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Methodology to Solve Severe Load Curtailment at Pakistan's Wind Corridor and Cost Effectively Utilizing Maximum Wind Energy

Saddam Hussain[1*], Sonia Bibi[2], Farzana Rauf Abro[3] and Irfan Ahmed Halepoto[3]

[1]National Power Control Center, NTDCL, Pakistan; saddam@ntdc.com.pk
[2]Pakistan Tele Communication Limited, Pakistan
[3]Department of Electronic Engineering, Mehran UET, Jamshoro, Sindh, Pakistan

Abstract

From lightening a house to functionalizing industry energy plays a significant role. Generating energy is not the only issue but generating and then utilizing it appropriately is the main issue. From 2011, Pakistan has shifted its sight on renewable energy to cut its power starved national grid's dependency from fossil fuel power plants. Since then a number of solar parks and wind power plants have been initiated and few of them are already operational. Focusing just on wind energy, by August 2016 total six wind power plants are fully functional capable of producing 300 MW of generation as per availability of wind. But this 300 MW of wind energy is facing regular load curtailments due to overloading or unavailability of the dispatch circuits. There are ups and downs in generating energy depending upon the speed of wind. In this paper, impacts of generating energy when wind speed is normal that is 7 meter per second and when it is at maximum have been discussed and analyzed accordingly. The maximum dispatch generation capacity at the national grid is not more than to 259 MW. When the generation is a lot more than that of the capacity of lines then this extra generation is wasted deliberately. This research suggests the solution to these current circumstances at the wind corridors. Number of solutions have been introduced like constructing 220 kv grid station, upgrading existing 132 kv THT-SJW-BSK-TMK(O)-TMKR, all SLM lifted at wind corridor and connected circuit or constructing direct circuitry in between Jhampir and TM Khan Road with a capacity of 400A while the other in between Nooriabad and Jamshoro New with the capacity of 500A. After comparing and analyzing all the solutions constructing two 132kv transmission lines between Jhampir and Thatta and other between Nooriabad and Jamshoro New is the best solution.

Keywords: Common Dispatch Point, Independent Power Producers, Scheduled Load Management

1. Introduction

On 18th June, 2016, Pakistan's National Grid achieved a national record of 17,272 MW of generation at 1915 hours[1], still lacking to fulfill the national power demand of 19,000 to 20,000 MW. To overcome this shortfall the Government of Pakistan has diverted its attention towards renewable power sources (i.e. Wind, Solar, Hydro) as 70% power of the national system depends upon imported fossil fuels that strains the financial position of the country[2]. The Ministry of Water and Power has stated that, "Pakistan has 1,046 km coastline in Sindh and Baluchistan available for the purpose of Wind Power Plants", whereas wind projects are only being installed in Sindh's 9,700 sq. km with an average wind speed of 7 meter-per-second round the clock. A report from Pakistan Meteorological Department estimates the potential of wind power to be around 43,000 MW, with the electric power generation that can be exploited being around 11,000 MW[3]. Presently, six wind power plants are operating two near

**Author for correspondence*

Thatta and four near Jhampir each of 50MW of installed capacity whereas two more are expected to be added later in 2016 while five more could possibly join the wind corridor by the start of 2017 but as stated in the latest report by NEPRA that Pakistan's Transmission line system is incapable of drawing maximum power out of IPPs. For that purpose this paper would cover all the present status of wind corridor, the amount of power produced, the amount of power successfully added to the national grid through CDP points, the amount of wind power dispatched to consumer grids before adding the remainder to the national system, the number of restrictions on wind power exerted by the National Power Control Center (NTDC) due to failure to conduct the wind power cause of unavailability of transmission lines and the other technical problems existing in the wind corridor and its possible solutions. Doing this, it is mentioned that this paper covers and answers only to the issues existing in the present setup, all the future projects are out of its scope. This paper is based on an analysis of the current situation of wind corridor and methods to improve the transmission of power generated by the existing operational wind power plants.

