW RE generation by 2030 and achieved 150 GW RE capacity as on February 2022. This transition of energy sector creates several challenges which need to be addressed for proper integration of RE sources into the grid. In this paper, at first, the background of power sector reform is briefly discussed and the role of each segment (generation, transmission and distribution) in transition of the entire energy sector is also highlighted. The role of Electricity Act 2003 in power sector reform or transition is discussed. Furthermore, various policy issues related to RE and the integration challenges into the grid are also outlined. Moreover, the effect of RE on several power system parameters such as system strength, inertia, rate of change of frequency (ROCOF) etc. are elaborated. In this context, few case studies are highlighted to show the impact of RE integration into the existing grid. Finally, few recommendations are provided to address the RE integration challenges.

Keywords: Energy transition, Electricity Act 2003, RE integration, inertia, rate of change of frequency (ROCOF)

1.0 Introduction

The transition of the energy sector has been seen in order to meet the several objectives such as emission reduction, supply quality and reliable power to all, strengthening of the whole power system covering generation, transmission and distribution. The erstwhile state electricity boards (SEBs) were vertically integrated monolithic entities and with the passage of time as well as expansion of the system, the SEBs become unmanageable and unsustainable. The SEBs also turned out to be loss making entities. The level of accountability and responsibility was difficult to fix. At the same time, it was difficult to pinpoint which segment either generation or transmission or distribution was responsible for incurring the losses. The power supply interruptions were common and the consumers had to face poor quality and shortage of power supply. This degradation in the performance of the SEBs took place gradually over time and ultimately become out of control. However, there were few exceptions also.

As suggested by various studies, it was impressed upon by the government that major reforms should be undertaken in the power sector. The SEBs are unbundled into separate segment like generation, transmission and distribution. Further, to meet the global emission reduction target and to achieve sustainable growth, the emphasis is given gradually on the renewable energy (RE) sector. In this context, several policies, schemes, incentive mechanisms are introduced by the government over the years to promote the RE generation. This resulted in the transition of the power sector from purely conventional fossil fuel based generation into mix energy (conventional+RE) based generation. However, the RE penetration into the grid has created various technical as well as operational challenges. The challenges of RE integration are to be addressed properly in order to maintain the reliable and secured operation of the future RE based greener grid.

2.0 Transition of the grid

The transition of the electric power grid has started after introducing the Electricity Act (EA) 2003 [1]. The objective of the EA 2003 was to promote the competition in the market. Over the last two decades, various technological advancements, regulatory frameworks, government initiatives etc. played a major role in transforming the conventional grid into smart grid (SG). The journey of SG is still continued with the gradual increase of renewable share in the grid.

Mr. Mehebub Alam, Executive Engineer (Electrical), MTPS, DVC. E-mail: mehebubjgec1990@gmail.com

3.0 Reforms in the power sector

The power sector reform in India took place when EA 2003 came into existence. The reform in the power sector was undertaken due to the following factors:

- Huge T&D loss
- Large subsidies
- No proper metering, delayed and defective billing
- No energy accounting
- Poor management, control and size of SEBs
- Lack of clear responsibility and accountability
- Lack of policy reward/punishment/performance

In the pre-reform era, Indian power sector had the following scenarios:

- Power shortage was about 6-7% and peak shortage was about 14-15%
- Half of the population of the country did not have access of the electricity

The power sector reform was done considering the following issues:

- Guidelines for power system development was provided by Central Electricity Authority (CEA). This includes the sizing of power plants, transmission lines, substations, equipment etc. and utility had no option to modify any parameter.
- All the projects were funded by GOI through planning commission. The financial institutions were not very keen to fund the projects due to uncertainty of returns
- Time overrun of the projects was inevitable due to various issues such as procurement delay, lack of standardization
- Maintenance of power equipment and system always received less priority
- Load shedding and power interruptions were very common and taken casually by the utilities
- No authority was empowered to regulate and redress the power consumer grievances legally

After reform, the following changes in the entire power sector have been observed:

- The power network was unbundled into generation, transmission and distribution segment. This brought the financial discipline in the power sector.
- Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commission (SERC) are formed to look into the interstate matter and state matter respectively covering tariff and supply related issues
- Appellate Tribunal of Electricity (ATE) has been empowered to address the legal matters in connection with the power sector such as tariff related appeals/ disputes
- Power trading brought the grid discipline and reliability of power.
- Private players come up in a big way in power generation and transmission sector.

