Interconnected System Operation of Electric Power Companies

I do not know whether the particular phase of the electrical industry that I am going to talk about this afternoon will be of interest to many of you or not. I am not familiar with the type of talks that you usually have or in what direction most of your interests or work are centered. I am fully conscious of the great difficulty that I have in not being able to speak your language. I hope that some day I may be able to do that. I will try and talk slowly and stop for translation as we go along.

The subject which I throught might interest some of you is to tell you how large electric systems operate all tied together in synchronizm and yet each independent company generates and controls its own load.

It took many years of experience to learn how to do this and they are still trying to improve some of the procedures so that it will work faster and more accurately.

It would be well to point out at first that we are dealing with many electric systems instead of just one company like the Korea Electric Power Co. there are over 100 differently owned electric companies all tied together by big transmission lines. the voltages are usually 138,000, 220,000 or 330,000.

The reason that they spend money to tie together like this is in order to help each other out in cases of emergency and thus have just as few interruptions to any customer as possible. In some cases one company can generate

Power cheaper than the other and it is profitable to buy and sell. In other Cases a steam power plant area can help out a hydro plant area. There are many other reasons why it is good business to operate this way but at the same time have each company in full control of the generation for its own Customers.

Before we get into a description of the way in which the Control works in would be well to say that one of the first requirements must be to have a very good and well maintained relay protective scheme, so that any disturbance on one system is not transmitted to another system. Of course good relaying is one of the necessities of any system large or small, but here the responsibilities and obligations are extended.

Maybe the best way to start explaining the method of operation is to start with only two electric power companies tied together with one transmission line. All they have to do is watch the flow of power on that one line to know that each is generating enough for his own load when no power flows on the line. However such a balanced condition could exist and the frequency be high at $60\frac{1}{2}$ cycles, or maybe low at $59\frac{1}{2}$ Cycles. To Correct the frequency there will have to be an agreement as to who should control frequency. Generally a simple operation of two Companies or just a few Companies operating in parallel is accomplished by one Company being designated to Control frequency and all other Companies Control load flow on the tie lines. Such a Scheme is allright for Companies connected by radial lines, and particularly if they are arranged like the spokes of a wheel. In such a case the Center Company would naturally control frequency and all others would control load. It might appear that the frequency control company has the easiest job but it does not work out that way because the frequency control company gets the impact of the major load changes originating in any of the companies. Therefore he may be picking up or dropping load that really belongs to some other company.

The frequency control company must do a very accurate job of keeping the frequency on 60 cycles otherwise the other companies have a right to complain. High frequency causes an increase of load and low frequency results in a reduction of load. To be fair to everyone every effort must be made to keep it just as close to 60 cycles as possible.

Frequency control can be accomplished by manual adjustments of speed but if the operator is not watching it every minute it will drift away from 60. Also a man cannot detect minor variations from 60 as quickly as an electrical instrument can. Therefore automatic control of frequency is desirable. The sensitive frequency meter can be equipped with contacts which will be connected to the turbine throttle so that more power is generated when the frequency is low and less power when the frequency is high.

Still keeping the simple radial system that we started to describe if we now have the center company controlling frequency automatically he is not going to be satisfied if his neighbors control load by hand, because the load on a line will have to be far enough out of adjustment for the operator to notice it, then when the operator starts correcting it he will probably go too far in the opposite direction. Thus it can be seen that load control would be a continual process of increasing load then reducing load.

It therefore follows that the next logical step is to adjust load on the tie line by automatic equipment. To do this is more complicated because the metering point on a tie line may be located many miles from a generation station, and if there is more than one generating station you may desire to control at on station under some circumstances, and at another station under other conditions. Automatic tie line load control generally requires the installation of remote metering. This is sometimes done over telephone wires and in other cases with carrier current impulse circuit. Once a circuit is provided from the tie line meterring point to the generating station, then automatic raising and lowering of load can be accomplished. Automatic raising and lowering of load can be accomplished. Automatic action will tend to minimize the drift on either side of an absolute 60 cycles.

So far we have only mentioned generating stations and transmission tie lines, but all of these operations we have been describing usually come under the supervision of a load dispatcher. The dispatcher can have an indication of frequency in his office by simply connecting a graphic instrument into any outlet on the system. It is very impostant that it be a graphic instead of indicating instrument so that the trend of a slow change can be observed, or any major disturbance noted. A graphic frequency meter is a real barometer or indicator of things that are happening on an electric system. It is very desirable to have the scale of this graphic frequency meter easily readable down to 1/100 of a cycle. On a chart about 6 inches wide the scale should be 59 to 61, or not greater than 58 to 62.

The dispatcher will also want to have complete and instantaneous graphic information in front of him about the flow of power on transmission tie lines. This is usually done by routing the telephone line or the carrier current circuits described above through the dispatcher office, so that he is supplied with the same information that the power plant is getting. The dispatcher will also want to know what load the generating plant is carrying and how it is responding to load changes. Telephoned information is too slow and unreliable.