2. The Wind Corridor Analysis

Presently in Pakistan, Sindh's 9,700 sq.km of area comprising between Tando Mohammad Khan, Jhampir, Thatta, Gharo, Mirpur Sakro and Nooriabad has been declared as the wind corridor as this cluster of land provides with average wind speed of 7 to 8 meter-per-second which could rise to as good as 13 meter-per-second and higher in the better part of the year. As of August, 2016 six wind power plants are fully functional namely: Foundation Wind Energy Limited-I (FWEL-I), Foundation Wind Energy Limited-II (FWEL-II), Zorlu Energy Private Ltd (ZEPL), Fauji Fertilizer Company Energy Ltd (FFCEL), Three Gorges Wind Farm (TGF), Sapphire Wind Farm (Sapphire) each of approximately 50 MW of installed capacity making it a total 300MW of wind power generating cluster while Metro Wind Power Plant and Yunus Wind Power Plant also of 50 MW each are soon expected to join the wind brigade making it a total of 400 MW. The sources to which this 300MW of load cluster is connected are 500 kV Jamshoro New (JMSN) and 220 kV Tando Mohammad Khan Road (TMKR) Grid Stations. For acquiring proper grasp we should examine the single key diagram in Figure 1.

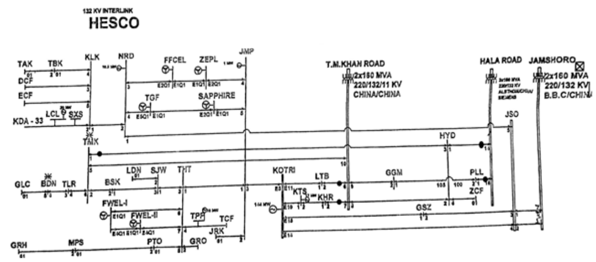

Figure 1. Single line key diagram of 132kv HESCO interlink at Wind Corridor.

Table 1 demonstrates the maximum loads of the consumer grids connected to the wind corridor, considering the fact due to theft of electricity and failure of bills recovery.

Table 1. Evaluated load of HESCO Consumer grids

S. No	Grid	Maximum Load without SLM	Maximum Load without SLM	Impact C.B of Wind corridor
1	Jamshoro old	28 MW	20 MW	JSO-5,E5/E7 (Jamshoro new)
2	Latifabad	56 MW	52 MW	E-11 (KTR-12) at Kotri P/H
3	Nooriabad	15 MW	10 MW	NDR- 3/4
4	Jheruk	01 MW	0.5 MW	
5	Thatta	22 MW	20 MW	THT-1/3
6	Bulri Shah Karim	10 MW	08 MW	THT-3
7	Gulshan Shahbaz	18 MW	15N MW	E5/7 (Jamshoro new)
8	Kohisar and Kotri site	60 MW	58 MW	E-10 (KTR-1) at Kotri P/H
9	Jhampir	10 MW	08 MW	E-5 (KTR-9) at Kotri P/H
10	Thatta Cement and Thatta Power Plant	02 MW	01 MW	
11	PirPatho, Mirpur Sakro, Garho	10 MW	9 MW	THT-3
12	Sajawal, Ladiun	10 MW	08 MW	THT-3
Total		242 MW	209.5 MW	

Table 2. Rated current carrying capacity and their restricted capacity along with the length of conductor of essential transmission lines at wind corridor[5].

S. No	Transmi-ssion line	Conductor length	Rated capacity	Restricted capacity	Restric-tion cause
1	132kV KTR P/H-JMP	60 Km	388/488 A	400A (80 MW)	Deterio-rated
2	132kV JSO – JMSN D/C	05 Km	330/488 A	350A (70 MW)	Deterio-rated
3	132kV NRD-JSO	41 Km	700 A	500A (100MW)	CT ratio issue
4	132kV THT-JMP	40 Km	330/488 A	225A (45 MW)	Severely Deterio-rated
5	132kV THT – SJW –BSK TMK (0) TMKR	179 Km	300/400 A	250A (50 MW)	Severely Deterio-rated
6	132kV KTR P/H-KTS (Radial)	6 Km	330/400 A	300A (60 MW)	Lower CT ratio
7	132kV KTR P/H-LTB (Radial)	10 Km	300/400 A	500A (100MW)	Lower CT ratio

Here, it could be seen that although the rated capacity of the installed conductors is way too much but the authorities who control these lines have imposed restrictions that reduces operational capacity of many lines to half of the rated capacity. As the load increases from the restricted capacity, these lines trip and many times result in the cascaded tripping of the interconnected circuits as well. While in case of 132 kv NRD-JSO line although the circuit is of superior capacity but failure to install a CT of higher turn ratio with the circuit breaker is the cause of not utilizing circuit's maximum capability same goes with 132 kv KTR P/H – KTS and 132kv KTR P/H – LTB transmission lines which are normally operated radically. A reason to utilize these lines radically is due to a limit of 300A cause of lower CT ratio. Apart from the restrictions imposed by the controlling authorities the behavior of the all above lines must be studied as well.