However, the distribution sector by and large is still in the control of state utilities due to low return on investment, deployment of large manpower and public accountability.

- Open access has resulted competitions in the market
- Tariff is determined with transparent manner under section 62 (cost plus basis) and section 63 (competitive bidding) by appropriate commission
- Renewable energy has made a revolution the power sector

4.0 Role of different sectors in transition

The government is committed to provide 24×7 power supply and this necessitates the strengthening of generation, transmission and distribution sector.

4.1 Generation

The following points need to be considered for generation segment augmentation:

- The PLF and consistency of generation
- Domestic coal supply
- Less breakdown of the thermal power plants
- Gas based generation may be bundled with other sources to meet the peak demand
- Emphasis on renewable capacity addition specially for solar and wind energy
- There is need to operationalize existing pumped storage plants and plan for additional capacity addition during next 10 years period to meet the peak demand and manage the variability of RE sources
- With huge penetration of RE, ancillary services like frequency balancing mechanism through gas turbine, hydro plants, pumped storage and emerging cost effective storage technologies are to be promoted

4.2 Transmission

It is important to develop adequate infrastructure to meet the growing energy needs of the different part of the country. Though, all the regions are interconnected, there are persisting congestion problem and corridor bottlenecks constraining the exchange of power from surplus region to deficit region. Insufficient transmission network impacts the market transactions and creates bottlenecks in the flow of power from surplus region to deficit regions and between states. The recommendations for transmission system planning and augmentation are as follows:

- Policy for realistic compensation for land acquisition
- Optimum utilization of existing right of way (ROW) by

constructing multi-circuit lines and upgradation of existing transmission corridor through re-conductoring

- Use of high performance conductor i.e., high temperature low sag (HTLS) needs to be taken up to increase the power transfer capability
- Loadability of the existing system should be increased by adding adequate reactive power compensation, dynamic shunt compensation
- Transmission infrastructure is to be developed at intra state, inter-state and inter-regional levels to evacuate additional capacities of RE and remove the transmission constraints

4.3 Distribution

The poor performance of the distribution utilities is basically due to high aggregate technical and commercial (AT&C) losses. The distribution sector accounts for nearly 20.93% AT&C losses at National level during FY 2019-20. A 10% reduction of losses can augment the supply of electricity by nearly 100 BU. Few recommendations for reform in distribution sector are as follows:

- Installation of HT/ LT capacitors
- Network reconfiguration
- Adoption of high voltage distribution system (HVDS)
- Replacement of overloaded transformers
- Load balancing of distribution transformer (DT)
- DT relocate near load center
- Theft drive
- 100% sealing of meter to avoid any tampering
- Improvement in reactive power of feeder
- Energy accounting transformer wise

5.0 RE integration into the grid: transition and policies

Evolving policies at central and state level have played a major role in building investor confidence. With many barriers and bottleneck in the RE sector, India has been successful in testing and identifying alternate approaches and solutions. Few of these innovative approaches include tariff bundling, payment security mechanism, encouraging solar parks as well as solar wing hybrid parks to improve the utilization factor.

5.1 Pre-2010 scenarios: private sector participation and prioritizing renewables

The unbundling of electricity generation under EA-2003 and mandating the power procurement through competitive bidding under National Tariff Policy (NTP) 2006 were game changing reforms toward increasing private sector investment in power generation. The NTP 2006 permitted DISCOMs to procure RE at tariff fixed by their respective SERCs, also called feed in tariffs (FiTs). The SERCs determined the FiTs based on tariff determination regulations. Central regulation in turn guided these regulations. The CERC notified the first guidelines for tariff determination in 2009 [2].

5.2 Post-2010 policies for solar power deployment

The Introduction of Jawaharlal Nehru National Solar Mission (JNNSM) [3] in 2010 resulted a massive jump in solar capacity addition. The JNNSM was to be implemented in three phases:

- The first phase upto 2013 (target was 1000 MW)
- In second phase 2014-17 (cumulative target was 10000 MW)
- In third phase 2018-22 (target 100 GW including ultra-mega solar power projects)

As a cumulative effect, 50,304 MW solar power capacity has been installed as of February 2022 [4]. The NSM addressed the offtake and payment risks through signing long terms power purchase agreement (PPAs) with project proponents. The payment and offtake risk arose from the higher cost of solar power generations opposed to existing conventional power tariffs and poor financial health of DISCOMs. The JNNSM progressed from FiTs regime to competitive bidding regime and was successful in increasing solar capacity deployment:

5.3 Post-2010 policies for wind power deployment

The competitive bidding also became mandatory for wind power in 2017 [5]. The main objective of these guidelines is to provide framework for procurement of wind power through transparent process of bidding. These guidelines aimed to enable DISCOMs to procure wind power at competitive rate in a cost effective manner. The CERC has introduced new tariff regulations-2020 for renewable energy. These regulations will be effective from 1st July 2020 till 2023. With the implementation of this scheme, specific tariff regulation can be adopted rather than generic tariff regulation keeping in mind the variability of project cost from state to state. Before implementation of reverse bidding, the feed-in rate was about INR 5-6/unit. Tariff rates have been decreased considerably since 2016-17.

5.4 Renewable Purchase Obligation (RPO)

The various policies such as National solar Mission, solar park policy and other incentives were supply side measures. The incentive mechanisms were introduced to reduce the investment risks. However, the need was to create the demand for RE because RE was considerably more expensive than conventional power in 2010. The demand for RE was created through the introduction of the scheme named Renewable Purchase Obligation (RPO) [6]. The NTP 2006 addressed the SERCs to fix the RPOs "taking into account the availability of such resources in the region and the impact on retail tariffs". In the absence of any specific obligation, few states notified the purchase obligations. The initiative takers were Gujarat (2005), Kerala (2006), Rajasthan (2007), and Madhya Pradesh (2008). In 2011, the NTP 2006 was amended - the SERCs shall also reserve a minimum percentage for the purchase of solar energy.

5.5 Post RE integration policies

As the RE generations are intermittent in nature, the integration of RE into the grid has the impact on power quality issues. In India, CEA provide the guidelines to control the power quality when connecting RE into the grid. Clause B of CEA guidelines 2013 talks about "connectivity standards applicable to wind generating stations and generating stations using inverters"[7]. The guidelines covers the following requirements:

- Harmonic current injection shall not exceed the limit prescribed by IEEE 519 [8]
- The generating stations shall not introduce flicker beyond the limit specified in IEC 61000-33-7
- Measurement of harmonic current, DC injection, and flicker shall be done at least once in a year in presence of the parties concerned and the indicative date shall be mentioned in the connection agreement
- The generating stations shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within limit of 0.85 lagging to 0.95 leading

6.0 The impact of RE integration

6.1 System strength aspects

Syste strength [9] basically reflects the sensitivity of the power system variables to disturbances. The RE sources are basically known as inverter based resources (IBRs) which are grid following inverters that require a relatively clean and stable voltage waveform. IBRs take the voltage and frequency reference from the network. Therefore, disturbance to the voltage waveform can result in an unstable response from these inverters. The factors influencing the system strength are:

- Density of inverter based generation: The concentration of multiple IBRs in close proximity of each other
- Scarcity of synchronous generations: Lack of sufficient online synchronous machine support due to either dispatch scenario or retirement
- Sparsity of the network: Remoteness of the area in which IBRs are connected.

The system strength parameters [9] are:

- Short circuit ratio (SCR)
- Weighted short circuit ratio (WSCR)
- Inverter interaction level short circuit ratio (IILSCR)

The most basic and easily applied metric to determine the strength of power system is SCR which is defined as:

$$SCR = \frac{SCMVA_k}{P_{IBRk}} \quad \text{... (1)}$$

Where $SCMVA_k$ is the short circuit capacity at the POI without the current contribution of the inverter-based resource, and P_{IBRK} is the nominal power rating of the IBR. SCR is a measure of the venin impedance of AC system. A low SCR system indicates the high sensitivity of voltage to active and reactive power injection or consumption. Conversely, the high SCR indicates the low sensitivity and therefore implies the system is strong or stiff. SCR is appropriate indication of system strength considering single IBR. However, in case of multiple IBRs, they may interact with each other and oscillate which will affect the system stability. In this regard, WSCR is more accurate metric to evaluate the system strength which is defined as:

$$WSCR = \frac{\sum_{k=1}^{N} SCMVA_k * P_{IBRk}}{\left(\sum_{k=1}^{N} P_{IBRk}\right)^2} \quad \text{... (2)}$$

