A Monitoring System Development for a new-type of Korean FNET

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Abstract—**As the scale of power systems has become larger, intelligence for wide-area protection has been required. Among these, the frequency monitoring network (FNET) has been an important rule. Many PMUs (phase measurement unit) have been developed for wide-area protection, but a frequency-based one has not developed yet. In this paper, a monitoring system development for a new-type of Korean FNET is introduced. Simulation results are given to show the validation of the proposed system.**

Keywords; Frequency Estimation, Frequency Monitoring Network, Frequency Monitoring System

I. INTRODUCTION

There is an increasing importance of constant monitoring to achieve stable power supply. A power monitoring system monitors power system status based on real-time compilation of data acquired by various sensor elements installed on power transmission line(T/L) and facilities[1]. The power frequency is an important operating parameter of a power system. Due to the sudden change in generation and loads or faults in power system, the frequency is supposed to deviate from its nominal value. It is essential that the frequency of a power system be maintained very close to its nominal frequency. As well, it is very significant to the frequency and frequency deviation for special applications such as generator protection, synchronism checking, load shedding frequency protection relays, and volts per Hertz relay. Thus, frequency measurement device and frequency estimator should be fast and accurate in determining of frequency of power system. Accurate monitoring of the power frequency is essential to optimum operation and prevention for wide area blackout[2,3], too. Recently, time synchronized frequency estimation methods for GPS-based FNET(Frequency Monitoring Network) and GPS(Global Positioning System)-based PMU(Phasor Measurement Unit) have been attracted[4-8].

In this paper, a monitoring system development for a new-type of Korean FNET is introduced. We propose a new network-based frequency monitoring system using frequency estimation technique based on phasor angle difference algorithm for wide-area protection and control[9-11]. The Power system model, real 765[kV] T/L, is simulated by the EMTP-RV program. We used the voltage signals, which were sampled with 720[Hz] per cycle obtained from EMTP-RV simulation[12]. The frequency monitoring S/W was implemented using VS 6.0.

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This paper is organized as follows: In section II, we describe frequency estimation technique using DFT filter based phasor angle difference algorithm. In section III, the power system model used for the simulation is described. In section IV, the developed frequency monitoring system for a new-type Korean FNET is presented, followed by the conclusions.

II. FREQUENCY ESTIMATION TECHNIQUE

Consider that frequency response of the DFT filter can be expressed by equation (1).

$$H(Z) = \sum_{k=0}^{n-1} V_z Z^{-k} \tag{1}$$

For extraction of fundamental frequency component using DFT filter, the real and imaginary parts computed using samples corresponding to n-th data window can be used to represent the signal in phasor form by equation (2).

$$\overline{V_n} = V_{rn} + jV_{in} \tag{2}$$

Where V_{rn} and V_{in} are the real and imaginary parts computed using samples from the *n*th data window. Similarly, V_{rn+1} and V_{in+1} are the real and imaginary parts computed using samples from the *(n+1)*th data window.

Fig.1 depicts the fundamental frequency phasors corresponding to *n*th and *(n+1)*th data windows. As can be seen from Fig.1, The phase angle difference $(\theta_{n+1} - \theta_n)$, equation (3), represents the rotation of the phasors as data window is advanced by one sample.

$$\theta_{n+1} - \theta_n = \tan^{-1}\left[\frac{V_{rn}V_{i(n+1)} - V_{in}V_{r(n+1)}}{V_{rn}V_{i(n+1)} + V_{in}V_{r(n+1)}}\right] \tag{3}$$

Finally, estimation frequency can be obtained by equation (4).

$$f = \frac{\theta_{n+1} - \theta_n}{\dfrac{2\pi}{F_s}} \tag{4}$$

Where F_s is the sampling frequency.

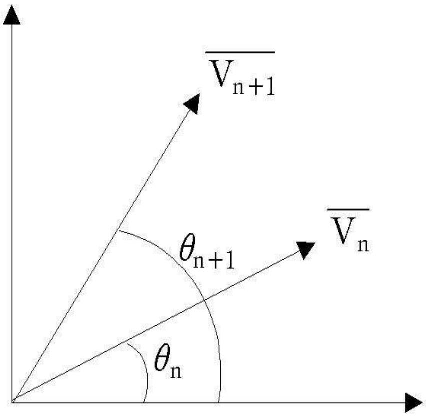

Figure 1. Fundamental frequency phasors corresponding to *n* th and *n+1* th data windows

III. POWER SYSTEM MODEL[12]

For an evaluation of the implemented frequency monitoring S/W, the voltage signals were used. The voltage data were obtained from EMTP–RV simulation sampled with 12[S/C]. The 765[kV] T/L system in Korea is simulated by EMTP-RV. Fig. 2 shows the power system model used for the simulation.