2.1 Power Flow at Wind Corridor

Figure 2 illustrates a single-line key diagram provided by NPCC during a normal day with moderate wind speed provides an insight of how power flows when wind speed is around 7 to 8 m/sec.

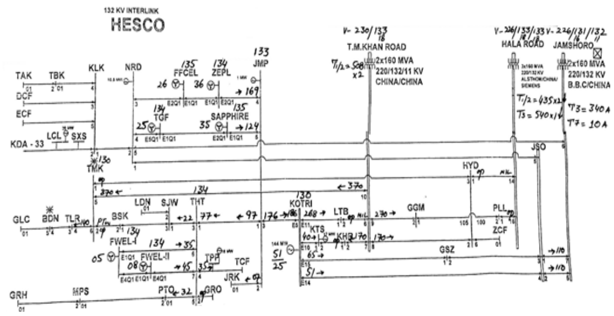

Figure 2. Single line key diagram of 132 kv HESCO Interlink at wind corridor with average wind speed of 7 to 8 m/sec[6].

Some points to be considered from the above mentioned power flow diagram and status of wind power plants is as under:

Plant	Capacity	Comments
FWEL-I	05 MW	(45 MW below its rated capacity)
FWEL-II	08 MW	(42 MW below its rated capacity)
FFCEL	26 MW	(24 MW below its rated capacity)
ZEPL	36 MW	(14 MW below its rated capacity)
TGF	25 MW	(25 MW below its rated capacity)
Sapphire	35 MW	(15 MW below its rated capacity)
GTPS Kotri	51 MW	(58 MW below its operational capacity)

So, as the above power flow from NPCC record the total generation at the wind corridor is 186 MW whereas the unavailability of power due to low wind speed and low gas quota in case of GTPS Kotri results in a loss of 223 MW of generation that could be produced in the studied region. On the other hand loading position of the essential transmission lines connecting wind corridor to national grid is as under:

Feeder	Capacity	Comments
132Kv KTR P/H – JMP	186 A	can withstand 214 A more
132Kv JMSN – JSO D/C	110 Ax2	can withstand 240x2 A more
132Kv THT – SJW	22 A	can withstand 228 A more
132Kv KTR P/H – LTB	268 A	providing radial power to LTB
132Kv KTR P/H – KTS	40 A	providing radial power to KTS

Interesting fact must be noted here is that generation at wind corridor being at 45.4% of its capable output. 132 kv KTR P/H–JMP is already at half of its restricted limit. Before diving to a conclusion we must look at the condition when wind generation is at maximum. Now in Figure 3, a single-line key diagram provided by NPCC during a day with good wind speed helps to study power flow when wind speed is around 11 to 12 m/sec.

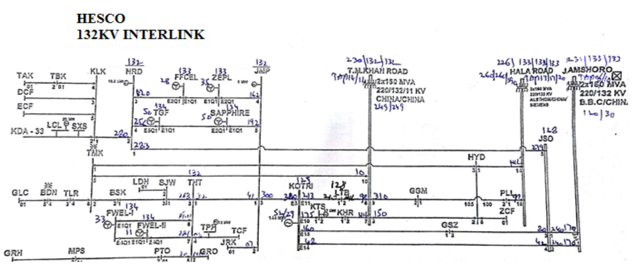

Figure 3. Single line key diagram of 132 kv HESCO Interlink of Wind Corridor at the average wind speed around 11 to 12 m/sec[7]

If the same analysis be carried out, the condition is as:

Feeder	Comments
FWEL-I	33 MW (17 MW reduced due to overloading on THT-3)
FWEL-II	11 MW (39 MW reduced due to overloading on THT-3)
FFCEL	28 MW (22 MW reduced due to overloading on THT-3)
ZEPL	35 MW (15 MW reduced due to overloading on THT-3)
TGF	50 MW (at maximum)
Sapphire	50 MW (at maximum)
GTPS Kotri	52 MW (57 MW below its operational capacity)

Status of connected transmission lines are as:

Feeder	Comments
132Kv KTR P/H – JMP	380 A, can withstand 20 A more
132Kv JMSN – JSO Double Circuit	170 A x 2, can withstand 180x2 A more
132Kv THT – SJW	263 A, 13 A more than the given restriction
132Kv KTR P/H – LTB	213 A, providing radial power to LTB
132Kv KTR P/H – KTS	175 A, providing radial power to KTS