Where $SCMVA_k$ is the short circuit MVA at k^{th} bus before the connection of IBR and P_{IBRK} is the MW rating of IBR to be connected. N is the number of IBRs fully interacting with each other and k is the IBR index. The WSCR calculation method is based on the assumption of full interaction between the IBRs as shown in Fig.1. This is equivalent to assuming all IBRs are connected at the same point of interest (POI). For a real power system, there is typically some electrical distance between POIs and all IBRs will not fully interact with each other. Further, interaction level short circuit ratio (IILSCR) tracks the amount of power output from the IBRs to reûect the interactions between IBRs. Therefore, equalization of renewable energy resources installed in the vicinity and calculation of the boundaries are not required. The IILSCR is calculated as:

$$IILSCR = \frac{SCMVA_k}{P_{IBRk} + \sum_{m=1, m\neq k}^{N} P_{IBR,m-k}} \quad \text{... (3)}$$

Where P_{IBRK} is the capacity of the IBR installed at k^{th} bus and $P_{IBR,m-k}$ is the inflow from nearby IBRs.

6.2 Inertia

Inertia [10-11] is the first and fastest line of defense after transient period followed by disturbance or contingency event in arresting frequency drops. When sufficient inertia is available, severe frequency drops can be avoided both in terms of ROCOF. As penetration level of IBRs continue to increase and displace synchronous generators in a power system, the inertia will inevitably decline. Worldwide RE rich transmission survey report shows that "decreasing inertia is the most important issue of the modern power system". Low inertia lead to large ROCOF following disturbance. At large ROCOF @2Hz/sec, synchronous generators and IBRs will face synchronization instability [11]. The following points are to be noted:

- There is a critical inertia level below which existing frequency response mechanisms are not fast enough to arrest frequency.