Everything described so far works well for companies interconnected like the spokes of a wheel. such a condition does not last long because these same companies find it desirable to connect more directly with each other and we have a pattern like the rim of the wheel in addition to the spokes. Iso by that time several more companies have decided to join the group and we have developed a spider web or net work.

Now instead of watching the load on one line the dispatcher may be concerned with many lines to different companies. when this happens the only way in which he can determine whether he is exporting power or importing power is to have all the tie lines telemetered into his dispatching office and after each one has gone thru a graphic meter, totalize all of them algebraically so that the last graphic meter shows the net sum of all the lines in and out. It is this net sum of all the lines which tells the story of whether the company is generating all the power necessary to supply its own customers, or whether it is generating too much or not enough.

The dispatcher should have complete information in front of him so that he knows what the total load is on his sytem and how it is increasing or decreasing. This will require a telemetered circuit from each generating plant plus the tie lines we have just mentioned. All of this information is required so that sufficient reserve capacity can always be kept in readiness to handle emergency conditions. The information about all the plants added to the information about all the tie lines when added together will represent the total company load.

Up until this point in our description we have been assuming that one company will control frequency and all other companies control tie line load. This is not a fair and equitable method because with a very large interconnected system the normal load changes and all the errors in system regulation will be imposed first of all on the frequency control company. Shortly afterward this disturbed line loading will becom evident to the load control companies and they will start to automatically make adjustments. Such an arrangement causes the frequency control company to keep loading and unloading a plant for the benefit of his neighbors.

The problem now is to find a way for every company to do his share of the frequency control at the same time that he is making load control adjustments. The technical name which has been devised for this method of operation is called biased frequency control. When operating in this manner every company needs an accurate frequency control meter which operates with a very slight slope instead of a level line at 60 cycles.

This needs to be explained. We will try and do it by an example. Assume two Companies A and B. A is not generating enough power for its own use therefore some power is flowing from B to A. At the same time the frequency is low at 59.98 cycles. A will start to generate more power to offset the amount that is being supplied from B, but that is not enough. It needs to generate still more power to raise the frequency to 60 cycles. So it will continue to increase generation until the frequency has reached 60 and the tie line load is balanced. At the same time B Company's meters show that they are over generating but the frequency is low. Therefore B Company will increase its generation in spite of the fact that the tie line is allready sending power out of the system. At the same time the load on the tie line has to be reduced so it will adjust by recognizing both these factors and reduce its generation more slowly than it would do if the frequency was at 60 cycles.

In all the examples and description up to this point we have emphasized keeping the tie line balanced so that every Company is generating its own load. it is only a simple variation of this principle to arrange for one company to set the scale on its meters so that it will over generate 25,000 KW, and some other Company will at the same time set its instruments to under generate 25,000 KW. then they are selling and buying power, on a prearranged basis.

An emergency may occure at some place where a generator drops off the line. If this happens the Companies Surrounding the trouble feed power into that area until the trouble is corrected.

When every company is equipped with all the instruments described above then an unlimited number of companies can operate in parallel and have complete control of their own generation and load.

Over 100 large companies are now operating in one large network in the United States, covering a square mile area over twenty times as large as Korea, and totalizing load 135 times as much as that in Korea.

The best index of how well the system operates is the accuracy of any electric clock connected to the system. That clock should record correct time within the range of 3 seconds fast or 3 seconds slow.

Maybe something more should be said about the biased frequency. The degree or amount of bias that is used is an adjustable feature on the instruments. After much testing and experimenting it has been found that a good result is obtained by using an amount on each systems which is proportional to its size. The generally accepted rule for this is 2 percent of the annual system peak load per 1/10 of a cycle frequency variation. If this rule is expressed in figures a system with an annual peak load of 1,000,000 KW would utilize 20,000 KW additional input into the whole system to help raise the frequency from 59.90 to 60.0 cycles. If the frequency were 60.1 it would do the reverse and utilize 20,000 KW drag on the system to lower it from 60.10 to 60.0 cycles.

All the companies install this equipment and operate according to an agreed upon set of rules by a voluntary understanding. No body tells them that they must to it.

They do it because it is mutually good for everyone.

There is one feature that is lacking on this scheme of operation and that is for each company to have an instrument to compare frequency with absolute standard time, and them initiate load changes to compensate for this. This refinement for every company has not yet been found economically justifiable. Another method of making this correction has been adopted. Whenever an error of 3 seconds has been reached an appointed referee company sends out word on the dispatching telephone net work that a time correction operation will start at a specified time. Then all companies go off the 60 cycle basis and either operate at 60.02 or 59.98 to gain or loose the necessary time. After the end of time required to make the adjustment they all go back to exactly 60 cycles. This has been a very satisfactory way of doing this instead of installing some very expensive instruments.

That about covers the description of operating many companies in a very large net work in a very smooth and helpful way. Maybe there are some features that I have not made clear to you and if so I would be pleased to answer any questions.

It has been a pleasure meeting with you and I hope that the subject has been worth while listening to in a foreign language.

A. L. Richmond
June 15. 1957

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