The modeling for the governor and exciter of Uljin N/P and Dangjin T/P were obtained based on real data, and T/L between Shin-gapyung and Shin-ansung was simulated based on the places where the construction will be done. From the 765[kV] T/L system as shown in Fig. 2, voltages were measured of six regions (Dangjin, Shin-seosan, Shin-ansung, Shin-gapyung, Shin-taebaek, and Uljin). All the frequencies are estimated from the measured voltage data as shown in Fig. 2, and each frequency for local area is analyzed using the monitoring S/W. Fig. 3 shows the simulated EMTP voltage data of the power system model.

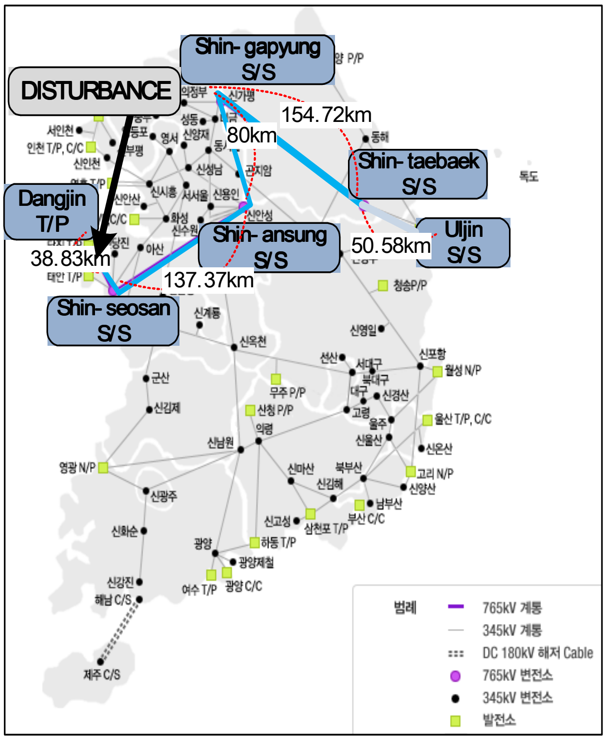

Figure 2. Power system model of EMTP-RV used for the simulation

	A	B	C	D	E	F	G	H
1	시간(s)	당진	신서산	신안성	신가평	신태백(앞단)	신태백(뒷단)	울진
2	19.96643	215832.79	495031.07	532420.28	523154.88	206269.3	158585.52	459428.88
3	19.96782	102813.45	263720.86	363348.32	355880.5	106914.14	21822.252	240344.42
4	19.96921	-38013.927	-38919.321	95996.511	92344.964	-21360.571	-120845.79	-43751.55
5	19.9706	-168560.18	-331034.06	-197320.25	-196166.26	-143854.43	-230820.93	-316006.55
6	19.97198	-253516.04	-533612.99	-437263.11	-431611.95	-227431.31	-278350.03	-502772.3
7	19.97337	-269902.47	-591861.61	-558929.5	-550304.92	-249483.01	-250574.04	-553527.29
8	19.97476	-213286.43	-490022.86	-529408.98	-520139.31	-204045.03	-155006.88	-454543.33
9	19.97615	-98980.485	-255640.45	-356685.95	-349275.43	-103409.87	-17502.84	-232598.9
10	19.97754	42098.304	47890.077	-87480.647	-83932.703	25198.353	124737.99	52265.04
11	19.97892	171790.52	338467.96	205387.84	204112.44	146988.52	233233.68	322987.14
12	19.98031	255015.82	537494.26	442698.6	436942.13	229014.09	278631.36	506332.08
13	19.9817	269261.94	591132.44	560258.13	551574.21	249085.73	248648.36	552701.9
14	19.98309	210674.57	484871.78	526265.24	516999.54	201773.89	151395.34	449553.22
15	19.98448	95100.447	247453.64	349914.08	342570.65	99877.691	13182.255	224790.45
16	19.98586	-46198.469	-56901.715	78907.958	75472.283	-29037.512	-128599.32	-60782.758
17	19.98725	-175000.95	-345865.92	-213444.02	-212042.06	-150097.04	-235591.9	-329912.04
18	19.98864	-256465.28	-541272.24	-448057.34	-442195.35	-230551.25	-278849.23	-509791.23
19	19.99003	-268554.26	-590260.5	-561465.32	-552726.86	-248635.06	-246667.49	-551758.1
20	19.99142	-207996.9	-479577.07	-522988.17	-513734.95	-199456.05	-147751.8	-444458.92
21	19.9928	-91173.842	-239161.4	-343033.13	-335766.67	-96318.123	-8861.5197	-216920.23
22	19.99419	50313.243	65951.855	-70280.102	-66965.229	32877.313	132428.93	69303.077
23	19.99558	178189.96	353224.77	221486.35	219952.98	153179.25	237895.13	336779.58
24	19.99697	257862.99	544943.88	453336.79	447369.47	232042.23	279003.74	513148.49
25	19.99836	267778.45	589243.65	562549.12	553761.28	248130.81	244632.02	550695.39
26	19.99975	205253.2	474138.15	519576.95	510344.96	197091.69	144077.19	439260.8
27	20.00113	87201.247	230764.8	336043.64	328864.06	92731.703	4541.6379	208989.39
28	20.00252	-55430.618	-77019.865	61601.237	58416.277	-36716.832	-136225.8	-77824.016
29	20.00391	-182295	-362483.79	-230771.87	-228873.42	-156674.19	-240204.93	-344578.47