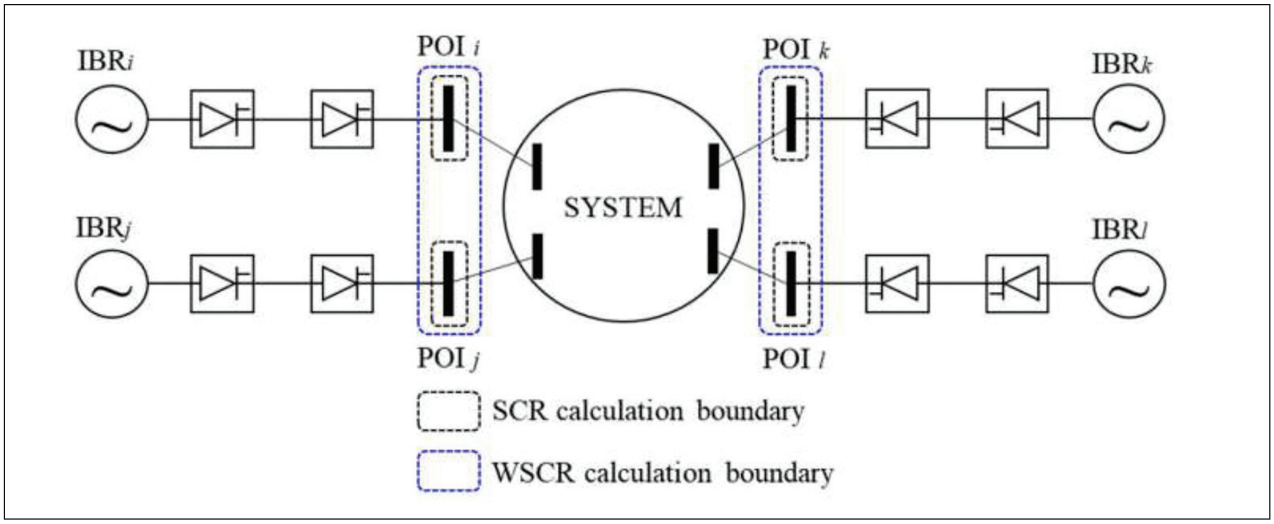

Fig.1: System strength evaluation considering multiple IBRs

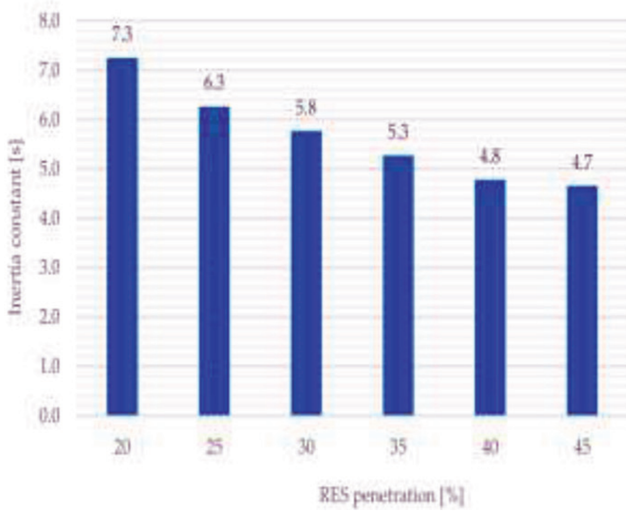

Fig.2: Variation of inertia with RES penetration

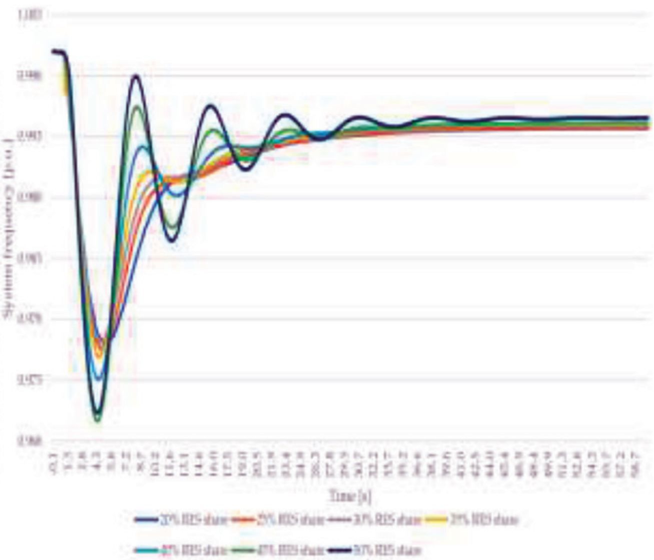

Fig.3: Variation of system frequency with RES penetration

- If system inertia falls below critical value, the system operators have to follow procedures to start more synchronous generators or to consider the ancillary services in order to increase the inertia online (provided regulation permits). The critical inertia level is determined as follows

$$E_{cr} = \Delta P \frac{f_n}{2*ROCOF} + E_{lost} \quad \text{... (4)}$$

Where E_{cr} is the minimum or critical system inertia (MW*sec), ΔP is the worst case multiple contingency (MW), ROCOF is the pre-defined rate of change of frequency in Hz/sec and E_{lost} is the amount of system inertia lost (MW*sec). Estimation of system inertia reduction between 20% and 50% renewable energy source (RES) share is shown in Fig.2. It can be seen from Fig.2 that the inertia reduces linearly as the share of RES share increases.

The estimated system frequency response is shown in Fig.3 from which the following points are concluded:

- As the inertia decreases the rate of change of frequency increases which will have consequences for system protection settings (ROCOF relays).
- Increased frequency nadir may lead to trigger of under-frequency load shedding schemes
- Oscillations increase with the increase of RES share which reduces the system stability as critical modes move toward the y-axis in the complex plane (eigenvalue)

6.3 ROCOF

A direct threat of inertia is large ROCOF [11]. Though inertia limits are not derived yet in India, but ROCOF is already defined with extreme contingencies. This value can be monitored in to ensure adherence to the operational limit as provided from respective authorities. The ROCOF is calculated as:

$$ROCOF = \frac{System\ frequnecy x Active\ power\ lost}{2x(System\ inerta - Inertia\ lost)} \quad ...\ (5)$$

6.4 System non-synchronous penetration ratio (SNSP)

This metric provides the penetration level of RE into the grid. As on date, no regulation is there for limiting the penetration level of RE in India. However, looking into future scenario and impact of RE on system strength and inertia, the SNSP is to be derived. The SNSP will be helpful in system operation, planning and monitoring. The SNSP is defined as:

$$SNSP = \frac{Non\ Synchronous\ generation + HVDC\ Import}{Synchronous\ generation + HVDC\ Export} X100 \quad ...\ (6)$$

SNSP is derived for max RE scenario of Gujarat grid and it was 37% [11]. But as per greening the grid report, SNSP seems to be more than 50% by 2022. Thus, this metric is another crucial tool for system security aspects.

6.5 Case Study

IEEE 39 bus system is used for case study purpose. The conventional generators installed at buses 35 and 36 have been replaced with IBR. The vulnerable buses are selected based on SCR, WSCR and IILSCR. The two different case studies are conducted and summarized in Table 1 [9]. Figs. 4–6 show the response of active power output, reactive power output, and voltage magnitude in time-domain dynamic simulation following a fault in the system. It can be seen for case 1, with IILSCR 3.33, the oscillations are recovered after fault. However, for case 2 with IILSCR 2.64 the oscillations are persisting after fault. It can be concluded that large IILSCR assists the system in achieving the stable operating point.