Flow diagram given in Figure 5 has been taken at 2000 hrs, 29 May 2016 as it is considered as the optimum time to analyze the system because the system load is usually at peak value during this time. Also wind speed was at maximum as well with respect to generation. With such conditions a logical assumption could be made that at the moment of this power flow wind corridor could have provided maximum generation to power starved national grid but it could not. With the above stated setup only 259 MW that is 63.3% generation of the Wind Mills and GTPS Kotri could be utilized and added to the system, losing out to 150 MW of further power that could have been possibly added to the system. The status of the transmission circuits also show that 132 kv THT – SJW line is operating above the restricted load which could trip at any time if the overloading is not resolved, resulting in further possible generation reduction as it is the only way to get rid of this problem. 132 kv KTR P/H – JMP circuit is also operating at 95% of its rated capacity which according to HESCO authorities is considered severely overloaded too. In the present setting if THT-3 (132 kv THT-SJW) line trips the entire load of the line would rush towards 132kv KTR P/H–JMP line, with no margin of carrying any further power it would trip too and might cause a further cascaded tripping till the CDP points. By looking at 132 kv JMSN – JSO double circuits as it shows quite nominal margin to carry further load but the entire flow of current could not be concentrated on these circuits without opening the other lines (opening THT-3) which would definitely cause lower stability as the connection with other CDP point (i.e. 220 kv TM Khan Road) would be lost.

3. Findings from Power Flow Diagrams

Following findings could be concluded from the power flow taken at the peak load time on a hot summer day with maximum wind speed. Only 259 MW (63.3%) of generation from the available 409 MW could be utilized. Out of four most essential circuits connecting these IPPs to the CDP points, two of them were founded severely overloaded i.e. 132 kv THT – SJW and 132 kv KTR P/H–JMP transmission lines. Overloaded lines may trip any time due to their poor performance under loaded conditions which might cause cascaded tripping of the entire wind corridor. Presently load has been curtailed at four out of six wind plants which obligate the state authority to refund them some amount percentage as penalty per unit loss as settled down in their contract.

4. Proposed Methods to Solve Problems Outlined at Wind Corridor

To eliminate these problems from the system few methods are devised, if implemented these solutions could increase the system's ability to draw more power from the wind corridor. Every method provided here has its own pros and cons, which would be discussed thoroughly and a choice would be made at the most suitable trade off.

4.1 To Construct a 220 kV Grid Station to Regulate all the Wind IPPs

The advantages includes: Efficient dispatch of the wind generation. Addition of another CDP point to the national grid. Less number of tripping due to fog and humidity as frequency of momentary tripping on 220 kv side is much lower than the 132 kv side. Long term solution as a 220 kv grid would be capable of facilitating more wind power stations in future as well. The disadvantages are: Very high initial cost required. Construction time is longer, requires approval of several higher state authorities, additional auto-transformers and 132 kv line for dispersal of load to the consumer grids.

4.2 All Scheduled Load Management (SLM) must be lifted at the Wind Corridor and the Connected Circuits

The advantages will be Power flow at 132 kv side could be easily predicted and therefore could be controlled more effectively. Least reduction of generation would be required as the generated load could easily be consumed at 132kv side round the clock. All six wind IPPs can operate on maximum most of the time. The disadvantages can be considering the present condition of Pakistan, lifting all SLM around the wind corridor is highly unlikely. As the area connected is mostly categorized as "High-Loss Area" where maximum load-shedding is carried out due to extremely low bill recovery leaving aside electricity theft which is a household norm. Figure.6 presented below from Energy Unit SDPI projects the line losses in the HESCO area where wind corridor is situated. It could be easily seen that line losses tolls up to 30-35% which makes lifting of load-shedding impossible.

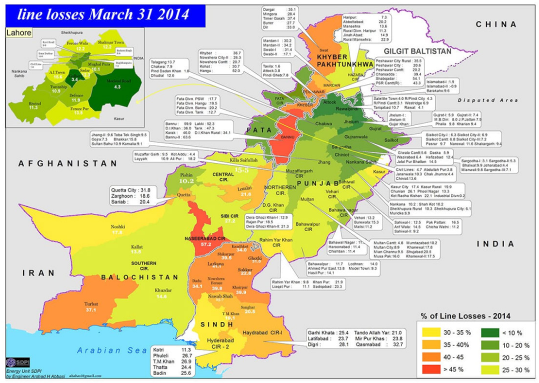

Figure 4. Map provided by SDPI energy unit to provide status of Line Losses in Pakistan as of 2014.