Figure 3. Simulated EMTP voltage data

IV. IMPLEMENTATION OF A NEW-TYPE KOREAN FNET

In this section, the implemented new-type Korean FNET is introduced. The monitoring S/W consists of five parts: data acquisition, DFT filtering, frequency estimation, stability determination, and GUI for display. The data acquisition is a charge in reading local voltage data of power system model using EMTP-RV. The parts composed of DFT filtering and frequency estimation estimates the corresponding frequency based on the voltage data. At the same time, or it is determined whether or not the system is stable based on IEEE Std C50.13TM-2005[13] as Table 2 in real-time manner. As such, after the frequency is estimated and the stability is checked, the results are displayed on monitor. Fig. 4 shows the monitoring flowchart of the proposed Korean FNET. Fig. 5 shows the screenshot of the graphic user interface (GUI) implemented for the monitoring system. The GUI provides two monitoring modes: the wide-area ((A) in Fig. 5) and local-area ((B) in Fig. 5) monitoring modes. Once the wide-area monitoring mode as shown in (A) of Fig. 5 is selected, overall status of the power system including the voltage ((C) in Fig. 5), the frequency ((D) in Fig. 5), and the stability index ((E) in Fig. 5) can be monitored in real-time manner. As well, by clicking the interesting spot (marked as the circle in Fig. 5), the supervisor can switch the current (wide-area) monitoring mode to local-area one, and check the status of the region. Fig. 6 shows the screenshot of local-area monitoring GUI.

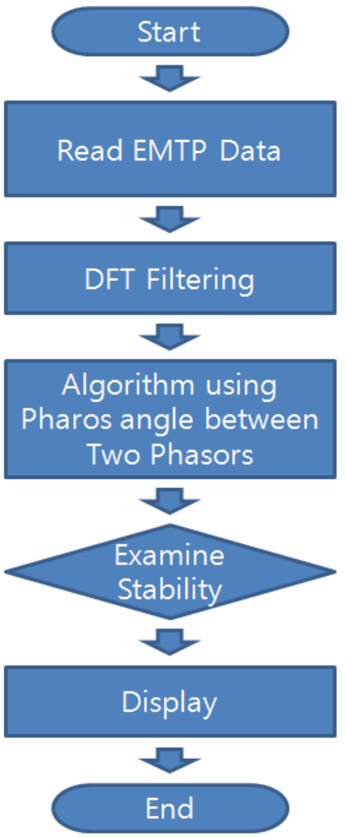

Figure 4. Monitoring flowchart of Korean FNET

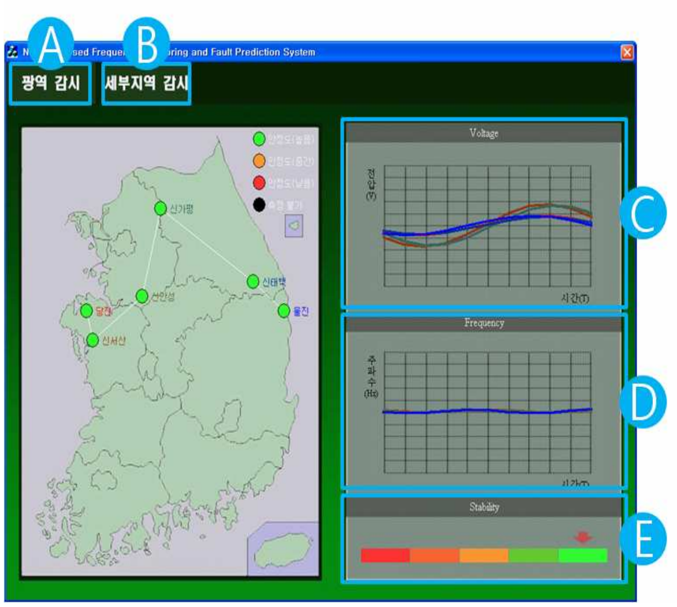

Figure 5. A screenshot of the monitoring system

Figure 6. A screenshot of local-area monitoring

V. CONCLUSIONE

In this paper, a new network-based frequency monitoring system is implemented and examined for the validation. For the implementation of the proposed monitoring system, first the modeling for real 765[kV] T/L system was done using EMTP-RV, and the corresponding voltages were obtained in 6 regions for the model of power system. Based on the phasor angle difference algorithm, the system could estimate the frequency and check its stability in real time. With two monitoring modes, it is expected that the proposed monitoring system could provide an easy and intuitive monitoring environment to users.

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