6.6. Recommendation

Synchronous condensers are generally effective means of improving system strength due to inherent characteristics like inertia, heavy rotating mass, dynamic reactive power compensation, ride through capabilities, excellent short circuit support etc. A typical example [11] of the synchronous condenser application in the weaker (wind based IBR

Table 1: Comparison of various parameters for two cases

Case	Bus no.	SCC MVA	IBR capacity (MW)	SCR	WSCR	Inflow from nearby IBRs (MW)	Total IBRs inflow (MW)	IILSCR
Case 1	35	2127	531.6	4	2	-	531.6	4
	36	1624	405.9	4		81.5	487.4	3.33
Case 2	35	2127	708.8	3	1.6	-	708.8	3
	36	1624	541.2	3		73.6	614.9	2.64

Table 2: Comparison of various parameters for two cases

Wind Farm	GETCO grid susbstation	SC MVA	Connected IBR(MW)	Without synchronous condensor		With synchronous condensor	
				SCR	WSCR	SCR	WSCR
Lamda	132 KV substation	998	22.5	3.69	4.53	8.69	5.53
Navdra			21.6				
Bhogat			204.6				
Gandhavi			22.1				

Table 3: Comparison of various parameters for two cases

Attribute	Actual system inertia (GW*sec)	ROCOF(Hz/Sec) w/o synch condensor	ROCOF (Hz/Sec) withsynch condensor
Max wind 9 Aug	136	0.374	0.371
Max demand 11 June	146	0.356	0.353
Max demand 20 July	155	0.323	0.320
Max demand 30 Oct	130	0.394	0.391
Max demand 20 15 Sept	141	0.371	0.368

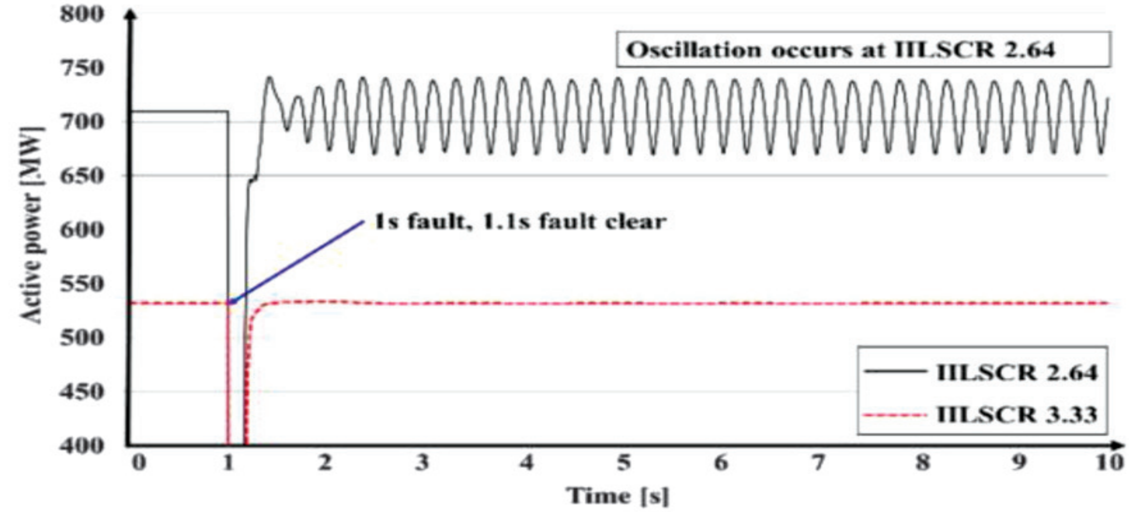

Fig.4: Active power variation at bus 36 following a fault in IEEE 39 bus test system