4.3 Upgrading Existing 132Kv THT-SJW-BSK-TMK (O)-TMKR Transmission Line Complete Section: Which Is Restricted To A Load Carrying Capacity of 250 A (50 MW) rather than 400 A (80 MW) which is the Normal Capacity of a 132 kv Transmission Line

It might come to mind that replacing the deteriorated conductor could solve the problem as the restriction on current carrying capacity would get lifted. Let's view this option as well. The advantages can be: After upgrade the transmission line would be able to conduct 150A (30 MW) more of wind generation, which could not be utilized presently. The advantages can be: High construction or upgrade cost as the entire transmission line segment is 179 km ± 10 km long which is quite a high bargain just to get 150A (30 MW) more. Most of the transmission line would still be present in the high fog/humidity zone, keeping it open for the increases number of tripping.

4.4 Constructing two 132 kV Transmission Lines i.e. 132 kV Jhampir-T. M. Khan Road T/L with Capacity of 400A (80MW) and 132 kV Nooriabad-Jamshoro New T/L with Capacity of 500A (100 MW)

The advantages are: construction of the above mentioned transmission lines would add current carrying capacity of the wind corridor. These both circuits would provide us the option to connect with two CDP points resulting in higher stability. Conjoining the length of both transmission lines the length of the conductor would still be lesser than the length of 132 kv THT-SJW-BSK-TMK(O)-TMKR transmission line(s) section which was 179km ± 10km, whereas the length of the conductor for both the circuits could be given as:

132 kv JMP – TMKR = 70 km ± 5 km
132 kv NRD – JMSN = 65 km ± 5 km
Total = 135 km ± 10 km

Both the proposed circuits would also allow avoiding treacherous fog/humidity area. As the far ends of both the circuits i.e. 500kv Jamshoro New and 220kv TM Khan Road are situated in low fog/humidity area even in the extreme conditions.

5. Discussion and Conclusion

From all the proposed options building two circuits i.e. 132 kv JMP – TMKR and 132 kv JMSN – NRD transmission lines would add 180 MW (900A) more capacity which should allow maximum dispersal of the wind generation in the present condition. With a direct connection from 132 kv Jhampir grid station to 220 kv TM Khan Road the load from 132 kv KTR P/H–JMP line would get divided equally and along with providing excess carrying capacity would also resolve the overloading condition of 132 kv KTR P/H–JMP line. A LYNX conductor can do the task fine as it would provide with at least 400A of the current holding capacity which is same to 132kv JMP-KTR P/H circuit. The other circuit to be constructed is 132 kv NRD – JMSN because the entire load of four wind IPPs (i.e. FFCEL, ZEPL, TGF, Sapphire) rush towards two grid stations one at 132 kv Jhampir and second at 132 kv Nooriabad grids. From there only two circuits (one circuit at each grid) from both grids dispatch this generation towards CDP points. As we doubled the dispatch circuit at 132kv Jhampir similarly we need to add another circuit from 132 kv Nooriabad towards the nearest CDP point (i.e. 500 kv Jamshoro New) so that overloading of 132 kv NRD – JSO line could be avoided as it is the only circuit connecting wind IPPs towards 500 kv Jamshoro end. The reason why E7 and E5 at Jamshoro New shows a margin of additional load is because the generation coming from 132 kv Nooriabad grid through a single circuit (i.e. 132 kv NRD–JSO) gets equally divided on E5 and E7 at JMSN. To resolve this issue a 132 kv NRD–JMSN transmission line must be constructed so that the load on this circuit could be divided equally as well. A RAILE conductor with a capacity as same of 132 kv NRD–JSO line must be installed and a C.T. with higher ratio must be provided on both circuits so that maximum capacity of the conductor could be utilized. Despite of being 700A of rated capacity 132 kv NRD –JSO is being operated with a load restriction of 500A.

By implementing this procedure maximum available power could be easily drawn from the wind power plants and GTPS Kotri and dispersed to the national grid, SLM conducted by HESCO to overcome line losses would not be affected, increased stability would be provided to the wind corridor and flexibility to shift load and manage the power flow could be attained.

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