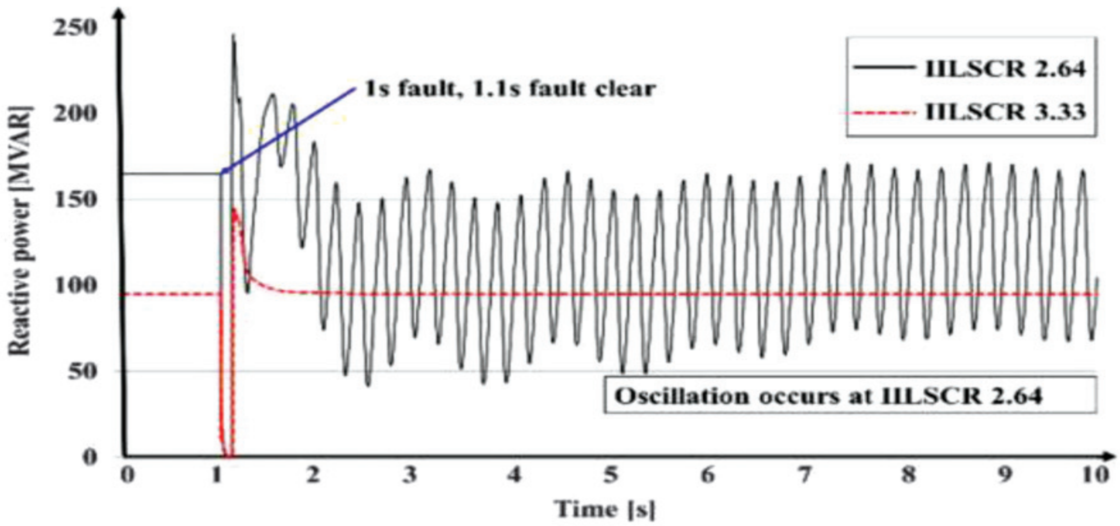

Fig.5: Reactive power variation at bus 36 following a fault in IEEE 39 bus test system

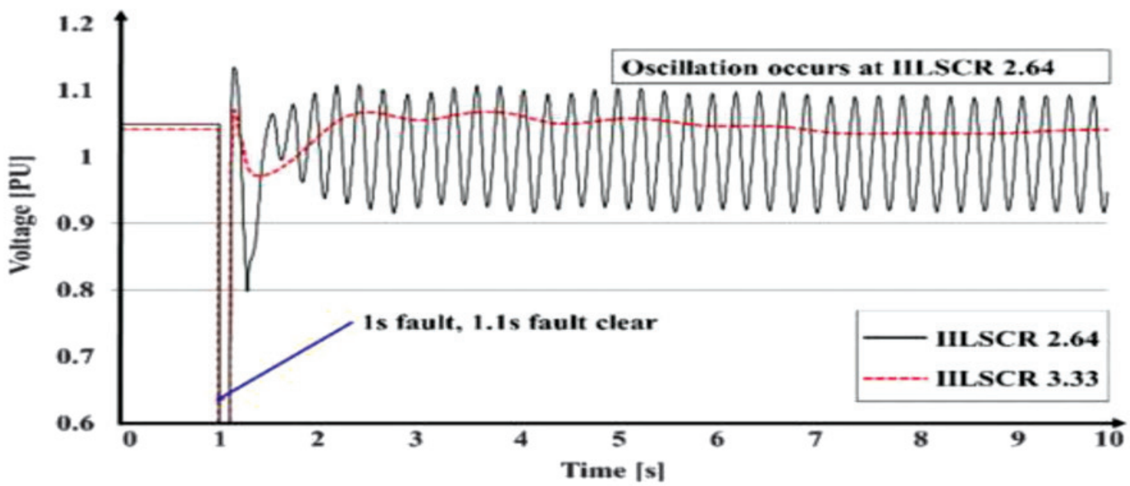

Fig.6: Voltage variation at bus 2 following a fault in IEEE 39 bus test system

penetrated area) part of the Gujarat Electricity Transmission company (GETCO) grid is shown in Table 2 and it is observed that SCR as well as WSCR are improved. Further, the improvement of ROCOF with synchronous condenser is presented in Table 3 which implies the improvement of 0.003 Hz/Sec ROCOF.

7.0 Conclusion

Indian power sector observed a paradigm shift since last two decades in each sector covering generation, transmission and distribution segment. Further, the power sector has moved from conventional based generation to mix energy based generation. In this context, India has a very optimistic target of 40% contribution from RE by 2030. In this regard, very rapid integration of RE is being taken place in India. The Gujarat is found to be most progressive state in RE integration with 34% share to the total capacity of Gujarat. Several milestones we have achieved during the transition of energy sector. However, there are so many things such as introduction of new flexible policy framework, minimizing forecasting and scheduling errors, latest technology implementation are the prime requirement to ensure the stable and reliable operation of future RE rich power grid. The real time monitoring of the system strength, inertia, ROCOF etc. are also be considered to maintain the grid stability. In this context, the government, stakeholders and various utilities should come forward and work together for seamless transition of the conventional grid into the RE rich greener smart grid.

References

1. The Electricity ACT 2003, available: http://cercind.gov.in/Act-with -amendment.pdf
2. CERC Terms and conditions of Tariff regulations-2009, available: http://cercind.gov.in/2016/regulation/2.pdf
3. Jawaharlal Nehru National Solar Mission (JNNSM), Ministry of power, GOI
4. Power sector at a glance ALL INDIA, available: http://powermin.gov.in/en/content/overview
5. Guidelines for tariff based competitive bidding: Ministry of power, available: http://mnre.gov.in/wind/schemes.pdf
6. Shah et al., “Renewable energy policies and regulation in India” Proceeding of the conference on power reforms, 25-26 May, Gujarat, 2022.
7. Central Electricity Authority of India, Notification 15th December 2015
8. IEEE standard 519TM-2014 “IEEE recommended practice and requirements for harmonic control in Electric Power Systems”
9. Kim et al., “Evaluating influence of inverter based resources on system strength considering inverter interaction level” *Sustainability*, Vol. 12, pp. 1-18, 2022
10. POSOCO report- assessment of inertia in Indian Power System-January 2022
11. A.J. Chavda and N.M. Sheth “Impact of large scale renewable on system strength and inertia-emerging tools and techniques for analysis, monitoring and maintaining stability& reliability of RE rich greener grid” Proceeding of the conference on power reforms, 25-26 May, Gujarat, 2022.

(Continued from page 216)

LIST OF SPECIAL NUMBERS PUBLISHED (1952-2019)

65. ADB-Assisted Power & Irrigation Projects (1988)
66. Power - 1987 Annual Review (1988)
67. Optimum use of Hydroelectric Resources (1989)
68. Power - 1988 Annual Review (1989)
69. Ramagundam Super Thermal Power Project II (1989)
70. Sardar Sarovar Narmada Project (1990)
71. Recent Technique in Thermal Power Plant Construction (1990)
72. Power - 1989-90 Annual Review (1990)
73. Power Development in Orissa (1991)
74. Power - 1991 Annual Review (1991)
75. Hydro Power Development (1992)
76. Power - 1992 Annual Review (1992)
77. Barrage & Dam Construction: Equipment, Materials and Practice (1993)
78. Power - 1993 Annual Review (1993)
79. Chamera Hydroelectric Project (1994)
80. Development in Nuclear Power Generation in India (1994)
81. Power - 1994 Annual Review (1994)
82. 45th Anniversary Numnber (1995)
83. Gas Turbine and Combined-Cycle Power Systems (1996)
84. Power Development in Gujarat (1996)
85. DVC Special Number (1996)
86. Power –1996 Annual Review (1996)
87. Hydropower Development (1997)
88. Special issue on NTPC (1997)
89. Power–1997 Annual Review (1997)
90. Special issue on PowerGrid (1998)
91. Power–1998 Annual Review (1998)
92. Special Issue on ONGC (1999)
93. Hydropower Development in South-East Asia (1999)
94. 100 Years of Thermal Power Generation in India (1999)
95. Coal for Power Generation: Issues Management vis-a-vis Quality (2000)
96. NTPC Projects Number (2000)
97. NHPC - A Success Story (2000)
98. Karnataka Power Corporation Ltd - Major Strides (2000)
99. Golden Jubilee Number (2001)
100. Special issue on GAIL (2001)
101. Power – 2001 Annual Review (2002)
102. Power Development in West Bengal (2002)
103. Accelerated Hydropower Development (2003)
104. Nathpa Jhakri Project Number (2004)
105. India’s Energy Vision to 2030 (2004)
106. Power – 2003 Annual Review (2004)
107. Parbati Hydroelectric Stage II (2005)
108. Power Development in Rajasthan (2005)
109. Power Development in Punjab (2005)
110. Powergrid - A Success Story (2005)
111. Power – 2005 Annual Review (2005)
112. Dhauliganga HE Project (2006)
113. Electricity–The Energy Carrier for the Present & Future (2007)
114 Hydropower Development (2007)
115 Power – 2007 Annual Review (2008)
116 Special Issue on NEEPCO (2009)
117 Power – 2009 Annual Review (2009)
118 Hydropower Development (2010)
119 Power – 2011 Annual Review (2011)
120 Water Energy & Climate: Towards a Sustainable Global Future (2014)
121 OTPC – a success story (2018)
122 Thermal power generation: Challenges Ahead (2019)